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Abundance and distribution of eggs and larvae of anchovy (*Engraulis encrasicolus*, Linnaeus, 1758) and horse mackerel (*Trachurus mediterraneus*, Steindachner, 1868) on the coasts of the eastern Black Sea

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Abstract: Sampling for this survey was performed in 5 stations located in the bays of Sürmene and Rize in the eastern Black Sea between April and October 2006. During the sampling, the quantities and distributions of eggs and larvae of anchovies (*Engraulis encrasicolus*) and horse mackerel (*Trachurus mediterraneus*) were determined. For horizontal towing carried out from the surface (0–5 m), a plankton net of 50 cm in diameter and 500 µm mesh. The eggs of anchovy and horse mackerel sampled in plankton tows were found to be 438.33 ind./100 m^3 and 5.71 ind./100 m^3 for horizontal tows. During horizontal tows, the larvae of anchovy and horse mackerel were found to be 8.00 ind./100 m^3 and 0.68 ind./100 m^3, respectively. During the surveys, a total of 14,535 anchovy eggs, 147 horse mackerel eggs, 256 anchovy larvae, and 7 horse mackerel larvae were sampled. Mortality rates were calculated as 81.18% for anchovy and 37.41% for horse mackerel. According to our results, the ranges of spawning periods for anchovy and horse mackerel were determined as May–September and June–August, respectively.

Key words: Abundance, anchovy, eastern Black Sea, egg, horse mackerel, ichthyoplankton, larva

1. Introduction

In Turkey's seafood products industry, anchovy and horse mackerel are ranked in the top 2 positions within the species obtained by fishing from natural resources. These 2 small pelagic species of fish are the major species in the Black Sea and constitute approximately 59% of the seafood production in Turkey. Anchovy and horse mackerel that are landed in the eastern Black Sea constitute 27.4% (184,417 t) and 4.1% (17,755 t) of the total marine fish catch of Turkey (TÜİK, 2012). These species, possessing such significance in Turkey's fishing industry, must be observed in all phases of their life cycle in order to ensure the sustainability of their stocks. The most important of these phases are the ichthyoplankton phases (eggs and larvae). Slastenenko (1956) provided significant information concerning the spawning characteristics, egg types, and egg sizes of the fish in the Black Sea for the first time. The following have also been investigated: morphologies and ecologies of certain bony fish (teleosts) in the Marmara Sea and Black Sea (Arım, 1957); pelagic eggs and larvae of teleosts in Turkish waters (Demir, 1974); distribution of fish eggs and larvae at the Black Sea entrance of the İstanbul straits (Mater and Cihangir, 1990, 1997); distribution and abundance of pelagic eggs and larvae of teleost fish in the northern Marmara Sea (Yüksek, 1993); distribution of anchovy eggs and larvae in the Black Sea (Niermann et al., 1994); seasonal distribution of certain teleost fishes in the Bay of Sürmene (Başar, 1996); distribution of fish eggs and larvae off the coast of Trabzon (Ak, 2009); the effect of environmental conditions in the distribution of the eggs and larvae of anchovies in the Black Sea (Kideys et al., 1999); and ichthyoplankton of Feodosiya Bay (Klimova, 2009).

An egg survey is required in order to determine the spawning periods and spawning areas of the fish and the periodic changes taking place in these environments, the losses in the egg and larvae phases, the ratio of entry into the adult stocks, and the number of spawning adult individuals in the stocks and their relationship with the environment. Although there are a significant number of studies in the Black Sea in this context, egg survey investigations are scant in the eastern Black Sea region. Along with the seasonal abundance of eggs and larvae, the determination of their horizontal distribution was performed in this research in order to be able to make proper decisions about the future of the anchovy and horse

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mackerel stocks, which have an economic significance for the region.

2. Materials and methods

The survey was carried out in the eastern Black Sea on the Trabzon Sürmene, İyidere, and Rize coasts between April 2006 and October 2006. Samplings were performed horizontally at 5 stations (A1, A2, B1, C1, C2) using the research vessel "R/V DENAR–1" belonging to Karadeniz Technical University. The distances between the coastal stations are 13 NM (A1–B1) and 10 NM (B1–C1), respectively. For the offshore stations (A2–C2), the distance is 5 NM from the coast. The depths of stations were determined as 18 m, 415 m, 14 m, 15 m, and 310 m, respectively (Figure 1).

For horizontal samplings, a 50-cm-diameter and 500-µm-mesh plankton net was used. Samplings were carried out during the day at depth intervals of 0–5 m by towing the net for 10–15 min at a vessel speed of 2.5 miles h^{-1}. Temperature and salinity measurements were conducted at stations A2 and C2 throughout the survey. The temperature and salinity values were determined by using equipment by Aanderaa Instruments, the RCM9 model CTD and YSI 85 model probe, during the uptake of the material. The collected material was preserved in 4% formaldehyde solution with a borax buffer (Smith and Richardson, 1977). Samples of ichthyoplankton were sorted from the zooplankton material and species identification was performed. For the determination of egg and larvae species, the works of Arım (1957), Dekhnik (1973), Russell (1976), Yüksek and Gücü (1994), Mater and Çoker (2002), and Çoker (2003) were utilized as references. Abundances and distributions of eggs and larvae according to stations were calculated utilizing the individual per m^3 B = C / V relationship in horizontal tows, where B is abundance (ind./m^3), C is total number of samples in horizontal sampling, and V is volume of water filtered (m^3). The water volume V was obtained by V = A × r × c, where A = area of net mouth (m^2), r = flowmeter rotation number, and c = flowmeter calibration rate (m / rotation). The determination was done with a Hydro-Bios 438 115 model flowmeter (Smith and Richardson, 1977). Flowmeter calibration rate was 0.3.

Dead eggs were determined according to Iseki and Kiyomoto (1997) and Yüksek and Gücü (1994) as abnormally developed eggs, such as those with decomposition process of the embryo, and physically decayed eggs without categorized embryo stage and with decomposition of the perivitelline layer of the eggs.

A normality test (Shapiro–Wilk) was applied to larvae and egg number distributions between stations and months. ANOVA for parametric and Kruskal–Wallis analysis for nonparametric data were conducted using the software packages PAST (version 1.8) (Hammer et al., 2001) and Sigma Plot (version 11.0). Statistical analyses were considerate significantly different at the level of α = 0.05.

3. Results

3.1. Physicochemical properties of water column

The maximum surface water temperature of station A2 was found to be 23.90 °C in July and the minimum was 13.80

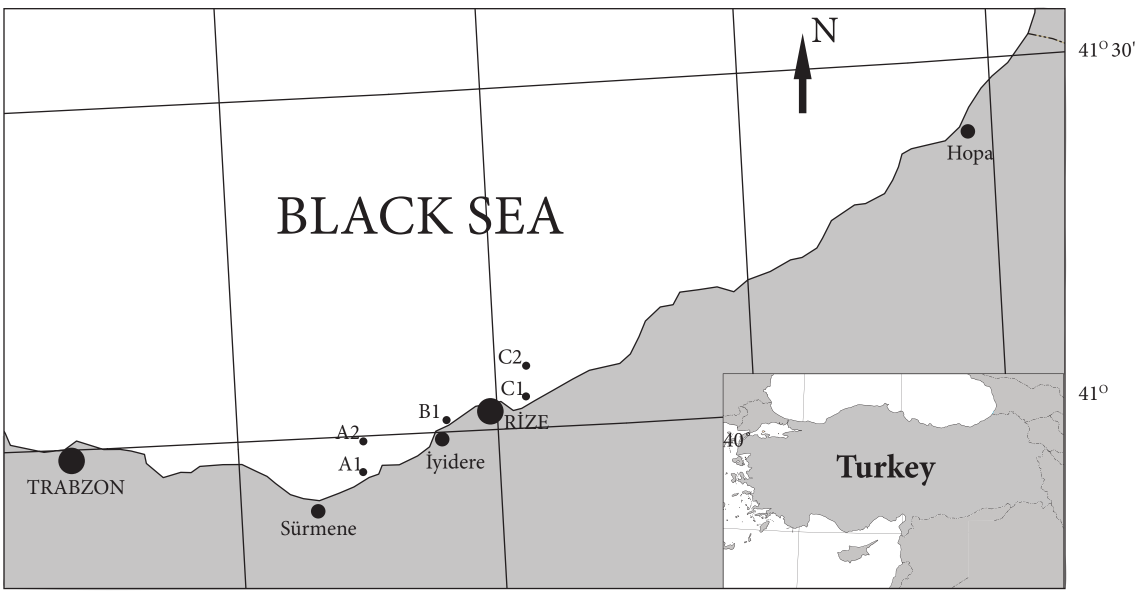

Figure 1. Sampling area.

°C in April; the maximum at station C2 was found to be 25.5 °C in August and the minimum was found to be 12.34 °C in April. Throughout the sampling, the average surface water temperature at stations A2 and C2 was calculated to be 20.12 ± 4.43 °C and 20.68 ± 0.84 °C, respectively (Figure 2). The minimum surface water salinity of station A2 was 17.24‰ in April and the maximum was 18.39‰ in September; the minimum at station C2 was 17.11‰ in June and the maximum was 17.68‰ in September. The average surface water salinity at stations A2 and C2 was measured to be 17.81 ± 0.36‰ and 17.50 ± 0.32‰, respectively (Figure 3). The average temperatures measured to a depth of 50 m were respectively 15.12 ± 5.866 °C and 16.46 ± 6.227 °C, while average salinities were 18.49 ± 1.216‰ and 18.56 ± 1.131‰. Temperature of the surface water was found to be 21.18 °C in June and 23.90 °C in July. Salinity was determined to be 17.68‰ in June and 17.90‰ in July.

3.2. Ichthyoplankton

During the sampling done at the survey sites, anchovy eggs were encountered during the months of May through September and 14,535 eggs were sampled. Measurements of the eggs showed the average egg diameter to be 1.28 ± 0.07 × 0.83 ± 0.04 mm. A total of 256 anchovy larvae were collected. The spawning period of the species was determined to be between May and September.

Horse mackerel eggs were obtained during June–August and a total of 147 eggs were sampled. Measurements of the sampled eggs showed the average egg diameter to be 0.83 ± 0.04 mm and the oil droplet diameter to be 0.24 ± 0.01 mm. During the survey, a total of 7 larvae belonging to this species were sampled. The spawning period of this species was determined to be between June and September.

3.2.1. Horizontal distribution, abundance, and mortality rates of anchovy (*Engraulis encrasicolus*) eggs

During horizontal samplings, 438.33 ind./100 m^3 eggs (a total of 14,535 eggs) and 8.00 ind./100 m^3 larvae (a total of 256) were collected between May and September. In June, the maximum numbers of eggs (8430 total) were encountered. In the horizontal distribution, the largest number of eggs was found in June at station A2 (2401.43 ind./100 m^3). Anchovy eggs were found only in stations B1 and C1 in May. During June and July, anchovy eggs were encountered at all stations. During September, 2.06 ind./100 m^3 and 229.82 ind./100 m^3 eggs were calculated at stations A2 and C2, respectively. The most larvae in the horizontal samplings were found during August at station B1 (37.84 ind./100 m^3) (Table 1).

The eggs were obtained at all stations in June and July in the survey. The monthly distribution of the total collected eggs was 8430 (58%) in June and 5649 (39%) in July (Figure 4).

When the monthly distribution of eggs collected at stations during the survey was assessed, the greatest abundance of eggs was observed in July at station A1 (20.14%). Anchovy eggs were observed in May only at stations B1 (0.15%) and C1 (0.01%), and in September only at stations A2 (0.03%) and C2 (1.13%).

During the sampling, a total of 256 larvae was collected, of which 67 (26%) were collected in June and 121 (47%) were collected in August. *E. encrasicolus* larvae were collected in all months with the exception of May, and their monthly distributions are shown in Figure 4. When the larval distribution was evaluated according to stations, the greatest abundance of larvae was observed in

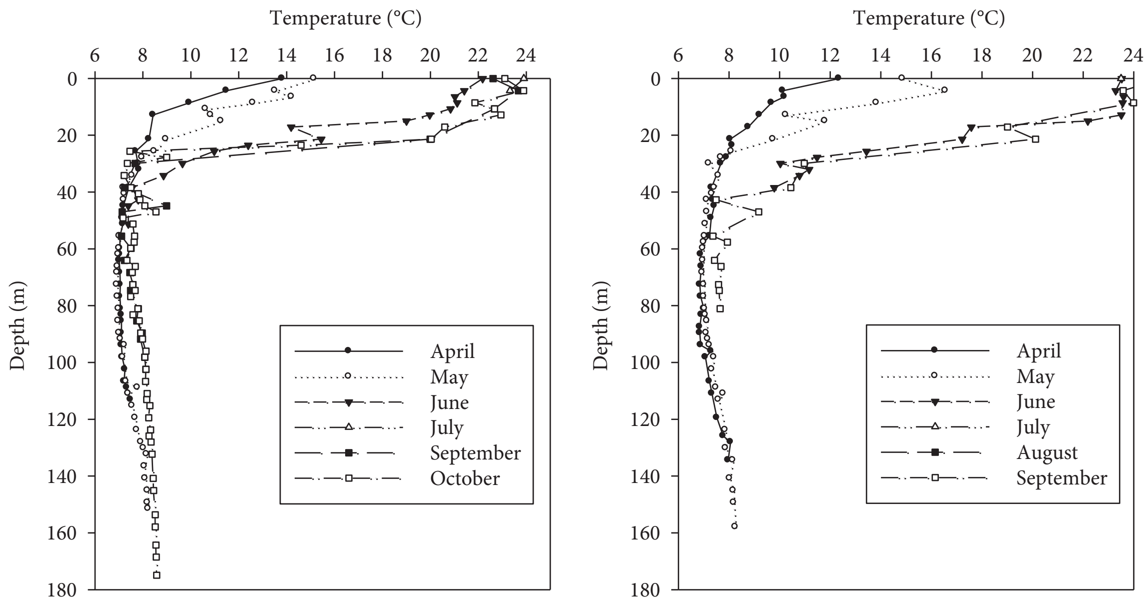

Figure 2. Monthly vertical profiles of temperature.

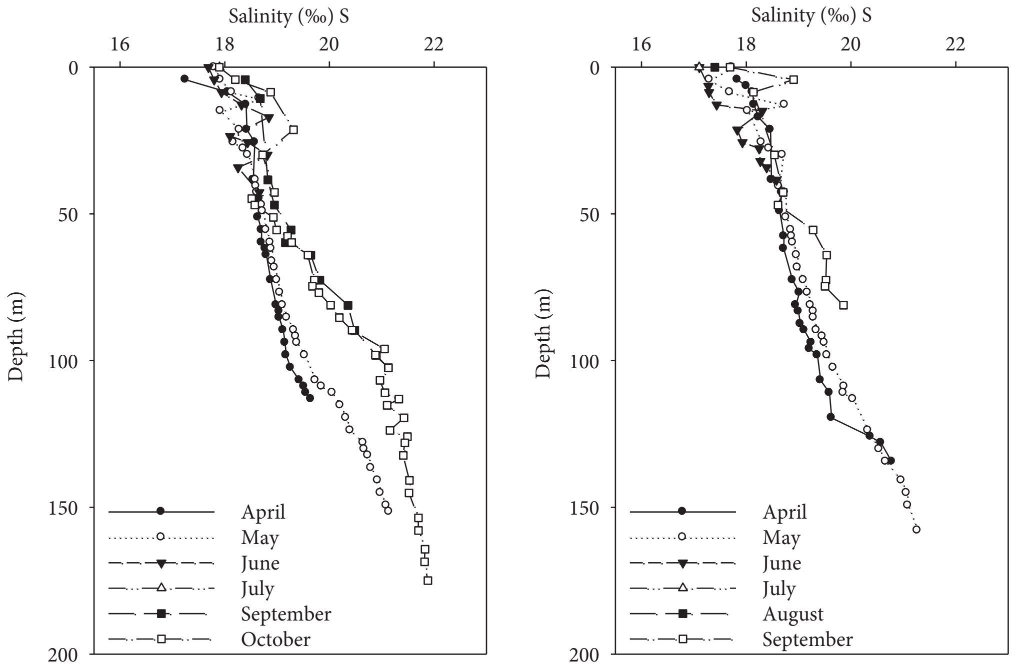

Figure 3. Monthly vertical profiles of salinity.

Table 1. Abundances of anchovy eggs and larvae encountered in horizontal tows (ind./100 m^3).

Eggs										
Station	A1		A2		B1		C1		C2	
Month	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3
May	0	0	0	0	22	19.36	2	1.35	0	0
Jun	1410	476.06	2183	2401.43	2250	2272.29	1262	1440.44	1325	554.34
Jul	2928	1380.92	1120	495.77	25	26.50	505	262.80	1071	398.12
Aug	-	-	-	-	8	7.50	2	0.97	253	111.96
Sep	0	0	4	2.06	0	0	0	0	165	229.82
Total	4338		3307		2305		1771		2814	
Larvae										
	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3
Jun	1	0.33	3	3.30	5	5.04	0	0	58	24.26
Jul	6	2.82	1	0.44	0	0	12	6.24	15	5.57
Aug	-	-	-	-	53	37.84	51	24.80	17	7.52
Sep	24	13.66	1	0.51	3	3.26	0	0	6	8.35
Total	31		5		61		63		96	

June at station C2 (22.70%). Statistical analysis was applied in order to determine the significance of the differences in egg and larvae distribution among stations and months. While the differences in distribution for both eggs and larvae among stations were not significant ($P > 0.05$), it was determined that the differences in egg and larvae distribution among months were significant ($P < 0.05$).

During the survey, 2735 of the *E. encrasicolus* eggs were found to be alive and 11,800 were dead. When the egg ratios were examined, the overall mortality was calculated to be 81.20%. When the mortality according to month is considered, the highest was seen in July at 96.50%, with the lowest seen in September at 30.17%. In other months, the mortality rate was found to be higher than 70%.

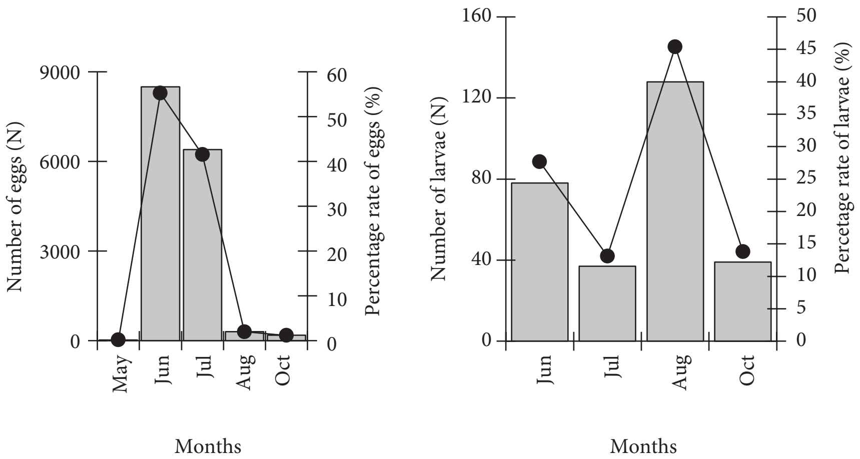

Figure 4. Monthly number and percentage of *E. encrasicolus* eggs and larvae.

Table 2. Abundances according to stations of horse mackerel eggs and larvae encountered in horizontal tows (ind./100 m^3).

Eggs										
Station	A1		A2		B1		C1		C2	
Month	n	Ind./100 m^3	n	Ind./100 m^3	N	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3
Jun	12	4.05	8	8.80	6	6.05	0	0	24	10.04
Jul	69	32.54	4	1.77	0	0	9	4.68	5	1.85
Aug	-	-	-	-	0	0	0	0	10	4.42
Total	81		12		6		9		39	
Larvae										
	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3	n	Ind./100 m^3
Aug	-	-	-	-	1	0.93	2	0.97	0	0
Sep	2	1.14	0	0	0	0	1	0.99	1	1.39
Total	2		0		1		3		1	

Throughout the sampling at survey sites, a total of 2735 live eggs and 256 larvae were collected. Accordingly, the hatching ratio of larvae was estimated to be 9.36%.

3.2.2. Horizontal distribution, abundance, and mortality rates of horse mackerel (*Trachurus mediterraneus*) eggs and larvae

During the monthly horizontal sampling throughout the survey, horse mackerel eggs were encountered first in June, while larvae were encountered in August. The horizontal tows between June and August collected 5.71 ind./100 m^3 eggs (a total of 147 eggs) and 0.68 ind./100 m^3 larvae (total 7). The greatest abundance of eggs in horizontal distribution was in July at station A1 (32.54 ind./100 m^3). No eggs were observed at station C1 in June or at station B1 in July. During August, eggs were observed only at station C2. The most larvae were collected in September at station C2 during the sampling (1.39 ind./100 m^3) (Table 2). According to statistical analysis, it was found that the variance between stations ($P > 0.05$) and months ($P > 0.05$) was insignificant.

When the distribution according to months of *T. mediterraneus* eggs was evaluated, it was found that the greatest abundance of eggs was obtained at station A1 (46.94%) in July. At station C2, 6.80% of the total eggs were found during August (Figure 5). *T. mediterraneus* larvae were found at stations B1 (14.29%) and C1 (28.57%) in August, and at stations A1 (28.57%), C1 (14.29%), and C2 (14.29%) in September. When the distribution of eggs was analyzed by month, the greatest abundance of eggs was observed in July at 59%. When the monthly abundance of larvae was taken into account, it was observed that the greatest abundance was reached in September at 57% (Figure 5).

Of the *T. mediterraneus* eggs, 92 were obtained live and 55 dead, with the overall mortality set at 37.41%. During sampling, a total of 92 live eggs and 7 larvae were found, with an estimated hatching rate of larvae at 7.60%.

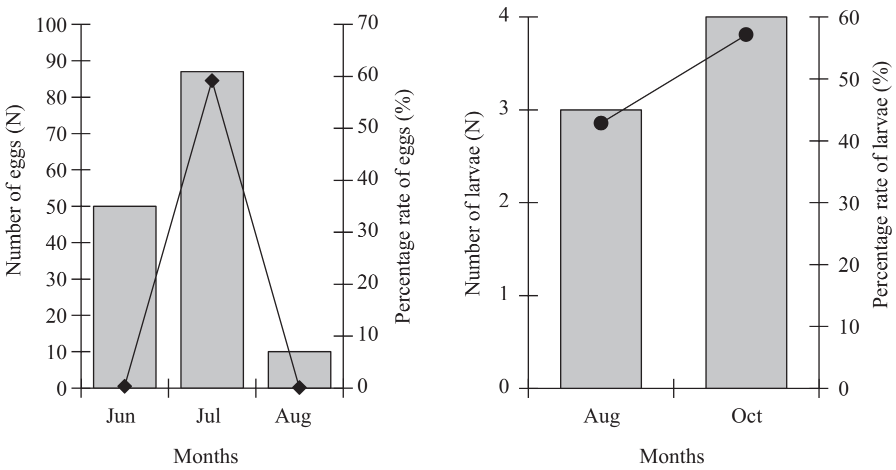

Figure 5. Monthly number and percentage of *T. mediterraneus* eggs and larvae.

4. Discussion

The objective of this survey was to determine the abundances and distribution of eggs and larvae of anchovy and horse mackerel stocks in the eastern Black Sea spawning areas. For this purpose, egg surveys were carried out at 5 stations on the coasts of Trabzon (Sürmene) and Rize. The results obtained were compared with other studies, and the situation in the region was indicated.

4.1. Anchovy

In the study area it was observed that spawning of anchovy showed a peak in June and July above a water temperature of 20 °C and at 17‰ salinity. In a study conducted on the coast of Sinop in the Black Sea, the temperature range was found to be between 16.5 and 24 °C, with an average of 23 °C, and the salinity was between 17.4‰ and 17.9‰, with an average of 17.9‰ (Satılmış, 2005). In the study conducted in the eastern Black Sea by Niermann et al. (1994), the temperature in July was found to be between 20.2 °C and 22.5 °C. When these results were considered, the ideal temperature at which anchovy stocks intensively lay eggs along the Turkish coast was found to be above 20 °C with salinity at 17‰. Similar results were reached by Bat et al. (2007), where the maximum egg-laying temperature was above 20 °C, with salinity ranging between 12‰ and 18‰ and pH between 8.3 and 8.4. It may be concluded that the eastern Black Sea where the study was conducted has the optimum conditions for the spawning of anchovy.

Anchovy eggs and larvae were observed in the survey sites during the months of May through September. Variances in the diameter of anchovy eggs were noticed in surveys conducted by other investigators in the Black Sea and other seas (Table 3). Demir conducted a study in 1974 of Turkish seas, where he found that diameters of anchovy eggs shrunk as salinity rose.

During the survey, the spawning period was found to be between May and September. This was similar to spawning periods determined in other surveys carried out in the region (Demir, 1974; Yüksek, 1993; Başar, 1996; Gordina et al., 1997).

In the horizontal sampling, anchovy eggs and larvae were sampled between May and September. There is a similarity with the horizontal sampling done by Başar (1996) in the same investigation area (Table 3). Gordina et al. (2005) carried out horizontal sampling in June through August 2000 of anchovy eggs in Ukrainian waters, where they found 62.5 ind./100 m^3, and in the Sinop region 104.6 ind./100 m^3; larvae in Ukrainian waters were 0.9 ind./100 m^3 and in the Sinop region 0.2 ind./100 m^3. Satılmış (2005) found the quantity of eggs in the Sinop region during June and July to be 42.63 ind./100 m^3, with the larvae at 1.75 ind./100 m^3. In the present investigation, 438.34 ind./100 m^3 eggs and 8.00 ind./100 m^3 larvae were sampled between June and September.

When investigations conducted at different regions of the Black Sea were considered, major variances were observed. It can be said that reproduction was more intense in the eastern Black Sea during the 2006 spawning season compared to other regions, and that this variance is due to the fact that stocks preferred this region as a spawning area compared to the past. When the results of this investigation were taken into account, it was seen that reproduction in the eastern Black Sea fields was increasing in addition to in the northwestern parts of the Black Sea, which is the major spawning area for anchovies (Arım, 1957; Niermann et al., 1994; Gordina et al., 1997; Başar and Okumuş, 1997; Kideys et al., 1999; Satılmış et al., 2003).

When the surveys conducted were assessed, it was seen that there were major densities of eggs and larvae of anchovies in the western and eastern regions of the Black Sea. Contrary to past surveys, the surveys conducted in recent years and the present one indicate that the eastern Black Sea is a significant spawning area for anchovies.

Table 3. Characteristics of *E. encrasicolus* eggs and availability periods according to different investigators.

Author	Region	Longitudinal diameter (mm)	Transverse diameter (mm)	Period
Demir (1974)	Black Sea	0.95–1.75	0.65–1.00	May–August
Demir (1974)	Marmara Sea	0.85–1.50	0.50–0.85	April–October
Demir (1974)	Aegean Sea	0.90–1.55	0.40–0.65	April–November
Demir (1974)	Mediterranean Sea	0.95–1.50	0.45–0.60	March–December
Mater (1981)	Bay of İzmir	1.00–1.55	0.37–0.63	March–November
Yüksek (1993)	Marmara Sea	1.05–1.55	0.65–0.80	May–September
Başar (1996)	Black Sea	1.00–1.50	0.61–0.73	May–September
Gordina et al. (1997)	Black Sea	1.00–1.55	0.62–0.87	-
Başar (1996)	Black Sea	1.00–1.50	0.61–0.73	June–November
Çoker (2003)	Bay of İzmir	0.97–1.57	0.39–0.68	March–November
Türker Çakır (2004)	Bay of Edremit	1.32–1.43	0.54-.62	April–November
Ak (2004)	Mediterranean Sea	1.13–1.57	0.49–0.68	March–August
Ak (2009)	Black Sea	1.05–1.55	0.65–0.68	May–November
This research (2007)	Black Sea	1.12–1.63	0.71–0.99	May–September

Satılmış (2005) conducted a survey on the coast of Sinop where he found a total of 1248 anchovy eggs, with 20 live and 1228 dead eggs, resulting in a mortality rate of 98.4%. In the present survey, a total of 14,535 anchovy eggs were sampled, with 2735 live and 11,800 dead eggs determined. The overall mortality rate was determined to be 81.18%. This variance could be due to surveys being conducted in different years at different geographical regions, as well as due to ecological conditions in the eastern Black Sea being more suitable for the reproduction of anchovy stocks. The surveys indicate that significant changes have taken place in the ecological conditions of the Black Sea in the past 20 years. Construction of dams on major rivers that provide freshwater input caused changes in the concentration of nutritional salts entering the environment. This situation has caused a decrease in the phytoplankton and thus in the zooplankton (Copepoda) that constitute the feeding source of the larvae (Humborg et al., 1997; Kideys et al., 2000; Bat et al., 2007; Salekhova, 2007; Klimova et al., 2009, 2010). Generally, during the breeding period of the anchovy, high mortality rates take place in the egg and larval periods. The occurrence in the present survey of the hatching rate from the laying of the eggs to the larval phase as 9.36% indicates that significant losses take place in the spawning period.

4.2. Horse mackerel

Horse mackerel eggs and larvae were determined during June–September. During the month of July, when the greatest abundance of horse mackerel eggs exists, the temperature of the surface waters was found to be 23.90 °C (23.65 ± 0.286) and salinity 17.90‰ (17.56 ± 0.0.413‰). In the present survey and in the surveys carried out by other authors, egg and oil droplet diameters were found to be the same. The spawning period shows a similarity to the survey conducted by Demir (1961) (Table 4). Başar (1996) did not encounter any horse mackerel eggs or larvae in a survey conducted in the same region.

During the horizontal tows, varying abundance values of horse mackerel eggs and larvae were found (Table 2). Yüksek (1993) found egg distribution to be 0.01–1.98 ind./100 m^3. Satılmış (2005) observed that egg distribution varied between 0.4–6.2 ind./100 m^3. The greater abundance of horse mackerel eggs in the eastern Black Sea seen in results observed by other authors compared to data in the present survey may indicate that horse mackerel prefers this area as a spawning area compared to other regions.

Throughout the survey, the overall mortality rate was calculated to be 37.41%. Yüksek (1993) sampled 1175 eggs of which 94 were dead, while Satılmış (2005) sampled 62 eggs with 29 live and 33 dead and found the mortality to be 53.2%. Compared to the other Black Sea surveys, it was observed that the mortality rate in this region is lower than those of other regions. It can be said that this variance is due to the ecological conditions, survey sites, and the time when the survey was performed.

As a result, any kind of change taking place in the Black Sea ecosystem affects all living beings present in the environment. It was stressed in a study performed in the Black Sea during 2 time periods, before and after 1970, that there was a greater abundance before the 1970s of large pelagic fishes that migrate annually such as tuna and swordfish, in addition to blue fishes, bonito, mackerel,

Table 4. Characteristics of *T. mediterraneus* eggs according to various authors and availability periods.

Author	Region	Diameter (mm)	Drop oil diameter (mm)	Period
Demir (1958)	Black Sea	0.71–0.90	0.21–0.26	June–July
Demir (1961)	Black Sea	0.71–0.90	0.21–0.26	May–August
Dekhnik (1973)	Black Sea	0.73–1.00	0.19–0.25	Summer months
Yüksek (1993)	Marmara Sea	0.75–0.95	0.19–0.28	April–September
Satılmış (2003)	Black Sea	-	-	May–August
Satılmış (2005)	Black Sea	-	-	April–September
Ak (2009)	Black Sea	0.70–0.80	0.20–0.25	May–September
This research (2007)	Black Sea	0.74–0.92	0.20–0.26	June–August

and horse mackerel. Meanwhile, gelatinous planktons were scarce and zooplanktons were plentiful with high oxygen content. After the 1970s, just the opposite took place. There was a collapse in the stocks of large pelagic fish and of regularly migrating fish, excessive increase in the biomass of gelatinous plankton, and collapses in the zooplankton biomass (Humborg et al., 1997; Shiganova, 1998; Shiganova et al., 2001; Daskalov, 2002). Therefore, there was a major ecological change in the Black Sea after the 1970s. As the Black Sea is the largest closed sea of the world and is surrounded by the territories of many countries, the release of inland and coastal wastewaters and industrial wastes into the sea, and ships of the dense sea traffic dumping their ballast water into the sea, caused ecological changes in the marine ecosystem. This change primarily affected phytoplankton and zooplankton, which constitute the basic link of the food chain. This change in the spawning area caused the anchovy to prefer different spawning areas (Zaitsev, 1982; Cociasu et al., 1996; Satılmış et al., 2003; Oguz et al., 2006; Bat et al., 2007). When the results were compared, similar findings were valid for horse mackerel as well. When the results obtained in this survey were assessed along with past horizontal surveys in the Black Sea, it could be concluded that anchovies and horse mackerel prefer the eastern Black Sea as a spawning area. This preference may be due to the lack of major settlements along the river systems of the eastern Black Sea region and the low level of industrial wastes. Construction of hydroelectric power plants above the capacities of rivers in the eastern Black Sea region may threaten this spawning area in the future, as it has in other regions. Therefore, the sustainability of the stocks may be ensured by determining changes in the habitat and spawning area and changes taking place in these areas, losses in the egg and larval phases, and quantities that are added to the stocks.

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