Stock assessments of the Black Sea anchovy during the period 1979-1993

K.B. PRODANOV and M.D.STOYANOVA

Institute of Oceanology, P.O.Box 152, 9000 Varna, Bulgaria
e-mail: bio@io-bas.bg

Abstract

The stock assessments of the Black Sea anchovy during the period 1979-1993 were made by Age- and Length-structured VPA. According to the obtained results, the initial anchovy exploited biomass varied from 1421.3 (1979) to 243.3 thousand tons (1990). In 1979 the mean exploited biomass was 1036.5 thousand tons. Both assessments are very close because the mean biomass at F=0.5 has to be 73.71% from the initial one.

The comparatively low level of fishing activity from 1968-1977 (mean value of F was 0.2407) and the increase in Black Sea productivity predetermined the increase in anchovy biomass during the period 1979-1983. This rise in productivity of the Black Sea implies higher values of the anchovy exploited biomass, but this did not occur due to the increased fishing mortality upon the anchovy, which kept its abundance and biomass at considerably lower levels. The mean value of F was 0.7348 during the period 1983-1986 and reached 1.2487 in 1987-1988.

The mean anchovy biomass in 1991 and 1992 was 179.1 and 314.0 thousand tons. In the same years the initial anchovy biomass was 430.5 and 592.1 thousand tons. The mean value of the fishing mortality coefficient in 1991 and 1992 was 0.3889 and 0.6353, respectively. Consequently, the decrease of fishing mortality during the specified years was one of the main reasons for the recovery of anchovy biomass during the period 1992-1995.

Keywords: Black Sea productivity, Stock assessments, Anchovy exploited biomass.

Introduction

The Black Sea anchovy *(Engraulis encrasicolus)* is a very important commercial fish species whose biomass varies widely according to the environmental conditions and fishing mortality rate. The aim of the assessments was to establish the reduction level of the anchovy stock in the Black Sea during the period 1989-1991. The first estimate for anchovy biomass off the Turkish coast was performed by OSRODEK (1975) by means of hydroacoustic survey in March 26-31, 1972. According to this assessment, the anchovy biomass was worked out at 990.0 thousand tons. On the basis of these data and the fact that the assessment was related only to the wintering stock off the Anatolian coast, Ivanov and Beverton (1985) estimated the anchovy stock at about 1500 thousand tons for the whole Black Sea. IVANOV & MIKHAILOV (1991) gave an average estimate of the anchovy

Medit. Mar. Sci., 2/2, 2001, 7-15

7

exploited biomass of 1000 thousand tons, assuming that it would have peaked values of 1300 thousand tons in some years. PRODANOV *et al.* (1997) calculated the anchovy exploited biomass during the period 1967-1993 by Age-structured VPA. Subsequently, it turned out that the preliminary data for Turkish anchovy catches during the period 1990-1993 used in the latter assessment, differed from those published in the Turkish official fishery statistics. This imposes the necessity of the carrying out of a new assessment, including the use of other methods such as Age- and Length-structured VPA, with a view to more precise calculation of the anchovy initial and mean biomasses, especially during the period 1991-1992, when were registered the lowest anchovy catches. Length-structured VPA is more appropriate for fish species with a short life span, like anchovy, than the Age-structured one, because the more greater number of size groups than those of age groups allows "abating" of possible mistakes made in F_{st} determination.

Materials and Methods

Input data for anchovy catches by year are obtained from all Black Sea countries in relation to the joint project "Environmental management of fish resources in the Black Sea and their rational exploitation" under the Research Support Scheme of the Central European University, published in Studies and Reviews No.68, FAO (Prodanov *et. al.,* 1997). Then catches are distributed in size and age groups by using of age-size keys from the data of all Black Sea countries. For the growth parameters L_∞ and k are used, those values estimated by OZDAMAR *et.al.* (1994). The rate of natural mortality coefficient M is accepted to be equal to 0.82 (SCHLYAHOV *et. al.,* 1990), because the value of M, estimated by MIKHAILOV, PRODANOV (1983) is very close (M = 0.81) to that assessment. We

use the values of the coefficient Fst by years, calculated by PRODANOV *et. al.* (1997).

The assessments of the Black Sea anchovy initial and mean exploited biomasses were made by means of Age-based VPA and Length-based VPA with pseudocohorts using FiSAT software (GAYANILO, SPARRE, PAULY, 1996). The catch-at-length data for the Length-based VPA were at first computed with "smoothing data" procedure in order to fit the length groups of all the Black Sea countries with each other.

The Age-based VPA is based on the equations proposed by BARANOV (1926) & BEVERTON, HOLT (1957). The reconstruction of the population abundance by age groups starts by estimating the abundance of the oldest age group. The initial biomasses by age groups are estimated by multiplying the initial abundance for each age group with the corresponding weight and finally summing up results for all age groups – equations (1 and 2):

$$B_t = W_t * N_t \qquad (1)$$

$$B = \sum_{t=0+}^{t=t_\lambda} B_t \qquad (2)$$

where: B = investigated species biomass in the beginning of the year; t_λ = oldest age group of the investigated species; B_t = biomass by age groups.

The Length-based VPA is modified from Jones (1981) and utilizes basically the same approach as age-based VPA, but is adapted for length frequencies. According to Spare, Venema (1992), the total mean number of fish in general is – equation (3);

$$\sum \overline{N}\left(L_i, L_{i+1}\right) * \Delta_t \qquad (3)$$

where:
$$\overline{N}\left(L_i, L_{i+1}\right) * \Delta_t = \left[N\left(L_1\right) - N\left(L_2\right)\right] / Z$$

The mean biomass in each length group is – equation (4):

$$\overline{B}\left(L_1, L_2\right) * \varDelta_t = \\ = \overline{N}\left(L_1, L_2\right) * \varDelta_t * \overline{W}\left(L_1, L_2\right) \quad (4)$$

Where: $\overline{W}\left(L_1, L_2\right) = a * \left[\dfrac{\left(L_1 + L_2\right)}{2}\right]^b$;

a, b – constants of the length-weight relationship.

The average biomass during the life span of a cohort, in general is – equation (5):

$$\sum_i \overline{B}\left(L_i, L_{i+1}\right) * \varDelta_t \quad (5)$$

Results

The mean anchovy biomasses in 1991 and 1992 were estimated at 179.1 and 314.0 thousand tons, respectively – Tables 1 and 2. In the same years the initial anchovy biomasses were 430.5 and 592.1 thousand tons (PRODANOV *et al.*, 1997). Therefore, the mean anchovy biomasses present a 41.6% and 53% difference from the initial ones, respectively. The catches in 1991 and 1992 were 86.5 and 171.2 thousand tons, respectively. The mean value of the fishing mortality coefficient in 1991 and 1992 was 0.3889 and 0.6353, respectively. According to the last value of F the mean exploited biomass should present a 71.92% from the initial one, if the recruitment is constant. Hence, the anchovy initial biomass was probably around

Table 1
Length frequency data of the Black Sea anchovy used for Length-based VPA of 1991 and the output results.

L, mm	C_N	N	$\overline{B}$	F
48-52	3.040	742253.550	7073.41	0.0003
53-57	6.700	664827.100	8874.67	0.0008
58-62	106.610	592616.550	10807.61	0.0131
63-67	601.056	524572.200	12759.22	0.0800
68-72	2383.483	456958.450	14338.13	0.3558
73-77	2916.639	378186.050	15219.20	0.5086
78-82	4170.181	301999.500	15080.83	0.8977
83-87	3563.422	222203.425	13936.69	1.0029
88-92	2995.922	157433.063	12239.78	1.1475
93-97	1670.585	106065.825	10560.93	0.8779
98-102	621.960	73756.506	9576.64	0.4230
103-107	247.831	55480.869	9165.13	0.2051
108-112	259.093	43094.406	8759.37	0.2594
113-117	252.059	32313.859	8059.49	0.3151
118-122	320.600	23234.277	6931.06	0.5323
123-127	254.356	15089.375	5482.52	0.6064
128-132	164.780	9106.550	4089.46	0.5953
133-137	130.018	5189.008	2780.47	0.7772
138-142	63.172	2517.110	1701.80	0.6912
143-147	38.875	1135.931	909.65	0.8879
148-152	9.719	388.150	434.36	0.5168
153-157	4.859	136.740	275.04	0.4520

where: C_N = total annual catch in numbers (*10^6 individuals); N = reconstructed population in numbers (*10^6 individuals); $\overline{B}$ = mean biomass by length classes; F= fishing mortality coefficient; L_∞=17.09, k=0.308, Ft_λ=0.4517, M=0.82, a=0.0049082, b= 3.1226, t_λ=5.

Table 2
**Length frequency data of the Black Sea anchovy used for Length-based VPA of 1992
and the output results.**

L, mm	C_N	N	$\overline{B}$	F
48-52	4.54	140550.050	12989.28	0.0003
53-57	83.37	125890.050	16158.96	0.0050
58-62	577.98	112149.738	19491.13	0.0375
63-67	1380.182	98918.613	22780.71	0.0976
68-72	1974.545	85937.163	25804.49	0.1543
73-77	2979.197	73466.906	28249.12	0.2621
78-82	4024.329	61167.475	29652.74	0.4103
83-87	4913.477	49099.531	29566.68	0.6038
88-92	4650.905	37513.316	27997.52	0.7179
93-97	3288.058	27549.916	25753.00	0.6501
98-102	2432.614	20114.672	23350.98	0.6198
103-107	2704.461	14463.734	19966.33	0.9345
108-112	3146.163	9386.166	14426.30	1.7327
113-117	1842.157	4751.181	8633.91	1.9401
118-122	886.159	2130.409	4659.25	1.9679
123-127	402.224	874.989	2269.22	2.0758
128-132	127.738	313.878	1058.39	1.5921
133-137	37.961	120.350	546.21	1.0281
138-142	15.96	52.111	299.44	0.8806
143-147	6.38	21.285	334.03	0.3510

where: L_∞=17.09, k=0.308, Ft_λ=0.3507, M=0.82, a=0.0054728, b= 3.036, t_λ=5.

450 thousand tons in 1992, if the assessment obtained by Length-based VPA is true. On the other hand, if the assessment calculated by Age-based VPA is true (592.1 thousand tons) the mean anchovy exploited biomass was around 425.8 thousand tons. The differences could be explained by the specific peculiarities of the methods under consideration. The initial exploited biomass of the Black Sea anchovy (by age groups) is presented on Fig. 1. The anchovy catches and initial explaited biornasses during the period 1979 - 1982 are given on Fig.2.

The total anchovy catch in 1979 was 244.2 thousand tons, i.e. the catch represented only 17.18% of the initial exploited biomass (Fig. 2). For the period 1979-1982 the mean catch was 347.3 thousand tons. In this period the mean value of the anchovy initial biomass was 1256.5 thousand tons. As is obvious, during the period under consideration the mean catch represented 27.4% of the anchovy initial biomass. The mean catch for the period 1983-1986 was 410.2 thousand tons. During the same period the mean value of anchovy initial biomass slightly declined to 1157.7 thousand tons. Therefore, the mean catch represented 35.6 % of the anchovy initial biomass. The specified anchovy biomass continued to decrease during the next two years - 1987 and 1988. Its mean value was 918.4 thousand tons. The mean catch in the same years was 411.4 thousand tons. This catch represented 46.8% of the anchovy initial biomass. The last sharp decline was during the period 1989-1992. The calculated mean value of the initial biomass was 407.9 thousand tons. The mean anchovy catch during the period under consideration was 126.0 thousand tons, i.e. it represented 30.9% of the anchovy initial biomass.

Figure 3 shows the mass development of the new ctenophore species *Mnemiopsis leidyi* whose biomass attained its maximum in 1991 (by data of Sorokin and Sorokolit YugNIRO).
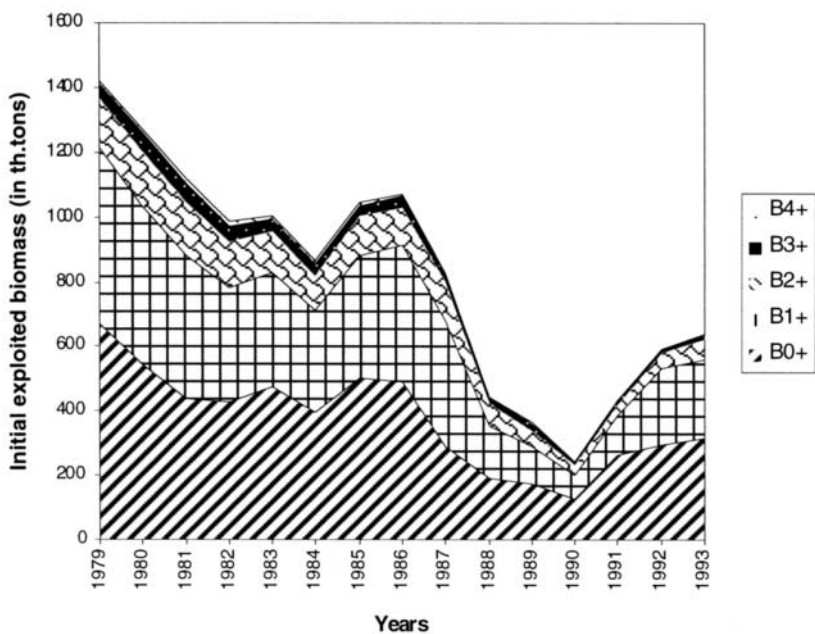
Fig. 1: Initial exploited biomass of the Black Sea anchovy (by age groups) during the period 1979 - 1993 (in thousand tons).
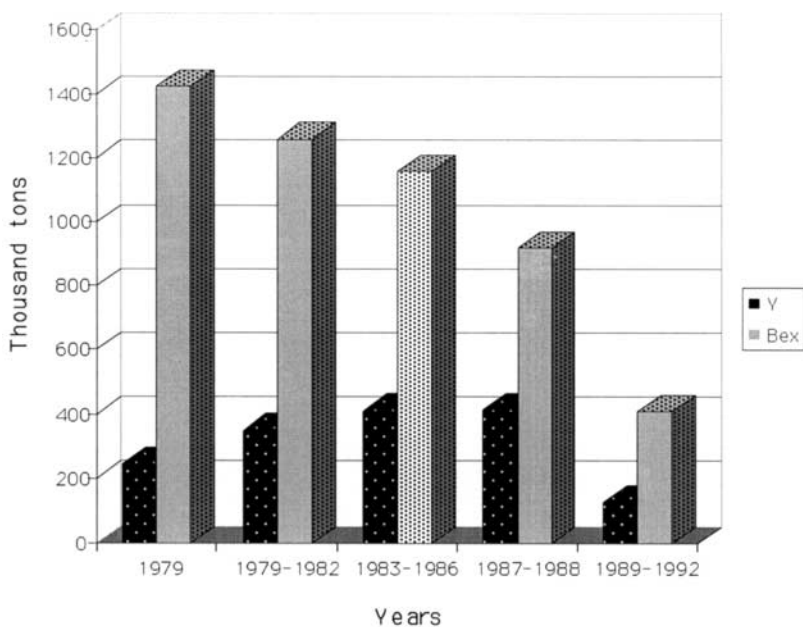

Fig. 2: Anchovy initial exploited biomasses and catches during the period 1979-1992, where Y = catch in th.tons, Bex = exploited biomass.
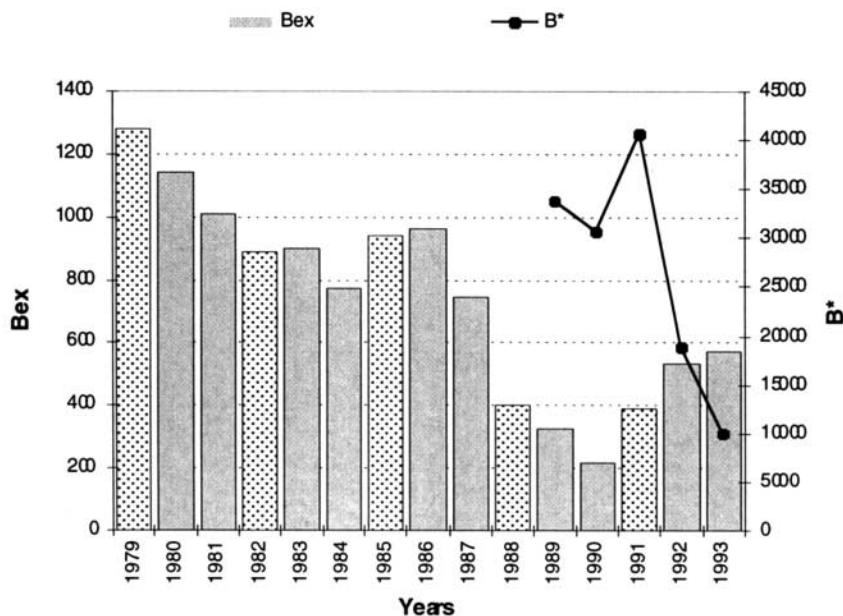
Fig. 3: Initial exploited biomass of the Black Sea anchovy during the period 1979-1993 Bex (in th. tons) and Mnemiopsis biomass – B* (in th.tons).

Discussion

The results of the initial exploited biomass of the Black Sea anchovy (by age groups) - Fig. 1 differ from those presented by PRODANOV *et al.* (1997) mainly during the period 1991-1993. The accomplishment of new stock assessment during the period 1968-1993 was imposed in view of the following:

1. In the previous estimate the provisional data of the Turkish anchovy catches for the fishing seasons 1991/1992 and 1992/1993 turned out to be significantly lower than the Turkish official fishery statistics data.

2. Specifying the data for the fishing effort applied during the period 1968-1994 - BINGEL *et al.* (1995).

In 1979 the initial anchovy exploited biomass calculated by Age-based VPA, was the highest - 1421.3 thousand tons. This assessment is very close to Ivanov & Beverton (1985) – which estimated the anchovy initial biomass at 1500 thousand tons. According to the Length-based VPA the mean anchovy

exploited biomass was 1036.9 thousand tons in the same year (Table 3). Hence, the mean exploited biomass presents 72.95% from the initial one. Both assessments are very close because the mean biomass at F=0.5 has to be 73.71% from the initial one. During the period (1979-1982) the mean value of fishing mortality rate was 0.5427.

For the period 1979-1982 the mean anchovy catch represented 27.4% of the anchovy initial biomass while for the period 1983-1986 the mean catch represented 35.6% of the anchovy initial biomass. The anchovy biomass continued to decrease during the next two years - 1987 and 1988. The last sharp decline was during the period 1989-1992. The mean anchovy catch during the period under consideration was 126.0 thousand tons, i.e. it represented 30.9% of the anchovy initial biomass. One of the main reasons for the decline in biomass is that during the investigated period the environmental conditions underwent some considerable changes. The initial period (1979-1987) was

Table 3
Length frequency data of the Black Sea anchovy used for Length-based VPA of 1979
and the output results.

L, mm	C_N	N	$\overline{B}$	F
71-75	456.51	197406.750	72511.08	0.0141
76-80	1115.24	170337.213	80305.31	0.0381
81-85	1365.48	145216.800	87017.45	00522
86-90	895.44	122394.313	92649.59	0.0385
91-95	991.48	102440.131	97022.13	0.0483
96-100	1147.71	84631.381	99617.68	0.0641
104-105	1550.79	68802.969	99906.78	1.0088
106-110	1403.36	54632.875	97835.37	0.1079
111-115	1558.91	42560.134	93375.98	0.1444
116-120	3384.28	32150.744	83463.59	0.4012
121-125	6028.01	21848.909	62357.74	1.0877
126-130	4469.77	11276.380	35985.06	1.5813
131-135	1773.98	4488.755	17688.38	1.4378
136-140	526.17	1703.026	8945.66	0.9454
141-145	279.32	720.483	4415.83	1.1353
146-150	100.77	239.413	3375.69	0.5960

where: $L_\infty = 17.51$, $k = 0.277$, $Ft_\lambda = 0.5959$, $M = 0.82$, $a = 0.0047$, $b = 3.1002$, $t_\lambda = 5$.

characterized by high eutrophication of the basin, resulting in mass phytoplankton blooms. The second period (1989-1990) was distinguished by mass development of the new ctenophore species *Mnemiopsis leidyi* whose biomass attained its maximum in 1991 (by data of Sorokin and Sorokolit YugNIRO) – Figure 3. Thus, the Black Sea ecosystem, including its fish population, underwent the corresponding alterations.

As is well known, the Black Sea ecosystem is relatively simple because there are few abundant species. Thus the most abundant are some phyto- and zooplankton-feeders, two jellyfish species, one native ctenophore species – *Pleurobrachia rhodopis* and fishes - anchovy, sprat and partially the horse mackerel. Therefore, increased phyto- and zooplankton production requires an adequate increase of abundance and biomass of the mentioned fish species. The retention of specified biomasses at lower levels due to intensive fisheries, leads to an enhancement of imbalance between different food web links. The removal of such imbalance could be obtained in two ways: by increasing the abundance of the respective biomass of *N. scintilans, Aurelia aurita,*

Rhizostoma pulmo and *P. rhodopis* or by involving new species in the Black Sea ecosystem. Initially, the niche of planktivorous fishes was occupied by the jellyfish *A. aurita,* whose biomass increased from 50 million tons in 1965 to 400 million tons. The density of *N. scintilans* increased 10 fold, but this could not compensate for the depleted biomass of planktivorous fishes. Hence, the door for a more voracious animal has been opened (Sorokin, 1994). As is well known, in 1982 a new ctenophore species *Mnemiopsis leidyi* was discovered in the Black Sea (ZAIKA & SERGEEVE, 1990) and subsequently developed intensively (1988-1989), i.e. the two possible ways occured (ZAITZEV, ALEXANDROV, 1997). The *Mnemiopsis* feeds on fodder zooplankton in great quantity which results in competition between ctenophore and planktivorous pelagic fish (ZAIKA, 1994). According to Harbison, VOLOVIK (1994) "the introduction of *Mnemiopsis leidyi* into the Black and Azov Seas has caused a dramatic reduction in local pelagic fisheries". *Mnemiopsis leidyi* affected fisheries mainly by reducing biomass of fodder zooplankton and by feeding on eggs and fish

larval stages. Losses for the Black Sea fisheries due to *M. leidyi* are estimated at about 250 million dollars U.S. (CADDY, manuscript – in HARBISON, VOLOVIK, 1994). Some authors recommend: "totally stop fisheries for anchovy and *Clupeonella* and maybe also for *Sprattus* in the Black Sea and adjacent seas. Hopefully, within 3-5 years the *Mnemiopsis* should disappear gradually and be replaced by a stronger competitor." (SOROKIN, 1994). In 1997 another ctenophore species *(Beroe ovata)* preying on *M. leidyi* was found (KONSULOV A., KAMBURSKA L., 1998).

From our point of view, the biomass of intensively exploited fish species like anchovy can recover faster when the fishing mortality rate has been decreased.

During the period 1979-1982 the enhancement of the basin's productivity masked the negative fishery impact and an increase in anchovy biomass was registered. The comparatively low level of fishery during 1968-1977 (mean value of F was 0.2407) and the increase of the Black Sea productivity predetermined the growth of anchovy biomass during the period 1979-1983. The rise in productivity implied higher values of the anchovy exploited biomass. However, this did not occur due to the increased fishing mortality upon the anchovy, which kept its abundance and biomass at considerably lower levels than those which the changed food availability required. The mean value of F was 0.7348 during the period 1983-1986. Its mean value in 1987-1988 reached 1.2487. Consequently, the decrease in fishing mortality in 1990 and 1991 (0.2649 and 0.3889, respectively) was one of the main reasons for the increasing in anchovy biomass during the period 1992-1995.

Conclusions

The obtained results for Black Sea anchovy exploited biomass during the period 1979-1993 allowed the following conclusions to be made:

- The anchovy exploited biomass varied from 1421.3 (1979) to 243.3 (1990) thousand tons.
- The increase in the anchovy biomass during the period 1992-1995 is due to the declining fishing mortality rate in 1990 and 1992.
- The decrease in the anchovy catches after 1995 is probably predetermined by over-fishing 1995 - 376.2 thousand tons.
- The decline in the anchovy biomass will probably lead to dramatic changes in the Black Sea ecosystem again because it is the most abundant plankton-feeding fish.

References

BARANOV, F.I., 1926. On the question of the biological basis of fisheries. Nauchn. Issled. Ikhtiol. Inst. Izv., 1:81-128 (in Russian).

BEVERTON, R.J.H. & S.J. HOLT, 1957. On the dynamics of exploited fish populations. Fish. Invest. Minist. Agric. Fish. Food G.B. (2 sea Fish.), 19:533p.

BINGEL F., DOGAN M., GUCU A.C., KAYIKCI Y., STEPHNOWSKI A., AVSAR D., NIERMANN U., MUTU E., UYSAL Z., KIDEYS A.E., & BEKIROGLU Y. 1995. Stock assessment Studies for the Turkish Black Sea Coast. Final report. Institute of Marine Sciences, Middle East Technical University, Turkey, 159 pp.

GAYANILO F.C., SPARRE P., & PAULY D., 1996. FAO-ICLARM Stock Assessment Tools (FiSAT), Computerized Information Series, vol.8, FAO.

JONES, R., 1981. The use of length composition data in fish stock assessment (with notes on VPA and cohort analysis). FAO Fish. Circ. (734), p 55.

HARBISON, G.R. & VOLOVIK, S.P., 1994. Methods for the control of populations of the ctenophore *Mnemiopsis leidyi,* in the Black and Azov seas. General Fisheries Council for the Mediterranean, Second technical consultation on stock assessment in the Black Sea. FAO Fisheries report No 495, 56-68 pp.

IVANOV L, S. & BEVERTON, R.J.H., 1985. The fisheries resources of the Mediterranean. Part two: Black Sea. FAO Studies and Reviews, 60;135 pp.

IVANOV, L. S. & MIKHAILOV, K., 1991. On the relation between catch, stock and production of the Black Sea anchovy (*Engraulis encrasicolus* Aleksandrov). Oceanology, Sofia, 20, 16-25.

KONSULOV, A. KAMBURSKA, L., 1998. Ecological Determination of the New Ctenophora-*Beroe ovata* Invasion in the Black Sea. Oceanology, vol.2

MIKHAILOV, K. K. PRODANOV, 1983. Approximate assessment of the natural mortality coefficient for the Bulgarian part of the Black Sea., Proc. of Inst.Fish.Res.-Varna, vol.XX, 173-182 pp.

OSRODEK, W., 1975. Stidia I materialy. Szcowanie I identyficacja ryb metodami hydroakustycznymi, MIR, Seria C, 26, Gdania.

OZDAMAR E., I. ERKOYUNCU, M. ERDEM, S. CHEN, 1994. The effect of fishing activity on the recent decrease in the Black Sea anchovy (Engraulis encrasicolus L.) stock. Proceeding of the Black Sea Symposium. Ecological problems and economical prospects, Istanbul. Fisheries College, University of Ondokuz Mayis.

PRODANOV, K., MIKHAILOV, K., DASKALOV, G., MAXIM K., OZDAMAR, E., CHASHCHIN A., ARKHIPOV, A., SHLYAKHOV, V. 1997. Final report of the project "Environmental management of fish resources in the Black Sea and their rational exploitation". General Fisheries Council for the Mediterranean, Studies and Reviews, No 68, FAO, Rome, 178pp.

SCHLYAHOV, V.A., A. K. CHASHCHIN, N. I. KORKOSH, 1990. Intensity of catch and dynamics of the Black Sea anchovy stock. Proc. VNIRO"Biological resources of the sea", 93-102 pp.

SOROKIN Y., 1994. Essay on ecological situation in the Black Sea. FAO Fisheries report N.495: 69-77.

SPARE, P. & S.C. VENEMA, 1992. Introduction to fish stock assessment. FAO Fish. Tech. Pap. 306/1, Rev.1.

ZAIKA, V.E. & SERGEEVA N.G, 1990. Morphology and development of *Mnemiopsis mccradyi* (Ctenophora, Lobata) in the Black Sea. Hydrobiol. J.26(1):1-6. Zool. Zh. 69, vol.2, 5-11 pp.

ZAIKA, V.E., 1994. The drop IN anchovy stock in the Black Sea: result of biological pollution? General Fisheries Council for the Mediterranean, Second technical consultation on stock assessment in the Black Sea. FAO Fisheries report No 495, 78-83 pp.

ZAITZEV, Yu. P & B. G. ALEXANDROV, 1997. Recent Man-Made Changes in the Black Sea Ecosystem. NATO ASI Series, 2,/27, 25-31.