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# New data on the morphological differences of anchovy eggs (*Engraulis encrasicolus* L) in the Black Sea

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**Abstract**

A survey was carried out on anchovy eggs in the Black Sea, within the framework of the international ComsBlack programme, during the main spawning period in July 1992. Length measurements of anchovy eggs displayed regional differences, as did egg shape. The mean size of eggs found in the northern area was: longitudinal diameter, 1.18 mm (range 1.00–1.37 mm); transverse diameter, 0.74 mm (range 0.62–0.87 mm). The mean size of eggs found in the southern area was: longitudinal diameter, 1.11 mm (range 0.95–1.25 mm); transverse diameter, 0.66 mm (range 0.50–0.80 mm). Eggs in the northern Black Sea were bigger and oval in shape, while both oval and elongated eggs occurred in the southern Black Sea, and of these the elongated eggs were mainly found in coastal regions. The size and shape of the anchovy eggs could not be correlated with salinity and temperature. The occurrence of smaller, elongated eggs in the southern Black Sea, which are characteristic of the Marmara anchovy, might indicate migration of the Marmara anchovy into the Black Sea, which has not previously been recorded. © 1997 Published by Elsevier Science B.V.

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## 1. Introduction

Anchovy (*Engraulis* spp.) are found world-wide and are adapted to a wide range of temperature (8–22.5°C) and salinity (7–39‰) (Fage, 1920; Aleksandrov, 1927; Pusanov, 1936). Majarova and Chugunova (1954) divided the Black Sea anchovy (*E. encrasicolus ponticus*) into two forms and differentiated an eastern (*E. encr. ponticus natio orientalis*) and a western (*E. encr. natio occidentalis*) form. Another sub-species is the Azov anchovy (*E. encr. maeoticus*), which migrates through the Kerch strait between the Azov Sea and the Black Sea for feeding and spawning and may form a hybrid with the Black Sea anchovy (Chashchin, 1985).

In the Black Sea, spawning takes place between the second half of June and the end of August, with a peak in mid-July (Einarson and Gürtürk, 1960; Dekhnik, 1973; Niermann et al., 1994). The eggs of the Black Sea anchovy have an elongate ellipsoid form. The perivitelline space is very narrow, and the yolk is transparent. The yolk is structured in a similar way to clupeid eggs. No oil drops are present (Vodyanitsky and Kasanova, 1954; Dekhnik, 1973). The longitudinal diameter of Black Sea anchovy eggs varies between 1.00 and 1.90 mm, and the transverse diameter between 0.66 and 1.20 mm

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(Vodyanitsky, 1930, 1936; Malyatsky, 1940; Vodyanitsky and Kasanova, 1954; Pavlovskaya, 1955; Zaitsev, 1958, 1959; Lugovaya, 1963; Dekhnik, 1973). The size and shape of an anchovy egg is related to the time of spawning. Egg sizes decrease towards the end of the spawning season. In the Black Sea, longitudinal egg diameters decreased from 1.34 to 1.04 mm and transverse diameters from 0.81 to 0.72 mm from the end of May to August 1960 (data from Lugovaya, 1963). This decrease in egg size of late-spawning fish has been reported for other fish species (e.g. whiting, Hislop, 1975, and European and American mackerel, Ehrenbaum, 1923).

With increasing salinity, anchovy egg sizes decrease and their shape becomes more slender (Zaitsev, 1959; Lugovaya, 1963; Demir, 1968). Demir (1959) compared data on egg sizes of anchovy from the Black Sea, the Sea of Marmara, the Aegean, the Adriatic and the eastern Mediterranean and found that the relationship between the transverse and longitudinal diameters of anchovy eggs is a sensitive indicator of the water characteristics where spawning takes place.

Apart from modifications due to physical and physiological parameters, the size and shape of fish eggs can be defined as stable morphological characters of a species or sub-species (Rass, 1953). However, the Marmara anchovy stock could be distinguished from the Black Sea population by their more elongated egg shape, with transverse diameter ranging from 0.50 to 0.79 mm (Arım, 1957).

It is not clear to what extent mixing occurs between the different Black Sea anchovy populations, or whether there is mixing of the Black Sea anchovy stock with the Marmara anchovy stock. Eggs collected during an international quasi-synoptic survey in July 1992 provided an opportunity to analyze the shape of anchovy eggs sampled in different areas of the Black Sea during the same time period, with an emphasis on separating different anchovy stocks within the Black Sea.

## 2. Material and methods

Anchovy eggs were collected within the framework of the international ComsBlack programme by the research vessels *Bilim* (Institute of Marine Sciences (IMS), Middle East Technical University of Turkey) and *Prof. Vodyanitsky* (Institute of Biology of the Southern Seas (IBSS), Ukrainian Academy of Science). Each vessel worked in its own exclusive economic zone (EEZ). Eggs were collected from five areas in the Black Sea during July 1992 (Fig. 1).

Eggs were collected by vertical hauls at 32 stations (Area V in Fig. 1) with a Hensen net (opening diameter 70 cm, mesh size 300 μm), and at 66 stations (Areas I–IV in Fig. 1) with a Bogorov Rass net (opening diameter 80 cm, mesh size 500 μm, Rass and Kazanova, 1966). The towing speed of both nets was 1 m $s^{-1}$.

The Bogorov Rass net hauls operated from 100 m to the surface, and the Hensen net hauls from the anoxic layer ($H_2S$ layer) to the surface. The depth of the $H_2S$ layer (according to the equation $\sigma\theta = 16.4$; Tuğrul et al., 1992) was estimated by using a CTD probe (Seabird). The depth of the anoxic zone varied from 80 m in the central gyres to about 170 m on the continental shelf. Temperature, salinity and conductivity were recorded at every station (Area V in Fig. 1).

The eggs were stored in 4% formaldehyde, buffered with borax, and were measured (always by the same person) using a stereoscopic microscope micrometer. Stations with fewer than five eggs were not included in the analysis.

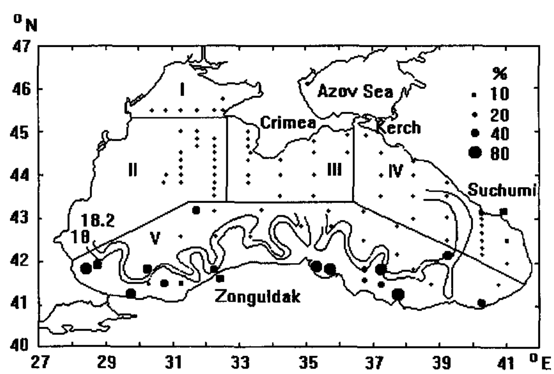


Fig. 1. Station grid and distribution of elongated anchovy eggs (% in upper right-hand corner) in the Black Sea in July 1992. The rim current, indicated by the isohalines 18.2‰ and 18.0‰ in a depth of 25 m, is only shown for the southern Black Sea. Areas of collection: I, northwestern shelf; II, western area; III, Crimea; IV, Caucasus (CIS Exclusive Economic Zone); V, southern Black Sea (Turkish Exclusive Economic Zone).

To compare the shapes of anchovy eggs collected in the southern (Turkish EEZ) and northern (CIS EEZ) Black Sea, discriminant analysis (Kendall, 1975) and the MGLH program of the SYSTAT package (Wilkinson, 1990) were applied, using the longitudinal and transverse diameters of the eggs as parameters.

## 3. Area of investigation

The Black Sea (423 000 km$^2$) is a deep basin with steep slopes of the order of 4–6°. A major shelf area exists only in its northwestern region, which comprises 27% of the total area. The shelf areas, especially in the southeastern region, are very narrow. The striking hydrodynamic features are the cyclonically meandering rim current, together with two interior (western and eastern) gyres and several mesoscale anticyclonic eddies (Oğuz et al., 1993). A permanent halocline exists at depths of 80–160 m (Tuğrul et al., 1992). Below the halocline, hydrogen sulphide is present. Above the halocline, the salinity varies between 18–18.5‰ in the central Black Sea. The areas between the rim current and the coast have a lower salinity (18–17.5‰). In the western Black Sea the salinity drops below 16‰ in near-shore areas due to the influence of the river Danube (Oğuz et al., 1993). In the open sea, the summer temperatures above the thermocline vary between 23 and 27°C and the winter temperatures vary between 5 and 7°C, while in the northwestern shelf area the temperature falls to 2°C in winter (Sur et al., 1994).

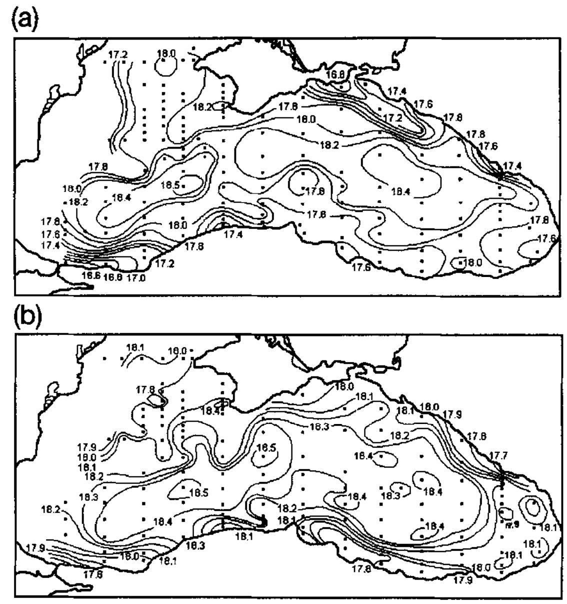

Fig. 2. (a) Salinity distribution in 5 m depth in the Black Sea in July 1992. (b) Salinity distribution in 25 m depth in the Black Sea in July 1992.

## 4. Results

The salinity at 5 m depth varied between 17.2 and 18.8‰ (Fig. 2(a)). The salinity of the water layer

Table 1
Longitudinal and transverse diameters of anchovy eggs (*Engraulis encrasicolus*) of the northern and southern Black Sea during July 1992, and of earlier Black Sea and Sea of Marmara expeditions

| Study region | *n* | Longitudinal diameter | | Transverse diameter | | Long./Trans. | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Mean | SD |
| I Northwest shelf | 11 | 1.24 | 0.05 | 0.78 | 0.05 | 1.59 | 0.10 |
| II Western area | 46 | 1.20 | 0.07 | 0.75 | 0.04 | 1.60 | 0.10 |
| III Crimea coast | 51 | 1.19 | 0.07 | 0.74 | 0.04 | 1.60 | 0.12 |
| IV Caucasus coast | 191 | 1.16 | 0.06 | 0.73 | 0.03 | 1.57 | 0.11 |
| Total northern area (EEZ of CIS) | 299 | 1.18 | 0.07 | 0.74 | 0.04 | 1.58 | 0.11 |
| Total southern area (Turkish EEZ) | 663 | 1.11 | 0.07 | 0.66 | 0.05 | 1.68 | 0.15 |
| Black Sea (Demir, 1959, 1974) | 365 | 1.19 | 0.11 | 0.74 | 0.06 | 1.60 | – |
| Sea of Marmara (Demir, 1959, 1974) | 2200 | 1.22 | 0.10 | 0.65 | 0.05 | 1.80 | – |

*n*, number of eggs measured.
Long./Trans., elongation index ((longitudinal diameter)/(transverse diameter)).

above the thermocline (approximately 25 m) varied between 17.7 and 18.5‰ (Fig. 2(b)). Regions with a salinity below 17.5‰ were found in the western Black Sea; these are influenced by the Danube waters and can be traced as far as Zonguldak. Another area of low salinity occurs off and southwest of the entrance of the Sea of Azov. In the central Black Sea the salinity was over 18‰ (Fig. 2).

A total of 299 eggs were measured in the northern Black Sea and 663 eggs in the southern area. Egg sizes and shapes were not correlated with the temperature or salinity of the upper thermocline layer (5 and 25 m).

Eggs collected in the four northern areas (Fig. 1) did not differ in longitudinal and transverse diameters ($t$-test $p = 0.05$; Table 1). The mean longitudinal diameter of eggs found in the northern area was 1.18 mm (range 1.00–1.37 mm) and the mean trans-

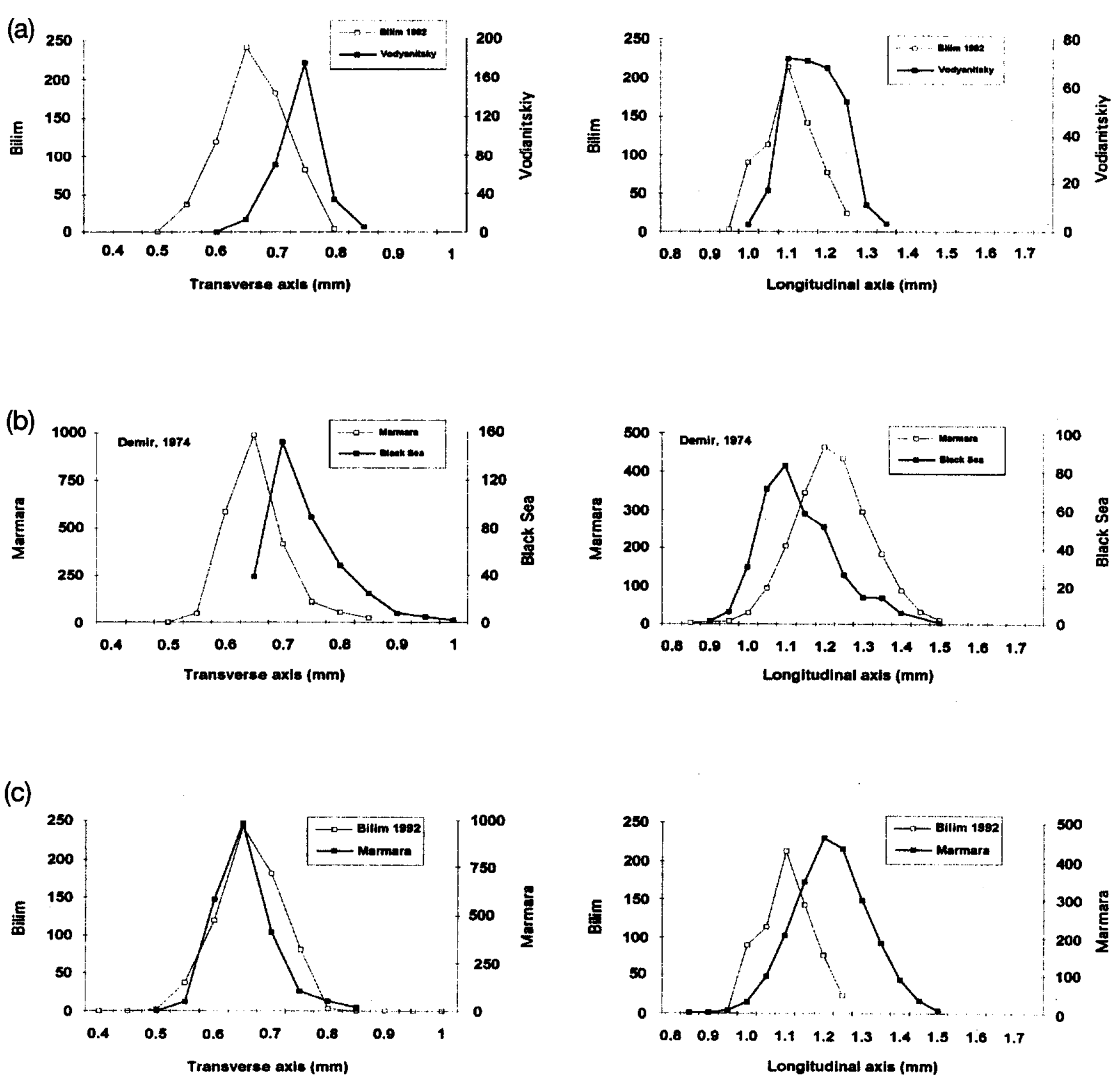


Fig. 3. Size distribution of the longitudinal and transverse axes of anchovy eggs (*Engraulis encrasicolus*). (a) Eggs sampled in the northern (R/V *Vodyanitsky*) and southern (R/V *Bilim*) areas of the Black Sea during July 1992. (b) Anchovy eggs from the Black Sea and the Sea of Marmara (Demir, 1974). (c) Anchovy eggs sampled by R/V *Bilim* in July 1992 compared with eggs from the Sea of Marmara (Demir, 1974).

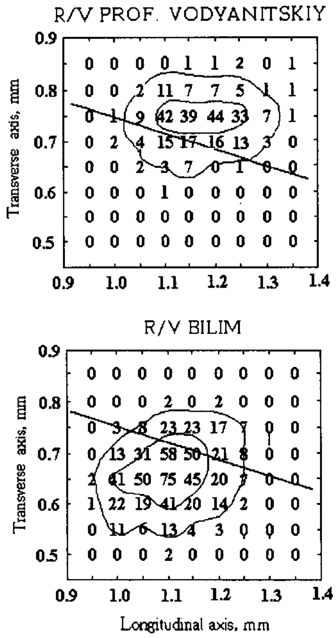


Fig. 4. Numbers of anchovy eggs. Plots of longitudinal diameters against transverse diameters for anchovy eggs collected by (a) R/V *Vodyanitsky* and (b) R.V. *Bilim*. The straight line dividing the egg size-groups was calculated by discriminant analysis according to Kendall (1975).

verse diameter was 0.74 mm (range 0.62–0.87 mm). The eggs in the southern part of the Black Sea (Turkish EEZ) were on average smaller and more elongated than those in the northern area: the mean longitudinal diameter was 1.11 mm (range 0.95–1.25 mm) and the mean transverse diameter was 0.66 mm (range 0.50–0.80 mm). The more slender egg shape in the southern Black Sea was also obvious from the quotient (longitudinal diameter)/(transverse diameter), which showed highly significant differences ($t$-test; $p = 0.05$) between the northern (1.58; SD $\pm 0.11$) and southern (1.65; SD $\pm 0.15$) areas. The difference in shape is due mainly to the shorter transverse axis rather than any differences in the longitudinal axis, as indicated in Fig. 3(a).

The existence of different egg groups in northern and southern areas is also obvious from plots of the longitudinal diameter of the eggs against the transverse diameter (Fig. 4). Application of the distance function (discriminant analysis; Kendall, 1975) revealed that egg sizes in the southern Black Sea (Turkish EEZ) and egg sizes in the northern Black Sea (CIS EEZ) can be differentiated by the function

$$DF = 5.61L + 17.01T - 17.98$$

where $L$ is the longitudinal diameter (mm), $T$ is the transverse diameter (mm) and $D$ is the discriminant function.

In accordance with the above equation, separation of the egg groups can be described by

$$T = 1.08 - 0.33L$$

From Fig. 4, where $T$ is plotted as a straight line, it can be seen that 88% of the eggs collected in the northern Black Sea were of an oval shape (Fig. 4(a)), while 75% of those found in the southern Black Sea were elongated (Fig. 4(b)). The error of discrimination for northern Black Sea samples was less than 12%, and for southern Black Sea samples it was about 25%. The small error value for eggs collected in the CIS EEZ reflects the homogeneous composition of the eggs in the northern Black Sea, while the larger error value for southern Black Sea egg samples indicates the occurrence of different egg types.

Stations with high numbers of elongated eggs (transverse diameter $< 0.7$ mm) were found, with only a few exceptions, in coastal waters in the southern and southeastern areas between the coast and the rim current (Fig. 1).

In summary, the size and shape of anchovy eggs found in the Black Sea in July 1992 did not correlate with salinity or temperature. Whilst eggs in the northern Black Sea were oval, both oval and elongated forms occurred in the southern Black Sea. Of these, the elongated eggs were found mainly in coastal regions.

## 5. Discussion

The size distribution and form of the anchovy eggs collected in July 1992 in the northern part of the Black Sea corresponded to size distributions reported in the literature (Vodyanitsky, 1930, 1936; Malyatsky, 1940; Vodyanitsky and Kasanova, 1954; Pavlovskaya, 1955; Zaitsev, 1958, 1959; Demir, 1959, 1974; Lugovaya, 1963; Dekhnik, 1973). However, in southern and southwestern coastal waters of similar salinity, in addition to the oval eggs which are characteristic for the Black Sea (average transverse diameter > 0.70–0.80 mm; Table 1, Fig. 3(b)), many elongated eggs were found, with a small transverse diameter (0.55–0.70 mm) and an average elongation index of about 1.7 (SD ±0.15), which is characteristic of anchovy eggs of the Sea of Marmara (Table 1, Fig. 3(b,c)). Unfortunately a direct statistical comparison of both data sets could not be carried out because the original data of Demir (1959, 1974) were not available.

About 80% (Fig. 4) of the eggs found in the boundary of the rim current in coastal waters of the southern Black Sea in July 1992 (Fig. 1) displayed the same characteristics as eggs spawned by the Marmara anchovy stock. These findings led us to form the hypothesis that migration of the Marmara anchovy stock into the Black Sea may take place, resulting in mixing of the populations. Usually, the spawning period of the Sea of Marmara population of anchovy coincides with that of the Black Sea population. Maximum spawning of both groups occurs from the end of June to August (Dekhnik, 1973; Demir, 1974).

It is well known that the Black Sea anchovy migrates into the Marmara Sea in autumn to overwinter and migrates back into the Black Sea for feeding and spawning in spring (Danilevsky, 1961; Demir, 1974), but until now it was not known whether the Marmara anchovy stock migrates into the Black Sea.

A similar migration of Black Sea anchovy into the Sea of Azov was observed by Majarova and Chugunova (1954). At times of unfavourable food conditions the Black Sea anchovy migrates to the Azov Sea to feed, and in some years it also spawns there (Danilevsky, 1960).

It is possible that the Sea of Marmara anchovy behave similarly in that they migrate during summer into the Black Sea and spawn along the Turkish coast. The detection of the wide size-range of anchovy eggs in the southern Black Sea may be a first indication of the occurrence of a different anchovy population in this region. The anchovy stock occurring in the Sea of Marmara has not yet been studied sufficiently to relate it to the Black Sea anchovy stock. Therefore, it is worth studying the anchovy populations in this region using biochemical (serological, genetic) and ichthyological methods. If the hypothesis stated here is correct, a modified approach for the estimation of anchovy stocks with respect to management of the anchovy fishery is needed.

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