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# Age and Growth of Marine and Translocated Freshwater Populations of *Atherina boyeri* Risso, 1810 (Atherinidae) in Turkey

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**Abstract:** The sand smelt, *Atherina boyeri*, is a short-lived euryhaline fish that inhabits coastal and estuarine waters. It has also been illegally translocated into inland freshwater lakes and reservoirs for fisheries purposes in Turkey, and has become an invader in fresh water. The aim of this study was to compare the growth performance of translocated inland water populations and natural marine and brackish populations of *A. boyeri* in order to assess its adaptation potential to fresh water. The age, body length and weight parameters of native populations of *A. boyeri* were studied at six locations in the Mediterranean Sea, Black Sea, Sea of Marmara, Aegean Sea, and one in Köyceğiz Lake lagoon. The same parameters of translocated inland populations were studied in two reservoirs (Aslantaş and Hirfanlı) and in two freshwater lakes (Eğirdir and İznik). The findings show that *A. boyeri* exhibit similar growth performance in the marine, brackish, and fresh water studied, indicating that this species is successful in adaptation to various environmental conditions that favours its invasive potential in Turkey.

**Key words:** Sand smelt, invasive fish, inland populations, age, condition.

## Introduction

The introduction and/or translocation of fish species is a common practice worldwide, especially since the last century. Fisheries and aquaculture are among the most significant causes of intentional fish transportation (Lockwood et al. 2007, Tarkan et al. 2015). Although some introduced species provide new sources of income due to their commercial, recreational, and ornamental value, native and non-native species introductions frequently result in economic loss, both locally and globally. Today, the introduced and translocated species are considered to be among the most important human-mediated threats to the ecology and economy (Crivelli 1995, Pimentel et al. 2005, Kettunen et al. 2008, Gozlan et al. 2010).

Turkey has the richest freshwater ichthyofauna in the Mediterranean region, with approximately 380 freshwater fish species (Freyhof et al. 2014, Çiçek et al. 2016, Froese & Pauly 2019). Of these, 21 species are non-native and 28 native species are considered native translocated species (Tarkan et al. 2015). It has been reported that both non-native and translocated species can have adverse effects on native fish fauna due to their invasive characteristics (Bogutskaya & Naseka 2002); therefore, invasive species pose a serious threat to Turkey's rich freshwater fish biodiversity, in addition to such threats as pollution, excessive

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water abstraction, and overfishing (Ekmekçi et al. 2013).

The sand smelt, *Atherina boyeri* Risso, 1810 (Atherinidae), is one of the most widespread translocated species in Turkey (Ekmekçi et al. 2013, Tarkan et al. 2015). *Atherina boyeri* is naturally a marine species widely distributed throughout the north-eastern coast of the Atlantic Ocean, Mediterranean Sea, Black Sea, and Caspian Sea (Kottelat & Freyhof 2007). It is an euryhaline fish with a short life span that primarily inhabits coastal and estuarine waters. It has also been introduced into freshwater lakes and reservoirs for fishery purposes in many European countries, as well as in Turkey (Kottelat & Freyhof 2007).

*Atherina boyeri* was first observed in the Turkish freshwater systems in Sapanca Lake (Battalgil 1941) and thereafter it has been observed in the Sakarya and Menderes river basins in the 1970s (Altun 1991). After the 1990s, the species has rapidly invaded the Turkish freshwater lakes and reservoirs, including the Aksu, Kızılırmak, Seyhan, Ceyhan, and Asi river basins (Ekmekçi et al. 2013). Tarkan et al. (2015) reported that *A. boyeri* has been deliberately introduced into the Turkish inland waters for fisheries, and that it has extensive self-sustaining populations in many natural and artificial lakes in Turkey. In fact, *A. boyeri* is currently one of the most valuable commercial (exported) fish species in the inland waters in Turkey (Atalay et al. 2017).

Despite its commercial value, *A. boyeri* is considered an invasive and problematic fish species in Turkey (Tarkan et al. 2015), and its ecological and economic effects in inland waters are a cause for concern (Küçük et al. 2006, Atalay et al. 2017). It is found out that the establishment success of *A. boyeri* in different ecosystems could be related to its growth, reproductive, and feeding characteristics (Gençoğlu & Ekmekçi 2016, Gençoğlu et al. 2017). However, there are a few studies on the species life-history traits and ecological effects in native marine habitats and recipient freshwater environments with the aim to assess its potential risks to inland waters. The fact that there are only a few life-history studies on the sand smelt populations in Turkey (Gaygusuz 2006, Tarkan et al. 2007, Özeren 2009, Gençoğlu & Ekmekçi 2016, Gençoğlu et al. 2017) could be the reason why its risk ranking in freshwater systems has been considered to be moderate (Tarkan et al. 2015). Yet, a species categorisation of medium risk does not imply that it possesses no risk (Tarkan et al. 2015). For instance, Gençoğlu et al. (2017) report that *A. boyeri* may have a negative effect on the zooplankton communities in Hirfanlı Reservoir in Turkey via selective predation.

In order to determine the effect of an invasive organism on the native species and on the ecosystem functioning, observational and experimental studies are required. Monitoring the life history characteristics of an invasive fish species in different locations is a component of such research (Garcia-Berthou 2007). To prevent the spread and establishment of new populations of *A. boyeri*, and to develop management strategies for its previously established populations, its biological characteristics should be determined in different habitats.

The objectives of the present study were to evaluate and compare the variability in growth parameters among six natural marine populations, one lagoon population, and four translocated freshwater populations of *A. boyeri*, in order to assess the species adaptation potential in freshwater ecosystems. To the best of our knowledge the present study is the first to concurrently examine the age and growth parameters of *A. boyeri* in a relatively wide range of ecologically different aquatic ecosystems.

# Materials and Methods

The fish samples were collected between 2015 and 2017 from the Mediterranean Sea, Aegean Sea, Black Sea, Sea of Marmara, Köyceğiz Lake lagoon, and from multiple regions of Anatolia, including Aslantaş and Hirfanlı reservoirs, and the freshwater lakes Eğirdir and İznik (Fig. 1). The sampling was conducted at least three times at each sampling location during the spring months, when *A. boyeri* used the shores extensively. The samples were taken by a beach seine net.

The fish individuals caught were preserved in 4% formaldehyde solution and transported to the laboratory for further analysis. The total length (TL) was measured to the nearest 0.05 mm, and the weight (W) was measured to the nearest 0.001 g. The age determination was performed using scales and otoliths, and was validated using the Bhattacharya method and length frequency distribution. The scales were removed, cleansed with water, and placed on two slides, then evaluated twice by independent researchers using a binocular microscope (Lagler 1966). The sagittal otoliths were cleansed with alcohol and water, and then evaluated twice by independent researchers under a microscope in 10% glycerin solution.

The length-weight relationship (LWR) was determined using linear regression analysis. Log-

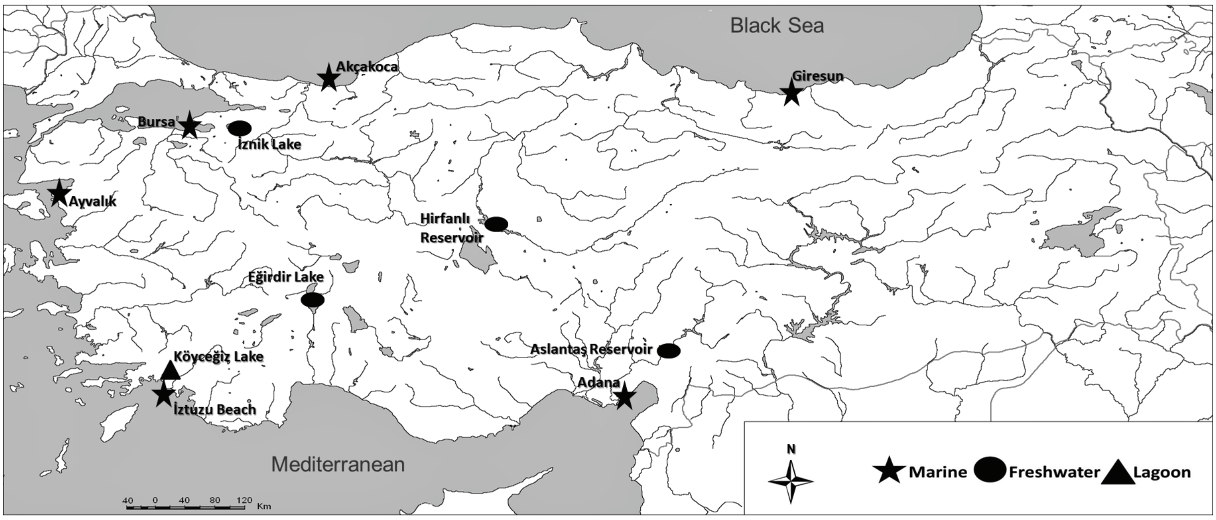


**Fig. 1.** Sampling locations of *Atherina boyeri*. The marine habitats are marked with a star, the freshwater habitats – with a circle, while the lagoon habitat – with a triangle.

transformed data were used to establish the LWR. The parameters *a* and *b* were calculated using least-squares regression (Le Cren 1951). Fulton's condition factor (K) was calculated by the equation $K=(W/L^3)\times100$, where W is the total body weight (g) and L is the total length (cm) (Le Cren 1951). Both, the comparison of the slopes of the length-weight regression between sexes and the variation in coefficient *b* from 3 were tested using Student's t-test (Zar 1999). Analysis of variance (ANOVA) followed by the Bonferroni post-hoc comparison test were performed using Microsoft Excel (2016) and Daniel's XL Toolbox add-in for Excel (version 7.3.2) to determine significance of the difference in length, weight, and condition factor values between populations and habitats.

The parameters of the von Bertalanffy growth equation ($L_\infty$ – asymptotic length; *k* – growth coefficient; $t_0$ – hypothetical age at which length is 0) and the growth performance index [$\Phi$'=2log ($L_\infty$)+log (*k*)] were calculated using the ELEFAN I method (Gayanilo et al. 1988). The physical and chemical parameters of the surface water at each sampling location, including the temperature (T), the electrical conductivity (C), and the salinity, were measured in situ using a YSI ProPlus Multiparameter water quality meter.

# Results

The sampling locations had characteristic salinity values in accordance with the Venice Symposium Salinity System Specifications for marine, brackish water, and freshwater habitats (Anonymous 1959). The salinity of marine environment was >15 ppt, versus approximately 1.5 ppt of the lagoon, and <1 ppt of freshwater environment. The conductivity exhibited a pattern similar to that of salinity; the mean values ranged between 25,167 and 55,415 µS/cm in the marine environment, from 235 to 1,551 µS/cm in the freshwater environment, while the mean value in the lagoon was 3,096 µS/cm. During the sampling period, the mean water temperature ranged from 19.60–25.57°C, 24.60°C, and 14.75–22.40°C, in the marine, lagoon, and freshwater environment, respectively (Table 1).

In total, five age groups (0+ – 4+) were identified in the populations of *A. boyeri*. The dominant age group varied between sampling locations, while regarding habitats (marine, lagoon, and freshwater), the 1+ and 2+ age groups were dominant at all habitats (Fig. 2).

The total length range was from 21.25–142.96 mm in the marine populations, 27.93–97.03 mm in the lagoon population, and 23.87–115.65 mm in the freshwater populations. Except for the İztuzu (Aegean Sea) and Adana (eastern Mediterranean) populations, the individuals of >60 mm in length were dominant (Fig. 3). The ANOVA showed that there were significant differences in length frequencies between populations and habitats: between populations: F=364.49, df=10, and $P<0.05$; between marine and freshwater habitats: F=6.05, df=1, and $P<0.05$; freshwater – lagoon habitats: F=73.66, df=1, $P<0.05$; and marine – lagoon habitats: F=57.72, df=1, and $P<0.05$). The Bonferroni post-hoc comparison also showed that there were significant differences in the length frequencies between habitats.

The body weight range was 0.04–24.18 g in

**Table 1.** Sampling locations, number of *Atherina boyeri* individuals caught (N), and physical and chemical parameters measured: water temperature (T), conductivity (C), and salinity.

| Sampling locations | | | N | T (°C) Mean ± SD | C (µS/cm) Mean ± SD | Salinity (ppt) Mean ± SD |
|---|---|---|---|---|---|---|
| Marine | Giresun (Black Sea) | N 40º 54′ 55,98″ E 38º 25′ 0,24″ | 485 | 20.50±5.23 | 26,282±2,158 | 16.15±2.52 |
| | Akçakoca (Black Sea) | N 41º 04′ 39,5″ E 31º 04′ 05,2″ | 373 | 19.60±0.99 | 25,167±950 | 17.55±0.16 |
| | Bursa (Sea of Marmara) | N 40º 22′ 46,39″ E 28º 52′ 10,83″ (Mudanya) | 291 | 19.90±4.92 | 34,725±10,981 | 23.40±5.48 |
| | | N 40º 47′ 70,46″ E 29º 08′ 38,72″ (Gemlik) | | | | |
| | Ayvalık (Aegean Sea) | N 39º 20′ 36,17″ E 26º 41′ 18,66″ | 378 | 22.33±3.44 | 55,415±11,431 | 39.13±8.43 |
| | İztuzu Beach (Aegean Sea) | N 36º 46′ 49,1″ E 28º 37′ 55,3″ | 275 | 25.57±9.13 | 38,752±18,333 | 24.75±6.39 |
| | Adana (Mediterranean Sea) | N 36º 44′ 46,2″ E 35º 38′ 06,3″ | 346 | 25.57±5.76 | 50,478±4,830 | 33.36±5.85 |
| Lagoon | Köyceğiz Lake (Muğla) | N 36º 57′ 25,6″ E 28º 40′ 24,8″ | 355 | 24.60±6.55 | 3,096±2,089 | 1.46±1.08 |
| Freshwater | İznik Lake | N 40º 22′ 56,9″ E 29º 34′ 03,1″ | 290 | 22.17±4.42 | 940±170 | 0.48±0.10 |
| | Eğirdir Lake | N 37º 52′ 53,84″ E 30º 49′ 13,13″ | 464 | 14.75±4.60 | 235±26 | 0.14 |
| | Hirfanlı Reservoir | N 39º 09′ 44,04″ E 33º 38′ 14,96″ | 369 | 19.93±4.12 | 1,551±320 | 0.83±0.15 |
| | Aslantaş Reservoir | N 37º 22′ 57,2″ E 36º 16′ 38,2″ | 409 | 22.40±9.48 | 370±10 | 0.19±0.04 |

the marine populations, 0.12–6.60 g in the lagoon population, and 0.08–10.94 g in the freshwater populations. The ANOVA showed that there were significant differences in weight frequencies between habitats: between populations: F=363.62, df=10, and $P<0.05$; between marine and freshwater habitats: F=79.36, df=1, and $P<0.05$; freshwater – lagoon: F=69.19, df=1, and $P<0.05$; and marine – lagoon habitats: F=86.65, df=1, and $P<0.05$). The Bonferroni post-hoc comparison also showed that there were significant differences in the weight frequencies between habitats.

The estimates of parameter *b* in the length-weight relationships varied between 2.77 and 3.35 in the populations, and the determination coefficient ($r^2$) values were close to 1. The difference in *b* values between the marine and freshwater populations was not significant (Student's t-test, $P>0.05$). The mean value of the condition factor ranged from 0.53 to 0.63 in the marine populations, from 0.53 to 0.61 in the freshwater populations, and it was 0.52 in the lagoon population (Table 2). There were significant differences in the condition factor between populations and habitats (ANOVA): between populations: F=51.61, df=10, and $P<0.05$; between marine and freshwater habitats: F=627.66, df=1, and $P<0.05$; freshwater –lagoon: F=2400.13, df=1, and $P<0.05$; and marine – lagoon habitats: F=4890.16, df=1, and $P<0.05$). The Bonferroni post-hoc comparison also showed that there were significant differences in the condition of *A. boyeri* between habitats. The growth coefficient (*k*) range was from 0.16–0.79 in the marine populations, 0.23–0.49 in the freshwater populations, and 0.29 in the lagoon population. The growth performance index values ranged from 7.67 to 9.96 in the marine populations, from 8.14 to 8.89 in the freshwater populations, and it was 8.10 in the lagoon population (Table 2).

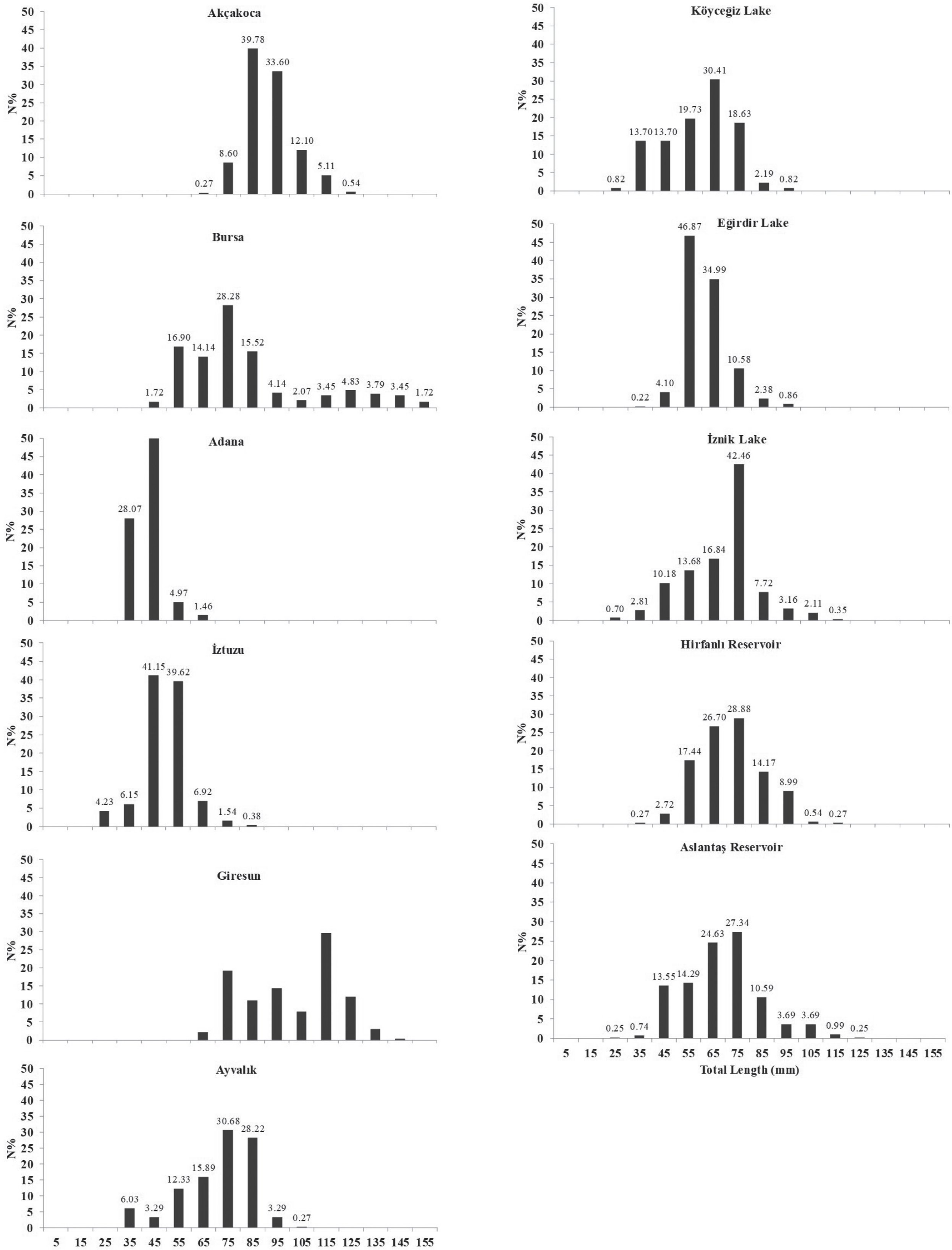


**Fig. 2.** Age distribution of *Atherina boyeri* at the studied locations. N – number of individuals (percentages, %); Age (years).

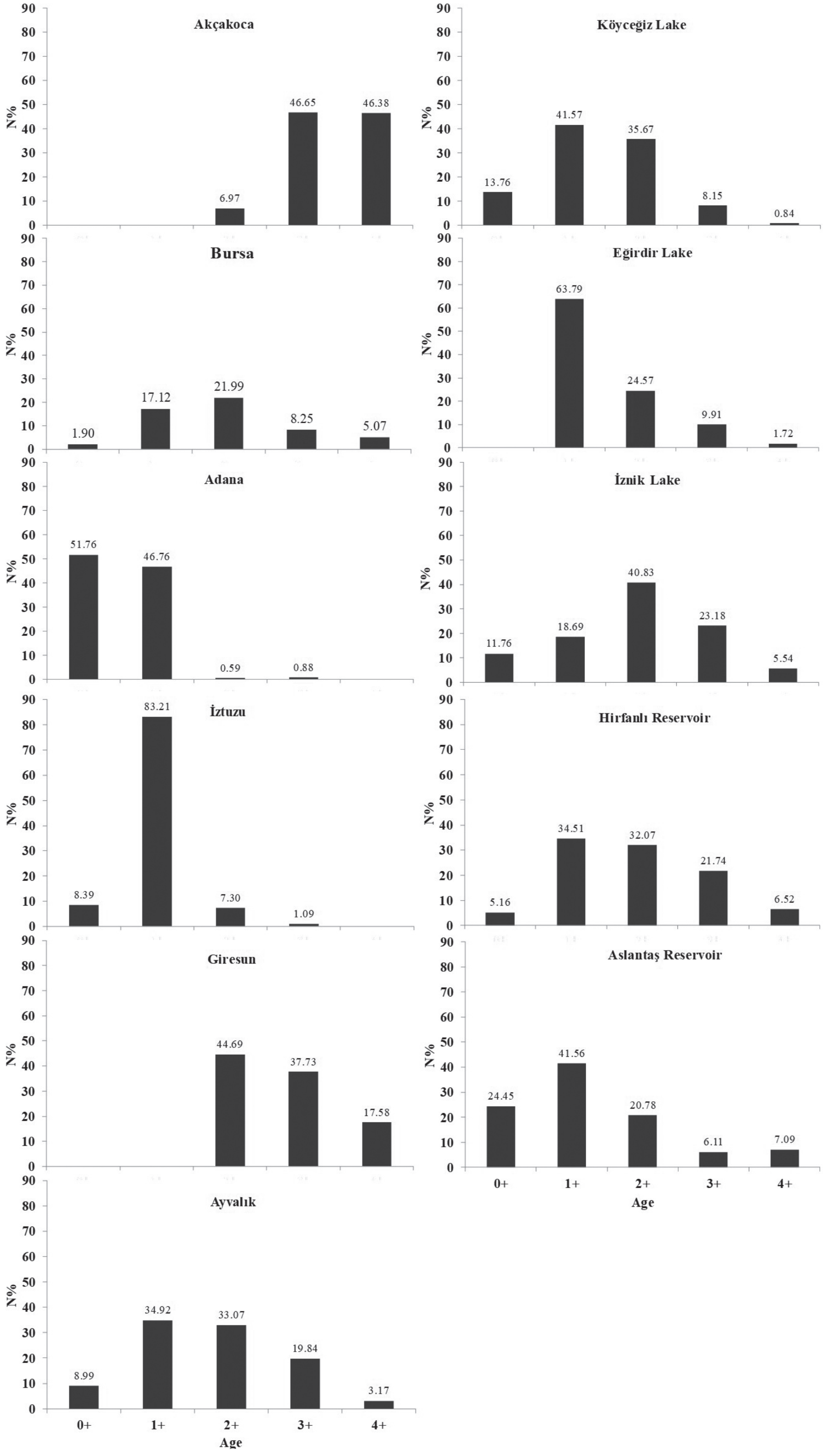


**Fig. 3.** Length frequency histograms of *Atherina boyeri.* N – number of individuals (percentages, %); Total length (mm).

**Table 2.** Estimated length-weight relationship and von Bertalanffy parameters, as well as growth performance indices of *Atherina boyeri* populations at the studied locations. TL – total length; W – total body weight; a and b – parameters of the equations; $r^2$ – coefficient of determination; * – exponent *b* differed significantly from 3; $L_\infty$, *k* and $t_0$ – parameters of the von Bertalanffy equation. For further explanation, please see Materials and Methods.

| Sampling locations | | TL (mm) | | W (g) | | Regression parameters | | | | Condition factor (Mean±SD) | The von Bertalanffy growth equation parameters | | | Growth performance index |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Min | Max | *a* | *b* | $r^2$ | *t*-value | | $L_\infty$ (cm) | *k* | $t_0$ | |
| **Marine** | Giresun | 54.45 | 142.96 | 1.13 | 17.24 | -1.904 | 2.767 | 0.957 | 10.13* | 0.59±0.07 | 14.3 | 0.36 | -0.20 | 8.90 |
| | Akçakoca | 69.77 | 129.77 | 1.85 | 17.87 | -2.351 | 3.271 | 0.905 | 4.297* | 0.63±0.07 | 13.6 | 0.55 | -0.57 | 9.23 |
| | Bursa | 43.18 | 139.24 | 0.52 | 24.18 | -1.953 | 2.776 | 0.992 | 20.36* | 0.62±0.08 | 16.4 | 0.79 | -0.84 | 9.96 |
| | Ayvalık | 33.36 | 102.43 | 0.24 | 5.90 | -2.293 | 3.119 | 0.980 | 5.17* | 0.56±0.07 | 12.8 | 0.16 | -0.34 | 7.87 |
| | İztuzu | 21.25 | 83.71 | 0.04 | 3.80 | -2.454 | 3.353 | 0.978 | 11.39* | 0.53±0.07 | 9.9 | 0.42 | -0.82 | 8.33 |
| | Adana | 33.48 | 69.13 | 0.20 | 2.01 | -2.275 | 3.075 | 0.929 | 1.63 | 0.53±0.06 | 9.6 | 0.23 | -0.91 | 7.67 |
| **Lagoon** | Köyceğiz Lake | 27.93 | 97.03 | 0.12 | 6.60 | -2.355 | 3.206 | 0.953 | 5.57* | 0.52±0.09 | 10.6 | 0.29 | -0.66 | 8.10 |
| **Freshwater** | İznik Lake | 27.21 | 115.65 | 0.08 | 9.79 | -2.279 | 3.131 | 0.9658 | 5.17* | 0.59±0.09 | 12.1 | 0.49 | -0.95 | 8.89 |
| | Eğirdir Lake | 34.43 | 95.45 | 0.39 | 6.67 | -2.233 | 3.075 | 0.941 | 1.965* | 0.53±0.10 | 10.9 | 0.29 | -0.62 | 8.14 |
| | Hirfanlı Reservoir | 38.64 | 113.20 | 0.34 | 10.94 | -2.160 | 3.011 | 0.917 | 0.23 | 0.56±0.07 | 14.1 | 0.23 | -0.27 | 8.43 |
| | Aslantaş Reservoir | 23.87 | 115.35 | 0.11 | 9.64 | -2.247 | 3.106 | 0.978 | 4.61* | 0.61±0.07 | 16.0 | 0.23 | -0.37 | 8.68 |

# Discussion

Populations of *A. boyeri* in marine, brackish, and fresh water are exposed to several environmental stressors and such widely-fluctuating conditions as salinity, conductivity, and temperature. Although salinity and temperature are thought to be the primary environmental constraints that directly or indirectly affect fish communities (Wootton 1994), in the present study the factors with the greatest effects on the growth performance of *A. boyeri* are salinity and conductivity because of the compulsory osmoregulation adaptation.

Except for the Black Sea populations, the age composition of the marine, brackish and freshwater populations of *A. boyeri* does not differ significantly. The length-frequency distribution of *A. boyeri* follows a similar pattern as the age composition; larger individuals are predominant in the Black Sea populations, whereas smaller individuals dominate in other populations. Our findings and those reported in previous studies indicate that the life span of *A. boyeri* covers a short period of up to 4+ years (Altun 1986, Creech 1992, Rosecchi & Crivelli 1992, Bozdağ 1999, Leonardos & Sinis 2000, Andreu-Soler et al. 2003, Bartulović et al. 2004a, Koutrakis et al. 2004, Pombo et al. 2005, Sezen 2005, Gaygusuz 2006, Küçük et al. 2006, Tarkan et al. 2007, Özeren 2009, Patimar et al. 2009, Keskin & Gaygusuz 2010, Bök et al. 2011, Gürkan et al. 2014, Sevinç 2014, Apaydin Yağci et al. 2015, İlhan & Sari 2015, Gençoğlu & Ekmekçi 2016). In addition to the short life span, *A. boyeri* is also known to have early maturation and the ability to spawn repeatedly (Creech 1992, Rosecchi & Crivelli 1992, Patimar et al. 2009. Gençoğlu & Ekmekçi 2016). Early maturation and multiple spawning are typical characteristics of the invasive species, along with a short life span (Bogutskaya & Naseka 2002, Grabowska & Przybylski 2014).

The exponent *b* in the length-weight relationship in the present study varies between 2 and 4, but often is a value close to 3; a value of 3 indicates isometric growth and values other than 3 indicate allometric growth (Tesch 1971). The present findings show that positive allometric growth ($b>3$, $P<0.05$) is common in the marine, lagoon, and freshwater populations of *A. boyeri* in Turkey, whereas the growth model is negative allometric in two marine populations (Giresun and Bursa: $b<3$ and $P<0.05$), and isometric in two freshwater populations (Adana and Hirfanlı: $b=3$ and $P>0.05$). In other words, the weight increase rates are slightly lower than the length increase in the Giresun, Bursa, Adana, and Hirfanlı populations, although there is a similar growth rate in other native and translocated populations. The LWR can be indicative of spatial and temporal variations related to water temperature, food availability, and reproductive activity (Wootton 1994). The LWR parameters *a* and *b* are affected by a number of factors, including sex, gonad maturity, health status, season, habitat, nutrition, environmental conditions as temperature and salinity, stomach fullness, general fish condition, differences in length range of fish individuals, and collection gear (Tesch 1971, Froese 2006). According to the present findings, growth performance of *A. boyeri* is not affected by the environmental conditions, especially, salinity in the freshwater habitats, in contrast to our expectations.

Studies on population dynamics have shown that high values of the condition factor indicate favorable environmental conditions, including habitat and prey availability (Blackwell et al. 2000). The condition factor of *A. boyeri* in different habitats with varying salinity shows similar values in the present study. Moreover, condition factor values in different habitats reported previously (Bozdağ 1999, Gaygusuz 2006, Özeren 2009, Gençoğlu & Ekmekçı 2016) are similar to our findings. Differences in the condition factor of each population in the present study could be considered indicative of the feeding conditions. *Atherina boyeri* is primarily a zooplanktivorous fish species with opportunistic feeding behaviour, which prefers the most abundant and large organisms in different ecosystems (Gon & Ben-Tuvia 1983, Mantilacci et al. 1990, Danilova 1991, Rosecchi & Crivelli 1992, Trabelsi et al. 1994, Bartulovic et al. 2004b, Chrisafi et al. 2007, Doulka et al. 2012, Apaydin Yağci et al. 2013). For example, in Hirfanlı Reservoir, a freshwater sampling location in the present study, *A. boyeri* prefers large food organisms, such as cladocerans, copepods, and even its own larvae, in accordance with variations in seasonal abundance of these organisms, and avoids small rotiferans even though the rotiferans are abundant throughout the year (Yiğit & Altındağ 2005, Gençoğlu et al. 2017).

Other studies on the feeding behaviour of *A. boyeri* have shown that when the zooplankton is scarce due to a season or habitat, this species tends to feed on benthic organisms depending on their abundance (Rosecchi & Crivelli 1992, Trabelsi et al. 1994, Bartulovic et al. 2004b). Due to this favoured feeding behaviour, it could be expected that *A. boyeri* consumes the most available and beneficial food organisms with the lowest energy cost; therefore, feeding conditions that could be challenging and unfavorable for growth performance of many other fish species do not affect the growth performance of *A. boyeri* in different habitats.

The von Bertalanffy equation parameters and growth performance index values for *A. boyeri* in marine environments have not been calculated in earlier studies (Bozdağ 1999, Keskin & Gaygusuz 2010, Bök et al. 2011, Gürkan et al. 2014) and, therefore, comparisons with the present study cannot be made. However, our findings are similar to those of previous studies on populations in lagoons (Creech 1992, Rosecchi & Crivelli 1992, Leonardos & Sinis 2000, Andreu-Soler et al. 2003, Bartulović et al. 2004a, Koutrakis et al. 2004, Pombo et al. 2005, Sezen 2005, Patimar et al. 2009) and fresh water (Altun 1986, Gaygusuz 2006, Küçük et al. 2006, Tarkan et al. 2007, Özeren 2009, Sevinç 2014, Apaydin Yağci et al. 2015, İlhan & Sari 2015, Gençoğlu & Ekmekçı 2016). The von Bertalanffy equation parameters for *A. boyeri* populations in both the present and previous studies indicate that these parameters are not significantly affected by habitat differences.

The translocation of any given species to a new environment can induce changes in its life-history traits, especially if an increase in energy cost (e.g., for physiological regulation, survival, escaping new predators and foraging) is involved (Rosecchi et al. 2001). In the present study, the growth parameters, including condition factor, LWR, and von Bertalanffy growth parameters, at 11 sampling locations, are in general similar despite the significant differences in salinity and conductivity. The observed similarity in growth performance might have been due to the physiological tolerance and adaptation success of *A. boyeri*. This species is known to live along the coast of the seas surrounding Anatolia and in its lagoon systems. Hengeveld & van den Bosch (1996) suggest that the rate of spread is higher when a species has been introduced to an environment close to its native range. This may explain the rapid expansion and dispersal of *A. boyeri* as the lower parts of rivers connected with the seas or the lagoon provide suitable habitats for *A. boyeri*. Many atherinids, especially *A. boyeri*, have a high degree of intraspecific morphological variability that can be linked to their native estuarine and lagoon habitats. Such habitats are physically highly variable which has resulted in the atherinid morphology, physiology, and behaviour adapting to a wide range of conditions. This plasticity pre-adapts the atherinids to invade fresh waters (Bamber & Henderson 1988). The present findings suggest that the invasive success of *A. boyeri* is facilitated by its ability to tolerate salinity changes via physiological plasticity. Despite of the salinity changes no significant variation in the growth performance of this species has been observed. Further studies are required to determine more clearly the role of the physiological tolerance of *A. boyeri* for its invasive success and potential effects on the ecosystems.

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