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Northwest Atlantic Mackerel

Stock Assessment - 1981

by

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Abstract

An index of effort calculated from the USA commercial catch rate was used to fine tune ages 6-7-8 fishing mortalities. A 1980 F = 0.066 was considered to best represent the ages 6 and older stock status. Partial recruitment on age 2 was adjusted to obtain a 1978 year-class size at age 1 of 2 billion fish while P.R. on ages 1, 3, 4, and 5 were adjusted to obtain year-class size at age 1 of approximately the smallest size observed. Various Y/R calculations and projections were made. These indicated that a 1982 catch of 115,000 mt would not adversely affect the stock status.

Résumé

Un indice de l'effort dérivé des taux de captures commerciaux américains a été utilisé pour ajuster les mortalités par pêche sur les âges 6-7-8. Un F = 0.066 en 1980 a semblé donné la meilleure représentation de l'état du stock de 6 ans et plus en 1980. Le recrutement partiel des poissons de 2 ans a été ajusté pour que la classe d'âge de 1978 soit de 2 milliards de poissons à 1 an alors que les recrutement partiels sur les âges 1, 3, 4, et 5 ont été ajustés pour obtenir des classes d'âges à 1 an approximativement égales à la plus petite classe d'âge observée. Différents calculs de rendement par recrue et projections ont été effectués. Elles indiquent qu'une capture de 115,000 tm en 1982 n'affecterait pas le stock de façon défavorable.

Introduction

The Northwest Atlantic mackerel stock has produced relatively good year-classes between 1965 and 1974 with the 1967 year-class being approximately twice the size of any other observed at close to 8 billion fish (Anderson, 1980; Maguire, 1980). Prior to 1961 Canada and the USA were the only countries involved in the mackerel fishery but the late sixties and early seventies saw the involvement of East European countries in that fishery. The nominal catches (commercial and recreational USA) (Table 1) went from 10,000 mt in 1961 to 430,000 mt in 1973. Following the extension of their jurisdication over fisheries by Canada and the USA, the mackerel resource is again, since 1978, mainly exploited by these two countries.

1980 Catches

The total 1980 nominal catches are down to about 27,500 mt (Table 2) from almost 36,000 mt in 1979. Canada caught approximately 75% of the total (20,552 mt), the USA about 23% (estimated 6,300 for the commercial and recreational catches combined) and various other countries caught the remaining 2%.

The lack of market appears to have kept the 1980 catches by the Maritime Provinces low even if over the side sales were arranged because the factory trawlers had problems being at the appropriate location at the right time. This led to dumping of significant quantities of mackerel in northern New Brunswick and Prince Edward Island in early June. A fishermen's strike in Newfoundland during the summer of 1980 is believed to be, at least partly responsible for the halving of the Newfoundland mackerel nominal catches from 1979 to 1980.

Catch at age

The 1980 removals at age for the Maritimes catch were calculated by Hunt[1] and by Moores[2] (pers. comm.) for the Newfoundland catches (Table 3). Their numbers were prorated upwards to account for the unsampled catches of other countries. The Newfoundland catch at age indicate very low contribution of the 1977 year-class compared to the 1978 year-class while the Maritimes data indicate a reasonable contribution of the 1977 year-class but abnormally low contribution of the 1976 year-class. Since the catch of younger age-groups is more significant in the Maritimes the relative contribution of the 1977 and 1976 year-classes of the total catch at age reflects more the Maritimes catch at age. Although those two year-classes are believed to be very weak, recent indications were that the 1977 year-class was weaker than the 1976 year-class. The 1962 to 1979 catch at age was taken from Anderson (1980), Table 4a-b, and Canadian catch at age Table 4c and 4d.

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[2] J.A. Moores, Fisheries and Oceans, P.O. Box 5667, St. John's, Newfoundland A1C 5X1

Stock Size Indices

As for last year's assessment (Maguire, 1980) the main sources of information on this stock's status are coming from the USA research vessel surveys catch per tow and from the US commercial catch per standardized day. Due to lack of time it has been impossible to calculate the northern population spawning stock size estimate from egg data. The US data are given in Tables 5 and 6 and both show an increase in 1980 over 1979. The RV spring survey indicates that the 1980 value is about 1.6 times the 1979 value and the commercial 1980 value is almost twice the 1979 value. It should also be noted that the USA granted a special permit to Polish vessels to fish for mackerel in NAFO Subarea 5 and Statistical Area 6 in 1981. Those boats were initially allocated 2,000 mt which they caught relatively rapidly and later were given another 2,000 mt (Anderson[1] pers. com.). It appears that even after 4 years of non participation in the fishery, Polish captains are still relatively good at mackerel fishing. Their catch per day in 1981 was approximately 60 mt/day (which may have been limited by the ship's processing capacity, Anderson pers. com.). The most efficient vessels of the Polish fleet between 1970 and 1976 was the B-418 category
($>$ 1800 GRT). Their catch rates for that period were (Anderson and Paciorkowski, 1978):

Year	Catch/Day
1970	34.6
1971	29.0
1972	50.5
1973	41.6
1974	72.4
1975	34.1
1976	19.2

The results of the 1981 Polish mackerel fishery would thus indicate biomasses similar to the 1972 to 1974 levels.

The 1980 USA autumn RV survey indicated that the 1978 year-class is probably relatively strong with possibly a reasonably strong 1980 year-class (Anderson, pers. com.). The 1981 USA spring survey is presently being conducted and preliminary information (Anderson, pers. com.) indicates that the stock size index will probably be higher than the 1980 value. It thus appears that, as expected, the stock is further recovering after the removal of the foreign fishing effort since April 1, 1977.

Sequential Population Analysis

The removals at age given in Table 4a were used in a Virtual Population Analysis (ages 1 to 11 only). The partial recruitment multipliers from last year's assessment (Table 8, Maguire 1980) were used for ages 1, 2 and 3 with full recruitment at age 4 and older.

[1] Dr. E.D. Andersons, NMFS, Northeast Fisheries Center, Woods Hole Laboratory, Woods Hole, Massachussetts 02543

Since all indices indicated a recovery of the stock (Figure 1) and given the low catches, a low 1980 fishing mortality was postulated, so an initial VPA run was made with the selectivity at age quoted above and a fully recruited F of 0.05. An examination of the fishing mortalities at age generated by that run indicated an older age of full recruitment in 1978 and 1979 and to a lesser extent in 1977 when the effect of the Distant Water Fleet could still be seen with high fishing mortalities at ages 3 and 4. The 1973 and 1974 year-classes were then the most numerous in the stock and it is likely that the foreign fleet concentrated their effort on them.

The fishing mortalities at age for 1978 from this initial run were used to calculate a new vector of partial recruitment multipliers with full recruitment at age 6 and after (Table 9). This vector was used in subsequent tuning of VPA. In all VPA runs, the fishing mortality on the oldest age was taken as the average of ages 6-7-8 fishing mortalities (adjusted iteratively).

The indices available for fine tuning were:

1. the US spring research vessel catch/tow in kg;
2. the US commercial catch per standardized day; and
3. the US fall research vessel catch/tow.

The third index was not used in this analysis due to the very low catches made during that survey. A number of preliminary VPA runs indicated that different indices of mackerel biomass versus the US spring research vessel catch per tow were totally insensitive to the 1980 fishing mortality input values. The same indices of mackerel biomass versus the US catch per standardized day did not show any useful relationships. The same problems with these indices were encountered last year (Maguire, 1980). A relative effort index was calculated using the total international catch divided by the US catch per standardized day (Table 7) and the average fishing mortalities on ages 6, 7 and 8 were regressed against that index.

The mackerel catch at age data are not very reliable before 1968 and the $\overline{F}_{6-7-8}$ vs relative effort from 1964 to 1967 indicated a lot of scatter and added considerable noise to the relationship. Other runs were made with the 1968 to 1980 F and effort values. These indicated that this relationship did not have a high discriminatory power either. This was mainly caused by the slow convergence of the F at age table. The 1977 to 1980 F values are much below those of preceeding years and it soon became obvious that it would be impossible to base a decision on a line fitted using these points.

Another series of runs was made in an attempt to find the 1980 fishing mortality that gave the best relationship for the 1968 to 1976 period. Runs were made a F_{80} = .025, .05, .075, 0.10, .15 and

0.066. The results are given in Table 10. The two highest correlation coefficients were obtained with F_{80} = .05 (r = .825) and F_{80} = .075 (r = .822). The relationship deteriorated significantly at F_{80} = 0.025 and F_{80} = .15. The 1980 predicted value with F_{80} = .05 was 0.065 and the same value was 0.068 with F_{80} = 0.075. A final run at F_{80} = 0.066 was made resulting in r = .827, and a predicted 1980 value of 0.068. F_{80} = 0.066 on fully recruited ages was thus accepted as best representing the stock status in 1980 (Figure 3).

Examination of the population at age table showed that the 1976 to 1980 year-class sizes at age 1 were low. The 1980 partial recruitment multipliers were adjusted to obtain reasonable year-class sizes for the 1976, 1977 and 1979 year-classes. There is some evidence from the Newfoundland fishery, the US research vessel surveys and the US commercial fishery that the 1978 year-class is relatively strong, (about 2 billion fish, Anderson, 1980) so the PR at age 2 in 1980 was adjusted accordingly. The adjusted PR multipliers are given in Table 14a, and the resulting population at age, biomass at age and F's at age are shown in Tables 11, 12 and 13 and the 2+ biomass in Figure 2. The population biomass of Table 12 is calculated with the "stock" weights given by Anderson (1980) (Table 8) and, for 1980, will be different than the biomass given in the projections table where different weights at age were used.

Yield per recruit

Anderson (1980) calculated the mean partial recruitment multipliers from the Canadian fishery during 1968-79 (excluding the high and low values at each age). This vector (Table 14a) is probably the most representative of the expected selectivity of the Canadian fishery in the future. That P.R. vector as well as the one used to obtain the 1980 population estimates at age were used with the average weights at age observed in the 1980 Canadian fishery and the average weights at age in the catch, calculated by Anderson (1980) (Table 14a) to calculate yield per recruit by the method of Thompson and Bell. The results of these four yield per recruit calculations are given in Table 14b. The exploitation pattern observed in the 1980 fishery is such that the maximum yield per recruit is obtained at a very high fishing mortality. This is due to the high age of full recruitment and rapid growth rate of mackerel. The average exploitation pattern calculated by Anderson (1980) for the Canadian fishery gives results that are more realistic. Whether the post 1977 exploitation pattern is due to some peculiar behavior of young mackerel or of the fishery or whether it is the result of an overestimation of the 1976 to 1979 year-classes remains to be determined.

Projections:

Using the 1980 population estimates obtained by fine tuning VPA (Table 11) and the geometric mean recruitment at age 1 of the 1961 to

1975 year-classes (1, 585 x 10^6 fish) as input values for recruiting year-classes, projections were made, fishing at each of the four $F_{0.1}$ values given in Table 14b for both of 1981 and 1982, using the appropriate partial recruitment multipliers and weights at age. No TAC has been set for this stock for 1981, but it is most likely that the 1981 catch will be below the $F_{0.1}$ level. If such is the case, the 1982 $F_{0.1}$ projected catch would be higher than presented in Table 15.

Table 15 shows that, depending on the parameters used, the projected 1981 $F_{0.1}$ catch could be between 168,000 mt and 306,000 mt, while that projected for 1982 would be between 118,000 mt and 271,000 mt. It should be noted that these catches would be for NAFO SA 3-6, the entire range of the Northwest Atlantic mackerel stock.

Conclusion:

This mackerel stock appears to have recovered from the high exploitation rates it experienced during the late sixties to mid-seventies. It should be noted, however, that the fishing mortalities for the period 1970 to 1976 presented in this analysis are not as high as previous estimates. It is not suggested that the fishing mortalities of Table 13 are more realistic than those previously estimated, but rather that the under-reporting of catches suggested from overflights (Brennan, 1976) really occurred. If this were the case, the 1980 stock status could essentially be the same but the slope of the relationship between F and effort would be greater.

Mackerel year-class sizes are highly variable and since 1962 have shown differences of more than one order of magnitude. Consequently projections incorporating geometric mean estimates of year-class size for the most recent year-classes may not estimate future yields well, and thus potentially substantial fluctuations in yield, from that projected, must be expected.

References

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Table 1. Mackerel nominal catch (mt) from NAFO SA 3-6 since 1962 and TAC since 1973.

Year	USA Commercial	USA Recreational	Canada	Other Countries	Total	TAC
1962	938	3565	6801	175	11479	-
1963	1320	3981	6363	1299	12963	-
1964	1644	4343	10786	801	17574	-
1965	1998	4292	11185	2945	20420	-
1966	2724	4535	11577	7951	26787	-
1967	3891	4498	11181	19047	38617	-
1968	3929	7781	11134	65747	88591	-
1969	4364	13050	13257	114189	144860	-
1970	4049	16039	15690	210864	246642	-
1971	2406	16426	14735	355892	389459	-
1972	2006	15588	16254	391464	425312	-
1973	1336	10723	21247	396759	430065	450000[3]
1974	1042	7640	16701	321837	347220	359000[4]
1975	1974	5190	13544	271719	292427	355000
1976	2712	4202	15746	223275	245935	310000
1977	1376	522	20362	56067	78328	105000
1978	1605	6571	25429	841	34446	105000
1979[1]	1989[2]	3315[2]	30237	440	35981	
1980[1]	3300[2]	3000[2]	20552	557	27409	

1 Provisional
2 Estimated
3 NAFO SA5-6 only
4 NAFO SA3-6

Table 2. Mackerel 1980 Nominal Catches Breakdown (mt)

Canada - Maritimes-Quebec	13381
Canada - Newfoundland	7171
USA - Commercial	3300
USA - Recreational	3000
Others	557
Total	27409

Table 3. Mackerel catch at age ('000) for 1980

	1	2	3	4	5	6	7	8	9	10	11+	Total
Maritimes												
Quarter 2	3	492	930	714	2066	3231	1972	976	661	232	216	11494
Quarter 3	3	866	1209	520	1750	3258	1833	720	353	187	225	10923
Newfoundland												
3K	0	15.4	3.8	33.4	169.6	511.4	339.2	122.3	93.7	41.2	108.1	1438.1
3L	0	60.8	12.5	160.1	841.9	2324.6	1610.5	674.3	399.6	241.2	623.2	6948.7
3P	0	0	.4	.5	11.6	30.6	19.5	9.2	7.7	4.8	11.8	96.1
4R	0	21.2	.5	34.9	248.2	477	373.6	190.1	88.7	23.1	85.0	1542.3
Total Sampled Catch	6	1455.4	2156.2	1462.9	5087.3	9832.6	6147.8	2691.9	1603.7	729.3	1269.1	32436.2
Total Sampled and Unsampled Catch	8.0	1941	2876	1951	6786	13116	8201	3591	2139	973	1693	43267

Table 4a NORTHWEST ATLANTIC MACKEREL INTERNATIONAL CATCH AT AGE (million fish). 10/ 5/81

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	0.0	0.0	0.0	0.0	0.0	1.8	1.1	4.0	4.8	2.4	3.6	4.0	2.0	3.7	0.0	0.0	0.0	0.0	0.0
1	16.1	1.1	12.9	9.0	24.0	0.8	141.4	7.1	193.5	74.6	22.1	161.8	95.9	373.7	12.5	2.0	0.1	0.4	0.0
2	2.8	4.2	7.0	3.6	11.5	26.7	61.5	262.1	54.5	294.2	85.7	283.2	242.2	431.4	353.5	27.0	0.2	0.6	1.9
3	15.2	1.3	4.1	2.9	5.3	19.8	59.3	160.7	522.1	127.4	256.2	285.1	264.4	113.7	272.5	101.0	4.7	1.3	2.9
4	3.8	26.3	4.0	4.0	2.6	3.5	38.1	65.8	162.9	558.9	182.6	233.6	101.5	100.8	85.7	54.0	17.4	7.1	2.0
5	1.2	6.0	19.4	5.2	4.7	3.3	14.3	5.7	27.6	203.5	390.4	192.4	114.3	58.6	52.4	12.0	13.3	18.6	6.8
6	1.6	0.3	4.1	19.5	7.9	5.1	6.6	3.0	7.0	34.6	87.3	197.2	111.8	67.8	27.3	9.9	8.4	13.1	13.1
7	1.4	0.2	3.9	4.2	21.8	6.1	0.7	2.0	5.3	8.9	24.0	31.2	108.3	51.9	40.5	5.6	4.7	6.2	8.2
8	0.8	0.2	0.7	4.0	0.5	32.3	1.0	3.1	9.9	3.6	4.2	11.0	25.7	50.5	34.6	6.3	2.2	2.6	3.6
9	0.4	0.2	0.8	0.7	0.2	0.3	6.1	2.2	10.0	4.3	8.2	4.1	6.4	12.5	22.6	3.8	4.5	2.2	2.1
10	0.1	0.1	0.2	0.0	0.0	0.0	0.1	8.3	3.8	8.1	3.8	3.8	2.5	2.3	13.4	3.6	1.5	2.2	1.0
11	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	2.8	7.2	5.6	1.6	0.8	1.0	1.4	0.6	5.8	2.1	1.7
0+	43.7	40.0	57.1	53.1	78.5	99.7	330.2	524.0	1004.2	1327.7	1073.7	1409.0	1075.8	1267.9	916.4	225.8	62.8	56.4	43.3

Table 4b. PERCENTAGE COMPOSITION OF THE INTERNATIONAL MACKEREL CATCH AT AGE 10/ 5/81

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	0.000	0.000	0.000	0.000	0.000	0.018	0.003	0.008	0.005	0.002	0.003	0.003	0.002	0.003	0.000	0.000	0.000	0.000	0.000
1	0.368	0.027	0.226	0.169	0.306	0.008	0.428	0.014	0.193	0.056	0.021	0.115	0.089	0.295	0.014	0.009	0.002	0.007	0.000
2	0.064	0.105	0.123	0.068	0.146	0.268	0.186	0.500	0.054	0.222	0.080	0.201	0.225	0.340	0.386	0.120	0.003	0.011	0.045
3	0.348	0.032	0.072	0.055	0.068	0.199	0.180	0.307	0.520	0.096	0.239	0.202	0.246	0.090	0.297	0.447	0.075	0.023	0.066
4	0.087	0.657	0.070	0.075	0.033	0.035	0.115	0.126	0.162	0.421	0.170	0.166	0.094	0.080	0.094	0.239	0.277	0.126	0.045
5	0.027	0.150	0.340	0.098	0.060	0.033	0.043	0.011	0.027	0.153	0.364	0.137	0.106	0.046	0.057	0.053	0.212	0.330	0.157
6	0.037	0.007	0.072	0.367	0.101	0.051	0.020	0.006	0.007	0.026	0.081	0.140	0.104	0.053	0.030	0.044	0.134	0.232	0.303
7	0.032	0.005	0.068	0.079	0.278	0.061	0.002	0.004	0.005	0.007	0.022	0.022	0.101	0.041	0.044	0.025	0.075	0.110	0.190
8	0.018	0.005	0.012	0.075	0.006	0.324	0.003	0.006	0.010	0.003	0.004	0.008	0.024	0.040	0.038	0.028	0.035	0.046	0.083
9	0.009	0.005	0.014	0.013	0.003	0.003	0.018	0.004	0.010	0.003	0.008	0.003	0.006	0.010	0.025	0.017	0.072	0.039	0.049
10	0.002	0.002	0.004	0.000	0.000	0.000	0.000	0.016	0.004	0.006	0.004	0.003	0.002	0.002	0.015	0.016	0.024	0.039	0.022
11	0.007	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.005	0.005	0.001	0.001	0.001	0.002	0.003	0.092	0.037	0.039
0+	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 4c. CANADIAN MACKEREL CATCH AT AGE ('000 fish) 10/ 5/81

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	0	0	0	922	0	254	0	0	0	0	0	0	0
1	22991	4049	15165	4365	0	5139	3223	5306	803	647	2	204	6
2	3821	18751	2733	4507	99	11550	9103	9302	10082	6243	182	480	1455
3	5522	12845	25117	1038	3199	5404	9987	4874	12910	19742	3831	1189	2156
4	3947	1442	6018	21917	4028	5227	5461	4346	5230	9902	14733	6615	1463
5	1505	661	1867	4648	18046	7825	4710	2634	3686	3222	11575	17202	5087
6	720	608	337	1069	3616	12485	4644	2811	1842	2248	6358	12321	9833
7	385	782	318	1344	3815	4658	5751	2038	2344	708	3157	5590	6148
8	885	313	1180	931	56	1552	1516	1463	1894	1262	1649	2282	2692
9	5566	329	1230	1146	397	469	641	308	1487	785	1402	1702	1604
10	52	6869	871	605	2	375	315	121	340	1204	1098	759	729
11	0	0	2371	2760	4965	523	339	96	215	302	1399	1698	1269
0+	45394	46649	57207	45252	38223	55461	45690	33299	40833	46265	45386	50042	32442

Table 4d. PERCENTAGE COMPOSITION OF THE CANADIAN MACKEREL CATCH AT AGE 10/ 5/81

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
0	0,000	0,000	0,000	0,020	0,000	0,005	0,000	0,000	0,000	0,000	0,000	0,000	0,000
1	0,506	0,087	0,265	0,096	0,000	0,093	0,071	0,159	0,020	0,014	0,000	0,004	0,000
2	0,084	0,402	0,048	0,100	0,003	0,208	0,199	0,279	0,247	0,135	0,004	0,010	0,045
3	0,122	0,275	0,439	0,023	0,084	0,097	0,219	0,146	0,316	0,427	0,084	0,024	0,066
4	0,087	0,031	0,105	0,484	0,105	0,094	0,120	0,131	0,128	0,214	0,325	0,132	0,045
5	0,033	0,014	0,033	0,103	0,472	0,141	0,103	0,079	0,090	0,070	0,255	0,344	0,157
6	0,016	0,013	0,006	0,024	0,095	0,225	0,102	0,084	0,045	0,049	0,140	0,246	0,303
7	0,008	0,017	0,006	0,030	0,100	0,084	0,126	0,061	0,057	0,015	0,070	0,112	0,190
8	0,019	0,007	0,021	0,021	0,001	0,028	0,033	0,044	0,046	0,027	0,036	0,046	0,083
9	0,123	0,007	0,022	0,025	0,010	0,008	0,014	0,009	0,036	0,017	0,031	0,034	0,049
10	0,001	0,147	0,015	0,013	0,000	0,007	0,007	0,004	0,008	0,026	0,024	0,015	0,022
11	0,000	0,000	0,041	0,061	0,130	0,009	0,007	0,003	0,005	0,007	0,031	0,034	0,039
0+	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table 5. Mackerel stratified mean catch (kg) per tow (retransformed) from USA spring bottom trawl surveys (strata 1-25, 61-76) and autumn (strata 1-42, 49) (from Anderson 1980)

YEAR	SPRING[1]	AUTUMN[2]
1963	-	.02
1964	-	<.01
1965	-	.03
1966	-	.04
1967	-	.15
1968	4.00	.10
1969	.06	.19
1970	2.04	.05
1971	1.97	.04
1972	1.33	.11
1973	.75	.05
1974	.77	.05
1975	.26	.01
1976	.32	.04
1977	.20	.04
1978	.45	.10
1979	.22	.06[3]
1980	.35	.06[3]

[1] Based on catches with No. 41 trawl; 1968-72 catches were with No. 36 trawl and were adjusted to equivalent No. 41 catches using a 3.25:1 ratio (41/36)

[2] Based on catches with No. 36 trawl

[3] Dr. E. D. Anderson (pers. comm.)
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, Massachussets 02543.

Table 6. Mackerel catch per standarized US day fished (Anderson, 1980).

YEAR	CATCH PER DAY (mt)
1964	.43
1965	.49
1966	.84
1967	1.75
1968	2.80
1969	1.92
1970	2.07
1971	1.29
1972	.84
1973	.53
1974	.17
1975	.53
1976	.59
1977	.52
1978	.48
1979	.69[1]
1980	1.35[1]

[1] Dr. E. D. Anderson pers. comm. op. cit.

Table 7. Calculation of relative effort index for mackerel based on the USA mackerel catch per standardized US day fished.

Year	International Catch (mt)	US Standard Catch/Day (mt)	Effort
1964	17574	.43	40870
1965	20420	.49	41673
66	26787	.84	31889
67	38617	1.75	22067
68	88591	2.80	31640
69	144860	1.92	75448
1970	246662	2.07	119160
71	389666	1.29	302067
72	425312	.84	506324
73	430437	.53	812145
74	347220	.53[1]	655132
1975	292427	.53	551749
76	245935	.59	416839
77	78328	.52	150631
78	34446	.48	71763
79	35658	.69	51678
1980	27409	1.35	20303

[1] average of 1973-75

Table 8. Atlantic mackerel mean weight at age (from Anderson 1980) and from this study. Weight is in kg.

Age	Stock[1]	Catch[2]	Canadian 1980 catch
1	.096	.143	.161
2	.178	.231	.387
3	.267	.320	.426
4	.353	.405	.509
5	.436	.480	.600
6	.507	.546	.641
7	.570	.601	.662
8	.622	.646	.701
9	.661	.683	.744
10	.695	.713	.770
11	.725	.737	.798

[1]As of January 1st.

[2]As of June 1st.

Table 9. Northwest Atlantic mackerel. Calculations of initial partial recruitment multipliers for VPA

Age	Initial P.R. used in VPA $F_{80} = 0.05$	Resulting 1978 F's at age	P.R. Multipliers[1]
1	.26	.001	.015
2	.60	.003	.047
3	.90	.018	.309
4	1.0	.033	.581
5	1.0	.04	.703
6	1.0	.057	1.0
7	1.0	.055	1.0
8	1.0	.054	1.0
9	1.0	.066	1.0
10	1.0	.028	1.0
11	1.0	.051	1.0

[1] Obtained by dividing the F's at age by 0.066. The highest F value in the table and assuming full recruitment at age 6.

Table 10. Northwest Atlantic Mackerel. Fine Tuning of VPA

YEAR	EFFORT	AVERAGE F AT AGES 6-7-8						
1964	40870	.523	.523	.523	.523	.524	.523	
1965	41673	1.409	1.411	1.411	1.412	1.412	1.411	
1966	31889	.270	.274	.276	.276	.277	.275	
1967	22067	.147	.157	.161	.163	.165	.160	
1968	31640	.031	.034	.035	.036	.036	.035	
1969	75448	.038	.041	.043	.043	.044	.042	
1970	119160	.155	.174	.183	.187	.192	.180	
1971	302067	.184	.214	.226	.233	.240	.222	1
1972	506324	.258	.304	.324	.335	.348	.319	
1973	812145	.207	.267	.297	.316	.337	.288	
1974	655132	.207	.284	.326	.355	.390	.313	
1975	551749	.134	.214	.267	.306	.359	.250	
1976	416839	.159	.272	.357	.424	.522	.329	
1977	150631	.043	.08	.110	.137	.180	.100	
1978	71763	.029	.055	.079	.100	.137	.071	
1979	51678	.027	.053	.078	.101	.145	.069	
1980	20303	.025	.05	.075	.100	.150	.066	
Starting F		.025	.05	.075	.10	.15	.066	
r		.74	.825	.822	.80	.76	.827	
Intercept		.045	.058	.059	.056	.046	.059	
Coefficient		2.80×10^{-7}	3.69×10^{-7}	4.4×10^{-7}	4.99×10^{-7}	5.91×10^{-7}	4.16×10^{-7}	
Predicted 1980 value		.050	.065	.068	.066	.058	.068	

[1] Period used to calculate the relationship.

Table 11. POPULATION NUMBERS (million fish). 10/ 5/81

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	863	447	419	536	1169	3107	9305	3678	3716	1814	2037	1706	2518	2375	661	345	422	2000	520
2	785	626	330	299	390	845	2301	6772	2718	2587	1280	1490	1126	1783	1440	479	254	312	1481
3	740	579	460	238	219	279	603	1652	4793	1967	1665	875	862	628	954	766	332	188	231
4	38	535	428	337	174	157	190	396	1086	3104	1348	1015	407	415	368	476	482	242	138
5	21	25	374	314	246	127	114	108	237	666	1823	843	553	215	221	200	306	342	173
6	5	15	13	261	228	178	91	72	75	152	321	1018	461	312	109	119	138	215	237
7	3	3	11	6	176	162	128	62	51	50	83	163	586	246	174	58	80	95	148
8	2	1	2	5	1	112	115	94	44	33	29	41	94	342	138	94	38	55	65
9	1	1	1	1	0	0	56	84	67	24	21	18	21	48	210	73	64	26	39
10	2	0	0	0	0	0	0	36	60	41	14	9	10	10	25	136	51	44	18
11	1	1	0	0	0	0	0	0	20	42	24	7	3	5	6	7	98	36	31
1+	2461	2232	2037	1997	2603	4968	12902	12954	12868	10481	8646	7187	6642	6380	4308	2754	2264	3555	3080
2+	1598	1785	1618	1461	1434	1861	3597	9277	9152	8666	6609	5480	4124	4005	3647	2409	1842	1556	2561
3+	813	1160	1289	1161	1045	1016	1296	2504	6433	6079	5329	3990	2998	2222	2206	1930	1589	1243	1079
4+	73	581	829	923	826	737	693	852	1641	4112	3664	3115	2136	1594	1252	1164	1257	1056	849

STOP SET
VPAJJ[56]

→56

Table 12. POPULATION BIOMASS (thousand mt). 10/ 5/81

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	83	43	40	51	112	298	893	353	357	174	196	164	242	228	63	33	40	192	50
2	140	111	59	53	69	150	410	1205	484	461	228	265	200	317	256	85	45	56	264
3	198	155	123	64	58	74	161	441	1280	525	445	234	230	168	255	205	89	50	62
4	13	189	151	119	61	56	67	140	383	1096	476	358	144	146	130	168	170	85	49
5	9	11	163	137	107	55	50	47	104	290	795	368	241	94	97	87	133	149	75
6	3	8	7	132	115	90	46	36	38	77	163	516	234	158	55	61	70	109	120
7	2	1	6	4	101	92	73	35	29	28	48	93	334	140	99	33	46	54	85
8	1	1	1	3	1	70	71	59	27	21	18	26	59	213	86	59	24	34	40
9	0	0	1	0	0	0	37	56	44	16	14	12	14	32	139	48	43	17	26
10	1	0	0	0	0	0	0	25	42	29	10	6	7	7	17	95	35	31	12
11	1	1	0	0	0	0	0	0	14	30	17	5	2	4	4	5	71	26	22
1+	451	520	550	563	626	887	1808	2397	2802	2747	2408	2047	1707	1507	1202	879	766	804	805
2+	368	477	510	512	513	589	914	2044	2445	2573	2213	1883	1465	1279	1139	845	725	612	755
3+	228	366	452	458	444	438	505	839	1962	2112	1985	1618	1265	962	882	760	680	556	491
4+	30	211	329	395	386	364	344	398	682	1587	1540	1384	1035	794	627	555	592	506	429

STOP SET
VPAJJ[59]

Table 13. FISHING MORTALITY 10/ 5/81

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	0.022	0.003	0.036	0.020	0.024	0.000	0.018	0.002	0.062	0.049	0.013	0.116	0.045	0.200	0.022	0.007	0.000	0.000	0.000
2	0.004	0.008	0.025	0.014	0.035	0.037	0.031	0.046	0.023	0.141	0.080	0.247	0.284	0.325	0.331	0.067	0.001	0.002	0.002
3	0.024	0.003	0.010	0.014	0.028	0.086	0.120	0.119	0.134	0.078	0.195	0.467	0.432	0.234	0.396	0.165	0.017	0.008	0.015
4	0.123	0.058	0.011	0.014	0.017	0.026	0.263	0.212	0.190	0.232	0.170	0.307	0.338	0.327	0.311	0.140	0.043	0.035	0.016
5	0.067	0.325	0.062	0.019	0.022	0.031	0.157	0.063	0.144	0.431	0.283	0.304	0.271	0.375	0.317	0.072	0.052	0.065	0.046
6	0.416	0.024	0.437	0.090	0.041	0.034	0.087	0.049	0.114	0.302	0.374	0.252	0.327	0.287	0.338	0.101	0.073	0.073	0.066
7	0.630	0.092	0.537	1.352	0.154	0.045	0.006	0.038	0.128	0.231	0.400	0.248	0.239	0.277	0.312	0.119	0.070	0.079	0.066
8	0.844	0.188	0.597	2.792	0.631	0.401	0.010	0.039	0.298	0.134	0.181	0.363	0.374	0.186	0.339	0.080	0.069	0.056	0.066
9	1.433	0.598	8.994	8.432	5.806	1.214	0.135	0.031	0.189	0.228	0.574	0.302	0.421	0.354	0.132	0.062	0.084	0.102	0.066
10	0.069	7.917	9.244	0.164	0.104	0.025	5.631	0.308	0.075	0.257	0.364	0.662	0.343	0.294	0.932	0.031	0.035	0.060	0.066
11	0.630	0.101	0.523	1.411	0.275	0.160	0.035	0.042	0.180	0.222	0.319	0.288	0.313	0.250	0.329	0.100	0.071	0.069	0.066
1+	0.388	0.847	1.861	1.302	0.649	0.187	0.590	0.086	0.140	0.210	0.268	0.323	0.308	0.283	0.342	0.086	0.047	0.050	0.043

Table 14a. Atlantic Mackerel Parameters for Y/R calculations.

	Partial Recruitment		Weights (kg)	
AGE	Cohort	Average Canadian	Canadian Fishery 1980	Catch (1962-79 average)
	A	B	C	D
1	.00027	.15	.161	.130
2	.023	.35	.387	.216
3	.22	.70	.426	.306
4	.25	1.00	.509	.392
5	.703	1.00	.60	.469
6	1.00	1.00	.641	.536
7	1.00	1.00	.662	.593
8	1.00	1.00	.701	.640
9	1.00	1.00	.744	.678
10	1.00	1.00	.770	.709
11	1.00	1.00	.798	.733

Table 14b. Atlantic mackerel yield per recruit calculations results (M = 0.3)

	$F_{0.1}$	Y/R (kg)	F_{max}	Y/R (kg)
A-C	.682	.143	13.35	.223
A-D	.581	.108	11.63	.129
B-C	.477	.170	2.118	.205
B-D	.402	.119	1.449	.137

Table 15. Northwest Atlantic mackerel projection results. Sizes of incoming year-classes equal to the GM mean year-class size at age 1 for the 1961 to 1975 year-classes (1585 x 10^6 fish) fishing at $F_{0.1}$.

	P.R. from cohort, weights from 1980 fishery		Average P.R., weights from 1980 fishery		P.R. from Cohort, average weights for 1962-79		Average P.R., average weights for 1962-79	
Year	Catch ('000 mt)	1+ Biomass ('000 mt)	Catch ('000 mt)	1+ Biomass ('000 mt)	Catch ('000 mt)	1+ Biomass ('000 mt)	Catch ('000 mt)	1+ Biomass ('000 mt)
1980	27	1292	27	1292	23	912	23	912
1981	231	1341	306	1341	168	1025	207	1025
1982	156	1401	271	1304	118	1027	185	975

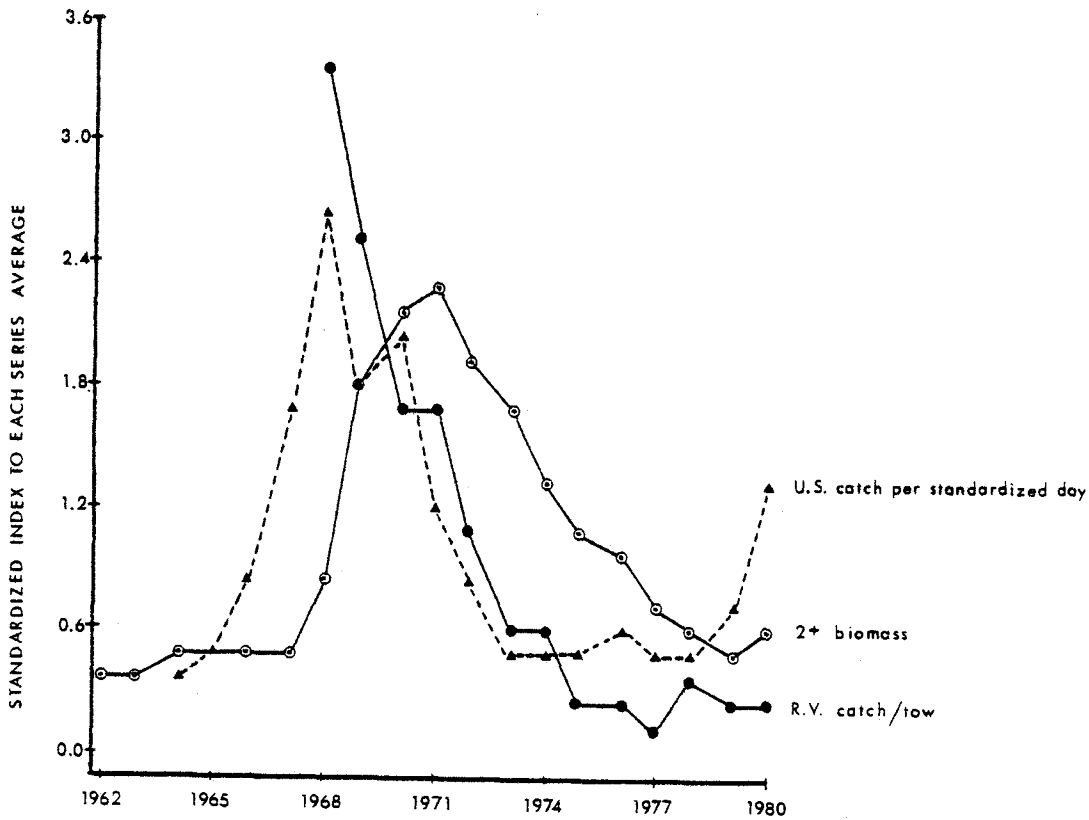

Figure 1. Mackerel 2+ biomass, U.S. catch per day, and R.V. c/tow standardized to their respective mean.

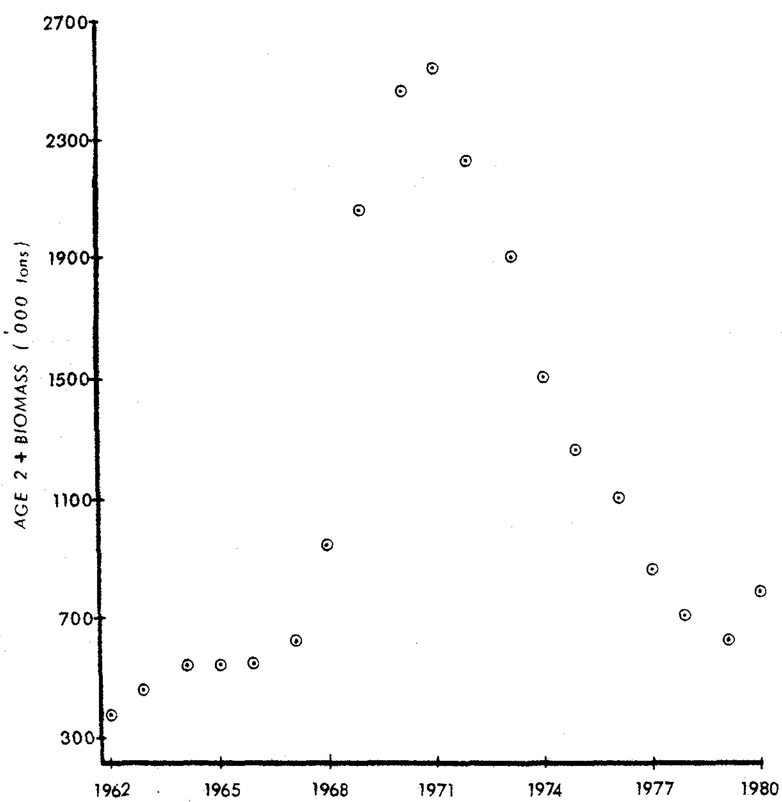

FIGURE 2. MACKEREL AGE 2+BIOMASS FROM VPA SINCE 1962.

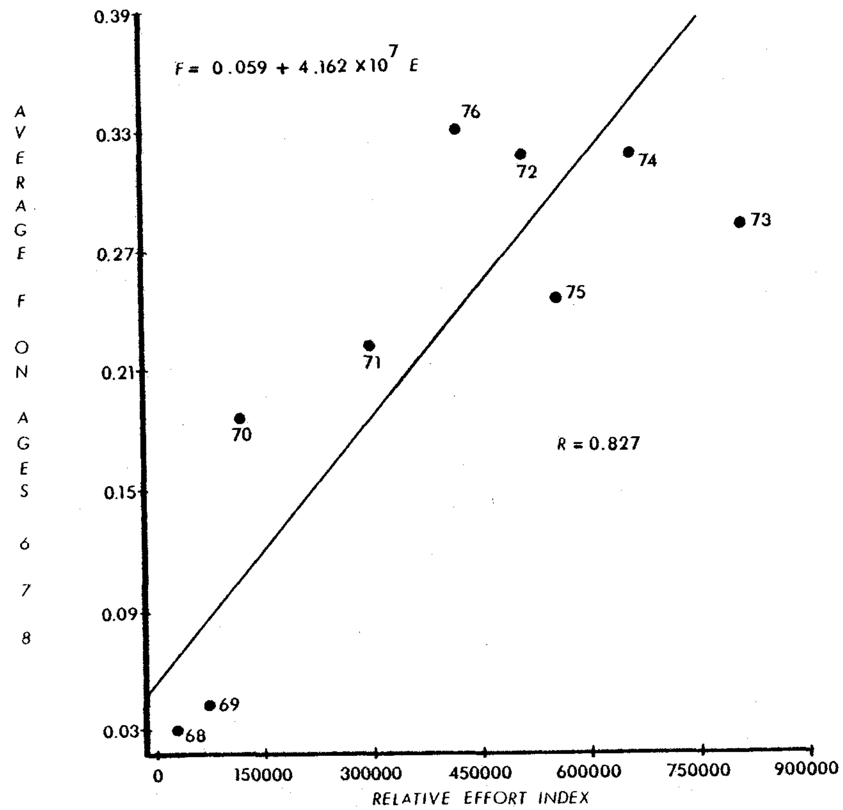

FIGURE 3. AVERAGE FISHING MORTALITY ON AGE 6-7-8 vs. RELATIVE EFFORT INDEX FOR FULLY RECRUITED F IN 1980 OF 0.066