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-RESEARCH ARTICLE-

The Introduction of a Marine Species *Atherina boyeri* into Bayramiç Reservoir, Çanakkale

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Abstract

This study reports the first recorded instance of *Atherina boyeri* (Risso, 1810) in the Bayramiç Reservoir, located on the Karamenderes Stream. Since 2005, ichthyological researches have been carried out in the Bayramiç Reservoir by various researchers, but none of them have noted the existence of *A. boyeri* in this reservoir. In the field studies conducted between May 2016 and July 2017, a total of 98 *A. boyeri* specimens was caught. In these samplings, a 70 m long and 2 m wide beach seine net with 10 mm a mesh size was used. Although a small number of *A. boyeri* was caught during the first observation in October 2016, more individuals were observed in July 2017. The fork length of the *A. boyeri* observed was between 2.7-8.8 cm and the weight ranged between 0.06-4.31 g. The bimodal length distribution of the specimens indicates that there have been multiple incidents of adult specimens entering the reservoir and that these individuals have given birth to new offspring. The translocation of *A. boyeri* into the Bayramiç Reservoir might have been due to unauthorized introduction by fishermen or through illegal release by anglers as fish bait. However, the distribution map of *A. boyeri* in inland waters in Turkey shows significant overlap with the migration routes of big waterfowl. The waterfowl might partially be responsible for the spread of the adult specimens across short distances.

Keywords:
Invasive marine species, establishment, dispersion, fisheries, spread.

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Introduction

Turkey is rich in both fish diversity and endemism (Kuru, 2004; Kuru et al., 2014). However, freshwater fish are more sensitive to environmental threats than marine species. Invasive species are one of the most serious biotic environmental threats when introduced to new ecosystems, either intentionally or accidentally, and may cause direct or indirect negative consequences on the ecosystem that they enter by contributing to habitat loss and degradation (Innal, 2012; Innal & Erk'akan, 2006; Tarkan et al., 2015). When invasive species have a suitable habitat, it is easier for them to establish themselves into their new environments (Lockwood et al., 2007; Tarkan et al., 2012). Reservoirs built on streams change the dynamic structure and form lentic systems in the stream (Gozlan et al., 2010; Pringle, 2003). These stagnant water systems create suitable environments for biota, which prefer lentic environments. Thus, the modified inland water systems offer new opportunities for the introduction and spread of alien species (Tarkan et al., 2012). The reservoirs built on stagnant water systems can create suitable habitats for even marine/brackish species, such as big-scale sand smelt *Atherina boyeri* (Risso, 1810).

A. boyeri is generally distributed among the stagnant water systems of the Mediterranean coast, the Black Sea, the Azov Sea and the Caspian Sea (Kottelat & Freyhof, 2007). Although their natural distribution areas are marine and transition water systems, they have entered into freshwater resources and are described as alien species in these habitats (Tarkan et al., 2014). The first recorded finding of *A. boyeri* in Turkey's fresh waters was reported in the Lake Sapanca (Battalgil, 1941). After a long time, the species was identified in the Lake Durusu (Özuluğ, 2008), the Aslantaş Reservoir, the Obruk Reservoir, the Kılıçkaya Reservoir, the Süreyyabey Reservoir, the Babaoğlu Reservoir (Kırankaya et al., 2016), the Devegeçidi Reservoir (Ünlü et al., 2017), the Süreyyabey Reservoir (Benzer, 2018) and the Seyhan Reservoir (Çevik et al., 2018). It has been noted that this species has been introduced into some inland waters in Turkey by fishermen, either accidentally or deliberately because introducing the species can have economic value (Gençoğlu & Ekmekçi, 2016; Innal & Erk'akan, 2006; Küçük et al., 2009). In Turkey, *A. boyeri* has become a prominent commercial fishing species after successfully establishing itself in various new habitats. *A. boyeri* is now the second most economically important species, consisting of 19.2% of the total inland commercial fishing catch, according to the data of 2000-2013 (Atalay et al., 2017). It is unknown whether this species has been successfully established in the Bayramiç Reservoir and whether it has similar economic importance in that region. The early records regarding fish species in the Bayramiç Reservoir show that the species that existed in this habitat included *Cyprinus carpio*, *Capoeta tinca*, *Squalius cephalus* and *Scardinius erythrophthalmus* (Çolakoğlu & Akyurt, 2011). There were several studies in the Karamenderes Stream, where the Bayramiç Reservoir is located (Partal & Yalçın Özdilek, 2017; Yalçın Özdilek, 2017; Yalçın Özdilek & Jones, 2014) but none of them recorded finding specimens of *A. boyeri* individuals in the Karamenderes river system, including in reservoirs.

The length-weight frequency distribution and growth parameters of a population of a non-native species in a new ecosystem is partly an indicator of the success of the species' establishment in the new environment (Cushing, 1987). The length-weight relationships measured in the fish can provide information about the growth characteristics of the species' population (Ilhan & Gücer, 2018; Petrakis & Stergiou, 1995). The positive allometry means that fish especially grow in mass more than in length (Ricker, 1975) and positive allometry is also an indicator of growth performance (Vaccaro et al., 2004). On the other hand, condition factor is also good indicator of growth (Bagenal, 1978) and high growth performance with the high condition factor may contribute to understand establishment success of a species in a community. The aim of this study is to provide a new record of data and to determine establishment success of *A. boyeri* in the Bayramiç reservoir using the length-weight frequency distribution of the specimens. Thus, this study will reveal that altered stream ecosystems provide opportunities for the establishment of alien species. Additionally, the study will discuss possible pathways for the introduction of this species in the region.

Material and Methods

The samplings were carried out on a monthly basis between May 2016 and July 2017 in the Bayramiç Reservoir on the Karamenderes Stream of Çanakkale (Figure 1). The Karamenderes Stream originates from the Kaz and Ağı Mountains and flows into the Dardanelles. The flow rate is 65-1530 m^3 (min.-max.) and approximately 115 km in length (Yalçın Özdilek & Jones, 2014). The Bayramiç Reservoir has an area of 5.84 km^2, body volume of 3.82 hm^3, and a height of 45.5 m. As sampling tool, a seine-net (2 m - 70 m) was used. Photographs of the samples captured in the Bayramiç Reservoir are presented in Figure 2.

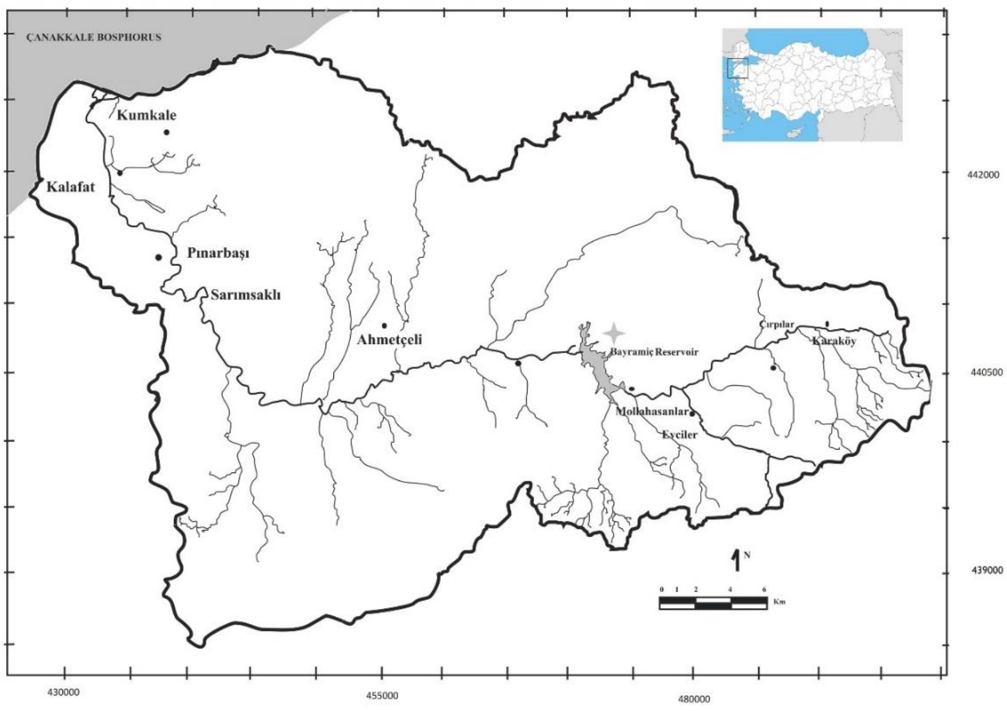

Figure 1. The map of Bayramiç Reservoir (adapted from Partal & Yalçın Özdilek, 2017).

Figure 2. *A. boyeri* image.

Fork lengths (L) of the samples were measured on a scale of 0.1 mm. Weights (W) were measured on the scales with a precision of 0.01 g. Fulton's condition factor was calculated as $C = 100*W/L^3$. The mean length, weight and condition factor values of the specimens in consecutive years were compared using the Student t-test and 95% confidence limits were assumed. In order to ascertain the degree of success the species has had in establishing itself in the Bayramiç Reservoir, the length-weight relationships of the samples, which are indicators of body allometry, were determined using the $W=aL^b$ equation (Bagenal, 1978). The length-weight model was transformed to a linear model by taking the natural logarithms and confidence limits of slope (b) and intercept, Log(a) were also calculated (Zar, 2010). The information obtained from the length distribution, Fulton's condition factor with the length-weight regression models (isometry/allometry) were used in order to estimate the establishment success of this species. The length distribution was estimated as a percentage of the number of each length group.

Results

A total of 98 specimens were caught in the Bayramiç Reservoir. Of these 98 specimens, 6.12% (6 specimens) were caught during October-November 2016 and 93.88% (92 specimens) were caught during the sampling in July 2017. Among all specimens, the fork lengths and the weights varied between 2.4-8.2 cm and 0.06-4.31 g, respectively. The fork lengths of the specimens caught in the October-November 2016 samples were between 4.0-6.9 cm and the weights were between 0.40-2.50 g. Among the July 2017 samples, the minimum fork length was 2.4 cm and the maximum fork length was 8.2 cm. The minimum weight among the July 2017 samples was 0.06 g and the maximum weight was 4.31 g. The length-frequency distributions of the specimens caught during all the sampling are provided in Figure 3. According to these measurements, the fork length frequency of *A. boyeri* specimens caught in the Bayramiç Reservoir was determined to be 83.3% in October-November 2016 (5 specimens) and 28.3% (26 specimens) in July 2017 (Figure 3).

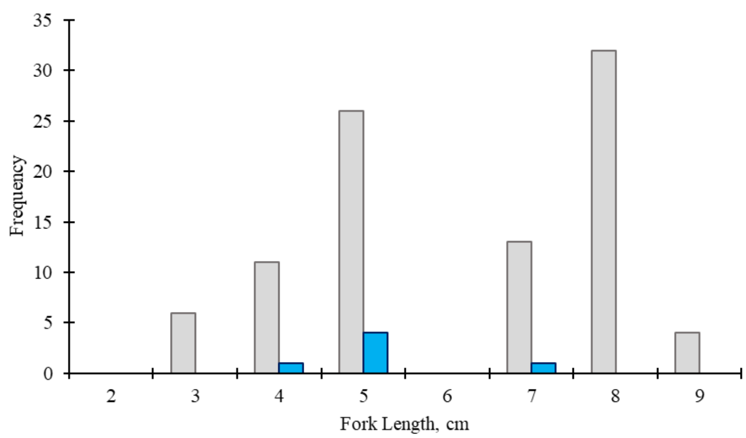

Figure 3. The length-frequency distribution of *A. boyeri* (grey columns indicates specimens capture in 2016, blue columns indicates specimens capture in 2017).

The mean fork length and mean weight of the examined specimens was 5.74 ± 1.74 cm and 1.71 ± 1.30 g, respectively. The mean fork length and of the specimens sampled in October-November 2016 was 4.76 ± 1.06 cm and the mean weight was 0.86 ± 0.81 g. Among the specimens sampled in July 2017, the mean fork length was 5.80 ± 1.76 cm and the mean weight was 1.76 ± 1.31 g. There was a significant difference between the mean lengths and mean weights of specimens sampled in the consecutive years, with greater mean lengths and weights in the second year ($t_{6,92} = 2.2$; $p < 0.05$; $t_{6,92} = 2.5$; $p < 0.05$). The mean condition factors were determined as 0.68 ± 0.09 in all specimens examined. The mean condition factors were 0.68 ± 0.15 in the 2016 specimens and 0.68 ± 0.09 in the 2017 specimens. There was no significant difference between the condition factor values of the specimens from the two consecutive years ($t_{6,92} = 0.02$; $p > 0.05$).

There was a positive allometric growth type in the length-weight relationship of *A. boyeri* specimens in both years. The b-value was determined to be 3.2556 ± 0.070 and Log(a) was -2.3587±0.053 in $W=aL^b$ equation (Figure 4). The fact that the r^2 value was close to 1 indicates a strong length-weight relationship.

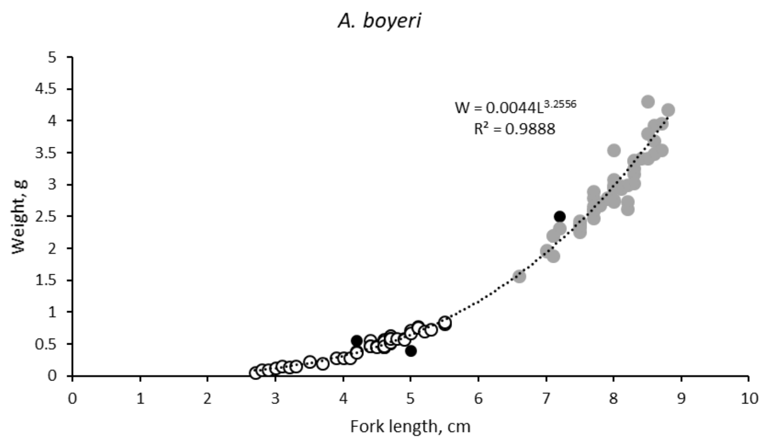

Figure 4. The length-weight relationship of *A. boyeri* from Bayramiç Reservoir. The black circles indicates specimens capture in 2016, grey circles indicates the adults and white circles indicates the juveniles in 2017.

Discussion

This study is the first recorded finding of *A. boyeri* in the Bayramiç Reservoir.The length-weight relationship is widely used in fish biology and provides some information about growth type (Wootton, 1990). In this relationship, in contrast to the isometric growth pattern (b = 3), the shape of the fish is affected by the length and weight increments, where b < 3 indicates negative allometry and b > 3 indicates positive allometry (Ricker, 1975). In general, when the fish mature, the length increment remains the same, but the weight may still increase in a positively allometric growth pattern. In Turkey, the length-weight relationship (Table 1) of the *A. boyeri* show a mostly positive allometric growth pattern (Altun, 1991; Tarkan et al., 2006; Gaygusuz, 2006; Ozeren, 2009; Kırankaya et al., 2014) such as in the specimens found in the Bayramiç Reservoir. However, *A. boyeri* specimens show negative allometry in some reservoirs and lagoons (Acarli et al., 2014; Ilhan & Sari, 2015; Tarkan et al., 2006).

Table 1. Comparison the growth characteristics of *A. boyeri* species.

Area	Length (L; min-max)	Weight (W; min-max)	Growth coefficient	Growth features	Reference
Küçükçekmece, İstanbul	3.5-11 cm (SL)		3.15	Positive allometry	Altun, 1991

Küçükçekmece, İstanbul	3.9-11.1 cm (TL)		3.31	Positive allometry	Tarkan et al., 2006 (Tarkan et al., 2006)(Tarkan et al., 2006)
Küçükçekmece, İstanbul	3.7-10.4 cm (SL)				Gaygusuz et al. 2006
Lake Iznik, Bursa	27-119 mm (TL)	0.1008-10.3646 g.	3.35	Positive allometry	Gaygusuz, 2006
Lake Iznik, Bursa	8-115 mm (TL)	0.001-11g	3.21	Positive allometry	Özeren, 2009
Lake Iznik, Bursa	2-10.6 cm (FL)	0.06-10.5 g			Çetinkaya et al., 2011
Ömerli Reservoir, İstanbul	7.7-12.9 cm (TL)		2.66	Negative allometry	Tarkan et al., 2006
Ömerli Reservoir, İstanbul	7.5-11.8 mm (SL)				Gaygusuz et al., 2006
Lake Durusu, İstanbul	95-98 mm (TL)				Özuluğ, 2008
Homa Lagoon, İzmir	3.4–10.6 cm (TL)	0.29–8.40 g	2.63	Negative allometry	Acarlı et al., 2014
Lake Marmara, Manisa	3.7-8.7 cm (TL)	0.40-5.40 g	2.91	Negative allometry	Ilhan and Sarı 2015
Lake Bafa, Aydın-Muğla	4.5-7.4 cm (SL)				Güçlü et al., 2013
Lake Eğirdir, Isparta	83.5±0.99 cm (TL-mean±SD)	3.96±0.12 g (mean±SD)			Küçük et al., 2012
Hirfanlı Reservoir, Kırşehir	40.98-110.25 mm (TL)			Positive allometry	Kırankaya et al., 2014
Hirfanlı Reservoir, Kırşehir	5.76-115.65 mm (TL)	0.01-10.48 g			Gençoğlu & Ekmekçi, 2016
Hirfanlı Reservoir, Kırşehir	24.35-107.77 mm (TL)				Gençoğlu et al., 2017
Devegeçidi Reservoir, Diyarbakır	40.3–55.1 mm (FL)	0.7-8 g			Ünlü et al., 2017
Seyhan Reservoir, Adana	66–92 mm (FL)	2.1-5.9 g			Çevik et al., 2018
Bayramiç Reservoir, Çanakkale	6.19±1.87 cm (TL)	1.71±1.3 g	3. 26	Positive allometry	This study

The positive allometric growth rate of *A. boyeri* individuals in the Bayramiç Dam indicates that they could potentially succeed in establishing themselves in this habitat in subsequent years. *A. boyeri* have a high degree of adaptation ability, mature early, have rapid growth rates (Leonardos, 2001) and prioritize growth by postponing their spawning period depending on their habitat (Henderson & Bamber, 1987). These characteristics provide this species with the ability to easily fill empty niches in the lake ecosystem. On the other hand, another invasive species, *Carassius gibelio*, has been more successful when introduced to reservoirs and easily establishes itself by using empty niches in reservoirs (Tarkan et al., 2012). *C. gibelio* was first recorded in the Karamenderes river system in 2007 (Yalçın Özdilek, 2008). The dispersion of this species from the Bayramiç Reservoir to the Karamenderes River and its ability to fill empty niches, particularly at the river mouth stations, was discussed in Yalçın Özdilek et al. (2019), but a smaller population of this species was later found in the Bayramiç Reservoir (Partal & Yalçın Özdilek, 2018). The rapid increase in the abundance of *A. boyeri*, especially in the spawning period (Henderson & Bamber, 1987), is consistent with the literature (Andreu-Soler et al., 1988; Leonardos, 2001), indicating that this species may begin to constitute a large portion of fish community in the reservoir. *A. boyeri* is widely known as a generalist species and as an opportunistic carnivore (Gençoğlu et al., 2017; Vizzini & Mazzola, 2005). Having a carnivorous feeding strategy may give

A. boyeri a particularly effective role in the top-down control of the reservoir community. On the other hand, they also feed on plankton (Copepoda Calanoida) and benthic (Copepoda Harpacticoida, Amphipoda, Isopoda) organisms (Chrisafi et al., 2007; Vizzini & Mazzola, 2005) and so may have to compete with *Alburnus cfattalus*, a species with the same feeding strategy. In this case, competitive exclusion or resource partitioning may be occurring in the reservoir. Although the first record of *A. boyeri* in the Bayramiç Reservoir has now been noted, it is recommended that the population and its effects on other species should be examined and monitored. Further studies on community interactions and the monitoring of populations in the Bayramiç Reservoir in subsequent years are recommended.

Although there were juvenile specimens smaller than 5 cm length and the adult specimens, the average 5 cm (4.7-6 cm) length specimens of *A. boyeri* was hardly observed in this population. Individuals in this length range are often considered young individuals, according to the Fernández-Delgado et al. (1988). The absence of young individuals in the Bayramiç Reservoir may be because the species had not yet reached a notable population size in 2016. It may be concluded that the individuals entering the reservoir are adults and that they entered the reservoir during the spawning period from April to July (Henderson & Bamber, 1987) and produced offspring (Gaygusuz, 2006; Gençoğlu a& Ekmekçi, 2016) which would be observed in consecutive years.

The importance of vectors in spreading alien species is well understood (Lockwood et al., 2007). In particular, migratory waterfowl resting in wetland areas can also be an effective vector for spreading some species (Hirsch et al., 2018). For example, migratory waterfowl such as *Platalea leucorodia* are known to consume *A. boyeri* (Aguilera et al., 1996). These birds are typical wetlands migratory birds. Although *P. leucorodia* are generally distributed in shallow lakes, reeds and lagoons, they are considered transit migratory birds in Turkey (Heinzel et al., 1995) and follow typical bird migration routes (as seen in Figure 5). When the distribution map of *A. boyeri* in inland waters in Turkey is examined (Ekmekçi et al., 2013), it is interesting to note that there is an overlap between the recorded locations of *A boyeri* and the locations of wetlands along bird migration routes (Çalışkan, 2008). It is known that *A. boyeri* was introduced in some of the areas illegally by fishermen, as in the case of Aslantaş and Gelingüllü Reservoirs (Kırankaya et al., 2016). However, this paper presents a hypothesis that waterfowl may also play a role in the spreading this species over short distances among watersheds that are near each other (Figure 5).

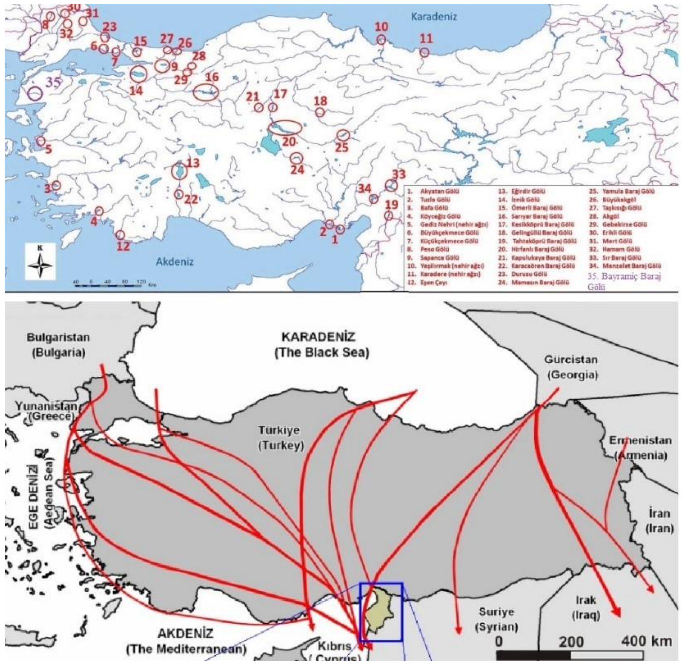

Figure 5. The distribution of *A. boyeri* n Turkey inland waters and routes of migratory birds migrating through Turkey (adapted from Çalışkan, 2008; Ekmekçi et al., 2013).

The *A. boyeri* population has not yet become commercial fish species in the Bayramiç Reservoir. The condition factor of this species is compatible with literature records in that *A. boyeri* has successfully established populations (Gaygusuz, 2006; Çetinkaya et al., 2011; Kırankaya et al., 2014). However, the growth parameter and condition values indicate that the population size of this species would be large enough to become commercially viable in the near future. However, the species interactions among populations of fish species, including predation and competition, may affect the population structure of *A. boyeri*. On the other hand, this species might be detrimental effects on the native fish fauna and food web. Therefore, the functional roles of all fish species in the reservoir community and their feeding relationships should be further investigated. The potential commercial significance or impact synthesis of invasiveness of this species in the Bayramiç Reservoir should be assessed in terms of sustainable fishing management practices and ecological approaches.

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