Fish Diversity and Distribution in the Aksu River Estuary (Antalya-Turkey), in Relation to Environmental Variables

DENİZ İNNAL
Department of Biology, Mehmet Akif Ersoy University, 15100, Burdur, Turkey
E-mail: innald@gmail.com

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Abstract
Seasonal changes in abundance, species composition, and life-style categories of the fish assemblage in a shallow Mediterranean estuary of southwestern Turkey are described. Fishes were sampled monthly by different nets in Aksu River Estuary from October 2006 and March 2008. In total, 3347 individuals from 26 species were captured. *Mugil cephalus*, *Vimba vimba* and *Liza aurata* were the dominant species and comprised over 50% of the total number. The fish comprised 10 marine, 14 freshwater and 2 migrant. The index of species richness, Shannon-wiener diversity, and evenness each showed a consistent seasonal pattern. Canonical correspondance analysis indicated that salinity correlated with the seasonal pattern in the fish assemblage.

Key words: Fish assemblage, Salinity, Estuary, Aksu River, Mediterranean.

Introduction
Estuaries are transitional systems where seasonally fluctuating freshwater river flows meet the daily fluctuating marine tides (Neves et al. 2011). Estuaries are also dynamic systems that undergo wide fluctuations in both short-term and long-term environmental conditions (Kupschus & Tremain 2001). Estuaries and coastal lagoons are used by large numbers of fish as nursery sites, migration routes, feeding and/or breeding areas. For these reasons, estuaries represent important environments, which support high levels of fish production (Malavasi et al. 2004). Fish assemblages in estuaries can include larvae, juveniles and adults of species of both marine and freshwater origin, with migratory or sedentary behaviour (Chicharo et al. 2006). Fish distributions within biologically and physically complex estuarine systems may be influenced by many mechanisms. In addition to biological factors, abiotic factors affect occurrences of fishes within estuaries. These factors include salinity, temperature, turbidity, dissolved oxygen (DO), freshwater inflow, structural attributes of habitat, depth, geographic distance from the estuary mouth, and hydrography (Akn et al. 2005). Fish assemblages in estuaries have been widely studied in both tropical and temperate regions (Blaber 2000; Elliott & Hemingway 2002). In Mediterranean estuaries of Turkey, information about the fish assemblage composition and seasonal or spatial variation in density and biomass is rare, with the exception of studies in Koycegiz Lagoon Estuary (Akn et al. 2005) and the Goksu River estuary (Küçük et al. 2007). To protect and manage estuarine fish stocks properly, resource managers must know and understand the factors that influence the distribution and abundance of the species of interest. Fish assemblage composition of Aksu Estuary are still poorly understood. The aims of the present study were (1)
to describe the seasonal pattern in the community of fishes, and (2) to analyze environmental factors influencing or controlling spatial or temporal variations in diversity, species abundances and assemblages.

Material and Methods

Study Site
The Aksu River is located in western part of Taurus Mountains which is the longest tectonic unit extending between southwest and southeast of Anatolia. It springs from Isparta and flows to Mediterranean Sea in Antalya. The main channel of the estuary (Aksu-Antalya) was divided into two areas (upper and lower estuary) according to physicochemical gradients. The upstream area is characterized by agriculture farming, the lower estuary area is dominated by touristic activities.

Sampling collection and data analysis
Six sampling stations were selected in different parts of the Estuary. Fish species were caught monthly between October 2006 and March 2008 (18 sampling dates) with gill nets of various mesh sizes (310 m total long; 10, 17, 23, 30 mm bar lengths), fish traps and fyke nets. Water quality parameters were measured at each survey site at the start of each field. Temperature (C), salinity, pH and oxygen concentration were determined by using WTW 340i. Secchi depths were estimated by Secchi disk. Water quality parameters were analysed using ANOVA to measure the significant difference among sampling sites. Captured fishes were anesthetized, then fixed in 4\% formalin in the field. Fish specimens were identified to species level according to Aksiray (1987) and Gelday & Balik (1988). Fish species in Aksu Estuary have been categorized in terms of salinity preference and migratory behaviour into marine, migratory, estuarine and freshwater (Araujo et al. 1999). Exotic or native taxa were identified by reference to Innal & Erk’akan (2006). The fish samples were weighed and the total weight per species determined. The fish community were characterized using either the species richness S (total number of species obtained at each sampling), or the Shannon-Wiener diversity index H’. Distribution of individuals was measured by the uniformity or ‘evenness’ index, J (Magurran 1988). A two-way ANOVA was used to test for significant differences in environmental variables, species richness, and abundance among sites and months. Prior to analysis of variance, all variables were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variances (Cochran tests). Associations between species abundance and log-transformed environmental variables were examined with the canonical correspondence analysis (CCA) using CANOCO (Ter Braak & Smilauer 2002). To reduce the effects of rare species, only species catching in two or more sites were included in CCA. Interset correlations between environmental variables (Salinity, Dissolved oxygen and Secchi depth) and CCA axes were used to assess each variable’s contribution. MonteCarlo permutation analysis simulation and the forward selection option within the CANOCO package were used to test the significance (p<0.05) of each variable’s contribution to each CCA axis.

Results

Environmental parameters
Water quality parameters are given in Figure 1. Water temperature of Aksu Estuary, ranged from 12 °C to 26.4 °C. Although water temperature tended to decrease from site 1 (18 °C) to site 6 (17.3 °C), this decrease was not statistically significant (p>0.05). Mean monthly Secchi depth did not show a strong seasonal pattern. These mean values varied from a minimum of 0.2 m to a maximum of 1 m and were significantly different between sites (p<0.05). Salinity values ranged from 0.2 to 17.5. The highest and lowest mean salinity values were measured for summer and winter months, respectively. Salinity showed a spatial gradient along the length of estuary. Decreasing progressively from the mouths to the upstream sites. This decrease was statistically significant (p<0.05). Mean monthly pH values did not show a strong seasonal pattern. pH readings were not significantly different between sites. Dissolved Oxygen concentration varied from a minimum of 7 mg/l to a maximum of 9.5 mg/l. Dissolved Oxygen concentration were not significantly different between sites (p>0.05).
Figure 1. Water quality parameters per station and per sampling month of Aksu Estuary.
**Fish community composition**

Ecological data, total abundance, and biomass of fishes caught in Aksu Estuary are given in Table 1. Twenty-six fish species, representing 12 families, were recorded in the Aksu Estuary. A total of 3347 individuals (531.75 kg total biomass) was caught throughout the study. Cyprinidae was the family most represented in terms of number of species. Cyprinidae was followed in number of species by Mugilidae (five species) and Clupeidae (two species). In contrast, the remaining families (Anguillidae, Characidae, Claridae, Moronidae, Percidae, Poeciliidae, Salmonidae, Sciaenidae, Sparidae) were all represented by one species.

Species of the Mugulidae family were among the most abundant species, accounting for 42.93% of the total catch. The flathead mullet *Mugil cephalus* was the dominant species (28.47%), following by *Vimba vimba* (15.98%), *Liza aurata* (12.55%).

Table 1. Ecological data and total abundance, biomass of fishes caught in Aksu Estuary. Abbreviations: origin 1,2 (1-native; 2-alien); habitat 1,2,3 (1-freshwater; 2-marine; 3-migrant); life cycles 1,2 (1-juvenile + adult individuals; 2- only adult individuals).

| Species               | Origin | Habitat | Life cycles | Occurrence (%) | N   | %    | Rank | Biomass (kg) | %    | Rank |
|-----------------------|--------|---------|-------------|----------------|-----|------|------|--------------|------|------|
| *Mugil cephalus*      | 1      | 2       | 1           | 100            | 953 | 28.47| 1    | 147.9        | 27.81| 1    |
| *Carassius gibelio*   | 2      | 1       | 2           | 100            | 351 | 10.49| 4    | 70.3         | 13.22| 2    |
| *Cyprinus carpio*     | 1      | 1       | 2           | 77.78          | 271 | 8.1  | 5    | 53.94        | 10.14| 3    |
| *Liza aurata*         | 1      | 2       | 1           | 100            | 420 | 12.55| 3    | 52.67        | 9.91 | 4    |
| *Anguilla anguilla*   | 1      | 3       | 2           | 88.89          | 67  | 2    | 9    | 39.94        | 7.51 | 5    |
| *Vimba vimba*         | 1      | 1       | 1           | 100            | 535 | 15.98| 2    | 36.05        | 6.78 | 6    |
| *Clarias gariepinus*  | 1      | 1       | 2           | 61.11          | 79  | 2.36 | 8    | 34.85        | 6.55 | 7    |
| *Dicentrarchus labrax*| 1      | 2       | 2           | 100            | 162 | 4.84 | 7    | 33.52        | 6.3  | 8    |
| *Capoeta antalyensis* | 1      | 1       | 2           | 100            | 199 | 5.95 | 6    | 32.94        | 6.2  | 9    |
| *Umbrina cirrosa*     | 1      | 2       | 1           | 44.44          | 34  | 1.02 | 13   | 8.1          | 1.52 | 10   |
| *Chelon labrosus*     | 1      | 2       | 2           | 50             | 33  | 0.99 | 14   | 5.05         | 0.95 | 11   |
| *Sander lucioperca*   | 2      | 1       | 2           | 22.22          | 14  | 0.42 | 19   | 4.37         | 0.82 | 12   |
| *Carassius auratus*   | 2      | 1       | 2           | 44.44          | 17  | 0.51 | 16-17| 2.06         | 0.39 | 13   |
| *Carassius carassius* | 2      | 1       | 2           | 27.78          | 19  | 0.57 | 15   | 1.88         | 0.35 | 14   |
| *Liza ramada*         | 1      | 2       | 2           | 38.97          | 17  | 0.51 | 16-17| 1.81         | 0.34 | 15   |
| *Pygocentrus nattereri*| 2     | 1       | 2           | 5.56           | 1   | 0.03 | 23-26| 1.63         | 0.31 | 16   |
| *Alosa fallax*        | 1      | 3       | 2           | 33.33          | 35  | 1.05 | 12   | 1.38         | 0.26 | 17   |
| *Sparus aurata*       | 1      | 2       | 2           | 27.78          | 15  | 0.45 | 18   | 1.14         | 0.21 | 18   |
| *Liza saliens*        | 1      | 2       | 2           | 38.99          | 14  | 0.42 | 20   | 0.92         | 0.17 | 19   |
| *Tonca tinca*         | 2      | 1       | 2           | 5.56           | 1   | 1.02 | 23-26| 0.38         | 0.07 | 20   |
| *Pseudorasbora parva* | 2      | 1       | 2           | 66.67          | 40  | 1.2  | 11   | 0.37         | 0.07 | 21   |
| *Dicentrarchus punctatus* | 1     | 2     | 2           | 5.56           | 2   | 0.06 | 22   | 0.17         | 0.03 | 22   |
| *Onchorhynchus mykiss* | 2     | 1     | 2           | 5.56           | 1   | 0.03 | 23-26| 0.15         | 0.03 | 23   |
| *Sardinella aurita*   | 1      | 2       | 2           | 5.56           | 3   | 0.09 | 21   | 0.14         | 0.03 | 24   |
| *Pseudophoxinus alii* | 1      | 1       | 2           | 5.56           | 1   | 0.03 | 23-26| 0.06         | 0.01 | 25   |
| *Gambasia holbrooki*   | 2      | 1       | 1           | 33.33          | 63  | 1.88 | 10   | 0.03         | 0.01 | 26   |

Total 3347 100 531.75 100
M. cephalus, L. aurata, Dicentrarchus labrax, Capoeta antalyensis, V. vimba and Carassius gibelio were present throughout the whole sampling period.

Fishes have been categorized as marine, freshwater and migratory species. The marine species of Aksu Estuary, with ten species (38.46%), represented the highest abundance (49.39%) and biomass (47.28%). The freshwater species, with fourteen species (53.85%), represented 47.56% of abundance and 44.95% of biomass. Two migrant species represented the 3.05% of the total abundance and the 7.77% of the total biomass.

Nine introduced species (Carassius gibelio, Carassius auratus, Carassius carassius, Sander lucioperca, Pygocentrus nattereri, Tinca tinca, Pseudorasbora parva, Oncorhynchus mykiss, Gambusia holbrooki) comprised 34.62% of the catches in terms of number of specimens. Six of these species are alien species of Turkey.

Spatial and temporal variation in fish abundance and species richness
Spatial and temporal variation in species richness (number of species sampled), biomass, and diversity indices (Shannon–Wiener diversity index and evenness index) of fishes is given in Figure 2. Number of species varied from 6 (January 2008) to 19 (October 2006) in Aksu Estuary. Based on the Shannon-Wiener’s diversity index (H’), the highest ecological diversity was recorded in April 2007 (2.45) and the lowest in January 2008 (1.37). In the other hand, the evenness index had its highest value in February 2007 (0.8) and the lowest in September 2007 (0.43). Highest H’ value was found in Site 2. In general, Number of Species and values of Shannon diversity index was higher during fall and spring-summer months than winter months. Number of Species and values of diversity index exhibited a strong spatial and temporal variation throughout the study.

Figure 2. Temporal and spatial variations of biomass, Shannon and Evenness index.
Fish abundance was highest during October-November 2006 and June-October 2007. *M. cephalus* and *L. aurata* achieved their peak abundance in these months. The highest and lowest mean abundance values were obtained at sites A1 and A5. The period between January-March 2007 and December 2007 - March 2008 was characterized by low biomass.

Canonical correspondence analysis ordination plot for sites and species, illustrating distribution patterns based upon environmental conditions is given in Figure 3. CCA eigenvalues of the first four multivariate axes were 0.298 (CCA1), 0.050 (CCA2), 0.021 (CCA3), and 0.043 (CCA4). Correlations between species and the environmental parameters axes are high for the first three axes (0.99, 0.95 and 0.63). Cumulative percentage variance of species for the four axes (CCA 1-4) was 84.7. The first and second axes modeled 70.8% and 11.8% of species data, respectively, and they cumulatively accounted for 88% of the variance of species-environment relationships modeled by CCA. Among the three examined environmental factors, Salinity best explained the seasonal pattern of species composition in Aksu Estuary.

![Figure 3](image_url)

**Figure 3.** Plot of site and species scores with 3 environmental variables in the first two CCA axes.

**Discussion**

According to this study, 26 species permanently or temporarily occupy the study area. Number of fish species of Aksu Estuary is fewer than previous studies carried out in other areas such as Richmond River Estuary (Australia, 64 species) and Clarence River Estuary (Australia, 66 species) (West & Walford 2000); Strymon River Estuary (Greece, 43 species) and Ríhios River Estuary (Greece, 29 species) (Koutrakis *et al.* 2000); more than Kakanui River Estuary (New Zealand, 20 species) (Jellyman *et al.* 1997); Solway River...
Estuary (England, 22 species) (Elliott & Dewailly 1995), Waitaki River Estuary (New Zealand, 16 species), Clutha River Estuary (New Zealand, 14 species), Waiau River Estuary (New Zealand, 14 species) and Mohako River Estuary (New Zealand, 13 species) (Jellyman et al. 1997) Occurrence, distribution and movement of fishes in estuary systems are certainly determined by a complex combination of both biotic and abiotic factors (Martino & Able 2003; Jaureguizar et al. 2006; Sosa-Lopez et al. 2007).

The functional group of the Aksu estuary was mainly composed of freshwater species in terms of number of species. The reason for the dominance of freshwater species may be related to the introduction of non-native species in estuary. Nine of freshwater species were anthropogenically introduced in Aksu Estuary. Turkey’s natural river systems have been anthropogenically altered in the past century. The number of introduced fish has apparently increased in recent years and the variety of freshwater fish fauna has changed in Turkey (Innal & Erk’akan 2006).

Freshwater species, mostly restricted on the upper reaches of the estuary, consisted of more species than marine species. Freshwater species belonging to six families were recorded. Of these freshwater fishes, Cyprinidae, the dominant family in terms of species number. Cyprinids constitute the main component of the Anatolian freshwater ichthyofauna and occur in almost every kind of freshwater habitat throughout Turkey (Fricke et al. 2007). Two (C. antalyensis and P. alii) of freshwater fishes in Aksu Estuary are endemic to the river basin. These species are under considerable pressure from a range of anthropogenic activities. One of the main threats to fishes is flow control engineering works. Another impact is the presence of dams that alter the normal river flow and may restrict the movement of these species along the natural river channel. Chemical pesticides, often used on agriculture, may constitute a high risk to C. antalyensis and P. alii. Another potential risk factor is the introduction of the non-native fish species (Pseudorasbora parva, Carassius gibelio, Oncorhynchus mykiss and Gambusia holbrooki). Most of the freshwater species appeared in low numbers and were mainly caught in the upstream sites of estuary. The dominant freshwater species in the study area, V. vimba, showed an increasing linear trend from the lower reaches to the upper reaches. The occurrence of this species in the mouth of estuary during this study is due to the tolerance of fluctuating environmental conditions in this system.

Near half of caught species are commercially important suggesting the importance of Aksu Estuary for supporting the fishery resources in the adjacent region. The occurrence of economically important species is common in estuaries and coastal lagoons (Day et al. 1989), due to the great abundance of food resources provided by these ecosystems.

The dominance of Mugilids in the Aksu Estuary is typical of many estuaries worldwide (Koutrakis et al. 2000, Tzeng et al. 2002). Mugilidae are in general, euryhaline and able to tolerate wide fluctuations in water temperature and salinity (Whitfield 1998). Juveniles of M. cephalus and L. aurata were recorded in Aksu Estuary. This result suggests that Aksu estuary could be considered as nursey area for these species. Estuaries enhance growth and survival of juvenile fish because they provide high food availability, low predation risk, warm water temperatures and protection from adverse weather conditions (Abookire et al. 2000).

Species richness was higher during fall and spring-summer months than winter months. Similar results reported in previous studies (Spach et al. 2004; Akin et al. 2005; Prato 2010). This study also shows considerable changes in diversity during the study period. The wide range (1.37 - 2.45) of Shannon-Wiener diversity index reflects the large numbers of species that inhabit the lagoon on a seasonal basis. Seasonal change in the specific diversity was also observed in other studies of fish populations in the previous studies (Jellyman et al. 1997; Methven et al. 2001; Greenwood & Hill 2003; Barreiros et al. 2009).

In the Aksu River, except Anguilla anguilla, for all species the changes in abundance and biomass values shows a significant difference (two-way ANOVA) for study areas and study periods. Salinity was the most important parameter influencing the distribution of species between sites (Permutation tests and forward selection methods also showed that this variable was the most important variable). The main effects of salinity seem to be in controlling the distribution of fish and in the attraction of larvae, post-larvae and juveniles into the estuaries (Elliott & Hemingway 2002). Research on fish assemblages in estuaries has shown that salinity plays a major role in shaping assemblage structure (Edgar et al. 1999; Wagner & Austin 1999; Plavan et al. 2010; Marshall & Elliott 1998; Pombo et al. 2005; Neves et al. 2011).

In conclusion, the Aksu Estuary is inhabited by more than 26 fish species, some of which are very rare and previously unstudied. However, due to anthropogenic pressures such as industry, tourism, fisheries, and other maritime activities, it is necessary to effectively protect and monitor this important fish habitat.
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