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Determination of the Black Sea anchovy stocks during the period 1968 - 1993 by Ivanov's combined method

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1. Introduction

Assessments of the Black Sea anchovy stocks exist in the literature, but for single years (Johanneson, Losse, 1977; Ivanov, Beverton, 1985; Ivanov, Mikhailov, 1991) and for some periods (Shlyakhov et al., 1990; Prodanov et al., 1997).

Recently, new data for the applicated fishing efforts on the anchovy stocks were reported (Bingel et al., 1995; Prodanov, Stoyanova, 1999). They, putted together with data of Age and Length structures of the catch allow computing the stocks size by using Ivanov's combined method (Ivanov, 1994; 1995) and which is the goal of the present paper. The methodology and computation are made by Ivanov and analysis and results summarise – by both authors.

1.1 Input statistical data

Data of catches in numbers by age groups, reported by Prodanov, Stoyanova (1999) are used, but recalculated in new way: fishing year includes catches from October to September (X - IX) – Table 1. The catches from May to September (V - IX) are presented separately – Table 2. For the initial individual weights (Wt) are used those, established by Prodanov et al. (1997), Prodanov, Stoyanova, Mikhailov (1998), but with some changes – Table 3. The number of fishing efforts (f – engine power), given by Bingel et al. (1995) and specified for all Black Sea countries by years from Prodanov, Stoyanova (1999) are recalculated in fishing years by a weighted with months number. One effort is equal to 1000 engine powers. The input data for fishing mortality coefficients of the anchovy exploited stocks (F_{ex}) are the rates of F_{0+-4+}, which are derived from Shlyakhov et al. (1990) and given in Table 34 of the Prodanov's et al. (1997) publication. The relationship between F_{ex} and f is showed from the following equation:

$$\lg F_{ex} = -0.944 + 0.498 \lg f \quad (1)$$

$$F_{ex} = 0.1138\, f^{0.498} \quad (1.1)$$

The mortality caused from one effort (catchability: $q=F_{ex}/f$) is expressed from equilateral hyperbola equation:

$$\lg q = -0.944 - 0.498 \lg f \quad (2)$$

$$q = 0.1138\, f^{-0.498} \quad (2.1)$$

Equations (1) and (2) are presented graphically on the Fig. 1 and the rates of F_{ex} by fishing years – on Table 4.

2. Combined method essence.

Method allows determination of the initial, average exploited and total stocks by years, age, generations and the difference between them (reserve availability or absence). The reserve is that part from one age group and from all, which was not joined to the exploited stock or it was in the stock, but later was left.

The following symbols are used:

- t – age, age group, year;
- C_N, C_B – catch in numbers and weight in 10^6 specimens and tons;
- f – number of fishing efforts (1 effort = 1000 engine powers);
- W, $\overline{W}$ -initial and average individual weights in g;
- N_{ex}, $\overline{N}_{ex}$, N, $\overline{N}$ - initial and average abundance of the exploited and total stocks, respectively in 10^6 or 10^9 specimens;

Table 1. Catches in numbers (C_N in 10^6 specimens), catches in tones (C_B in m.t) and average individual masses ($\overline{W}$ in g) of the Black Sea anchovy in the average exploited stocks ($\overline{N}_{ex}$, XI-X).

Fishing year (XI – X)	Catch	A G E					Total average
		0+ - 1+	1+ - 2+	2+ - 3+	3+ - 4+	4+ ….	
1968/69	C_N	4438.3	3192.1	972.2	309.7	93.4	9005.7
	C_B	21042.7	38248.6	15869.4	5889.0	1989.4	83039.1
	$\overline{W}$	4.741	11.982	16.323	19.015	21.3	9.221
1969/70	C_N	5445.1	3906.8	1190.9	387.1	120.7	11050.6
	C_B	25645.5	46594.3	19416.5	7355.6	2570.9	101582.8
	$\overline{W}$	4.709	11.926	16.304	19.002	21.3	9.193
1970/71	C_N	8899.5	4395.9	1459.7	407.1	123.0	15285.2
	C_B	41979.5	52407.6	23816.4	7738.7	2619.9	128562.1
	$\overline{W}$	4.717	11.922	16.316	19.009	21.3	8.411
1971/72	C_N	5070.9	5196.2	2617.0	757.4	113.8	13755.3
	C_B	23946.4	62061.6	42729.0	14402.9	2423.9	145563.8
	$\overline{W}$	4.722	11.944	16.327	19.016	21.3	10.582
1972/73	C_N	6808.1	4778.6	2564.4	756.3	198.6	15106.0
	C_B	32204.0	57027.3	41855.0	14383.5	4230.2	149700.0
	$\overline{W}$	4.730	11.934	16.322	19.018	21.3	9.910
1973/74	C_N	8263.5	6192.2	2368.1	854.4	145.7	17823.9
	C_B	38962.9	73923.0	38635.3	16239.8	3103.4	170864.4
	$\overline{W}$	4.715	11.938	16.315	19.007	21.3	9.586
1974/75	C_N	9782.2	6186.1	1897.1	491.7	130.8	18487.9
	C_B	46088.1	73667.4	30950.4	9349.9	2786.0	162841.8
	$\overline{W}$	4.711	11.909	16.315	19.015	21.3	8.808
1975/76	C_N	9027.4	5555.8	1781.9	750.1	173.9	17289.1
	C_B	42447.4	66138.0	29053.6	14254.7	3704.1	155597.8
	$\overline{W}$	4.702	11.904	16.305	19.004	21.3	9.0
1976/77	C_N	17926.6	7682.7	3129.0	616.1	144.3	29498.7
	C_B	84598.4	91699.0	51066.2	11715.8	3073.3	242152.7
	$\overline{W}$	4.719	11.932	46.320	19.016	21.3	8.209
1977/78	C_N	12198.7	7646.9	2365.3	473.2	97.1	22781.2
	C_B	57374.4	91204.1	38597.8	8993.9	2068.2	198238.4
	$\overline{W}$	4.703	11.927	16.318	19.007	21.3	8.702
1978/79	C_N	16024.6	7598.4	2033.7	504.2	118.9	26279.8
	C_B	75721.5	90910.9	33187.3	9593.2	2532.6	211945.5
	$\overline{W}$	4.725	11.964	16.319	19.027	21.3	8.065
1979/80	C_N	16020.4	9290.6	1849.5	384.3	124.4	27669.2
	C_B	75698.1	110696.5	30164.3	7310.3	2649.7	226518.9
	$\overline{W}$	4.725	11.915	16.309	19.022	21.3	8.187
1980/81	C_N	31418.7	14010.4	1894.2	636.0	175.5	48134.8
	C_B	149771.0	167114.5	30908.9	12089.5	3738.2	363622.1
	$\overline{W}$	4.767	11.928	16.318	19.009	21.3	7.554

Table 1. contiuied

Fishing year (XI – X)	Catch	A G E					Total average
		0+ - 1+	1+ - 2+	2+ - 3+	3+ - 4+	4+ ….	
1981/82	C_N	25213.4	15186.1	3106.5	757.5	201.1	44464.6
	C_B	119374.4	181115.0	50712.6	14404.1	4283.4	369889.5
	$\overline{W}$	4.735	11.926	16.325	19.015	21.3	8.319
1982/83	C_N	27149.9	15005.7	4037.1	1069.8	288.2	47550.7
	C_B	128536.1	178782.8	65857.1	20328.2	6138.7	399642.9
	$\overline{W}$	4.734	11.914	16.313	19.002	21.3	8.405
1983/84	C_N	20020.7	17090.8	5117.2	1918.7	296.6	44444.0
	C_B	94575.9	203958.0	83502.3	36494.9	6317.6	424848.7
	$\overline{W}$	4.724	11.934	16.318	19.021	21.3	9.559
1984/85	C_N	21390.0	23436.2	4492.9	1027.1	211.1	50557.3
	C_B	101214.3	279487.4	73362.9	19656.6	4496.4	478217.6
	$\overline{W}$	4.732	11.925	16.329	19.138	21.3	9.456
1985/86	C_N	10347.4	15446.5	3037.5	588.7	128.0	29548.1
	C_B	48687.3	183987.8	49528.1	11187.1	2726.4	296116.7
	$\overline{W}$	4.705	11.911	16.306	19.003	21.3	10.022
1862/87	C_N	18582.5	19503.2	3457.7	547.7	81.3	42172.4
	C_B	87618.3	232268.7	56401.3	10418.7	1731.7	388438.7
	$\overline{W}$	4.715	11.909	16.312	19.023	213	9.211
1987/88	C_N	19543.4	18253.8	3864.1	490.4	83.0	42234.7
	C_B	92351.2	217252.6	62995.5	9318.9	1767.9	383686.1
	$\overline{W}$	4.725	11.902	16.303	19.003	21.3	9.085
1988/89	C_N	20596.0	24771.7	3991.5	476.7	49.2	49885.1
	C_B	98693.2	294809.5	65063.5	9058.0	1048.0	468672.2
	$\overline{W}$	4.792	11.901	16.301	19.001	21.3	9.395
1989/90	C_N	9065.9	8080.3	1059.9	124.1	13.8	18344.0
	C_B	42623.2	96156.9	17276.5	2358.0	293.9	158708.5
	$\overline{W}$	4.701	11.900	16.300	19.0	21.3	8.290
1990/91	C_N	8614.8	2653.0	775.2	189.6	55.3	12287.9
	C_B	40492.9	31571.1	12635.8	3602.4	1177.9	89480.1
	$\overline{W}$	4.700	11.900	16.300	19.0	21.3	7.282
1991/92	C_N	9315.9	2893.4	731.0	178.6	0	13118.9
	C_B	43794.6	34433.5	11915.5	3393.4	0	93537.0
	$\overline{W}$	4.701	11.901	16.300	19.0	-	7.130
1992/93	C_N	17760.7	4519.6	1087.7	430.4	0	23798.4
	C_B	83493.5	53803.7	17729.7	8177.6	0	163204.5
	$\overline{W}$	4.701	11.905	16.300	19.0	-	6.858
1993/94	C_N	13601.2	8369.2	2235.0	437.8	0	24643.2
	C_B	63997.4	99605.1	36430.7	8318.3	0	208351.5
	$\overline{W}$	4.705	11.901	16.300	19.0	-	8.455
1994/95	C_N	20495.0	9297.7	3014.9	664.3	150.0	33621.9
	C_B	96419.7	110660.2	49144.6	12622.0	3195.0	272041.5
	$\overline{W}$	4.705	11.902	16.301	19.0	21.3	8.091

Table 2. Black Sea anchovy catches during the period V –X in in numbers (C_N in 10^6 specimens) and catches in tones (C_B in m.t).

Year (V – X)	Catch	AGE					Sum
		1 – 1+	2 – 2+	3 – 3+	4 – 4+	5 – 5+	
1969	C_N	39.2	119.4	16.7	4.1	-	179.4
	C_B	366.9	16.83.5	294.8	82.6	-	2427.8
1970	C_N	11.5	47.0	3.6	0.6	-	62.7
	C_B	107.6	662.7	63.5	12.1	-	845.9
1971	C_N	32.6	43.8	17.2	3.3	-	96.9
	C_B	305.1	617.6	303.6	66.5	-	1292.8
1972	C_N	24.3	103.1	53.3	10.7	-	191.4
	C_B	227.4	1453.7	940.7	215.6	-	2837.4
1973	C_N	44.2	73.6	41.0	12.0	-	170.8
	C_B	413.7	1037.8	723.6	241.8	-	2416.9
1974	C_N	26.7	107.2	26.1	5.4	-	165.4
	C_B	249.9	1511.5	460.7	108.8	-	2330.9
1975	C_N	24.0	24.0	20.5	6.6	-	75.1
	C_B	224.6	338.4	361.8	133.0	-	1057.8
1976	C_N	4.0	10.9	6.4	2.4	-	23.7
	C_B	37.4	153.7	113.0	48.4	-	352.5
1977	C_N	73.7	111.3	47.0	8.6	-	240.6
	C_B	689.8	1569.3	829.6	173.3	-	32620.0
1978	C_N	8.7	93.6	32.2	2.7	-	137.2
	C_B	81.4	1319.8	568.3	54.4	-	2023.9
1979	C_N	87.1	222.7	28.1	11.6	-	349.5
	C_B	815.3	3140.1	496.0	233.7	-	4685.1
1980	C_N	86.3	62.9	12.9	7.5	-	169.6
	C_B	807.8	886.9	227.7	151.1	-	2073.5
1981	C_N	451.3	177.6	24.8	4.8	-	658.5
	C_B	4224.2	2504.2	437.7	96.7	-	7262.8
1982	C_N	187.0	182.0	56.8	10.1	-	435.9
	C_B	1750.3	2566.2	1002.5	203.5	-	5522.5
1983	C_N	199.9	97.7	38.8	1.7	-	338.1
	C_B	1871.1	1377.6	684.8	34.3	-	3967.8
1984	C_N	102.7	262.5	68.1	34.4	-	467.7
	C_B	961.3	3701.2	1202.0	693.2	-	6557.7
1985	C_N	146.2	271.2	95.3	7.0	-	519.7
	C_B	1368.4	3823.9	1682.0	141.0	-	7015.3
1986	C_N	11.7	79.3	12.5	1.6	-	105.1
	C_B	109.5	1118.1	220.6	32.2	-	1480.4
1987	C_N	60.2	82.1	30.3	10.8	-	183.4
	C_B	563.5	1157.6	534.8	217.6	-	2473.5
1988	C_N	106.7	14.7	7.9	1.1	-	130.4
	C_B	998.7	207.3	139.4	22.2	-	1367.6
1989	C_N	406.0	12.0	1.5	0.6	-	420.1
	C_B	3800.2	169.2	26.5	12.1	-	4008.0
1990	C_N	2.9	0.6	0.1	0.1	-	3.7
	C_B	27.1	8.5	1.8	2.0	-	39.4
1991	C_N	0.7	0.2	0	0	-	0.9
	C_B	6.6	2.8	0	0	-	9.4
1992	C_N	2.1	0.9	0.1	0	-	3.1
	C_B	19.7	12.7	1.8	0	-	34.2
1993	C_N	3.9	0.7	0.1	0	-	4.7
	C_B	36.5	28.8	1.8	0	-	67.1
1994	C_N	15.4	5.3	0.2	0.1	-	21.0
	C_B	144.1	74.7	3.5	2.0	-	224.3
1995	C_N	20.0	8.0	1.3	0.3		29.6
	C_B	187.2	112.8	22.9	6.0		328.9

Table 3. Initial (W_t in g) and average ($\overline{W}$ in g) individual weights of the Black Sea anchovy

Data	Season (months)	Individual weight	AGE				
			0+ - 1 1 – 1+	1+ - 2 2 – 2+	2+ - 3 3 – 3+	3+ - 4 4 – 4+	4+ - 5 5 – 5+
Accepted by us data	X	W	4.7	11.9	16.3	19.0	21.3
	X – IV	$\overline{W}$	4.7	11.9	16.3	19.0	21.3
	V	W	6.83	11.9	16.3	19.0	21.3
	X	W	11.9	16.3	19.0	21.3	23.0
	V – IX	$\overline{W}$	9.36	14.1	17.65	20.15	22.15
	X – IX	$\overline{W}$	From table 1				
Prodanov et al, 1997, 1998 data	XI	W	4.7	11.9	16.3	19.25	21.3
	V	W	6.83	11.64	15.48	18.20	20.01

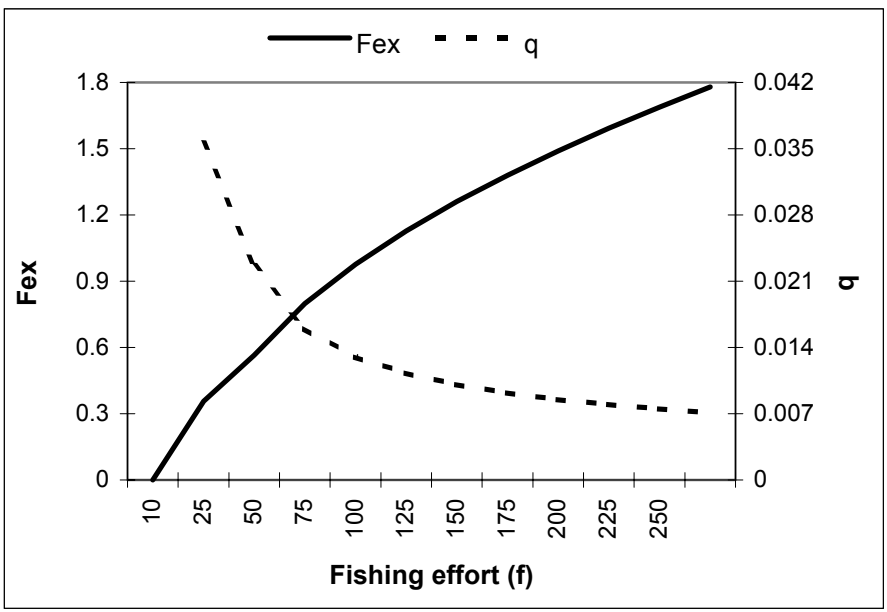

Fig. 1. Relationship between fishing effort (f), fishing mortality rate (Fex) and catchability coefficient (q) of the Black Sea anchovy

- B_{ex}, $\overline{B}_{ex}$, B, $\overline{B}$ - initial and average biomasses of the exploited and total stocks, respectively in tons or 10^3 tons;

- N_r, $\overline{N}_r$, B_r, $\overline{B}_r$ - initial and average abundance and biomass of the reserve in 10^6 specimens and tons;

- N_p, $\overline{N}_p$, B_p, $\overline{B}_p$ – initial and average spawning stocks - in numbers and their biomasses - in tons;

- Fex, Fex,N, Fex,B – fishing mortality coefficients of the average exploited stocks;

- F_N, F_B – fishing mortality of the average total stocks;

M – natural mortality coefficient: M for fishing year (X-IX) is 0.8, for spawning

Table 4. Fishing efforts number (f) and fishing mortality coefficient rates (F_{ex}) at age of 0+ - 4+ by fishing years (X – IX), calculated according equation 1.

Fishing year (X – IX)	Efforts number	F_{ex} (X – IX)	$q=F_{ex}/f$
1968/69	8.4	0.3283	0.039
1969/70	10.3	0.3634	0.035
1970/71	11.0	0.3755	0.034
1971/72	12.1	0.3938	0.033
1972/73	15.1	0.4396	0.029
1973/74	20.6	0.5133	0.025
1974/75	35.1	0.6692	0.019
1975/76	58.4	0.8624	0.015
1976/77	61.3	0.8835	0.014
1977/78	61.4	0.8841	0.014
1978/79	61.5	0.8849	0.014
1979/80	66.1	0.9173	0.014
1980/81	72.7	0.9616	0.009
1981/82	104.2	1.150	0.011
1982/83	123.3	1.249	0.010
1983/84	138.0	1.323	0.010
1984/85	136.7	1.317	0.010
1985/86	162.3	1.434	0.009
1986/87	162.5	1.435	0.009
1987/88	219.6	1.667	0.008
1988/89	257.8	1.806	0.007
1989/90	232.2	1.715	0.007
1990/91	200.0	1.592	0.008
1991/92	159.0	1.420	0.009
1992/93	129.8	1.283	0.010
1993/94	160.3	1.426	0.009
1994/95	209.6	1.629	0.008
1995/96	269.1	1.845	0.007
1996/97	176.7	1.496	0.008

season (V-IX) is 0.4;

- $Z_{ex} = F_{ex} + M$ – total mortality coefficient (X-IX);
- F_p, M_p, Z_p –mortality coefficients in the spawning season (V-IX);
- $U_{ex,N}$, U_N –utilization coefficients of the initial, exploited and total stocks, respectively in number;
- $U_{ex,B}$, U_B –utilization coefficients of the initial, exploited and total stocks respectively in biomass;
- S_{ex} – survival coefficient of the exploited stocks (X-IX);
- $1-S_{ex}$ – coefficient of total elimination from the exploited stocks;
- S, 1-S – survival and elimination coefficients when only natural mortality influence is considered;
- S_p, $1-S_p$ - survival and elimination coefficients of the spawning stocks;
- R – generation; it's marked with the calendar year of hatching;
- Fishing year from October to September is marked, for example as 1968/69;
- Σ – sum
- av – average.
- Calculation are made by generations and then the results are distributed by fishing years.

2.1. Computation of the exploited and total stocks by age groups and for each generation.

Table 5 is composed for each generation. For example, we use the generation of 1969. In columns 1 and 2 are given the fishing years and the age of generation at the beginning

(October) of the year, during which the generation was formed the stocks. Data for F_{ex} (column 3) are taken from Table 4. The following coefficients are calculated for the each age group: $Z_{ex} = F_{ex} + M$; $S_{ex} = e^{-Zex}$, $1-S_{ex}$ and $U_{ex} = \frac{F_{ex}}{Z_{ex}} (1-e^{-Zex})$. These coefficients are used for exploited stocks computing. The coefficients $S = e^{-M}$ and 1-S are applied to the reserve, which is eliminated only from the mortality of natural causes. The data for C_N, C_B and $\overline{W}$ (columns 11, 12 and 14 from Table 5) are taken from Table 1 in diagonal order and for W – from Table. 3 (October – start of the fishing year). Now we can start applying the original part of the combined method for generation stocks computing.

The initial abundance of the age group of generation is calculated from the equality:

$$N_{ex,t} = \frac{C_{N,t}}{U_{ex,N,t}} = \frac{C_{N,t}}{\frac{F_{ex,N,t}}{Z_{ex,t}}\left(1-e^{-Z_{ex,t}}\right)} \quad (3),$$

where: $C_{N,t}$ – from column 11, $U_{ex,N,t}$ – from column 8 of Table 5.

The data for $N_{ex,t}$ (column 11) and survival coefficient $S_{ex,t}$ (column 6) by ages are compared with $N_{ex,t+1}$ rates by inequality:

$$N_{ex,t}*S_{ex,t} > N_{ex,t+1} \quad (4)$$

The inequality implies that the exploited stock size at this age is equal to the total stock size ($N_{ex,t}=N_t$) and the reserve is zero ($N_{r,t} = 0$).

For the each other age group of the generation is received:

$$N_t = N_{ex,t} + N_{r,t} \quad (5)$$

If it is noted consecutively with t the age, at which $N_{ex,t}$ and $N_{r,t}$ are known, we can estimate the initial abundance of the reserve, respectively for the younger ($N_{r,t-1}$) and the older ($N_{r,t+1}$) age group, using the following equations:

$$N_{r,t-1}=(N_{ex,t} - N_{ex,t-1}*S_{ex,t-1}+N_{r,t})/S_{t-1} \quad (6)$$

$$N_{r,t+1} = N_{ex,t}*S_{ex,t} - N_{ex,t+1}+N_{r,t}*S_t \quad (7)$$

When the inequality 3 is noted at several ages, then all cases must be investigated consecutively and for the true age is selected that, at which $N_{r,t}$ has positive value.

When the inequality 3 is not observed at anyone age of the generation, it is accepted that it exists at the oldest age (4 years for anchovy – i.e $N_{r,4+} = 0$).

The calculations precision is checked with the equation:

$$N_{t+1} = N_{ex,t}*S_{ex,t} + N_{r,t}*S_t \quad (8)$$

For example, $N_{r,t} = 0$ is observed at the age of 2+ (Table 5) for the 1969's generation. All results for $N_{r,t}$ and N_t are given in columns 16 and 17 of Table 5.

The average abundance for each age of the generation is computed by expressions:

$$\overline{N}_{ex,t} = \frac{N_{ex,t}}{Z_{ex,t}}\left(1-e^{-Z_{ex,t}}\right) \quad (9)$$

where: $N_{ex,t}$ – from column 15, $1-e^{-Zex,t} = 1- S_{ex,t}$ – from column 7, Table 5.

$$\overline{N}_{r,t} = \frac{N_{r,t}}{M}\left(1-e^{-M}\right) \quad (10)$$

where: $N_{r,t}$ - from column 16, $1 - e^{-M} = 1- S$ – from column 10, Table 5.

$$\overline{N}_t = \overline{N}_{ex,t} + \overline{N}_{r,t} \quad (11)$$

The outputs for $\overline{N}_{ex,t}$, $\overline{N}_{r,t}$ and $\overline{N}_t$ of the 1969's generation are given in columns 18, 19 and 20 of Table 5.

The initial abundance at each age of the generation is equal to:

$$B_{ex,t} = N_{ex,t} * W_t \quad (12)$$

where: $N_{ex,t}$ – from column 15, W_t – from column 13, Table 5.

$$B_{r,t} = N_{r,t} * W_t \quad (13)$$

where: $N_{r,t}$ - from column 16, Table 5.

$$B_t = B_{ex,t} + B_{r,t} \quad (14)$$

The outputs for $B_{ex,t}$, $B_{r,t}$ and B_t of the 1969's generation are placed in columns 21, 22 and 23 of Table 5.

The average biomass at each age of the generation is equal to:

$$\overline{B}_{ex,t} = \overline{N}_{ex,t} * \overline{W}_t \quad (15)$$

where: $\overline{N}_{ex,t}$ – from column 18, $\overline{W}$ - from column 14 of Table 5.

$$\overline{B}_{r,t} = \overline{N}_{r,t} * \overline{W}_t \quad (16)$$

where: $N_{r,t}$ - from column 19, Table 5.

$$\overline{B}_t = \overline{B}_{ex,t} + \overline{B}_{r,t} \quad (17)$$

The outputs for $\overline{B}_{ex,t}$, $\overline{B}_{r,t}$ and $\overline{B}_t$ of the 1969's generation are given in columns 24, 25 and 26 of Table 5.

Table 5. Calculation of the exploited and total Black sea anchovy stocks – 1969's generation (abundance in 10^6 specimens, biomass – in tones, individual weight – in g)

Fishing year	t	F_{ex}	M	Z_{ex}	S_{ex}	1 - S_{ex}	U_{ex}	S	1 - S
1	2	3	4	5	6	7	8	9	10
1969/70	0+	0.3634	0.8	1.1634	0.31245	0.68755	0.214726	0.4493	0.5507
1970/71	1+	0.3735	0.8	1.1755	0.30870	0.69130	0.220828	0.4493	0.5507
1971/72	2+	0.3938	0.8	1.1938	0.30306	0.69694	0.229900	0.4493	0.5507
1972/73	3+	0.4396	0.8	1.2396	0.28952	0.71048	0.251958	0.4493	0.5507
1973/74	4+	0.5133	0.8	1.3133	0.26891	0.73109	0.285745	0.4493	0.5507
Σ	0+ - 4+								
Σ	1+ - 4+								

Table 5. Continued

C_N	C_B	W	$\overline{W}$	N_{ex}	N_r	N	$\overline{N}_{ex}$
11	12	13	14	15	16	17	18
5445.1	25645.5	4.7	4.709	25358	52617	77975	14986
4395.9	52407.6	11.9	11.922	19906	11658	31564	11707
2617.0	42729.0	16.3	16.327	11383	0	11383	6645
756.3	14383.5	19.0	19.018	3002	448	3450	1721
145.7	3103.4	21.3	21.3	510	560	1070	284
13360.0	138269.0			60159	65283	125442	35343
7914.9	112623.5			34801	12666	47467	20357

Table 5. Continued

$\overline{N}_r$	$\overline{N}$	B_{ex}	B_r	B	$\overline{B}_{ex}$	$\overline{B}_r$	$\overline{B}$
19	20	21	22	23	24	25	26
36220	51206	119183	247300	366483	70569	170560	241129
8025	19732	236881	138730	375611	139571	95674	235245
0	6645	185543	0	185543	108493	0	108493
308	2029	57038	8512	65550	32730	5858	38588
385	669	10863	11928	22791	6049	8200	14249
44938	80281	609508	406470	1015978	357412	280292	637704
8718	29075	490325	159170	649495	286843	109732	396575

2.2. Estimation of the anchovy exploited and total stocks by fishing years.

The data of stocks size by generations, given in the tables, similar to these for the 1969's generation (Table 5), are distributed by fishing years. Separated table is constituted for the each year (Table 6). For example, the output for 1969/70 stocks (Table 6). The values in columns 1 and 2 are the generations and the age at which, each of them form the stock of the corresponding fishing year. C_N and C_B rates (columns 15 and 16, Table 6) for this year must be equal to these, given in Table 1.

The following coefficients are estimated for each age group and totally:

$$F_{ex,N,t} = \frac{C_{N,t}}{\overline{N}_{ex,t}} \qquad (18)$$

$F_{ex,N,t}$ and F_{ex} for 0+ - 4+ and 1+ - 4+ age groups should be equal to F_{ex} for the year under consideration, given in Table 4 (some differences in the 4th and 3rd sign after zero are due to stocks abundance rounding off

Table 6. Black sea anchovy stocks in 1969/70 (October – September (X-IX); abundance in 10^6 specimens, biomass – in tones, individual weight – in g)

Generation R	t	N_{ex}	N_r	N	$\overline{N}_{ex}$	$\overline{N}_r$	$\overline{N}$
1	2	3	4	5	6	7	8
1969	0+	25358	52617	77975	14986	36220	51206
1968	1+	18194	8266	26460	10752	5690	16442
1967	2+	5546	247	5793	3278	170	3448
1966	3+	1803	0	1803	1066	0	1066
1965	4+	563	0	563	333	0	333
Σ, av	0+ - 4+	51464	61130	112594	30415	42080	72495
Σ, av	1+ - 4+	26106	8513	34619	15429	5860	21289

Table 6. Continued

B_{ex}	B_r	B	$\overline{B}_{ex}$	$\overline{B}_r$	$\overline{B}$	C_N	C_B
9	10	11	12	13	14	15	16
119183	247300	366483	70569	170560	241129	5445.1	25645.5
216509	98365	314874	128228	67859	196087	3906.8	46594.3
90400	4026	94426	53445	2772	56217	1190.9	19416.5
34257	0	34257	20256	0	20256	387.1	7355.6
11992	0	11992	7093	0	7093	120.7	2570.9
469341	349691	819032	279591	241191	520782	11050.6	101582.8
350158	102391	452249	209022	70631	279653	5605.5	75937.3

Table 6. Continued

$F_{ex,N}$	$F_{ex,B}$	F_N	F_B	$U_{ex,N}$	$U_{ex,B}$	U_N	U_B
17	18	19	20	21	22	23	24
0.3634	0.3634	0.1063	0.1063	0.2147	0.2152	0.0698	0.0700
0.3634	0.3634	0.2376	0.2376	0.2147	0.2152	0.1476	0.1480
0.3633	0.3633	0.3454	0.3454	0.2147	0.2148	0.2056	0.2056
0.3631	0.3631	0.3631	0.3631	0.2147	0.2147	0.2147	0.2147
0.3625	0.3625	0.3625	0.3625	0.2146	0.2144	0.2146	0.2144
0.3633	0.3633	0.1524	0.1921	0.2147	0.2164	0.0981	0.1240
0.3633	0.3633	0.2333	0.2715	0.2147	0.2169	0.1619	0.1678

with 1 million accuracy).

$$F_{ex,B,t} = \frac{C_{B,t}}{\overline{B}_{ex,t}} \quad (19)$$

$$F_{N,t} = \frac{C_{N,t}}{\overline{N}_t} \quad (20)$$

$$F_{B,t} = \frac{C_{B,t}}{\overline{B}_t} \quad (21)$$

$$U_{ex,N,t} = \frac{C_{N,t}}{N_{ex,t}} \quad (22)$$

$$U_{ex,B,t} = \frac{C_{B,t}}{B_{ex,t}} \quad (23)$$

$$U_{N,t} = \frac{C_{N,t}}{N_t} \quad (24)$$

$$U_{B,t} = \frac{C_{B,t}}{B_t} \quad (25)$$

$F_{ex,N}$ and $U_{ex,N}$ are the same for all age groups during the considered fishing year because $N_{ex,}$ $\overline{N}_{ex}$ and C_N have the equivalent

relative age structure (age composition in % is equivalent).

The coefficients $F_{N,t}$ and $U_{N,t}$ for total stocks have different rates depending on the age, except the ages at which $N_{r,t} = 0$. These discrepancies are caused by different reserve abundance ($N_{r,t}$), which is very high at age of 1+ (Table 6). The identity or difference between $F_{ex,N,t}$ and $F_{ex,B,t}$, $F_{N,t}$ and $F_{B,t}$, $U_{ex,N,t}$ and $U_{ex,B,t}$, $U_{N,t}$ and $U_{B,t}$ is associated with the accepted or estimated individual weights (W_t, $\overline{W}_t$), as it is seen from Table 3, the W_t values,
although different at ages, are accepted to be equal during the period October-April. At the beginning of May is observed rise only in W_1 value. Table 1 shows that $\overline{W}_t$ rates are almost similar to these of W_t, because the main quantity of the catches is realised during the period October-April.

The average coefficient values at the ages 0+ - 4+ and 1+ - 4+ are computed by equations (19-25), but the sum of catches is placed in the numerator and the sum of the corresponded stock – in the denominator.

2.3. Estimation of the spawning stock size.

Maturity age of the Black Sea anchovy is 1 year. The spawning period begins in the end of May and lasts to the middle of September, when the individual growth rate is highest.

2.3.1. Spawning stocks by age groups of the generation (R_p).

We compose Table 7 for each generation. The calculations will be presented for the 1969's generation (Table 7), which take part in reproducing process during the period May-September with 1-4 age groups. Data of $C_{N,t}$ (column 12, Table 7) are taken from Table 2 in diagonal order. In column 1 are placed calendar years (V-IX), in column 2 – age groups from 1 to 4 (May) and 1+ - 4+ (September). The abundance N_t in the end of September (column 11, Table 7) is known and can be taken from the tables of stocks by generations, for example – for the 1969's generation – Table 5, column 17, age groups 1+ - 4+. The W_t (May) and $\overline{W}_t$ (May-September) are taken from Table 3. The abundance of ages 1-4 (beginning of May) is unknown. It is estimated for each age by equation:

$$N_{p,t} = \frac{N_{t+,IX}}{S_{p,t,V-IX}} \qquad (26)$$

but in the following condition:

$$U_{p,t} * N_{p,t} = \overline{N}_{p,t} * F_{p,t} = C_{N,p,t} \qquad (27)$$

$C_{N,p,t}$ should be subtracted from $N_{p,t}$, but as we take into account the low rates of the catch quantities during the period May-September (V-IX) and the circumstance that the individuals, before catching, have been spawned, the correction is not necessary.

For the equations 26 and 27 solving, we proceed in this manner: give the certain value of $Z'_{p,t}$ ($Z'_{p,t} = 0.401$ is the used value) and find $F'_{p,t} = Z'_{p,t} - 0.5M$, $S_{p,t}$, $1 - S_{p,t}$, $U_{p,t}$, $N'_{p,t}$ and $C_{N,p,t}$, using the equations 26 and 27. After this procedure we find the quested rate of $F_{p,t}$ by the proportion:

$$F_{p,t} = \frac{C_{N,p,t} * F'_{p,t}}{C'_{N,p,t}} \qquad (28)$$

Results for $F_{p,t}$, $Z_{p,t} = F_{p,t} + 0.5M$, $S_{p,t} = e^{-Zp,t}$, $1 - S_{p,t}$, $U_{p,t}$ and $N_{p,t}$ are noted down in the Table 7, columns 3, 5, 6, 7, 8 and 13.

The average abundance ($\overline{N}_{p,t}$), initial biomass ($B_{p,t}$) and average biomass ($\overline{B}_{p,t}$) can be calculated by the expressions:

$$\overline{N}_{p,t} = \frac{N_{p,t}}{Z_p}\left(1 - e^{-Z_{p,t}}\right) \qquad (29)$$

$$B_{p,t} = N_{p,t} * W_{p,t} \qquad (30)$$

$$\overline{B}_{p,t} = \overline{N}_{p,t} * \overline{W}_{p,t} \qquad (31)$$

The results for $\overline{N}_{p,t}$, $B_{p,t}$ and $\overline{B}_{p,t}$ are filled in Table 7, columns 14, 15 and 16.

2.3.2. Estimation of the spawning stocks size by calendar years

We use the obtained results by generations (R_p). For each year Table 8 is composed. We will display the Table 8 filling with the stocks of 1969 (V-IX).

The average rate of $\overline{F}_p$ is:

$$\overline{F}_p = \frac{\sum C_{N,p,t}}{\sum \overline{N}_{p,t}} \qquad (32)$$

We enter the $\overline{F}_p$ value in the last row of the column 3, Table 8.

3. Results

The initial and average stocks by years and by generations during the period 1968/69 – 1992/93, fishing years (X-IX), totally for the age of 0+ - 4+ and separately for the 1+ -

Table 7. Anchovy spawning stocks by age groups and totally for the 1969's generation (May – September (V-IX),); abundance in 10^6 specimens, individual weight – in g)

Year (V-IX)	t (V-IX)	Z_p	0.5M	F_p	S_p	1 - S_p	U_p
1	2	3	4	5	6	7	8
1970	1 - 1+	0.4003	0.4	0.0003	0.67012	0.32988	0.000247
1971	2 - 2+	0.4031	0.4	0.0031	0.6623	0.33177	0.002551
1972	3 - 3+	0.4125	0.4	0.0125	0.662	0.338	0.010242
1973	4 - 4+	0.4091	0.4	0.0091	0.66424	0.33576	0.007469
Σ							

Table 7. Continued

W_p (V)	$\overline{W}_p$ (V - IX)	N_t (IX)	$C_{N,p}$ (V - IX)	N_p (V)	$\overline{N}_p$ (V - IX)	B_p (V)	$\overline{B}_p$ (V - IX)
9	10	11	12	13	14	15	16
6.83	9.36	31564	11.5	47120	38816	321707	363318
11.9	14.1	11383	43.8	17035	14021	202716	197696
16.3	17.65	3450	53.3	5211	4270	84939	75366
19.0	20.15	1070	12.0	1611	1322	30609	26638
				70959	58429	639971	663018

Table 8. Anchovy spawning stocks in 1969 (abundance in 10^6 specimens, biomass– in tones)

Generation R_p	t (V-IX)	Fp	N_p (V)	$\overline{N}_p$ (V - IX)	B_p (V)	$\overline{B}_p$ (V - IX)	$C_{N,p}$ (V - IX)
1	2	3	4	5	6	7	8
1968	1 - 1+	0.0012	39518	32548	269908	304649	39.2
1967	2 - 2+	0.0165	8786	7186	104553	101323	119.4
1966	3 - 3+	0.0075	2710	2226	44173	39289	16.7
1965	4 - 4+	0.007	714	587	13566	11826	4.1
av., Σ		0.0042	51728	42547	432200	457087	179.4

4+ are summarised by number in Table 9 and by biomass – in Table 10. The initial abundance and biomass by age groups at the beginning of the fishing year (October) are given in Tables 11 and 12, respectively. The average coefficients rates of the fishing mortality (F) and utilization (U) of the initial exploited and total stocks by number and by biomass at the ages 0+ - 4+ and 1+ - 4+, are given in Table 13. The fishing mortality coefficients of the total stocks by number and by age groups ($F_{N,t}$) are presented in Table 14. The total initial (May) and average (May-September) spawning stock sizes by years and generations, respectively by number and biomass at the age of 1-4, are generalized in Tables 15 and 16. The initial spawning stocks (May) by number ($N_{p,t}$) and biomass ($B_{p,t}$) by age groups 1-4 during the period 1968-1993 are given in Table 17.

In Tables 11, 12, 14 and 17 in diagonal order can be traced the corresponded quantities by generations.

4. Discussion

As we pointed, the stocks estimates are made with accuracy of 10^6 individuals and 1 ton, but in the summarized tables (9-12, 14-17) and in the paper, the reported quantities are in 10^9 individuals and 10^3 tons. The all relative quantities are obtained with higher accuracy. For brevity, we will refer to the initial exploited

Table 9. Initial exploited (N_{ex}), total (N), average exploited ($\overline{N}_{ex}$) and average total ($\overline{N}$) anchovy stocks for age groups 0+ - 4+ and 1+ - 4+ by years and generations – in 10^9 specimens 1968/69 – fishing year X-IX, 1968 – generation)

Fishing year	Years				Generations			
	N_{ex}	N	$\overline{N}_{ex}$	$\overline{N}$	N_{ex}	N	$\overline{N}_{ex}$	$\overline{N}$
1	2	3	4	5	6	7	8	9
1968/69								
0+ - 4+	45.8	90.2	27.4	58.0	51.4	105.4	30.5	67.6
1+ - 4+	23.2	25.0	13.9	15.1	28.9	40.2	17.0	24.8
1969/70								
0+ - 4+	51.5	112.6	30.4	72.5	60.2	125.4	35.3	80.3
1+ - 4+	26.1	34.6	15.4	21.3	34.8	47.5	20.4	29.1
1970/71								
0+ - 4+	69.2	123.3	40.7	77.9	76.4	124.2	44.6	77.5
1+ - 4+	28.9	43.3	17.0	27.0	36.1	44.3	20.9	26.5
1971/72								
0+ - 4+	59.8	108.5	34.9	68.4	51.1	99.4	29.3	62.5
1+ - 4+	37.8	45.5	22.1	27.4	29.1	36.3	16.4	21.4
1972/73								
0+ - 4+	60.0	120.0	34.4	75.7	56.2	120.6	31.4	75.7
1+ - 4+	32.9	39.8	18.9	23.6	29.2	40.4	15.9	23.7
1973/74								
0+ - 4+	62.4	102.8	34.7	62.6	52.4	87.3	28.2	52.2
1+ - 4+	33.5	44.0	18.6	25.9	23.4	28.5	12.1	15.6
1974/75								
0+ - 4+	52.7	97.7	27.6	58.6	49.8	99.8	25.3	59.7
1+ - 4+	24.8	30.8	13.0	17.2	21.9	32.9	10.7	18.2
1975/76								
0+ - 4+	41.1	98.6	20.0	59.6	46.4	98.7	22.5	58.5
1+ - 4+	19.7	32.1	9.6	18.1	25.0	32.1	12.1	17.0
1976/77								
0+ - 4+	69.0	110.5	33.4	62.0	65.9	108.4	31.8	61.1
1+ - 4+	27.1	33.4	13.1	17.5	23.9	31.2	11.5	16.6
1977/78								
0+ - 4+	53.3	103.2	25.8	60.2	52.3	105.2	25.2	61.6
1+ - 4+	24.8	31.4	12.0	16.6	23.8	33.3	11.4	18.0
1978/79								
0+ - 4+	61.4	120.0	29.7	70.0	64.9	127.6	31.1	74.3
1+ - 4+	24.0	32.3	11.6	17.3	27.4	39.9	13.0	21.6
1979/80								
0+ - 4+	63.1	152.1	30.2	91.4	76.2	169.3	35.8	99.8
1+ - 4+	26.6	37.6	12.7	20.3	39.7	54.8	18.4	28.8
1980/81								
0+ - 4+	106.5	206.0	50.1	118.6	111.0	222.4	50.7	127.4
1+ - 4+	37.0	51.3	17.4	27.2	41.5	67.6	18.0	36.0

Table 9. Continued

Fishing year	Years				Generations			
	N_{ex}	N	$\overline{N}_{ex}$	$\overline{N}$	N_{ex}	N	$\overline{N}_{ex}$	$\overline{N}$
1	2	3	4	5	6	7	8	9
1981/82								
0+ - 4+	87.9	195.8	38.7	112.9	89.5	190.2	38.7	108.0
1+ - 4+	38.1	63.0	16.7	33.9	39.7	57.4	16.8	28.9
1982/83								
0+ - 4+	89.5	190.2	38.1	107.3	91.7	180.7	38.5	99.7
1+ - 4+	38.4	60.9	16.3	31.8	40.5	51.4	16.8	24.3
1983/84								
0+ - 4+	81.0	184.5	33.6	104.9	85.7	180.8	35.5	100.9
1+ - 4+	44.5	56.7	18.5	26.8	49.2	52.9	23.3	22.9
1984/85								
0+ - 4+	92.4	162.2	38.4	86.4	72.9	148.1	29.7	81.5
1+ - 4+	53.3	56.1	22.1	24.1	33.9	42.1	13.5	19.2
1985/86								
0+ - 4+	51.6	147.2	20.6	86.4	59.1	153.1	23.4	88.1
1+ - 4+	33.5	42.4	13.4	19.5	41.0	48.4	16.2	21.3
1986/87								
0+ - 4+	73.6	157.2	29.4	86.7	68.4	153.4	26.2	84.7
1+ - 4+	41.1	48.5	16.4	21.5	36.0	44.6	13.3	19.2
1987/88								
0+ - 4+	68.3	157.0	25.3	86.4	72.2	153.6	26.2	82.2
1+ - 4+	36.7	45.5	13.6	19.6	40.6	42.1	14.5	15.6
1988/89								
0+ - 4+	77.7	104.9	27.6	46.0	46.6	75.7	16.7	36.5
1+ - 4+	45.6	45.6	16.2	16.2	14.5	16.9	5.3	6.7
1989/90								
0+ - 4+	29.3	51.0	10.7	25.7	20.9	45.9	7.8	25.3
1+ - 4+	14.8	17.8	5.4	7.4	6.5	12.6	2.5	7.1
1990/91								
0+ - 4+	20.3	51.7	7.7	29.3	22.4	57.6	8.7	32.9
1+ - 4+	6.1	12.1	2.3	6.5	8.1	18.0	3.3	10.1
1991/92								
0+ - 4+	23.0	68.3	9.2	40.4	29.8	77.2	12.1	44.7
1+ - 4+	6.7	15.7	2.7	8.9	13.5	24.6	5.5	13.2
1992/93								
0+ - 4+	44.1	101.7	18.5	58.2	53.5	110.8	21.9	61.3
1+ - 4+	11.2	22.8	4.7	12.7	20.6	31.9	8.1	15.9

Table 10. Initial exploited (B_{ex}), total (B), average exploited ($\overline{B}_{ex}$) and average total (B) anchovy stocks for age groups 0+ - 4+ and 1+ - 4+ by years and generations – in 10^3 tons (1968/69 – fishing year X-IX, 1968 – generation)

Fishing year	Years				Generations			
	B_{ex}	B	$\overline{B}_{ex}$	$\overline{B}$	B_{ex}	B	$\overline{B}_{ex}$	$\overline{B}$
1	2	3	4	5	6	7	8	9
1968/69								
0+ - 4+	419.3	643.9	252.9	408.9	509.4	858.1	301.9	543.4
1+ - 4+	313.5	333.7	188.8	205.6	403.6	551.9	237.8	340.1
1969/70								
0+ - 4+	469,3	819,0	279,6	520,8	609,5	1016,0	357,4	637,7
1+ - 4+	350,2	452,5	209,0	279,7	490,3	649,5	286,8	396,6
1970/71								
0+ - 4+	580,9	951,5	342,4	608,2	689,1	976,8	400,4	599,2
1+ - 4+	391,5	575,8	230,6	357,7	508,6	601,1	288,6	358,7
1971/72								
0+ - 4+	631,3	916,2	369,6	566,6	499,9	787,2	284,1	482,6
1+ - 4+	527,6	619,9	308,8	372,6	396,2	490,9	223,3	288,6
1972/73								
0+ - 4+	592,4	929,7	340,6	574,0	514,2	902,8	283,5	552,4
1+ - 4+	465,4	553,0	267,3	327,7	387,2	526,1	210,3	306,2
1973/74								
0+ - 4+	596,5	868,2	332,9	520,4	447,2	647,7	235,3	378,0
1+ - 4+	460,6	591,9	256,9	347,2	311,2	371,4	159,4	205,1
1974/75								
0+ - 4+	463,8	733,8	243,3	429,6	434,7	751,2	216,4	434,4
1+ - 4+	332,7	419,5	174,5	234,3	303,6	436,8	147,5	239,1
1975/76								
0+ - 4+	370,0	732,4	180,4	434,3	433,5	734,6	210,4	417,9
1+ - 4+	269,1	419,5	131,2	239,1	332,6	421,7	161,2	222,7
1976/77								
0+ - 4+	565,1	805,9	274,0	440,4	512,4	773,6	248,3	428,6
1+ - 4+	367,9	443,5	178,3	230,5	315,3	411,2	152,5	218,7
1977/78								
0+ - 4+	463,0	750,8	224,2	422,5	449,5	778,7	216,8	443,9
1+ - 4+	328,9	413,2	159,3	217,5	315,4	441,1	151,9	238,8
1978/79								
0+ - 4+	493,2	834,7	239,5	475,8	536,7	939,1	255,8	535,2
1+ - 4+	317,2	422,3	153,9	226,6	360,6	526,7	170,3	286,1
1979/80								
0+ - 4+	515,6	1026,7	246,9	600,2	690,5	1258,3	321,5	714,0
1+ - 4+	343,8	488,8	164,4	264,4	518,7	720,4	238,9	378,1
1980/81								
0+ - 4+	798,7	1386,8	378,2	787,2	882,5	1619,4	397,0	908,6
1+ - 4+	472,1	659,3	222,4	351,5	555,9	891,9	241,2	472,9

Table 10. Continued

Fishing year	Years				Generations			
	B_{ex}	B	$\overline{B}_{ex}$	$\overline{B}$	B_{ex}	B	$\overline{B}_{ex}$	$\overline{B}$
1	2	3	4	5	6	7	8	9
1981/82								
0+ - 4+	728,6	1435,5	321,7	812,1	763,0	1370,6	326,9	747,3
1+ - 4+	494,3	811,1	217,8	437,7	528,7	746,2	223,1	372,9
1982/83								
0+ - 4+	750,4	1415,1	320,0	779,6	767,4	1264,9	321,8	666,3
1+ - 4+	510,0	807,8	217,1	422,2	527,1	657,6	218,9	309,0
1983/84								
0+ - 4+	772,3	1353,6	321,1	723,1	788,6	1266,7	326,6	657,3
1+ - 4+	600,7	752,7	249,6	354,5	617,1	665,8	165,1	288,7
1984/85								
0+ - 4+	871,1	1220,6	363,1	605,2	619,4	1034,0	250,6	537,6
1+ - 4+	687,4	722,1	286,3	310,2	435,7	535,6	173,8	242,6
1985/86								
0+ - 4+	516,2	1034,9	206,5	563,9	606,1	1183,6	238,8	581,6
1+ - 4+	431,4	542,7	172,5	249,2	521,1	691,3	204,8	266,9
1986/87								
0+ - 4+	676,6	1247,8	270,7	580,1	610,7	1073,9	229,5	548,7
1+ - 4+	524,3	613,5	209,7	271,1	458,3	562,6	168,5	239,7
1987/88								
0+ - 4+	619,6	1101,8	230,2	563,5	641,3	1042,4	231,0	508,4
1+ - 4+	471,0	577,6	174,8	248,1	492,8	518,2	175,6	193,0
1988/89								
0+ - 4+	725,6	850,9	259,5	347,8	331,1	479,5	121,1	226,5
1+ - 4+	574,8	574,8	204,9	204,8	180,3	203,3	66,4	83,6
1989/90								
0+ - 4+	253,2	383,9	92,5	182,0	156,2	330,5	59,4	179,4
1+ - 4+	185,2	227,6	67,7	96,4	88,2	174,3	34,6	93,8
1990/91								
0+ - 4+	148,0	341,7	56,2	190,9	180,0	428,1	71,3	242,1
1+ - 4+	81,0	155,7	30,8	83,5	113,0	242,2	45,9	134,8
1991/92								
0+ - 4+	164,0	448,7	65,9	261,8	263,0	572,4	106,8	320,0
1+ - 4+	87,2	201,6	35,0	113,8	186,2	325,3	76,0	171,8
1992/93								
0+ - 4+	302,6	665,4	127,2	377,0	426,9	783,2	124,2	369,5
1+ - 4+	147,8	294,6	62,1	163,3	272,1	412,4	59,1	155,7

and total stocks during the periods 1968/69 and 1992/93 (X-IX), as we noted the years with 1968-1992 (X). During the investigated 25 years period we have noted:

- fluctuations in the initial exploited abundance (N_{ex}) from 20.3 (1990/91) to 106.5 (1980/81) at age of 0+ - 4+ and from 6.1 (1990/91) to 45.6 (1988/89) at age of 1+ - 2+ (Table 9);
- total initial abundance fluctuations (N) - from 51.0 (1989/90) to 206.0 (1980/81) at age of 0+ - 4+ and from 12.1 (1990/91) to 63.0 (1981/82) at age of 1+ - 4+ (Table 9);

Table 11. Initial exploited ($N_{ex,t}$) and total (N_t) anchovy stocks (October) for age groups by years (in 10^9 specimens)

Fishing year	A G E									
	0+		1+		2+		3+		4+	
X - IX	N_{ex}	N	N_{ex}	N	N_{ex}	N	N_{ex}	N	N_{ex}	N
1	2	3	4	5	6	7	8	9	10	11
1968/69	22.6	65.2	16.2	17.4	4.9	5.4	1.6	1.7	0.5	0.5
1969/70	25.4	78.0	18.2	26.5	5.5	5.8	1.8	1.8	0.6	0.6
1970/71	40.3	79.9	19.9	31.6	6.6	9.4	1.8	1.8	0.6	0.6
1971/72	22.1	63.0	22.6	30.2	11.4	11.4	3.3	3.3	0.5	0.6
1972/73	27.0	80.2	19.0	25.1	10.2	10.3	3.0	3.5	0.8	1.0
1973/74	28.9	58.8	21.7	31.7	8.3	8.3	3.0	3.0	0.5	1.1
1974/75	27.9	66.9	17.6	21.2	5.4	6.6	1.4	2.2	0.4	0.8
1975/76	21.5	66.6	13.2	23.9	4.2	5.7	1.8	1.8	0.4	0.7
1976/77	42.0	77.1	18.0	24.3	7.3	7.3	1.4	1.4	0.3	0.3
1977/78	28.5	71.8	17.9	23.6	5.5	6.2	1.1	1.4	0.2	0.3
1978/79	37.5	87.7	17.8	24.7	4.8	5.9	1.2	1.3	0.3	0.3
1979/80	36.6	77.9	21.2	29.5	4.2	6.4	0.9	1.4	0.3	0.3
1980/81	69.5	154.8	31.0	41.6	4.2	7.6	1.4	1.8	0.4	0.4
1981/82	49.8	132.8	30.0	50.3	6.1	10.1	1.5	2.2	0.4	0.4
1982/83	51.1	129.2	28.3	44.4	7.6	13.4	2.0	2.6	0.5	0.5
1983/84	36.5	127.9	31.2	41.7	9.3	10.9	3.5	3.6	0.5	0.5
1984/85	39.1	106.0	42.8	45.4	8.2	8.5	1.9	1.9	0.4	0.4
1985/86	18.1	104.7	27.0	34.8	5.3	6.3	1.0	1.1	0.2	0.2
1986/87	32.4	108.8	34.0	40.9	6.0	6.4	1.0	1.0	0.1	0.1
1987/88	31.6	111.5	29.5	37.8	6.2	6.7	0.8	0.8	0.1	0.1
1988/89	32.1	58.9	38.6	38.6	6.2	6.2	0.7	0.7	0.1	0.1
1989/90	14.5	33.2	12.9	14.4	1.7	2.8	0.2	0.5	+	+
1990/91	14.2	39.6	4.4	9.6	1.3	1.7	0.3	0.7	0.1	0.1
1991/92	16.3	52.6	5.1	12.7	1.3	2.7	0.3	0.3	0	0
1992/93	32.9	78.9	8.4	18.1	2.0	4.0	0.8	0.8	0	0

- fluctuations in the formed by generations initial exploited abundance (N_{ex}) from 20.9 (1989/90) to 111.0 (1980/81) at age of 0+ - 4+ and from 6.5 (1989/90) to 41.5 (1980/81) at age of 1+ - 2+ (Table 9);
- fluctuations in the formed by generations total initial abundance (N) from 45.9 (1989/90) to 222.4 (1980/81) at age of 0+ - 4+ and from 12.6 (1989/90) to 67.6 (1980/81) at age of 1+ - 4+ (Table 9);
- initial exploited biomass fluctuations (B_{ex}) - from 148.0 (1990/91) to 871.1 (1984/85) at age of 0+ - 4+ and from 81.0 (1990/91) to 687.4 (1984/85) at age of 1+ - 4+ (Table 10);
- total initial biomass fluctuations (B) - from 341.7 (1990/91) to 1435.5 (1981/82) at age of 0+ - 4+ and from 155.7 (1990/91) to 811.1 (1981/82) at age of 1+ - 4+ (Table 10);
- fluctuations of the formed by generations initial exploited biomass (B_{ex}) - from 156.2 (1989/90) to 882.5 (1980/81) at age of 0+ - 4+ and from 88.2 (1989/90) to 555.9 (1980/81) at age of 1+ - 2+ (Table10);
- fluctuations of the formed by generations total initial biomass (B) - from
- 330.5 (1989/90) to 1619.4 (1980/81) at age of 0+ - 4+ and from 174.3 (1989/90) to 891.9 (1981/82) at age of 1+ - 4+ (Table 10);
- fluctuations in the exploited abundance (N_{ex}) of the generations at age of 0+ from 14.2 (1990) to 69.5 (1980) and in the total abundance from 33.2 (1989/90) to 154.8 (1980/81) – Table 11.

Table 12. Initial exploited ($B_{ex,t}$) and total (B_t) anchovy stocks (October) for age groups by years (in 10^3 tons)

Fishing year X - IX	AGE									
	0+		1+		2+		3+		4+	
	B_{ex}	B	B_{ex}	B	B_{ex}	B	B_{ex}	B	B_{ex}	B
1	2	3	4	5	6	7	8	9	10	11
1968/69	105.8	306.2	193.0	207.5	80.5	87.9	29.9	32.2	10.1	10.1
1969/70	119.2	366.5	216.5	314.9	90.4	94.4	34.3	34.3	12.0	12.0
1970/71	189.4	375.7	236.9	375.6	107.7	153.2	35.0	35.0	11.9	12.0
1971/72	103.7	296.3	269.0	359.7	185.5	185.5	62.6	62.6	10.5	12.1
1972/73	127.0	376.8	225.7	298.7	165.9	167.5	57.0	65.6	16.8	21.3
1973/74	135.9	276.3	257.9	377.2	135.1	135.1	56.8	56.8	10.9	22.8
1974/75	131.1	314.3	209.9	252.3	88.2	107.7	26.6	42.3	7.9	17.1
1975/76	100.9	312.9	157.3	284.8	69.1	86.0	33.9	33.9	8.8	14.8
1976/77	197.2	362.4	214.0	289.6	119.3	119.3	27.4	27.4	7.2	7.2
1977/78	134.1	337.6	212.8	280.7	90.2	101.0	21.0	25.8	4.8	5.7
1978/79	176.1	412.4	211.4	294.5	77.5	95.9	22.4	25.2	5.9	6.9
1979/80	171.8	537.9	252.3	351.6	68.8	104.8	16.7	26.4	6.0	6.0
1980/81	326.6	727.5	368.8	494.6	68.3	123.1	26.7	33.3	8.3	8.3
1981/82	234.3	624.4	357.3	598.1	100.1	164.2	28.5	40.4	8.5	8.5
1982/83	240.3	607.3	336.3	528.2	123.9	217.8	38.3	50.2	11.6	11.6
1983/84	171.5	600.9	370.7	495.9	152.0	177.5	66.4	67.8	11.5	11.5
1984/85	183.7	498.4	509.7	540.5	133.8	137.8	35.7	35.7	8.2	8.2
1985/86	84.9	492.2	320.7	414.0	86.4	103.0	19.5	20.9	4.8	4.8
1986/87	152.3	511.3	404.8	486.4	98.3	104.5	18.1	19.5	3.0	3.0
1987/88	148.5	524.2	351.3	449.7	101.9	109.6	15.1	15.5	2.9	2.9
1988/89	150.8	276.2	459.3	459.3	101.4	101.4	14.1	14.1	1.6	1.6
1989/90	68.0	156.3	153.4	171.3	27.6	46.4	3.8	8.7	0.5	1.2
1990/91	67.0	186.0	52.2	114.3	20.9	26.1	6.0	12.5	1.9	2.8
1991/92	76.8	247.1	60.4	150.9	20.9	44.8	5.9	5.9	0	0
1992/93	154.8	370.8	99.7	214.8	32.9	64.7	15.1	15.1	0	0

The stock sizes by number and biomass had been high during the period 1979/80 – 1988/89 and the stocks sizes, formed by generations, was high during the period 1978-1987.

As it is seen from Fig. 2, the total initial biomass dynamics at age of 0+ - 4+, calculated by the combined method, in great extent coincides with results, obtained by Prodanov, Stoyanova, Mikhailov (1998) by VPA method. On the same figure are shown the obtained from us exploited biomasses at age of 0+ - 4+ (B_{ex}) and the results, computed by the modified from Chashchin Baranov's method (Prodanov et. al., 1997). On the figure, the data of these authors are shifted with 1-year right. The difference between B_{ex} and B at age of 1+ - 4+ (Fig. 3) is less compared with that at age of 0+ - 4+ (Fig. 2).

The spawning stock sizes totally by numbers and biomass (Tables 15 and 16) and by age groups (Table 17) had been high and sufficient for covering of natural reproduction during the period 1970-1988 and extremely low during the period 1989-1992, as it is seen on the Figure 4. The calculated dynamics of the initial anchovy spawning biomass (May) by the combined method is very similar to that, computed from Prodanov, Stoyanova, Mikhailov (1998) by the VPA method.

Table 13. Average coefficients of fishing mortality (F) and utilization (U) of the average exploited ($F_{ex,N}$; $F_{ex,B}$), initial exploited ($U_{ex,N}$; $U_{ex,B}$), average total (F_N; F_B) and initial total (U_N; U_B) anchovy stocks for age groups 0+ - 4+ and 1+ - 4+ by years and generations

Fishing year	$F_{ex,N}$	$F_{ex,B}$	F_N	F_B	$U_{ex,N}$	$U_{ex,B}$	U_N	U_B
1	2	3	4	5	6	7	8	9
1968/69								
0+ - 4+	0.3283	0.3283	0.1552	0.2031	0.1968	0.1981	0.0998	0.1290
1+ - 4+	0.3283	0.3283	0.3016	0.3016	0.1968	0.1978	0.1827	0.1836
1969/70								
0+ - 4+	0.3633	0.3633	0.1524	0.1921	0.2147	0.2164	0.0981	0.1240
1+ - 4+	0.3633	0.3633	0.2633	0.2715	0.2147	0.2169	0.1619	0.1678
1970/71								
0+ - 4+	0.3755	0.3755	0.1961	0.2114	0.2208	0.2213	0.1240	0.1351
1+ - 4+	0.3755	0.3755	0.2369	0.2421	0.2208	0.2211	0.1472	0.1504
1971/72								
0+ - 4+	0.3938	0.3937	0.2010	0.2569	0.2299	0.2306	0.1268	0.1589
1+ - 4+	0.3938	0.3938	0.3175	0.3264	0.2299	0.2305	0.1910	0.1962
1972/73								
0+ - 4+	0.4396	0.4396	0.1996	0.2608	0.2520	0.2527	0.1259	0.1610
1+ - 4+	0.4396	0.4396	0.3513	0.3585	0.2519	0.2524	0.2084	0.2125
1973/74								
0+ - 4+	0.5133	0.5133	0.2848	0.3283	0.2857	0.2864	0.1733	0.1968
1+ - 4+	0.5133	0.5133	0.3689	0.3799	0.2857	0.2864	0.2171	0.2228
1974/75								
0+ - 4+	0.6692	0.6692	0.3154	0.3507	0.3507	0.3511	0.1892	0.2219
1+ - 4+	0.6692	0.6692	0.5076	0.4983	0.3507	0.3509	0.2823	0.2783
1975/76								
0+ - 4+	0.8624	0.8624	0.2899	0.3583	0.4204	0.4205	0.1753	0.2125
1+ - 4+	0.8624	0.8624	0.4557	0.4733	0.4204	0.4205	0.2576	0.2697
1976/77								
0+ - 4+	0.8835	0.8837	0.4761	0.5498	0.4273	0.4285	0.2669	0.3005
1+ - 4+	0.8835	0.8838	0.6624	0.6836	0.4273	0.4283	0.3461	0.3553
1977/78								
0+ - 4+	0.8841	0.8841	0.3787	0.4692	0.4275	0.4282	0.2207	0.2640
1+ - 4+	0.8841	0.8841	0.6393	0.6477	0.4275	0.4283	0.3369	0.3409
1978/79								
0+ - 4+	0.8849	0.8849	0.3753	0.4455	0.4278	0.4297	0.2190	0.2539
1+ - 4+	0.8849	0.8849	0.5928	0.6011	0.4278	0.4295	0.3178	0.3226
1979/80								
0+ - 4+	0.9173	0.9173	0.3027	0.3774	0.4382	0.4393	0.1819	0.2206
1+ - 4+	0.9173	0.9173	0.5734	0.5705	0.4382	0.4387	0.3094	0.3085
1980/81								
0+ - 4+	0.9616	0.9616	0.4058	0.4619	0.1703	0.4553	0.2336	0.2622
1+ - 4+	0.9616	0.9616	0.6142	0.6083	0.4521	0.4530	0.3261	0.3244

Table 13. Continued

Fishing year	$F_{ex,N}$	$F_{ex,B}$	F_N	F_B	$U_{ex,N}$	$U_{ex,B}$	U_N	U_B
1	2	3	4	5	6	7	8	9
1981/82								
0+ - 4+	1.150	1.150	0.3936	0.4555	0.5058	0.5077	0.2271	0.2577
1+ - 4+	1.150	1.150	0.5682	0.5723	0.5058	0.5068	0.3058	0.3088
1982/83								
0+ - 4+	1.249	1.249	0.4431	0.5126	0.5310	0.5326	0.2501	0.2824
1+ - 4+	1.249	1.249	0.6409	0.6421	0.5310	0.5315	0.3348	0.3356
1983/84								
0+ - 4+	1.323	1.323	0.4239	0.5876	0.5486	0.5501	0.2409	0.3139
1+ - 4+	1.323	1.323	0.9104	0.9317	0.5486	0.5498	0.4310	0.4388
1984/85								
0+ - 4+	1.317	1.317	0.5849	0.7902	0.5472	0.5490	0.3117	0.3918
1+ - 4+	1.317	1.317	1.2105	1.2152	0.5472	0.5485	0.5196	0.5221
1985/86								
0+ - 4+	1.434	1.434	0.3419	0.5251	0.5731	0.5736	0.2008	0.2861
1+ - 4+	1.434	1.434	0.9827	0.9928	0.5732	0.5736	0.4525	0.4559
1986/87								
0+ - 4+	1.435	1.435	0.4864	0.6696	0.5734	0.5741	0.2682	0.3113
1+ - 4+	1.435	1.435	1.0985	1.1097	0.5733	0.5738	0.4868	0.4904
1987/88								
0+ - 4+	1.667	1.667	0.4889	0.6809	0.6184	0.6193	0.2690	0.3482
1+ - 4+	1.667	1.667	1.1551	1.1741	0.6184	0.6185	0.4992	0.5044
1988/89								
0+ - 4+	1.8060	1.8060	1.0834	1.348	0.6418	0.6459	0.4774	0.5508
1+ - 4+	1.8060	1.8060	1.8060	1.8060	0.6418	0.6437	0.6418	0.6437
1989/90								
0+ - 4+	1.715	1.715	0.7149	0.8721	0.6268	0.6268	0.3597	0.4134
1+ - 4+	1.715	1.715	1.2464	1.2048	0.6268	0.6268	0.3597	0.5100
1990/91								
0+ - 4+	1.592	1.592	0.4193	0.4688	0.6047	0.6047	0.2378	0.2619
1+ - 4+	1.592	1.592	0.5681	0.5865	0.6047	0.6047	0.3032	0.3146
1991/92								
0+ - 4+	1.420	1.420	0.3245	0.3572	0.5702	0.5702	0.1921	0.2085
1+ - 4+	1.420	1.420	0.4263	0.4372	0.5702	0.5702	0.2416	0.2467
1992/93								
0+ - 4+	1.283	1.283	0.4091	0.4329	0.5392	0.5394	0.2340	0.2453
1+ - 4+	1.283	1.283	0.4751	0.4883	0.5392	0.5394	0.2646	0.2705

The different categories of the fishing mortality are given in the Table 13. For brevity, we can consider only the annual changes in fishing mortality coefficients by numbers for the total (F_N) and exploited stocks ($F_{ex,N}$). Whereas $F_{ex,N}$ remains the same for all age groups during certain year (Table 13), then the F_N is very low at age of 0+ and higher at age of 0+ -4+ (Table 14). The average trends of $F_{ex,N}$ and F_N indicate sharp increase from 1968 to 1988, when reach their maximum rates (Figure 5). The lowest curves on the same figure show the almost completely coincidence between the average

Table 14. Fishing mortality coefficients of the total anchovy stocks (in numbers) by age groups (F_N) in the fishing years (X - IX)

Fishing year	AGE				
	0+	1+	2+	3+	4+
1968/69	0.1035	0.3023	0.2969	0.3019	0.3277
1969/70	0.1063	0.2376	0.3454	0.3631	0.3625
1970/71	0.1746	0.2228	0.2514	0.3756	0.3705
1971/72	0.1234	0.2818	0.3938	0.3938	0.3347
1972/73	0.1308	0.3166	0.4366	0.3727	0.3327
1973/74	0.2254	0.3265	0.5134	0.5134	0.2178
1974/75	0.2360	0.5290	0.5182	0.3771	0.2659
1975/76	0.2175	0.4020	0.5856	0.8622	0.4403
1976/77	0.4029	0.5878	0.8836	0.8839	0.8852
1977/78	0.2798	0.6082	0.7554	0.6674	0.7036
1978/79	0.3039	0.5673	0.6616	0.7525	0.7340
1979/80	0.2254	0.5854	0.5226	0.4984	0.9147
1980/81	0.3438	0.6413	0.4420	0.7059	0.9642
1981/82	0.3189	0.5596	0.5745	0.6508	1.1500
1982/83	0.3596	0.6491	0.5609	0.8312	1.2476
1983/84	0.2566	0.8478	1.0355	1.2800	1.3240
1984/85	0.3431	0.1971	1.2554	1.3170	1.3190
1985/86	0.1547	0.9553	1.0775	1.2826	1.4066
1986/87	0.2836	1.0649	1.2945	1.2708	1.4263
1987/88	0.2928	1.0969	1.4615	1.5871	1.6600
1988/89	0.6905	1.8060	1.8060	1.8060	1.822
1989/90	0.4977	1.4062	0.7490	0.4925	0.4452
1990/91	0.3772	0.5044	0.9850	0.5341	0.8641
1991/92	0.3000	0.3979	0.4504	1.4170	-
1992/93	0.3906	0.4440	0.4967	1.285	-
Average	0.2855	0.6215	0.7341	0.8329	0.7807

rates of F_N at age of 0+ -4+, calculated by two different methods – combined method and by VPA (P r o d a n o v, S t o y a n o v a, M i k h a i l o v, 1998). It has been wrong to conclude from $F_{N,0+-4+}$, that the anchovy stock is underexploited. The values of $F_{N,0+-4+}$ (the upper dotted curve) are more higher. According to Ivanov (1988), the admissible coefficient of fishing mortality (F_{ex}) is within the limits of 0.4-0.6 and only in exceptional cases when the stocks are very high, it can get near to $F_{ex} \leq 0.8$. The curves on Figure 5 and the data in Table 13 display, that F_{ex} has been inadmissible high during the period 1975/76 – 1992/93 – from 0.8624 to 1.806, and $F_{N,0+-4+}$ during the period 1983/84-1989/90 – from 0.9104 to 1.806.

The stocks (Fig. 2, 3 and 4) and fishing mortality coefficient (Fig. 5) dynamics allows to find out the reasons for decrease in anchovy stocks during the period 1989/90 – 1991/92, described earlier by P r o d a n o v et. al. (1997). The abundance (Tabl.15 and 17) and the biomass (Tabl.16) of the anchovy spawning stock in 1988 are still comparatively high, but their generation, at age of 0+ (October) is turned out over 2.5 fold lower then the previous year (Tabl.17: 1987 – 57.7; 1988 – 22.0). The main reason is the ctenophore *Mnemiopsis leidyi* impact (P r o d a n o v et. al., 1997). During the period November-March of the fishing year 1988/89, the anchovy stock is subject of overexploitation: $F_{N,0+}=0.6905$ (Tabl.14), $F_{N,0+-4+}=1.0834$, $F_{ex} = F_{N,1+-4+} = 1.806$ (Tabl.13, Fig.5).

Table 15. Total initial and average spawning anchovy stocks at age of 1 - 4 years by generations (in 10^9 specimens)

Year	BY YEARS			BY GENERATIONS	
	$\overline{F}_{p,N}$	N_p	$\overline{N}_p$	N_p	$\overline{N}_p$
1968	-	-	-	60.0	49.4
1969	0.0042	51.7	42.5	71.0	58.4
1970	0.0012	64.8	53.4	66.3	54.6
1971	0.0017	68.0	56.0	54.3	44.7
1972	0.0039	59.6	49.1	60.5	49.8
1973	0.0034	65.9	50.5	42.7	35.2
1974	0.0044	46.2	38.0	49.2	40.5
1975	0.0019	47.9	39.5	47.7	38.4
1976	0.0006	49.4	39.9	46.9	38.5
1977	0.0062	47.1	38.7	50.0	41.1
1978	0.0035	48.3	39.8	59.7	49.1
1979	0.0075	56.6	46.5	82.2	67.7
1980	0.0027	76.7	63.3	101.7	83.5
1981	0.0085	94.7	77.8	86.0	70.8
1982	0.0058	91.4	75.2	77.3	63.5
1983	0.0048	85.0	69.9	79.4	65.2
1984	0.0068	84.3	69.3	63.1	51.9
1985	0.0099	63.9	52.5	72.3	59.6
1986	0.0018	72.4	59.6	66.6	54.9
1987	0.0033	68.0	56.0	62.9	51.8
1988	0.0023	68.2	56.2	24.5	20.0
1989	0.0190	27.0	22.1	19.6	16.2
1990	0.0002	18.1	14.9	26.9	22.2
1991	0.0001	23.1	19.0	36.7	30.3
1992	0.0001	34.0	28.1	47.6	39.3
1993	0.0001	46.6	38.4		

The anchovy exploited and total stocks decline sharply during the period 1989/90 – 1991/92 (Tabl.9 and 10) and the spawning stocks – during the period 1989–1992 (Tables 15 and 16). The offsprings of these years were turned out with low abundance (Table 17). The stock recovering begins from 1992-1993 (Fig. 2, 3 and 4) and lasts during the next years (P r o d a n o v, S t o y a n o v a, M i k h a i l o v, 1998).

The accuracy of the obtained results for stock dynamics and fishing mortality coefficient rate depends on precise determination of the age composition of the catches.

The age composition of total catches (Table 2) and accepted values of F_{ex} (Table 4) specify functionally the exploited ($N_{ex,t}$) and total (N_t) abundance of the age groups. The exploited abundance towards to the total abundance, averaging for 25 years, has been represented in %: 0+ - 37.9, 1+ -72.1, 2+ - 80.3, 3+ - 86.9 and 4+ - 86.9 (Table 18). The equality $N_{ex,t}=N_t$. has been noted by agegroups, as follows: 4+ - 12 times, 3+ - 10 times, 2+ - 4 times, 1+ - once (1988) and 0+ - never. It is evident that, if the part of 0+ aged individuals increases, the total stocks number (N_t) will drop, approximating to the $N_{ex,t}$. Down bellow we will discuss some data for the relative share of the individuals at ages 0+ and 1 year in the catches. For brevity, the share of 1+ - 4+ aged individuals hasn't been pointed. We haven't bend the share of 0+ and 1 years aged individuals in percents for all years, derived from Tables 1 and 2, but only

Table 16. Total anchovy spawning stocks at age of 1-4 years by years and generations (in 10^3 tons)

Year	BY YEARS		BY GENERATIONS	
	B_p	$\overline{B}_p$	B_p	$\overline{B}_p$
1968	-	-	546.4	564.5
1969	432.2	457.1	640.0	663.0
1970	550.1	580.7	588.6	612.1
1971	604.0	631.4	478.7	499.1
1972	553.3	568.1	495.6	527.7
1973	575.7	601.1	360.0	380.5
1974	412.7	428.0	417.3	440.4
1975	408.5	430.0	397.4	413.3
1976	419.6	435.6	392.2	414.6
1977	394.3	416.7	423.9	446.1
1978	400.0	424.5	507.2	533.8
1979	461.8	491.2	686.2	727.3
1980	613.3	659.4	855.0	901.5
1981	763.4	815.3	702.2	796.1
1982	774.6	816.2	612.9	657.5
1983	723.9	809.2	609.0	660.5
1984	676.3	723.0	493.3	532.6
1985	507.1	543.2	556.9	605.2
1986	560.8	608.1	511.1	556.3
1987	530.5	573.6	460.8	508.4
1988	525.1	570.7	180.6	197.5
1989	213.5	228.5	166.1	175.5
1990	148.2	157.9	234.0	245.2
1991	178.0	193.6	308.8	327.2
1992	273.8	293.9	386.9	414.1
1993	375.3	402.7		

for certain periods for which Ivanov, Beverton (1985) reported summarised data of USSR authors for Western and Eastern parts of the Black Sea. The main part of 0+ (autumn) and 1-years old (spring) in % had been:

Late autumn (age 0+)

USSR data	Western part	Eastern part
1955-1973	58.2	68.0
1974-1979	75.4	83.3

Data from Table 1 for all countries catches:

1968-1973	47.5
1974-1979	56.4

spring (age of 1 year)

USSR data	Western part	Eastern part
1955-1973	50.2	68.6
1974-1979	70.6	76.3

Data from Table 2 for all countries catches:

1969-1973	22.5
1974-1979	21.1

The average catch in % at age of 1 year had been: 45.4 – in spring catches of Bulgaria during the period 1952-1979 and 30.3 - in Romanian spring-summer catches during the period 1956-1979 (Ivanov, Beverton, 1985).

The calculated average coefficient $F_{0+ - 4+}$ during the period 1979/80 – 1989/90 by USSR data is 1.545 (Prodanov et al., 1997). If the M=0.8, Z will be 2.345. In equilibrium state, the offsprings share, composed mainly from age of 0+, is equal to 90.4%. For the same 11-years long period, the main part of age 0+ in summed catches(Table 1), is 49.1%. The high anchovy catches of the former USSR and the low Bulgarian and Romanian catches should predetermine not low, as it is in the summed

Table 17. Initial anchovy spawning stocks (May) by age groups and years (in 10^9 ind. and 10^3 tons)

Year	$N_{p,t}$				$B_{p,t}$			
	1	2	3	4	1	2	3	4
1	2	3	4	5	6	7	8	9
1968	-	-	-	-	-	-	-	-
1969	39.5	8.8	2.7	0.7	269.9	104.6	44.2	13.5
1970	47.1	14.1	2.8	0.8	321.7	167.5	44.9	16.0
1971	45.1	17.0	4.9	0.9	308.2	102.7	80.5	12.6
1972	37.5	15.4	5.2	1.5	256.0	183.9	84.9	28.5
1973	47.3	12.5	4.5	1.6	323.3	148.2	73.5	30.6
1974	31.7	10.0	3.3	1.2	216.2	118.9	54.7	22.9
1975	35.7	8.5	2.7	1.0	244.1	100.8	43.8	19.8
1976	35.8	10.9	2.2	0.5	244.7	130.1	35.2	9.6
1977	35.3	9.3	2.1	0.4	240.9	11.6	34.0	7.8
1978	36.9	8.9	2.0	0.5	252.2	105.8	32.8	9.1
1979	44.2	9.9	2.1	0.4	301.8	117.4	34.3	8.3
1980	62.1	11.4	2.6	0.6	424.2	135.0	42.9	11.2
1981	75.5	15.2	3.4	0.6	515.8	181.4	54.8	11.4
1982	66.4	20.2	4.0	0.8	453.8	239.9	65.3	15.6
1983	62.4	16.4	5.4	0.8	426.3	194.7	87.5	15.4
1984	67.9	12.9	2.9	0.6	463.6	153.9	47.0	11.8
1985	52.1	9.8	1.7	0.3	355.7	116.2	28.6	6.6
1986	61.0	9.7	1.5	0.2	416.6	114.9	25.2	4.1
1987	56.4	10.1	1.3	0.2	385.5	120.5	20.4	4.1
1988	57.7	9.3	1.1	0.1	394.1	110.6	18.2	2.2
1989	22.0	4.2	0.7	0.1	150.0	50.7	11.2	1.6
1990	14.3	2.6	1.0	0.2	97.9	30.5	16.0	3.8
1991	18.9	4.1	0	0	129.2	48.8	0	0
1992	26.9	5.9	1.2	0	184.0	70.4	19.4	0
1993	36.9	8.0	1.7	0	252.2	95.7	27.4	0

catches, but high share of the age 0+ in total catches.

5. Conclusions

The anchovy exploited, total and spawning stocks are calculated by Ivanov's combined method. The coefficients of fishing mortality (F) and utilization (U) of the stocks are computed by number and by biomass. The age composition data of the summed catches of all Black Sea countries during the period 1968/69–1992/93 are used (Prodanov et al., 1997; Prodanov, Stoyanova, 1999).

The great extent of coincidence of dynamics of total initial stock at age of 0+ - 4+, initial spawning stocks at age of 1-4 and average fishing mortality coefficients at age of0+ - 4+ is established between results of both methods – combined method and VPA (Prodanov et al., 1998).

It is corroborated that the major factors (ctenophore *Mnemiopsis leidyi* impact and anchovy overfishing in the winter quarter areas), lead to sharp decline in anchovy stocks during the period 1989/90 – 1991/92. The low rates of average fishing mortality coefficients (F) at the age of 0+ - 4+ in total stocks make the wrong impression - that the stocks are underexploited. from the fishery. The inadmissible high rates of the fishing mortality coefficients are recorded during the periods 1975/76 – 1992/93: for F_{ex} – from 0.8624 to 1.806; during 1983/84 – 1989/90; for F in total stocks at age of 1+ - 4+ - from 0.9104 to 1.806. According to Ivanov (1998), the admissible value for coefficient of fishing mortality in the exploited stocks (F_{ex}) is between 0.4-0.6 and only if the stocks are

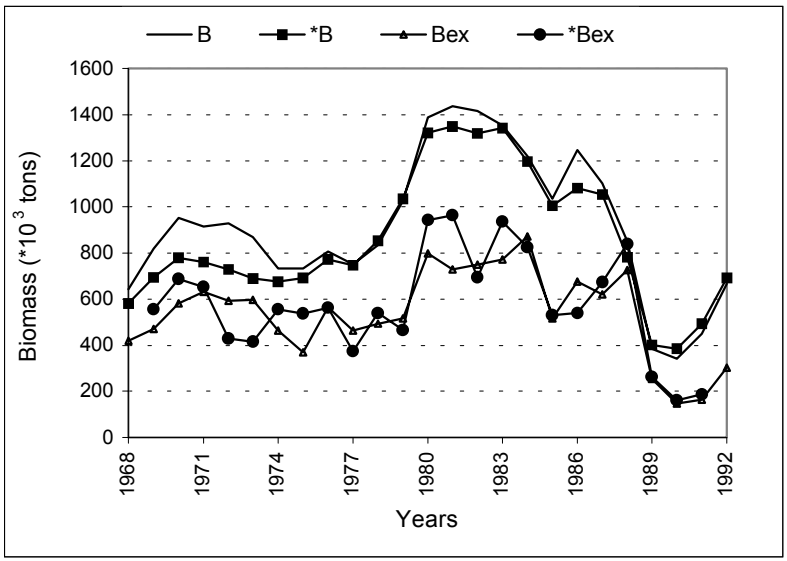

Fig. 2. Summed biomasses of the total (B) and exploited anchovy stocks (B_{ex}) at age of 0+ - 4+ (October) in 10^3 tones:
B – authors data from tabl.10, column 3, *B – according to Prodanov et. al, 1998, B_{ex} – authors data from tabl.10, column 2, *B_{ex} - according to Prodanov et. al, 1997

Fig. 3. Initial summed biomass (October) of the exploited (Bex) and total (B) anchovy stocks at age of 1+ - 4+ in 10^3 tons (table 10, columns 2 and 3)

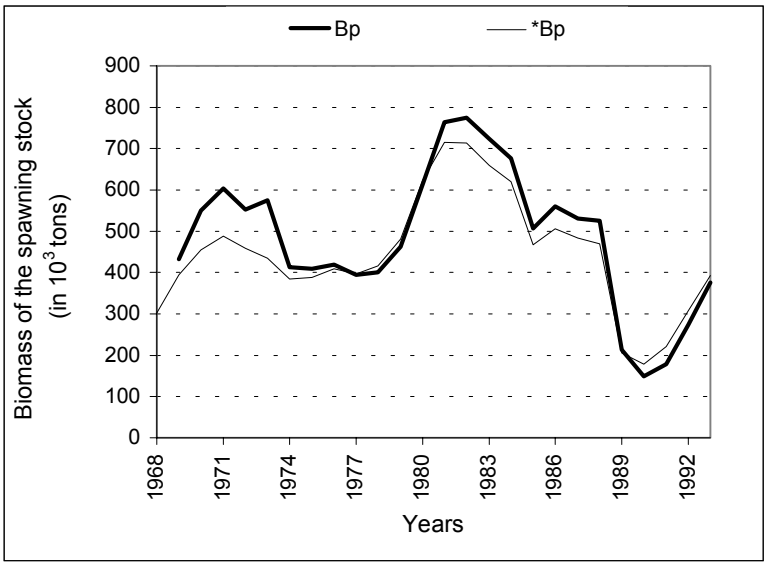

Fig. 4. Initial anchovy spawning stocks (Bp) at age of 1 - 4 (May) in 10^3 tons Bp – authors data from tabl.16, column 2, *Bp - according to Prodanov and Stoyanova, 2000

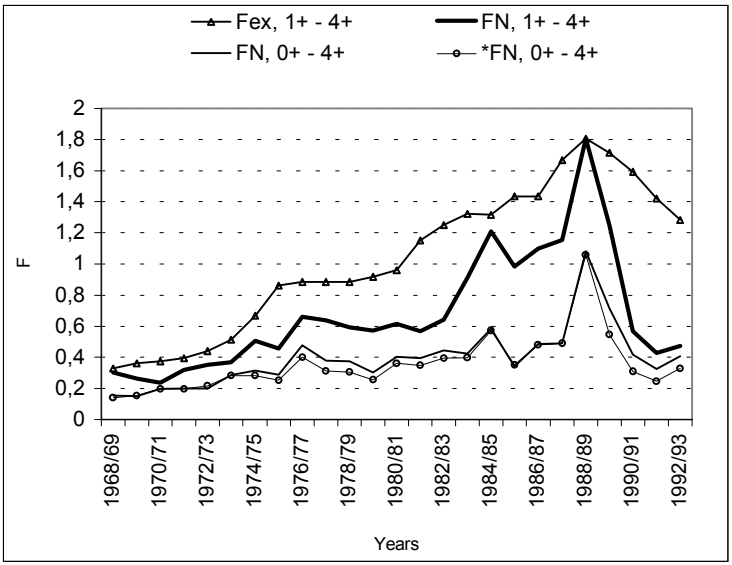

Fig. 5. Fishing mortality coefficients of the anchovy exploited ($F_{ex,N}$) and total (F_N) stocks:
$F_{ex, N, 0+-4+ = 1+-4+}$ - authors data from Tabl.13, column 2, $F_{N, 1+-4+}$ - authors data from Tabl.13, column 4, $F_{N, 0+-4+}$ - authors data from tabl.13, column 4, $*F_{N, 0+-4+}$ - according to Prodanov et. al, 1998

Table 18. The relative part (in %) of the initial exploited abundance ($N_{ex,t}$) from the total abundance (N_t = 100%) by age groups

Year (October)	0+	1+	2+	3+	4+
1968	34.6	93.0	91.5	92.9	100
1969	32.5	68.8	95.7	100	100
1970	50.4	63.1	70.3	100	98.9
1971	35.0	74.8	100	100	87.0
1972	33.7	75.6	99.1	87.0	79.0
1973	49.2	68.4	100	100	47.7
1974	41.7	83.2	81.8	62.9	46.4
1975	32.3	55.2	74.9	100	59.7
1976	54.5	73.9	100	100	100
1977	39.7	75.8	89.3	81.4	84.7
1978	42.7	71.8	80.8	89.0	87.1
1979	31.9	71.8	65.6	63.1	100
1980	44.9	74.6	55.5	80.2	100
1981	37.5	59.7	61.0	67.1	100
1982	39.6	63.7	56.9	76.3	100
1983	28.5	74.8	85.7	98.0	100
1984	36.9	94.3	97.1	100	100
1985	17.2	77.5	83.9	93.5	98.7
1986	29.8	83.2	94.1	93.1	100
1987	28.3	78.1	92.9	97.3	100
1988	54.5	100	100	100	100
1989	43.5	89.6	59.4	43.1	40.0
1990	36.0	45.7	74.6	47.8	68.4
1991	31.1	40.0	46.7	100	-
1992	41.8	46.4	50.8	100	-
Average	37.9	72.1	80.3	86.9	86.9

extremely high it can draw to $F_{ex} \leq 0.8$.

The analysis of the published data shows that the part of age groups 0+ and 1 year in the former USSR catches had been very high, which does not coincide with the low part of these groups in the summed catches presented in the collective elaboration of the scientists from the Black Sea countries(Prodanov et al., 1997; Prodanov, Stoyanova, 1999). As quoted Turkish authors, Prodanov, Stoyanova (1999) noted, that the part of 0+ age group in Turkish catches is very high.

In all cases, the F_{ex} rates must be calculated only by completely introduced age groups in the catches and stocks ($F_{ex} \approx F_t$), synchronised with the efforts number.

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Определяне на запасите на черноморската хамсия по комбинирания метод на Иванов през годините 1968 - 1993

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(Резюме)

Чрез комбинирания метод на Иванов са определени по възраст, поколения и години експлоатационните, общите и размножителните запаси на хамсията; коефициентите на риболовна смъртност (F) и утилизация (U) на запасите по численост и биомаса, като са използвани данните за възрастовия състав на сумарните улови на всички черноморски държави през периода 1968/69 – 1992/93 г. Установена е висока степен на съвпадане на динамиката на общите начални запаси на възраст 0+ - 4+, на началните размножителни запаси на възраст 1 - 4 г. и на средните коефициенти на риболовната смъртност на възраст 0+ - 4+, определени по комбинирания метод на Иванов и по метода на VPA (Prodanov, Stoyanova, Mikhailov, 1998). Потвърждават се главните фактори (въздействието на ктенофората *Mnemiopsis leidyi* и свръхриболовът в местата на зимуване на хамсията), довели до рязкото спадане на запасите от хамсия през периода 1989/90 – 1991/92 г.

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