BLACK SEA MACKEREL, *SCOMBER SCOMBRUS* LINNAEUS

Due to its great commercial importance, the mackerel has been intensively studied in almost all Black Sea countries. However, there exist many discrepancies concerning the species biology that impeded the solution of the problem of rational exploitation of stocks (Ivanov, 1966). Mackerel landings have dramatically declined and since 1968 vanished along the coasts of Bulgaria, Romania and the former USSR (**Table 76**). During the period 1952-1968 the former Soviet Union had the highest landings averaging 1503.4 tonnes, or 49.42% of the total mackerel catch in the Black Sea (3042.2 tonnes). The next in size were the Turkish and Bulgarian catches amounting to 908.2 tonnes (29.85%) and 561.2 tonnes (18.45%), respectively. The Romanian landings were the lowest: 69.5 tonnes (2.28%). **Table 76** also shows that since 1968, mackerel are harvested only off the Turkish coast. The mean annual catch during the period 1969-1992 was 215.5 tonnes, i.e. one fourteenth of those during 1952-1968.

The Black Sea mackerel spawns in the Sea of Marmara (Zernov, 1913; Netchaev, 1941; Numman, 1954; Demir and Acara, 1955). However, some authors have reported the occurrence of fish in ripe running condition in the Black Sea, also (Drensky, 1922; Nechaev, 1934, 1941; Zambriborz, 1955).

Migrations of mackerel can be inferred from fisheries' data, as well as from tagging of fish in the Bosporus and along the Bulgarian coast (Netchaev, 1933; Numman, 1956; Ivanov, 1966). Fishery statistical data show that the mackerel was fished heavily in the Bosporus in December-January and in April, off the Bulgarian coast in May-June and in November- December, and in the north-western part of the basin from July to September. The landings along the Anatolian and Caucasian coasts and in the Kertch Strait were insignificant and irregular (Ivanov, 1966). Therefore, the data given in **Table 77** are of great interest.

TABLE 76. Mackerel (*Scomber scombrus*) catches in the Black Sea (in tonnes) during the period 1942-1992

Years	Bulgaria	Romania	former USSR	Turkey	Total
1942	2025.0	113.0	161.7	1570.6	3870.3
1943	1868.0	5.0	183.0	1021.4	3077.4
1944	740.0	1.0	no data	2766.8	5009.6
1945	1026.0	50.0	286.0	1679.8	3041.6
1946	460.0	33.0	437.0	1843.7	2774.7
1947	326.0	20.0	386.0	933.0	1665.0
1948	344.0	29.0	141.0	1625.7	2139.7
1949	667.0	51.0	257.0	2159.0	3134.0
1950	1296.0	54.0	942.8	2716.8	5009.6
1951	318.0	10.5	380.0	1200.0	1908.5
1952	380.0	43.7	696.1	2274.5	3394.3
1953	941.0	31.6	1838.4	3260.0	6071.0
1954	1405.0	201.5	4871.9	1590.0	8068.4
1955	182.0	43.1	917.8	380.0	1522.9
1956	3.0	0.1	0.0	240.0	243.1
1957	4.0	1.2	0.0	70.0	75.2
1958	206.0	19.8	96.4	290.0	612.2
1959	438.0	68.7	1859.2	410.0	2774.9
1960	1526.0	104.1	1756.3	500.0	3886.4
1961	399.0	143.2	2091.9	500.0	3134.1
1962	672.4	233.4	1603.7	500.0	3011.5
1963	311.3	121.5	3223.3	960.0	4636.1
1964	1671.0	73.4	2156.2	550.0	4450.6
1965	974.5	96.1	2949.7	777.2	4797.5
1966	234.5	0.0	1327.4	2144.6	3706.5
1967	159.7	0.0	168.4	507.9	836.1
1968	32.3	0.0	0.0	485.0	517.3
1969	0.0	0.0	0.0	483.1	483.1
1970	0.0	0.0	0.0	522.9	522.9
1971	0.0	0.0	0.0	6.6	9.6
1972	0.0	0.0	0.0	175.7	175.7
1973	0.0	0.0	0.0	125.4	125.4
1974	0.0	0.0	0.0	0.2	0.2
1975	0.0	0.0	0.0	76.6	76.6
1976	0.0	0.0	0.0	4.1	4.1
1977	0.0	0.0	0.0	0.3	0.3
1978	0.0	0.0	0.0	30.1	30.1
1979	0.0	0.0	0.0	743.1	743.1
1980	0.0	0.0	0.0	4.0	4.0
1981	0.0	0.0	0.0	8.0	8.0
1982	0.0	0.0	0.0	9.0	9.0
1983	0.0	0.0	0.0	14.0	14.0
1984	0.0	0.0	0.0	23.0	23.0
1985	0.0	0.0	0.0	413.0	413.0
1986	0.0	0.0	0.0	247.0	247.0
1987	0.0	0.0	0.0	654.0	654.0
1988	0.0	0.0	0.0	534.0	534.0
1989	0.0	0.0	0.0	39.0	39.0
1990	0.0	0.0	0.0	56.0	56.0
1991	0.0	0.0	0.0	780.0	780.0
1992	0.0	0.0	0.0	224.0	224.0

TABLE 77. Turkish catches of mackerel (*Scomber scombrus*) in the Black Sea, Marmara, Aegean and Mediterranean during 1967-1992 (in tonnes)

Years	Eastern part of the Black Sea	Western part of the Black Sea	Black Sea Total	Sea of Marmara	Aegean Sea	White Sea (Mediter-ranean)	TOTAL
1967			836.1	2064.0	4.4	3.6	2580.0
1968			517.3	1131.8	21.4	12.9	1651.2
1969			483.1	115.7	20.9	3.6	620.8
1970			522.9	5.5	11.2	0.3	539.9
1971			6.6	16.4	14.7	0.0	37.7
1972	175.7	0.0	175.7	183.2	13.1	0.0	372.0
1973	0.0	125.4	125.4	194.1	78.8	0.6	398.9
1974	0.2	0.0	0.2	128.1	22.0	3.9	154.2
1975	64.8	11.8	76.6	366.3	40.2	5.3	488.4
1976	4.1	0.0	4.1	40.0	16.4	5.5	66.0
1977	0.0	0.3	0.3	88.4	31.6	75.2	195.5
1978	0.05	30.1	30.2	222.7	21.9	50.1	329.9
1979	664.9	78.2	743.1	42.9	16.1	12.4	814.5
1980	0.0	4.0	4.0	24.0	62.0	2.0	92.0
1981	0.0	8.0	8.0	51.0	134.0	7.0	200.0
1982	0.0	9.0	9.0	52.0	137.0	8.0	206.0
1983	0.0	14.0	14.0	263.0	154.0	14.0	445.0
1984	0.0	23.0	23.0	211.0	197.0	10.0	441.8
1985	0.0	413.0	413.0	948.0	62.0	30.0	1453.0
1986	37.0	210.0	247.0	168.0	108.0	0.0	523.0
1987	98.0	556.0	654.0	445.0	286.0	30.0	1385.0
1988	138.0	396.0	534.0	485.0	526.0	0.0	1545.0
1989	39.0	0.0	39.0	98.0	488.0	51.0	676.0
1990	12.0	44.0	56.0	266.0	455.0	0.0	777.0
1991	622.0	158.0	780.0	200.0	554.0	0.0	1534.0
1992	62.0	0.0	62.0	224.0	864.0	1.0	1151.0
Mean			237.1	336.0	133.7	12.5	719.3
%			32.96	46.71	18.59	1.74	100.0

As one can see during the period 1967-1992 the mean catch in the Black Sea was 237.1 tonnes (32.96%) and in the Marmara, Aegean and White Sea (Mediterranean), 336 (46.71%), 133.7 (18.59%) and 12.5 tonnes (1.74%), respectively, totalling 719.3 tonnes. It is quite curious that after the extinction of the species from the north-western and western parts of the Black Sea including the Bulgarian coast, landings in the eastern part (the Anatolian coast of Turkey to the east of Sinop) increased considerably. The averages catch in the eastern part (east of Sinop) was 99.1 tonnes (52.05%) during the period 1972-1992 while that in the western part (west of Sinop) was 91.3 tonnes (47.95%). From the data presented it is evident that mackerel is fished there even now although the species is considered extinct off Bulgarian, Romanian and the former USSR coasts. The problem is further complicated as the Black Sea mackerel does not differ morphometrically from the mackerel in the Atlantic and Mediterranean (Ivanov, 1966), i.e. they represent distinct populations of one and the same species (*Scomber scombrus*) characterised by their own biological parameters (age at first maturity, growth rate in length and weight, etc.). According to these peculiarities, the mackerel in the Black Sea, is more akin to that in the Mediterranean (Ivanov, 1966), making it almost impossible to distinguish them, especially in the Aegean Sea. The former has always been considered to spawn in Marmara and trophically to be a Black Sea stock. For this reason it is very hard without special research to establish the population, the mackerel caught at present belongs to the Black Sea or the Mediterranean stock, since the latter has entered the Black Sea in the past (Krotov, 1940; Zabriborz, 1955; Ivanov, 1966). The problem appears further more when taking into consideration that in these seas the Atlantic (Spanish) mackerel, *Scomber japonicus* is also present. From **Table 78** it is seen that during the period 1967-1992 the catches of the latter species ranged between 112.3 and 32 280.0 tonnes, with a mean of 8 674.5 tonnes, i.e. since 1975 this species has predominated over the other (*Scomber scombrus*) native Black Sea mackerel stock.

It is also apparent that Turkish catches of *S. japonicus* in the Black Sea were harvested in its western part (west of Sinop). Nevertheless off the Bulgarian coast, the catches were negligible and were not recorded in the fishery statistics. From our observations during the period 1985-1987, around 40-60 kg were occasionally captured. It is also interesting to note that since 1988, catches of these species have steadily decreased, accompanied by their increase in the Aegean and Mediterranean, although the common trend has been towards a decrease of total catches. This indicates that the fish enters the Black Sea when its biomass increases, as a result of which its capabilities for feeding in the Marmara, Aegean and Mediterranean are lower. The current species distribution, primarily in the eastern part of the Black Sea (east of Sinop), may be regarded as indirect evidence of the deteriorated conditions of life in the western part of the basin.

Table 79 shows the age composition of Black Sea *S. Scombrus* mackerel catches during the period 1952-1968. The latter is reestimated using Ukrainian data for the age composition of the former USSR catches, as well as the data of Ivanov (1966) and Ivanov and Beverton (1985). The Romanian and Turkish data relate to the years when the size composition of the catches had been determined . As was pointed out (**Table 77**) the combined catches of Bulgaria and the former USSR during the period 1952-1968 made up 68% of the total catch in the Black Sea, i.e. covered the major portion, thus making the age composition mentioned representative and allowing stock assessments to be carried out. The VPA with tuning of F_{ST} for the oldest age groups was used for this purpose.

TABLE 78.Mackerel (*Scomber japonicus*) catches in the Black Sea, Marmara, Aegean and Mediterranean during the period 1967 - 1992 (in tonnes)

Years	Eastern part of Black Sea	Western part of Black Sea	Black Sea Total	Sea of Marmara	Aegean Sea	White Sea	Grand total
1967			83.4	543.2	20.4	6.7	653.7
1968			5.6	259.6	25.1	45.6	335.9
1969			512.5	293.5	25.7	15.2	846.9
1970			7.3	38.1	62.7	4.2	112.3
1971			3.0	116.7	7.0	10.2	136.9
1972	2.4	240.6	243.0	349.0	68.5	25.5	686.0
1973	4.0	10.1	14.1	62.7	10.4	25.6	112.8
1974	0.0	10.5	10.5	357.3	12.0	20.0	399.8
1975	0.0	48.3	48.3	192.6	44.8	151.6	437.3
1976	13.3	3.1	16.4	545.7	591.0	170.1	1323.2
1977	0.0	24.8	24.8	1150.4	376.9	114.2	1666.3
1978	12.0	205.0	217.0	765.3	532.7	95.1	1610.1
1979	0.0	2134.6	2134.6	794.9	90.9	65.6	3086.0
1980	0.0	1936.0	1936.0	1971.0	364.0	67.0	4338.0
1981	0.0	1483.0	1483.0	3062.0	295.0	132.0	4972.0
1982	0.0	2687.0	2687.0	5548.0	537.0	239.0	9011.0
1983	0.0	646.0	646.0	2296.0	602.0	511.0	4055.0
1984	0.0	935.0	935.0	940.0	770.0	364.0	3099.0
1985	2262.0	12796.0	15058.0	4695.0	1669.0	818.0	22700.0
1986	594.0	8231.0	8825.0	15600.0	1634.0	1315.0	27400.0
1987	693.0	9597.0	10290.0	18190.0	2132.0	1348.0	31960.0
1988	1293.0	10517.0	11810.0	16500.0	2455.0	1515.0	32280.0
1989	416.0	10631.0	11047.0	11209.0	2158.0	1886.0	26300.0
1990	1264.0	5515.0	6779.0	5956.0	4002.0	2413.0	19150.0
1991	686.0	6744.0	7430.0	1476.0	3512.0	2260.0	14678
1992	0.0	3691.0	3691.0	2625.0	3345.0	5101.0	14762
Mean	344.7*	3718.4*	3305.3 4063.1*	3674.5	974.7	720.0	8674.5
%	8.48*	91.52*	38.10 100.00*	42.36	11.24	8.30	100.00

TABLE 79. Age composition in numbers (x 10^{-6}) of total mackerel (*S. scombrus*) catches in the Black Sea during 1952 - 1968

Years	0+	1,1+	2,2+	3,3+	4,4+	5,5+	CN	W
1952	9.9744	15.0062	3.3154	0.7941	0.1829	0.0034	29.2764	115.94
1953	29.1121	30.6204	3.1182	0.3580	0.0732	0.0076	62.7315	96.78
1954	9.2813	50.9778	7.5967	0.2420	0.4404	0.0047	68.5429	117.71
1955	0.0001	5.8123	4.1935	0.1894	0.0286	0.0000	10.2249	148.94
1956	0.6286	0.5013	0.2533	0.2989	0.0107	0.0000	1.6928	143.61
1957	0.3742	0.1783	0.0812	0.0367	0.0072	0.0000	0.6776	110.97
1958	5.7640	0.0650	0.0057	0.0013	0.0002	0.0000	5.8362	104.90
1959	14.8774	10.4684	1.0525	0.0396	0.0000	0.0000	26.4379	104.96
1960	14.1240	16.6310	1.7389	0.3525	0.0479	0.0000	32.8943	118.15
1961	5.8795	12.1199	5.2408	0.2153	0.0298	0.0077	23.4930	133.41
1962	8.6878	10.6650	5.1815	0.4831	0.0647	0.0065	25.0884	120.04
1963	2.4073	21.1060	6.0774	1.9727	0.1734	0.0167	31.7535	146.00
1964	14.9457	10.2886	9.1876	1.1514	0.0953	0.0098	35.6783	124.74
1965	11.6562	17.9387	4.9528	1.2281	0.3172	0.0423	36.1353	132.76
1966	1.1818	8.3870	10.0343	1.4409	0.8457	0.1721	22.0618	168.01
1967	3.3259	0.3459	0.6178	0.7261	0.6130	0.3764	6.0050	139.23
1968								

On the basis of the age compositon of the Bulgarian catches as well as of its predators' catches Ivanov and Beverton (1985) noted that during the periods 1954-1958 and 1959-1965 the Z, M and F values were as follows:

Total mortality	1954 - 1958 Age 1	2	3	4	1959 - 1965 Age 1	2	3	4
Z_t	1.83	2.53	3.22	-	1.14	1.97	2.93	4.02
M_t	1.39	2.08	2.77	-	0.69	1.52	2.48	3.57
F_t	0.44	0.45	0.45	-	0.45	0.45	0.45	0.45

The above values of F_t and M_t were obtained under the assumption that during the two periods the fishing mortality rates by age groups were equal.

According to the data of average age composition of the total catches, during the same two periods the Z values are the following:

Total mortality	1954 - 1958 Age 1	2	3	4	Mean	1959 - 1965 Age 1	2	3	4	Mean
Z_t	1.56	2.76	0.46	4.65	2.206	1.09	1.82	2.14	2.04	1.813

* The mean values of Z were estimated by linear regression between the mean numbers of the corresponding age groups.

From the above values, apparently the mean Z value was lower by roughly 0.393 during the second period. This may be explained in two ways. The first assumes that the decline in mean Z is due to the lowered fishing effort. The second assumes that the mean M decreased owing to the depletion of predators (bonito and blue fish to a certain extent). Ivanov and Beverton (1985) believed the second hypothesis, adopting a constant fishing mortality rate during the two periods of F = 0.45. From the author's data for M_t the mean values were retained to be 1 514 and 0.960 for the corresponding periods. Working on the mean Z values as estimated by us, it was established that the mean F values have been 0.692 and 0.853 respectively. These agree well with the fishery statistical data, showing that the average mackerel landings in the Black Sea during the two periods concerned have been 2 855.3 tonnes (1954-1958) and 3 813.0 tonnes (1959-1965). Consequently, the average catch has increased by 1.34 times during the second period and the mean value of F by 1.23 times. This is because the magnitude of the catches depends on the fishing effort, but also on the stock size. Therefore, when conducting the VPA for the different periods, initially the following mortality coefficients were used:

Mortality rates	1952-1953	1954-1958	1959-1965	1966-1968
F_{ST}	0.692	0.692	0.853	0.377
M	0.960	1.514	0.960	1.241
Z	1.652	2.206	1.813	1.618

* the average catch in the Black Sea during the period 1966 - 1968 was 1686.6 tonnes, by reason of which the figure 0.377 was applied as initial value for F_{ST}.

During the period 1966-1968 the average bonito landing was 18 545.5 tonnes, while in 1954-1958 it was 36 250.0 tonnes. Bearing in mind that the difference between the mean values of M during 1954-1958 and 1959-1965 was 0.55 it has been concluded that during 1966-1968 M was probably around 1 241.

The mean weights at age used are those of Ivanov (1966) for the spring when the species completes the corresponding biological age and therefore the estimated initial biomass coincides with the initial exploited biomass that is recruited in autumn. Hence, the estimated exploited stocks (B1+) in spring are almost equal to the spawning stock size.

Tables 80, 81 and **Figure 27** present the VPA results with tuning of the values for the oldest age groups.

TABLE 80. Stock assessment (in numbers x 10^{-6} and x 10^{-3} tonnes) of mackerel in the Black Sea in the period 1952 - 1968

Year	0+	1,1+	2,2+	3,3+	4,4+	5,5+	B0+	B1+
1952	219.23	37.79	13.03	1.42	0.29	0.01	27.84	4.82
1953	400.26	80.71	6.39	3.21	1.29	0.02	49.74	7.72
1954	103.98	140.84	14.70	0.79	1.06	0.01	24.22	13.30
1955	37.08	19.00	11.56	0.56	0.08	0.00	6.87	2.97
1956	43.62	8.16	1.91	0.95	0.05	0.00	5.61	1.03
1957	77.52	9.33	1.58	0.32	0.09	0.00	9.14	1.0
1958	140.19	16.90	1.98	0.31	0.05	0.00	16.36	1.64
1959	171.03	28.41	3.69	0.43	0.00	0.00	20.73	2.77
1960	208.42	56.72	5.00	0.81	0.14	0.00	27.16	5.27
1961	223.30	71.46	12.24	0.93	0.12	0.03	30.76	7.32
1962	415.48	82.01	20.31	1.79	0.23	0.03	52.88	9.26
1963	199.61	153.92	25.16	4.80	0.41	0.05	37.03	16.07
1964	229.46	75.00	46.59	6.14	0.74	0.06	36.62	12.53
1965	65.75	79.03	22.70	12.52	1.68	0.23	18.13	11.22
1966	5.81	18.40	19.92	5.83	4.07	0.46	6.13	5.52
1967	7.23	1.11	1.56	1.34	1.00	0.77	1.58	0.82
1968	33.76	0.60	0.16	0.17	0.07	0.03	4.33	0.11

TABLE 81. Fishing mortality rate of mackerel in the Black Sea during the period 1952-1968

Years	0+	1,1+	2,2+	3,3+	4,4+	5,5+	F_{1-4}
1952	0.0720	0.8499	0.4730	1.4730	1.8555	1.1673	1.1628
1953	0.1172	0.7757	1.1643	0.1848	1.5195	0.9208	0.9111
1954	0.1856	0.9858	1.7572	0.7838	1.2184	1.2184	1.1863
1955	0.0001	0.7812	0.9885	0.8999	0.9780	0.0000	0.9119
1956	0.0283	0.1250	0.2854	0.8142	0.4957	0.0000	0.4301
1957	0.0094	0.0376	0.1035	0.2466	0.1603	0.0000	0.1370
1958	0.0824	0.0075	0.0057	0.0079	0.0079	0.0000	0.0072
1959	0.1437	0.7770	0.5535	0.1517	0.0000	0.0000	0.3705
1960	0.1104	0.5733	0.7172	0.9849	0.6865	0.0000	0.7405
1961	0.0417	0.2981	0.9648	0.4257	0.4854	0.5437	0.5435
1962	0.0330	0.2217	0.4819	0.5182	0.5333	0.4391	0.4388
1963	0.0189	0.2350	0.4509	0.9072	0.9569	0.6383	0.6375
1964	0.1059	0.2351	0.3544	0.3346	0.2184	0.2862	0.2856
1965	0.3135	0.4183	0.3991	0.1634	0.3366	0.3299	0.3293
1966	0.4167	1.2304	1.4574	0.5265	0.4274	0.9114	0.9104
1967	1.2488	0.7101	0.9932	1.6622	2.1668	1.3879	1.3831
1968	0.1856	0.5336	0.7245	0.6729	0.7940	0.6812	0.6813

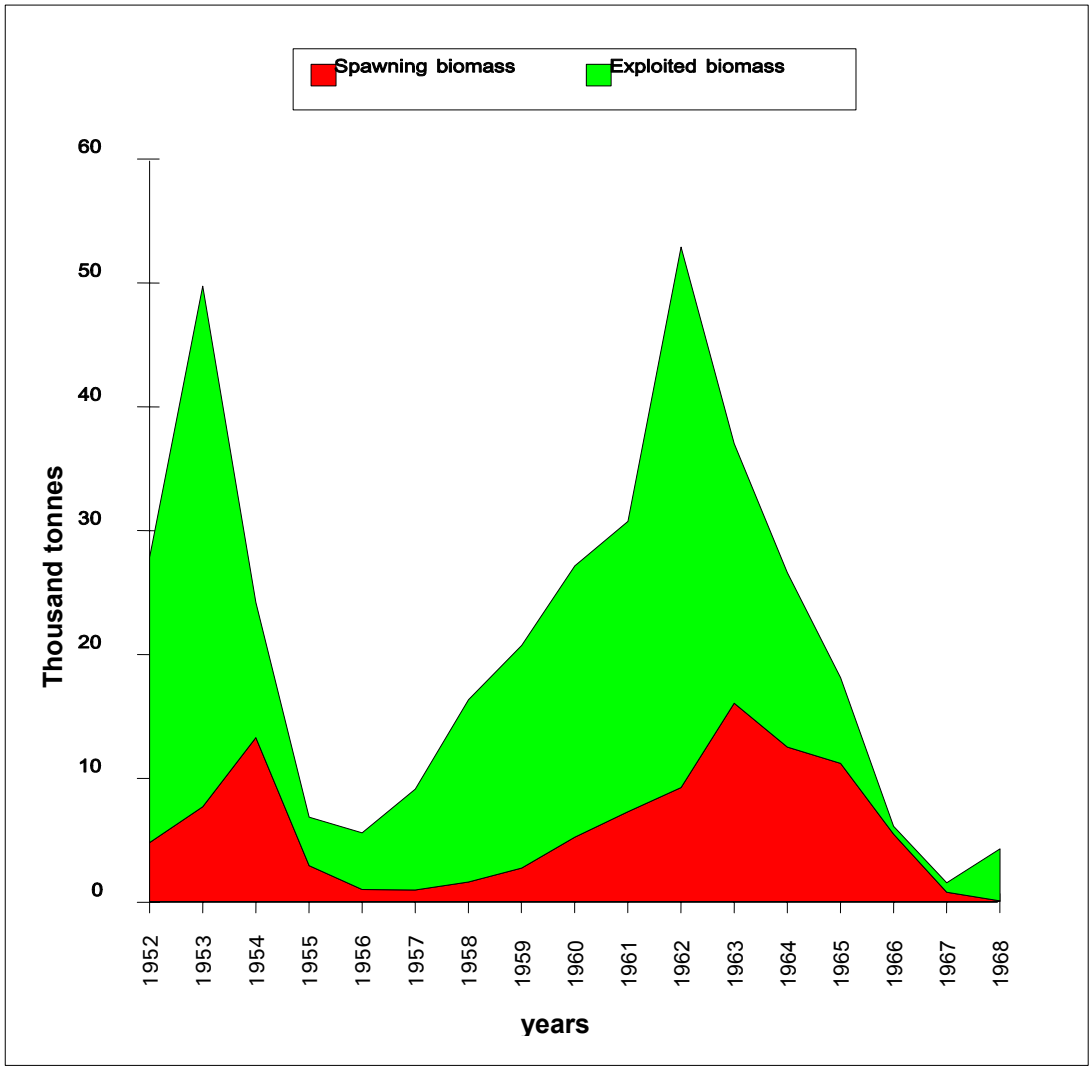

FIGURE 27. Spawning and exploited biomasses of mackerel in the Black Sea

From **Table 80** it can be seen that the initial (May-June) exploited stock (B_{1+}) varied between 112 (1968) and 16070 tonnes (1963) during the period 1952-1968. The same stock at the end of July-August receives recruits of mackerel offspring that are intensively caught off the former USSR, Romanian and Bulgarian coast, mainly during in the autumn (September-November). This stock moves along the coast of the above-mentioned countries towards its wintering grounds in the Sea of Marmara, where it spawns in the next year (April). The Black Sea mackerel population matures when the fish become one year old (Ivanov, 1966).

The strong variations of total exploited biomass (B0+) are due to the different abundance of the particular year classes. During the period under consideration this biomass has ranged from 1580 (1967) to 52800 tonnes (1962). The strongest year classes have been those of 1962 (415.5 x 10-6) and 1953 (400.3 x 10-6). Conversely, the 1966 and 1967 year classes have been low in abundance (5.81 x 10-6 and 7.23 x 10-6, respectively). Besides, these year classes have been subject to an intensive elimination from the commercial fishery. The values of F during the corresponding years were 0.4167 and 1.2488. This is also the period when the mackerel predators showed major growth in stock size (1968-1972).

In **Table 82** are shown the parameters in the following equations:

(12) R = a*B*exp (-bB)

(13) R = a*B*exp (-bB - cY)

(14) R = a + bB - cY

R - number of 0+ year old fish of mackerel; B - mackerel spawning biomass (Â1+); Y - bonito catch

TABLE 82. Values of the parameters "a", "b" and "c" in the equations (12) - (14)

Parameters	Equation 12	Equation 13	Equation 14
a	51.283445	53.696925	111.8385
b	0.1149556	0.1169585	13.0746
c		0.0022465	2.6223
Bopt	8.699	8.550*	
Rmax	164.117	168.897*	
r	0.4762	0.4864	0.4480
D%	22.68	23.66	20.07
S%	77.32	76.34	79.93

* - at Y = 0

In **Table 83** are given the parameters in the following equations:

(15) Y = a - bX1 ; (16) Y = a - cX2 ; (17) Y = a - dX3

(18) Y = a - bX1 - cX2 - dX3

(19) Y = a - bX1 - cX2 - dX3 - eX4 - fX5 -gX6

Y is the catch of mackerel during the year observed; X_1 is the catch of bonito during the previous year; X_2 is the catch of blue fish during the previous year; X_3 is the catch of mackerel during the previous year; X_4, X_5 and X_6 are the summarised catches, respectively of bonito, blue fish and mackerel during the previous 2 years.

TABLE 83. Values of the parameters in the equations (15) - (19)

Parameters	Equation (15)	Equation (16)	Equation (17)	Equation (18)	Equation (19)
a	429.1708	755.7533	382.6174	693.4530	721.8199
b	0.3410			0.3435	0.4523
c		1.4805		0.3244	0.2936
d			-0.3933	-0.3936	-0.6897
e					-0.0912
f					0.1978
g					0.1526
r	0.459	0.350	0.388	0.604	0.628
D%	21.07	12.25	15.05	36.48	39.44
S%	78.93	87.75	74.95	63.52	60.56

It is seen that mackerel catches increase inversely to the bonito and blue fish catches during previous years, and vice-versa. Hence, if the values of the catches of the three species are adequate to the size of their stocks, then Ivanov's and Beverton's (1985) conclusions, are true. According to these authors, strong declines of mackerel stocks have been recorded during 1892-1894, 1910-1914, 1935-1939, 1955-1958 and from 1966 till now. During the first 4 periods the decline of mackerel stocks has been caused by a considerable increase in the biomass of bonito and blue fish, which are predators of the youngest mackerel group (0+). However, during the periods pointed out, the blue fish stocks have been under the mean annual level, because of which the mackerel managed to overcome the negative consequences of growth in abundance, and biomass of bonito. Practically the almost complete disappearance of mackerel from the Black Sea after 1968 was determined by the coincident increase of bonito and the blue fish stocks and also by the increased fishing mortality on the recruitment, especially in 1966 and 1967. Since mackerel spawns in the Sea of Marmara that is much smaller than the Black Sea, the possibility of mackerel offspring avoiding its predator is considerably lower. Probably this is the major reason for the Black Sea mackerel population almost disappearing; in 1968 its total biomass (B0+) dropped to 4 332 tonnes. In the same year the offspring biomass was 4 220 tonnes and the bonito catch reached its maximum value (27 969.2 tonnes).

The disastrous decline of the mackerel stock and the almost full disappearance of this species in the Black Sea proves without any doubt, the necessity for a new ecological approach to exploitation of the living resources with a view to their preserving and recovery.

According to the theory of the dynamics of fish populations the total allowable catch (TAC) or maximum sustainable yield (MSY) are defined by means of theoretically derived values for $F_{opt} = F_{0.1}$ or F_{msy}. However, when estimating these mortality coefficients, the influence of various abiotic and biotic factors of the environment is rarely taken into consideration.

It is assumed (Prodanov, 1990) that the values of the coefficient mentioned are not constant, and depend on the size of the stock and on the abundance of its predators, since the latter ones have a direct effect on the level of its natural mortality. The same involves the environmental conditions which in some years are favourable for the reproduction and survival of new generations, and in others, just the contrary.

On the basis of Ivanov and Beverton's data (1985) for the level of the natural mortality coefficient and weight growth by age groups of mackerel during 1955-1958 and 1959-1965, it is established that in the first period $F_{0.1} = F_{msy}$ had to be 0.09 and in the second, 0.58 (See Figure 28 and box).

During years 1966-1969 the situation had been as in 1955-1958, i.e high predator abundance. The fishing mortality was 0.60-1.38 instead of 0.09. Hence, an irrational increase in the mackerel fishery at the time of increase of its predators is the main cause for dramatic collapse of mackerel stocks.

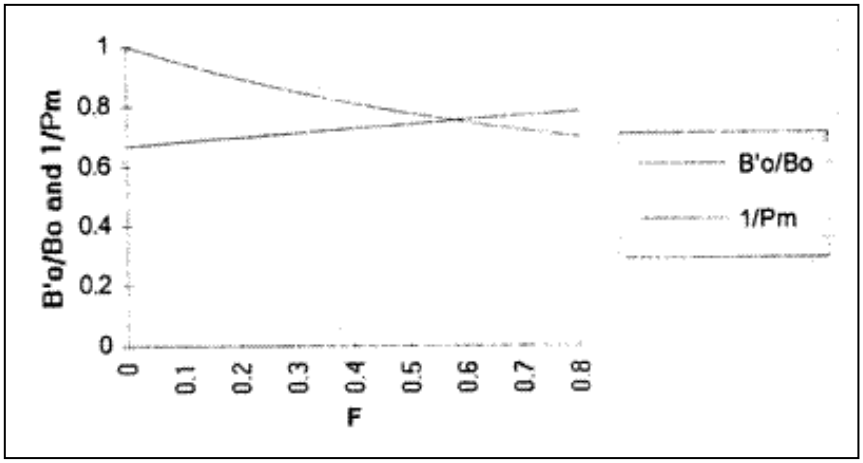

Fig. 28a Determining of the F_{opt} value at $C_{max} = Y_E$

The B'_0/B_0 ratio decreases with F at a constant recruitment with normal levels of natural mortality (1959-1965).

The $1/P_m$ ratio increases with F reflecting the growth in weight by age groups of mackerel during the period 1959-1965. $F_{opt} = 0.58$

For more details see Prodanov (1989).

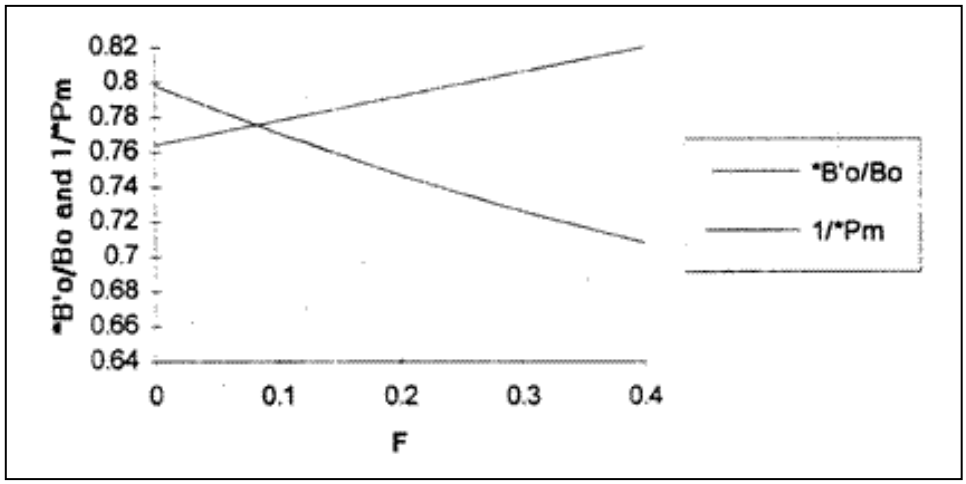

Figure 28b. Determining of F_{opt} value at $C_{max} = Y_E$

The $*B'_0/B_0$ ratio decreases at constant recruitment, increased natural mortality and increased weight growth by age groups.

The $1/*P_m$ ratio increases with F reflecting the weight growth by age groups of mackerel during the period 1954-1958.

$$F_{opt} = 0.09$$

The second case shows that with increase of natural mortality, the mackerel stock will begin to decline if the recruitment does not increase, despite increased growth in weight by age groups. In order to avoid the stock decline due to the negative impact of the predators in this situation, it is necessary to abruptly decrease the fishing mortality.