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ESTIMATION OF NATURAL AND TOTAL MORTALITY RATES OF NORTHWEST ATLANTIC MACKEREL

by

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Introduction

The assessment of abundance and optimal yield levels of Northwest Atlantic mackerel (*Scomber scombrus*) has generally been complicated by divergent conclusions as to the appropriate level of natural and fishing mortality rates. The level of natural mortality (M) currently being used in cohort analyses (M = 0.30) was arrived at more by compromise consensus than from data analyses (Anon. 1974). In addition estimates of terminal fishing mortality in 1976, for example range from 0.48 (Lett and Marshall 1978) to 0.85 (Anderson and Paciorkowski 1978). Although extensive data have been made available from commercial and research sampling activities during the past decade, these have not been analyzed with regard to definitive evaluation of the natural mortality rate of mackerel. Such analysis form the basis of this report.

Methods and Materials

The basic data used were catch at-age and effort index measures (relative exploitation index) as reported by Anderson and Paciorkowski (1978). Three methods of arriving at estimates of M involving catch and effort data were used although it is realized that these are essentially three treatments of the same data and as such are not independent estimates.

Results

Regression of Z (Paloheimo) on fishing effort

From numbers caught at age in each year and the relative exploitation index (E) in each year, age-specific catch-per-unit effort data have been calculated for the period 1968-77. Selectivity changes (eg. partial recruitment rate) between years for each year-class have been adjusted by the following formula.

$$CPU'_t = CPU_t \cdot \frac{q_t + 1}{q_t} \qquad \text{............ (1)}$$

where CPU_t = age-specific catch-per-unit effort in year t

and q_t = catchability coefficient (estimated by the ratio F/E from cohort analyses (Anderson and Paciorkowski 1978)

Total instantaneous mortality rates (Z) have then been computed for age-groups 2-10 by the method of Paloheimo (1961) and are plotted against the average relative exploitation index in Fig.1. Functional regression analyses (Ricker 1973) produced an intercept value of 0.37 which is an estimate of the natural mortality rate during the period 1968-77.

Regression of Z (cohort analysis) on fishing effort

Trial runs of cohort analyses (M = 0.35) indicate a rapid convergence of estimates of F in 1974 with varying input levels of F in the terminal year (1977). Consequently a functional regression of F (2+) from cohort analyses on the relative exploitation index was calculated for the period 1968-74 (Fig. 2) resulting in an intercept value of M = 0.36.

Silliman method

The recruitment of the very large 1967 year-class as 1-year-olds in 1968 attracted a substantial displacement of international effort towards mackerel during the late 1960's and early 1970's with the result that fishing effort increased from about 25,000 units in 1968 to an average of 735,000 units in the period 1974-76. (Anderson and Paciorkowski 1978).

Catch-at-age data are available for the period just prior to heavy exploitation (1962-67) and in the absence of fishing effort data for that period it is assumed that catch varied in direct proportion to changes in effort ie. stable abundance. This assumption is not unreasonable when considered in relation to estimates of biomass from cohort analyses for the period 1962-67 (Anderson and Paciorkowski 1978).

Thus, from numbers caught at age and the corresponding effort (= catch) index, adjusted CPU values were calculated from equation (1) from which were derived estimates of Z (2+) by the Paloheimo (1961) linear formula. These estimates are given below.

Z	1962/63	1963/64	1964/65	1965/66	1966/67	Mean
	.325	.650	.296	.520	.320	.420

Cohort analyses (Anderson and Paciorkowski 1978) suggest that fishing mortality was low during this period and hence an average level of effort equal to the 1968 level (25,000 units) was assumed for the period 1962-67. This is compared to the period of high effort level (1974-76) and the corresponding Z by the method of Silliman (1943) as follows:

$Z_1 = F_1 + M$ (1962-67)

$Z_2 = F_2 + M$ (1974-76)

whence by simultaneous solution results in an estimate of M = 0.405.

Discussion and Conclusions

Estimates of M for mackerel by the above method ($0.36 \leq M \leq 0.41$) is substantially above the level (M = 0.30) assumed for this species in previous assessments. Such estimates compare for example with a level of M = 0.15 calculated for the Northeast Atlantic mackerel stocks (Anon. 1978) and M = 0.20 estimated for Southern Gulf herring (Winters and Hodder 1975) and Fortune Bay herring (Winters and Moores 1977).

The estimate of natural mortality for Northeast Atlantic mackerel was derived from tagging data (Hamre 1975) but given the uncertainties relating to recovery data from tagging experiments involving internal tags (Winters 1977, Winters and Beckett 1978) confidence limits on such a point estimate would be quite large. Nevertheless, the Northeast Atlantic mackerel stocks tend to be slower growing and later maturing (mean maturation age of 3 years CF 2 years for Northwest Atlantic mackerel) than Northwest Atlantic mackerel and a lower value of M would therefore be probable.

In comparison to Northwest Atlantic herring stocks, mackerel are much faster growing and mature much earlier (2 years CF 4 years for herring) and thus a natural mortality level substantially above 0.20 would be expected. In addition the unreported catch of mackerel is probably substantial, accruing not only from discards and/or under reporting of commercial catches but also from its extensive use as bait and its exploitation as a recreational sport fishery. Furthermore because of their temperature specificity mackerel are highly vulnerable to sudden temperature changes and to thermal entrapment. For example mass mortalities of mackerel due to thermal shock are a common occurrence along northeast Newfoundland during late fall (Anon. 1977); a mass mortality of 10,000 m tons of mackerel was estimated for a small area in Notre Dame Bay, Newfoundland, in 1976 (Anon. 1977) - the actual figure for the entire bay was undoubtedly much higher.

From the regressions given in Fig. 1-2 and effort index for 1977 calculated by Anderson and Paciorkowski (1978) the total instantaneous mortality rate (2+) for 1977 is estimated in the range of 0.62-0.63. Subtracting the mean value of M calculated in this report ($\bar{M} = 0.38$) implies a terminal F (F_T) of 0.25-0.26 in 1977. Accepting the strength of the 1974 and 1975 year-classes as estimated (at age-groups 0, 2 and 3) by Anderson and Paciorkowski (1978) (2300 and 800 millions respectively) results in population numbers-at-age from cohort analyses as shown in Table 1. The strengths of the 1976 and 1977 year-classes at age-group I have been estimated from the relationship between temperature and mackerel recruitment as determined by Winters (1976). The implied partial recruitment pattern under these assumptions of year-class strength is 1% (age-group 1), 20% (age-group 2), 70% (age-group 3) and 100% (age-group 4+). Yield-per-recruit analyses under such an exploitation pattern provides an estimate of $F_{0.1} = 0.52$ (Fig. 3). Application of this fishing mortality rate to the projected 1978 population age-structure results in an optimum yield of 115,000 m tons.

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Table 1. Results of cohort analyses (M = 0.38) for Northwest Atlantic mackerel, 1969-78

AGE	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	4659	4394	2148	2146	1460	2282	2300	800	(1750)	(650)
2	7537	3180	2834	1405	1450	865	1481	1241	540	1190
3	2255	4907	2127	1686	889	758	391	655	569	345
4	516	1391	2896	1345	938	373	300	173	225	310
5	147	291	807	1502	767	450	171	122	48	120
6	104	95	175	378	699	366	213	68	40	26
7	84	69	58	90	185	315	157	90	24	21
8	106	56	42	32	42	101	126	65	28	13
9	80	69	29	25	19	19	47	44	16	15
10	29	52	39	17	11	10	8	22	12	9
11	4	12	32	20	8	4	4	4	4	8
No. (2+)	10862	10121	9040	6500	5007	3261	2900	2433	1506	2057
Wt. (2+)	2403	2685	2640	2118	1659	1125	860	665	418	515

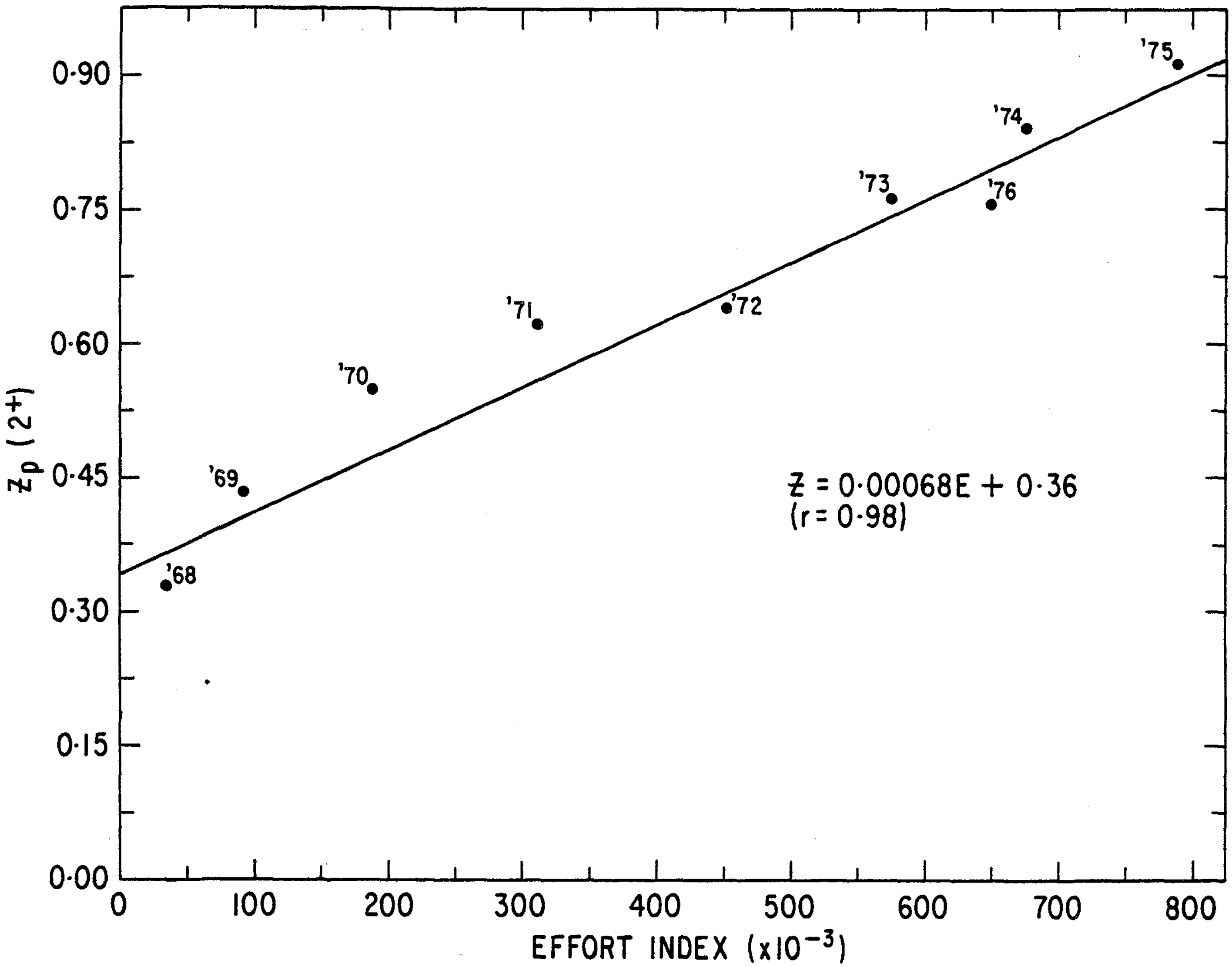

Fig. 1. Functional regression of total instantaneous mortalities (2+) by the method of Paloheimo on the fishing effort index.

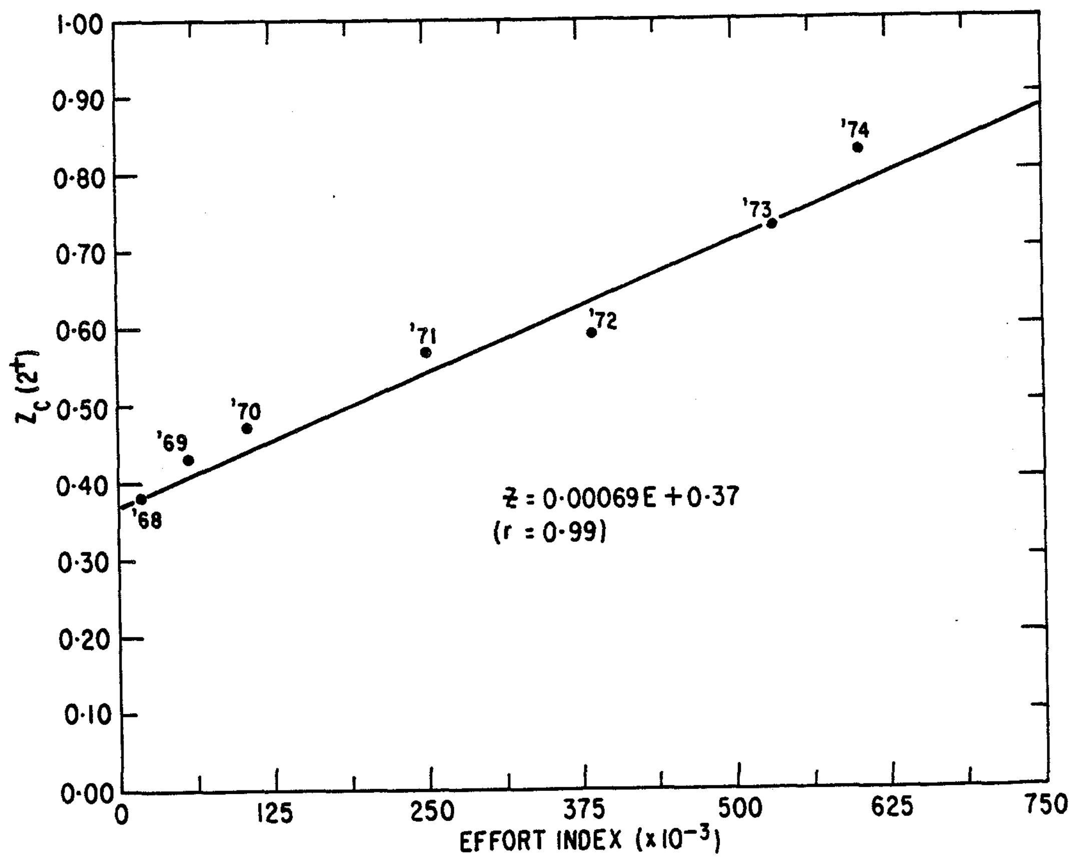

Fig. 2. Functional regression of total instantaneous mortalities (2+) from cohort analyses on the fishing effort index.

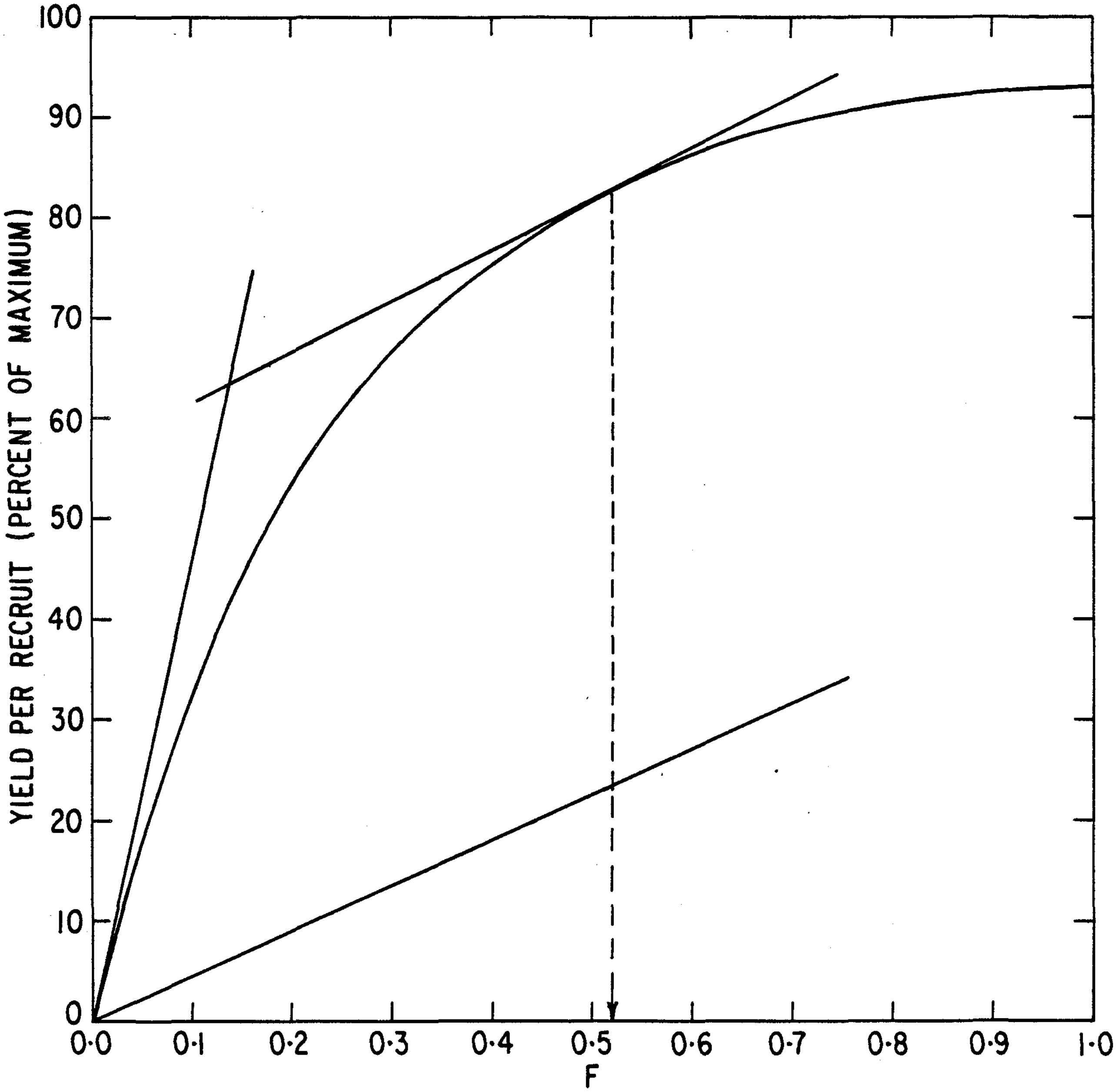

Fig. 3. Yield per recruit analysis of Northwest Atlantic mackerel (M = 0.38).