COMU J Mar Sci Fish 2024 7(2): 183-194
https://doi.org/10.46384/jmsf.1581960 e-ISSN: 2651-5326

COMU Journal of Marine Sciences and Fisheries

Journal Home-Page: http://jmsf.dergi.comu.edu.tr Online Submission: http://dergipark.org.tr/jmsf

RESEARCH ARTICLE

Changes on the Temporal Patterns of Ichthyoplankton Assemblages in the Çanakkale Strait, Türkiye

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Received: 12.11.2024 /Accepted: 12.12.2024 / Published online: 25.12.2024

Keywords:

Fish egg
Fish larvae
Abundance
Biodiversity

Abstract: Monitoring studies in a particular area after a long period of time can provide opportunities to understand environmental, physical and biological events that have occurred over time. From this point of view, we aimed to reveal ichthyoplankton assemblages in the Çanakkale Strait after 10 year period. Our findings indicated a 3 ºC difference in sea surface termperature in the late spring and early winter compared to earlier studies. As expected, the highest mean abundance and biodiversity of ichthyoplankton were found in the late spring-early summer period but they showed rapid fluctuations even in consecutive weeks. Coastal resident species such as *Diplodus annularis*, *Gobius niger*, and *Spicara maena* were found to be abundant. In Çanakale Strait, larvae of mesopelagic species were sampled for the first time in this study. The occurrence of mesopelagic species far from their natal habitat in the northern Aegean deep sea trench may indicate a change in the region's hydrodynamics.

Anahtar kelimeler:

Balık yumurtaları
Balık larvaları
Bolluk
Biyoçeşitlilik

Çanakkale Boğazı'nda İhtiyoplankton Topluluklarının Zamansal Değişimi

Öz: Belirli bir bölgede uzun süre aradan sonra yapılan izleme çalışmaları zamanla gerçekleşen çevresel, fiziksel ve biyolojik olayları anlama fırsatı sunar. Bu amaçla, 10 yıl aradan sonra Çanakkale Boğazı ihtiyoplankton topluluğunun ortaya konması amaçlanmıştır. Deniz suyunun beklenenden yaklaşık 3 derece geç ısındığı ve geç soğuduğu belirlenmiş, ancak bu durumun ihtiyoplankton kompozisyonuna etki etmediği tespit edilmiştir. Beklendiği gibi en yüksek ihtiyoplankton bolluk ve biyoçeşitliliği ilkbahar sonu-yaz başı döneminde görülmüş ancak birbirini takip eden haftalarda bile önemli dalgalanmalar tespit edilmiştir. *Diplodus annularis, Gobius niger* ve *Spicara maena* gibi kıyısal yerleşik türlerin daha baskın hale geldiği belirlenmiştir. Mezopelajik Derinsu larvaları ilk kez bu çalışmada Çanakkale Boğzı'nda örneklenmiştir. Bu türlerin varoluş alanı olan Kuzey Ege derin deniz çukurundan bu kadar sürüklenmiş olmaları, bölge hidrdinamiğinin değiştiğini göstermektedir.

Introduction

Icthyoplankton surveys provide essential data for stock assessment, understanding ecosystem functions, and investigating spawning strategies, behavior, and biology. They also play a key role in determining closed areas, closed seasons, and marine protected areas. In addition, icthyoplankton surveys provide a cost-effective and simpler fishery-independent research tool (Doyle et al., 2002). Understanding variabilities and success in fish recruitment is one of the most critical issues for stock management (Hjort, 1926). Sudden changes, influenced by environmental conditions, chemical pollutants, and human-induced factors, lead to high mortality rates in early life stages. In addition, predation and challenges during early feeding contribute to very high losses due to limited morphological and physiological development (Rodriguez et al., 2009; Cuttitta et al., 2016). Thus, ichthyoplankton studies are crucial for understanding species biology and interpreting effects of sudden or long-term variables.

Continuous and uninterrupted data collection can undoubtedly yield more reliable results for monitoring. Some successful examples have been realised in the Gulf of Alaska (McClatchie et al., 2014) and the Gulf of California (Smith and Moser, 2003). However, due to the high costs of continuous monitoring, obtaining such data in every region of the world has not been feasible. Nevertheless, ichthyoplankton studies conducted in the same geographic area at regular time intervals, could provide valuable insights for monitoring.

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How to cite this article: Daban, İ.B., Ayaz, O., & İşmen, A. (2024). Changes on the temporal patterns of ichthyoplankton assemblages in the Çanakkale Strait, Türkiye COMU J. Mar. Sci. Fish, 7 (2): 183-194. doi: 10.46384/jmsf.1581960

Ichthyoplankton studies in Türkiye started approximately 70 years ago, with the study of Arım (1957). To date, several important studies have been carried out in the North Aegean Sea and in the Marmara Sea (Somarakis et al., 2002; Demirel, 2004; Türker Çakır, 2004; Isari et al., 2008, Somarakis et al., 2011; Kara, 2015; Daban and Işmen, 2020). However, there have been no ichthyoplankton studies conducted in the Çanakkale Strait. Daban (2013) presented the first ichthyoplankton results of the Çanakkale Strait.

This study aims to investigate the ichthyoplankton composition and compare abundance and biodiversity of ichthyoplankton in the Çanakkale Strait, over a 10-year period.

Material and Methods

In the late spring and summer, ichthyoplankton abundance and biodiversity reach the highest level throughout the Mediterranean Sea (Sabates and Olivar, 1996; Somarakis et al., 2002). Therefore, sampling design of the present study was structured to account for these seasonal conditions. Samplings were performed weekly between May 18th to December 7th, 2023, for a period of 27 weeks. Stations were located at the end of the European side of the Çanakkale Strait (Fig. 1) at the specified coordinates (P1: 40° 02' 35.7972" N lat. 26° 11' 36.8586" E long. P2: 40° 02' 54.1356" N lat. 26° 12' 35.4924" E long.).

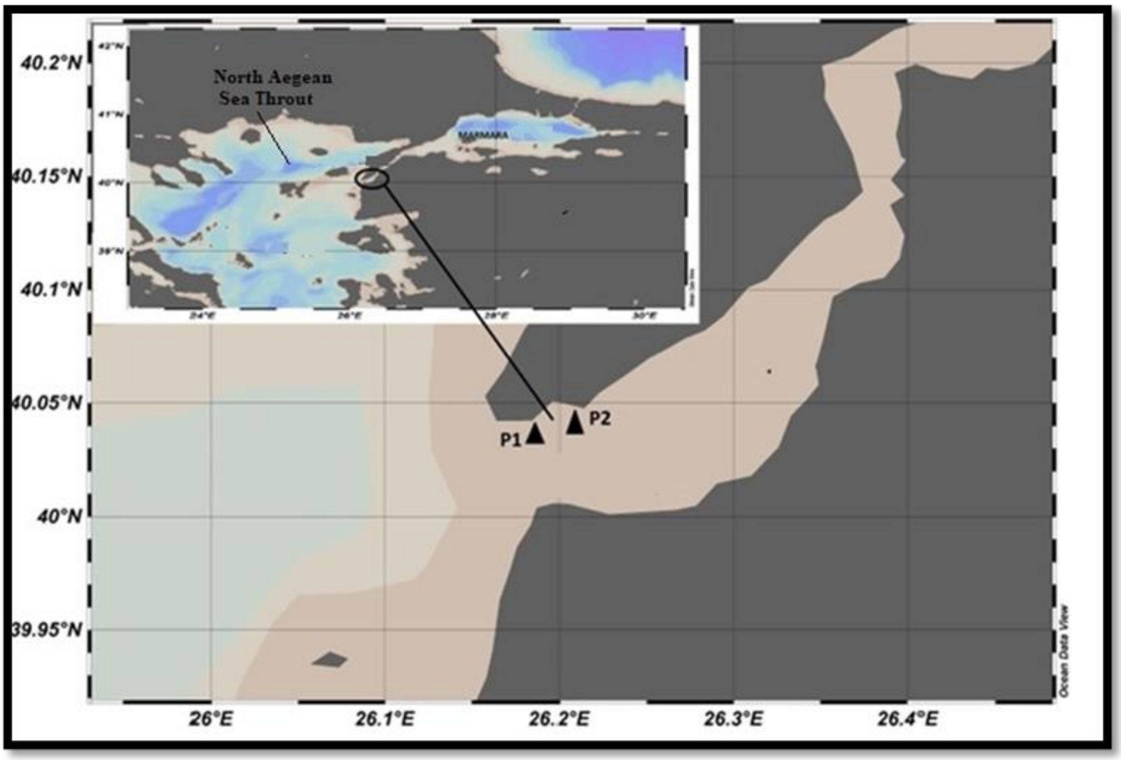

Figure 1. Study area and locations of sampling stations in the Çanakkale Strait, Türkiye

Ichthyoplankton tows were conducted using a WP-2 type plankton net (3 m length, 57 cm frame diameter, 350 μm mesh size) with vertical tows performed from above the thermocline layer to the surface.

Ichthyoplankton samples were fixed with 4% formaldehyde solution. Before species identification, all fish eggs and larvae were seperated from other plankton samples. Species identification were based on Dekhnik (1973), Russell (1976), and Rodríguez et al. (2017).

The embryonic development of fish eggs were staged according to Dekhnik (1973). Fish egg and larval abundance in a unit area (n/10 m^2) was calculated according to FAO Fisheries Technical Paper No: 175. PAST Version 2.17. was used for calculating biodiversity indices Shannon Wiener (*H'*) and dominance (*D*) (Hammer et al. 2001). *H'* index ranges between 0 and 5, with higher values indicating greater diversity of species in a particular community. D represents the dominance of certain groups within a community, with values ranging from 0 to 1, where higher values indicate greater dominance.

Sea surface temperature, salinity and dissolved oxygen values were recorded with a YSI 6600 Model Multiple Water Analysis Probe. Mean values were presented as mean ±standard error. Temporal variations of the physico-chemical variations and mean abundance were analyzed with ANOVA. The statistical differences between groups were tested with Tukey's pairwise comparisons. PCA analyses was used for determining the relationship between mean abundance/biodiversity and temporal variations of ichthyoplankton (Jolliffe, 2002).

Results

Physico-chemical parameters

SST ranged between 15.5 Cº and 24.4 Cº. The lowest and the highest SST values were measured on May 17th and August 5th, respectively. SST on December 7th (17.6 Cº) was higher than that in May. Similarly, the mean SST in November (19.2 Cº) was higher than that in May and similar to that in June (19.6 Cº).

The mean dissolved oxygen (DO) was 7.66±0.15 mg/lt. The lowest DO levels were measured in July and August, when the SST was highest. The relatively high dissolved oxygen (DO) values may be due to the study area's distance from industrial facilities and the high surface flow in the Çanakkale Strait. The surface salinity (S) values ranged between 23.2 - 29.5 ppt, with a mean of 25.5±0.23 ppt. The lowest salinity levels were measured in July and August, whereas the highest salinity was detected on October 30th with 29.5 ppt. The highest monthly mean salinity was in November with 27.9±0.09 ppt.

The temporal variations of monthly mean SST (df:8, F: 37.219; P<0.05), DO (df:8; F:2.640; P<0,05) and S (df:8; F:4.763; P<0,05) values were significantly different. The highest variations were observed for SST. According to Tukey Pairwise comparisons, it was detected that the mean SST of May was significantly different from the SST of all months. Mean SST in June was significantly different from that in July, August and September. Also, mean SST in August and September were significantly different from those in November and December SST values in July, August and September reflect the typical summer conditions. The mean salinity levels in November and December were significantly different from those in other months. Mean DO in July and August were significantly different from those in the remaining months.

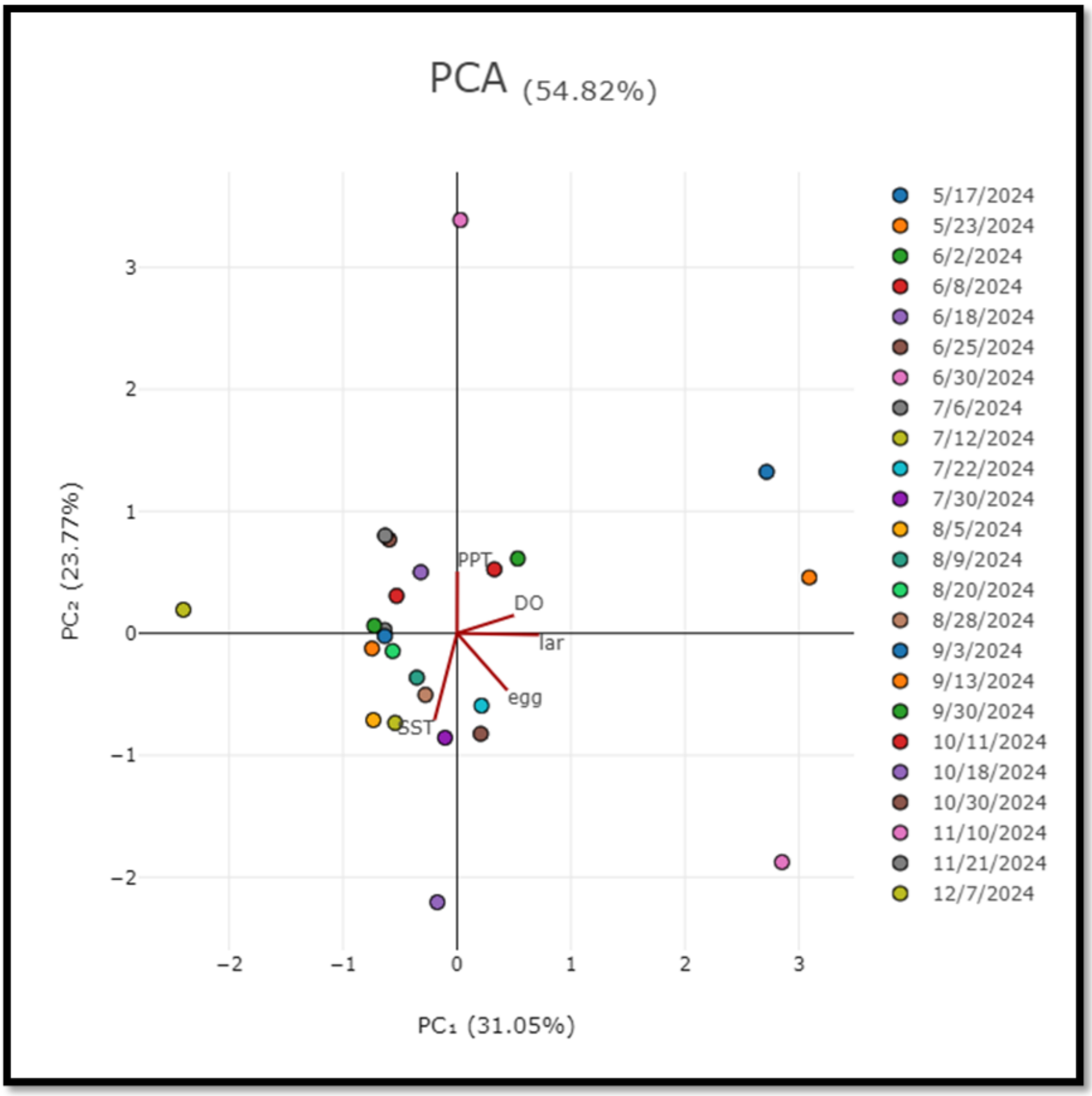

Fig. 8. PCA plot for relationship with biological and physico-chemical parameters.

PCA was performed to determine the relationship between environmental variables and the number of ichthyoplankton species and abundance. PCA1 axis explained 31.05% of the total variance in the study, and PCA2 axis explained 23.77% of the total variance. Both dimensions explained 54.82% of the total variance. SST was detected as the most important variable for fish egg abundance and the salinity negatively effected the larval biomass.

Table 1. Ichthyoplankton assemblages in the Çanakkale Strait, Türkiye

Order:	Clupeiformes		Stage
	Family:	Engraulidae	
		Engraulis encrasicolus (Linnaeus, 1758)	E - Pre - Post
	Family:	Clupeidae	
		Sardina pilchardus (Walbaum, 1792)	E
Order:	Syngnathiformes		
	Family:	Syngnathidae	
		Hippocampus hippocampus (Linnaeus, 1758)	Post
Order:	Perciformes		
	Family:	Serranidae	
		Serranus cabrilla (Linnaeus, 1758)	E - Pre - Post
Order:	Carangiformes		
	Family:	Carangidae	
		Trachurus trachurus (Linnaeus, 1758)	E - Pre - Post
		Trachurus mediterraneus (Steindachner, 1868)	E - Pre
Order:	Eupercaria		
	Family:	Sparidae	
		Diplodus annularis (Linnaeus, 1758)	E - Pre - Post
		Diplodus puntazzo (Linnaeus, 1758)	E
		Pagellus erythrinus (Linnaeus, 1758)	E
		Boops boops (Linnaeus, 1758)	E - Post
		Pagrus pagrus (Linnaeus, 1758)	E - Pre - Post
		Spicara maena (Linnaeus, 1758)	E - Pre - Post
	Family:	Sciaenidae	
		Sciaena umbra Linnaeus, 1758	Post
	Family:	Labridae	
		Thalassoma pavo (Linnaeus, 1758)	Post
		Symphodus ocellatus	E - Pre - Post
Order:	Blenniiformes		
	Family:	Blenniidae	
		Blennius ocellaris Linnaeus, 1758	Post
Order:	Mulliformes		
	Family:	Mullidae	
		Mullus barbatus Linnaeus, 1758	E - Pre - Post
		Mullus surmuletus Linnaeus, 1758	E - Pre - Post

Table 1. Continued

Order:	Callionymiformes		
	Family:	Callionymidae	
		Callionymus lyra Linnaeus, 1758	E - Post
Order:	Gobiiformes		
	Family:	Gobiidae	
		Gobius niger Linnaeus, 1758	Pre - Post
		Gobius paganellus Linnaeus, 1758	Post
		Gobius sp.	Pre - Post
Order:	Carangaria		
	Family:	Sphyraenidae	
		Sphyraena sphyraena (Linnaeus, 1758)	Pre - Post
Order:	Pleuronectiformes		
	Family:	Bothidae	
		Arnoglossus thori Kyle, 1913	Post
		Arnoglossus kessleri Schmidt, 1915	E- Post
	Family:	Soleidae	
		Microchirus variegatus (Donovan, 1808)	E
		Solea solea (Linnaeus, 1758)	E
		Buglossidium luteum (Risso, 1810)	E
Order:	Myctophiformes		
	Family:	Myctophidae	
		Electrona risso (Coco, 1829)	Post
		Myctophum punctatum Rafinesque, 1810	Post
		Ceratoscopelus maderensis (Lowe, 1839)	Post
		Hygophum benoiti (Cocco, 1838)	Post

*Abbreviations: E: Fish egg; Pre: Prelarvae; Post: Postlarvae

Fish eggs

In the present study, sampled eggs were assigned to 19 different fish species belonging to 7 orders and 10 families (Table 1). Sparidae and Soleidae families were the most represented families with 6 and 3 species, respectively. Of the sampled eggs, 62.9% belonged to *Engraulis encrasicolus* and the abundance of all other 18 species was <10%. (Fig. 2).

Eggs belonging to *D. annularis*, *Spicara maena* and *Trachurus trachurus* were represented with higher abundances compared to other species. The total mean fish egg abundance was calculated as 3607.9 eggs/10 m^2. Mean fish egg abundances were found as 4221.8 egg/10 m^2 and 2865.5 eggs/10 m^2 at P1 and P2, respectively. Of the 4786 fish eggs sampled, 2391 eggs were dead corresponding to a mortality rate of 49.96%.

In terms of development, the majority of eggs were at stage 3 and 4 (Fig. 3). Eggs at stages 1, 5 and 6 had frequencies <10% (Fig. 3).

With respect to temporal variations in species richness, eggs sampled in in May and June had higher richness and were represented by 13 and 9 fish species, respectively. The lowest richness was detected in November with only 2 species. The highest *H'* index was observed in May (1.13) and June (1.19). Similarly, the lowest *D* index was detected in May (0.456) and June (0.468).

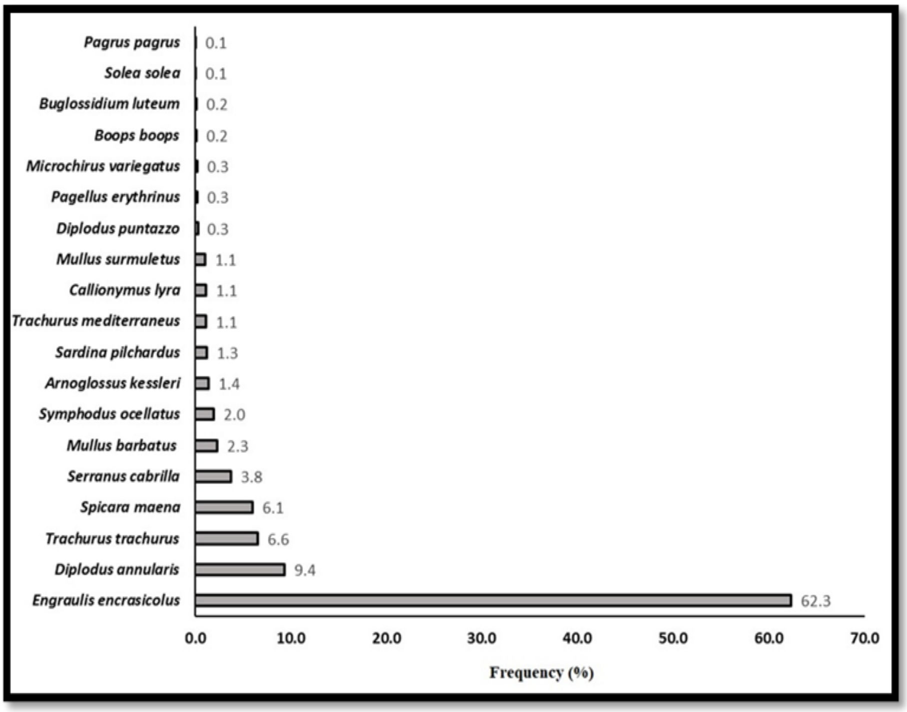

Figure 2. Numerical dominancy of the fish egg species distributed in the Çanakkale Strait

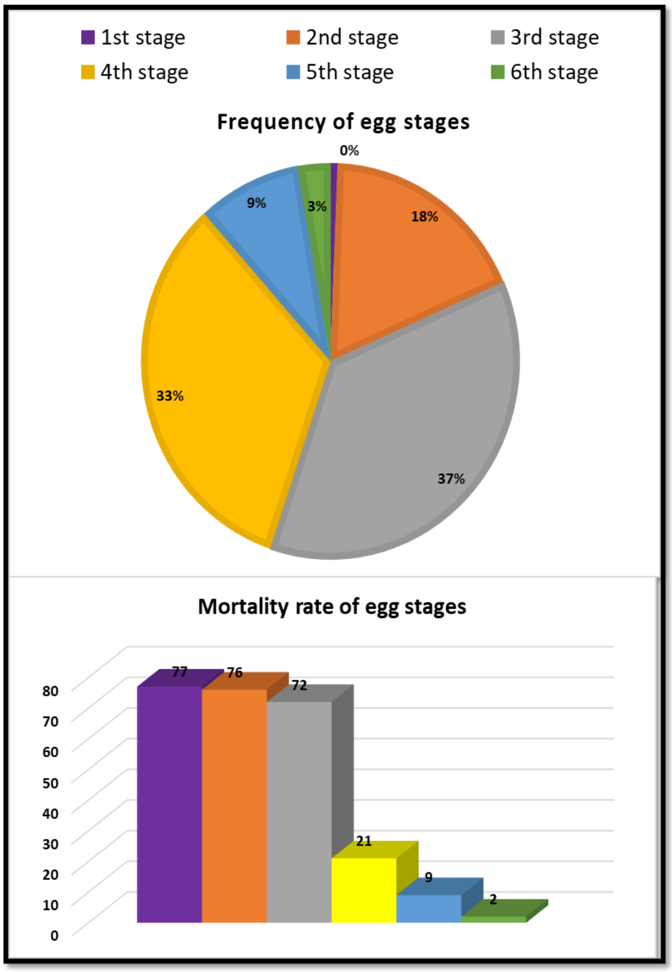

Figure 3. Fish egg development stages and associated mortality rates.

Fish larvae

Sampled larvae were assigned to 27 fish species belonging to 12 ordo and 15 families (Table 1). In terms of the development phase, prelarvae of 13 species and postlarvae of 25 species were identified. Of the total larvae sampled, 71.7% belonged to three species: *E. encrasicolus, D. annularis* and *G. niger* (Fig. 4).

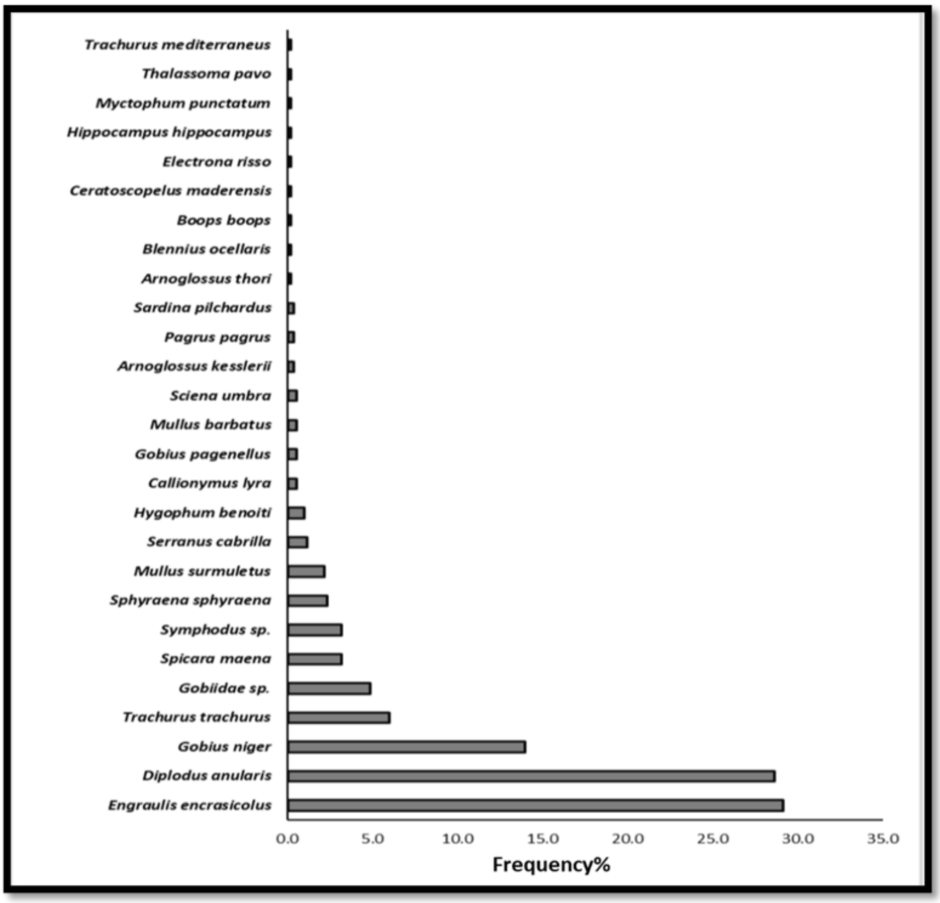

Figure 4. Frequency of occurrence of the fish larvae species distributed in the Çanakkale Strait.

Mean prelarvae, postlarvae and total larvae abundance were found as 33.3 larvae/10 m^2, 419.8 larvae/10 m^2 and 453.2 larvae/10 m^2, respectively (Fig 5). The mean fish larvae abundance found in P1 was slightly higher than that in P2.

The families with the highest percentages were Sparidae and Myctophidae, each represented by four species. The highest number of species, 15, was recorded in June. Species richness was also high in May and July, with 12 and 11 species, respectively. In terms of weekly temporal variations, the highest number of fish larvae was found on May 23rd with 114 specimens, whereas highest taxa number was found on May 23rd and June 25th, with 10 species. Weekly temporal variations of biodiversity indices are given in Figure 5. Between May 17th and December 7th, mean *H'* index and *D* index were found as 1.08 and 0.45, respectively. The highest mean biodiversity was detected between June 2nd and August 28th, corresponding to the *H'* index value of 1.22. The highest biodiversity was detected on August 28th, with 18 fish larvae belonging to 6 different species Larvae biodiversity was also higher on July 22nd and June 2nd with *H'* index values of 1.642 and 1.635, respectively. Larval biodiversity exhibited high weekly variations and the larvae biodiversity indice could not calculated after November 10th, due to the presence of only single species. The lowest larvae biodiversity was 0.198 on September 13th, corresponding to a total of 20 larvae belonging two species.

The dominancy of fish larvae showed strong variations across the sampling period (Fig. 6). Gobiidae members were important representatives until September. *D.annularis* was the major representative larval species in May. *S. maena* was mostly found in June. The other 20 species were poorly distributed until October. *E.encrasicolus* dominated the study area in September and October. By November, abundant species leave the area, the winter spawners begin to appear and abundance decreases.

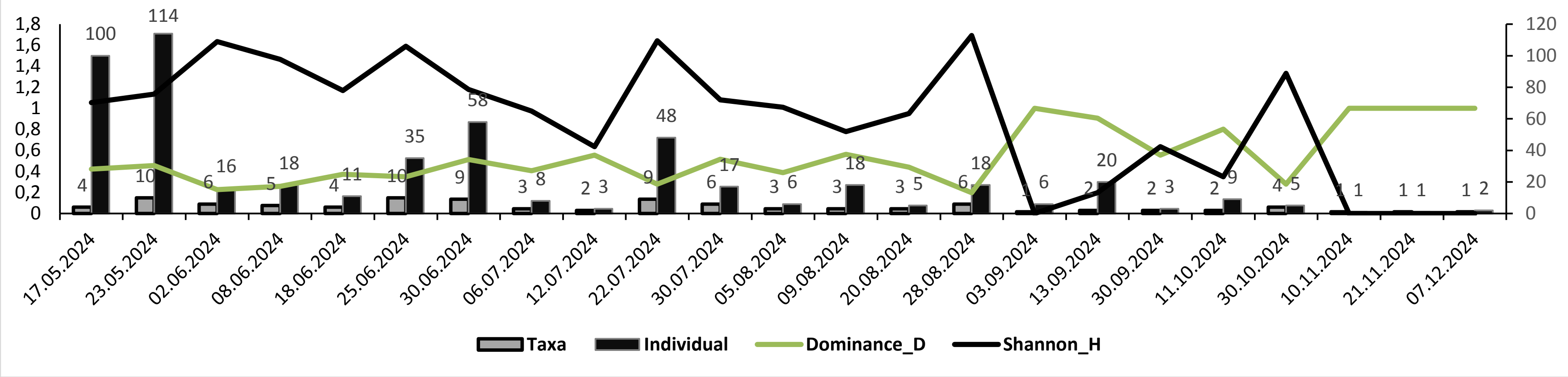

Figure 5. Temporal variation of fish larvae taxa number, abundance, dominance index and Shannon biodiversity index

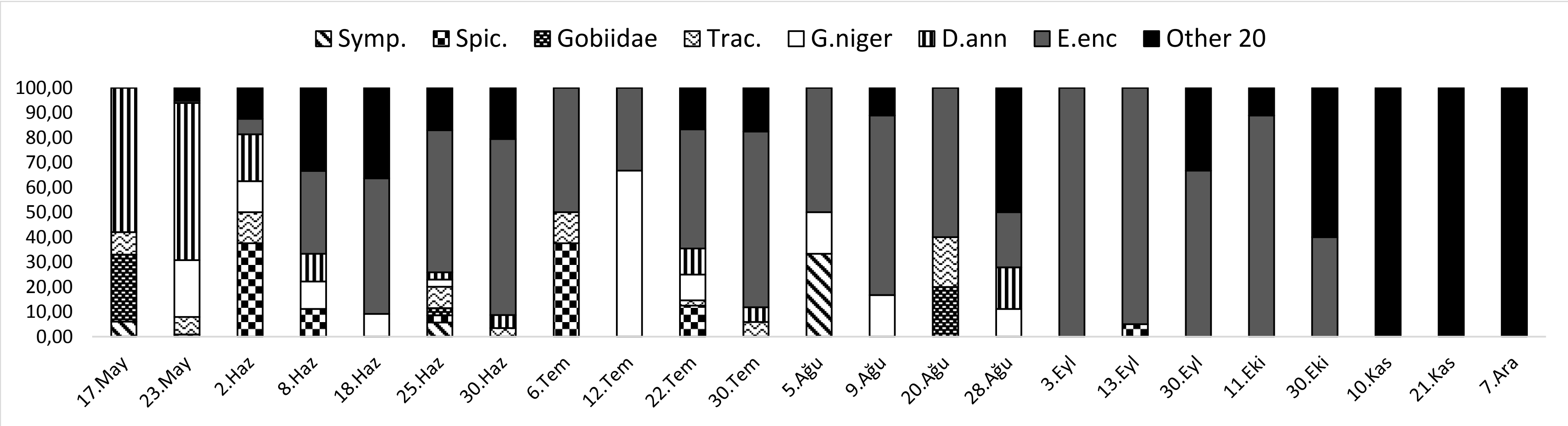

Figure 6. Weekly variation in the dominancy of fish larvae (Symp: *Symphodus ocellatus*; Spic: *Spicara maena*; Trac: *Trachurus trachurus*; D.ann: *Diplodus annularis*; E.enc: *Engraulis encrasicolus*)

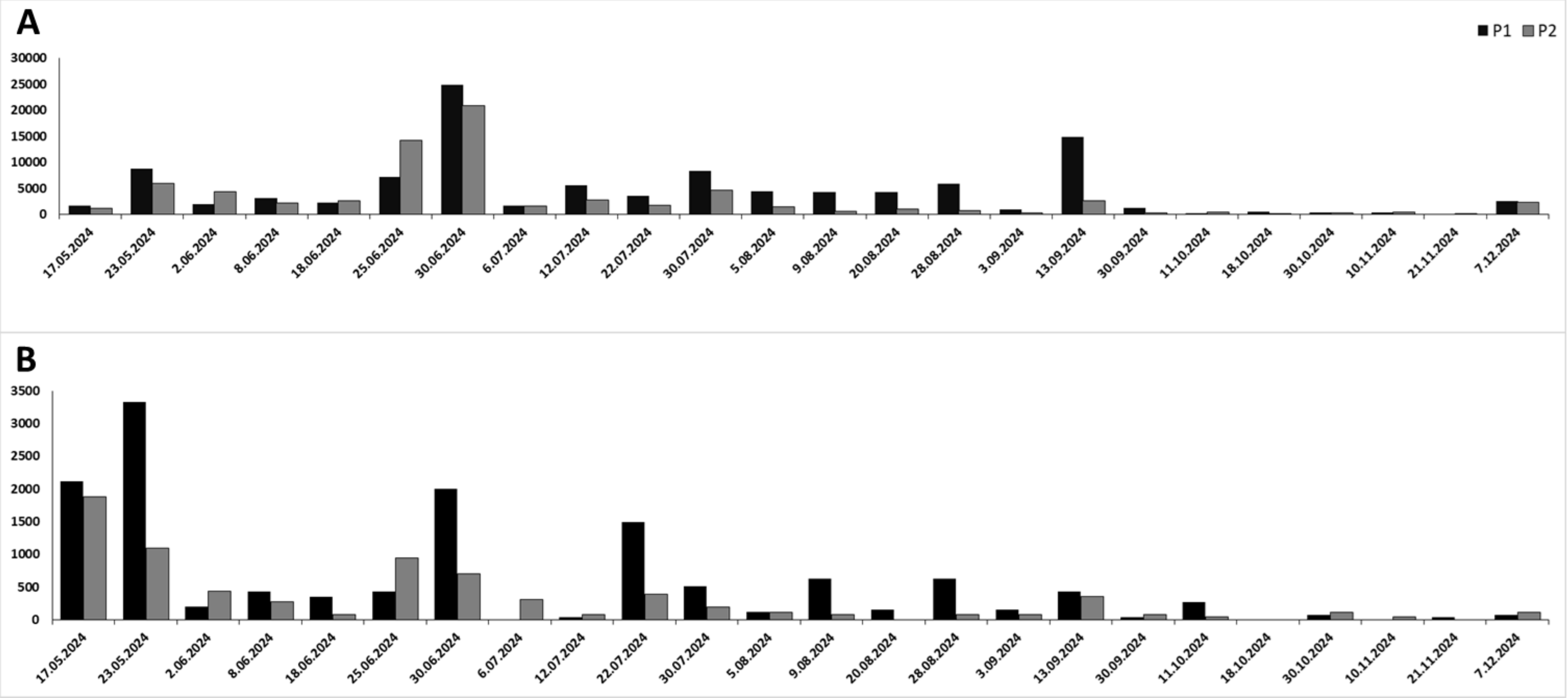

Figure 7. Weekly temporal variation in mean abundance of fish eggs (A) and larvae (B)

Discussion

The onset of spawning in fish species distributed throughout the Mediterranean is primarily attributed to late-spring and early-summer spawners (Tsikliras et al., 2010). Spring-summer ichthyoplankton abundance and biodiversity also were detected as highest around NW Mediterranean by various researchers (Palomera and Olivar, 1996; Sabatés et al., 2003; de Puelles et al., 2007). In the present study, we aimed to assess ichthyoplankton abundance and biodiversity under summer conditions in an area known for its low biodiversity. The data obtained from weekly sampling intervals allowed us to observe rapid fluctuations. According to SST data from the study area, a potential seasonal shift in the temperature regime was observed in comparison to previous studies. Surprisingly, the SST in November (20 °C) and December (17.6 °C) were higher than that in May (15.8 °C). Türkoğlu (2010) reported that SST was 18-19 °C in May and around 14 °C on December 7th, in the Çanakkale Strait. Similarly, Daban ve Yüksek (2017) reported a SST of 18 °C in May and 14 °C in December in the Çanakkale Strait. Differences in SST between the present study and earlier studies may suggest a seasonal shift but more data are needed. The delayed warming up of water temperature did not lead to a decrease in the diversity and abundance of spawning species. In contrast mean fish egg abundance peaked in the May (Fig 7) and species richness of fish larvae remained relatively high in May. Seasonal variations of species richness and ichthyoplankton abundance were similar to those reported in previous studies (Demirel, 2004; Kara, 2015; Daban and Yüksek, 2017). For instance, the highest number of ichthyoplankton taxa was found in May, and it rapidly decreased by the beginning of November. In addition, with the onset of November, autumn-winter spawners such as *Pagrus pagrus* and *Sardina pilchardus* began spawning, as expected. The spring-summer spawners completed their spawning activity although SST remained high. Also, ichthyoplankton abundance was highest in May and started to decrease by September. Alvarez et al. (2012) stated that high spawning activity in early June associated with high metobolism rate, high larval growth rate and low dispersal rate related summer physico-chemical conditions and demersal productivity peak. Thus, the results of this study showed that spawning strategies of Mediterranean teleost species depends on complex and varied biological and abiotic variables and cannot be explained with temporal shift of a several parameters such as SST, salinity or dissolved oxygen. The results of PCA analyses also confirmed this pattern and did not give clear relationship with ichthyoplankton abundance/biodiversity and physical-chemical parameters (SST, salinity and DO%).

In terms of the ichthyoplankton biodiversity, one of the most surprising result was the occurrence of mesopelagic fish species such as *Electrona risso, Myctophum punctatum, Ceratoscopelus maderensis* and *Hygophum benoiti*, which has not been sampled in the ichthyoplankton studies conducted in the Marmara Sea before. Of the species mentioned above, three (excluding *C. maderensis*) and three (excluding *E. risso*) were previously found around Gökçeada Island in the northern Aegean Sea (Daban and İşmen, 2020) and Sığacık Bay in the central Aegean Sea (Uygun and Hoşsucu, 2024), respectively. In addition, all these species were identified in the Greek part of the north Aegean Sea (Isari et al., 2008). Mesopelagic fish species are already well-known in the central and southern part of the Aegean Sea but little is known about their presence in the Sea of Marmara and the Black Sea. The results of this study provide evidence that the distribution areas of these species are expanding. The occurrance of the larvae of the mesopelagic fish species around the northern exist of the Çanakkale Strait may be due to the drifting patterns associated with the cyclonic gyre around Gökçeada and Samothraki. This dispersal pattern may pose challenges to their survival as they move away from their natal habitats into unfamiliar environments, such as the shallower waters of the Çanakkale Strait.

The remaining ichthyoplankton species richness and the mean abundance were similar to those found in previous studies carried out in the adjacent areas. Daban and Yüksek (2017) found 28 ichthyoplankton species in the late spring and summer seasons. When these two studies are compared, the mean abundance of Gobiidae (*G. niger*, *G. pagenellus* and Gobiidae sp.) showed an increase and reached 25% of total larvae abundance. In addition, *D. annularis* (Family: Sparidae) larvae was more abundant after 10 years and the occurrence of relatively high *Mullus barbatus* and *Mullus surmuletus* larvae was noticable. The occurrence of *Hippocampus hippocampus* larvae in both studies is also encouraging in terms of marine biodiversity which may be attributed to to bans on demersal and beam trawling. *H. hippocampus*, is listed as as “Data Deficient” and “Near Threatened” in the Mediterranean as it is subject to high fishing pressure, habitat degredation and limited offspring number according to IUCN (IUCN, 2024). Furthermore, larvae of *Sphyraena sphyraena, P. pagrus* and *Sciaena umbra*, which are highly economic species, were reported for the first time in the study area. Among these species, the occurrence of *S.umbra* is promising as it is listed as “Near Threatened” and is considered at risk of extinction in the near future by IUCN (Chao, 2020). When compared with previous studies in which fish eggs and larvae were identified by Kara (2015), Demirel, (2004), Daban and Yüksek, (2017) in the Sea of Marmara Sea, no Scombridae larvae (*Scomber colias, Scomber scombrus*, and Thunnus sp.) were found in the present study. This may be due to the increased fishing pressure from seine net fisheries on these species.

The development stages fish eggs reveals information about the spatial proximity of the spawning areas. The vast majority of fish eggs (70%) were found at stages 3rd and 4th of their development. Due to the stratified conditions in the study area, water currents flow from north to south in the upper layer. First-stage eggs suggest that spawning occurs in a nearby area, as the time interval between developmental stages is relatively short. (Pauly and Pullin, 1988). Considering the surface current direction, since the study area is located downstream, it is likely that pelagic eggs are tranported from the Sea of Marmara to the Aegean Sea. Higher mortality rate of early development stages of fish eggs found in the present study aligns well with previous reports of high mortality during the early egg development stages, specifically during cleavage (Thompson, 1981) and gastrulation (Rombough, 1996). It has been stated that as the embyonic development advances, mortality rate decreases (Bunn et al., 2000). Thus, lower occurence of eggs with late development stages in the present study may indicate high mortality rates and can be considered negatively in terms of sustainability.

In summary, it was found that the ichthyoplankton biodiversity of the Çanakkale Strait was mostly derived from coastal resident species. Members of Gobiidae and Labridae and *S. maena*, appears to be successful in competing with the coastal species with increasing abundance over time. Previous studies over the past 10 years showed that ichthyoplankton biodiversity has mostly remained similar. The recent occurrences of some larvae species such as *P. pagrus*, *S. umbra* etc. may be related to the weekly sampling interval, which increased the likelihood of encountering low-abundance species. In addition, abundance and biodiversity values exhibited constant changes on a weekly basis. Therefore, in order to detect species with short developmental periods, frequent sampling intervals are required.

Acknowledgement

This work was supported by Çanakkale Onsekiz Mart University The Scientific Research Coordination Unit, Project number: FBA-2023-4464. Also, authors would like to thanks Şafak Fındık to the helps on the vessel during sampling.

Conflict of Interest

The authors declare that there are no conflicts of interest or competing interests.

Author Contributions

Ismail Burak DABAN: Designing of the study, identification of species, data analysis, writing original draft preparation. Oğuzhan AYAZ: Sample collections, Ali İŞMEN: Data analysis, checking-original draft preparation.

Ethics Approval

Ethics committee approval is not necessary for this study.

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