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RESEARCH ARTICLE

New record and rare occurrence of European eel (*Anguilla anguilla*) from freshwater bodies in Karaburun Peninsula (İzmir, Türkiye): Anthropogenic pressures on the fish movements

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Abstract

Objective: Fish can be used as bio-indicators to determine whether freshwater habitat has been altered. As habitat discontinuity occurs due to the presence of mechanical barriers, species composition can be altered upstream and downstream. Since the beginning of the 1980s, the amount of European eel *Anguilla anguilla* entering inland waters in Türkiye and European countries has decreased significantly. Our study describes for the first time the presence of *A. anguilla* from the freshwater bodies in the Karaburun Peninsula.

Materials and Methods: From November 2020 to August 2021, fish specimens were collected through electrofishing in one lotic system and three transitional waters of the study area. Clove oil was used to anesthetize live fish specimens after capture. Total length (TL) was measured for each sample to the nearest 1.0 mm. With a digital balance that was accurate to 0.01 g, we weighed the total body weight (W).

Results: We collected four adult specimens of *A. anguilla* from the study area. Total lengths and body weights of the specimens were 311 mm and 62.4 g for Balıklıova Stream; 360 mm and 95.3 g for Küçükbahçe Stream; 325 mm 56.3 g for Salman Reservoir and 280 mm and 34.7 g for Yelkentaş Stream, respectively.

Conclusion: We could not discuss our findings since no study has been done in the study area before, but it is thought that the low number of individuals caught may be related to the habitat degradation and different types of constructions at the stream mouths. The construction of fishways suitable for the study area can be a start to solving the distribution problem of this species.

Keywords: Habitat destruction, Barriers, Inland water, Fish passages

Introduction

Habitat degradation is one of the major causes of biodiversity loss. Various ecosystem services, including maintenance of natural habitats, provision of food, recreation, and food cycling are negatively affected by river disruption caused by human-made barriers (Birnie-Gauvin, *et al*., 2017). Through mechanical barriers, backwater impoundments change upstream river hydraulics, resulting in pond-like habitats that are favorable to the species (Parasiewicz, *et al*., 2022). A barrier can alter the composition of species upstream and downstream due to habitat discontinuity (Jones, *et al*., 2020). Thus, over a million artificial barriers cut off the waters of European rivers, limiting or blocking aquatic species' migration and causing freshwater habitats to be lost (Belletti, *et al*., 2020).

Bio-indicators such as fish can provide information about habitat alteration of freshwaters (Pont, *et al*., 2006). Despite their geographical differences, many species share similar habitats. It is common for aquatic organisms, including fish, to be well adapted to specific environments based on location and time (Parasiewicz, *et al*., 2022). Aquatic fauna and flora in different habitat mosaics exhibit unique community structures (Poff & Ward, 1990). Even though human actions are acceleratingly shaping local habitats either directly or implicitly, catchment-level characteristics independent of human actions are what are needed to predict the status and structure of ichthyofauna on a country scale (Britton, *et al*., 2021; Parasiewicz, *et al*., 2022). It is possible to reduce the impact of human activities on aquatic species if these characteristics are known and considered.

According to their life cycles, diadromous fish prefer to live both in freshwater and marine habitats. These fish are divided into anadromous and catadromous fishes. The term catadromous fish refers to fish that reproduce in marine environments but then transition to freshwater for growth/development until they reach back to their breeding zones. Catadromous fish include the European eels, *Anguilla anguilla*. This species constitutes one of the most spectacular migrations in the animal world, and comprise one of the most important fisheries in Europe (Gross, *et al*., 1998; Starkie, 2003).

At the end of its journey that lasts about two years to the east along with the ocean flows, *A. anguilla*, which began as a larva in the Sargasso Sea, enters all rivers with a coast on the Western European coasts, West African coasts, and the Mediterranean (Weber, 1986; Dekker, 2003). However, the population of *A. anguilla* has declined drastically since the 1980s, making this species critically endangered according to the IUCN Red List (Drouineau, *et al*., 2018; Pike, *et al*., 2020). Although the exact reason for the decline is uncertain, habitat changes, artificial barriers, and overfishing may have contributed to the decline (Starkie, 2003). When the European Union recovery plan constituted in 2007 ends, it will be important to know the migration strategies adopted by early life cycles of this species in order to predict recruitment of the species to freshwater (Dekker, 2018; Cresci, 2020).

In Türkiye, besides the Aegean Sea, the Black Sea, the Marmara Sea, the Mediterranean Sea, and their associated lakes, there is also *A. anguilla* populations in freshwater resources that drain into these seas (Memiş, *et al*., 2020). This fish has been found in several Turkish freshwater resources, according to the previous studies (e.g., Oray, 1987; Geldiay & Balık, 1988; İkiz, *et al.*, 1998; Güven, *et al*., 2002; Yalçın Özdilek, *et al.*, 2006; Güven, *et al*., 2016; Küçük, *et al*., 2016). In this study, we report for the first time, the occurrence of *A. anguilla* from Turkish freshwater bodies in a Peninsula (Karaburun, İzmir). Additionally, we attempted to emphasize whether human-induced factors restrict the movement of this species in the study area.

Material and Methods

Study area: The localities where the field studies were conducted were shown in Figure 1. Various sizes of agricultural irrigation and utility water reservoirs are located in the Karaburun Peninsula, and the largest of one is Eğlenhoca Reservoir, which is built in 2007 and approximately 0.05% of the surface area of the district (İZKA, 2014). There are also three reservoirs built between 2014 and 2018, Bozköy, Karareis, and Parlak Reservoirs, which are used for the same purposes (İZKA, 2014). Salman Reservoir was built in 2017 for the purpose of providing irrigation, drinking, and utility water. Although Salman Reservoir and Küçükbahçe Stream seem to be connected to each other, there is a barrier between them. Furthermore, Balıklıova Stream and Yelkentaş Stream have a direct connection with the sea.

Sampling: Although all localities in the study area were visited between November 2020 and August 2021, fish samples (e.g. Fig. 2) were only obtained using a portable electro-shocker (SAMUS 1000; frequency 55-60 Hz) from one lotic ecosystem (Salman Reservoir) and three transitional waters (Balıklıova Stream, Küçükbahçe

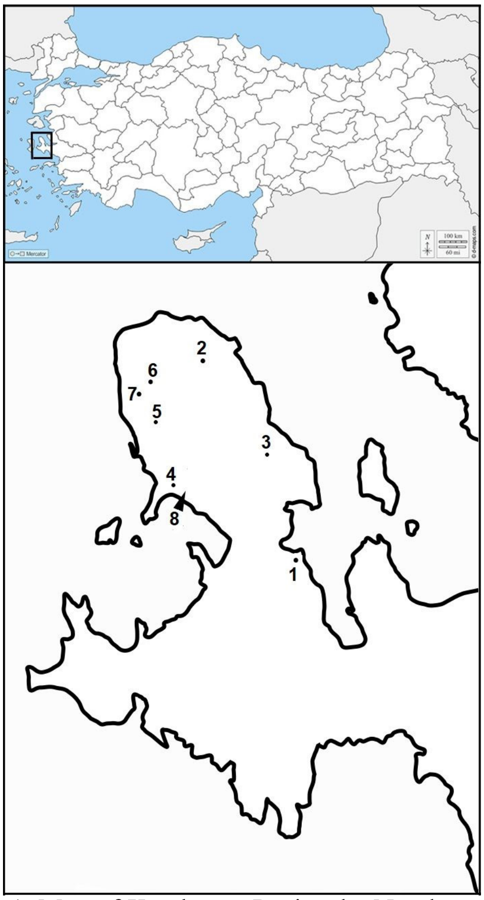

Figure 1. Map of Karaburun Peninsula. Numbers refer to studied water bodies in the peninsula (1: Balıklıova Stream, 2: Bozköy Reservoir, 3: Eğlenhoca Reservoir, 4: Karareis Reservoir, 5: Küçükbahçe Stream, 6: Parlak Reservoir, 7: Salman Reservoir, 8: Yelkentaş Stream).

Stream, and Yelkentaş Stream) of Karaburun Peninsula (Fig. 1 and Fig. 3). After capturing, alive fish specimens were anaesthetized with clove oil. Each fish sample was measured to the nearest 1.0 mm for total length (TL) and total body weight (W) was weighed on a digital balance with a 0.01 g accuracy. After examination, fish samples were released back to the water bodies. Fish data on the sampling locations were listed in Table 1.

Figure 2. *Anguilla anguilla* specimen caught in Salman Reservoir, İzmir, Türkiye on 31 May 2021. Photograph by Ümit Acar.

Figure 3. Sampling locations where fish samples were caught in Karaburun Peninsula. Water bodies are indicated by numbers (1: Balıklıova Stream, 2: Küçükbahçe Stream, 3: Salman Reservoir, 4: Yelkentaş Stream). Photograph by Ümit Acar.

Results and Discussion

As a result of the field surveys carried out in eight localities in the Karaburun Peninsula, four adult specimens of *A. anguilla* were collected from one lotic ecosystem and three transitional waters (one specimen for each sampling location) of Karaburun Peninsula (Table 1). The total lengths and body weights of the individuals were 311 mm and 62.4 g for Balıklıova Stream; 360 mm and 95.3 g for Küçükbahçe Stream; 325 mm 56.3 g for Salman Reservoir and 280 mm and 34.7 g for Yelkentaş Stream, respectively.

A fragmented river system can have serious consequences for fish species that migrate long distances, leading to their eventual extinction for species such as *A. anguilla* (Larinier & Travade, 2002; Callen & Greenberg, 2009). Additionally, through structural modifications to fish habitats, turning flowing waters into semi-lentic systems, and blocking fish movements, instream structures (i.e., dams, weirs, culverts) can negatively impact fish populations (Buisson, et al., 2008; Taylor, et al., 2008). The world's freshwater migratory fish population has declined by 96% over the last 50 years - the biggest decline of any vertebrates (Deinet, et al., 2020). The rising fragmentation of rivers has contributed to this decline (Belletti, et al., 2020). Thus, to implement corrective activities such as dam removal and construction of fishways, it is essential to understand how fish composition changes in rivers are disrupted by artificial barriers (Kornis, *et al*., 2015).

Considering some studies on the occurrence of *A. anguilla* in the marine habitats of Karaburun Peninsula (Sunlu & Egemen, 1998; Veryeri, 2006), this species had not previously recorded from the freshwater bodies of Karaburun Peninsula, therefore, this is the first occurrence of the species from these water resources of the peninsula. It is thought that this species has not been recorded since no studies have been carried out in the freshwater resources of the Karaburun Peninsula before, but because it is a part of the life cycle of the species, it is thought to have entered suitable habitats in the peninsula for feeding and survival. However, *A. anguilla* was rarely found in

Table 1. Fish data on the sampling locations of *Anguilla anguilla* in Karaburun Peninsula.

Sampling sites			Sampling dates
Locality no	**Locality name**	**Coordinates**	
1	Balıklıova Stream	38.420043, 26.589001	May 2021
2	Bozköy Reservoir	38.626234, 26.465123	-
3	Eğlenhoca Reservoir	38.526560, 26.559442	-
4	Karareis Reservoir	38.495556, 26.427778	-
5	Küçükbahçe Stream	38.562778, 26.367500	November 2020
6	Parlak Reservoir	38.613056, 26.406667	-
7	Salman Reservoir	38.583611, 26.389167	May 2021
8	Yelkentaş Stream	38.476944, 26.438333	August 2021

the freshwater bodies on the Karaburun Peninsula. Due to habitat modification and water pollution, the current situation seems compatible with the worldwide extinction of this species (Küçük, *et al*., 2018). Conversely, it can be argued that *A. anguilla* may reach the inland waters of the peninsula before the dams and physical barriers were built on the streams. There are no *A. anguilla* specimens were found in any of the four reservoirs studied (i.e., Bozköy Reservoir, Eğlenhoca Reservoir, Karareis Reservoir, and Parlak Reservoir), suggesting that the reservoirs may be preventing this species from accessing the freshwater bodies of the peninsula. As a result of the build of culverts, weirs and barriers, *A. anguilla* now inhabits only in the streams between the reservoirs and the sea. Hence, this species can't migrate across the dams built on rivers since these dams do not have fish passages.

ICES (2017) and Wgeel (2017) reports indicate that fishing and aquaculture activities represent the two most direct anthropological pressures on *A. anguilla* stocks. Furthermore, turbines of hydroelectric power plants and pumps indirectly affect fish migration, while water pollution and altered habitats contribute to the problem (Küçük, *et al*., 2018). The main reasons for the rare occurrence of *A. anguilla* stocks in the study area may be habitat loss due to human activities (e.g. Fig. 4) such as water pollution, excessive decrease in water level, destructions such as sand removal and streambed arrangements, artificial barriers such as regulators and dams, the regulation of river mouths for tourism purposes, and motor water vehicles (Küçük, *et al*., 2018). A decrease in *A. anguilla* stocks may also be attributed to the lack of fish passages, which are absent at all of the sites used in this study on the Karaburun Peninsula, where freshwater resources are quite limited.

Figure 4. An example of habitat degradation in the Karaburun Peninsula. Photograph by Sevan Ağdamar.

As a result of the present study, *A. anguilla* was described for the first time in the freshwater bodies of the Karaburun Peninsula. In total, only four fish samples were determined during the field surveys. We suggest to all stakeholders, as a solution-providing model application, that fish passages suitable for the study area are built, reform of up-down migrations, and reconstruction of the population of the species.

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