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DISTRIBUTION OF ANCHOVY EGGS AND LARVAE (*ENGRAULIS ENCRASICOLUS* CUV.) IN THE BLACK SEA IN 1991 AND 1992 IN COMPARISON TO FORMER SURVEYS

by

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ABSTRACT

Two international surveys of anchovy eggs and larvae were carried out in the Black Sea at the beginning of the spawning season in June 1991 and at the main spawning time in July 1992. Horizontal tows demonstrated, that the bulk of anchovy eggs and larvae were distributed in the upper 3 m layer, but in downwelling areas eggs and larvae were found down to 70 m depth. In contrast to former surveys, vertical hauls of the present investigation imply a shift of the main spawning areas of anchovy from the northern to the southern Black Sea. Long term sampling by the Institute of Biology of Southern Seas, Sevastopol, shows a decline in the population of anchovy ichthyoplankton after 1988 in the northern part of the Black Sea compared to the sixties. The sudden decline of anchovy ichthyoplankton in 1989 supports the hypothesis that the recently introduced species *Mnemiopsis mccradyi* (Ctenophora) has played an important role in diminishing the Black Sea anchovy fisheries, though the drastic changes in the Black Sea ecosystem (due to pollution, eutrophication and heavy fishery) have also an effect.

INTRODUCTION

During the last few decades, the world's largest landlocked marine ecosystem, the Black Sea, has been subject to dramatic changes primarily as a result of increased nutrient input via the major rivers in the northern region (BALKAS et al. 1990, VOLOVIK et al., 1992, ZAITSEV, 1992). Originally this sea was classified amongst the oligotrophic seas of the 1940s (SOROKIN 1983) but it has changed progressively to display first mesotrophic and later eutrophic features (CADDY 1993). The shallow northwestern part of this sea has sometimes even shown dystrophic properties (ZAITSEV, 1993).

Until recently, ever increasing eutrophication levels, heavy fishing and strongly reduced numbers of predators were probably the major factors for the steady rise in the biomass of small pelagics in the Black Sea, where anchovy is the dominant fish (CADDY 1993). The total catch of small pelagic fish doubled in the 1980s from a level of 350 thousand tons in the late 1970s (CADDY 1993) despite a large strong increase in the population of jelly fish *Aurelia aurita* (up to 400 million tons in the whole of the Black Sea in the early 1980s), which competes for zooplanktonic food with the small pelagics (CADDY 1993, SHUSKINA & MUSAYEVA 1983, ZAITSEV 1992).

In the middle of the 1980s, the accidental introduction of the northwestern Atlantic ctenophore *Mnemiopsis mccradyi*, which originated from eutrophic lagoons in North America radically affected the entire pelagic fauna of the Black Sea (VINOGRADOV et al., 1989, ZAIKA & SERGEEVA 1991). Reaching the remarkable biomass of 800 million tons in the summer of 1988 (VINOGRADOV et al., 1989), this voracious ctenophore consumed a considerable fraction of the forage zooplankton production which was the food for pelagic fish and their larvae previous to the appearance *Mnemiopsis* (CADDY 1993).

Since 1988 there have been sharp decreases in the fish catches of all the riparian countries around the Black Sea. The Turkish anchovy catch decreased from 295 thousand tons in 1988 to 66 thousand tons in 1990 (DIE, 1968-1992). Anchovy catches of the former USSR plummeted to 21,000 t in 1991 from 224,000 t in 1986 (GFCM, 1991; CHASHCIN, 1992). Thus Turkish catches declined about four fold, whilst Russian catches declined about 10 fold. The total catches of the Azov Sea fisheries dropped 30 fold from 89.5 thousand tons in 1988 to 2.9 thousand t in 1990 (VOLOVIK et al. 1992). Along the Romanian coasts anchovy had virtually disappeared by 1989 though in 1986 2,5 thousand tons had been landed.

In general, fish are most vulnerable to changes in environmental conditions in their early life. In order to assess the impact of a changing environment on anchovy and its recruitment, monitoring of the egg and larval stages is essential.

The first ichthyoplankton studies in the Black Sea started in the 1930's (DEKHNIK, 1954; MAJOROVA & CHUGUNOVA, 1954; VODYANITSKY, 1936). Systematic surveys were carried out by the Institute of the Biology of Southern Seas (IBSS) during 1957-1965. DEKHNIK et al. (1970) found the peak spawning of anchovy to take place in July, with temporal and spatial variations arising from physical factors and the conditions of the parent stock. These authors also showed the numbers of anchovy eggs and larvae to be correlated closely with water temperature and available food (zooplankton) organisms. Similar results were obtained by Bulgarian authors (DIMOV, 1968). There are only a few surveys concerning fish eggs and larvae in the southern Black Sea (i.e. Turkish coasts: ARIM 1957; EINARSSON & GÜRTÜRK 1960; MATER & CIHANGIR 1990). Egg and larvae samples taken from both inshore and offshore areas showed that anchovy spawn throughout the entire Black Sea (MAJOROVA & CHUGUNOVA 1954; EINARSSON & GÜRTÜRK 1960) but the heaviest spawning occurred in the western (EINARSSON & GÜRTÜRK 1960) or north-western region close to shore (IVANOV & BEVERTON 1985).

This study is aimed to examine whether the changing of environmental conditions and the decline of the anchovy stock affects the abundance of egg and larvae of the anchovy in different areas of the Black Sea. Therefore the distribution of the eggs and larvae of anchovy in the Black Sea was investigated by basin wide surveys performed between the riparian countries and the results obtained have been compared with those from previous studies.

MATERIAL AND METHODS

The ichthyoplankton of the Black Sea were studied during two international joint cruises in June 1991 and in July 1992. In both years the Institute of Marine Sciences (IMS), Middle East Technical University of Turkey and the Institute of Biology of the Southern Seas (IBSS), Ukrainian Academy of Science participated with their research vessels "BILIM" and "Prof. VODJANITSKI", respectively. Additionally in July 1992 the Institute of Oceanology (BAS) of Bulgaria and the Romanian Marine Research Institute of Romania joined the survey with the Bulgarian R/V "AKADEMIK". During all cruises each vessel worked in its own Exclusive Economic Zone (EEZ).

The ichthyoplankton were collected by vertical hauls at 116 stations in 1991 and at 241 stations in 1992 (see Figs. 2 and 3). Additional horizontal tows were performed at 14 stations in the Ukrainian EEZ in July 1992. Details of nets, vessels, and other related information concerning the sampling procedure is given in Table 1.

Methodological differences particularly in the mesh sizes of the nets used between the cooperating organizations were retained in order to obtain data comparable with studies previously carried out by each institute. An intercomparison of the equipment and sampling methods employed by the vessels was made at two stations along the borderline of the EEZ's in June 1991. Due to bad weather conditions no intercomparison was possible in 1992.

AREA OF INVESTIGATION

The cyclonically meandering Rim Current constitutes the unique basin-scale feature of the Black Sea (Fig. 1). Along the axis of the Rim Current geostrophic currents have speeds of 0.2-0.3m s^{-1} (OGUZ et al. 1993). The interior of the Rim Current is formed by two separate cyclonic cells occupying the western (Western Gyre) and eastern halves (Eastern Gyre) of the basin. In addition to these features a series of mesoscale anticyclonic eddies is distributed between the Rim Current and the coast. The two most persistent eddies are the Batumi- and the Sevastopol Eddy. Along the Turkish coast three other quasi-permanent anticyclonic eddies, related to regional topography, are situated in the south western part of the basin (Bosphorus Eddy), and off Sakarya and Kizilirmak rivers. Along the north eastern coast, the Crimean and Caucasian Eddies are the most pronounced quasi-permanent features of this region. An irregular offshore protrusion of the meandering Rim Current along the Caucasian coast is a common feature. Another apparently recurrent feature, is the Kali-Akra Eddy in front of the Bulgarian coast (OGUZ et al. 1993).

RESULTS

INTERCOMPARISON

Intercomparison stations had to be chosen in the open sea, but unfortunately in June 1991 ichtyoplankton was very sparse at the three intercomparison stations. The Ukrainian samples contained no eggs or larvae. In the Turkish samples only a total of 4 eggs (maximum one egg per haul) were caught in the seven replicate hauls. In July 1992 none of the intercomparison stations could be visited due to bad weather conditions.

VERTICAL DISTRIBUTION

In order to estimate differences between the hauls from the surface down to the H_2S-layer (120-180 m) and the hauls from the surface down to the thermocline (20-45 m), comparative catches were carried out at 4 stations in the Turkish EEZ. No significant differences (U-test; Wilcoxon, Mann & Whitney, 1947) were found between the deep and the shallow hauls.

Horizontal tows performed by the Institute of Biology of Southern Seas, Sevastopol, in the northern part of the Black Sea in 1992 (Ukrainian EEZ) displayed that the majority of eggs and larvae were obtained from the surface layer (1-3 m), where the temperature was highest (range 20.1-24.6°C; Table 2).

Although the bulk of the anchovy eggs and larvae were above the thermocline, at 7 stations in downwelling regions some eggs and larvae were found below the thermocline at a depth of 50 - 70 m in July 1992. These stations were located at convergence zones along the outer edge of the rim current, in the downwelling areas of the north eastern part the Black Sea and in the downwelling area of the quasistable anticyclonic Sevastopol eddy. In July 1992 about 18 % (range: 6-44 %) of the total amount of anchovy eggs found at the 7 stations were beneath the thermocline. Larvae beneath the thermocline were found only at the nearshore station 30, corresponding to main convergence zone. At this station, the number of eggs and larvae were distributed unevenly down to 50 m with a maximum amount of larvae (76 %, n = 28) concentrated below the thermocline. However only larvae of advanced stages both live and in good condition were found between 50-70 m depth range, smaller (younger) stages were dead.

HORIZONTAL DISTRIBUTION OF ANCHOVY EGGS AND LARVAE

June 1991

In June 1991 the water temperature was below 20°C throughout the Black Sea (Fig. 2). The southwestern region displayed temperatures below 16°C. The eastern part of the Black Sea was warmer than the western area where surface temperatures (at 5 m depth) varied between 17.8-19°C. Spawning had started mainly in the eastern part of the Black Sea at coastal areas (between east of Samsun and west of Rize, between east of Kerch and Suchumi and south of Odessa). Despite the low water temperatures of 15-16°C spawning had also started in the Bosphorus area.

The total number of anchovy eggs in coastal areas were between 10 to 30 eggs m^{-2}. In open waters egg numbers were mainly zero when eggs were present, their numbers were small compared to those of coastal areas (generally below 2 eggs m^{-2}; Fig. 2). In June 1991 a total of 154 eggs at 66 stations were found in the Turkish EEZ and 286 eggs at 66 stations were found in the Ukrainian EEZ.

During the whole study period in June 1991 almost no larvae were found. Only at two stations situated between off Novorossisk and Suchumi which had relatively warm water (>19.5°C), were two anchovy larvae m^{-2} found.

In July 1992 the surface temperatures (20.2°C to 22.5°C) were higher than in June 1991 and relatively uniform throughout the whole Black Sea area (Fig. 3). Only in some areas in the eastern part the surface water was slightly elevated (23°C to 24°C).

In July 1992 a total of 4256 anchovy eggs at 241 stations were found. Maximum egg numbers occurred in the coastal waters of the southeastern as well as in the southwest and western areas of the Black Sea (Fig. 3).

The distribution of anchovy larvae was in accordance with that of the eggs in July 1992, however their quantities were small (maximum 26 larvae m-2; Fig. 4).

DISCUSSION

INTERCOMPARISON

The main disadvantages of these international surveys were the use of different sampling gears and the lack of good intercomparison data. In 1991 the stations chosen for this aim were poor terms of ichthyoplankton and in 1992 no intercomparison was made due to bad weather conditions. The low egg numbers achieved in the Ukrainian EEZ compared to the Turkish EEZ in July 1992 could be due to differences in sampling gear (Fig. 3), but when Ukrainian and Turkish data of June 1991 were compared no differences occurred (Fig. 2).

According to comparison samples at 4 stations in the Turkish EEZ, the different depths of vertical sampling, 100 m (as done in Bulgarian, Romanian and Ukrainian waters) and down to the H_2S-level in the Turkish waters had no influence on the results. Also EINARSSON & GÜRTÜRK (1960) noted, that the egg number was lower in vertical hauls from 100 m to surface than in vertical hauls from 30 m depth to surface. Since all hauls were made vertically the presentation of data per m^2 allows to compare the different regions of the Black Sea at least semi quantitatively.

VERTICAL DISTRIBUTION

Spawning of anchovy in the Black Sea and in the Mediterranean occurs above the thermocline at depths of 0-10 m (DEKHNIK 1973, PALOMERA, 1990, 1991). Eggs and larvae are distributed between 0-30 m. At night the larvae migrate close to the surface (EINARSSON & GÜRTÜRK 1960). According to the present study the depth range of the distribution of the anchovy eggs is very narrow: the majority of eggs occurred both day and night at a depth between 0 - 3 m beneath the surface.

In regions of downwelling anchovy eggs and larvae could also be pushed under the thermocline. GORDINA et al. (1990) found in the Black Sea, that in areas of convergence, usually at the outer border of the rim current, live eggs and larvae of anchovy and horse mackerel were dispersed down to 100 m depth. In these downwelling areas in 1988 the number of anchovy eggs under the thermocline was up to 70 % of the total number sampled per 1 m^2 (GORDINA et al. 1990). Similar results were found in the present survey. An average of 18 % (maximum 70 %) of eggs occurred under the thermocline in downwelling areas. In July 1992 however only larvae in the advanced stages, live and in good condition were found in the 50-70 m depth range, smaller (younger) stages were dead. Transport of larvae in the early stages below the thermocline (through downwelling) may result in high mortality. Larger larvae (advanced stages) which undergo vertical migration seemed less vulnerable to low temperature than younger stages.

SPAWNING TEMPERATURE

The maturing of Anchovy gonads starts at a minimum temperature of 13°C, spawning occurs between temperatures of 13°C/14°C - 26°C, with maximal spawning activity higher than 20°C (DEKHNIK 1954, DEMIR, 1959). During the survey in June 1991 the water temperatures in the upper layer (5 m depth) were exceptionally cold being 1.5-2°C less than the average temperatures of previous decades (ALTMAN et al., 1987). Thus the low number of anchovy eggs and the scarcity of larvae found during the survey in June 1991 could be explained by delayed spawning due to the low water temperatures all the entire Black Sea.

In July 1992 the water temperature due to the cold and late spring period was 2 - 2.5°C below the longterm average for previous years (ALTMAN et al., 1987). Yet the comparatively uniform surface temperatures of 20.2 to 22.5°C and above (Fig. 3) were high enough to lead to successful spawning.

HORIZONTAL DISTRIBUTION

According to IVANOV & BEVERTON (1985) anchovy spawn throughout the whole of the Black Sea but mainly in the northern half (Fig. 5). EINARSSON & GÜRTÜRK (1960) found also a high number of anchovy eggs in the Bosphorus area in July 1957 (Fig. 6). The main spawning zones between 1950 to the 80's were in near surface waters between the coast and the rim current (ARKHIPOV et al., 1992; CADDY & GRIFFITHS, 1990; GORDINA et al., 1990).

Ukrainian surveys showed that, by the beginning of 1988, changes in the spawning areas of anchovy were notable. In 1988 the most abundant areas with respect to anchovy eggs and larvae had shifted to the open sea along the offshore boundary of the rim current and to the center of mesoscale eddies (GORDINA et al., 1990).

The July 1992 survey showed that the spawning areas now had concentrated in the southern half of the Black Sea (Fig. 3) in contrast to earlier spawning pattern (IVANOV & BEVERTON 1985; Fig. 5). This development was also seen by comparing the distribution of anchovy eggs in the 1992 survey, with the 1957 survey carried out by EINARSSON & GÜRTÜRK (1960; Fig. 6)). While the northern part of the Black Sea displayed nearly the same numbers of anchovy eggs in 1957 and 1992, egg numbers in the southern part was significantly higher in 1992 indicating a shift of the spawning areas to the southern Black Sea (Fig. 7).

According to the well known high fluctuation of anchovy stocks all over the world it is of course problematic to verify changes in the spawning areas of the Black Sea anchovy within two surveys.

Previous surveys of the Institute of Biology of Southern Seas, Sevastopol, based on the same net type and sampling procedure, gave the opportunity to compare the occurrence of anchovy eggs and larvae in 1991 - 1992 with those from 1957 to 1965 (DEKHNIK et al., 1970; DEKHNIK, 1973) and 1986-1990 cruises.

A longterm ichtyoplankton sampling has been carried out in front of the Crimea peninsula (in waters less than 100 m depth). Since 1986 additional samples were done in waters > 100 m (black columns in Fig. 8).

The same result, which was achieved comparing the 1957 and the 1992 surveys is also apparent in the Ukrainian data set: no significant difference between the numbers of anchovy eggs in the late fifties (1957 and 1959) and 1992. The egg numbers varied about 25 eggs m^{-2}. In the early sixties the number of eggs increased continually (up to 390 eggs m^{-2} in 1962). From 1963 to 1986 no sampling was carried out. Due to an extreme cold water temperature the egg number was very low in 1986. A recovery of eggs was found in 1988. In the year 1989 and 1990 a sudden decline of anchovy eggs was noted. A slight increase of eggs was observed during 1991 and 1992.

The average number of anchovy larvae collected in every July since 1957 displayed the same patterns, high values in the sixties and in 1988, a harsh decline from 1989 - 1990 and a slight increase in numbers in 1992 (Fig. 8)

According to unpublished data of the Institute of Biology of Southern Seas, Sevastopol, the same patterns of fluctuation of anchovy egg and larvae distribution was observed in other areas of the western and northern Black Sea (Zaika, pers. com.): Moderate to high egg and larvae numbers before 1960, a period of very high egg numbers in the early sixties and a sudden decrease after 1988 in the years 1989 to 1990.

CONCLUSION

The following description of anchovy spawning is consistent with the results of our studies: The increase of the temperature and the stabilization of the thermocline during early summer triggers the spawning which starts in near-shore waters in the north eastern part of the Black Sea. This region generally warms up earlier than the south western coastal areas and the open sea. The subsequent increase of temperature causes an expansion of the spawning areas to include open waters and a shift of areas displaying high egg numbers from the near-shore to the outer boundary of rim current. Thermal limitation of spawning then disappears and water dynamics and food conditions become the main factors controlling the spawning area.

The shifting southward of the spawning regions is consistent with the northern part of the Black Sea becoming in the last two decades more eutrophic and polluted than the southern part (see reviews: BALKAS et al. 1990, MEE 1991, VOLOVIK et al., 1991, ZAITZEV, 1992). It may be assumed that the changing environment, the increased density of microalgae and protozoa and the replacement of large copepod species by smaller species (ZAITSEV, 1992) has led to a deterioration of the food quality and availability, which results in a stronger summer migration of anchovy to the southern part of the Black Sea.

The low egg and larvae numbers in 1957 and 1959 reflect the mesotrophic state of the Black Sea in the late 1950s. With the increasing eutrophication, the anchovy stock enlarged in the early 1960s, and consequently egg and larvae numbers increased. The very low egg and larvae numbers after 1988 reflect the drastic decline in the parent anchovy stock in 1988.

The decline in anchovy eggs and larvae in 1988 could be related not only to overfishing but also to the above mentioned eutrophication of the Black Sea. The plankton enriched water have now created the basic conditions for the outburst of the ctenophore *Mnemiopsis* observed in the years 1987 to 1989. *Mnemiopsis* in the Black Sea competes for zooplanktonic food with anchovy, as well as preying on anchovy eggs and larvae (DEKHNIK et al., 1970; SERGEVA et al., 1990, TSIKHON-LUKANINA & REZNITCHENKO, 1991a, 1991b).

In 1988 the predation of the ctenophore on anchovy eggs and larvae was not of primary significance. Obviously, the rapid growth of *Mnemiopsis* biomass during the summer-autumn period in 1988 resulted in a dramatic food shortage for the anchovy larvae and juveniles, poor recruitment and eventually a frail parental stock in 1989. Thus, the increasing dominance by *Mnemiopsis* of the Black Sea pelagic community seems to be a major reason for the sharp decline in anchovy eggs and larvae number in 1989 - 1991, the severe reduction in the anchovy stock (BINGEL et al, 1993) and the drop in catches (CADDY & GRIFFITHS 1990, GFCM, 1991). In the summer of 1990 the population of *Mnemiopsis* probably passed through its peak and the numbers started to decline now (Vinogradov, pers. com.). This may be the reason for the increase in the anchovy egg and larvae numbers in 1991 and 1992.

Beside the effects of *Mnemiopsis* the anchovy stock shows signs of severe overfishing. The use of powerful fishery equipment since the beginning of the 80s, especially of wide ranging sonars, has placed the anchovy stock under heavy pressure. This is shown among other indications by the steady decline in the average size of the anchovies caught (BINGEL, et al. 1993). During their migration from the northern area of the Black Sea to the southern coastal areas in late winter nearly all anchovy shoals were caught quantitatively once they had appeared in the Turkish coastal waters (BINGEL et al. 1993). Thus, the reproductive stock has declined drastically. In Turkish waters the mean total length of captured anchovy dropped from 11 cm in 1988 - 89 to 7 cm in 1991/1992. The anchovy usually spawns at an age of 1 year having a total length of 10 cm, thus, a large proportion of the stock was caught prior to spawning, which is also consistent with the decline in the spawning stock (BINGEL et al. 1993).

It seems likely that overfishing and the competition for food between anchovy and *Mnemiopsis* would have led to the present size of the anchovy stock. Various examples show the spawning of anchovy to be also dependent on environmental conditions (LASKER, 1988). The spawning success is often related to the availability of specific phytoplankton to the newly hatched fry and to certain meteorological and hydrographical conditions such as wind speed, upwelling and the meandering of currents (LASKER, 1988). The upper layer circulation dynamics of the Black Sea are relatively well understood (for a review see Oguz et. al. 1991). Ongoing research programs, supported by satellite imagery, are investigating the extent to which phytoplankton blooms and the upper layer circulation in the Black Sea affect the abundance and distribution of eggs and larvae and eventually the subsequent year-class strength.

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Table 1: Data collection scheme of the joint cruises.
CIS = Commonwealth of Independent States

Research vessel	Turkish EEZ R/V BILIM	CIS EEZ R/V PROF. VODJANITSKI	Bulgarian & Romanian EEZ R/V AKADEMIK
Vertical hauls			
Number of stations (1991)	66	50	--
Number of stations (1992)	143	65	33
Net type and mesh size	Hensen 300µm	Bogorov-Rass 500µm	Djedi 150µm
Net opening diameter	70cm	80cm	36cm
Hauling speed	1m/s	1m/s	?
Depth recording	Angle and cable length	Angle and cable length	Angle and cable length
Depth of haul in 1991	100m-surface	100m-surface	-
Depth of haul in 1992	anoxic-surface layer (sigma σ_t=16.2)	100m-surface	100m - surface
Sorting large zooplankt.	on board	on board	-
Sorting ichthyoplankt.	in the Institute	on board	in the Institute
Fixation of the samples		4 % buffered Formalin	
Presentation of results		**Numbers per m^2**	
Horizontal hauls			
Net type and mesh size	-	Melnikov 1000µm	-
Number of stations 1992	-	14	-
Depth ranges	-	Some stat. 1-3m, 0-12m, 20-30m, 45-50m, 70m	-
Towing speed	-	3-4 knots	-
Duration of haul	-	10 min	-
Surface area of net mouth	-	0.2 m^2	-
Presentation of results	-	**Numbers per $100m^3$**	-
Intercomparison hauls		only made in June 1991	-
Number of stations		2	-
Number of replicate hauls		7	-

Table 2 Vertical distribution of anchovy eggs according to horizontal tows performed by RV "Prof. VODJANITSKI" in the northern part of the Black Sea.
(.)= no haul performed

Date	Station	Lat N	Lon E		egg number per 1000 m3						larvae number per 1000 m3							Temperature oC			
	No			1-3m	10-15m	20-25m	30m	45-50m	70m	1-3m	10-15m	20-25m	30m	45-50m	70m	1-3m	10-15m	20-25m	30m	45-50m	70m
5.7	1	45°45′	32°30′	204	55	0	.	.	.	0	9	0	.	.	.	20.1	20.0	17.8	.	.	.
8.7	13	43°49′	31°15′	0	0	.	0	.	.	0	0	.	0	.	0	21.0	21.0	.	8.0	.	.
8.7	12	44°00′	31°15′	694	74	83	.	.	139	0	27	0	.	.	0	21.8	21.8	16.0	.	.	6.5
10.7	19	45°00′	32°15′	324	9	37	.	37	.	0	0	9	.	0	.	20.2	20.2	8.7	.	6.5	.
10.7	22	44°30′	32°15′	120	9	.	0	.	.	0	0	.	0	0	.	21.9	20.6	.	8.5	.	.
10.7	25	44°01′	32°15′	28	0	.	.	.	.	27	0	.	.	.	.	21.2	11.3	.	.	.	.
11.7	28	43°30′	32°15′	130	18	.	.	9	.	0	0	.	.	0	.	21.5	21.4	.	.	7.1	.
12.7	30	44°50′	33°15′	991	18	157	.	.	158	9	0	9	.	.	19	21.4	21.3	9.6	.	.	6.5
12.7	32	44°30′	33°18′	74	9	0	.	.	27	0	0	0	.	.	0	21.1	20.6	10.2	.	.	2.7
12.7	34	44°00′	33°15′	46	0	0	.	0	.	0	0	0	.	0	.	21.2	21.2	7.6	.	6.5	.
20.7	54	43°30′	39°15′	172	134	55	.	55	.	9	0	0	.	0	.	24.2	22.0	10.2	.	7.3	.
21.7	57	42°10′	40°15′	18	27	0	.	36	.	0	0	0	.	0	.	22.1	12.0	7.8	.	6.5	.
21.7	61	42°50′	40°15′	778	0	55	.	0	.	0	0	9	.	.	.	24.6	23.6	9.4	.	6.9	.
21.7	63	43°09′	40°15′	911	194	204	333	.	.	110	27	18	0	.	.	23.7	22.9	21.5	10.7	.	.
sum				4490	547	591	333	137	324	155	63	45	0	0	19						

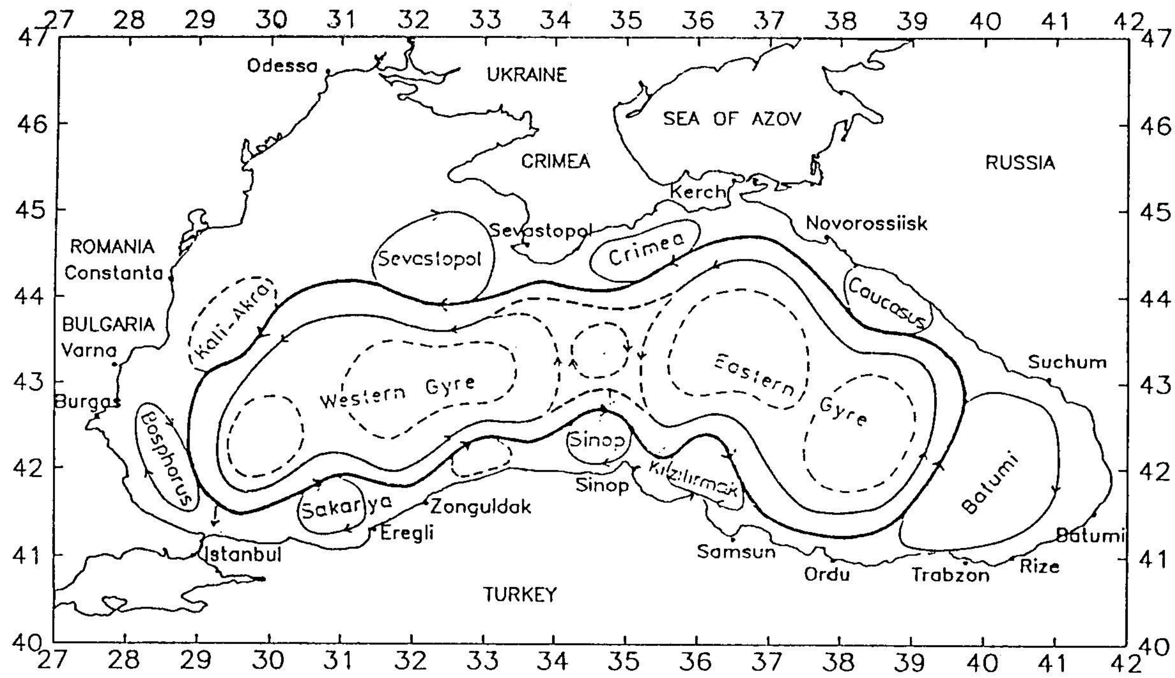

Figure 1 General circulation of surface currents in the Black Sea (redrawn from OGUZ et al., 1993). The bold line symbolizes the rim current.

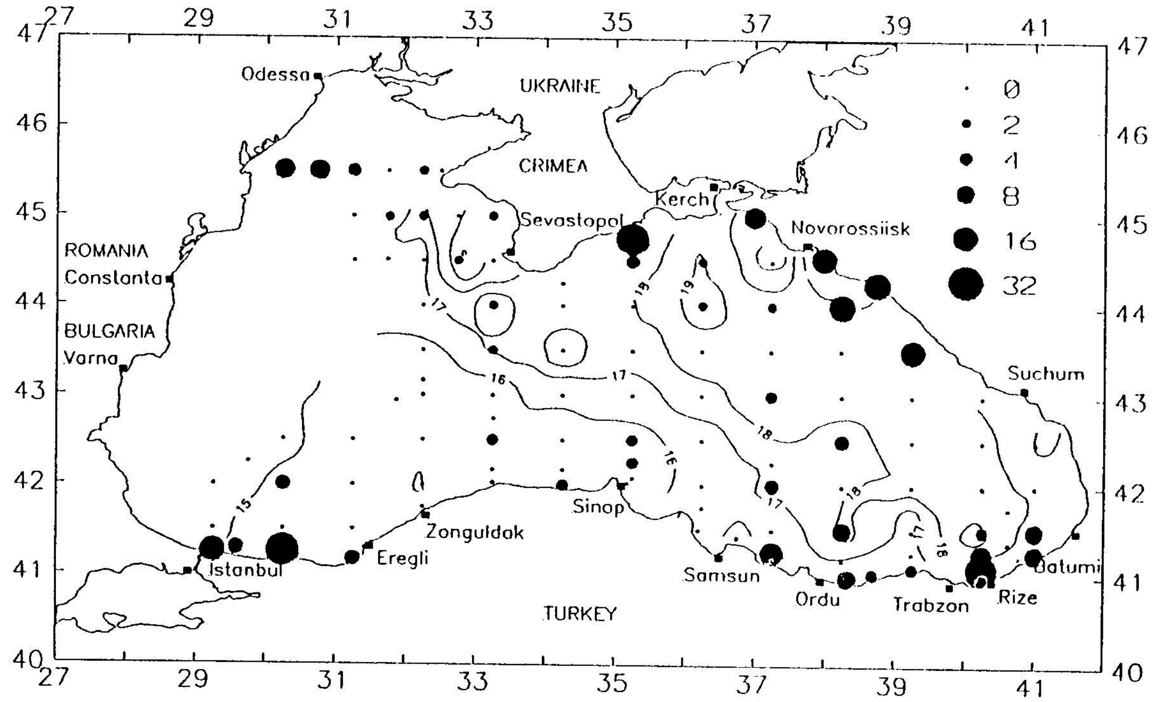

Figure 2 JUNE 1991: Anchovy eggs (number m^{-2}) and surface temperatures (°C; at 5 m depth) in the Black Sea. The largest circle is equal to 29 eggs m^{-2}. Numbers according to the area of the circle.

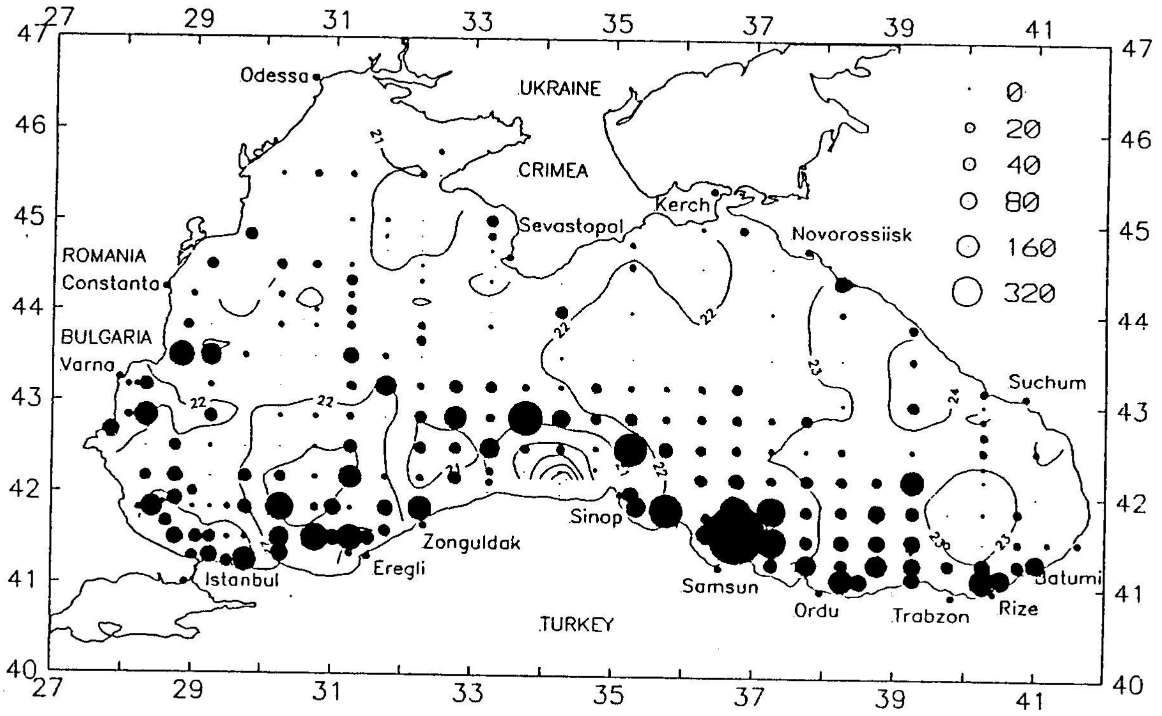

Figure 3 JULY 1992: Anchovy eggs (number m^{-2}) and surface temperature (°C; at 5 m depth) in the Black Sea. The largest circle is equal to 1167 eggs m^{-2}. Numbers according to the area of the circle.

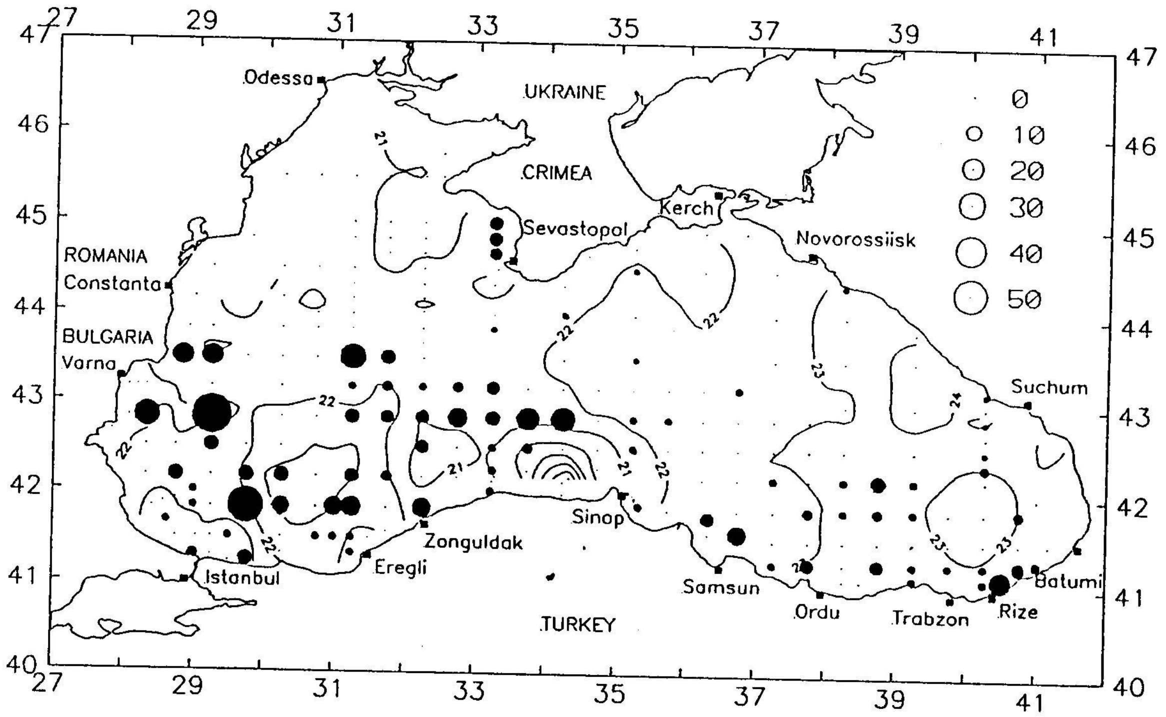

Figure 4 JULY 1992: Anchovy larvae (number m^{-2}) and surface temperature (°C; at 5 m depth) in the Black Sea. The largest circle is equal to 55 larvae m^{-2}. Numbers according to the area of the circle.

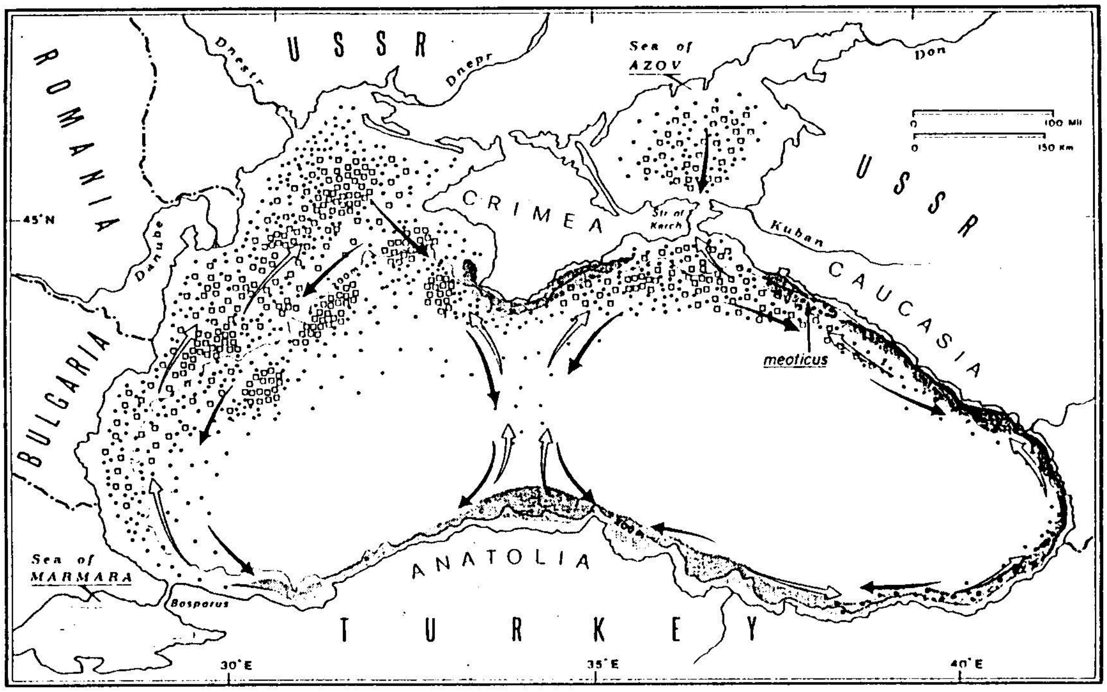

Figure 5 Spawning grounds of anchovy *Engraulis encrasicolus* in the Black Sea according to IVANOV & BEVERTON (1985). Squares: spawning areas. Circles: feeding areas. Dark grey: wintering areas

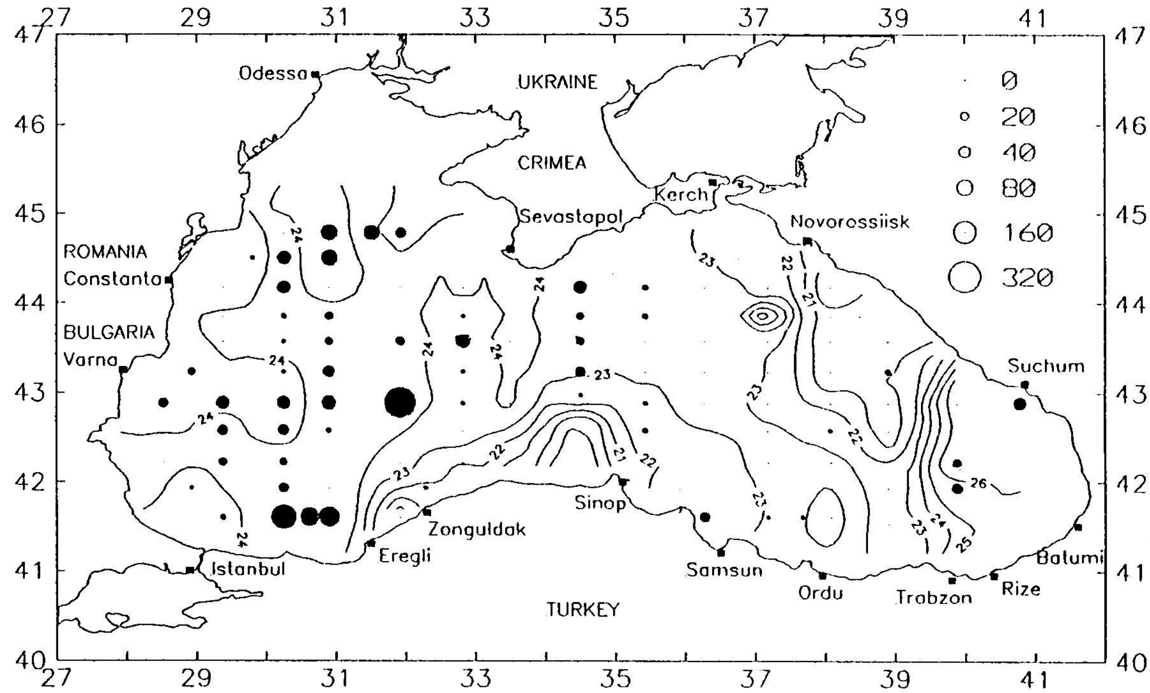

Figure 6 JULY 1957: Anchovy eggs and surface temperature (at 10 m depth) in the Black Sea (EINARSON & GÜRTÜRK, 1960). The largest circle is equal to 321 eggs m^{-2}. Numbers according to the area of the circle.

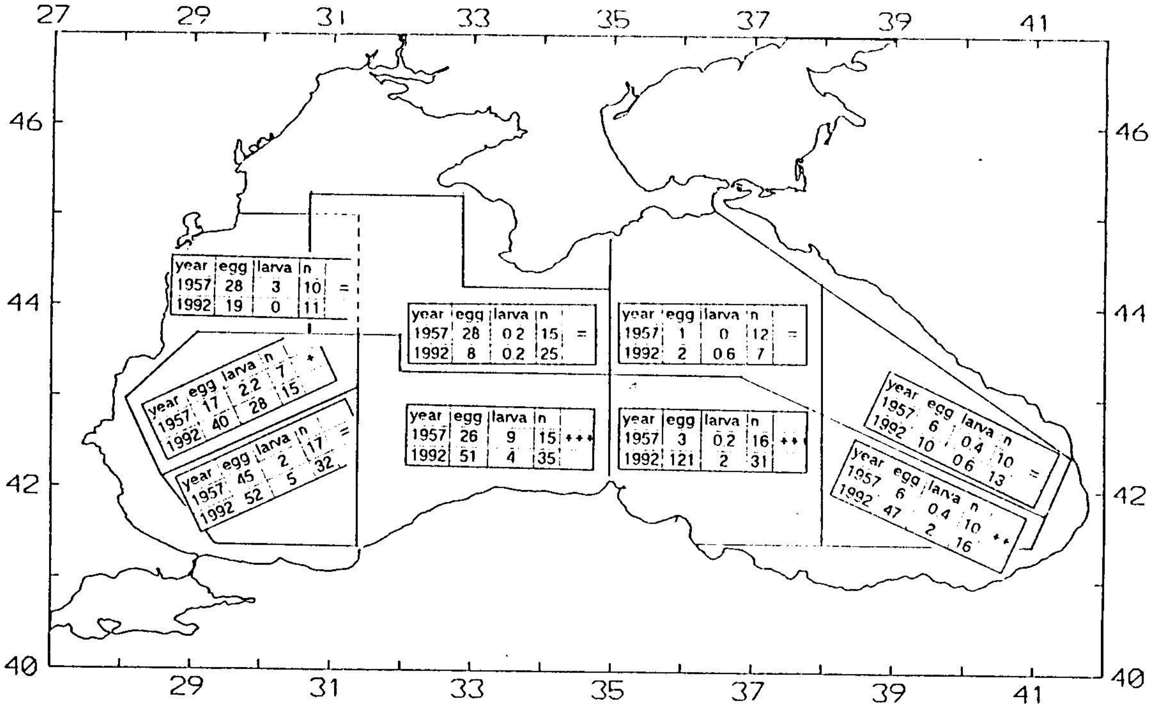

Figure 7 Comparison 1957 / 1992: Numbers of anchovy eggs and anchovy larvae (number m^{-2}) in 9 different areas of the Black Sea in 1957 (EINARSON & GÜRTÜRK, 1960) and in the joint survey 1992.
n = number of stations per area. =: not significantly different, *: significantly different, **: high significance, ***: very high significance

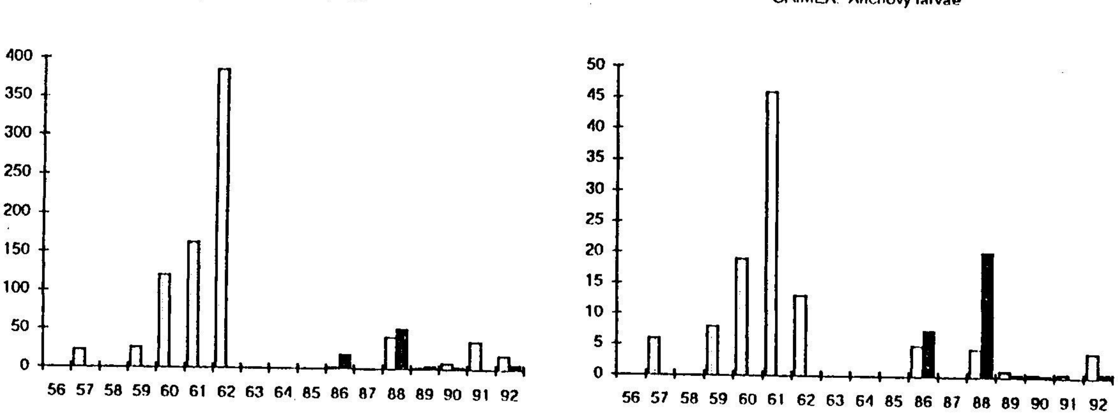

Figure 8 Fluctuation of anchovy eggs and larvae (numbers m^{-2}) in front of the Crimea peninsula (Sevastopol area; 1957 - 1992).
White columns: total water depth < 100 m.
Black columns: total water depth > 100 m.