J. Black Sea/Mediterranean Environment
Vol.13: 215-234 (2007)

Temporal Variation of Fish Assemblages in Different Shallow-water Habitats in Erdek Bay, Marmara Sea, Turkey

Erdek Körfezi Sığ Sularında Farklı Habitatlardaki Balık Topluluklarının Değişimi (Marmara Denizi, Türkiye)

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Abstract

The aim of this study was to invertigate the nearshore fish assemblages in seagrass meadows (*Cymodocea nodosa* and *Zostera marina*) and sandy habitat in Erdek Bay (Marmara Sea, Turkey).

A total of 24,488 individuals (61 species; 28 families) was recorded. In seagrass meadows, we observed 17,212 (51 species; 28 families) specimens and in sandy habitat 7,276 specimens (45 species; 23 families). *Atherina boyeri* was the most dominant species. Juveniles or sub-adults represented 48 % of all individuals.

The results showed that nearshore shallow waters (0-2 m) of Erdek Bay were used as a nursery area by juveniles. In this place, the abundance of economically interesting species has declined. Erdek Bay should be evaluated for protection, and the current fishery regulation should be revised to sustain the fishery.

Key words: Fish, seagrass meadows, sandy areas, seasonal variation, nursery areas

Introduction

In many parts of the world, the fish assemblages inhabiting seagrass beds are more diverse and abundant than those inhabiting bare substrata (e.g. Bell *et al.*, 1988; Bell and Pollard, 1989; Ferrell and Bell, 1991; Ruiz *et al.*, 1993; Connolly, $1994_{a,\ b}$; Guidetti, 2000; Guidetti and Bussotti, 2000, 2002; Bell *et*

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al., 2001; Moran *et al.*, 2003). Several authors have hypothesised that the structural complexity and productivity of seagrass meadows could explain these differences, with seagrass providing shelter from predators and abundant food (Adams, 1976_a; Orth and Heck, 1980; Bell and Westoby $1986_{a,\ b}$; Bell and Pollard, 1989; Guidetti and Bussotti, 2002). Seagrass meadows mainly support small species inhabiting cryptic habitats, juvenile stages of species that inhabit other habitat as adults (including many commercially important species) and some adults of large mobile fish (Bell and Harmelin-Vivien, 1982; Blaber *et al.,* 1992; Francour, 1997; Guidetti and Bussotti, 1998). On the other hand, adults of large mobile fish, or species gaining protection through schooling or by camouflage against sediments, were most abundant on bare habitats (Bell and Pollard, 1989).

The Marmara Sea is the smallest of the Turkish seas in surface area and volume, but it ranks second in fish catch, following the Black Sea. Turkey's annual marine fishery is 600×10^3 tonnes; 81.7 % of this comes from the Black Sea and 11 % from the Marmara Sea (Anonymous, 2003), reflecting the important contribution of the Marmara Sea to the Turkish fishing economy.

The Marmara Sea is a transition zone between the Black Sea and the Mediterranean Sea. It plays an important role for the protection of the marine biodiversity due to some peculiarities such as small and enclosed bays, seagrass communities, migratory pelagic fish species (Kocataş, *et al.,* 1993). It may contain the most important nursery areas for demersal and pelagic fish species in Turkey. Several large bays of the Marmara Sea as Erdek and Gemlik bays are important for both small scale fisheries (net fishing) and off-shore fisheries (trawling).

Erdek Bay is located in the southern part of the Marmara Sea, and supports traditional small-scale fishing activities. However, due to various reasons such as land-based pollution, eutrophication, ship-originated pollution, exotic invaders, and overfishing, fish resources of Erdek bay have been depleted for a decade (Zaitsev and Öztürk, 2001).

Most of the publications related with the Marmara Sea fish focus on taxonomy and species biology: Eryılmaz and Meriç (2005), Eryılmaz (2001), Eryılmaz (2000), Ünsal (1984, 1988), Oral and Ünsal (1992), Ünsal and Oral (1993).

The aim of this study is to provide temporal analysis on composition, abundance, demographic structure of fish assemblages in the Erdek Bay associated with seagrass meadows (*Zostera marina* and *Cymodacea nodosa*) and sandy habitats.

Material and Method

Study Area

The Marmara Sea is connected to the Black Sea via the Bosphorus Strait and to the Mediterranean through the Dardanelles Strait. While the surface waters of Marmara are affected by the Black Sea, its deeper waters are influenced by the Mediterranean Sea. The two water layers do not mix, and a stable density gradient prevents vertical mixing and hinders the transport of oxygen to deeper layers (Kocataş *et al.*, 1993).

Erdek Bay is located in the southern Marmara Sea (27°20'- 27°52' E and 40°18'- 40°28' N) (Fig. 1), the length of the coastline is 130 km, and maximum depth is 55 m. The Gönen Stream is the only freshwater inflow to the bay, and as in the Marmara Sea, the water column is stratified.

Sampling Method

Two habitats, seagrass meadows and bare sand, were sampled monthly between March 2000 and February 2001 in Erdek Bay (Fig. 1). Four replicates were collected during each month from each habitat using a 35 m long beach seine (each of them covering a surface of ~ 0.1 ha). Net depth at the beginning of wings was 40 cm, and 250 cm at the central part together with the sac. The mesh size was 6 mm in the wings and 4 mm at the central sac. The net was hauled along the shore (50 m), and from offshore to the coast (50 m): the two hauls were pooled and represent a single sample. We pooled months according to the season: Spring (March to May), Summer (June to August), Autumn (September to November) and Winter (December to February). The data therefore comprised 12 replicates for each habitat in each season.

Fish species were identified according to Soljan (1948), Whitehead *et al.* (1986), and Padoa *et al.* (1931-1956) and the number of individuals of each species was determined. The Gobiidae were not identified to species level, but were pooled as Gobiidae. All the individuals were counted by species and sized to the nearest millimetre.

Abiotic variables such as temperature (mercury thermometer), dissolved oxygen (DO; with Winkler's method), and salinity (Knudsen's method) were measured for each station and month.

Data Analysis

Comparisons of differences in species richness and total abundance between habitats and among seasons were carried out using two-way ANOVA. Homogeneity of variance were tested using Cochran's test, and data were log-transformed [log(x+1)] to meet homogeneous variances but ANOVA was on transformed data was still used, because it is fairly robust to heterogeneous variances when sample sizes are equal (Zar, 1999). When the null-hypothesis of equality between means was rejected, a Tukey's test was used to seek difference among samples.

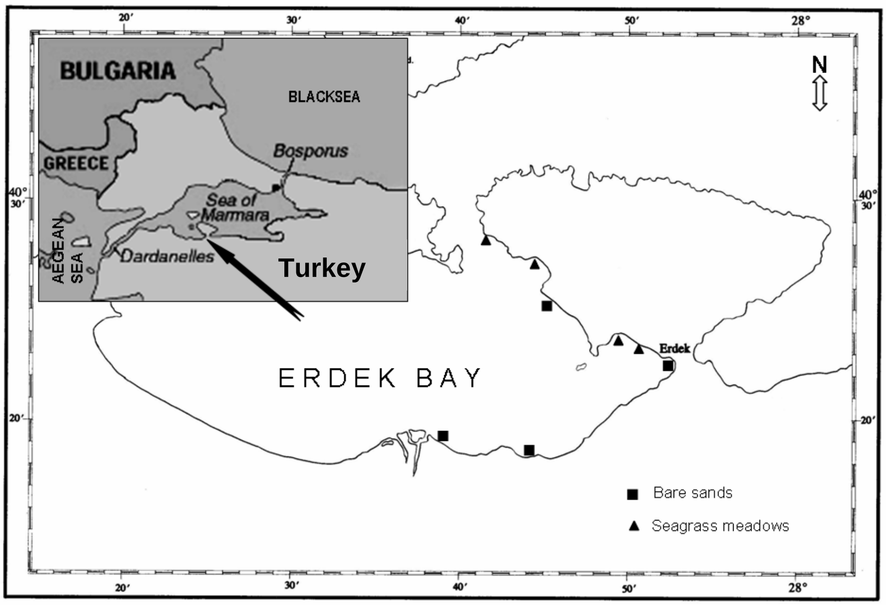

Figure 1. Location of the study area.

Correlation was used to assess the relationship between environmental variables and biotic factors (species richness, total abundance and abundance of key species). As the oxygen content is negatively correlated with temperature, we performed correlation analysis only with temperature and salinity.

Cluster analysis was used to highlight differences in species composition between habitats and among seasons, using the Euclidean distances and Ward's method.

Statistical tests were carried out by SPSS 10 and Statistica 6 programs.

Results

Environmental variables

Sea water temperature ranged from 11.16 °C in winter to 24.37 °C in summer. Salinity values ranged from 20.64 psu in autumn to 26.92 psu in spring, and oxygen concentration level fluctuated between 7.01 mg/L and 7.63 mg/L (Fig. 2).

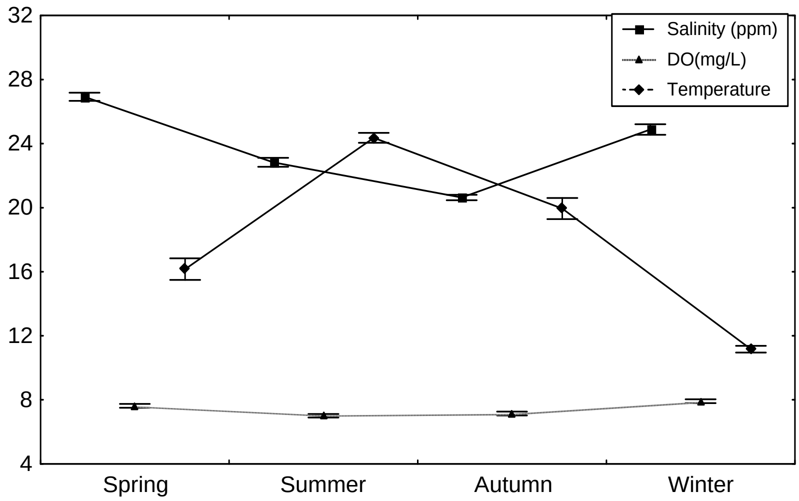

Figure 2. Seasonal variations of the water temperature (°C), salinity (psu) and dissolved oxygen (mg/L) (means ± SE, n = 12).

General description of fish assemblages

Sixty one species belonging to 27 families (except for Gobiidae) were collected in the Erdek Bay, with 51 species collected from seagrass meadows and 45 species from sandy habitat (Table 1). Mean species richness was higher in seagrass meadow than in sandy habitats (one way ANOVA; $p<0.05$).

With regard to necto-benthic fish species (46 species), *Nerophis maculatus, Microchirus variegatus, Serranus hepatus, Psetta maxima, Scophthalmus rhombus* and *Uranoscopus scaber* were collected only from sandy habitat; *Arnoglossus laterna*, *Callionymus fasciatus, C. maculatus, Diplecogaster bimaculata, Gasterosteus aculeatus*, *Gaidropsarus mediterraneus, Labrus viridis, Mullus barbatus, Monochirus hispidus, Parablennius incognitus, Sciaena umbra, Serranus cabrilla* and *S. scriba* were collected only from seagrass meadows. For the openwater (pelagic) fish (15 species), *Engraulis encrasicolus, Mugil cephalus, Trachurus trachurus* and *Gymnammodytes cicerelus* were collected only from sand habitats, and *Chelon labrosus*, *Pomatomus saltatrix* and *Sardinella aurita* were collected only from seagrass meadows.

Table 1. Mean abundance (number of individuals / 0.1 ha, ±SD, n=12) of each species in the two different habitats, and number of fish species sampled in each of the two habitats in Erdek Bay, and results of ANOVA testing for differences among habitats (significance evaluated at α=0.05). C: commercial fish species; SD: standard deviation; ns: p>0.05; *: p<0.05; **: p<0.01; ***: p<0.001

Family		Species	p value	Seagrass Meadows	SD	Sand	SD
Open water fish species							
Ammodytidae		*Gymnammodytes cicerelus*	ns	-	-	24.25	12.13
Atherinidae	C	*Atherina boyeri*	ns	656.92	101.19	316.58	61.41
	C	*Atherina hepsetus*	ns	82.58	28.25	34.83	10.10
Belonidae	C	*Belone belone*	ns	0.75	0.38	0.83	0.36
Carangidae	C	*Trachurus trachurus*	ns	-	-	0.17	0.05
Clupeidae	C	*Sardinella aurita*	ns	3.00	1.50	-	-
	C	*Sardina pilchardus*	ns	1.25	0.63	0.25	0.13
	C	*Sprattus sprattus*	ns	0.83	0.42	5.92	2.90
Engraulidae	C	*Engraulis encrasicolus*	ns	-	-	27.67	13.83
Mugilidae	C	*Liza aurata*	ns	70.92	14.04	50.17	10.76
	C	*Liza saliens*	ns	2.33	0.47	2.67	1.11
	C	*Oedalechilus labeo*	ns	2.25	0.87	1.17	0.32
		Chelon labrosus	ns	0.08	0.04	-	-
	C	*Mugil cephalus*	ns	-	-	0.08	0.04
Pomatomidae	C	*Pomatomus saltatrix*	ns	0.08	0.04	-	-
Necto-benthic fish species							
Blenniidae		*Parablennius tentacularis*	**	7.92	1.85	0.33	0.17
		Parablennius sanguinolentus	ns	0.08	0.04	1.92	0.96
		Salaria pavo	ns	0.08	0.04	0.17	0.08
		Parablennius incognitus	ns	0.25	0.13	-	-
Bothidae		*Arnoglassus kessleri*	ns	1.00	0.07	0.50	0.11
		Arnoglossus laterna	*	0.33	0.07	-	-
Callionymidae		*Callionymus risso*	ns	0.42	0.10	0.50	0.16
		Callionymus fasciatus	ns	0.25	0.04	-	-
		Callionymus pusillus	ns	0.08	0.04	0.08	0.04
		Callionymus maculatus	ns	0.08	0.04	-	-
Gasterosteidae		*Gasterosteus aculeatus*	ns	0.08	0.04	-	-

Cont. Table 1							
Family		**Species**	**p value**	**Seagrass Meadows**	**SD**	**Sand**	**SD**
Gadidae	C	*Gaidropsarus mediterraneus*	*	0.42	0.13	-	-
Gobiidae			ns	33.67	2.01	37.92	3.73
Gobiosocidae		*Diplecogaster bimaculata*	ns	0.25	0.08	-	-
Labridae		*Symphodus ocellatus*	***	342.25	68.17	32.67	6.35
		Symphodus cinereus	***	112.25	30.32	17.17	6.71
		Symphodus tinca	**	3.08	0.86	0.08	0.04
		Symphodus roissali	*	1.83	0.28	0.25	0.13
		Labrus viridis	ns	0.08	0.04	-	-
Mullidae	C	*Mullus surmuletus*	ns	1.92	0.96	1.42	0.71
	C	*Mullus barbatus*	*	0.50	0.16	-	-
Ophidiidae		*Ophidion rochei*	ns	0.17	0.08	0.08	0.04
Pleuronectidae	C	*Platichthys flesus*	ns	0.17	0.05	0.25	0.08
Sciaenidae	C	*Sciaena umbra*	ns	0.50	0.25	-	-
Serranidae		*Serranus cabrilla*	ns	0.08	0.04	-	-
		Serranus scriba	ns	0.08	0.04	-	-
		Serranus hepatus	ns	-	-	0.25	0.13
Scopthalmidae	C	*Scophthalmus rhombus*	ns	-	-	0.25	0.13
	C	*Psetta maxima*	ns	-	-	0.08	0.04
Scorpaenidae		*Scorpaena porcus*	*	2.75	0.76	0.17	0.05
Sparidae	C	*Diplodus puntazzo*	ns	1.92	0.38	0.75	0.32
	C	*Lithognathus mormyrus*	ns	0.92	0.16	1.00	0.15
		Diplodus annularis	*	0.75	0.14	0.08	0.04
	C	*Diplodus sargus*	ns	0.42	0.13	0.08	0.04
Soleidae	C	*Pegusa lascaris*	ns	0.25	0.08	0.25	0.08
	C	*Solea solea*	ns	0.08	0.04	0.08	0.04
		Monochirus hispidus	ns	0.25	0.08	-	-
		Buglossidium luteum	ns	0.17	0.05	0.08	0.04
		Microchirus variegatus	ns	-	-	0.17	0.08
Syngnathidae		*Syngnathus typhle*	***	32.67	4.81	17.75	3.40
		Syngnathus abaster	**	30.67	5.95	20.17	5.50
		Nerophis ophidion	***	32.08	3.26	5.00	1.22
		Syngnathus acus	ns	1.17	0.29	0.42	0.10
		Hippocampus guttulatus	ns	0.08	0.04	0.08	0.04
		Nerophis maculatus	ns	-	-	0.08	0.04
Triglidae	C	*Chelidonichthys lucernus*	ns	1.25	0.34	1.42	0.31
Uranoscopidae		*Uranoscopus scaber*	ns	-	-	0.25	0.13
Number of unique species				**16**		**10**	
Total of species				**51**		**45**	

Table 2. Results of two-ways ANOVA testing for differences in species richness between habitats and among seasons. Tukey's test at 0.05. sm: seagrass meadows; s: sand; sp: spring; su: summer; au: autumn; wi: winter; dF: degree of freedom; ms: mean square.

Source	**dF**	**ms**	**F**	**p**	**Tukey**
Habitat	1	486.0	47.24	<0.001	sm>s
Seasons	3	73.23	7.12	<0.001	su>au>sp>wi
Habitat * seasons	3	4.02	0.3	0.75	
Error	88	10.29			
Total	96				

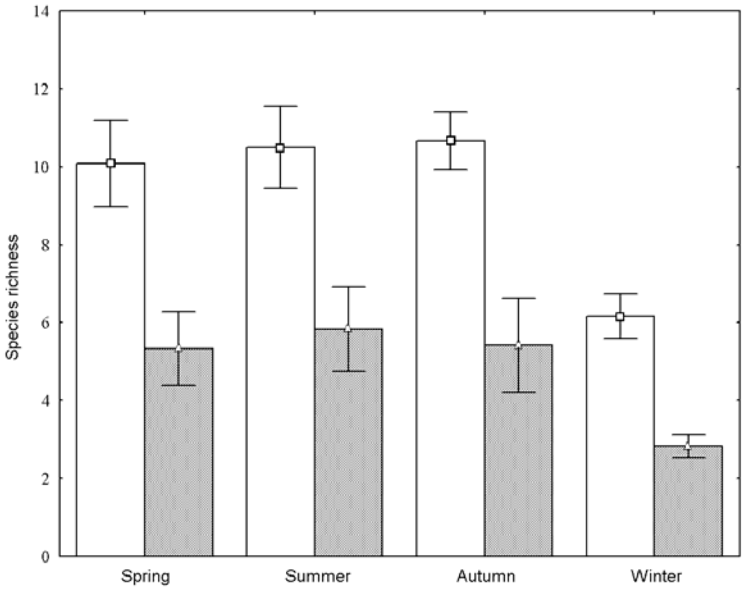

Figure 3. Seasonal variations of the mean species richness (means ± SE, n = 12) in Erdek Bay for seagrass meadows (white) and sandy habitats (grey).

Variations in mean abundance of fish assemblages

A total number of 24,488 individuals (61 species; 28 families) were collected during the study; 17,212 individuals were collected from seagrass meadows and 7,276 individuals were collected from the sandy habitat. Total fish abundance was significantly higher in the seagrass meadows than the sandy habitat in all seasons (Table 3; Fig. 4), and significantly lower in winter than the other seasons for both habitats (Table 3; Fig. 4).

The abundance of necto-benthic fish followed the same trend, being significantly higher in seagrass meadows than in sandy habitats during all seasons, and significantly lower in winter than other seasons for both habitats (Table 3; Fig. 5).

Table 3. Results of two-ways ANOVA testing for differences in total abundance between habitats and among seasons. Tukey's test at 0.05. sm: seagrass meadows; s: sand; sp: spring; su: summer; au: autumn; wi: winter; dF: degree of freedom; ms: mean square.

Source	dF	ms	F	p	Tukey
Total fish assemblage					
Habitat	1	469.38	42.71	<0.001	sm>s
Seasons	3	105.89	9.63	<0.001	au>su>sp>wi
Habitat * seasons	3	9.60	0.87	0.45	
Error	88	10.99			
Total	96				
Necto-benthic					
Habitat	1	340.69	38.36	<0.001	sm>s
Seasons	3	57.22	6.54	<0.001	au>su>sp>wi
Habitat * seasons	3	13.29	1.52	0.21	
Error	88	8.74			
Total	96				
Open-water					
Habitat	1	10.27	4.74	0.03	sm>s
Seasons	3	8.09	3.74	0.02	au>su>sp>wi
Habitat * seasons	3	0.65	0.30	0.83	
Error	88	2.16			
Total	96				
Open-water without atherinids					
Habitat	1	0.35	0.06	0.81	
Seasons	3	3.89	0.67	0.57	
Habitat * seasons	3	2.49	0.43	0.73	
Error	88	5.82			
Total	96				

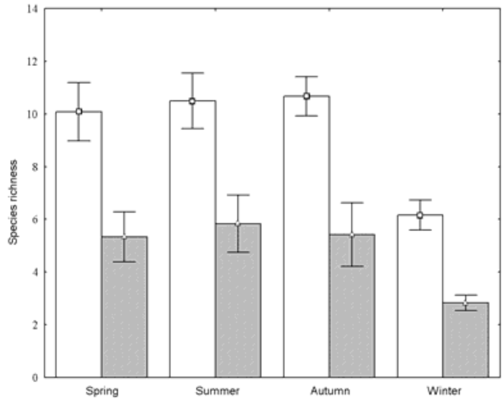

Figure 4. Mean fish abundance of whole assemblages (means ± SE, n = 12) in Erdek Bay for seagrass meadows (white) and sandy habitats (grey).

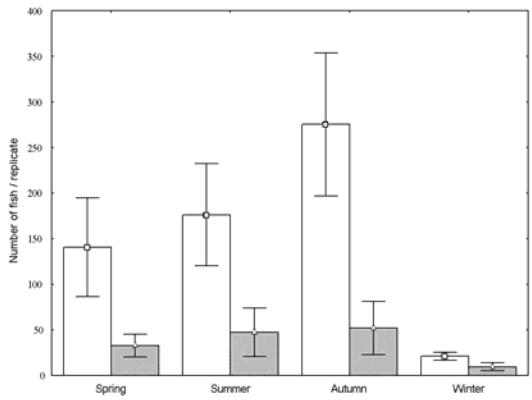

Figure 5. Mean abundance of necto-benthic fish assembladges (means ± SE, n = 12) in Erdek Bay for seagrass meadows (white) and sandy habitats (grey).

The abundance for open water fish was also higher in seagrass meadows than in sandy habitats (Table 3), but unlike necto-benthic fish, abundance in autumn was not significantly lower than in winter (Table 3). These results were due to the Atherinidae. If we removed the atherinids from analysis, there were no significant differences between habitats or among seasons (Table 3).

Mean abundances for each species are shown in Table 1. No significant differences between habitats were observed for any of the open water species, while significant differences between habitats were observed for 13 of the 46 necto-benthic species.

Seasonal variations in abundance of common species

Atherina boyeri (47.7 % of the total number of fish), *A. hepsetus* (5.8 %), *L. aurata* (5.9 %), *Symphodus ocellatus* (18.3 %), *S. cinereus* (6.3 %), *Syngnathus abaster* (2.5 %), *S. typhle* (2.5 %) and *Nerophis ophidion* (1.8 %) were the most abundant species, and were collected from both habitats. All these important species showed significant differences in abundance among seasons ($p<0.05$), except for *S. typhle* and *N. ophidion* (both $p= 0.14$). The mean abundance of *A. boyeri*, *A. hepsetus* and S. *abaster* were significantly lower in winter than in all seasons ($p<0.05$). In contrast, the mean abundance of *L. aurata* were higher in the cold seasons (winter and spring) than in the warm seasons (summer and autumn, $p<0.05$). The mean abundance of two labrid species, *S. ocellatus* and *S. cinereus,* were lower in winter in seagrass meadows ($p<0.05$), but did not differ significantly among seasons on the sandy habitat ($p<0.05$).

The cluster analysis indicated that catches were clustered in two groups of samples, largely separated according to the habitat, with a single exception, the winter samples from seagrass meadows (Figure 6).

Demographic structure of the economical fish

An analysis of the demographic structure of all species highlighted that more than 49 % of individuals were juveniles or sub-adults. In both habitats, 27 fish species of economical interest were recorded, and they amounted to 62.5 % of the total number of sampled fish, but only 9 % when the dominant *Atherina* spp. (species of economical interest in Turkey) are not taken into account. Except for *Diplodus puntazzo, Mullus surmuletus, Pegusa lascaris, Trachurus trachurus*, and two atherinids, all species were present only as juveniles (Table 4).

Correlation with abiotic parameters

Species richness, total abundance, abundance of all necto-benthic species, and abundance of *Atherina boyeri, Symphodus ocellatus, Syngnathus typhle* and *Liza aurata* were significantly correlated with the water temperature (all $p< 0.05$; Table 5). Abundance of *Liza aurata* showed a significant negative correlation with water temperature. Total abundance, abundance of all necto-benthic species, and abundance of *Atherina hepsetus, Symphodus ocellatus* were negatively correlated with salinity, while *A. boyeri* showed positive correlation with salinity ($p< 0.05$; Table 5).

Table 4. List of the economically most important fish species recorded in both habitats according to demographic structure. N: total number of individual; F: frequency; Size range (Total Length; cm).

		Adults		Subadults+juveniles	
Species	N	Size range	F (%)	Size range	F (%)
Atherina boyeri	11682	5.5 - 13	49.9	2.5 - 5.4	26.4
Atherina hepsetus	1409	5.9 - 14	0.26	3.3 - 4.8	8.94
Belone belone	19	-	-	3.4 - 12.0	0.12
Chelon labrosus	1	-	-	15.3	0.004
Diplodus puntazzo	32	12.4	0.007	2.8 - 7.1	0.20
Diplodus sargus	6	-	-	2.6 - 5.8	0.03
Engraulis encrasicolus	332	-	-	3.5 - 4.9	2.17
Gaidropsarus mediterraneus	5	-	-	5.0 - 6.9	0.03
Lithognathus mormyrus	23	-	-	2.2 - 12.6	0.15
Liza aurata	1453	-	-	2.4 - 15	8.39
Liza saliens	60	-	-	3.1 - 15.4	0.39
Mullus barbatus	6	-	-	4.6 – 9.0	0.03
Mullus surmuletus	40	10 - 1.3	0.02	4.7 - 9.4	0.24
Mugil cephalus	1	-	-	6.4	0.007
Oedalechilus labeo	41	-	-	2.5 - 4.7	0.26
Platichthys flesus	5	-	-	3.8 - 14.7	0.03
Psetta maxima	1	-	-	6.4	0.007
Pomatomus saltatrix	1	-	-	3	0.007
Sardinella aurita	36	-	-	4.0 - 4.5	0.23
Sardina pilchardus	18	-	-	4.7 - 5.5	0.11
Sprattus sprattus	81	-	-	3.8 - 7.1	0.52
Sciaena umbra	6	-	-	7.5 - 12	0.03
Scophthalmus rhombus	3	-	-	5.6 - 11.6	0.02
Pegusa lascaris	6	13.2 - 15.8	0.013	5.4 - 7.6	0.02
Solea solea	2	-	-	3.6 - 9.1	0.01
Chelidonichthys lucernus	32	-	-	5.0 - 11.3	0.20
Trachurus trachurus	2	13.6	0.007	9.3	0.007
Total	15303		50.21		49.79

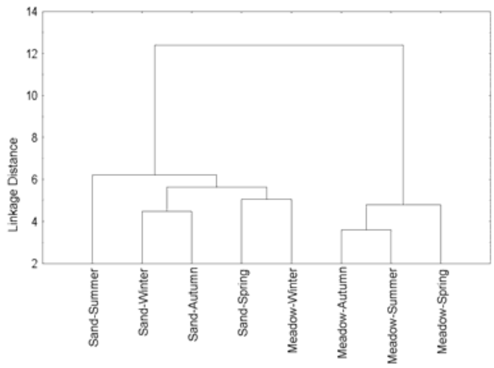

Figure 6. Cluster analysis of abundance of the common species by habitat and season, using Euclidean distance and Ward's method.

Table 5. Correlation coefficients (r) and significant level (p) between environmental variables with community parameters and abundance of the most common fish species (ns: p>0.05)

Parameters/ Species	Temperature		Salinity	
	r	**p**	**r**	**p**
Species richness	0.76	<0.01	-0.53	n.s.
Abundance of whole fish	0.82	<0.01	-0.59	<0.05
Abundance of necto-benthic species	0.77	<0.01	-0.69	<0.05
Atherina boyeri	0.68	<0.05	-0.43	n.s.
Atherina hepsetus	0.22	ns	0.64	<0.05
Symphodus ocellatus	0.72	<0.01	-0.61	<0.05
Symphodus cinereus	0.56	ns	-0.54	ns
Liza aurata	-0.68	<0.05	0.51	ns
Syngnathus typhle	0.59	<0.05	-0.43	ns
Syngnathus abaster	0.37	ns	-0.28	ns
Nerophis ophidion	0.07	ns	0.16	ns

Discussion

The record of salinity in this part of the Marmara Sea clearly showed a decrease from spring until the autumn, probably related to the inflow of the low salinity water coming from the Black Sea. This phenomenon, as mentioned by Beşiktepe *et al.* (2000), is a characteristic feature of this region. The fish assemblage in the Erdek Bay was negatively correlated with salinity, but positively correlated with water temperature (with a single exception for *Liza aurata,* which is negatively correlated to temperature). A significant correlation between salinity and abundance was noted only for *Atherina hepsetus* and *Symphodus ocellatus*, the two most common species. The water temperature is probably the most important factor that affects the distribution of species in Erdek Bay. Higher abundance and diversity of necto-benthic species during warm months is often mentioned in studies of seagrass fish assemblages (see Adam, 1976 $_b$; Bussotti, 2000; Dulčić *et al.*, 1997).

A total of 61 species were collected from Erdek Bay. According to Kocataş *et al.* (1987) and Kence and Bilgin (1996), 169 and 191 fish species were recorded in the Marmara Sea, respectively. In the littoral area of the Erdek Bay we recorded 37 % and 32 % of the Marmara Sea fish fauna, depending on the reference used.

The number of fish species and total abundance were higher in seagrass meadows than in sandy habitat in all seasons. Even disregarding open water species, which represented the majority of fish collected in both habitats, the abundance of the necto-benthic species was greater in seagrass meadow than in sandy habitat in all seasons. Many researchers have suggested that the complex structure of the seagrass meadows provide food and shelter from predators for resident and temporary species (e.g. Orth and Heck, 1980; Bell *et al.*, 1988; Bell and Pollard, 1989; Ferrell and Bell, 1991; Connolly, 1994$_a$; Edgar and Shaw, 1995$_a$).

A total of 35 species were caught in both habitats. Ferrell & Bell (1991) suggested that the differences in the fish assemblages between eelgrass and unvegetated habitat can also depend on how far unvegetated sites are from eelgrass. In Erdek Bay, most of the seagrass meadows are closely interspersed with sandy patches. This high level of fragmentation could explain the high proportion of species collected from both habitats. However, the high abundance of necto-benthic species in seagrass reinforces the idea that seagrass meadows in Erdek Bay still play an important ecological role as provider of food and shelter for juvenile and sub-adult fishes.

The cluster analysis we performed clearly indicated that the main differences in fish assemblages occurred between habitats, rather than among seasons. The only exception was the seagrass fish assemblages in winter which were more similar to the sandy habitat fish assemblage in spring. As the structural complexity of seagrass meadow explains the difference with bare substrate, we hypothesise that the reduction of the leaf density during the winter in the seagrass meadows explains the similarity with sandy habitat. Moreover, during the spring, most of the sandy patches are covered by algae (mainly *Chaetomorpha* spp.) and dead leaves of *Cymodocea* and *Zostera*. It increases the structural complexity of the previous bare substrate, and thus increases the similarity with a seagrass meadow with low complexity (winter).

The most abundant open-water species - *A. boyeri*, *A. hepsetus* and *L. aurata*- did not show significant differences in abundance between both habitats in any season. These small open-water species use seagrass meadow as a refuge during the night to escape predators (PF, personal observation). So, as mentioned by several authors (see Connolly, 1994_a; Guidetti and Bussotti, 2000; Guidetti and Bussotti, 2002), no difference is observed between habitats during the day time.

In contrast, the necto-benthic species as *S. ocellatus, S. cinereus, S. typhle, S. abaster*, and *N. ophidion*, exhibited a clear preference for the seagrass meadows. Connolly (1994_a), Edgar and Shaw (1995_a) and Moran *et al.* (2003) showed that Syngnathidae was the most dominant families in the Australian seagrass meadows. In the Mediterranean Sea, Labridae are the dominant family in *Posidonia oceanica* meadow (*S. ocellatus*; Francour, 1997) and in *Cymodocea nodosa* and *Zostera noltii* meadows (*S. ocellatus* and *S. cinereus*; Guidetti and Bussotti, 2000). In shallow areas of the Marmara Sea, Labridae and Syngnathidae are the dominant necto-benthic families.

Seasonal variations of fish assemblages in Erdek Bay were strongly linked to the seasonal fluctuations of the most abundant species abundance. These common species can be described as permanent or temporary residents according to BELL and Pollard (1989). For the resident species, individuals can be sampled throughout the year and all the size classes can be observed. In Erdek Bay, *A. boyeri, A. hepsetus, S. ocellatus, S. cinereus, Syngnathus typhle, S. abaster* and *N. ophidion* were resident species, and seasonal fluctuations in abundances of these species were due to recruitment and mortality processes (Bell and Pollard, 1989; Connolly, 1994_a). On the other hand, the temporary species spent one part of their life elsewhere and use the considered habitat only as nursery or reproductive ground. In Erdek Bay, *L. aurata* was a temporary species, caught only as juvenile.

In *Zostera* and *Cymodocea* meadows of Erdek Bay, we did not record any species that were represented only by adult individuals. As a whole, 48 % of the 24,488 individuals caught were juveniles or sub-adults. In *P. oceanica* meadow, two factors are often proposed to explain the presence of wandering adult individuals: the largest range of bathymetric distribution and the proximity of rocky areas (see Bell and Harmelin-Vivien, 1982; Francour, 1994, 1997). In *Posidonia oceanica*, the meadows extend from the surface to 40 m depth; the fish assemblages are quite different between shallow and deep waters (Francour, 1994). Several species, such as some

Labridae (*Symphodus tinca*) or Sparidae (*Diplodus annularis*, *Sarpa salpa*) move to shallow water (*S. tinca*, *D. annularis*) or to deep water (*S. salpa*) to reproduce (see Francour, 1997 and references cited therein). On the other hand, large predators such as *Dicentrachus labrax*, *Diplodus sargus* or *Conger conger* move from neighbouring rocky area to meadow to feed. In Erdek Bay, the bathymetric distribution of meadow is narrow and most of the bottoms of the bay are covered by sand or meadow, and rocky areas are absent. So, the fish assemblage is mainly composed of necto-benthic fish linked to meadow and open-water species. In addition, the temporary species use this area as a recruitment area and not as a hunting area.

Conclusions

In both habitats, 27 of the 61 fish species are considered in Turkey as economical species. Most of them were represented by juveniles or sub-adults. Several authors have highlighted the importance of seagrass meadows for economically important species (Kikuchi, 1974; Orth and Heck, 1980; Adams, 1976_a; Connolly, $1994_{a,\ b}$; Edgar and Shaw, $1995_{a,\ b}$; Guidetti and Bussotti, 2002). This study showed that the shallow waters (0-2 m) of Erdek Bay are used as a nursery area by juveniles of the economic value. Due to the decrease of economical species in the Marmara sea (Kocataş *et al.* 1993; Okus *et al.*, 1994), such shallow bays as Erdek Bay have to be considered for protection: the current fishery regulation should be revised to sustain a non-destructive fishery (as small-scale fishery without trawling gears), and the shallow meadows have to be preserved from destruction (e.g. prohibition of harbour or marina building, limitation of pollution). Habitat protection measures should be taken in the Erdek Bay.

Acknowledgements

I am thankful to Prof. Dr. Patrice Francour from Nice University for his great contributions, advice and help to prepare this publication. Thanks also to Prof. Dr. Nuran Ünsal. I would like to thank to Dr. Ayaka Amaha Öztürk and Prf. Dr. Bayram Öztürk. I am grateful to Özgür Emek İnanmaz for helping in the collection of the samples.

The present work was supported by the Research Fund of Istanbul University. Project No: T-918/06112000 is part of PhD thesis.

Özet

Bu çalışma Erdek Körfezi'nde (Marmara Denizi, Türkiye) yakın kıyı bölgelerindeki deniz çayırları (*Cymodocea nodosa* ve *Zostera marina*) ve kumluk habitatlarda bulunan balık topluluklarının yapısını araştırmak amacıyla yapılmıştır.

Toplam olarak; 28 familya, 61 türe ait 24,488 birey elde edilmiştir. Deniz çayırlarında 17,212 birey (28 familya; 51 tür) ve kumluk habitatlarda 7,276 birey

(23 familya; 45 tür) gözlemlenmiştir. *Atherina boyeri* en baskın türdür. Juvenil ya da sub-adult dönemdeki balıklar, tüm bireylerin % 48'ini temsil etmektedir.

Elde edilen sonuçlar; Erdek Körfezi'nin sığ kıyısal sularının (0-2 m) juvenil balıklar tarafından büyüme alanı olarak kullanıldığını göstermektedir. Bu bölgedeki ekonomik olarak önem taşıyan türlerin bolluğundaki azlık dikkat çekicidir. Erdek Körfezi'nde mevcut balıkçılık faaliyetlerinin yeniden gözden geçirilmesi ve koruma önlemlerinin geliştirilmesi, sürdürülebilir balıkçılık açısından gereklilik göstermektedir.

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Received: 18.04.2007

Accepted: 30.05.2007