[Turkish Journal of Zoology](https://journals.tubitak.gov.tr/zoology)

Volume 38 | Number 3 Article 13

1-1-2014

Seasonal distribution of Trachurus mediterraneus (Steindachner, 1868) in the Golden Horn Estuary, İstanbul

NAZLI DEMİREL

AHSEN YÜKSEK

Turkish Journal of Zoology
http://journals.tubitak.gov.tr/zoology/
Research Article

Turk J Zool
(2014) 38: 361-368

doi:10.3906/zoo-1308-20

Seasonal distribution of *Trachurus mediterraneus* (Steindachner, 1868) in the Golden Horn Estuary, İstanbul

Nazlı DEMİREL*, Ahsen YÜKSEK
Institute of Marine Science and Management, İstanbul University, Vefa, İstanbul, Turkey

Received: 13.08.2013 • **Accepted:** 07.01.2014 • **Published Online:** 21.03.2014 • **Printed:** 18.04.2014

Abstract: Seasonal changes in the distribution of an important commercial and recreational fish species, Trachurus mediterraneus (Steindachner, 1868), from the family Carangidae were investigated in the Golden Horn Estuary of İstanbul. Environmental conditions were also considered to evaluate distributional patterns in the region. Sampled fish size ranged between 7.5 and 20.1 cm in total length and 3.4 and 86.2 g in total weight during the sampling period. Adult individuals (>12.5 cm) preferred not to be in the estuary during the summer period, while only immature adults were found with a 7.5–12.5 cm total length size range from May to August 2009. It was observed that on a regional basis this species was only found at the entrance of the Golden Horn. Environmental parameters such as surface temperature, salinity, and dissolved oxygen values did not display significant correlations with its distribution throughout the study period. However, chlorophyll a and Secchi disk values displayed significant negative correlations with the distribution of immature adults in the Golden Horn.

Key words: Seasonality, Mediterranean horse mackerel, recreational fishery, estuary, Golden Horn

1. Introduction

The Mediterranean horse mackerel, *Trachurus mediterraneus* (Steindachner, 1868), is distributed in the temperate waters of the Atlantic Ocean (from Mauritania to the Bay of Biscay), the Mediterranean Sea, and the Black Sea. The habitat of this species includes a wide range of water types such as marine, brackish waters and the pelagic ocean (www.fishbase.org). Mediterranean horse mackerel constitutes one-fourth of the total marine fish catch of Turkey (TÜİK, 2012) and also provides income for the fishermen, who use simple fishing methods such as setlines, long lines, and gillnets. Additionally, it is the most common recreational fish for anglers and small-scale fishermen around the İstanbul region throughout the year. Especially in the summer season, İstanbul residents cluster around both sides of the İstanbul Strait and the entrance of the Golden Horn Estuary in order to angle. It is prohibited by Turkish fishery law to use any fishing gear or methods except angling in the Golden Horn Estuary.

The Golden Horn Estuary, İstanbul's urban waterfront area, is 8 km long in an east–west direction and 0.9 km (max.) wide. The main freshwater inputs are provided by 2 streams (Alibey and Kağıthane), but following the constructions of several dams in the watershed, freshwater inputs were significantly decreased (Müftüoğlu, 2002). The estuary has had significant socioeconomic importance for centuries with its flourishing natural living resources (Tekin, 1996). The entire estuary and its tributaries are known for their important fishing grounds with rich fish biodiversity (Güvengiriş, 1977), with the notable presence of top predators such as dolphins and blue fish from the ancient times (Tekin, 1996) until the 1950s (Güvengiriş, 1977).

The ecological guild of many marine fishes such as the species of genus *Trachurus* is known to be composed of marine stragglers or adventitious (Elliott et al., 2007; Franco et al., 2008). Nevertheless, we investigated the distributional pattern of the most important recreational fish species, *T. mediterraneus*, in a highly urbanized and altered estuary. To this end, seasonal changes in its distribution along the estuary were examined according to life stages. These results, then, were analyzed in the context of the hydrographical conditions in the estuary, and the relationships between the species distribution and estuarine physical conditions are discussed.

2. Materials and methods

2.1. Samplings

Fish samples were collected monthly between March 2009 and February 2010 from the anglers of the Galata and

* Correspondence: ndemirel@istanbul.edu.tr

Unkapanı bridges, both located on the lower estuary. More anglers preferred the Galata Bridge. In order to obtain a highly representative sampling, samples were collected randomly from different anglers on the 2 bridges. Anglers usually preferred to use sharpened and barbed hooks. Furthermore, gill nets were used to compare sampling bias caused by different angling methods. Gill nets were set vertically from a small fishing boat in 2 locations (middle estuary and between the 2 bridges) (Figure 1).

A total of 423 samples were collected during the study and 349 of them were obtained from the Galata Bridge (GH1 station). Unlike the fact that *T. mediterraneus* was the main species caught from the Galata Bridge, it was rarely observed from the Unkapanı Bridge (GH2 station). Thus, only a few *T. mediterraneus* specimens (<5 individuals) were collected monthly from anglers at the GH2 station. Additionally, only 11 specimens were caught via gill net in the lower estuary (between stations GH1 and GH2) and none were caught in the middle estuary (GH3 station). Finally, 92% of fish samples were collected from the Galata Bridge (GH1 station) via angling and all fish data of this study are based on those samples.

Ichthyoplankton samples were also collected monthly by vertical and horizontal tows of a 500-µm mesh Nansen net. The speed of each horizontal tow ranged between 3 and 5 knots with duration of 3–7 min along both bridges. Vertical hauls were carried out from 30 m of depth at the GH1 and GH2 stations and from 15 m at the GH3 station (Figure 1).

Several environmental parameters were also measured from April 2009 to January 2010. Seawater samples were collected with 5-L Niskin bottles from the surface waters (0.5 m depth) at the 3 stations mentioned above. Water salinity and temperature profiles were recorded by a CTD system while turbidity was measured by Secchi disk depth. It was not possible to sample in March 2009 or February 2010 due to technical problems with the research vessel.

A total of 60 hauls were performed for ichthyoplankton samplings both horizontally and vertically. No larvae of *T. mediterraneus* were found in the estuary. Many eggs were found that corresponded to a proper range of diameters for eggs and oil globules according to identification keys by Demir (1958) for the Sea of Marmara and Dekhnik (1971) for the Black Sea. However, no embryonic development was observed in the sampled fish eggs while 90% of proper eggs were already dead. Early-stage dead eggs were distributed from the lower entrance to the inner part of the Golden Horn.

For chlorophyll *a* analyses, the acetone extraction method was used (Parsons et al., 1984). Dissolved oxygen was quantified by the Winkler method, which uses reagents that form an acid compound, fixing the dissolved oxygen in the bottled water sample and then determining the titration of oxygen concentration (APHA, 1999).

2.2. Data analyses

Total length (TL) of each fish specimen was measured to the nearest centimeter and total weight (TW) was measured in grams. Fish sex was determined by macroscopic inspection

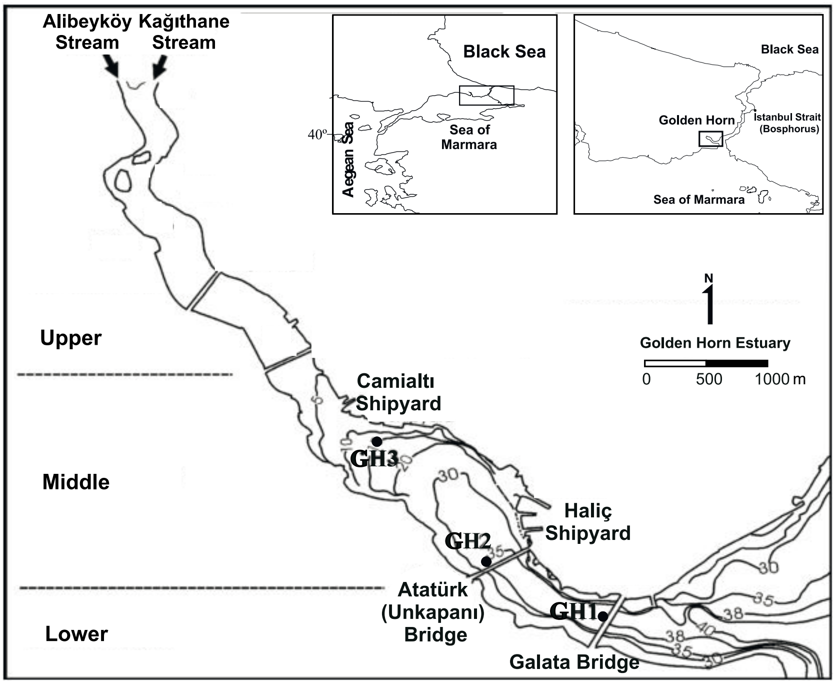

Figure 1. Map of Golden Horn Estuary and sampling locations.

of gonads. Gonads of all specimens were dissected and weighed to the nearest 0.001 g in order to calculate the gonadosomatic index (GSI).

Fish eggs and larvae were sorted from the ichthyoplankton samples. Eggs and larvae of *T. mediterraneus* were identified according to Demir (1958) and Dekhnik (1973).

Length–frequency distributions of fishes were plotted in 0.5-cm intervals. Each captured fish was classified into 1 of 2 life-stage groups by size and maturity class, immature adult (≤12.5 cm) or adult (>12.5 cm), considering the size-at-sexual-maturity (L_{50}) data for the Sea of Marmara (Demirel and Yüksek, 2013a). Length–weight relationships (LWRs) were estimated by regression analyses. The equation $W = aL^b$ was used for the relationship between TL (L) and TW (W). A logarithmic equivalent as linear relation $\log W = \log a + b \log L$ was assessed to estimate coefficients *a* and *b* (Ricker, 1975). The condition factor (CF) was calculated with the equation $CF = W / L^3$, which was then changed to the parameter *b* of LWRs instead of 3 (Froese, 2006). Differences of the sex ratio in fish samples were analyzed by chi-square test. GSI was assessed as a percentage of the ratio of gonad weight to the gonad-free weight of individuals with the formula $\%GSI = [GW / (W - GW)] \times 100$, where GW is the gonad weight and W is the total body weight (Nikolsky, 1969).

Regional and temporal changes in environmental parameters were tested by one-way ANOVA for the differences with factors "station" and "month". Pearson correlation was used to analyze the relationships between the measured environmental parameters and the life stages of *T. mediterraneus*. Logarithmic transformation $\log_e(x + 1)$ was performed to increase the normality of the data because each parameter had different units and decimal levels (Zar, 1984). All statistical analyses were performed with STATISTICA software.

3. Results

Environmental parameters were documented at 3 stations from April 2009 to January 2010. No environmental samplings could be performed in March 2009 or February 2010 due to some technical problems of the research vessel. Variability of environmental parameters was highly significant ($P < 0.01$) among the months whereas spatial patterns were uniform with respect to temperature, salinity, and dissolved oxygen values ($P > 0.05$) (Table 1). Surface temperature ranged between 8 and 23.8 °C (Figure 2A) and no significant differences were found between the lower and the middle estuary. Surface salinity ranged from 10.4 to 19.5 and a sharp decline was detected at the 2 inner stations (GH2 and GH3) in the winter season (Figure 2B), while values were more stable at the outermost station (GH1). Nevertheless, salinity values were not significantly different between the lower and the middle estuary ($P > 0.05$). Dissolved oxygen values ranged from 2.1 to 14.0 mg L^{-1} and the lowest values were detected in December (Figure 2C). Dissolved oxygen variation was insignificant ($P > 0.05$) among the stations, as well (Table 1). Chlorophyll *a* values ranged between 1.2 and 21.0 mg L^{-1}. Values peaked 2 times in the sampling period, once in April at GH1 and GH2 and once in August at GH3 (Figure 2D). Secchi disk depths ranged between 2 and 8 m and decreased gradually through the inner parts of the Golden Horn (Figure 2E).

Fish size ranged between 7.5 and 20.1 cm in TL and 3.4 and 86.2 g in TW. Monthly changes of fish size showed clear differences in the summer season (Figure 3). Adult fish (>12.5 cm) preferred not to be in the estuary, while only immature adults were found with a TL size range of 7.5–12.5 cm from May to August 2009. In August, species size range increased to between 11.7 and 14.0 cm. With regard to life-stage classification, immature adults were found with young adults (Figure 3). Adult fish were first collected in September again and the modal group of fish

Table 1. ANOVA results of environmental parameters and chlorophyll *a* for sampling time and locations.

Parameters	Factors			
	Stations		Months	
	$F_{2,29}$	P	$F_{9,29}$	P
Temperature (°C)	1.94	>0.05	60.88	0.000
Salinity	2.48	>0.05	4.56	0.003
Chlorophyll *a* (mg L^{-1})	10.40	0.001	5.92	0.003
Dissolved oxygen (mg L^{-1})	0.71	>0.05	10.60	0.000
Secchi disk (m)	17.55	0.000	5.20	0.001

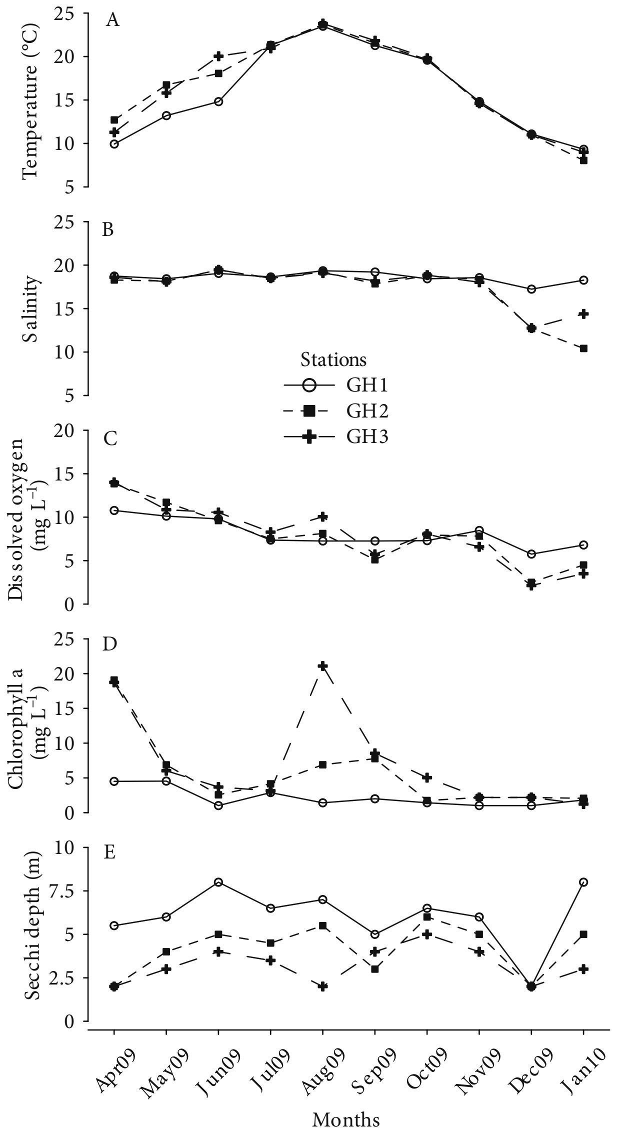

Figure 2. Monthly changes in A) water temperature, B) salinity, C) dissolved oxygen, D) chlorophyll *a* in surface waters, and E) Secchi disk depths as turbidity parameters in sampling stations.

size was 14.5 cm. Thereafter, immature adults decreased in number and in some months none were collected.

The relations between size-related fish groups and environmental parameters were also evaluated. Surface temperature, salinity, and dissolved oxygen values did not display significant correlations throughout the study period (Table 2). Chlorophyll *a* values, on the other hand, displayed weak but significant negative correlations with monthly frequencies of mature adults (r = –0.42, P < 0.01). Additionally, chlorophyll *a* and Secchi disk values displayed significant negative correlations with the monthly frequencies of immature adults (r = –0.30, P < 0.01 and r = –0.74, P < 0.01, respectively) (Table 2).

Sex ratios were evaluated for 10 months. There were no evaluations in June and July 2009 because of the low number of adult samples (Table 3). Differences in sex ratios were found to be significant according to chi-square tests on a monthly basis (χ^2 = 21, df = 9, P < 0.05). Sex ratios showed unsteady monthly distributions in the sampling period.

Seasonal differences of parameter *b* were significant and values were low between late spring and early autumn. CF values were higher in this period compared to the rest of the seasons. Mean GSI values were found to have less than 1% variation in the yearly cycle (Table 3). Furthermore, our observations of macroscopic aspects of gonads indicated adult individuals sampled in September and October 2009 were in resting stages while the remainders of the individuals were in inactive stages. Thus, no active spawners were observed in the estuary, but individuals with resting-stage gonads were evidence of spawning activity.

4. Discussion

4.1. Seasonal distribution

The Golden Horn is an altered estuary and the seasonal distribution of the most important recreational fish species, *T. mediterraneus*, was studied in this environment. Although its occurrence was observed throughout the whole year, seasonal changes in fish size and regional preferences were significant. Adult fish disappeared in summer and appeared again in late August. Macroscopic aspects of gonads in August and September 2009 were indicative of a resting stage, where fish had already released oocytes and sperms. Stability of low GSI values during the whole year including the spawning period also supported our observations. Previous studies indicated that *T. mediterraneus* spawns from May to September both in the Sea of Marmara (Demirel and Yüksek, 2013b) and in the Black Sea (Genç et al., 1998, Yankova, 2011). Furthermore, it has been reported that this species preferred not to spawn in the estuary and relocated to other regions in the Sea of Marmara (Demirel and Dalkara-Murat, 2012) as well as in the Black Sea through the İstanbul Strait (Yankova, 2013).

In our study, no adult fish with developmental gonad stages were caught, but fish were collected with resting stage gonads. Higher CF values in the summer period showed that immature fish were in a better condition than adult fish around the entrance of estuary. Moreover, CF values still remained higher together with the presence of young adults (12.5–14 cm) in August and September 2009. Perhaps not surprisingly, occurrences of immature adults in the summer season were probably related to the feeding and protection from predators. Our personal communications with regular anglers on the Galata Bridge

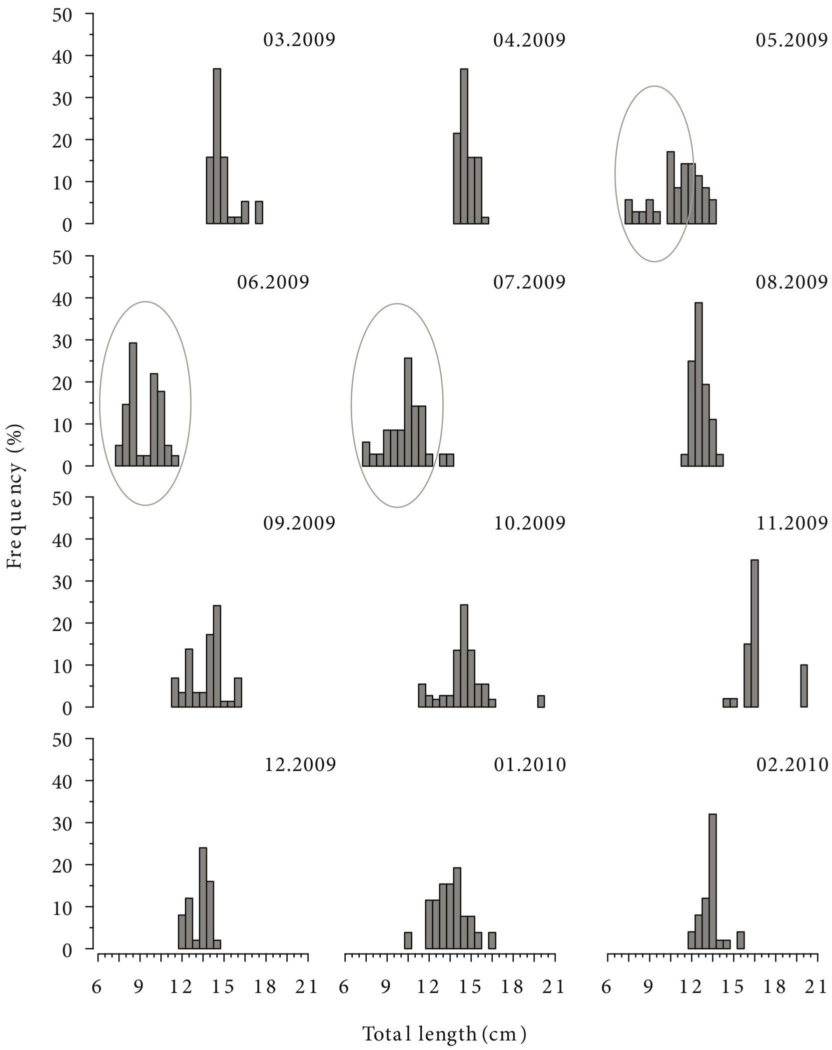

Figure 3. Length–frequency distributions of Mediterranean horse mackerel samples. Gray circles indicate occurrence of immature adults.

Table 2. Pearson correlation between fish size groups and environmental parameters with chlorophyll *a* at P < 0.01 significance level (values in square brackets indicate number of cases).

Size group	Temperature (°C)	Salinity	Chlorophyll *a* (mg L^{-1})	Dissolved oxygen (mg L^{-1})	Secchi disk (m)
Immature adults (<12.5 cm TL)	ns*	ns	–0.30 [10]	ns	–0.74 [10]
Mature adults (>12.5 cm TL)	ns	ns	–0.42 [10]	ns	ns

*: not significant.

emphasized that young individuals of Mediterranean horse mackerel were caught in the summer season and no adult fish were found until mid-August. Due to the popularity and importance of this fish, anglers pay attention to seasonal changes in size.

Besides the seasonal differences, our results showed that the distributions of *T. mediterraneus* individuals were confined to the lower entrance of the estuary around the Galata Bridge. Different fishing methods, such as gill net, were used to avoid the sampling bias of angling, which is

Table 3. Some biological characteristics of Mediterranean horse mackerel samples in the Golden Horn Estuary.

Sampling date	N_{tot}	♀ (>12.5 cm)	♂ (>12.5 cm)	♀/♂	Immature adults (≤12.5 cm)	Length–weight relationships b	SE	R^2	Condition factor, %	Mean GSI, %
Mar 09	19	14	5	0.36	0	3.44	0.41	0.81	0.25	0.89
Apr 09	19	13	6	0.46	0	3.08	0.56	0.64	0.64	1.02
May 09	36	6	7	1.17	23	3.02	0.11	0.96	0.77	0.64
Jun 09	41	1	0	-	40	2.74	0.16	0.88	1.99	0.62
Jul 09	35	2	2	-	31	3.05	0.12	0.94	0.72	0.51
Aug 09	36	20	13	0.65	3	2.92	0.20	0.61	1.05	0.80
Sep 09	29	18	9	0.50	2	2.76	0.18	0.90	1.57	0.96
Oct 09	39	24	11	0.46	4	3.30	0.16	0.92	0.39	0.84
Nov 09	20	14	6	0.43	0	3.38	0.17	0.95	0.33	0.57
Dec 09	25	8	13	1.63	4	3.54	0.40	0.77	0.18	0.48
Jan 10	26	10	15	1.50	1	3.40	0.19	0.93	0.26	0.65
Feb 10	25	10	14	1.40	1	3.43	0.29	0.86	0.24	0.72

a highly selective method. However, very few individuals were sampled both from the gill net experiment and from anglers from the inner side of the Galata Bridge to the Unkapanı Bridge and middle estuary. It was concluded that this species prefers not to enter or stay in the estuary. An exception to this finding was only in May 2009, when 30 individuals were sampled from the Unkapanı Bridge. This could be due to the physical conditions at that time. The Golden Horn is easily affected by southwestern winds, a characteristic wind regime for the İstanbul region that may change the water circulation in the İstanbul Strait (Okuş et al., 2010). Strong southwestern winds (approximately 20 km/h) occurred twice in May 2009 (TÜMAS, 2009). Young adults can be carried by strong wind conditions from the Galata Bridge to the Unkapanı Bridge. Another explanation may be prevention behavior of *T. mediterraneus* in response to predators such as bluefish or albacore, which migrate twice a year (spring and autumn) from the Sea of Marmara to the Black Sea and vice versa (Demir, 1958).

4.2. Habitat complexity

Many marine fishes are classified as visitors when they randomly appear in estuaries (McLusky and Elliott, 2004). Mediterranean horse mackerel was also evaluated as an irregular visitor to the Golden Horn Estuary; thus, no spawning or nursery dependency should be ascribed to this species.

On the other hand, hydrographical conditions of the Golden Horn do not reflect general estuaries characteristics such as the typical salinity or temperature gradient (McLusky and Elliott, 2004). According to our results, the middle estuary and lower estuary showed similar patterns with respect to temperature, salinity, and dissolved oxygen. Müftüoğlu (2002) recorded that physical oceanography of the Golden Horn from the lower to middle estuary has similar properties as the Sea of Marmara, which has an upper layer characterized by Black Sea waters and bottom waters (around 25 m depth) with higher salinity. Additionally, water temperature and salinity profiles showed that the lower estuary (GH1 and GH2) reflected the same stratification patterns as the Sea of Marmara (Müftüoğlu, 2002). It was reported that construction of a dam in the 1960s on the main freshwater inputs (Alibey Stream) of the estuarine was the primary reason for its physical changes in the following years (Müftüoğlu, 2002). However, the Golden Horn also shows dynamic properties from the middle to upper parts, with rapid changes in dissolved oxygen and Secchi disk depth as well as phytoplankton blooms and significantly higher chlorophyll *a* values. These dynamic features are often considered as estuarine characteristics (McLusky and Elliott, 2004; Bianchi, 2007).

In light of these considerations, the preference of *T. mediterraneus* and Golden Horn relationships were reexamined. Decreasing of the depth to the inner parts causes the distinct variability of dissolved oxygen caused by bacteriological (Aslan-Yılmaz et al., 2004) and phytoplanktonic (Taş et al., 2009) activity. Another gradient across the length of the Golden Horn is that of chlorophyll *a* and visibility (Secchi disk depths). Many marine fish larvae were defined as visual feeders and feeding activity occurred in daylight (Lasker, 1984). Distinct variability of visibility should lead to adult fish avoiding to spawn in the region to prevent unsuccessful feeding of their larvae. Additionally, Taş and Okuş (2011) reported that eutrophication in the Golden Horn provided the ground for phytoplankton blooms, and development of toxic taxa occurred frequently in April–September and caused water quality issues such as discoloration, odor, hyperoxia, anoxia, and pH change depending on the responsible microalgae.

In conclusion, the Mediterranean horse mackerel is proposed to be an irregular visitor to the estuary and was only found at the entrance. The Golden Horn had been an almost obsolete estuary from the 1950s to the 1990s. After the success of rehabilitation studies at the end of the 1990s, marine transportation throughout the estuary and settlement around the upper estuary has intensified. As a result of these disturbances, it is obvious that the ecosystem of the Golden Horn has changed considerably several times in the past years. Unfortunately, our knowledge on fish communities is too poor to evaluate long-term changes in fish fauna. Overall, it can be reasonably hypothesized that the Golden Horn offers insufficient integrity as a habitat for both larvae and adult individuals of *T. mediterraneus*. Environmental parameters such as surface temperature, salinity, and dissolved oxygen values did not display significant correlations with the distribution of this species throughout the study period. However, significant negative effects of high phytoplankton activity and low visibility affected the distribution pattern of this species, which preferred to be only at the entrance of the Golden Horn.

Acknowledgments

The authors would like to thank Elif Murat-Dalkara for her help in laboratory analysis, Dr İ Noyan Yılmaz and Dr Denizhan Vardar for their collaboration in sample collection, Dr Seyfettin Taş for chlorophyll *a* data, Dr Nuray Balkıs for dissolved oxygen data, and Dr Hüsne Altıok for CTD data.

References

APHA (1999). Standard Methods for the Examination of Water and Waste Water. Washington, DC, USA: American Public Health Association.

Aslan-Yılmaz A, Okuş E, Övez S (2004). Bacteriological indicators of anthropogenic impact prior to and during the recovery of water quality in an extremely polluted estuary, Golden Horn, Turkey. Mar Pollut Bull 49: 951–958.

Bianchi TS (2007). Biogeochemistry of Estuaries. New York, NY, USA: Oxford University Press.

Dekhnik TV (1973). Iktioplankton chernogo moria. Kiev, Ukraine: Haukova Dumka (in Russian).

Demir M (1958). On the reproduction of Mediterranean horse mackerel (*Trachurus mediterraneus* LUTKEN, 1880), I–In Black Sea. Hidrobiologi Mecmuası 4: 93–101 (in Turkish with English abstract).

Demir N (1958). On the morphological characteristics of eggs and larvae of the *Trachurus mediterraneaus* LTKN. (Mediterranean horse mackerel) from the Black Sea. Hidrobiologi Mecmuası 4: 85–92 (in Turkish with English abstract).

Demirel N, Murat-Dalkara E (2012). Weight-length relationship of 23 fish species in the Sea of Marmara. Turk J Zool 36: 785–791.

Demirel N, Yüksek A (2013a). Reproductive biology of *Trachurus mediterraneus*: a detailed study for the Marmara–Black Sea stock. J Mar Biol Assoc UK 93: 357–364.

Demirel N, Yüksek A (2013b). Spawning frequency of *Trachurus mediterraneus* (Carangidae) in the Sea of Marmara. Turk J Fish Aquat Sci 13: 441–446.

Elliott M, Whitfield AK, Potter CI, Blabber SJ, Cyrus DP, Nordlie FG, Harrison TD (2007). The guild approach to categorizing estuarine fish assemblages: a global review. Fish Fish 8: 214–268.

Franco A, Elliott M, Franzoi P, Torricelli P (2008). Life strategies of fishes in European estuaries: the functional guild approach. Mar Ecol Prog Ser 354: 219–228.

Froese R (2006). Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. J Appl Ichthyol 22: 241–253.

Genç Y, Zengin M, Başar S, Tabak İ, Ceylan B, Çiftçi Y, Üstündağ C, Akabulut B, Şahin T (1998). Research Project on Economic Marine Resources. Ankara, Turkey: Turkish National Center of Agricultural Research and Innovation (in Turkish with English abstract).

Güvengiriş AZ (1977). Marine pollution and the attitude of authorities. Balık ve Balıkçılık Dergisi 5: 4–7.

Lasker R (1984). Marine Fish Larvae. Seattle, WA, USA: University of Washington Press.

McLusky SD, Elliott M (2004). The Estuarine Ecosystems. New York, NY, USA: Oxford University Press.

Müftüoğlu E (2002). Physical Oceanography of the Golden Horn. MSc, İstanbul University, İstanbul, Turkey (in Turkish with English abstract).

Okuş E, Altıok H, Aslan-Yılmaz A, Övez S, Taş S, Kıratlı N, Yüksek A, Yılmaz N, Müftüoğlu AE, Sur HI (2010). Extreme conditions in the Strait of İstanbul (Bosphorus). Proceedings of the 39th CIESM Conference; 10–14 May 2010; Venice, Italy, p. 149.

Nikolsky GV (1969). The Theory of Fish Population Dynamics as the Biological Background for Rational Exploitation and Management of Fishery Resources. Edinburgh, UK: Oliver and Boyd.

Parsons TR, Maita Y, Lalli CM (1984). A Manual of Chemical and Biological Methods for Seawater Analysis. Oxford, UK: Pergamon Press.

Ricker WE (1975). Computation and interpretation of biological statistics of fish populations. Bull Fish Res B Can 191: 1–382.

Taş S, Okuş E (2011). A review on the bloom dynamics of a harmful dinoflagellate *Prorocentrum minimum* in the Golden Horn Estuary. Turk J Fish Aquat Sci 11: 523–531.

Taş S, Yılmaz N İ, Okuş E (2009). Phytoplankton as an indicator of improving water quality in the Golden Horn Estuary. Estuar Coast 32: 1205–1224.

Tekin O (1996). The Pelamydes of Byzantium and the Golden Horn. Anatolian Research 14: 470–478.

TÜİK (2012). Fisheries Production Statistics for 2011. Ankara, Turkey: Turkish Statistical Institute.

TÜMAS (2009). Weather Forecast of İstanbul Region. İstanbul, Turkey: Turkish State Meteorological Service.

Yankova M (2011). General reproductive biology of horse mackerel *Trachurus mediterraneus* in the Bulgarian Black Sea Coast. In: Gupta, VK, Verma AK, editors. Animal Diversity, Natural History and Conservation. Vol. 1. New Delhi, India: Daya Publishing House, pp. 241–247.

Yankova M (2013). An overview on the biology of horse mackerel, *Trachurus mediterraneus*, off the Bulgarian Black Sea coast. In: Gupta, VK, Verma AK, editors. Animal Diversity, Natural History and Conservation. Vol. 2. New Delhi, India: Daya Publishing House, pp. 165–179.

Zar JH (1984). Biostatistical Analysis. Upper Saddle River, NJ, USA: Prentice Hall.