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İSMAİL BURAK DABAN

ALİ İŞMEN

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Fish larvae assemblages of Gökçeada Island, North Aegean Sea: effect of weekly sampling interval on their incidences

İsmail Burak DABAN*, Ali İŞMEN
Department of Fisheries and Fish Processing, Faculty of Marine Science and Technology,
Çanakkale Onsekiz Mart University, Çanakkale, Turkey

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Abstract: The species composition and temporal variations of fish larvae in shallow waters (<20 m) of Gökçeada Island located in the North Aegean Sea were studied weekly using WP-2 plankton nets. In this study, a total of 2281 fish larvae belonging to 31 families and 55 species were sampled. The highest biomasses for families were for Clupeidae, Myctophidae, Engraulidae, and Sparidae, whereas the highest species richness for families were for Sparidae, Myctophidae, and Labridae. *Sardina pilchardus* larvae were the most predominant larval species with a total biomass of 8036.1 ind./1000 m^3 (55.1%). Significant differences in larval biomass were evident between the months, whereas there were no differences evident between species richness. Biomass and species richness of fish larvae were highest in the winter and summer. Compared with similar studies carried out on larger geographical areas, similar species diversity and biomass were also found in this study. It was observed that the occurrence of some larvae species that had shorter spawning duration increased with the frequent sampling interval.

Key words: Fish larvae, biomass, species richness, sampling frequency, Northeastern Aegean Sea

1. Introduction

Early life stages of fish are typically characterized by rapid changes in morphology, physiology, and behavior (Fuiman, 2002; Gisbert et al., 2002; Gisbert and Doroshov, 2006) with an embryonic and larval duration of <30 days (Raventós and Macpherson, 2001). These changes in ontogenetic development are considered critical in terms of larval survival and recruitment due to extremely high mortality rates that occur during the first month (Hjort, 1914). Therefore, elaboration of early life histories of fishes and their interactions with the environment are considered as one of the most important tools in studying marine fish populations and management of fishery resources (Fives et al., 2001; Govoni, 2005). Studying larval fish assemblages can provide information on reproduction periods of adult fish, mortality rates, food abundance, stock estimations, diversity, and monitoring of nonnative fishes (Rodriguez et al., 2017).

Studies on larval assemblages in the Eastern Mediterranean are relatively limited, particularly in the Turkish side of the North Aegean Sea. The Greek side of the North Aegean Sea has been studied more intensively (Somarakis et al., 2000; Zervakis et al., 2000; Isari et al., 2008). Somarakis et al. (2002) and Isari et al. (2008) found 77 and 59 fish larvae species in the Greek side of Northern Aegean Sea, respectively. The North Aegean Sea has been identified as the most productive area in this region (Isari et al., 2008). Higher productivity is mainly due to the input of brackish waters of the Black Sea through the Dardanelles (Zervakis et al., 2000) as well as other freshwater inputs from large rivers. Until now, only a single study on the biomass and spatial and temporal variations of ichthyoplankton in the Turkish side of the North Aegean Sea, in Edremit Bay, Balıkesir, reported a total of 49 larval species (Çakır, 2004).

The present study was carried out off Gökçeada Island (North Aegean Sea), which is the largest island of Turkey. Gökçeada is located in northwest Turkey, 20 km west off the Gallipoli peninsula, Çanakkale (40°05′N to 40°14′N, 25°40′E to 26°02′E). Gökçeada can be considered as a pristine environment due to its location, lower population, and lack of any major industry on the island. Gökçeada is located only 18 km south from the center of the Saros basin, which is the easternmost basin of the North Aegean Trough with a maximum depth of 1469 m (Velaoras and Lascaratos, 2005). This region is characterized by lower salinity (31.0–35.0 ppt) due to input from the Black Sea through the Dardanelles compared to the higher

* Correspondence: burakdaban@gmail.com.tr

salinity (39.1–39.1 ppt) of the South Aegean Sea and lower temperatures (Zodiatis, 1994). Geomorphologically, Gökçeada Island has two major contradicting habitats: deeper rocky coasts with a steep shelf in the north and sandy, shallow habitats in the south. All these factors contribute to high fish biodiversity observed in this area. For example, Gönülal and Güreşen (2014) reported a total of 179 Actinopterygii species from Gökçeada Island.

In this study, community structure and temporal changes of fish larvae collected from Gökçeada Island have been studied. To our knowledge this is the first study on larval fish assemblages in this region. The observed fish larvae species composition, time, and duration were also compared with assemblages previously described for the adjacent waters. Another major aspect of the study was the weekly sampling interval employed to better understand temporal variations in the abundance and the composition of larval assemblages and reproduction periods of adult populations in this region.

2. Materials and methods

Due to some limiting factors, such as limited sheltered fishing harbors around the island, technically inadequacy of survey vessels, and limited funds, we studied a specific section of the island in order to prevent interruption of weekly sampling by harsh weather conditions in autumn and winter. We chose the sampling area based on the outcomes of our preliminary studies around Gökçeada Island. These preliminary studies indicated that the northeastern part of the island has significantly more larval biomass and diversity. Thus, we conducted samplings around the northeastern part of Gökçeada Island (Figure 1).

Fish larvae samples were taken between May 2015 and February 2016. Samples were collected by horizontal tows with a WP-2 type plankton net (57 cm mouth diameter, 500 µm mesh size, and 3 m total length) from shallow waters (<20 m depth) with 2 nautical mile tow speed and 10 min tow duration. All plankton tows were performed at daylight. The plankton tows were mostly conducted at weekly intervals unless adverse weather conditions prevented it. The plankton samples were fixed in 4% formaldehyde solution for 9 h. Then larvae were preserved in 70% alcohol solution. Fish larvae were sorted and identified to the possible lowest taxon according to Dekhnik (1973), Russell (1976), and Yüksek and Gücü (1994). The quantities and percentages of larvae in the unit volume of tows (ind./m^3) were determined. Sea surface temperature and salinity were recorded with a YSI 556 Model Multiple Water Analysis Probe. ANOVA was used to analyze temporal changes in the larval biomass after log10 transformation of data. When ANOVA results were significant, we used the Tukey post hoc test (Winer et al., 1991) to test the differences between abundance and months. Confidence intervals (95%) for each parameter were calculated by using PAST version 3.02 (Hammer et al., 2001). Pearson correlation coefficients (R_s) were calculated for elucidation of the relationships between surface water temperatures, salinity, and fish larval biomass and diversity. Additionally, Shannon diversity (H') and dominance (D) indices were used to evaluate species richness and dominance.

3. Results

Weekly variations in sea surface temperatures and salinities between May 2015 and February 2016 are shown in Figure 2. In the study area, mean annual sea surface temperature and salinity were 19.2 ± 0.9 °C and 34.8 ± 0.07 ppt, respectively. Temperature values varied between 10.5 and 26.1 °C, whereas mean salinities ranged from 33.9 to 35.2 ppt. The lowest temperature was measured on 3 February and the highest was on 24 August. Salinity values were higher in the summer period and the minimum value was observed in February due to heavy rainfall.

A total of 2281 larvae belonging to 31 families and 55 species were sampled between May 2015 and February

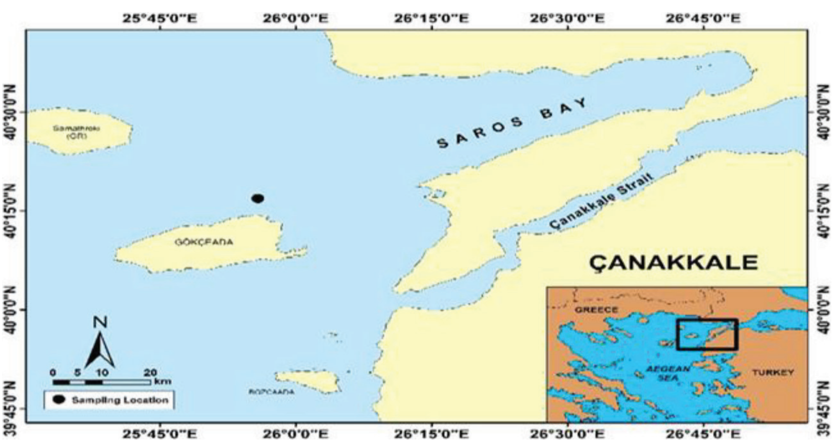

Figure 1. Map of the sampling location on Gökçeada Island, North Aegean Sea.

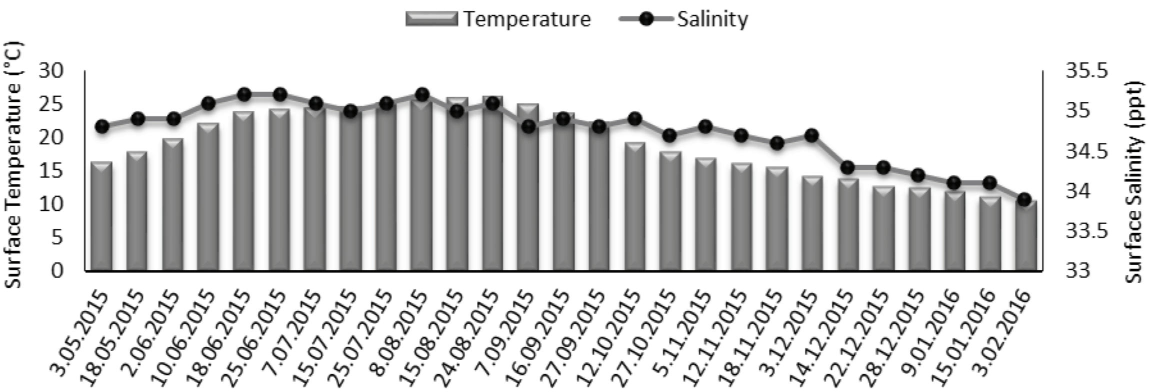

Figure 2. Temporal variations of sea surface temperature and salinity at the sampling location.

2016 from 27 different plankton tows (Table 1). Clupeidae, Myctophidae, Engraulidae, and Sparidae were the most represented families accounting for 59.1%, 11.4%, 11.4%, and 7.8% of all identified families, respectively. Sparidae, Myctophidae, and Labridae had the highest species richness, representing 8, 6, and 4 species, respectively.

The most abundant larval species was *Sardina pilchardus*, accounting for 55.4% of all sampled larvae. Of the total sampled species, 70.5% consisted of small pelagics (*S. pilchardus*, *Engraulis encrasicolus*, and *Sardinella aurita*). Larvae of Carangidae (0.22%) and Scombridae (0.35%), with adult forms commonly found around the northern Aegean Sea, had lower densities. Mesopelagic species such as *Electrona risso*, *Myctophum punctatum*, and *Hygophum benoiti* (11.1% of total larvae abundance) had relatively higher biomass. *Pagellus bogaraveo* and *Diplodus annularis* were the most abundant Sparidae species; however, they constituted only 7% of the total larval biomass. Larval fish biomass was higher in November, December, January, and June than in other months. Higher larval biomass in winter months was mostly associated with *S. pilchardus*, which constituted 57.9%, 43%, and 42% of the total biomass in November, December, and January, respectively. Larval fish biomass was generally lower in April, early May, late September, and October. Lower numbers of fish larvae were observed than expected in July. In June, *E. encrasicolus*, *Sardinella aurita*, and *D. annularis* were the most abundant larvae species, while *E. encrasicolus* and *D. annularis* exhibited the highest values in August. The mesopelagic fish species *Myctophum punctatum* was observed year round in plankton samples, while the other mesopelagics were mostly found during the winter period. Temporal variations of species richness were similar to fish larvae biomass. Species richness was low in May, September, and October, but had higher values in December and June with 21 and 20 fish larvae species identified, respectively (Figure 3).

There were significant differences ($F = 4.381$, $df = 9$, $P < 0.05$) in temporal variations of fish larvae biomass. The Tukey test showed that significant differences were found in December, January, and February compared to October, September, and May compared to January, and in November compared to August. There was no significant difference ($F = 2.335$, $df = 9$, $P = 0.0601$, $P > 0.05$) in temporal variations of species richness. Pearson correlation analysis indicated that fish larval biomass was significantly correlated with species richness ($r_s = 0.716$; $P < 0.01$). Moderate negative correlations were found between fish larval biomass and sea water temperature ($r_s = -0.417$; $P < 0.05$) and between species richness and sea water salinity ($r_s = -0.402$; $P < 0.05$).

In the present study, frequent (weekly) sampling allowed estimation of the timing of spawning events of some abundant species more accurately. The approximate start, end, and peak time of spawning was estimated via occurrence of the species of fish larvae in the plankton. Since fertilized eggs and incubation time are not considered in this study, the precise spawning date can show alterations from fertilization to sampling based on species. *Myctophum punctatum* had the longest spawning season as indicated by a year-round occurrence in plankton samples with a peak on 15 January. Spawning of *E. encrasicolus* started on 3 May and ended on 27 September, with a peak on 24 August. Spawning of *S. pilchardus* began on 12 October and ended on 3 February, with a peak on 14 December. *D. annularis* was observed in plankton between 18 March and 16 September, and it peaked on 18 July. Some abundant species such as *Sardinella aurita*, *Pagellus bogaraveo*, and *Electrona risso* had shorter occurrences in the plankton with a duration of about 6–8 weeks (Table 2).

With respect to biodiversity, maximum larval fish diversity index values were 1.8 on 2 June and 1.75 on 15 January. On 2 June, 44 individuals were sampled belonging to 11 different species, whereas on 15 January, 265 individuals were sampled belonging to 10 different species. Maximum dominance index was found on 25 July, 12 November, and 22 December. In July, *E. encrasicolus* larvae had the highest number (94% of total), while in

Table 1. Species composition and biomass of the fish larvae sampled at Gökçeada Island, North Aegean Sea.

		Individuals	Biomass	
Family	Species	(n)	%n	(n/1000 m^3)
Congridae	*Conger conger* (Linnaeus, 1758)	1	0.04	6.36
Clupeidae	*Sardina pilchardus* (Walbaum, 1792)	1264	55.41	8036.06
	Sardinella aurita Valenciennes, 1847	84	3.68	534.04
Engraulidae	*Engraulis encrasicolus* (Linnaeus, 1758)	260	11.40	1652.99
Sternoptychidae	*Argyropelecus hemigymnus* Cocco, 1829	2	0.09	12.72
Phosichthyidae	*Vinciguerra antennuata* (Cocco, 1838)	1	0.04	6.36
Stomiidae	*Stomias boa* (Risso, 1810)	2	0.09	12.72
Myctophidae	*Electrona risso* (Cocco, 1829)	114	5.00	724.77
	Myctophum punctatum Rafinesque, 1810	91	3.99	578.55
	Hygophum benoiti (Cocco, 1838)	49	2.15	311.52
	Benthosema glaciale (Reinhardt, 1837)	4	0.18	25.43
	Lampanyctus crocodilus (Risso, 1810)	2	0.09	12.72
	Lobianchia dofleini (Zugmayer, 1911)	1	0.04	6.36
Gadidae	Gadiculus argentatus Guichenot, 1850	1	0.04	6.36
Lotidae	*Gaidropsarus mediterraneus* (Linnaeus, 1758)	45	1.97	286.09
Phycidae	*Phycis blennoides* (Brünnich, 1768)	3	0.13	19.07
Merlucciidae	*Merluccius merluccius* (Linnaeus, 1758)	7	0.31	44.50
Gobiesocidae	Lepadogaster candolii Risso, 1810	14	0.61	89.01
Zeidae	*Zeus faber* Linnaeus, 1758	1	0.04	6.36
Sebastidae	*Helicolenus dactylopterus* (Delaroche, 1809)	2	0.09	12.72
Scorpaenidae	*Scorpaena porcus* Linnaeus, 1758	2	0.09	12.72
Triglidae	Chelidonichthys sp.	22	0.96	139.87
Moronidae	*Dicentrarchus labrax* (Linnaeus, 1758)	1	0.04	6.36
Serranidae	*Serranus hepatus* (Linnaeus, 1758)	5	0.22	31.79
	Serranus scriba (Linnaeus, 1758)	4	0.18	25.43
	Serranus cabrilla (Linnaeus, 1758)	3	0.13	19.07
Carangidae	*Trachurus trachurus* (Linnaeus, 1758)	3	0.13	19.07
	Caranx rhonchus Goeffroy Saint-Hilaire, 1817	1	0.04	6.36
	Trachurus mediterraneus (Steindachner, 1868)	1	0.04	6.36
Sparidae	*Pagellus bogaraveo* (Brünnich, 1768)	81	3.55	514.97
	Diplodus annularis (Linnaeus, 1758)	79	3.46	502.25
	Sparus aurata Linnaeus, 1758	10	0.44	63.58
	Diplodus sargus (Linnaeus, 1758)	4	0.18	25.43
	Boops boops (Linnaeus, 1758)	1	0.04	6.36
	Lithognathus mormyrus (Linnaeus, 1758)	1	0.04	6.36
	Pagellus erythrinus (Linnaeus, 1758)	1	0.04	6.36
	Pagrus pagrus (Linnaeus, 1758)	1	0.04	6.36
Mullidae	*Mullus barbatus barbatus* Linnaeus, 1758	2	0.09	12.72
Pomacentridae	*Chromis chromis* (Linnaeus, 1758)	1	0.04	6.36
Mugilidae	*Liza saliens* (Risso, 1810)	29	1.27	184.37

Table 1. (Continued).

Labridae	*Ctenolabrus rupestris* (Linnaeus, 1758)	5	0.22	31.79
	Thalassoma pavo (Linnaeuus, 1758)	3	0.13	19.07
	Symphodus cinereus (Bonnaterre, 1788)	2	0.09	12.72
	Symphodus melops (Linnaeus, 1758)	1	0.04	6.36
Ammodytidae	*Gymnammodytes cicerelus* (Rafinesque, 1810)	22	0.96	139.87
Blenniidae	*Blennius ocellaris* Linnaeus, 1758	3	0.13	19.07
Gobiidae	*Gobius niger* Linnaeus, 1758	15	0.66	95.36
	Pomatoschistus sp.	4	0.18	25.43
	Pomatoschistus marmoratus (Risso, 1810)	3	0.13	19.07
Trichiuridae	*Lepidopus caudatus* (Euphrasen, 1788)	3	0.13	19.07
Scombridae	*Scomber japonicus* Houttuyn, 1782	6	0.26	38.15
	Sarda sarda (Bloch, 1793)	2	0.09	12.72
Bothidae	*Arnoglossus thori* Kyle, 1913	9	0.39	57.22
	Arnoglossus kessleri Schmidt, 1915	2	0.09	12.72
Soleidae	*Pegusa lascaris* (Risso, 1810)	1	0.04	6.36
Total		2281	100	14501.78

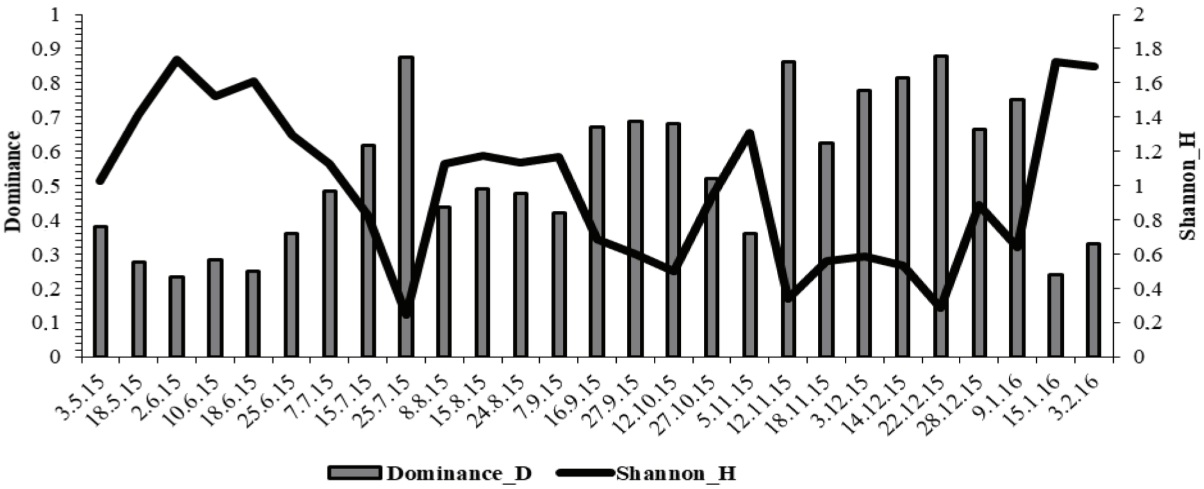

Figure 3. Temporal variations of Shannon_H biodiversity indices and dominance.

November and December, *S. pilchardus* dominated the species composition.

4. Discussion

In this study, plankton sampling on a weekly basis allowed us to make more accurate predictions on the timing of spawning events for a variety of species. Our results showed that some abundant species such as *P. bogaraevo*, *E. risso*, *Liza saliens*, and *Gaidropsarus mediterraneus* had relatively shorter spawning periods (<7 weeks) as indicated by the larval biomass in plankton samples. Ninety percent of the total larval biomass of these species was collected during the peak period, which lasted for about only 1 week. While some larval species were observed for a brief period only, others such as *E. engrasicolus*, *D. annularis*, and *S. pilchardus* were observed for longer periods, i.e. for up to 15 months. The presence of mesopelagic and bathypelagic species is notable as these species have not been reported from the Turkish side of the North Aegean Sea before and have been reported rarely from other locations in Turkey (Bilecenoğlu et al., 2014). The presence of these species in plankton samples can be explained by the proximity of Gökçeada Island to the North Aegean Trough in the north. Deep waters in this basin provide a suitable habitat for many mesopelagic and bathypelagic species. The presence of *Myctophum punctatum* larvae for a period in

Table 2. Estimate of approximate spawning seasons* of some abundant species found at Gökçeada Island, North Aegean Sea, via frequent sampling of fish larvae.

Abundant fish larvae species	SD**	May		Jun				Jul			Aug			Sep			Oct		Nov			Dec				Jan		Feb
		3.05.2015	18.05.2015	2.06.2015	10.06.2015	18.06.2015	25.06.2015	7.07.2015	15.07.2015	25.07.2015	8.08.2015	15.08.2015	24.08.2015	7.09.2015	16.09.2015	27.09.2015	12.10.2015	27.10.2015	5.11.2015	12.11.2015	18.11.2015	3.12.2015	14.12.2015	22.12.2015	28.12.2015	09.01.2016	15.01.2016	3.02.2016
Engraulis encrasicolus	20																											
Sardinella aurita	7																											
Diplodus annularis	17																											
Liza saliens	12																											
Sardina pilchardus	15																											
Pagellus bogaraveo	7																											
Hyghophum benoiti	14																											
Gaidropsarus mediterraneus	13																											
Electrona risso	5																											
Myctophum punctatum	All Year Round																											

*Approximate spawning season: The data obtained from larvae observations in plankton. The precise spawning date can show alterations from fertilization to sampling based on species. The gray boxes indicate the occurrence of fish larvae in related weeks and black boxes indicate the peak time of spawning derived from abundance data. **SD: Spawning duration: Occurrence of larvae in plankton weekly.

May and February indicated continuous spawning activity. Similar continuous spawning activity has been reported for *M. punctatum* in the northwestern Mediterranean between April and October (Sabates and Olivar, 1989). In contrast, larvae of *E. risso*, another mesopelagic species, were observed only briefly, covering a period of 4 weeks. A similar observation has been made for *Electrona* sp. in the Northern Benguela region (Sabates and Olivar, 1989). Such differences in larval abundances may indicate variations in reproduction strategies of these species.

Other species with longer spawning periods were *E. encrasicolus* and *S. pilchardus*. Plankton samples contained sample amounts of larvae for both of these species for a period of up to 4 months. The surface water temperatures when larvae of these two species were observed ranged between 16.8 and 24.1 °C for *E. encrasicolus* and 11.9 and 18.1 °C for *S. pilchardus*. Our data are similar to those reported earlier by others. For example, Olivar et al. (2003) stated that spawning of *S. pilchardus* began when sea surface temperature was 19 °C and peaked at temperatures below 19 °C in the northwest Mediterranean. In our study, the peak spawning of *S. pilchardus* was observed at 14.5 °C. Miranda et al. (1990) found that the development duration of *S. pilchardus* eggs takes place in 67 h at 15 °C. Considering the rapid embryonic development duration at peak spawning time (14.5 °C), the highest abundance of *S. pilchardus* may be due to this situation. For *E. encrasicolus*, the spawning activity was reported to occur between May and September at 17.0–25.0 °C in the northwestern Mediterranean (Palomera and Sabates, 1990). Similarities in spawning temperatures reported from different localities support temperature-dependent spawning behaviors of small pelagics.

In this study, a total of 55 species of larvae were identified during a 10-month period. Our findings are in accordance with earlier findings on the fish biodiversity of this region. Similar numbers of larval species have been reported from other locations in the Northern Aegean. For example, while Çakır (2004) found 49 fish larvae species in the Turkish side of the Northern Aegean Sea, from Edremit Bay, Balıkesir, Somarakis et al. (2002) and Isari et al. (2008) found 77 and 59 fish larvae species in the Greek side of Northern Aegean Sea. Conversely, for the reported fish larvae species in our study (Conversely, mesopelagic fish larvae species such as *Pagellus bogaraveo Argyropelecus hemigymnus, Vinciguerra antennuata, Stomias boa, Electrona risso, Myctophum punctatum, Hygophum benoiti, Benthosema glaciale, Lampanyctus crocodilus, Lobianchia dofleini,* both reported in the present study and in earlier studies from the North Aegean Sea (Somarakis et al., 2002; Isari et al., 2008) were not observed in Edremit Bay (Çakır, 2004). A major difference between the present study and those that reported earlier is the frequency of sampling interval. Sampling interval of earlier reports on the larval occurrences were less vigorous, i.e. either seasonal or monthly, which may have resulted in lower larval biodiversity.

The high biodiversity in this region was attributed to the inflow of the mesotrophic Black Sea waters into oligotrophic waters of the North Aegean Sea through the Dardanelles (Isari et al., 2008; Somarakis et al., 2011). The effect of Black Sea waters on physicochemical properties of the North Aegean Sea is more pronounced in the eastern part than in the western part due to dilution (Isari et al., 2008). As a result the surface waters of the eastern part are characterized by lower salinities and lower temperatures with higher primary production potential (Isari et al., 2008; Somarakis et al., 2011). The higher primary production renders the region a more suitable habitat for small pelagic fish (Somarakis et al., 2011) and explains the dominance of the larvae of small pelagics such as *E. encrasicolus* and *S. pilchardus* over other species observed in the present study.

Larval biodiversity, as indicated by Shannon H' biodiversity and dominance indices, showed variations throughout the year. As expected, biodiversity was higher in late spring and early summer with a decreasing trend until late December and an increasing trend in January and early February. In the Mediterranean, a higher larval biodiversity is usually associated with increasing water temperatures. The unexpected lower larval biomass and species richness in late July may be due to heavy rain and flood events, which had major effects due to the proximity of the study area. In reaction to this event, a sudden drop in salinity, intense sediment accumulation, and flow direction changes from shore to open sea were observed.

From the viewpoint of stock management, determination of the reproduction period of adult populations is particularly critical for species under heavy fishing pressure such as *S. pilchardus*. This small pelagic fish exhibit indeterminate fecundity and continuous spawning activity for longer periods (Fitzhugh et al., 2012). *S. pilchardus* spawning occurred between 12 October and 3 February, covering a period of 15 weeks. In Greece, fishing activity with purse seining is banned between mid-December and the end of February (Stergiou et al., 1997). However, in Turkey, the closed season runs from 15 April to 31 August, with no species-specific seasonal ban. In the case of *S. pilchardus*, current regulations should be reviewed and a no-fishing season that covers the spawning season of this commercially important small pelagic should be introduced in the North Aegean Sea. For *E. encrasicolus*, however, the closed season covers the majority of the spawning period, minimizing the effects of fishing pressure during the spawning period. For other commercially important species, species-specific no-fishing seasons based on area and time should be introduced to protect spawning adults and their offspring.

Our findings on larval assemblages provided valuable insights on the biodiversity and abundance as well as the reproduction period of adult fish populations in the Northern Aegean Sea. From the viewpoint of biodiversity, our results were similar to those carried out in adjacent waters and indicated that the Northern Aegean Sea has a rich larval fish fauna, including relatively rare mesopelagic and bathypelagic species. A weekly sampling interval has proven particularly valuable to accurately determine reproductive events of adult populations such as the onset, peak, and end of spawning periods for a variety of species, in particular those with relatively shorter spawning periods. Information on spawning periods is also important for introducing additional regulations for commercially important species. The present study also demonstrated that a considerably smaller inshore sampling site can successfully be used to study larval assemblages. The area is easily accessible, allowing frequent samplings, and offers a cost-effective way to study larval assemblages. Further studies in the area should elaborate the early life history of fish larvae, especially vital small pelagics for the area.

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