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ESTIMATION OF GROWTH PARAMETERS AND MORTALITY RATE OF PONTIC SHAD (*ALOSA IMMACULATA*, BENNETT, 1835) IN THE ROMANIAN SECTOR OF THE DANUBE RIVER, KM 169 - KM 197

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Abstract

Alosa immaculata represents one of the most appreciated fish, mainly due to the high nutritive quality of meat. This study aimed to investigate the age, structure, growth and mortality parameters for Pontic shad population in the Romanian sector of the Danube River (km 169- km 197). Sampling was carried out from March to June 2020 during the migration season. According to the age, distribution varied from 2 to 7 years, being dominated by 4-year-old fish. Using the ELEFAN program in the FiSAT II computer package, the growth parameters based on length-frequency analysis were: FL_∞=43.05, and K=0.51 year^{-1}. The length-weight relationship (L - W) was $W = 0.069 \times L^{2.400}$ (R^2 = 0.77). Total mortality (Z) had a value of 2.32, while the natural mortality (M) was 0.77 year^{-1} at an annual average temperature of 14.52˚C. The fishing mortality was computed as F = Z – M and had a value of 1.55 year^{-1}.

Key words*: Alosa immaculata, growth, weight, age, mortality, von Bertalanffy equation.*

INTRODUCTION

Alosa immaculata lives in the Black Sea and Azov Sea and migrates into the Danube and in others rivers tributary to the Black Sea and Azov Sea, Dnieper, Dniester, Don and Kuban for spawning. The migration starts in spring when the water temperature reaches 3.0-7.5°C, peaks in April-May when the water temperature reaches 9-17°C and ends in June-July, at 22-26°C (Schmutz, 2006; Năvodaru, 1997; Năvodaru, 1998). The Pontic shad migrates to spawn at three years, but according to Năvodaru (1998), frequently are found fish even at 4-5 years at the first reproduction. In Romania, most of the spawning occurs between kilometers 180 and 500 of the Danube River.
Unfortunately, the population registered a declining trend and, according to the IUCN Red List of Threatened Species, the species is classified as vulnerable (VU) (Freyhof and Kottelat, 2008). Between the major threat to the species, overfishing, pollution, climate change, and dam construction which has led to the loss of large areas of spawning grounds, conducted to a decrease of Pontic shad stocks (Kottelat & Freyhof, 2007). Knowledge of more information related to the age structure, growth parameters, and mortalities rates of a fish population offers the possibility to gather information about fish stocks, which are needed to understand the fish population response to environmental changes and the stock dynamics (Tribuzio et al., 2009; Wells et al., 2013). Also, this information is useful for the implementtation of fisheries management policies for sustainable fishery (Evans et al., 2015). Therefore, understanding the dynamics population of the Pontic shad is crucial for stock assessment and conservation.
In this study, population parameters such as the growth, mortality, and exploitation rate for Pontic shad caught in the Romanian sector of the Danube River, km 169 - km 197, were investigated.

MATERIALS AND METHODS

Study area. The fishing area was situated between km 169 of the River (Brăila) and km 197 of the River (Gropeni) (Figure 1). From the studied data, it seems that this sector is the most important for the reproduction of Pontic shad.

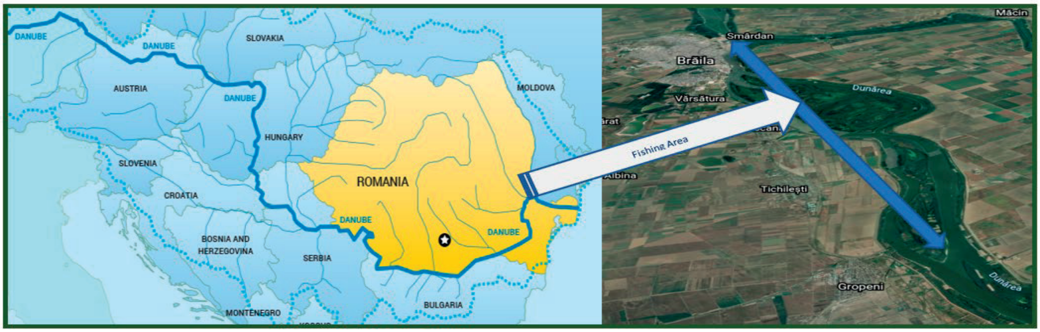

Figure 1. Reasearch area - km 169 (Brăila) and km 197 (Gropeni- Brăila)
Source: https://sos.danubis.org/eng/country-notes/romania/and google maps

Data collection. Fish samples were collected from scientific and commercial fishing. The fishing gear used was the shad gill nets, with a 30-32 mm mesh size. Samples were collected in the year 2020 during March - June 2020. In total, it was collected and sampled a number of 685 fish.

All fishes were measured for total length with an ichthyometer (±1 mm precision) and weighed with an electronic scale (±0.01 g precision).

At the same time, ten scales were removed from the anteromedial part of the body above the lateral line. The age was determined by reading the rings' annual growth on the scales using a stereo microscope with 1×10 magnification (Bagliniere et al., 1992; Yilmaz and Polat, 2002) (Figure 2).

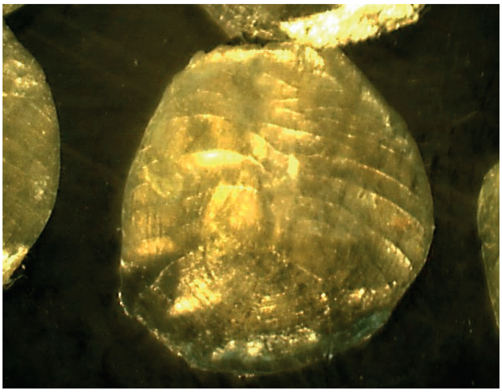

Figure 2. Age determination of Pontic shad
(original photo)

Data analysis. For data analysis, we used the software package FiSAT II (FAO - ICLARM Stock Assessment Tool) and Microsoft Excel 2019.

The length-weight relationship (L-W) for the whole population, females, and male, was estimated using the equation $W=a \times L^b$, where: W - total body weight (g), L - total length (cm), "a" -intercepts and "b" the slope.

Also, in order to evaluate the status of the "well-being" of the Pontic shad population, we calculate the Fulton coefficient, $K = (W/L^3) \times 100$ where: K = coefficient of Fulton; W=fish individual weight; L = length of the fish body (Ricker, 1975).

The growth and mortality parameters. The growth parameters (L_∞, k, t_0) were calculated for the whole population by the length-frequency analysis using the ELEFAN model. The t_0 was estimated using the following equation according to Pauly (1979):

$$\mathrm{Log}(-t_0) = -0.392-0.275\,\mathrm{Log}L_\infty -1.038\,\mathrm{Log}K.$$

To realize the length distribution for the study period, all the length measurements were grouped into 0.5 cm length classes. The resulting length-frequency distribution was then used to estimate the population parameters like growth and mortality rates.

The total mortality rate (Z), natural mortality rate (M), fishing mortality rate (F), and rate of exploitation (E) were estimated according to Pauly (1980) and Pauly (1983).

Total mortality (Z) was computed using the length converted catch curve analysis method in the FiSAT II computer software package.

The natural mortality (M) determination was calculated with the empirical formula developed by Pauly (1980): Log(M) = -0.0066-0.279 log ($L\infty$) + 0.6543 log(K)+0.4634 log(T), where: K and L_∞ are the growth parameters from Von Bertalanffy Growth function, T°C - is the average temperature from the Danube, which in our study was 14.50°C.

The *mortality determination through fishing (F)* has resulted from the difference between total mortality (Z) and natural mortality (M) (F = Z-M) (Gayanilo et al., 2003; Sparre and Venema, 1992). Also, we calculate the *exploitation rate (E)*, which is the report between fishing mortality and total mortality (E = F/Z) (Ricker, 1975). If the exploitation rate is under 0.5, the stocks are easily exploited, but if the values of E are 0.5-1, the stocks are heavily exploited.

RESULTS AND DISCUSSIONS

Length-frequency distribution and age structure. Of the 685 fish caught, 509 were females (74.31%) and 176 males (25.69%). Total length ranged from 23.9 cm to 41.5 cm, with significant differences between females and males ($p<0.05$).

The results are in line with those reported for Pontic shad in a previous study carried out by Ibănescu et al. (2017), on the same fishing area in 2009 (total length was between 24 and 39 cm, with an average value of 31.11 cm, while the individual weight was between 100 g and 400 g with a mean value of 276.72 g).

The females have a maximum total length of 41.5 cm and weight of 695 g, while the male maximum total length was 41 cm and weight of 565 g. However, the statistical analysis (T-Test) revealed significant differences between the total length and weight of females and males ($p<0.05$) (Table 1).

Information regarding the sex ratio (total numbers of females/total number of males) is important for understanding the relationship between fish and the reproductive potential of a population (Vicentini and Araujo, 2003). The female: male ratio was 1:0.34. Our results are in line with those reported for this species (1:0.51) by Năstase et al. (2018) for the Danube River, but lower than the sex ratio (1:0.62) reported by Țiganov et al. (2018) for the Black Sea.

The age structure of the *fish* was determined based on growth rings from scales and consisted of six age groups ranging from 2 to 7 years. The majority of the individuals caught during the migration of the year 2020 were four years old (41.90%), followed by six years (19.85%) and five years old (15.62%), three years (13.14%), seven years (8.32%), while only 1.17% of the population was two years old.

Regarding the sex structure population from 2020, dominated was females aging four years old (28.90%), followed by six years (19.71%) and five years (14.01%). The male population was represented mostly by fish of four years old (12.99%), followed by three years (9.78%) (Table 2).

Analyzing the structure of the population by ages and sexes, statistical differences ($p<0.05$) were observed between the length and weight of the two sexes.

Table 1. Values of the length and weight in Pontic shad

Sex	Fish number	Total length (cm)			Weight (g)		
		Min.	Average	Max.	Min.	Average	Max.
Female	509	23.9	33.10±3.19	41.5	200	318.18±97.13	695
Male	176	20.5	29.65±4.34	41	80	244.43±91.95	565
Both sexes	685	20.5	32.21±3.82	41.5	80	299.22±101.04	695

Note: n = the number of fish; SD - standard deviation

Table 2. The frequency, mean total length (cm), and weight (g) of Pontic shad during 2020 migration

Age	Female						Male					
	Freq. (N)	Fish (%)	Total length ±SD (cm)	c.v. (%)	Weight ±SD (g)	c.v (%)	Freq. (N)	Fish (%)	Total length ±SD (cm)	c.v. (%)	Weight ±SD (g)	c.v (%)
2	1	0.15	30	-	220	-	7	1.02	27.05±4.25	15.71	155.57±68.76	44.19
3	22	3.36	28.92±3.33	11.51	230.86±41.84	18.12	68	9.78	25.97±3.42	13.17	180.86±41.81	23.11
4	198	28.90	32.37±2.99	9.23	298.17±93.46	31.34	89	12.99	32.93±2.71	8.22	274.78±75.09	27.32
5	96	14.01	33.47±2.90	8.66	324.48±95.25	29.84	11	1.61	36.80±1.7	4.62	416.36±28.73	6.90
6	135	19.71	33.91±3.25	9.58	346.96±103.55	28.43	1	0.15	41	-	565	-
7	57	8.32	35.04±2.03	5.79	359.67±80.20	22.29	0	0	0	0	0	-

Note: n = the number of fish; SD - standard deviation

The length-weight relationships and Fulton coefficient. To evaluate the fish condition, we calculate the L-W relationship for the whole population and separately for females and males. These relationships in fishes can be affected by habitat, temperature, seasonal effect, gonad maturity, degree of stomach fullness, food availability, fish health, general fish condition (Wootton, 1990; Battes et al., 2008). The relationship between the total length and weight (Lt-W) for the Danube shad population during the study period was determined as $W = 0.069 \times L^{2.40}$, for females was $W = 0.044 \times L^{2.52}$ and for males was $W = 0.137 \times L^{2.19}$.

In our study, the "b" values of the whole captured population, females and males, displayed negative allometric growth, meaning that the increase in length was faster than in weight (Figures 3-5).

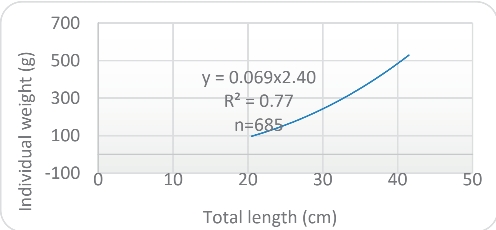

Figure 3. Length-Weight relationship for the females and male's population

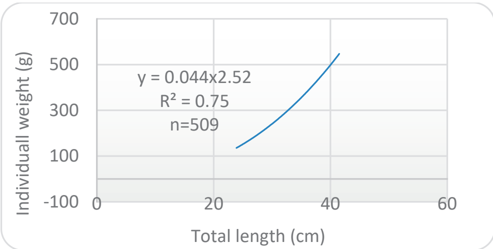

Figure 4. Length–Weight relationship for the female's population

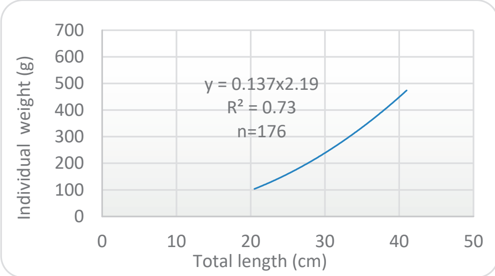

Figure 5. Length–Weight relationship for the male's population

However, the results of this study were similar to the general study trend shown by Ibănescu et al. (2017) ($W = 0.052 \times L^{2.487}$) for Pontic shad, on the same fishing area, for the year 2009. Also, Năvodaru (1997) obtained negative allometric growth (b = 2.45) for Pontic shad, for the Danube River.

Higher values were obtained by the Ţiganov et al. (2018) for the Black Sea coast ($W = 0.0057 \times L^{3.134}$).

The Fulton coefficient calculated for the whole population was 0.88 ± 0.17, 0.86 ± 0.13 for females, and 0.93 ± 0.26 for males. A lower Fulton coefficient for females is explained by the fact that during the spawning period, females lose weight.

Năvodaru and Năstase (2014) reported a Fulton coefficient for the Pontic shad in the period 1988-2014 equal to 1.42.

According to Năvodaru (1997), the Fulton coefficient values for Pontic shad tend to decrease with migration distance to the Danube River and reproduction due to the energy consumed for migration and spawning.

Of the 685 individuals captured during March-June 2020, 48.91% were captured in May, 43.21% in April, and only 4.08% and 3.80% in March and June, respectively (Figure 6).

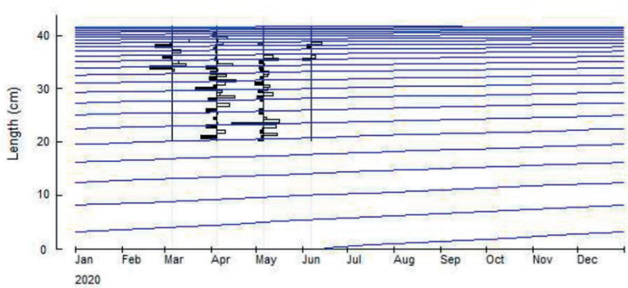

Figure 6. Length frequency distribution output from FISAT of Pontic shad fitted with growth curves

Growth parameters. The growth parameters ($L\infty$- asymptotic length, K- growth rate, and t_o- the age at zero-length) are useful in assessing the growth rates between and within individuals inhabiting various environments. For growth parameter estimation, the data set of 685 individuals was used to calculate Von Bertalanffy's growth parameters (FL_∞, K, t_0) which were presented in Table 3.
The asymptotic length obtained in our study (L_∞ = 43.05 cm) was very close to Ibănescu et al. (2017) (L_∞ = 40.43 cm) for Pontic shad for the year 2009, for the same Danube sector km 169 (Smârdan - Brăila) and km 197 (Gropeni-Brăila). Țiganov et al. (2018) obtained an L_∞ = 41.5 for Pontic shad (data obtained after a study period of two years, 2012-2013).

Table 3. The Von Bertalanffy growth parameters of Pontic shad

Species	Parameters	Estimated
Alosa immaculata	$FL\infty$ (cm)	43.05
	K (per year)	0.51
	t_0	-0.53

Regarding the constant growth K, the present study revealed a value of 0.51 year^{-1}. Our value is lower than those reported by Ibănescu et al. (2017) (K = 0.90 year^{-1}). Then, the t_0 was calculated as - 0.53 years using the empirical formula presented in the materials and methods section.

Mortality and estimation rate. The mortality coefficient (Z) was estimated using the length converted catch curve, and the values were 2.32 Natural mortality (M) calculated was 0.77, and fishing mortality (F) was 1.55. The value of the exploitation rate (E = 0.67) is over the optimum level of exploitation (E = 0.50), suggesting that in this Danube sector, the Pontic shad population is overexploited by fishing or by poaching (Figure 7).
It can be observed that in our study, the estimated mortality rates were found to be higher than estimates from other scientific studies regarding the Pontic shad, and the fishing mortality rate (F) was higher than the natural mortality (M) (Table 4).

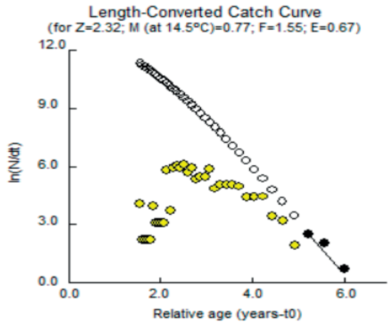

Figure 7. FiSAT II output of linearized length-converted catch curve for Pontic shad

Table 4. Mortality rates of *Pontic shad* population

Z	M	F	E	Year	Area	Reference
1.54	0.58	0.95	0.61	2009	Danube River, km 170-197	Ibănescu et al., 2017
1.71	0.58	1.13	0.66	2012	Black Sea	Tiganov et al., 2018
1.71	0.63	1.07	0.62	2013	Black Sea	Tiganov et al., 2018

CONCLUSIONS

From the studied population of Pontic shad from Danube km 169 (Smârdan - Brăila) and km 197 (Gropeni- Brăila), it can be concluded:

- ✓ Migration in the year 2020 was dominated by females and males aging 4-years.
- ✓ The length-weight relationship of Pontic shad, followed a negative allometric growth, the increase in length being greater than in weight.
- ✓ The fishing mortality rate (F) was higher than the natural mortality rate (M), indicating a fishing pressure on the Pontic shad population in this Danube sector.
- ✓ The value of exploitation rate was (E) was 0.67, indicating that the stock of this species is over exploited.

It could be concluded that the Pontic shad stock in this Danube sector is in a situation of over exploitation, and for the management purpose, the current exploitation rate should be reduced under 0.5. However, changes in the population structure and stock size must be monitored continuously, and some measures should be taken to reduce the pressure on fish stocks.

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