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RESEARCH ARTICLE

Spatial and temporal variations of anchovy eggs and larvae, *Engraulis encrasicolus* (Linnaeus, 1758), around Gökçeada Island, North Aegean Sea

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Abstract

This study describes the spatio-temporal distribution patterns of anchovy eggs and larvae around Gökçeada Island in the North Aegean Sea. Monthly vertical samplings were performed at nine stations in one year period between June 2013 and May 2014. In total, 306 eggs, 198 prelarvae and 248 postlarvae were sampled. It was observed that spawning season of anchovy was between May and October, whereas spawning took place at 15.9 °C and peaked at 20.8-23.2 °C in June and August. Total egg biomass was determined as 1199.8 ind/m² and mean egg biomass was 33.5 ind/m². Total prelarvae and postlarvae biomass were detected as 776.2 ind/m² and 972.2 ind/m², respectively. Maximum abundance of prelarvae and postlarvae were seen in August (540 n/m^2) and September (492 n/km^2), respectively. Total mortality of eggs was detected as 12.4%, highest mortality was observed in July (30.9%) and majority of mortality realized in gastrula stage (stage 3) (85%). It was understood that the eggs were concentrated in the east and the larvae in the South as strong north winds and currents effected their distribution.

Keywords: Anchovy, fish eggs, fish larvae, spawning, North Aegean Sea

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Introduction

The European anchovy, *Engraulis encrasicolus* (Linnaeus, 1758), is the major commercial fish species and the most consumed seafood product in Turkey. Despite the decrease, 43.4% of total catch was anchovy with 96,451 t landing (TUIK 2020). Small pelagic fish species have important role in connecting the lower and upper trophic levels (Palomera *et al.* 1991; Bakun 1996). Therefore population fluctuations should be monitored carefully to understand and the changes that may occur. The Turkish anchovy fishery suffered at the end of the 1980s. Fishing yield decreased to 60,000 t from 500,000 t owing to pollution, predator pressure (*Mnemiopsis leidyi*) and development of fishing fleet technology (Kideys *et al.* 1998). The fluctuations of anchovy fishing yield continue until today. However, the production, which was 228,000 t in 2011, tends to decrease and reached to 96,451 t in 2018 (TUIK 2020).

Sherman *et al.* (1983) recognized that ichthyoplankton surveys represent the most effective sampling strategy in measuring population abundance of large marine ecosystems. The poor fit in stock-recruitment relationship creates difficulties in understanding population dynamics of pelagic fish species, thus direct methods of assessment like acoustic and ichthyoplankton surveys become prominent (Gunderson 1993). Due to its easiness in sampling, lower cost of research and less time consuming, ichthyoplankton is a desirable tool for determining fish biodiversity (Yüksek 1993).

Historically, oldest studies for ichthyoplankton in Turkey are represented by Arım (1957), Dekhnik (1973) and Mater (1978). Niermann *et al.* (1994), Gordina *et al.* (1997), Kideys *et al.* (1999), Shiganova *et al.* (2001), Bat *et al.* (2004), Şahin and Hacimurtazaoğlu (2013), Gücü *et al.* (2016), Şahin and Düzgüneş (2019) carried out important studies about anchovy early life history in the Black Sea. Yüksek (1993) and Demirel (2004) conducted studies in the Marmara Sea. Ichthyoplankton surveys in the Aegean Sea have been focused on İzmir Bay. A considerable amount of studies dealing with ichthyoplankton abundance and biodiversity in İzmir Bay have been published (Mater 1977; Hoşsucu 1991; Hossucu and Ak 2002; Çoker 2003; Çakır and Hoşsucu 2006; Taylan and Hossucu 2008, 2015, 2016). In these studies, İzmir Bay was considered as an important spawning and nutrition area for anchovy. In another study conducted in Edremit Bay which is closer to Gökçeada Island (Çakır and Hoşsucu 2006), abundance, distribution, duration in the plankton and mortality rates of anchovy eggs and larvae were determined. In this study both anchovy eggs and larvae detected dominant in total ichthyoplankton and Edremit Bay was defined as a potential spawning area for anchovy. In the Çanakkale Strait (Dardanelles), anchovy larvae dominated the total catch and spawning occured from May to September (Daban and Yüksek 2017). Daban and İşmen (2020) found the anchovy larvae as the second abundant fish larvae species distributed in Gökçeada Island, the North Aegean Sea.

The North Aegean Sea is the most productive area within the Aegean Sea (Stergiou and Lascaratos 1997). This situation is due to the brackish water inflow through the Çanakkale Strait (Black Sea water) and discharge from large rivers (Zervakis *et al*. 2000). The previous studies conducted in the Greek part of the Aegean Sea indicated that the North Aegean Sea is a major spawning area for anchovy in Greek waters due to enrichment process (Black Sea water flow) (Somarakis 1993; Somarakis *et al.* 2002; Somarakis and Nikolioudakis 2007). The spawning period of anchovy in the central and North Aegean Sea is observed from May to September (Somarakis 1993, 1999; Machias *et al.* 2000; Tsianis 2003) and spawning peaks around in June (Somarakis 1993). Somarakis (1999) showed that Lemnos Island is a crucial spawning area for anchovy owing to direct influence of the Black Sea water flow.

This study reveals detailed and species specific knowledge on anchovy fish eggs and larvae in the Turkish part of the North Aegean Sea. The aim of this study is to determine spatial and temporal variations, abundance and mortality rate of anchovy eggs and larvae.

Materials and Methods

Study Area

Gökçeada Island is located in the North Aegean Sea (25°40'-26°02' E, 40°05'-40° 14'N). Gökçeada is the largest island of Turkey with its area of 279 km^2. The continental shelf of the island shows characteristics varied between north and south. In the north, the coastal structure suddenly deepens and has steep rocky slopes. The steep continental shelf arises from the North Aegean Sea Trough, which is located to the northwest and extends to the northern part of Gökçeada Island, whereas sandy shallower continental shelf is available in the south. The South parth of island has under the influence of the Black Sea Water (BSW) inflow due to the geographical proximity of the Dardanelles. The less saline and temperate waters trigger the primary production and increase productivity. The BSW inflow and strong north winds are the principal factors for motion and direction of the water masses and living organisms that depend on it. Beside some protective measures in force around study area. The Gökçeada Underwater National Park, which announced in 1999, is the first and only underwater park in Turkey. The underwater park located in the northeast of the island.

Sampling

This study was carried out monthly between June 2013-May 2014. Samples were collected from nine stations around Gökçeada (Figure 1). Sampling was conducted with a fishing vessel "Yalçınoğlu". Vertical plankton tows were realized for sampling fish eggs and larvae. For this purpose, a WP-2 type plankton net with 200 µm mesh size was performed above thermocline (30 m) to the surface. Samplings were performed in all stations during the daylight. The samples were fixed immediately after collection and preserved in 4% formaldehyde. Environmental parameters were measured by using CTD probe.

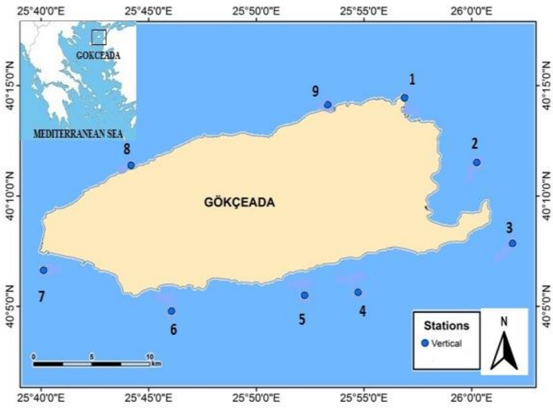

Figure 1. Study area and the location of sampling stations

Analyses

Anchovy eggs and larvae were sorted from the samples. The morphometric measuretments were operated with Q-Capture Image Analize Programme attached on the Olympus SZX7 stereomicroscope with using 1,6X magnification. The quantities and percentages of eggs and larvae in the unit volume for vertical tows (individuals/m^2) been determined. The spatio-temporal changes in the egg and larval abundance was tested by performing a one way ANOVA after data were log-transformed. Confidence intervals (95%) of each parameter were calculated. The statistical considerations were performed with PAST version 3.02. The determination of fish egg stages was conducted with Dekhnik's (1973) 6-stage development method.

Results

Hydrological Conditions

Temperature and salinity values were considered with surface and mixed (10, 20 and 30 m) separately. Sea surface temperature varied between 10.9-24.8 °C with an annual average surface temperature of 17.37±1.5 °C (Figure 2). Minimum sea surface temperature was observed in February and maximum in August. Sea surface salinity was ranged between 28.1-38 ppt with an annual average of 32.4±0.9 ppt. Minimum sea surface salinity was observed in June whereas maximum in October (Figure 3). Relatively low surface salinity value in June was stemmed from heavy rainflow and flood disaster in Gökçeada Island. Mean surface water dissolved oxygen was 7.78 mg/L and varied between 5.97 mg/L and 9.84 mg/L.

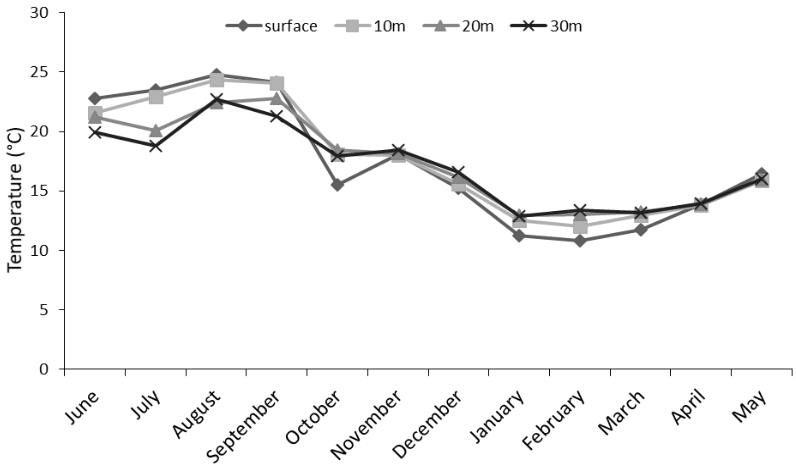

Figure 2. Monthly variations of tempereature at surface, 10m, 20 m and 30 m depth in Gökçeada Island, North Aegean Sea

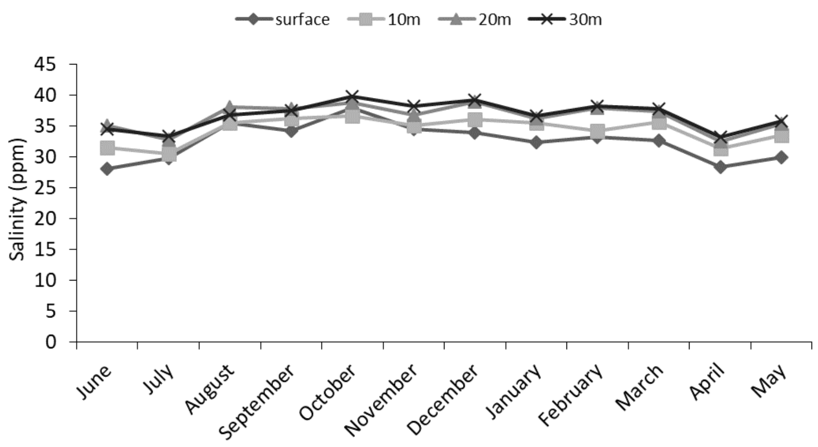

Figure 3. Monthly variations of salinity at surface, 10m, 20 m and 30 m depth in Gökçeada Island, North Aegean Sea

Spatial and Temporal Changes

A total of 306 eggs were sampled. Total fish egg biomass was determined as 1199.8 ind/m² with a mean fish egg biomass of 33.5 ind/m². Anchovy eggs were found between May and October. The highest anchovy egg abundance were found in June, July and August with 400, 396 and 396 ind/m², respectively. Significantly low egg density of *E. encrasicolus* were found in May and October in the beginning and the end of the spawning season (Figure

4). Spawning started at 16 °C in May and showed a strong peak at 20.8-23.2 °C in June and August.

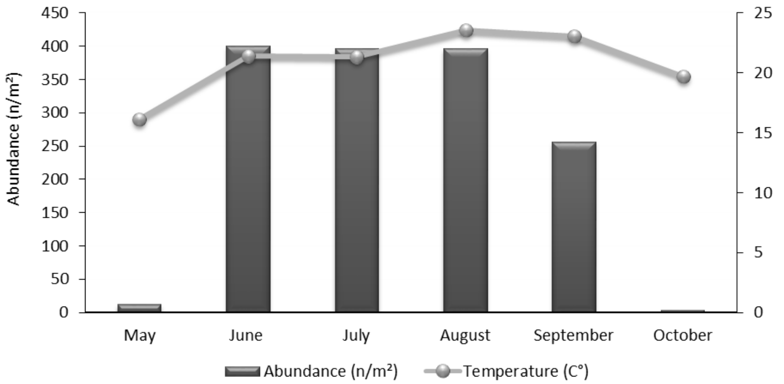

Figure 4. Temporal variations of surface water temperature and of the abundance of anchovy eggs around Gökçeada Island, North Aegean Sea

Anchovy eggs were present in all stations. Major egg densities mainly located around east and south of the island. Maximum abundance were seen at station 2 (280 ind/m²) and station 6 (216 ind/m²). Spatial variations of anchovy eggs examined, there were no significant difference between stations (ANOVA, df =8, F=0.63, p=0.74).

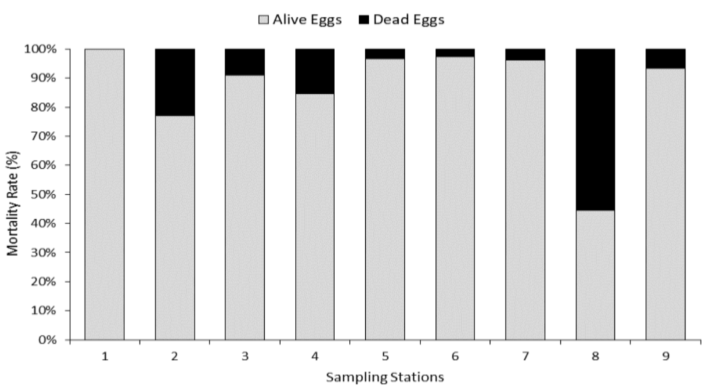

Figure 5. Mortality rate of anchovy eggs among stations around Gökçeada Island, North Aegean Sea

Total mortality of anchovy eggs was calculated as 12.4%. In terms of months, maximum mortality was found in July (30.9%) whereas the mortality rate was relatively low in June (7.3%) when highest spawning of anchovy realized. When examining mortality variations between stations (Figure 5), maximum mortality was clearly seen at station 8 (55.5%). In other stations, mortality rates were considerably lower.

With respect to embryological development of anchovy eggs, maximum abundance was found in stage 5 (tailed embryo) with 34% of total egg biomass. In stage 4 and 3, relatively high abundance were found with 22% and 20%, respectively. Maximum mortality was observed in critical stage 3 with 85% of total anchovy egg biomass. The mean egg diameter was detected as 0.90-1.24/0.40-0.67 mm.

Total abundance of prelarvae was determined as 776.2 ind/m². A great majority of prelarvae abundance were sampled in August (540 ind/m²). There was no significant difference (ANOVA, df=8, F=0.86, p=0.56) between spatial distribution of prelarvae around Gökçeada Island, whereas station 2 and 6 were more abundant in comparison with the other stations (Figure 4). Total length of prelarvae varied between 2.12 mm and 2.92 mm.

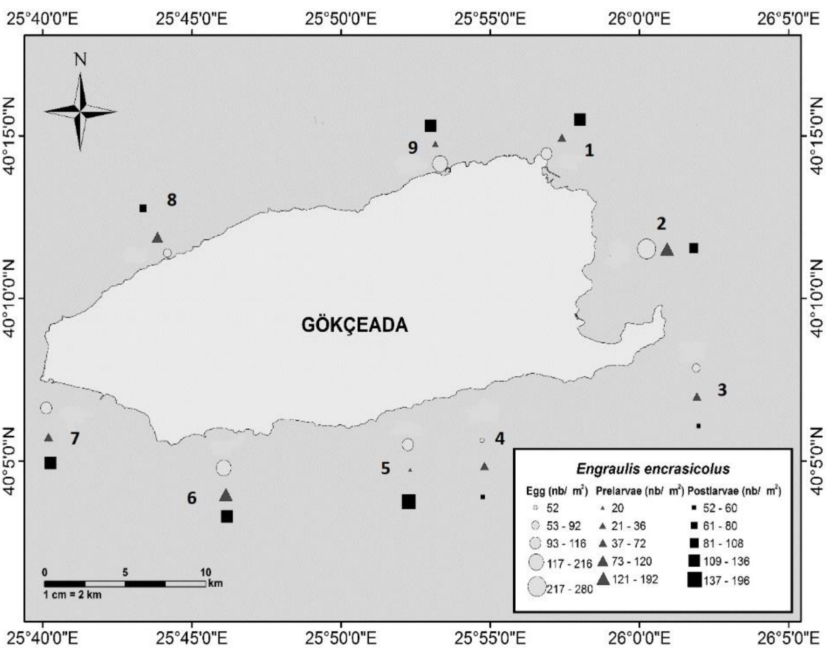

Figure 6. Spatial variation of the abundance of anchovy eggs and larvae around Gökçeada Island, North Aegean Sea

Total abundance of postlarvae was estimated as 972.2 ind/m². Maximum abundance was detected in September (492 ind/m²) (Figure 7). There was no significant difference (ANOVA, df =8, F=0.25, p=0.97) for spatial variation of anchovy postlarvae. On the other hand, relatively more abundance was observed around south part of the island. Total lenght of postlarvae varied between 3.02 mm and 19.22 mm.

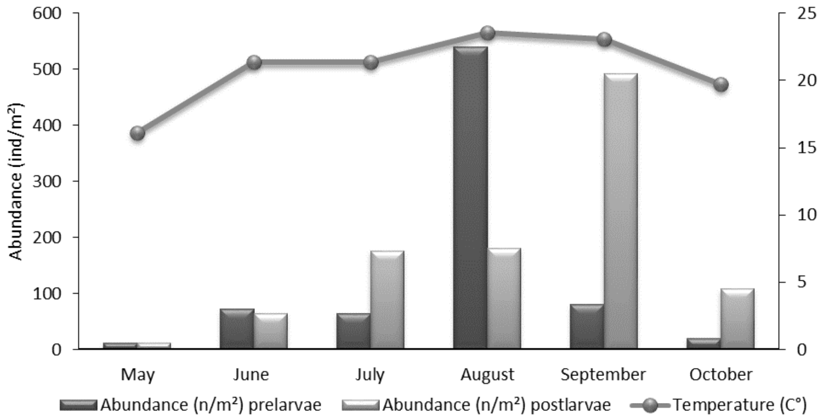

Figure 7. Temporal variations of surface water tempereature and of the abundance of anchovy larvae around Gökçeada Island, North Aegean Sea

Table 1. Comparison of the abundance of anchovy eggs and larvae in Turkish waters

Study	Year	Area	Season	Abundance (ind/m²)	
				Eggs	Larvae
Kideys *et al.* (1999)	1993	Black Sea	August	39	3.1
Kideys *et al.* (1999)	1996	Black Sea	June-July	90	4.3
Satılmış (2001)	1999-2000	Black Sea	June-August	31	5
Bat *et al.* (2004)	2004	Black Sea	June-August	23	12
Niermann *et al.* (1994)	1994	Black Sea	June	6	<1
Daban and Yüksek (2017)	2013	Dardanelles	May-September	19.3	52
Taylan and Hoşsucu (2016)	2010	Edremit Bay	July	36.5	
In this study		North Aegean Sea	May-October	33.5	40

Table 2. Comparison of the mortality rate of Anchovy eggs in Turkish waters.

Reference	Year	Area	Season	Mortality Rate (%)
Satılmış (2005)	2003	Black Sea	June; July	96.9; 99
Şahin and Hacımurtazaoğlu (2013)	2007	Black Sea	May-September	81.18
Çakır and Hoşsucu (2006)	2000	Aegean Sea	April-September	>50
Çoker (2003)	1994-2002	Izmir Bay (Inner; Middle; External)	March-November	68; 58; 40
Ak (2000)	1998; 1999	Mediterranean	March-October	17; 14
In this study		Gökçeada Island	May-October	12
In this study		Station 4	May-October	55

Table 3. Comparison of the spawning season of anchovy in Turkish waters and Greek part of the Aegean Sea

Reference	Year	Area	Spawning Season
Satılmış	2001,2005	Black Sea	May-Sep
Yüksek (1993)	1990,1991	Marmara	May-Sep
Somarakis	1993	North Aegean Sea	May-Sep
Çakır and Hoşsucu (2006)	2000	Aegean Sea (Edremit Bay)	Apr-Sep
Mater	1981	Aegean Sea (Izmır Bay)	Mar-Nov
Çoker (2003)	1994-2002	Aegean Sea (Izmır Bay)	Mar-Nov
Çakır and Hoşsucu (2006)	2000	Edremit Bay	Apr-Sep
Ak (2000)	1998-1999	Mediterranean	Mar-Oct
Ak (2004)	1998-2001	Mediterranean	Mar-Aug
Demir	1974	Medıterranean	Mar-Dec
Daban and Yüksek (2017)	2013-2014	Dardanelles	May
Daban and İşmen (2020)	2015-2016	Gökçeada Island	May
This study		Gökçeada Island	May

Discussion

Demir (1959) established that the minimum temperature for embryological development of anchovy was 13°C, egg laying was between 13/14-26°C and spawning peak occurred above 20°C. Spawning season of anchovy in the studies conducted in Turkish Seas were shown in Table 3. It can be seen clearly that the spawning season of anchovy extend with towards from North to South in the Mediterranean ecosystem. In our study, spawning season was detected between May and October and complied with the other studies in the close regions. When considering the spawning temperature in our study, egg laying started at 15.9°C and spawning peak occurred in June at 20.8°C. Our findings are highly coincide with Demir's (1959) findings. In terms of mean abundance of anchovy eggs, Kideys (1999) found 39 ind/ m^2 in August, Satılmıs (2001) found 32 ind/m² between June and August, Bat *et al*. (2004) found 23 ind /m² in July-August. In our study mean abundance was detected 33.5 ind/m² between May and October. Çakır and Hoşsucu (2006) found that total anchovy egg abundance was 2200 ind/m² in Edremit Bay between April-September at 10 stations. In our study total anchovy abundance was 1199.8 ind/m². The difference in abundance may be a result of extended spawning season in Edremit Bay.

Demir (1959) identified that anchovy egg diameter became smaller when the salinity increased. Mean diameter of anchovy eggs were found by Demir (1959) as 0.95-1.75/0.65-1.00 mm in the Black Sea, by Yüksek (1993) as 1.05-1.55/0.65-0.80 in the Marmara Sea, by Mater (1981) as 1.00-1.55/0.37-0.63 mm in the Aegean Sea and by Demir (1959) as 0.95-1.50/0.45-0.60 in the Mediterranean Sea. In our study, egg diameter was ranged within 0.90-1.24/0.40-0.67 mm. Our findings are consistent with the other studies and Demir's salinity hypothesis except Çakır and Hoşsucu (2006) which detected egg diameter ranging between 1.32-1.43/0.54-0.62 mm.

In this study the mortality rate of anchovy was calculated as 12.4%. The lower mortality rate for anchovy eggs around Gökçeada Island may be affined with the pristine environment of the area. Resident population of the island is lower than 10,000 and there is no industrial facility. Therefore the pollution both in air and sea is low. High dissolved O_2 values measured in this study supported this hypothesis. High currents and flows around Gökçeada Island may increase the oxygenation process. Hence, the mortality rate of fish eggs may lower via previous studies conducted around other areas. It was observed that the mortality rate for station 8 was higher than others. Station 8 is located in the Northwest part of the island and under tough hydrographic conditions (current, wind ect.). The temperature data was observed lower in station 8 than others. In the earlier studies mortality rate were detected considerably higher compared with our work. Satılmış *et al.* (2003) found that 96.9 and 99.9 % in June and July 2003. Çakır and Hoşsucu (2006) detected it over 50% (Table 2). The higher mortality rates are mostly caused low abundance of larvae. Larvae abundance were detected by Satılmış (2001) 5 ind/m², Kıdeyş (1998) 3.1 ind/m², Bat *et al.* (2004) 12 ind/m² in Black Sea. Daban and Yüksek (2017) found as 19.3 ind/ m² in Dardanelles. Çakır and Hoşsucu (2006) found that total abundance of larvae was 766 ind/m² between April-September with 10 stations (Table 1). Our results showed that mean abundance of larvae was 40 ind/m² and total abundance was 1820 ind/m² between June and October in 9 stations. High larvae abundance may be a result of low mortality rate of anchovy eggs.

Isarı *et al.* (2008) assumed that interannual variability of anchovy larvae is influenced by the advection of enriched less saline Black Sea Water. Somarakis (1993) observed that outflow of BSW is passing Canakkale Strait and recirculate south of Gökçeada Island. In addition to this, considering to the whole Northern Aegean Sea, eastern part was determined as more productive spawning areas for anchovy (Isarı *et al.* 2008). Higher abundance of eggs and larvae in our study via other's listed in Table 1 supported this findings. In our study, we observed that North and North west of island is not suitable spawning areas for anchovy (Figures 5 and 6). These areas has short continental shelf and steep shores. The abundance was relatively low via other areas due to lower seawater temperature and higher salinity.

The characteristics of the spawning areas are extremely important for the survival of the fish larvae as their morphological development is not fully completed. In our region, South and West of the island is under the influence of BSW, enriched with nutrients and lower salinity. Add to this, these areas has wide continental shelf, more temperate and less saline waters via North region. Currents effect spatial variability of anchovy eggs, clearly. We easily assumed that South east stations has under the influence of robust effect of water flow and fish egg abundance of these areas were low due to advection to Western part. But additional work needs to be conducted to determine the effect of current regime.

The restrictions on fisheries around area is important and implementations should be increased. The closed areas for trawl fishery (Saros Bay) and whole fishing activities (Gökçeada Underwater Park) may positively effects the spawning of the adults and pelagic larval duration, settlement and recruitment of the early life stages of fish. The national parks should be extended, increased and protected better. This results reveals that Gökçeada Island is an important spawning area for anchovy adults, southern part is an important nutrition and growth areas for anchovy larvae and has many areas to be sheltered.

Consequently, Gökçeada is in a very special location in the sense of shared stocks, hence fisheries management authorities must pay attention to conserve and sustain these stocks. For these purpose detailed current maps should be constituted and advection of eggs by outflow of BSW must be estimated. Stock monitoring studies should be carried out uninterruptedly. Finally more detailed early life history studies should be conducted.

Acknowledgements

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Kuzey Ege Denizi'nde, Gökçeada civarındaki hamsi *Engraulis encrasicolus* (Linnaeus, 1758) yumurta ve larvalarının alansal ve zamansal dağılımı

Öz

Bu çalışma hamsi yumurta ve larvalarının Kuzey Ege Denizi'nde yer alan Gökçeada etrafındaki alansal ve zamansal dağılımı üzerinedir. Bu amaçla, Haziran 2013 – Mayıs 2014 tarihleri arasında 9 istasyondan vertikal aylık örneklemeler gerçekleştirilmiştir. Örneklemeler sonucunda toplam 306 yumurta, 198 prelarva ve 248 postlarva tespit edilmiştir. Hamsinin üremesinin Mayıs ve Ekim arasında gerçekleştiği, üremenin 15,9 °C' de başladığı ve 20,8-23,2 °C sıcaklıklarında Haziran ve Ağustos arasında pik yaptığı tespit edilmiştir. Toplam yumurta bolluğu 1199,8 birey/m², ortalama yumurta bolluğu 33,5 birey/m² tespit edilmiştir. Toplam prelarva bolluğu 776,2 birey/m², toplam postlarva bolluğu ise 972,2 birey/m² olarak belirlenmiştir. Prelarva bolluğu en fazla Ağustos ayında (540 n/m^2), postlarva bolluğu ise Eylül ayında (492 n/km^2) görülmüştür. Toplam yumurta ölüm oranı %12,4 olarak tespit edilmiş, en yüksek mortalite Temmuz ayında görülmüş (%30,9) ve ölümlerin büyük çoğunluğunun gastrula evresinde (3. Evre) (%85) gerçekleştiği tespit edilmiştir. Yumurtaların doğu, larvaların ise güney bölümde yoğunlaştığı, dağılımlarında ise kuvvetli kuzeyli rüzgarlar ve akıntıların etkili olduğu anlaşılmıştır.

Anahtar kelimeler: Hamsi, balık yumurtası, balık larvası, üreme, değişim

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