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DISTRIBUTION OF EGGS AND LARVAE OF ANCHOVY WITH RESPECT TO AMBIENT CONDITIONS IN THE SOUTHERN BLACK SEA DURING 1993 AND 1996

AHMET E. KIDEYS[1], ANNA D. GORDINA[2], ULRICH NIERMANN[1], ZAHIT UYSAL[1] TAMARA A. SHIGANOVA[3] AND FERIT BINGEL[1]
1) Institute of Marine Sciences, P.O. Box 28, Erdemli, 33731 TURKEY
2) Institute of Biology of the Southern Seas, Ukranian Academy of Science, Nachimov Ave. 2, Sevastopol, UKRAINE
3) P.P. Shirshov Institute of Oceanology Russian Academy of Sciences, RUSSIA.

Abstract. Distribution of eggs and larvae of the anchovy were investigated with respect to ambient conditions in the southern Black Sea during August 1996 and June-July 1996. Highest egg and larva numbers were obtained in June-July 1996 compared to previous surveys in the southern Black Sea. Besides surface temperature and salinity, among the numerous biotic parameters tested, abundance of fodder zooplankton, both abundance and biomass of the ctenophore *Mnemiopsis* and microphytoplankton showed significant correlations with the distribution of either eggs or larvae of the anchovy.

1. Introduction

Events which have occurred in the Black Sea over the last few decades have led to pronounced changes in the ecology of the anchovy *Engraulis encrasicolus*. Initially its abundance and catch gradually increased (up to approx. 500 thousand tonnes; Figure 1). Besides newer technology used in fishing, this increase must also be due to several other factors such as the beneficial effects of nutrient increase particularly in the northwestern shelf [1], decreasing predator pressure and disturbance in benthic/pelagic coupling. However increasing eutrophication together with overfishing and the recent appearance of the competing invader *Mnemiopsis sp.* (Ctenophora) caused an abrupt decrease (more than 5 fold) in the catch of this most abundant fish of the Black Sea by the end of the 1980's [2] (Fig. 1). After this sudden decrease its catch is now again increasing consistently (approaching levels seen in Turkey prior to the decrease). Besides its abundance, the reproductive strategy of anchovy (inferred from the long term distribution of its early life stages) also displayed striking changes. In contrast to earlier studies, the southern Black Sea, particularly its southeastern region, contained higher egg numbers than in the northwestern region which was traditionally known as the main

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spawning area [3]. In this study, the distribution of anchovy eggs and larvae were investigated for the evaluation of the present situation with particular reference to physical and biological conditions.

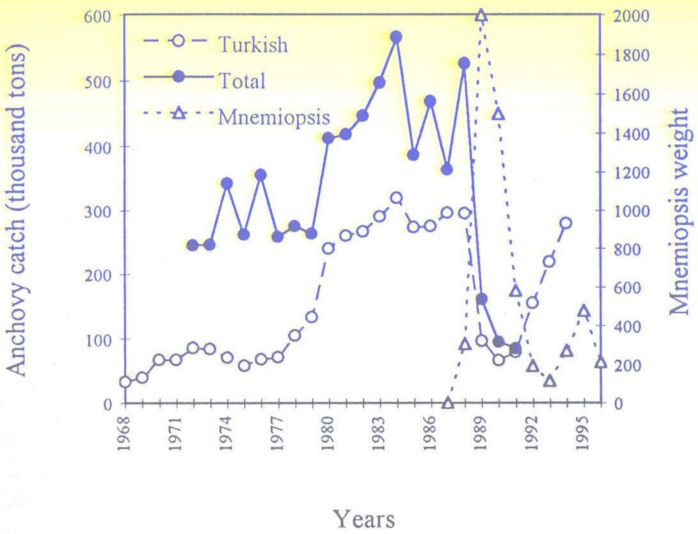

Figure 1. Anchovy catch values from the Black Sea. Dark circles = Turkish catch, open circles = total catch off all riparian countries. No total catch data available since 1991. Changes in the average *Mnemiopsis sp.* biomass in the Black Sea are also shown (triangles).

2. Materials and Methods

The ichthyoplankton was collected from a dense station grid in the Turkish Exclusive Economic Zone (TEEZ) covering the entire southern Black Sea with the R/V Bilim in two different surveys. First survey was during 4-22 August 1993 where 144 stations were sampled (Fig. 2) and the second was between 20 June and 6 July 1996 with a total of 120 stations (Fig. 3). All samples were obtained via vertical tows from the anoxic zone (of which depth changes spatially, however consistent at 16.2 in terms of sigma theta density unit) to the surface using a Hensen net (300 µm mesh size and 70 cm diameter of net opening). Bucket contents were filtered using a 2 mm sieve to retain gelatinous organisms which were also quantified. The volume of each ctenophore *Mnemiopsis leidyi* was measured, whilst diameter measurements of the ctenophore

Pleurobrachia pileus and the cnidarian *Aurelia aurita* were taken for all individuals. The filtrates were then fixed with buffered formalin (final concentation of 4%) for sorting in

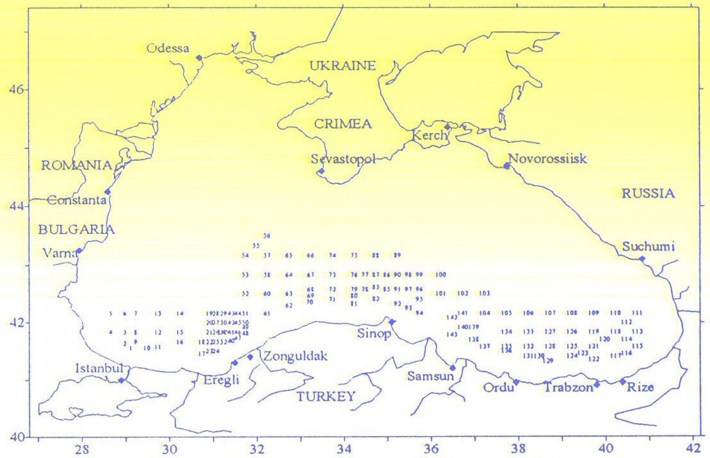

Figure 2. Sampling stations during the August 1993 survey.

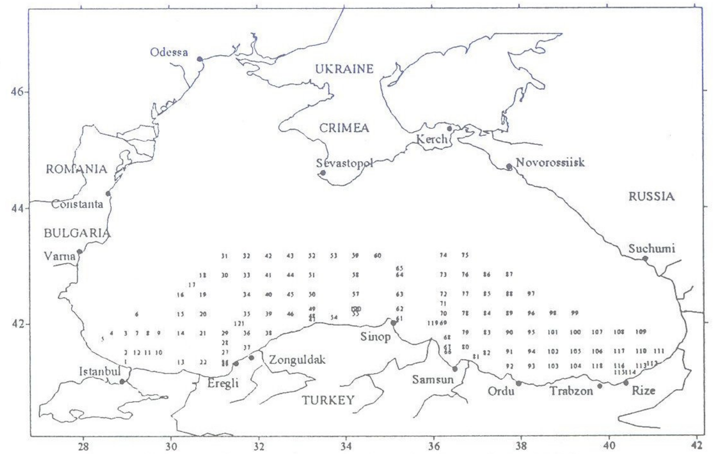

Figure 3. Sampling stations during the June-July 1996 survey.

the laboratory under a binocular microscope. All zooplankton (mainly copepods) were staged and counted along with ichthyoplankton. Using the literature conversion values [4], biomass values were also calculated for the zooplankton. One litre of surface seawater was taken and fixed with 2% formalin at each station for the determination of composition and biomass of phytoplankton after sedimenting a few weeks at the laboratory (only for the 1996 survey). Temperature, salinity, density of the water column were measured using a CTD probe at each station until the depth of sigma theta = 16.2. All correlation analyses were performed using the Spearman Rank Correlation test [5].

3. Results and Discussion

Distributions of eggs and larvae of the anchovy as well as the surface temperatures are shown in Figs. 4 and 5 for the years 1993 and 1996, respectively. Egg numbers during these surveys varied from zero to 718 eggs m^{-2} (0-39 larvae m^{-2}) during August 1993 and 0-577 eggs m^{-2} (0-44 larvae m^{-2}) during June-July 1996 (Table 1). An average egg number of 38.8 (per m^2) found in the August 1993 survey was lower than the 72.2 eggs m^{-2} for the July 1992 survey [3]. However the highest mean occurred for the June-July 1996 survey with a value of 89.5 eggs m^{-2}. Consistently low numbers recorded for the August 1993 survey could be explained by this month occurring towards the end of the spawning season [6]. Despite this, an increase trend in the numbers of anchovy egg and larva is notable for the recent years (Table 1) in parallel to the catch. The increase in the anchovy egg and larva could be taken as an indication for the recovery of the Black Sea ecosystem.

TABLE 1. Anchovy egg and larva numbers for different surveys in the southern Black Sea. References: 1) Einarson & Gurturk 1960, 2) Niermann *et al.*, 1994, 3) The present study

		Egg (no/m2)		Larva (no/m2)		
Year	Month	Range	Mean	Range	Mean	Reference
1957	July	0-321	≅18		≅2	1
1991	June	0-29	≅6	0-2	<<1	2
1992	July	0-1167	72	0-55	3.5	2
1993	August	0-718	39	0-39	3.1	3
1996	June-July	0-577	90	0-44	4.3	3

Whilst during August 1993 highest egg abundances were limited to the western part (in front of the Bosphorus and off Eregli), in June-July 1996 besides this western region, two coastal areas in the eastern Black Sea were the most abundant localities (off Samsun and between Trabzon and Rize). The distribution pattern in June-July 1996 survey was similar but not as uniform as in the July 1992 survey.

In these Figures the distribution of surface temperatures (at 5 m) is also given. The temperature during both surveys varied depending on the locality. Temperature distributions in these two surveys differed notably. During the August 1996 survey the temperature (maximum 28.8 °C, average 23.1 °C) was a few degree higher than that during the June-July 1996 survey (maximum 24.9 °C, average 21.4 °C). In the western Black Sea there was a frontal current system along the coast resulting in a sharp gradient during the August 1993 survey. Interestingly the main downwelling area of the Black Sea, the Batumi Gyre (7) was an upwelling area in this period. During the June-July1993 survey the only sharp gradient in surface temperature distribution was observed between Zonguldak and Sinop with temperatures down to 17 °C in the core. This upwelling region must be a consistent feature of the Black Sea hydrography during warm

summer months as it was also present during the 1957 and 1992 egg surveys [8;3]. Similar to results of those surveys, egg and larva numbers were either zero or very low in this region. This is not unexpected as maximum spawning of anchovy occurs at temperatures higher than 20 °C [9; 10]. For this reason , Niermann *et al.* [3] found very low eggs numbers overall (without any larvae) in another survey undertaken in June 1991 when surface temperatures were below 20 °C, unusual for this month. Niermann *et al.* [3] found plenty of eggs and larvae during the July 1992 survey with highest egg accumulations occurring in the eastern Black Sea which was warmer than the western region. We tested the effect of temperature on egg distribution using the data of Niermann *et al.* [3] and found a highly significant correlation value of 0.29 ($n = 142$, $P=0.0006$; Table 2). However whilst similar correlations for egg numbers were not found for either for the 1993 or the 1996 surveys, larva numbers in the 1996 survey gave a good correlation ($r=0.27$, $n=116$, $P=0.0034$) with temperature. As August is towards the end of the spawning season, the effect of temperature may not be clear, however lack of a correlation between temperature and egg numbers in the June-July 1996 survey suggests the importance of other factors in spawning.

According to Spearman's Rank Correlation analysis, salinity was another physical factor affecting the distribution of anchovy eggs during both July 1992 ($r= -0.22$, $n=142$, $P=0.0008$) and June-July 1996 ($r= -0.33$, $n=117$, $P=0.0003$), but not during August 1993 (Table 2). However, in contrast to temperature, salinity values negatively correlated with egg numbers. This means that besides the Danube affected area in front of Bosphorus [11], the Turkish coastal areas receiving a high fresh water supply (which is the case for the eastern Black Sea) must be suitable spawning grounds for the anchovy.

Total individual number of fodder zooplankton (excludes gelatinous organisms including the heterotrophic dinoflagellate *Noctiluca miliaris*) had also effect in the distribution of anchovy eggs. In the 1996 survey where plankton data are also available, a very high positive correlation ($r=0.33$, $n=120$, $P<0.0003$) occurred between the numbers of anchovy eggs and fodder zooplankton. It is known that anchovy continues feeding during spawning [6] and therefore abundance of fodder zooplankton being the food of anchovy is important for concentration of the spawning population. On the other hand, larval distribution was negatively correlated with biomass of surface microphytoplankton ($P<0.011$) (>=20 um) and microphytoplankton plus nanophytoplankton ($P<0.012$) but not with nanophytoplankton alone (<20 um) in the same period. It is difficult to explain this negative relationship between larva numbers and phytoplankton biomass. However it is worth mentioning that there was a very high correlation ($P<0.006$) between *Noctiluca* and microphytoplankton biomasses.

In all surveys, numbers of egg and larva always showed very high correlations ($P<0.0001$). This is expected since the life of an anchovy egg is as short as 24 hours before becoming a larva [6], and during sampling their cooccurence is inevitable. However the high correlation values between them also denotes that the main physical forces acting (i.e. water dynamics, particularly currents) are the same for both eggs and larvae. Probably partly due to this reason, the concentration of *Mnemiopsis* (abundance for the July 1992 survey and both abundance and biomass for the June-July 1996 survey) also showed very high correlations ($P<0.0007$) with egg numbers.

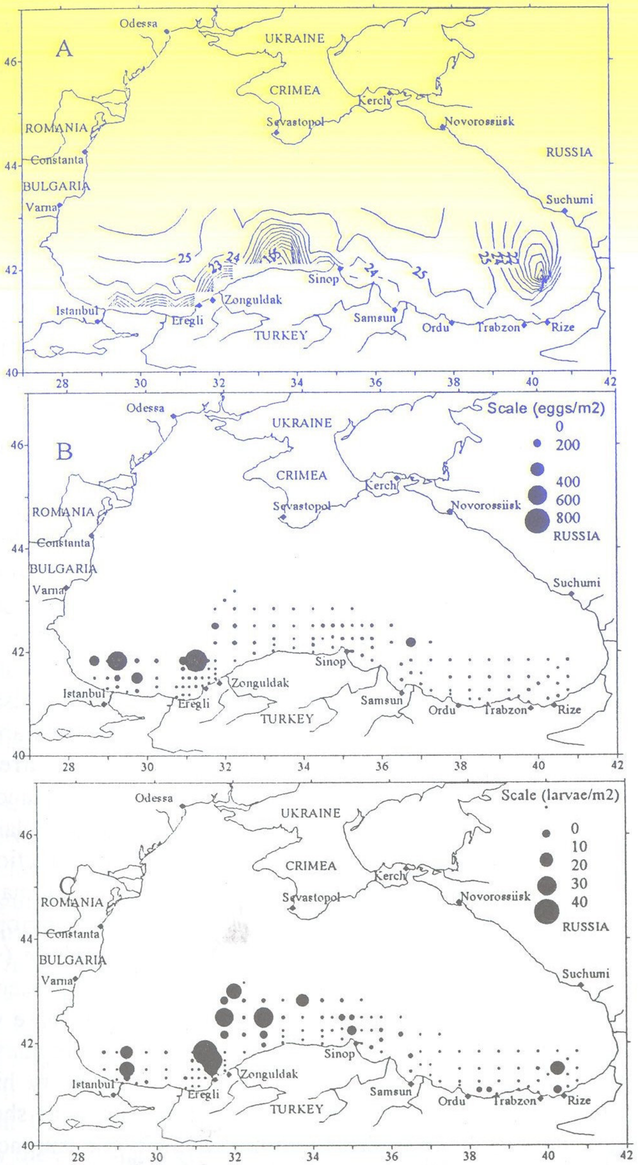

Figure 4. Distribution of [A] surface temperatures (as °C at 5 m depth), [B] anchovy eggs (numbers per square meter with a maximum number of 718), and [C] larvae (numbers per square meter with a maximum number of 39) in the southern Black Sea during the August 1993 survey.

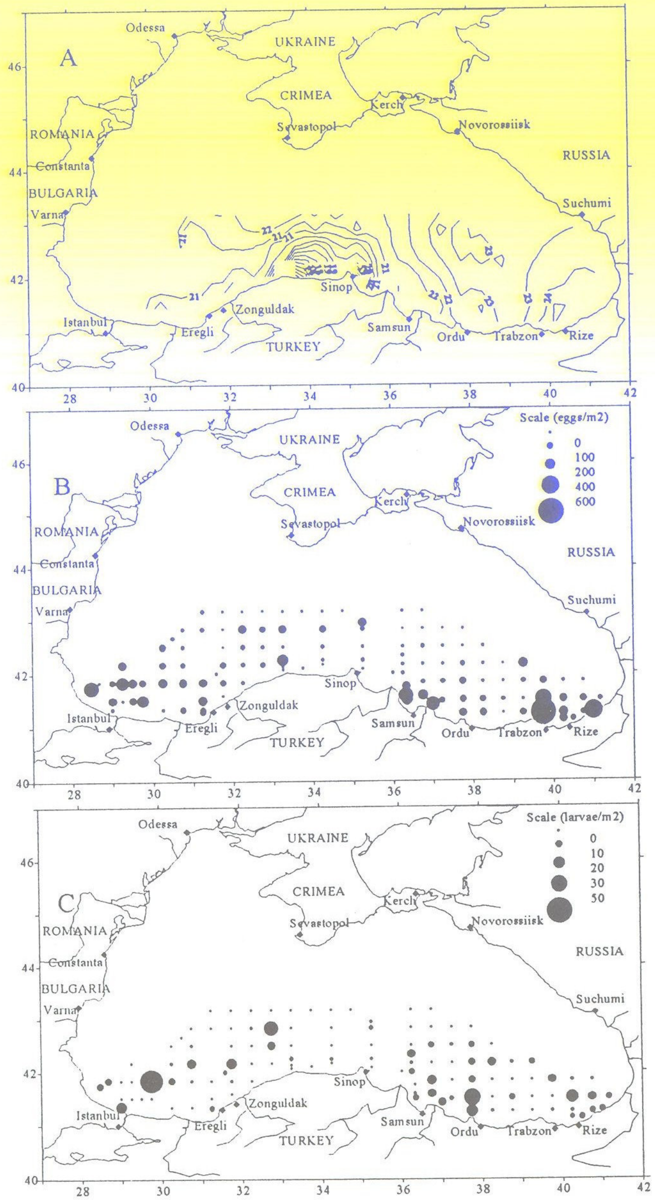

Figure 5. Distribution of [A] surface temperatures (as °C at 5 m depth), [B] anchovy eggs (numbers per square meter with a maximum number of 577), and [C] larvae (numbers per square meter with a maximum number of 44) in the southern Black Sea during the June-July 1996 survey.

TABLE 2. Spearman's Rank Correlation analyses between several biotic and abiotic factors during 1992, 1993 and 1996 surveys. Bold numbers indicate significant relationship. The negative sign denotes inverse relationship.

JUNE-JULY 1996	L	T	S	Nb	Zb	Za	Ma	Mb	MPa	NPa	TPa	MPb	NPb
Egg-#/m2 (E)	**0.0001**	-0.829	**-0.0004**	0.107	0.9535	**3E-04**	**0**	**0.0007**	-0.3	0.547	0.77	-0.83	0.316
Larva-#/m2 (L)		**0.0034**	-0.7218	0.489	-0.201	0.738	0.113	0.094	-0.07	-0.34	-0.2	**-0.01**	-0.58
Temperature-oC (T)			0.995	**-0**	0	0.323	**-0**	**-0.014**	-0.19	**-0.01**	-0.2	-0.07	**-0.01**
Salinity (S)				0.62	0.5135	0.645	**-0**	**-5E-04**	-0.45	-0.7	-0.6	-0.16	-0.74
Noctiluca biomass-mg/m2 (Nb)					**-3E-04**	0.797	0.06	0.1463	0.078	-0.53	1	**0.006**	-0.3
Zooplankton biomass-mg/m2 (Zb)						**0**	0.733	0.601	-0.31	-0.81	-0.7	-0.5	0.832
Zooplankton abundance-#/m2 (Za)							**0.025**	**0.0415**	-0.72	0.269	0.25	-0.83	0.431
Mnemiopsis abundance-#/m2 (Ma)								**0**	**0.044**	0.151	0.09	**0.006**	0.082
Mnemiopsis biomass-gr/m2 (Mb)									0.183	0.576	0.43	**0.034**	0.379
Microphytoplankton abundance-cells/l, Mpa										-0.78	**0.01**	**0**	0.982
Nanophytoplankton abundance-cells/l (Npa)											**0**	-0.7	**0**
Total Phytoplankton abundance-cells/l (Tpa)												0.081	**0**
Microphytoplankton biomass-mg/m3 (MPb)													0.875
Nanophytoplankton biomass-mg/m3 (NPb)													
Total Phytoplankton biomass-mg/m3 (TPb)													

AUGUST 1993	L	T	S	Za	Ma
Eggs-#/m2 (E)	0	0.248	0.19	0.608	0.7295
Larva-#/m2 (L)		0.895	0.93	0.355	0.5491
Temperature-oC (T)			**-0.0046**	-0.58	**0**
Salinity (S)				-0.25	**-2E-04**
Zooplankton abundance-#/m2 (Za)					-0.958

JULY 1992	S	L	E	Ma
Eggs-#/m2 (E)	0	**6E-4**	**-0.008**	0
Larva-#/m2 (L)		0.217	0.5541	0.558
Temperature-oC (T)			**0.008**	**2E-04**
Salinity (S)				-0.07

Both abundance and biomass of *Mnemiopsis* were found to correlate well with the abundance of fodder zooplankton in the water column ($P<0.04$). It is interesting that both *Mnemiopsis* and spawning anchovy, two competing species, concentrate in the areas where zooplankton abundance is high. However this competition is disadvantageous for the anchovy as its eggs and larvae are also consumed by *Mnemiopsis*.

Of several biotic parameters checked for correlation with eggs and larvae of anchovy, only the ones mentioned above gave significant correlations. However the inter-relationships between parameters mentioned above and those tested which produced no significant correlations are of certain importance with respect to the distribution of eggs and larvae of anchovy. Therefore, the factors governing the distribution of any planktonic organism including the eggs and larvae of anchovy are intricately interwoven in any ecosystem, including that of the Black Sea.

4. Conclusions

1) The present study confirms that Turkish coasts are now established as heavy spawning areas.
2) The best month for the sampling of anchovy eggs and larvae is July.
3) Since egg numbers reflect the size of parent stock, the high number of eggs and larvae obtained in June-July 1996 is an indication of improved conditions for anchovy in the Black Sea.
4) Temperature, salinity and fodder zooplankton are among the most important ambient parameters in the distribution of anchovy eggs.

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