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Age, Growth and Reproductive Biology of the Sand Smelt *Atherina boyeri*, Risso 1810 (Pisces: Atherinidae) in Lake Iznik, Turkey

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Abstract: The age, growth and reproductive properties of sand smelt, *Atherina boyeri* Risso 1810, caught from Lake Iznik (Northwest Turkey) were studied by sampling carried out between March 2000 and February 2001. A total of 922 specimens were examined. The age of this species varied from 0-IV and they were composed of 43.6% females, 25.3% males and 31.1% unidentified. The mean total length and weight of the individuals ranged from 12.6-98.2 mm and 0.02-6.89 g, respectively. The Von Bertalanffy Growth Parameters (VBGP) of the population were: L_∞ = 141.11 mm, K = 0.27 year^{-1}, t_0= -0.49 years for all individuals. Length-weight relationships were estimated as $W = 0.002\ TL^{3.485}$ for females and $W = 0.004\ TL^{3.062}$ for males. The sex ratio of males to females was 1:1.7. The spawning period recorded from March to July, with a peak in May. The diameter of ripe eggs ranged from 0.60-1.10 mm. Fecundity was calculated as 450 (1st age group) to 1724 (4th age group) eggs/females.

Key words: *Atherina boyeri*, age, growth, reproduction, Iznik lake

INTRODUCTION

The sand smelt, *Atherina boyeri* Risso 1810 is short-lived and euryhaline teleost fish, which usually inhabits coastal and estuarine waters as well as lagoons, salt marshes, shallow brackish waters (Andreu-Soler *et al*., 2003; Patimar *et al*., 2009) and more rarely inland waters from freshwater to hypersaline (Henderson and Bamber, 1987). The species, *A. boyeri* is a wide distribution including Mediterranean and adjacent seas, the Black Sea and the Atlantic coast of Spain to Mauritania and Madeira (Pombo *et al*., 2005; Patimar *et al*., 2009). Quignard and Pras (1986) reported that some isolated populations have been found on the coast of England and the Netherlands.

The age, growth, mortality, reproductive and feeding biology of this species has been investigated by several workers, from the upper Adriatic Sea (Boscolo, 1970), brackish water ponds and lagoons of Herault (Kohler, 1976) and Arcachon (Castel *et al*., 1977) in France, Aral Sea (Markevich, 1977), Bardawil lagoon on the Mediterranean cost of Sinai (Gon and Ben-Tuvia, 1983), English Channel (Henderson and Bamber, 1987), estuary of the Guadalquivir River in Spain (Fernandez-Delgado *et al*., 1988), Aberthaw Lagoon on the Bristol Channel in South Wales (Creech, 1992), brackish lagoons of Southern France (Tomasini *et al*., 1996), Mesolongi and Etolikon lagoons in the West Greece (Leaonardos and Sinis, 2000) in the Pantana Lagoon, Croatia (Pallaoro *et al*., 2002), Mar Menor coastal lagoon in the Southeastern Iberian Peninsula (Andreu-Soler *et al*., 2003), estuarine system of Northern Greece (Koutrakis *et al*., 2004), estuary of the Mala Neretva River in the South-Eastern and Middle-Eastern Adriatic, Crotia (Bartulovie *et al*., 2004a, b; 2006), estuarine lagoon in the Ria de Averio on the west coast of Portugal (Pombo *et al*., 2005), semi-enclosed basin in the Stagnone di Marsala, Western Mediterranean and the Gomisland wetland in the southeast Caspian Sea (Patimar *et al*., 2009).

Moreover, Tutman *et al*. (2000) gave some information on the occurrence of spinal deformities in natural populations of sand smelt in the Neretva River estuary, eastern Adriatic. There is little information on the biology of sand smelt from freshwaters (Rosecchi and Crivelli, 1992; Leonardos, 2001).

In Turkey, the sand smelt, *A. boyeri* is the most commercialized species, which is exported to abroad from Lake Iznik. The aim of this study was to determine the age, growth and reproductive biology of *A. boyeri* population in Lake Iznik.

MATERIALS AND METHODS

Iznik lake (40°26'N-29°32'E) is the 5th largest natural and tectonic origin freshwater lake in Turkey with a maximum length of 32 km, maximum width of 12 km and total area is 300 km^2. Surface area of Iznik lake is 29.830 ha. Iznik lake was classified as oligothrophic, but now, it turns of the mesotropic because of the organic

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pollution resulting of agricultural activity and domestic waste. The most important rivers feeding the lake are Karasu, Kirandere and Sölöz. The flow of Iznik lake is towards to the Gulf of Gemlik (Lahn, 1948).

Samples of sand smelt were collected monthly from March 2000 to November 2001, using a beach seine (800 m long and 5 mm mesh size) by professional fishermen. It was difficult to catch any specimens after October because the sand smelt dig down deep when the water temperature decreased. Totally 922 fish specimens were caught and transferred to the laboratory where total length (mm) measured to the nearest 0.1 mm and body weight (g) to the nearest 0.01 g. The age of the specimens was determined by scales. The sex was determined by examination of the gonad macroscopically. The length-weight relationship was calculated for all specimens and for each sex separately, according to the equation given by Ricker (1975):

$$W = a \times Tl^{b}$$

Where:
W = The weight in grams
TL = The total length in centimeters
a and b = Constants

The Condition Factor index (CF), which describes the condition of a population was estimated according to the equation given by Le Cren (1951):

$$CF = W/L^{3} \times 10^{5}$$

Where:
W = The weight (g)
L = The total length (mL)

Theoretical growth in length were estimated by fitting the Von Bertalanffy Growth Function (VBGF) to the mean length at age for all specimens, for males and for females described as:

$$L_t = L_\infty (1-e^{-K(t-to)})$$

Where:
L_t = The length at age t
K = The growth coefficient t_0 hypothetical age at birth

Growth performance, Phiprime ($\acute{\text{O}}$) expressed as (Sparre and Venema, 1998):

$$\acute{\text{O}} = \text{InK} + 2\text{ln}L_\infty$$

The gonads were removed and weighed to the nearest 0.01 g. The reproductive period was examined by means of monthly changes in the Gonadosomatic Index (GSI), which was calculated by using the formula (Wooton, 1990):

$$GSI = \frac{\text{Gonads weight}}{\text{Total weight}} \times 100$$

Egg diameter was measured to the nearest 0.05 mm by using digital caliper taken randomly from pieces of the ovary of 216 ripe females. The number of eggs was estimated by the gravimetric method using ovaries preserved in 4% formaldehyde (Crim and Glebe, 1990).

Statistical significance between growth, condition factor and gonadosomatic index for the males and females within the same age groups was tested by ANOVA and t-test, which were performed with SPSS 10 software package and a significant level 0.05 was accepted.

RESULTS

Age composition of the sand smelt, *A. boyeri*, from 922 specimens, caught from Iznik lake was between 0-4. According to the percentage occurrence of the age groups, 0 was the dominant (31.1%) and it was followed by the age group 4 (22.8%), 3 (18.9%), 2 (18.3%) and 1 (8.9%). Besides, the percentage occurrence of age groups (1-4) was 7.1, 3.7, 8.0, 6.5% in males and 1.8, 14.6, 10.7 and 16.3% in females, respectively.

Of the 922 specimens ranged in size and weight from 8.0-115.0 mm TL and 0.001-11.0 g respectively, 233 were males (25.3%), 402 were females (43.6%) and 287 unidentified (31.1%). Male TL ranged from 30.0-110.0 mm and females from 42.0-115.0 mm. Dominant length class in the total specimens (n = 922) was 15.0-19.0 mm, it was 65.0-74.0 mm for males and 75.0-79.0 mm for females (Fig. 1). Moreover, weight distribution was found to range from 0.1-9.0 g for males and from 0.5-11.0 g for females.

The relationship between total length and weight were $W = 0.004 \times L_T^{3.209}$; $R^2 = 0.978$; N = 922 for the entire population, $W = 0.004 \times L_T^{3.062}$; $R^2 = 0.933$; N = 233 for males and $W = 0.002 \times L_T^{3.485}$; $R^2 = 0.911$; N = 402 for females. The results of statistical analyses showed significant differences between males and females (t-test, $p<0.05$). The values b for males (3.062), for females (3.485) and both sexes (3.209) displayed a positive allometric growth.

Mean Condition Factor (CF) varied from 0.41 (July 2000) to 0.79 (March 2000) for all sand individuals, whereas, it was 0.59 (July 2001) to 0.80 (March 2000 and April 2001) for males and 0.64 (July 2001) to 0.78 (April 2000) for females (Fig. 2). The minimum condition factor recorded July 2000 (average 0.41), because of the 0 age groups.

The Von Bertalanffy Growth Functions (VBGF) were estimated as $L_\infty = 141.11$ mm, K = 0.27 year^{-1}, $t_0 = -0.49$ years for all individuals; $L_\infty = 121.11$ mm, K = 0.33 year^{-1}, $t_0 = -0.28$ years for males and $L_\infty = 155.31$ mm, K = 0.21 year^{-1}, $t_0 = -0.73$ years for females. The mean

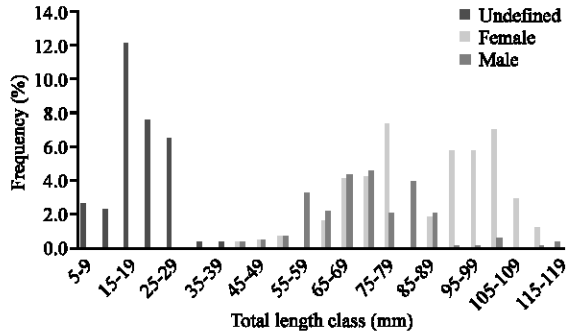

Fig. 1: Total length (mm) frequency of *Atherina boyeri* in Iznik lake

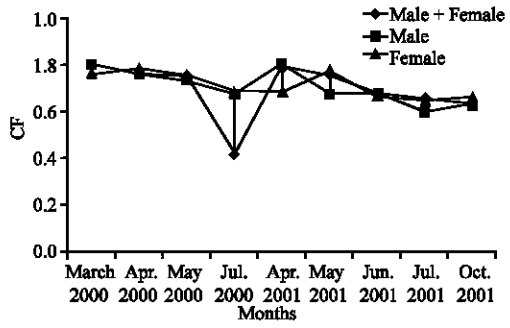

Fig. 2: Monthly mean Condition Factor (CF) variation of *Atherina boyeri* in Iznik lake

back-calculated total lengths of each age group were higher than the observed total lengths (Table 1). According to the back-calculations, growth was rapid in the first year of life-span. Females grew faster than males (Fig. 3), but the `Ø value for males (3.98) was slightly higher than that of females (3.89).

A total of 922 sand smelt individuals were caught from Iznik lake and 635 of specimens were sexed of which 233 (25.3%) males and 402 (43.6%) females. The sex ratio of sand smelt was 1:1.7 (M:F), with the proportion of females higher than that of males and the ratio of males and females shown significantly different from the ratio 1:1 ($p<0.05$). Gonads were macroscopically visible for individuals >30.0 mm TL for males and >42.0 mm TL for females. The sexual maturity age of both males and females is 1.

The Gonadosomatic Index (GSI), which is used to determine the reproductive period, was calculated from 233 males and 402 females. The highest average GSI values for the whole study period were recorded 11.02 and 11.72 for males and females, respectively in May 2000. The spawning period of sand smelt population in Lake Iznik extended from March until July with a peak in May (Fig. 4). The diameter of egg, which is correlated with GSI

Table 1: Mean observed and back-calculated total lengths (mm) for age of *Atherina boyeri* in Iznik lake, Turkey

Age (years)	0	1	2	3	4
Sexes combined					
Mean observed TL (mm)	12.6	43.7	67.1	77.1	98.2
Mean back-calculated TL (mm)	17.4	46.5	68.7	85.7	98.7
Males					
Mean observed TL (mm)	-	42.0	65.8	77.3	92.6
Mean back-calculated TL (mm)	-	42.2	64.6	80.6	92.1
Females					
Mean observed TL (mm)	-	47.0	70.0	76.8	99.3
Mean back-calculated TL (mm)	-	47.9	68.5	85.1	98.6

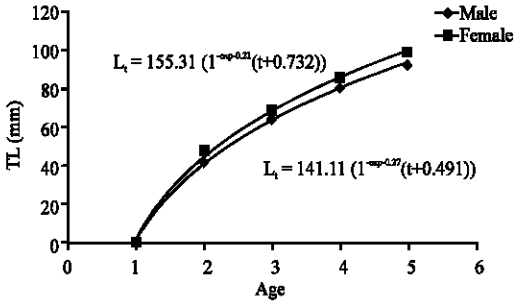

Fig. 3: The growth parameters of *Atherina boyeri* in Iznik lake

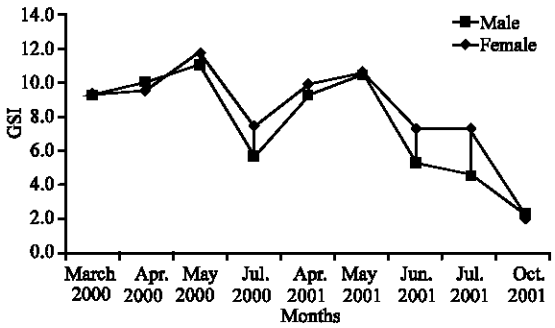

Fig. 4: Monthly mean Gonadosomatic Index (GSI) variations of *Atherina boyeri* in Iznik lake

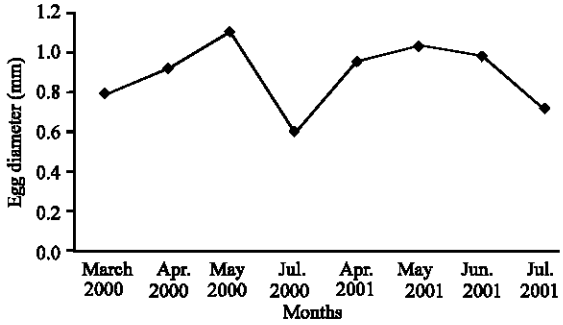

Fig. 5: Monthly mean egg diameters variations of *Atherina boyeri* in Iznik lake

value was calculated as 1.10 in May 2000 (Fig. 5). Fecundity was estimated from 216 ripe females, which

ranged from 46.5-98.2 mm TL and 0.55-7.17 g. Fecundity increased when the fish length, weight, gonad weight and age increased. According to this, relative fecundity was calculated 450 eggs female^{-1} (1st age group), 754 eggs female^{-1} (2nd age group), 1490 eggs female^{-} (^{1}3rd age group) and 1724 eggs female^{-1} (4th age group).

DISCUSSION

The sand smelt, *A. boyeri* is a commercial fish species in Iznik lake. The life span of sand smelt is short and five age classes (0-4) were observed. A similar age classes were reported from the English Channel (Henderson and Bamber, 1987), Trichonis lake, Western Greece (Leonardos, 2001) and Pantana Lagoon, Croatia (Pallaoro *et al*., 2002), Vistonis lake and Porto Lagos Lagoon, Northern Greece (Koutrakis *et al*., 2004), while a shorter life cycle (3 and 4 age classes) was reported from the Bardawil Lagoon, Sinai (Gon and Ben-Tuvia, 1983), Mesolongi and Etolikon lagoons, Greece (Leaonardos and Sinis, 2000), Mar Menor coastal lagoon, Iberian Peninsula (Andreu-Soler *et al*., 2003), Mala Neretva River, Croatia (Bartulovie *et al*., 2004a), Ria de Averio, Portugal (Pombo *et al*., 2005) and Gomishan wetland, Southern Caspian Sea (Patimar *et al*., 2009). Bartulovie *et al*. (2004a) mentioned that the life span of sand smelt is longer in the colder than in the warmer seas. Moreover, Henderson and Bamber (1987) indicated that sand smelt, *A. boyeri*, population can adapt its life span and morphology to environmental condition and growth and maximum size can reduce along an oceanic-coastal-estuarine-freshwater habitat range. The maximum observed total length and weight of sand smelt populations in Iznik lake were 110 mm and 9.0 g for males and 115.0 mm and 11.0 g for females, respectively. Similar results were reported by Leonardos (2001) and Bartulovie *et al*. (2004a). The exponential relationship between total length and weight indicated a positive allometric growth (b >3). The b-value estimated of the sand smelt population from the other studies (Leaonardos and Sinis, 2000; Leonardos, 2001; Andreu-Soler *et al*., 2003; Bartulovie *et al*., 2004a; Koutrakis *et al*., 2004 and Patimar *et al*., 2009) showed a positive allometric growth, while Gon and Ben-Tuvia (1983) reported a negative allometric growth from the Bardawil Lagoon, Sinai population where the salinity of water is 40-110% (hyperhaline) as 2.93. Patimar *et al*. (2009) mentioned that the variation 'b' values between populations can be affected differently, because of the geographic location and environmental conditions.

In this study, growth parameters fitting the von Bertalanffy growth parameters were calculated as L_{∞} = 141.11, K = 0.27 year^{-1} and t_0 = -0.49 year for combined sexes in Iznik lake and the value of L_{∞} was estimated higher in females than in males. In comparison with previous studies, similar L_{∞} value was estimated from the English Channel (Henderson and Bamber, 1987), Vistonis estuarine system, Greece (Koutrakis *et al*., 2004) and Gomishan wetland in the Caspian Sea (Patimar *et al*., 2009), whereas Gon and Ben-Tuvia (1983) calculated the lowest L_{∞} = 42 mm in the Bardawil Lagoon population (Table 2). The differences between the growth parameters from one region to another can be resulted from the habitat diversity, quantity of food, climatic factors and the physic-chemical contents of the water, which directly affected the biology of fishes. Everhart (1981) expressed that growth in fish is affected by species and age, amount of food, competition of food between species, prey-predator relationships, sexual maturity age, size, water temperature and amount of dissolved oxygen.

The overall sex ratio was 1:1.7 (M:F) and significantly different from the ratio 1:1 ($p<0.05$). In the previous study, the overall sex ratio was 1:1.24 in the Mesolongi and Etolikon lagoons (Leaonardos and Sinis, 2000), 1:1.30 in the Mala Neretva River system (Bartulovie *et al*., 2004a), 1:1.25 in an estuarine system of Northern Greece (Koutrakis *et al*., 2004), 1:1.30 in the Gomishan Wetland (Patimar *et al*., 2009) in favor of females. The minimum total length of the mature males and females was 30.0 and 42.0 mm, respectively. In comparison with previous studies, the smallest mature female was 34.0 mm in the Mesolongi and Etolikon lagoons (Leaonardos and Sinis, 2000) and 52.0 mm TL in the Mala Neretva River (Bartulovie *et al*., 2006). The sexual maturity age group of sand smelt, *A. boyeri*, population caught from Iznik lake was 1 for both sexes. Gon and Ben-Tuvia (1983) pointed out that the sand smelt population from the Mediterranean coast of Sinai Peninsula reached sexual maturity at an age of 2-3 months and they also expressed that this species is a batch spawner. The spawning period of the sand smelt in Iznik lake extends from March-July. Fernandez-Delgado *et al*. (1988) observed a maximum spawning period from May to July, Leaonardos and Sinis (2000) in March to the end of July and Patimar *et al*. (2009) in March to July. Fernandez-Delgado *et al*. (1988) mentioned that two spawning periods were found (from April to July and in September) in the Atlantic sand smelt investigated by Castel *et al*. (1977). The differences in the spawning period can be changed because of the latitude and climatic conditions (Fernandez-Delgado *et al*., 1988). According to Nikolskii (1980), the spawning properties of a fish alter in relation to the species and ecological characteristics of water system, which they inhabit.

Table 2: Comparison of the growth parameters (L_∞, K, t_0, 'Ø) of the *Atherina boyeri* in Iznik lake with previous studies

Study area	Sex	L_∞ (TL mm)	K (year^{-1})	t_0 (years)	'Ø	References
English Channel	M + F	138.00	0.70	-	9.49	Henderson and Bamber (1987)
Bardawil Lagoon, Sinai	M + F	42.00	2.93	-	8.55	Gon and Ben-Tuvia (1983)*
Aberthaw Lagoon, South Wales	M + F	92.00	-	-	-	Creech (1992)*
Mesolongi and Etolikon lagoons, Western Greece	M	74.97	0.67	-0.460	8.23	Leaonardos and Sinis (2000)
	F	84.58	0.81	-0.650	8.66	
Trichonis lake, Western Greece	M + F	112.46	0.42	-0.400	8.58	Leonardos (2001)
Mar Menor Coastal Lagoon, SE Iberian Peninsula	M	81.90	0.91	-0.450	8.72	Andreu-Soler *et al.* (2003)
	F	84.58	0.81	-0.650	8.66	
Estuary of the Mala Neretva River, Croatia	M	99.14	0.97	-0.190	9.16	Bartulovie *et al.* (2004a)
	F	105.77	1.19	-0.006	9.50	
Vistonis estuarine system, Northern Greece	M	128.09	0.26	-1.640	9.36	Koutrakis *et al.* (2004)
	F	166.54	0.16	-1.900	8.40	
Gomishan wetland, Souteast Caspian Sea	M	155.17	0.28	0.740	8.82	Patimar *et al.* (2009)
	F	162.77	0.27	0.730	8.87	
Iznik lake, Northwest Turkey	M	121.13	0.33	-0.290	7.95	Present study
	F	155.31	0.21	-0.730	7.78	

*Using SL (mm); M: Male; F: Female

In Iznik lake, the maximum GSI was reached in May for both sexes, whilst it was in April from brackish lagoons of Southern France (Bartulovie *et al*., 2006) and in March in the Gomishan wetland, Caspian Sea (Patimar *et al*., 2009). The egg diameter, which is related to Gonadosomatic Index (GSI) varied from 0.60-1.10 mm. The observed size of eggs were 1.34-1.94 mm in the Maugio, Perols and Mejean brackish lagoons of southern France (Tomasini *et al*., 1996) and 0.03-2.00 mm in the Gomishan Wetland, Caspian Sea (Patimar *et al*., 2009). Patimar *et al.* (2009) indicated that the great heterogeneity in egg size of sand smelt, *A. boyeri*, occurred due to the batch spawner behavior. Fecundity of sand smelt ranged from 450 (1st age group) to 1724 eggs female^{-1} (4th age group). Rosecchi and Crivelli (1992) reported that fecundity per spawning increased with size and weight of the female. It is also known that fecundity is affected by age, size, species, feeding, season and environmental conditions.

CONCLUSION

A. boyeri, which is an euryhaline species, population caught from Iznik lake shows a great variation in growth and reproduction properties from many other populations in its distribution range. Leonardos (2001) mentioned that sand smelt is well-adapted in variable habitats because of its high degree of pheonotypic plasticity. Revealed the biology of sand smelt population in Iznik lake, which is the 5th biggest freshwater natural lake in Turkey is very important to plan the fishery strategy in relation to its commercial value.

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