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ASSESSMENT OF GROWTH AND MORTALITY PARAMETERS OF *Alosa immaculata* (Bennet, 1835) FROM THE DANUBE DELTA

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Abstract

The aim of this study is to calculate the growth and mortality rates of Alosa immaculata, an important species whose population is in decline. Sampling was realized every month, from March to June 2022 from Sulina Branch Mm 34-18. Each of the specimens that were captured was weighed and measured individually, with weights ranging from 150 to 450 grams and total lengths ranging from 25 to 39 centimeters. The ELEFAN program from FiSAT II was utilized to determine the parameters for the von Bertalanffy growth function, resulting in the values of L∞ = 36.75 cm and k = 0.66 yr^{-1}. Using the linear regression analysis, the length-weight ratios were predicted based on log-transformed data using the equation $W = a \times L^b$. The mathematical relationship between the length and weight for the Pontic shad was: $W=0.0904\times Lt^{2.3198}$. The population of Pontic shad experienced high mortality rates, with a total mortality estimate at 1.83 and a natural mortality rate of 0.87. In addition, the calculated exploitation rate for the Pontic shad population exceeded the optimal value of 0.5, indicating slight overexploitation of the population.

Key words: *inland fishing, Length-Weight relationship, migratory fish, von Bertalanffy's equation.*

INTRODUCTION

The *Alosa immaculata* is a teleostean, predatory, marine, anadromous fish of the *Clupeidae* euryhaline species family. Its main habitats are the Black Sea, the Sea of Azov and the Caspian Sea (Whitehead, 1985; Coad, 1997). It migrates in large flocks, for reproduction in the rivers (Danube - going up to near the Iron Gates, Dnieper, Dniester, etc.), representing a species with an important economic value for commercial fishing in the Danube Delta, but also in the Danube (Leonov et al., 2022).

The food of the Pontic shad is made up of up to 75% of different species of small marine fish (shrimps, horse mackerels, anchovies, sea urchins) and then of invertebrates, especially crustaceans (Whitehead, 1985).

According to Navodaru & Waldman (2003) and Kottelat & Freyhof (2007), the spawning period of the Pontic shad occurs between April and August, with the main trigger for spawning being water temperatures above 15°C.

Also, the Pontic shad catch was correlated with the waters level of the Danube, especially those in May, reaching the conclusion that the shad catch fluctuations are directly proportional to the water level variations (Smederevac-Lalić et al., 2018).

The migration does not occur over long distances; given that this species only feeds in saltwater marine waters, not freshwater, traveling long distances requires a lot of energy and obviously the cessation of feeding (Balik, 2019).

Smederevac-Lalić et al. (2018) reported that the Pontic shad is highly susceptible to stress, including both natural and human-induced stressors. Due to excessive fishing, anthropogenic impact, extreme climate changes and habitat changes (construction of dams) in the area of the Danube River (Năvodaru, 1996).

The *Alosa immaculata* is included on the IUCN Red List, being considered a vulnerable species, the analysis of growth and mortality parameters analyzed in a study from 2017 (Ibănescu et al., 2017) concluded exactly this aspect. Overfishing can be a major threat to the survival of this species, with unsustainable fishing practices leading to a decline in population numbers.

According to a study carried out in 2016, it was shown that the females of *Alosa immaculata* have a higher survival rate than the male specimens, after reproduction in the Danube River and the Danube Delta. (Tiganov et al, 2016). The same thing was demonstrated in the study published in 2018, including data on shad catches from 2016 when the ratio between the sexes was M/F=0.51 (Năstase et al., 2018).

The primary aim of this investigation is to assess the present status of the *Alosa immaculata* population within the ecosystem of the Danube Delta.

The article presents an analysis of several biological parameters, such as length and weight, alongside the mortality ratio that is crucial in maintaining fish stocks at optimal levels to prevent overexploitation. Overall, the growth and mortality of *A. immaculata* are important factors to consider in the management and conservation of this species. Understanding the growth patterns and mortality rates can help inform effective management strategies to ensure the sustainability of its populations.

MATERIALS AND METHODS

Fishing area. Commercial fishing was realized during the year 2022 in the Danube Delta, Sulina Branch Mm 34-18 (Figure 1).

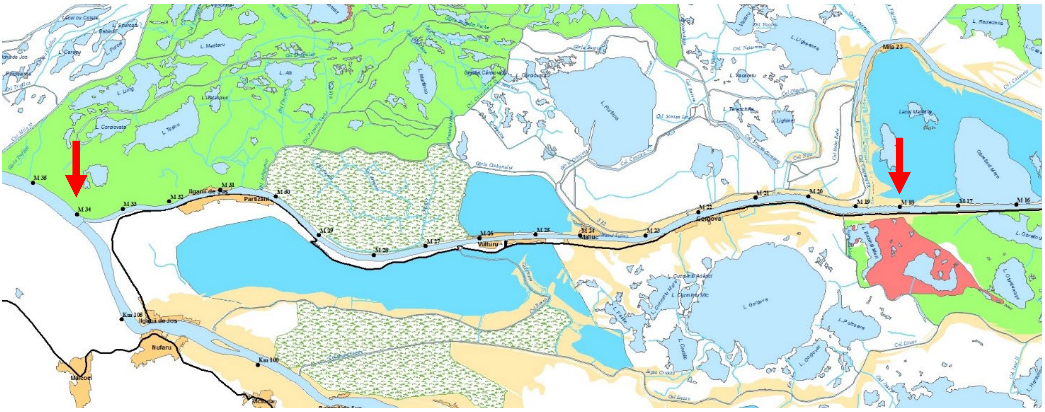

Figure 1. The Sulina Branch Mm 34-18

Data collection. Between March and June, a total of 70 *Alosa immaculata* specimens were captured using gillnets with a mesh size of 30-35 mm. The specimens were collected using a random sampling approach from commercial catches and included representatives from all length classes. The purpose of collecting these specimens was to evaluate the stock of Pontic shad in the studied region.

Total length (TL, in cm), fork length (FL, in cm), and height (h, in cm) were measured with an ichtyometer with an accuracy of 0.1 cm. In addition, the weight (W, in g) of the specimens was determined using an electronic weighing scale with a precision of 0.01 g.

In order to determine the correlations between the length-weight relationship (L-W) for the *Alosa immaculata* population, the relation $W = a \times L^b$ was used, where W represents the weight (in grams) of an individual, and L represents the total length (in cm) of that individual. The growth parameters ($L\infty$, k, t_0) were derived using the length frequency analysis with the ELEFAN model of the FiSAT II program

The mortality rates were calculated using Pauly's methods (1980, 1983), with the total mortality (Z) determined through the length converted catch curve analysis (Ricker, 1975) in FiSAT II. To predict the natural mortality (M), Pauly's formula (1980) was utilized, which takes into account the mean surface temperature (T). The formula was expressed as $\text{Log } M = -0.0066 - 0.279 \times \text{Log } (L\infty) + 0.6543 \times \text{Log } (k) + 0.4634 \times \text{Log } (T)$, where $L\infty$ represents the asymptotic length, T - the average of annual water temperature (12°C), and k - the growth rate coefficient of Von Bertalanffy.

To calculate fishing mortality (F), the formula F=Z-M (Gulland, 1971) was used, where Z - represents the total mortality, F represents the fishing mortality, and M represents the natural mortality. The formula E=F/Z (Gulland, 1971) was then used to determine the exploitation level (E). Fish stocks were considered easily exploited if the exploitation rate was below 0.5 and heavily exploited if E values were between 0.5-1.

For *data analysis*, the length frequency data were grouped into 3 cm intervals, and the FiSAT II software package (FAO-ICLARM Stock Assessment Tool) and Microsoft Excel 2019 were used.

RESULTS AND DISCUSSIONS

Each generation of Pontic shad, participating in migration, has its own characteristics relating to the size of the body. This is due to the specific environmental conditions in which individuals were born and where they lived, but it is also due to the different responses to these factors (Ibănescu et al., 2017).

From the whole Pontic shad captures, 62.5 % were represented by females and 37.5 % by males. The researchers utilized the growth rings present in the fish scales to determine the age distribution of the population. The analysis identified five distinct age groups, ranging from 2 to 6 years. The highest percentage of individuals captured were three-year-old, representing 33.33% of the total catch, while 26.38% were four-year-old, and 22.22% were two-year-old. The remaining 11.11% were five-year-olds, and a small proportion of only 6.94% were six-year-olds.

The captured fish had total lengths ranging from 25 cm to 39 cm, and there were significant differences between males and females ($p<0.05$). The most frequently observed size category was in the range of 29-31 cm. (Figure 2).

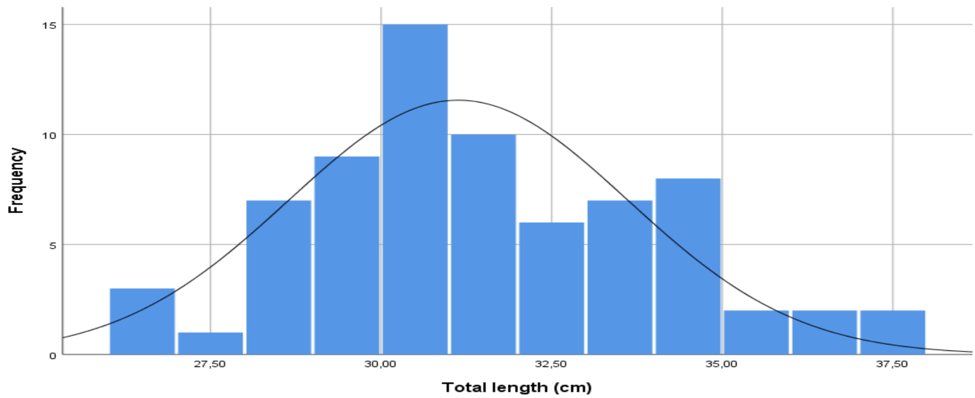

Figure 2. Distribution diagram of length – frequency of *Alosa immaculata*

Table 1 presents the descriptive statistics for the length and body weight of the Pontic shad.

Table 1. Length and body of Pontic shad

Specifications	Length (cm)	Body Mass (g)
Average±SD	31±2.89	274±68.48
Minimum	25	150
Maximum	39	450

The length-weight correlation is a crucial aspect of fishery stock management and ecology (Savaș & Nazmi, 2011). Le Cren (1951) highlighted that studying a fish's diet, reproductive development, and growth can offer valuable information. Tesch (1968) suggested that the coefficient 'b' derived from the L-W correlation can serve as an indicator of the fish's health and the surrounding environment, making it an effective means of comparing fatness and habitats.

The "b" coefficient in this study is 2.3198, indicating a negative allometric growth (increasing of weight is slower than the length).

The value of coefficient "b" obtained from the collected samples is lower compared to values reported by Stroe et al. (2020) and Mocanu et al. (2021) in their recent studies on the Danube River. The observed differences may indicate fluctuations in growth, as the length-weight correlation can be affected by various factors such as food availability, water temperature and salinity, or reproduction, as noted by Savaş & Nazmi (2011). Figure 3 presents the growth coefficients "a" and "b" derived from the length-weight relationship, with the population's L-W relationship expressed as $W = 0.0904 \times Lt^{2.3198}$ during the study period. This equation is comparable to the one determined by Iliescu in 1971 ($W = 0.0905 \times Lt^{2.4}$), and a high correlation ($R = 0.895$) was found between length and weight.

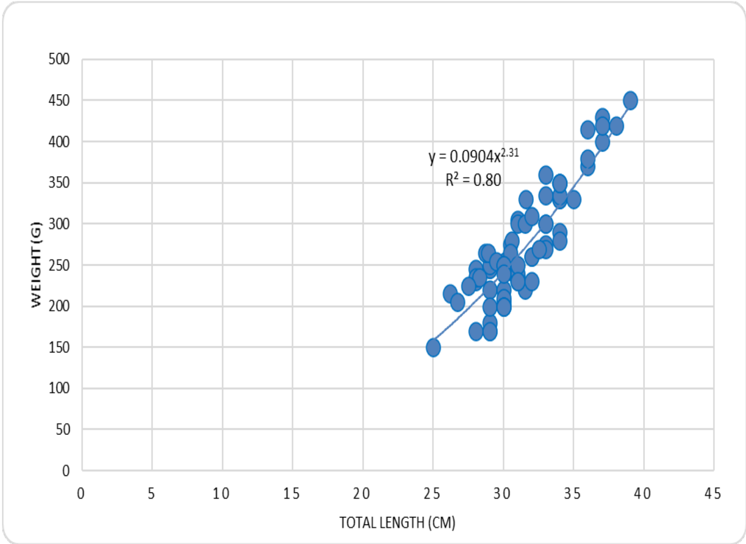

Figure 3. Length-weight correlation (L-W) of *Pontic shad*

The growth indicators $L\infty$, k, and t_0 are constants used in predicting the body size of a fish as it reaches a certain age. In this study, the estimates of these growth variables ($L\infty$, k, and t_0) are shown in Table 2.

Table 2. Growth parameters for Pontic shad in 2022 migration, Sulina

$L\infty$	k	t_0
36.75	0.66	-0.039

In recent studies conducted by other authors, growth parameters have been found to be similar to the data obtained from this study. (Rozdina, 2013; Ţiganov, 2023).

To ensure that fish stocks are not overexploited and remain sustainable, it is crucial to accurately estimate the mortality rates. This is important because if the mortality rate is underestimated, it could result in overfishing, leading to a decline in the fish population. On the other hand, if the mortality rate is overestimated, it could result in unnecessary restrictions on fishing, which could negatively impact the fishing industry. Therefore, accurate estimation of mortality rates is vital for effective fisheries management and the conservation of fish populations.

The estimate of the mortality rates (Z and M) for the Pontic shad population investigated was computed using the FiSAT II computer software package. The values are shown in Table 3 and Figure 4.

Table 3. Mortality rates for Pontic shad, 2022, Sulina

Species	Z	M	F	E
Alosa immaculata	1.83	0.87	0.96	0.53

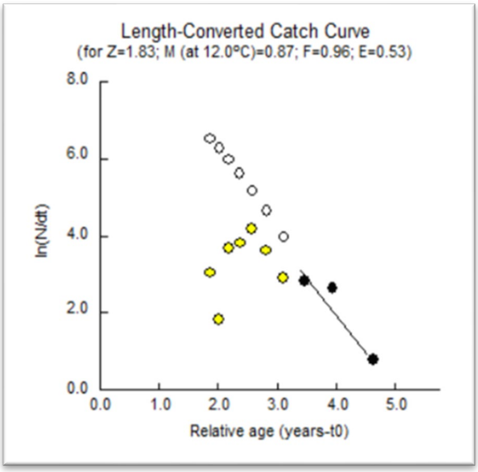

Figure 4. Length converted catch curve of Pontic shad, in Sulina branch, 2022

The exploitation rate (E) of 0.53 for *Alosa immaculata* estimated from the mortality rates, is a little larger than 0.5. It shows that the stock of this species in the Sulina Branch area is slightly overexploited. But it should be remembered that most of the Pontic shad specimens from the Danube River were fished on the St. George arm, which shows that the migration on the other arms of the delta was lower.

CONCLUSIONS

Considering the importance of Pontic shad for commercial fishing in Romania, and the fact that it is considered a vulnerable species and threatened by pollution, overfishing, and climate change, the annual studies lead to a current assessment of stocks that have the role of initiating necessary conservation measures

The study conducted on 70 specimens of *Alosa immaculata* from commercial fishermen caught in the Danube Delta, Sulina Branch Mm 34-18, in 2022 can be concluded:

- The Pontic shad sampled in the studied period had a total length interval between 25 and 39 cm and weight values interval between 150 and 450 g;
- Relationship L–W established was $W=0.0904*Lt^{2.3198}$;
- Growth parameters ($L\infty$, k, t_0) have values similar to those from specialized literature;
- The values of fishing mortality (F) and the rate of exploitation (E) show that *Alosa immaculata* stock is slightly overexploited despite the fact that the vast majority of Pontic shad cohorts migrate to Saint George's arm.

Therefore, it is considered important in future studies to evaluate the stocks of Pontic shad migrating in the Danube River on the Saint Gheorghe branch.

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