

SEX STRUCTURE AND FECUNDITY OF PONTIC SHAD (*ALOSA IMMACULATA* BENNETT, 1835) IN THE BULGARIAN SECTOR OF DANUBE

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Abstract

RAIKOVA-PETROVA, G., S. VELIKOVA and N. HAMWI, 2013. Sex structure and fecundity of Pontic Shad (*Alosa immaculata* Bennett, 1835) in the Bulgarian sector of Danube. *Bulg. J. Agric. Sci.*, Supplement 1: 88–93

The catches were made in April and May 2010 and 2011. The smallest mature male was two years with a length of 15.5 cm and a weight of 38 g, while the largest was 5 years with a length of 27.6 cm and a weight. The smallest female was with a length of 18.3 cm, weight of 54 g and age of 2 years and the largest had a length of 28.9 cm, weight of 264.5 g at 4 years. All age groups were dominated by males. They presented 70.65% of the fishes in 2010 and 93.08 % – the 2011 ratio of total population was ♂: ♀ = 84.86: 15.14 (%) is true different from 1: 1 because as $\chi^2 = 24.30 < \chi^2_{st} = 43.77$ (P = 0.95). The absolute fecundity of Pontic shad ranged from 3 287 to 93 829. The weighted average fertility of the entire population was 41 814 eggs. The relationship between length (L), weight (W), age (t) and fecundity (F) is described by the equations $F = 112\,910 \ln L - 330\,768$, $r = 0.98$; $F = 206.76 W - 9775.2$, $r = 0.99$ and $F = 4860t + 27234$, $r = 0.436$, respectively.

Key words: Pontic shad, sex structure, fecundity, Danube River

Introduction

Pontic Shad (*Alosa immaculata*) is the largest representative species of the family Clupeidae in the Black Sea. It is object of commercial fishing. Its number is constantly decreasing under the anthropogenic pressure. Data on Pontic shad in Bulgarian water area were published by Kovachev (1923), Drenski (1923, 1931, 1951, 1958), Kolarov (1958 a, 6; 1960 a, 6; 1962, 1964, 1965, 1978, 1979, 1980, 1982, 1983, 1991), Kolarov, Prodanov (1983), Stoianov et al. (1963), Marinov (1966), Karapetkova, Penchev (1973), Karapetkova (1974, 1975, 1976), Pehlivanov (1999), Sivkov (2000, 2003), Karapetkova et al. (2003), Trichkova et al. (2006), Shlyakhov and Daskalov (2009).

According to the Ministry of Agriculture and Food, in the period 2003–2011, the annual catch of Pontic shad in the Black Sea and the Danube has dropped an

average of 3.5 times. Targeted research on the reproduction of the species in the Bulgarian water areas have not been performed over the last 20 years.

The purpose of this paper is to determine the gender structure and fertility of the Pontic shad in the Bulgarian section of the Danube.

Material and Methods

The material was collected from three points of the Danube near the town of Lom. Two hundred fifty one fishes were caught in April and May 2010 and 2011 during their breeding migration. Catches have been conducted by trammel nets with mesh sizes from 32 to 88 mm and a length of 50 m.

Length was measured to the end of the scaly cover (L) with an accuracy of 1 mm. The total weight (W) and

the gutted weight (w) was measured with an accuracy of 1 g. Gonads were weighed with an accuracy of 0.0001 g.

The age of the fish was determined by the annual rings of the scales using a projector Documator, Carl Zeiss, Jena, at magnification 17.5 x.

Size-sex structure is studied according Anohina (1969). Statistical accuracy of the sex ratio was established using χ^2 – criteria (Lakin, 1973). $\chi^2 = (p - p')^2/p'$, where p is empirical, and p' is the corresponding theoretically expected (in this case 50%) ratio. If $\chi^2 > \chi^2_{st}$ null hypothesis is rejected.

Absolute individual fecundity (F) was determined by the weighing method.

The relative fecundity (RF) was determined in two ways:

1. RF = F/w (F – number of eggs; w – gutted weight);
2. RF = b (coefficient by the equation F = a + bw)

Results and Discussion

Period of reproduction

In 2010 and 2011 breeding began in early April, one to two months earlier than in the 60^s years of the last century (Kolarov, 1962, 1965).

Migration of the Pontic shad depends on the water temperature, which stimulates the maturation of sex products. Water temperature 4–5°C is sufficient for the first movements of breeding herd to the Black Sea and then to the mouth of the Danube River (Svetovidov, 1952, Kolarov, 1960 b). Migration starts when the water level in the Danube rises (Ciolic, 1998, 2004). Peak migration is during April-May at 9–17°C, and the end is in June-July at 22–26°C (Năvodaru, 1998, 2001).

Sex structure of the population

In the catch from 2010 and 2011 are four age groups (2, 3, 4 and 5 years old specimens) were presented. The most numerous were the second and third age group, 133 and 97 numbers respectively (Table 1). The most numerous are the size classes from 17 to 17.9 (46 numbers) and from 18 to 18.9 (37 numbers). In 2010, 4 and 5 years individuals were very small, 19 and 2 individuals resp. In the catch of 2011, there was no fish from the fifth age group.

The smallest mature male was two years with a length of 15.5 cm and a weight of 38 g, and the larg-

Table 1

Size-sex structure of the Pontic shad's population in the Bulgarian sector of Danube River

Size classes (cm)	Age (t, years)							
	2		3		4		5	
	♂	♀	♂	♀	♂	♀	♂	♀
15–15.9	2		2					
16–16.9	13							
17–17.9	34		12					
18–18.9	16	1	20		1			
19–19.9	7	2	5	3				
20–20.9	6	4	2					
21–21.9	5		3	1	1			
22–22.9	2		2		1			
23–23.9	4							
24–24.9	2		2		2			
25–25.9	2		5		3		1	
26–26.9	5		12	3	4	1		
27–27.9	8	2	7		2	2	1	
28–28.9	6	4	9	4		2		
29–29.9	1	5	1	1				
30–30.9	1	1		1				
31–31.9				1				
37–37.9			1					
Sum	114	19	83	14	14	5	2	–
%	45.42	7.57	33.07	5.58	5.58	1.99	0.80	–

est was five years with a length 27.6 cm and weight 243 g. The smallest female specimen size was 18.3 cm, weighed 54 g at the age of 2 years, and the largest had a length of 28.9 cm, weight 264.5 g at the age of 4 years.

In all age groups males was dominated. They were 70.65% of the studied fishes in 2010 and 93.08% in 2011. The ratio of population was ♂: ♀ = 84.86: 15.14 (%) or 5.61: 1.

The predominance of males in the catches is differently from 1:1, since $\chi^2 = 24.30 < \chi^2_{st} = 43.77$ (P = 0.95). The prevalence of the male Pontic shad in our results is due to catch the beginning of the breeding season for this section of the Danube, as males come first to the spawning places.

In Romanian catch in 2000–2001, there were specimens one year older than in our catch – from two to six years (Ciolic and Patriche, 2004). Three and four years old fishes predominated (77.35%), also one year older

than ours.

According Ciolac and Patriche (2004) from various stations on the Romanian side of the Danube, the sex ratio was 1:1. In the Black Sea Kolarov (1960a) and Kalayci et al. (2007) also published data on the ratio ♀: ♂ = 1:1 – 57.02%: 42.98% and 53.75%: 46.25%, respectively (Table 2).

Absolute fecundity

Individual absolute fecundity of shad ranged from 3287 to 93 829. The smallest fertility (3287 eggs) was recorded in case of a female with a length of 19 cm,

Table 2

Sex ratio of shad's populations in the area of *Alosa immaculata*

Water basin, authors	♀ (%)	♂ (%)
Danub River 2010, 2011 г. (our data)	15.14	84.86
Black Sea 1956, 1957 (Kolarov, 1960 a)	57.025	42.975
Danub River (Ciolac, Patriche, 2004)	49.875	50.125
Black Sea (Kalayci et al., 2007),	53.75	46.25

weight of 58 g and age of two years. The highest fertility (93 829 eggs) was case of a female with a 26.4 cm, weight of 317 g, and age of four years. The weighted average fertility of the whole population was 41 814 eggs.

The absolute fertility established by Svetovidov

(1964) is three times higher – ranging from 20 800 to 289 400 eggs. This difference is most likely due to the absence of older fish in our catch.

The average absolute fecundity increases naturally by increasing the length of the body – from 4692 eggs at size class 18–19.9 cm to 53 108 eggs at size class 30 – 31.9 cm (Table 3).

The average absolute fecundity in different weight classes is presented in Table 4. The lowest average fecundity was at size class 50.1–150 g (5450 eggs), and the highest was in the size class 300.1–450 g (59 296 eggs).

The average absolute fertility in different age groups is shown in Table 5. The lowest average fecundity was at age of 2 years (3287 eggs) and highest was at age of 4 years (93 829 eggs).

Dependence of the fecundity of length, weight and age

With increasing length (L), weight (W) and age (t) there is a clear trend of increasing absolute fecundity (F). The degree of relatedness of these values is very high ($r = 0.98 - 0.99$).

The relationship between length (L) and fecundity (F) is best described by a logarithmic function (Fig. 1).

$$F = 112910 \ln L - 330768, r = 0.98 \text{ (Figure 1)}$$

Table 3

Absolute fecundity (F, eggs) of Pontic shad *Alosa immaculata* in different size classes (cm)

Size classes	Average length, L, cm	Average weight, W, g.	Range of fecundity	Average fecundity, F, eggs	Numbers, n
18–19.9	19.2	69.7	3287–7322	4 692	6
20–21.9	20.5	84	3995–11 709	6 359	5
26–27.9	27	260	28 463–93 829	48 068	8
28–29.9	28.86	270.69	20 051–69 926	46 775	16
30–31.9	30.63	321	40 579–66 326	53 108	3

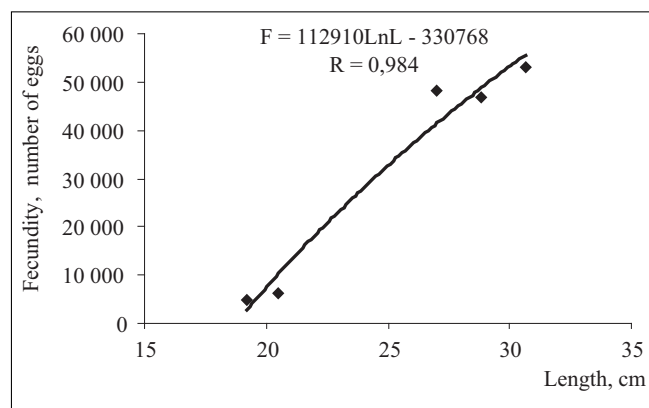
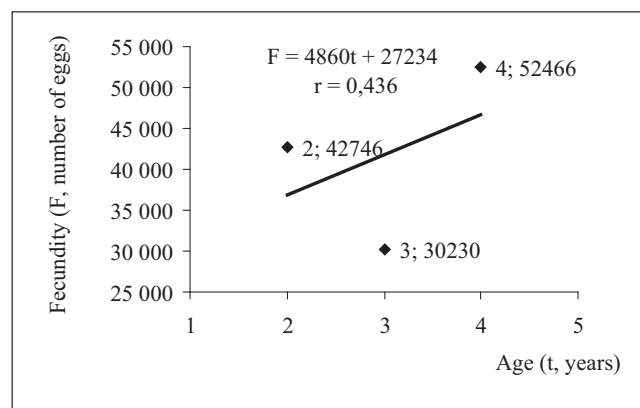
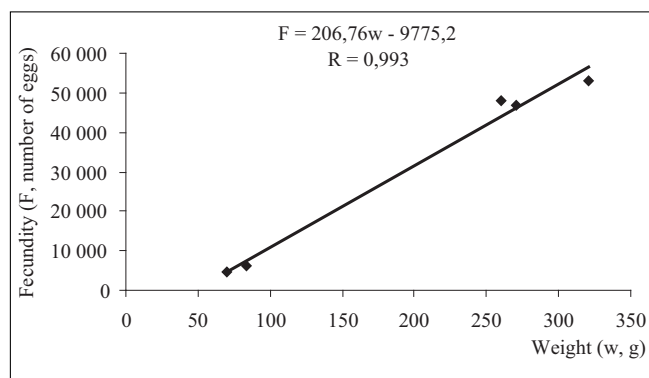
Table 4

Absolute fecundity (F, eggs) of Pontic shad *Alosa immaculata* in different weight classes (W, g)

Weight class, g	Average weight, g	Average gutted weight, w, g	Absolute fecundity, F, eggs		Gonad's average weight, g	Numbers, n
			Range	Average		
50.1–150	76.18	67.55	3287–11 709	5 450	3,22	11
150.1–300	258.31	227.371	28 463–69 926	45 418	23,18	21
300.1–450	324.5	270	40 579–93 829	59 296	32,16	6

Table 5**Absolute fecundity (F, eggs) of Pontic shad *Alosa immaculata* in different age group**

Age group, t, years	Average length, L, cm	Average weight, W, g	Range of fecundity	Average fecundity, F, eggs	Numbers, n
2	25.5	198.87	3287–69 926	35 997	19
3	25.9	217.36	5154–66 326	30 230	14
4	27.82	277.58	28 463–93 829	52 467	5

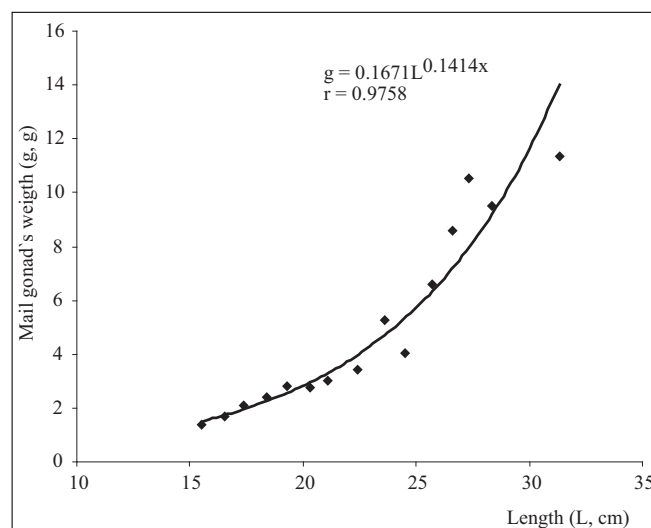
**Fig. 1. Relationship between fecundity (F, eggs) and length (L, cm)****Fig. 3. Relationship between fecundity (F, eggs) and age (t, years)****Fig. 2. Relationship between fecundity (F, eggs) and gutted weight (w, g)**

The relationship between fecundity and weight (F / W), and fertility and age (F / t) are described by the following linear functions:

$$F = 206.76w - 9775.2; r = 0.99 \text{ (Figure 2)}$$

$$F = 27234 + 4860t; r = 0.436 \text{ (Figure 3)}$$

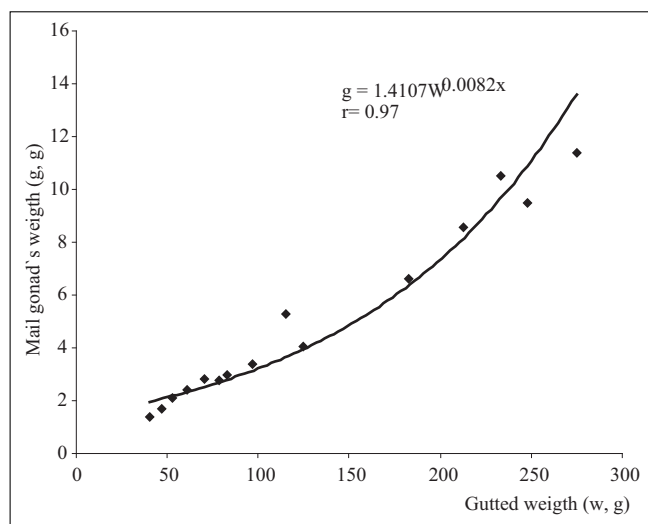
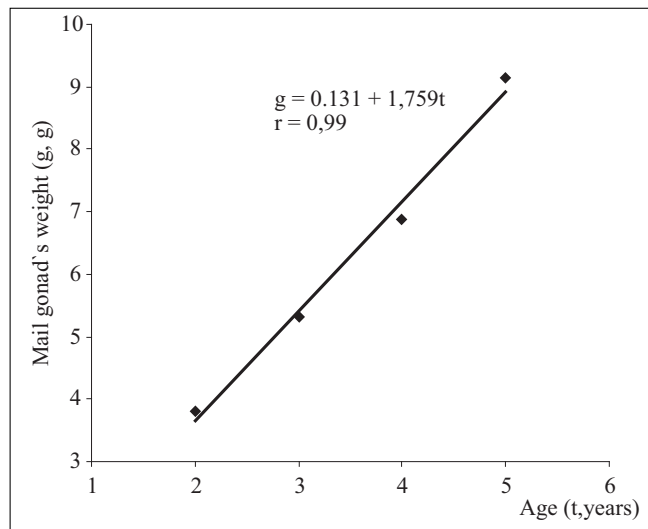
In male fish with increasing length (L), gutted weight (w) and the mass of the gonads (g) also increases. The degree of relatedness of these values is very high ($r = 0.98 - 0.99$).

**Fig. 4. Relationship between mail gonad's weight (g, g) and length (L, cm)**

The relationship between length (L) and weight of gonads (g) in male fish is best described by the exponential function $g = 0.1671L^{0.1414x}$ for $r = 0.97$ (Figure 4). The relationship between weight (w) and the mass of the gonads (g) in male fish is best described with the following function $g = 1.4107w^{0.0082w}$, $r = 0.97$ (Fig. 5).

Table 6**Relative fecundity of *Alosa immaculata* in different weight classes**

Weight classes, g	Average weight, W,g	Average fecundity, eggs	Relative fecundity, RF	Numbers, n
50.1–150	76.18	5450	71.54	11
150.1–300	258.31	45 418	175.83	21
300.1–450	324.5	59 296	182.73	6

**Fig. 5. Relationship between mail gonad's weight (g, g) and gutted weight (w, g)****Fig. 6. Relationship between mail gonad's weight (g, g) and age (t, years)**

The relationship between age (t) and the mass of the gonads (g) in male fish is best described with the following function $g = 0.131 + 1.757t$, $r = 0.99$ (Figure 6).

Relative fecundity

The relative fecundity as a relation F/w was 143.37 and as a coefficient of the dependence $F = a + bw$ was 206.76.

With increase of the average weight of the fish the average relative fecundity increased from 71.54 to 182.73 (Table 6).

Conclusions

Pontic shad in Bulgarian aquatories matures sexually at earliest in the species range – at age of two years with a minimum length of 19 cm and weight of 58 g.

The mature part of the Pontic shad's population in the Danube River during April-May 2010-2011 was composed from four age groups (from 2 to 5 years old specimens).

The weighted average fertility of the population was 41814 eggs.

The ratio between male (♂) and female (♀) individuals in the breeding part of the population was statistically different from 1:1 as $\chi^2 = 24.30 < \chi_{st}^2 = 43.77$ ($P = 0.95$).

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