

## Ichthyofauna of Sultan Marshes (Turkey) and Possible Effects of Fish Invasion from Seyhan Basin on Diversity and Conservation

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**Abstract:** Ichthyofauna of the Sultan Marshes and its drainage based on an extensive survey are presented. In addition, the suggestion of the IUCN criteria of the recently described fish species and the ecological quality of the marshes based on the EurAsian Fish Index (EAFI) were estimated. Furthermore, *Capoeta damascina*, *Garra turcica*, *Squalius seyhanensis*, and *Oxynoemacheilus seyhanensis* are reported for the first time in the Sultan Marshes, entered from the Seyhan basin via the Zamanti Tunnel. Based on the results, a total of 16 species belonging to 6 families have been identified with 9 translocated ones (58.3%). The estimated EAFI value for different parts of the marshes differs from 4 (Bad) to 30 (High) with a mean of 21.0 (Good) that shows the negative effect of both anthropogenic deterioration and occurrence of translocated species.

**Keywords:** Kızılırmak basin, Kayseri, fish index, translocated, ecological impact.

### Sultan Sazlığı Balık Faunası ve Seyhan Havzasından Giriş Yapan Balık Türlerinin Çeşitlilik ve Korunma Üzerine Olası Etkileri

**Öz:** Sultan Sazlığı havzasının balık faunası kapsamlı olarak ele alınmıştır. Ayrıca son yıllarda tanımlanmış olan balık türleri için IUCN kriteri önerisi yapılarak Avrasya Balık İndeksine (EAFI) dayalı olarak sulak alanın ekolojik kalite durumu belirlenmiştir. Ayrıca bu çalışmada Zamanti Tüneli ile Seyhan Havzasından Sultan Sazlığı Kapalı Havzasına giriş yapmış olan *Capoeta damascina*, *Garra turcica*, *Squalius seyhanensis* ve *Oxynoemacheilus seyhanensis* türleri ilk kez bildirilmektedir. Eldeki bulgular doğrultusunda havzada altı familyaya mensup toplam 16 tür dağılım göstermekte olup bunlardan dokuz tanesi havza için egzotik tür (%58,3) niteliğindedir. Sazlığın farklı kısımları için EAFI değeri 4 (Kötü) ile 30 (Yüksek) arasında değiştiği belirlenmiş olup, ortalama ekolojik durum değeri ise 21,0 (İyi) olarak belirlenmiş olup, bu değer düşük olduğu alanlarda antropojenik etkinin yüksek olduğu ve egzotik türlerin bulunduğu görülmüştür.

**Anahtar kelimeler:** Kızılırmak havzası, Kayseri, balık indeksi, yabancı tür, ekolojik etki.

### 1. Introduction

Turkey has important stopover, breeding, and even wintering sites for migratory bird species. In the migration period, the birds spend most of their time in the stopover areas to continue their journeys by recovering the energy they lost (Karaardıç & Erdoğan, 2019). Sultan Marshes National Park, located in the Kayseri Province of Turkey, is a unique natural wetland consisting of salt and freshwater lakes and marshes. These lakes and marshes are surrounded by wet meadows, salt steppes, and agricultural areas (Dadaser-Celik, Bauer, Brezonik, & Stefan, 2008a). This protected area was designated as one of Turkey's 14 Ramsar sites and is an Important Bird Area known as the second important bird paradise in Turkey. The location of the Sultan Marshes provides plenty of food during a stopover for migratory birds, which is extremely critical for migratory birds to reach the next stopover site or breeding grounds. Reporting over 250 bird species in the Sultan Marshes reveals its importance. Also, the marshes are an important ecosystem in terms of biodiversity and a critical habitat not only for avifauna but also for a variety of plant and animal species (Dadaser-Celik et al., 2008a).

Significant changes have occurred in the Sultan Marshes in the last two decades; for example, hydrologic,

physical, and biological characteristics of the marshes have altered by a major irrigation project (Develi Irrigation Project: DIP) (Dadaser-Celik, 2008). DIP was started to support a wide agricultural area around the Sultan Marshes in 1973 by the State Hydraulic Works (DSI: Devlet Su İşleri, in Turkish). Consequently, the natural balance and hydrologic cycle of the Sultan Marshes were destroyed in the following years due to dams, legal and illegal well-drilling, and drainage channels. The marshland area decreased from 3,900 to 400 ha during the last two decades. These phenomena were led to declining biodiversity, and particularly bird species richness. In 2011, the Zamanti Tunnel (Gicik Tunnel) was inaugurated to transfer water from the Seyhan Basin to the Sultan Marshes to avoid complete dryness of the Sultan Marshes (EAJ, 2018).

Anthropogenic activities, including habitat alteration, dam constructions on the rivers, underground water use by drilling, introduction of exotic fish, and pollution have been severely treated to fish biodiversity in the marshes. A recent analysis of the Sultan Marshes conditions showed that it is impossible to provide sustainability with today's usage (Sönmez & Somuncu, 2016). All of these abovementioned deteriorations indicate the necessity of some precautions to be introduced immediately to protect the fish biodiversity of marsh.

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Despite the numerous published articles on hydrology, flora, and avifauna, no comprehensive study has yet been made on fish. Therefore, little is known about fish composition, diversity, and conservation. The present study aimed to i) represent fish species diversity and distribution of fish species living in the marsh, ii) report the invasion of fish species from the Seyhan Basin to the marsh, iii) review the main threats to fish biodiversity, and iv) to suggest some recommendations for conservation.

## 2. Material and Methods

This ichthyological survey took place within Sultan Marshes from March 2013 to June 2018 (Fig. 1). Fish were sampled using gill-nets from the lakes and electrofishing

device (SAMUS 1000) from streams, springs, and shallow areas of the Sultan Marshes. The collected specimens were preserved in 10% buffered formalin after anaesthesia and then subsequently stored in 4% buffered formalin. All specimens were identified, according to Geldiay and Balık (2007), Bogutskaya (2007), Sungur, Jalili and Çiçek (2017), Sungur, Jalili, Eagderi and Çiçek (2018).

Indication of the Turkish fresh waters' ecological quality, a national fish-based assessment system, namely the EurAsian Fish Index (EAFI), was developed (Çiçek, Görgün, Bağra, & Sungur, 2018). Therefore, an estimation of EAFI value for different parts of the Sultan Marshes were performed based on Çiçek et al. (2018).

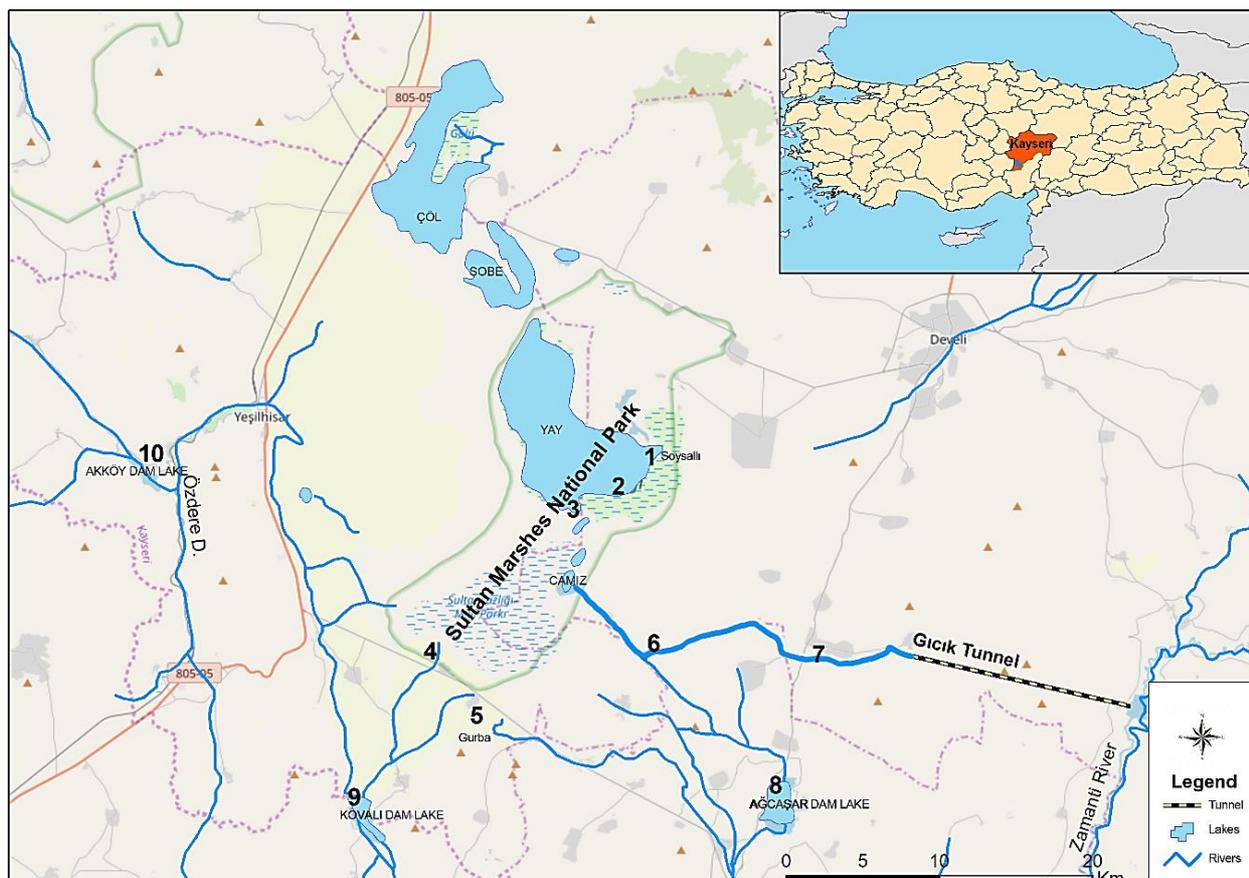


Figure 1. Study area and sampling stations (numbers).

## 3. Results

A total of 16 fish species were collected from the Sultan Marshes, including four species viz. *Alburnus escherichii*, *Capoeta tinca*, *Oncorhynchus mykiss*, and *Oxynoemacheilus angorae* from the Yahyalı, Yeşilhisar, and Dündarlı streams and 12 species from the marshlands five of which, including *Aphanius danfordii*, *Pseudophoxinus elizavetae*, *Cobitis joergbohleri*, *Oxynoemacheilus ciceki*, and *Seminemacheilus ahmeti*, are endemic. Seven others, including *C. damascina*, *Cyprinus carpio*, *Esox lucius*, *Garra turcica*, *Squalius seyhanensis*, *Tinca tinca*, and *O. seyhanensis* are considered as alien (translocated) species to the Sultan Marshes (Table 1). The collected fish belong to 4 orders (namely Esociformes, Cypriniformes and Cyprinodontiformes, and Salmoniformes), 6 families (Esocidae, Cyprinidae, Nemacheilidae, Cobitidae, Aphaniidae and Salmonidae), and 13 genera.

Based on the results, the Sultan Marshes ichthyofauna has significantly affected by introducing 9 translocated species (58.3%). *Cyprinus carpio*, *E. lucius*, and *T. tinca* are commercially valuable translocated species that have been introduced for fishery purposes directly into the Sultan Marshes. *C. damascina*, *G. turcica*, *S. seyhanensis*, and *O. seyhanensis* have entered the Sultan Marshes from the Seyhan basin via the Zamanti Tunnel that is reported for the first time in the current study.

Newly described species viz. *S. ahmeti*, *O. ciceki*, *C. joergbohleri*, and *P. elizavetae* have not been evaluated based on the IUCN criteria. Hence, we suggest the IUCN category as CR for them based on low population density, range of distribution, and high treats on the ecosystem.

The estimated EAFI value for different parts of the marsh varied from 4 (Bad) to 30 (High) with a mean value of 21.0 (Good). The highest EAFI value is estimated in

spring areas (Station 1: Soysalli and station 5: Gurba). The lowest values are estimated in stations 2, 8, and 10 where translocated species are found (Table 1).

#### 4. Discussion

Little information was available about ichthyofauna of the Sultan Marshes. Kasperek (1985) published a comprehensive study regarding the Sultan Marshes, which contains detailed information about the geographic and topographic structure, flora, and fauna of the area, reporting three fish species viz. *Phoxinellus meandri*,

*Neomacheilus lendli*, and *Aphanius chantrei*. Later, six fish species, *S. cephalus*, *O. angorae*, *S. lendlii*, *C. turcica*, *G. affinis*, and *A. faciatus*, were listed as the ichthyofauna of the Sultan Marshes (Yerli, Gündüz, & Akbulut, 1994, Yerli, Gündüz, & Akbulut, 1997). However, we believe that identification of these species is erroneous. The results of the present work increased the fish inventory of the Sultan Marshes to 16, including 9 translocated species. We could not find any native *Squalius* species except *S. seyhanensis* that has recently invaded the Sultan Marshes via the Zamanti Tunnel.

Table 1. Percentage Occurrence of fish species and EAFI scores in each station (H: High, G: Good, M: Moderate, B: Bad)

Species	Stations #									
	1	2	3	4	5	6	7	8	9	10
<i>Alburnus escherichii</i>										76.5
<i>Aphanius danfordii</i>	22.2	12.6	24.4	54.8	23.1	57.7				
<i>Capoeta damascina</i>						1.5	16.7			
<i>Capoeta tinca</i>									13.3	
<i>Cobitis joergbohleni</i>	2.8			4.1	3.8					
<i>Cyprinus carpio</i>		1.0						10	30.4	5.0
<i>Esox lucius</i>		1.0				1.4				
<i>Garra turcica</i>						1.4	9.2			
<i>Oncorhynchus mykiss</i>									4.1	
<i>Oxynoemacheilus angorae</i>									5.9	
<i>Oxynoemacheilus ciceki</i>	21.1		2.3	5.3	32.8					
<i>Oxynoemacheilus seyhanensis</i>							6.9			
<i>Pseudophoxinus elizavetae</i>	5.9	83.6	69.2	15.8	10.0	10.0				
<i>Seminemacheilus ahmeti</i>	3.7				4.1					
<i>Squalius seyhanensis</i>						1.4	3.0			
<i>Tinca tinca</i>		1.0								
EAFI Score	30	11	20	26	30	17	17	4	26	5
Ecological Status	H	M	G	G	H	M	M	B	G	B

Those specimens of the genera *Cobitis*, *Oxynoemacheilus*, and *Seminemacheilus* were recognized as *C. joergbohleni*, *O. ciceki*, and *S. ahmeti*, respectively (Sungur et al., 2017, 2018; Freyhof, Bayçelebi, & Geiger, 2018). They have localized occurrences and found in the Soysalli and Gurba springs, i.e., the habitats with clean water, sandy and/or muddy bottom without algae. *Cobitis joergbohleni* is mainly found inside the sandy bottoms. *Oxynoemacheilus ciceki* is the most dominant endemic species in the Sultan Marshes. *Pseudophoxinus elizavetae* is relatively widespread; however, it is localized in the vegetated areas of the wetland with high density.

We were unable to collect *G. holbrooki* that has been released into the Sultan Marshes as a control agent of *Anopheles (Plasmodium spp., malaria)* (Yerli et al., 1994). This is because *G. holbrooki* occupies almost the same niche as *Aphanius* species, they could not be probably successful in competition with the endemic, well-adapted *A. danfordii* in the Sultan Marshes. It is accepted that *G. holbrooki* has been known to have an adverse effect on native fishes through competition and/or predation (Zogaris, 2017; Keskin, 2016) and; thus, it was listed as one of the worst invasive alien species of the world (Lowe, Browne, Boudjelas, & De Poorter, 2000). *This species causes declining and/or extinction of native Aphanius species in many aquatic ecosystems* (Zogaris, 2017; Yoğurtçuoğlu & Ekmekçi, 2014). However, there was some evidence of niche segregation (Al-Daham, Hug, & Sharma, 1977). Some *Aphanius* species are more resistant to stress than *G. holbrooki*, and probably *A. danfordii* has won the competition. We also observed the same situation in the Lake Tuz basin where *G. holbrooki* was rare compared to *A. anatolia*. It seems that *Aphanius* species in these two habitats could overcome their livebearer counterpart by

some novel interactions (Radkhah, Eagderi, & Mousavi-Sabet, 2016). It is estimated that *Aphanius* species are an 'r' strategist forming dense, stunted populations limiting sources for *G. holbrooki*; but, this hypothesis needs to be tested in further studies.

Overcoming the lack of water budgeted, a new water source was given to the Sultan Marshes from the Seyhan basin via the Zamanti Tunnel with the inauguration in 2011. With the Zamanti Tunnel opening, *C. damascina*, *G. turcica*, *S. seyhanensis*, and *O. seyhanensis* entered to the Sultan Marshes. The distribution of these species are now restricted to some drainage channels in eastern parts of the marshes, and no adverse effect has yet been observed. Nevertheless, it is expected that these species will be distributed to the other parts of the Sultan Marshes and; thus, it may cause adverse effects. Besides, it can be expected that more translocated species will enter to the marsh via the Zamanti Tunnel causing a decrease in the population density of endemics and even their extinction. New records of native fish e.g., those translocated from the Seyhan basin, are good signs of biodiversity richness in the marshland. However, these fish movement beyond their natural range is a result of the ecological damaging caused by human activities. This reveals that an urgent measure should be taken to manage fish invasion from the Seyhan Basin via the Zamanti Tunnel.

The IUCN guidelines on invasive species specifically emphasize (I) improving understanding and awareness, (II) strengthening of the management responses (including prevention, eradication, and control), (III) providing appropriate legal and institutional mechanisms, and (IV) enhancing knowledge and research efforts (IUCN, 2020). The main problems are the limited understanding of the consistent and predictable impacts of non-native species

on native diversity. Hence, the complex interactions of exotic species with native ecosystems make invasion ecology an interesting and important area of research (Muralidharan, 2017). As it relates to the fish, integrated pest management has been used to combat the increased successful introductions of non-native fish (Phelps, Tripp, Bales, James, Hrabik, & Herzog, 2017). In addition, many ways are applied to prevent inter-basin fish species exchange. For example, an electric barrier is currently operated to inhibit the upstream dispersal of *Hypophthalmichthys nobilis* and *H. molitrix* from the Mississippi River basin to Lake Michigan (Parker, Rogers, Stewart, Glover, Finney, & Simmonds, 2014). The other barriers, such as acoustical deterrence, bubble barriers, and CO<sub>2</sub> chambers have also been researched with the hope of reducing the spread of non-native fish (Phelps et al., 2017). Consequently, governmental organizations should choose an effective way.

A total of 5 endemic species (*S. ahmeti*, *O. ciceki*, *C. joergbohleri*, *P. elizavetae*, and *A. danfordii*) are found only in the Sultan Marshes. Although the Sultan Marshes is located within the Kizilirmak Basin, the results revealed a weak faunistic relationship with this basin, showing unique endemism. Although *A. danfordii* was described from Elbistan, (Ceyhan basin), its lectotype was designed from the Sultan Marshes by Wildekamp, Küçük, Ünlüsayin, & Neer (1999) since this species was not found in the type locality. There is a confusion concerning the taxonomic status of *A. danfordii* that needs to be clarified. *Aphanius danfordii* is a widespread pelagic species in the Sultan Marshes. However, its populations have collapsed and disappeared in some areas e.g., Camizozu village vicinity, after the introduction of *E. lucius*. Distribution of *E. lucius* is restricted to pools in the northern parts of the marsh. However, if this species is introduced to other parts of the marshes, it will be chaotic phenomena since it adversely affects the marshes' small endemic fish. Mauck and Coble (1971) investigated the prey selection of *E. lucius*, showing its tendency to eat the smaller cyprinids as similar to the dominant fish fauna of the Sultan Marshes. Biological invasions are among the greatest threats to global biodiversity (Luque, Bellard, Bertelsmeier, Bonnaud, Genovesi, Simberloff, & Courchamp, 2014; Mousavi-Sabet & Eagderi, 2016; Eagderi, Nasri, & Çiçek, 2018). The introduction of the exotic species in an ecosystem is likely to present an ecological risk, because, if the species can integrate itself successfully into the ecosystem (Gozlan & Newton, 2009), that may result in possible detrimental interactions with native species and cause adverse effects even on ecosystem functioning (Gozlan, Britton, Cowx, & Copp, 2010). This situation may result in the extinction of the endemic species such as *Pseudophoxinus handlirschi* in the Lake Eğirdir, *Alburnus akili* in the Lake Beyşehir, *Aphanius splendens* in the Lake Gölcük, and *Alburnus nicaeensis* in the Lake Iznik due to the introduction of *Sander lucioperca* (Küçük, 2012; Freyhof, 2014 a,b).

Another observed anthropogenic effect in the Sultan Marshes is pollution from agricultural and domestic sources. The effect of pollution is now limited to the drainage channels. Therefore, it is crucial to prevent the sources of pollution to protect the marshland. Hydrologic changes in the Sultan Marshes were well-documented (Karadeniz, 1995, 1997; Dadaser-Celik, Brezonik, & Stefan,

2006; Dadaser-Celik et al., 2008a, Dadaser-Celik, Brezonik, & Stefan, 2008b, Dadaser-Celik, Coggins, Brezonik, & Stefan, 2009a, Dadaser-Celik, Brezonik, & Stefan, 2007; Dadaser-Celik, 2008, 2009; Jouma & Dadaser-Celik, 2016, 2017). According to these studies, because of the construction of dams, legal and illegal well-drilling, drainage channels and land use for agriculture, Sultan Marshes are destroyed year by year and; thus, its area is decreased from 3.900 ha to 400 ha. Biodiversity loss, including endemic fish species, has been reported in many wetlands due to dryness e.g., Lake Amik, Hotamiş Marshes, and Eşmekaya Marshes (Freyhof, Ekmekçi, Ali, Khamees, Özuluğ, Hamidan, Küçük, & Smith, 2014). For instance, drought caused the extinction of *Acanthobrama centisquama* in the Amik Lake and Al-Gab Lake (Syria), the Orontes drainage (Freyhof, 2014c; Baumsteiger & Moyle, 2017). Hence, it is crucial to manage water balance to overcome drying of the Sultan Marshes. Even though, the Zamanti Tunnel will provide a new water source for the Sultan Marshes, if water use is not managed, this temporal improvement will be short-lived (EAJ, 2018).

One of the key quality elements used to describe the status of aquatic resources is fish assemblage data. Fish are good indicators of ecological status since they occupy a range of ecological niches and their ecological processes operate over various spatial scales (Karr & Chu, 1999). Thus, fish assemblage data are commonly used in bio assessments, linking ecosystem conditions to human-related stressors (Daniels, Riva-Murray, Halliwell, Vana-Miller, & Bilger, 2002; Mebane, Maret, & Hughes, 2003; Bramblett, Johnson, Zale, & Heggem, 2005). The estimated EAFI value for different marsh parts varied from 4 to 30 with the mean value of 21.0. The ecological status of the anthropologically deteriorate areas is lower than that of the pristine area. The results revealed that the presence of the translocated species decreases EAFI value. Therefore, it is crucial to manage the introducing of exotic species in the marshes to overcome adverse effects on this ecosystem.

In conclusion, anthropogenic activities, including habitat alteration, dam constructions, underground water use by drilling, the introduction of exotic (translocated) fish, and pollution severely affect the fish biodiversity in the Sultan Marshes. In line with Sönmez & Somuncu (2016), our findings revealed that the actual threat is human activities in the Sultan Marshes and the surrounding areas. Hence, to protect this unique wetland's fish biodiversity, measures have to be introduced immediately. Therefore, all responsible governmental organizations have to discuss and made to measure for this situation.

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