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Age, Growth, and Mortality of Pontic Shad, *Alosa immaculata* Bennett, 1835, in the Danube River, Romania

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Abstract: This study aimed to evaluate the growth, mortality parameters, and exploitation rate of Pontic shad, *Alosa immaculata* Benett, 1835, in the Danube River, Romania (km 169–197). The sampling collection started with the first signs of Pontic shad migration, on 4 March 2023, and continued weekly until the beginning of June 2023, when the last specimens were caught in the nets. The estimation of the growth, mortality parameters, and exploitation rate was done in FiSAT (FAO-ICLARM Stock Assessment Tools). The von Bertalanffy growth equation was estimated at L_∞ = 36.75 cm, the growth coefficient was k = 0.68 year^{-1}, and the theoretical initial age was $t_0 = -0.67$ year^{-1}. The total mortality rate (Z) estimated was 2.76 year^{-1}, with a natural mortality rate (M) and fishing mortality rate (F) of 0.89 year^{-1} and 1.87 year^{-1}, respectively. The Z/k ratio was found to be 4.11 and the exploitation rate (E) was estimated at 0.68 year^{-1}, indicating the overexploitation of *Alosa immaculata* stocks. In conclusion, this study provides valuable insights into the population dynamics of Pontic shad in the Danube River, Romania. The assessments of the growth parameters, mortality rates, and exploitation rates highlight a level of overexploitation of *Alosa immaculata* stocks. These findings underscore the importance of applying effective fishery management strategies to ensure the sustainability and conservation of this valuable fish species in the Danube River ecosystem.

Keywords: pontic shad; stock estimation; growth parameters; fish mortality; exploitation rate

Key Contribution: This study regarding the *Alosa immaculata* stocks from the Danube River synthesizes important insights into the population dynamics, growth rates, mortality parameters, and environmental influences, contributing significantly to fishery science and providing a foundation for the informed conservation and management strategies of the species.

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1. Introduction

The Danube River, the second-largest river in Europe, represents a vital aquatic ecosystem that passes through multiple countries in Europe and harbors a diverse range of fish species, each contributing to the intricate balance of its aquatic environment. Among these species, the Pontic shad (*Alosa immaculata* Bennet, 1835) plays a pivotal role in the ichthyofaunal diversity of the Danube River in Romania. Endemic to the Black Sea and the

Sea of Azov, this species holds longstanding ecological and socio-economic significance in the region. For spawning, Pontic shad migrates in the Danube, Dnepr, Don, Dniester, and Bug [1].

The migratory pattern, reproductive biology, and population dynamics of *Alosa immaculata* are subjects of great interest for fishery management and the conservation of this unique species [2]. In Romania, *Alosa immaculata* undertakes migratory spawning journeys from south to north along the Black Sea coast of Bulgaria and Romania to the Danube River mouths, reaching up to "Iron Gate II" at kilometer 863.Before the construction of Iron Gate II's hydroelectric power plants (in the year 1984), the fish exhibited spawning migrations extending as far as kilometers 1650, encompassing the region up to Budapest [3]. The construction of the hydroelectric power plant has limited the species' historical spawning range, emphasizing the importance of comprehending the resulting impacts on the population dynamics and overall ecological health [4].

However, in addition to restricting the migration area, the Pontic shad population has encountered numerous challenges over the years, including habitat alterations, climate changes, pollution, and overfishing [5]. These pressures have raised concerns about the sustainability of this species and the need for effective management strategies.

Beyond its ecological importance, the Pontic shad carries cultural and economic impacts, serving as both a target species for local fisheries [2] and an integral component of Romania's natural heritage. Pontic shad has great popularity among consumers due to the delicious taste of its meat and its nutritional benefits [6], being consumed by the Christian population during religious fasting periods.

In Romania, according to data provided by the National Agency for Fisheries and Aquaculture [7], the catches are not stable and vary considerably from year to year. In the last decade, the catchments varied significantly with a minimum of 174.6 tons in 2015 and a maximum of 634.5 tons in 2019. Mainly, these fluctuating catches are influenced by the dynamics of the hydrological regime of the Danube, but until now, there has been no comprehensive analysis available [8,9]. A forecast analysis published by Smederevac et al. 2018 [10], based on the Danube River water level and catches of Pontic shad over 94 years (1920–2013), has predicted a gradual increase in *Alosa immaculata* catches in the period of 2024–2027, reaching around 1000 tons. After the year 2033, authors have predicted a decrease in annual catches.

Following the assessment of the IUCN Red List, *Alosa immaculata* is categorized as a vulnerable species [11]. Within the European Union, the species receives protection under Annex II of [12]. Additionally, it is included in Annex IV, imposing an obligation on Member States to safeguard against exploitation that may compromise its conservation status. Furthermore, at the national level, *Alosa immaculata* is afforded protection in compliance with the Emergency Government Ordinance 57/2007 [13].

In this context, the vulnerability status of the species underlines the imperative need for conservation efforts and management strategies to mitigate the threats and ensure the survival of this species. The monitoring of Pontic shad populations, habitat protection, and collaborative efforts to address specific challenges faced by *Alosa immaculata* in its natural environment can be a successful plan for species protection. Therefore, to address these concerns, comprehensive knowledge of its population parameters, such as the age and sex structure of migratory populations, growth, mortality rates, and recruitment dynamics, can offer important information. Thus, data regarding the age of fish can serve as a valuable tool in fishery management, being used as general background information for management decisions [14].

Therefore, the main goal of this paper is to assess the age and size structure, condition factor, growth rate, and mortality of the Pontic shad populations in the Danube River, Romania, during migration of the year 2023. All these parameters significantly influence population dynamics and are crucial for forecasting population growth patterns, serving as fundamental information in the field of fishery management.

2. Materials and Methods

2.1. Study Area and Sample Collection

This study was carried out during scientific fishing from March to June 2023, in the area situated between km 169 (Brăila) and km 197 (Gropeni), along the Danube River, Romania (Figure 1).

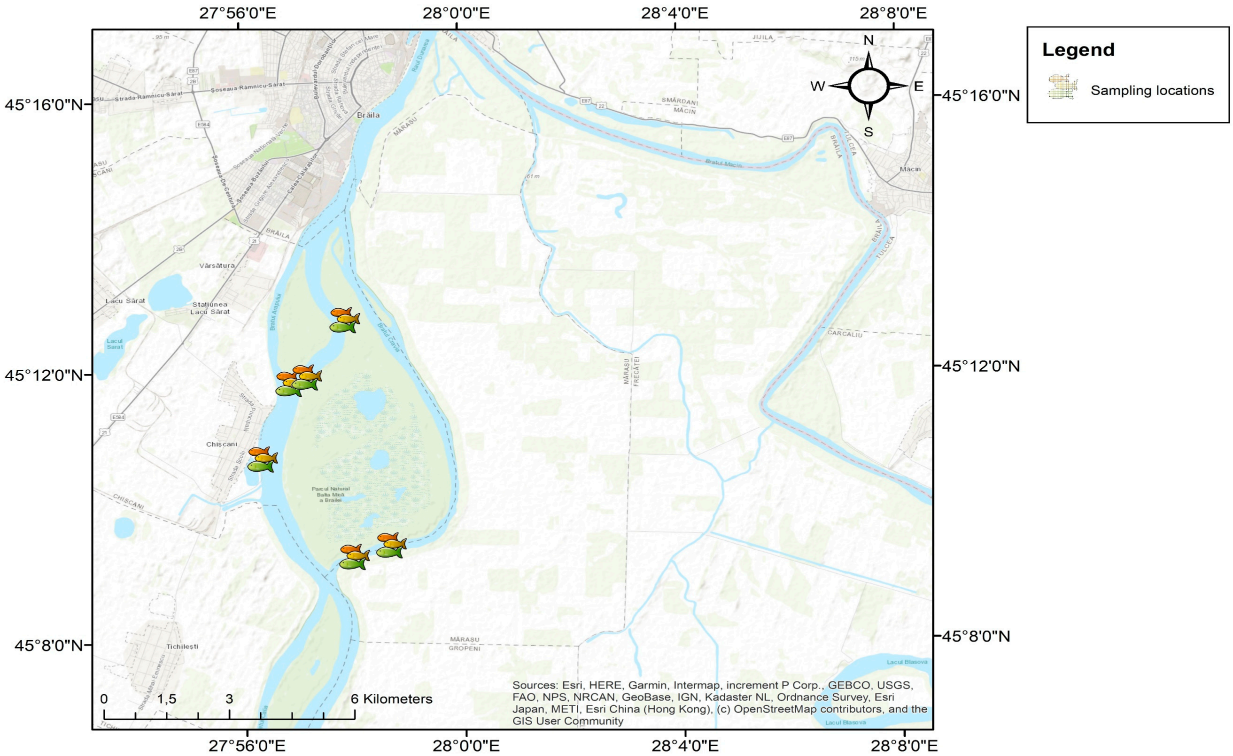


Figure 1. Sampling locations of *Alosa immaculata* in Danube River (169–197 km), Romania.

The samples were collected from scientific catches. The gillnets used for Pontic shad fishing have a mesh size of 30 mm × 30 mm, height of 4.20 m, and length of 190 m (2 pieces). Random selection of the fish specimens was done while sampling. Fish were measured (±0.1 cm precision) for total length (Lt), standard length (Ls), fork length (Lf), and body depth (H) and weighed with an electronic scale (±0.01 g precision).

2.2. Determination of Sex and Age

The sex was determined by macroscopic examination of gonads, while the age determination was made from the scales collected 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. Briefly, the scales were rinsed with distilled water and submerged in 96% ethanol for several minutes to eliminate residual water. Following this, ten scales from each fish were carefully mounted between two slides for preparation and read at microscope Kern OBN 135 (Kern and Sohn GmbH, Ziegelei, Balingen–Deutschland) [15,16].

The sex ratio was given as males: females (M:F), calculated using the formula: total number of males/total number of females [17]. The chi-square (χ^2) was used to verify the existence of significant differences between the sex ratio of the study species and the commonly expected 1:1 sex ratio.

2.3. Length–Weight Relationship

To determine the length–weight relationship, the power function, $W = a \times Lt^b$, was used, where W is the weight of the fish (g), L_t is the total length of the fish (cm), "a" is the condition factor, and "b" is the allometric growth factor [18,19].

2.4. Estimation of Growth Parameters

The length frequency distribution data (1 cm length classes) were analyzed using the computer software package FiSAT II version 1.2.2. (FAO-ICLARM Stock Assessment Tool).

The growth parameters were estimated through the von Bertalanffy growth function (VBGF) using monthly length-frequency data for both sexes (1 cm class interval). The mathematical model of the von Bertalanffy equation is:

$$L(t) = L_\infty[1 - e^{-k(t-t0)}] \quad (1)$$

where L(t) is the total length at t age (cm), L_∞ is the asymptotic total length (cm), k is growth coefficient ($year^{-1}$), t is the age of the sample (year), and t_0 is the theoretical initial age at which the total length is zero (year).

The asymptotic length (L_∞) and growth rate efficiency (k) were calculated using the ELEFAN I program in the FiSAT II program package, while the theoretical age at length zero (t_0) was calculated using Pauly's empirical equation [20]:

$$Log(-t_0) = -0.392 - 0.275\ LogL_\infty - 1.038\ Logk \quad (2)$$

The approximate longevity (t_{max}) was calculated according to Pauly and Munro, 1984 [21]:

$$t_{max} = 3/k \quad (3)$$

The growth performance index was estimated according to Pauly and Munro, 1984 [21]:

$$(\varphi') = \log k + 2\ \log L_\infty \quad (4)$$

where k and L_∞ are parameters of von Bertalanffy.

According to Ragonese et al. (2012) [22], this parameter indicates the proportional growth of a fish to its length and it is applicable for comparing growth performances either across various species or within the same species.

2.5. Total Mortality, Fishing Mortality, and Exploitation Rate

The total mortality rate (Z) was estimated by constructing linearized length-converted catch curves [23].

The natural mortality (M) was calculated by the length–base empirical relationship by Pauly (1980) [24], using a mean annual water temperature (T) of 12 °C:

$$\ln M = -0.0066 - 0.279\ \ln L_\infty + 0.6543\ \ln k + 0.463\ \ln T\ ^\circ C \quad (5)$$

Also, the natural mortality (M) was estimated based on growth parameters, according to Then et al. (2015) [25]:

$$\text{Estimation based on growth parameters: } M = 4.118\ K^{0.73}\ L_\infty{}^{-0.331} \quad (6)$$

The fishing mortality (F) is obtained by subtracting the instantaneous rate of natural mortality (M) from the total mortality coefficient (Z):

$$F = Z - M \quad (7)$$

The exploitation rate (E) was calculated by dividing the fishing mortality (F) by the total mortality rate (Z) [26]:

$$E = F/Z \quad (8)$$

2.6. Probability of Capture, Relative Yield per Recruit (Y/R), Relative Biomass per Recruit (B′/R), and Virtual Population Analysis (VPA)

The probability of length at the first capture (L_c), as well as the lengths at the 25th and 75th captures, was estimated, representing cumulative probabilities at 25% and 75%, respectively. This approach provides valuable insights into estimating the actual size of fish caught in a particular fishing area using specific gear. The probability of capture serves as a crucial metric for fishery managers engaged in sustainable fishery management [27].

Relative yield per recruit (Y/R) and relative biomass per recruit (B′/R) were calculated based on the Berverton and Holt model [28], assuming a knife edge recruitment.

The length-structured Virtual Population Analysis (VPA) was conducted to estimate the mortality in each length class caused by fishing. For the VPA analysis, the length frequency classes, the coefficient "a" and "b" from the length–weight relationship, natural mortality (M), the asymptotic length (L_∞), and the growth coefficient k were included.

2.7. Statistical Analyses

Statistical analyses were done in the FiSAT II (FAO-ICLARM Stock Assessment Tool), Microsoft Excel (Microsoft Office, 2019), and SPSS statistical software for Windows, Version 26.0, Chicago, IL, USA, SPSS Inc. The *t*-test was used to test whether the slopes (b) were significantly different or not.

3. Results

3.1. Sex Structure of Pontic Shad Population

The evaluation of growth parameters was made on 450 fish with a total biomass of 100.575 kg. From the measured fish, 238 were females (52.89%) and 212 were males (47.11%) (Table 1). The Males/Females sex ratio (M/F), calculated on 450 individuals, was 0.89. There were no significant differences between the number of females and males ($p > 0.05$), and the sex distribution is close to a 1:1 ratio (Chi-square test, $X^2 = 6.18$, df = 4, $p = 0.18$).

Table 1. Somatic measurements of Pontic shad catch for the year 2023, in the area situated between km 169 (Brăila) and km 197 (Gropeni), along the Danube River, Romania.

Sex	N	Mean W (g)	Mean Lt (cm)	Mean Ls (cm)	Mean Lf (cm)	Mean H (cm)
Females	238	247.88 ± 45.30	30.47 ± 1.76	26.97 ± 1.63	27.25 ± 1.68	6.15 ± 0.53
Males	212	196.13 ± 23.90	28.46 ± 1.09	25.21 ± 1.07	25.34 ± 1.06	5.55 ± 0.49
Both sexes	450	223.5 ± 44.95	29.53 ± 1.79	26.14 ± 1.65	26.35 ± 1.71	5.87 ± 0.59

N—number of specimens; Mean W—mean weight (g); Mean Lt—mean total weight (cm); Mean Ls—mean standard length (cm); Mean Lf—mean fork length (cm); Mean H—body depth (cm).

The size and weight of females ranged between 26.00 ÷ 35.50 cm and 140.00 ÷ 380.00 g, and the males ranged between 24.70 ÷ 32.00 cm and 120.00 ÷ 270.00 g. The smallest female was 4 years old with a total length of 26.00 cm and a weight of 140.00 g, while the smallest male was 3 years old with a total length of 24.70 cm and a weight of 160.00 g.

3.2. Length–Weight Relationship (L-W)

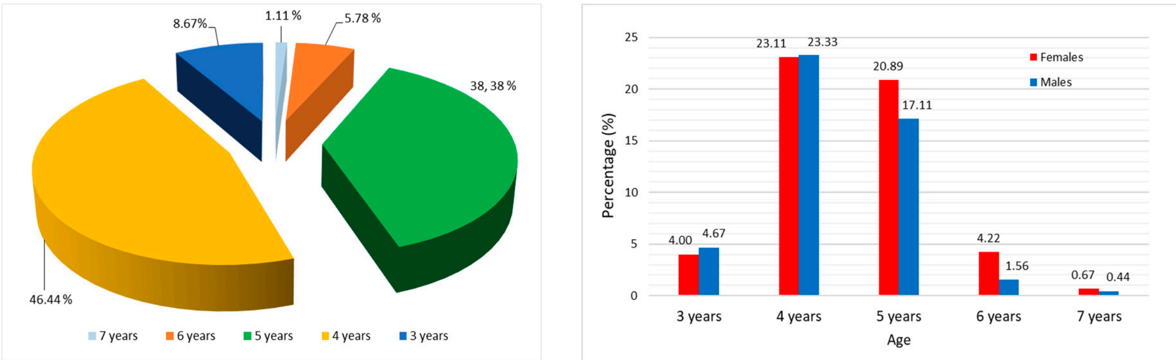
The results of the L-W relationship of Pontic shad are presented in Table 2. The calculated length–weight equation for both sexes was: $W = 0.0219 \times L_t^{2.72}$. The L-W regression for males was $W = 0.32 \times L_t^{2.92}$, and for females was $W = 0.0258 \times L_t^{2.68}$. The regression statistics for the length–weight relationship of the Pontic shad recorded the regression slopes or growth coefficients, a "b" of 2.92 in males, 2.68 in females, and 2.72 for combined sexes, with values being significantly less than three ($p < 0.05$).

Table 2. Length–weight relationship parameters for *Alosa immaculata*.

Sex	Number of Fish	Equation	R^2
Males	212	$W = 0.32 \times L_t^{2.92}$	0.63
Females	238	$W = 0.0258 \times L_t^{2.68}$	0.74
Males + Females	450	$W = 0.021 \times L_t^{2.72}$	0.72

3.3. Growth and Mortality Parameters

The migratory Pontic shad population of 2023 was dominated by cohorts of 4 years of age (46.44%—from which 23.33% is represented by males and 23.11% by females), followed by cohorts of 5 years of age (38% from which 20.89% is represented by females and 17.11% by males), while the cohorts of 3 years of age represent only 8.67% (4.67% males, and 4% females). The cohorts of 6 and 7 years of age have a relatively small percentage compared to the harvested fish population (5.78% and 1.11%, respectively) (Figure 2).



(**a**) (**b**)

Figure 2. (**a**) The age structure of *Alosa immaculata*'s ages fished in the Danube River, km 169–197; (**b**) the percentages of females and males of each age of *Alosa immaculata* fished in the Danube River, km 169–197.

From length-frequency data, the estimated von Bertalanffy growth constants for combined sexes are: $L_\infty = 36.75$ cm, $k = 0.68$ year^{-1}, and $t_0 = -0.67$ year^{-1} (Figure 3). The growth performance index (φ′) was 2.96. The restructured length frequency of *Alosa immaculata* with superimposed growth curves (Figure 3) shows that the majority of the captured fish were within the size of 27–30 cm in total length.

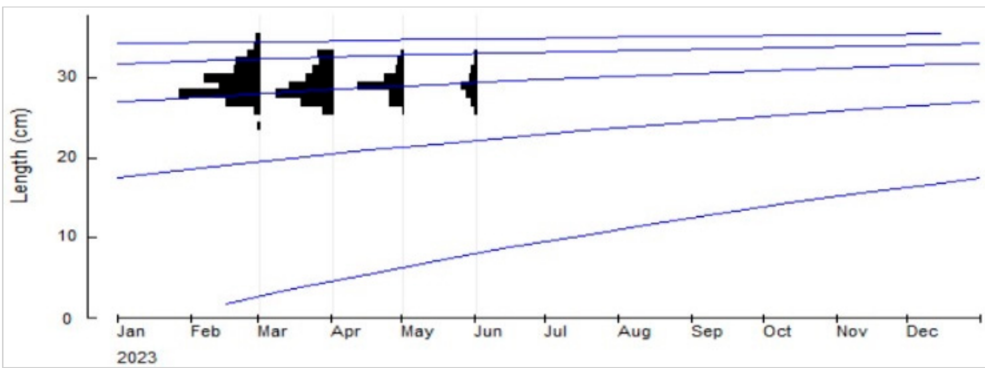


Figure 3. Length-frequency distribution output from FISAT II with growth curves for *Alosa immaculata*, fished in Danube River, km 169–197.

3.4. Total Mortality, Fishing Mortality, and Exploitation Rate

The length-converted catch curve (Figure 4) showed that the total mortality (Z) estimated for *Alosa immaculata* was 2.76 year^{-1}. The natural mortality (M) at 12 °C was

0.89 year^{-1}, while according to the formulae of Then et al. (2015) [25], the estimated natural mortality (M) based on growth parameters was 0.91 year^{-1}. The fishing mortality (F) was 1.87 year^{-1}. The exploitation ratio (E) was estimated at 0.66 year^{-1}.

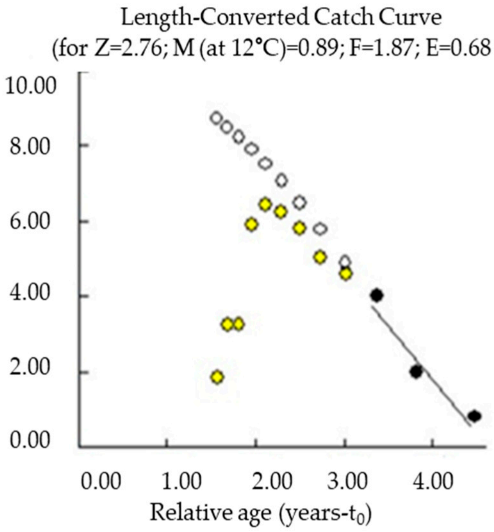


Figure 4. Length-converted catch curve for *Alosa immaculata* fished in Danube River, km 169–197.

Regarding the analysis of the growth parameters for separate sexes, it was found that the male's natural mortality (M) and fishing mortality (F) (M = 1.08 year^{-1}; F = 2.16 year^{-1}) was higher than the females (M = 0.76 year^{-1}; F = 1.43 year^{-1}). Also, the total mortality (Z) was higher in males (3.24 year^{-1}) than in females (2.19 year^{-1}). The exploitation rate (E) is quite similar between males (E = 0.67 year^{-1}) and females (E = 0.65 year^{-1}), indicating the overfishing of both sexes.

3.5. Probability of Capture, Relative Yield per Recruit (Y'/R), and Relative Biomass per Recruit (B'/R)

The logistic regression of the probability of capture is presented in Figure 5. The selectivity pattern observed for *Alosa immaculata* captured between km 169–197 of the Danube River, Romania, indicates that gillnets successfully caught a minimum of 25% of fish measuring 27.59 cm, 50% of fish measuring 30.25 cm, and 75% of all fish with a total length of 32.06 cm.

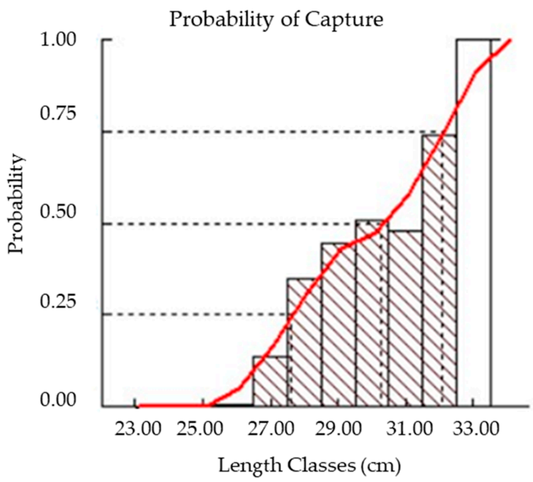
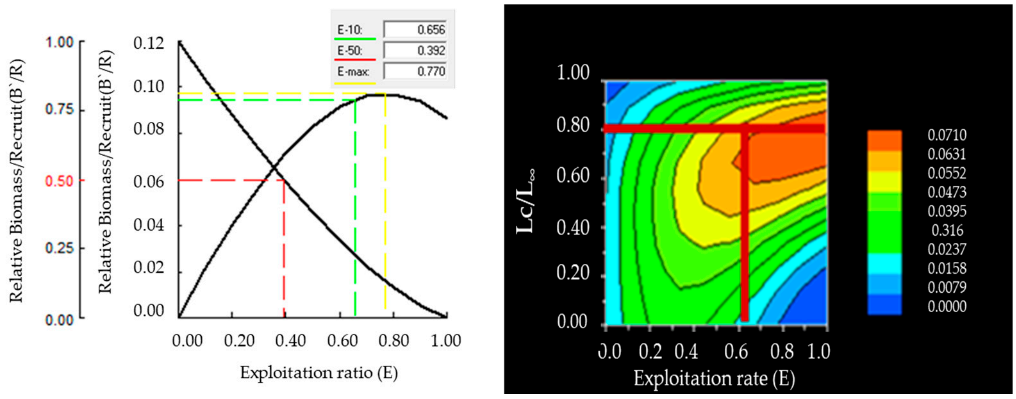


Figure 5. Estimated probability of capture by the length of *Alosa immaculata*, fished in Danube River, km 169–197.

The relative yield per recruit (Y′/R) and the relative biomass per recruit (B′/R) indicated values of Emax = 0.770, E10 = 0.656, and E50 = 0.392. The length-structured Virtual Population Analysis (VPA) was conducted to estimate the mortality of each length class caused by fishing (Figure 6a,b).



(**a**) (**b**)

Figure 6. Two-dimensional (**a**) and three-dimensional (**b**) representation of the relative production model per recruit for *Alosa immaculata*, fished in Danube River, km 169–197, based on knife-edge selection.

The length-based Virtual Population Analysis (Figure 7) showed that the natural losses were highest among individuals within the length range of 24 to 28 cm, while the highest fishing mortality was experienced by individuals within the interval of 27 to 32 cm.

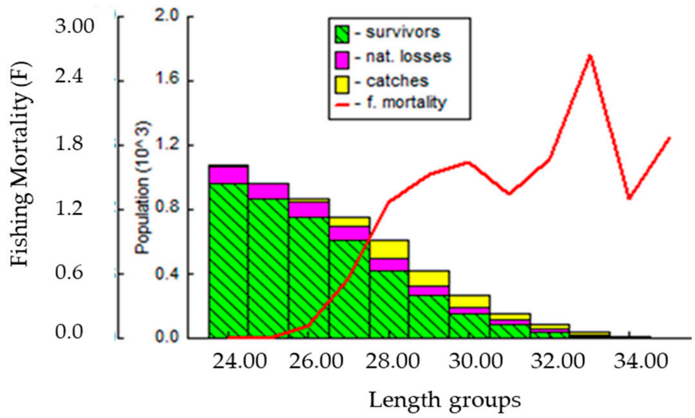


Figure 7. Histogram of the Virtual population of *Alosa immaculata* fished in the Danube River, km 169–197.

4. Discussion

Research on fish communities has an important role in the sustainable management of fishing practices. The estimation of growth and mortality population parameters, such as asymptotic length (L_∞), growth coefficient (k), mortality rates (Z, M, F), and exploitation levels (E), are important tools in understanding the biological characteristics of fish species, serving also as a basis for the good management and the preservation of aquatic resources [29–31].

Most spawning activities of Pontic shad are concentrated between 180 and 743 km of the Danube River [32,33], but the sections between km 169 and km 197 (Gropeni) represent an important point for reproduction [9]. In 2023, the first specimens of Pontic shad, at selected points were caught on March 4th, when the water temperature recorded a value of 6 °C [34], and the last specimens were caught in the nets at the end of June when the water temperature recorded a value of 23 °C [34]. However, the onset of Pontic shad migration varies annually based on the specific hydrometeorological conditions of each year. According to some authors [35,36], Pontic shad initiates migration when the water temperature reaches 4.5–6 °C, with the peak occurring between April and May when the water temperature ranges from 9–17 °C, and the migration completes in June–July when the water temperature reaches 22–26 °C.

Concerning the demographic structure of the Pontic shad population from the migration of the year 2023, there were five age groups reported, with predominant cohorts of 4 (46%) and 5 years of age(38%). The 3-year-old cohorts represented a smaller proportion (8.67%), while no cohorts of 2 years of age were identified. The findings align with the observations of Mocanu et al. (2021) [37], who reported, during the migration of Pontic shad from the year 2020, at the 169th km of the Danube River, dominant cohorts of 4 years of age (41.90%). The authors reported that the 6-, 5-, and 3-year-old cohorts represent 19.85%, 15.62%, and 13.14%, respectively, while individuals of 7 and 2 years represent a small part of the migratory population (8.32% and 1.17%, respectively). Other authors [38] report six age groups (from 2- to 7-year-old individuals) for Pontic shad in the Danube River, Romania. In a similar study, Leonov et al. (2023) [6] reported different structures of migratory Pontic shad (for the year 2022) at the Danube mouth (Sulina Branch Mm 34-18): the highest percentage of individuals captured were 3 years old (33.33%), followed by 4 years old (26.38%), while only a small percentage (11.11%) were 5 years old and 6 years old (6.94%).

According to some authors [35,36,39], sexual maturation occurs predominantly at the ages of 3 and 4 years. Moreover, the authors suggest that 2-year-old individuals (those with early sexual maturity) have a diminished role among breeders, while fish aged 7 years are seldom observed during the migration process.

In our study, we do not capture fish aged 2 years. However, the specific fishing gear we employed aligns with previous research methodologies and ensures consistency in sampling across different studies. For example, in a similar study [2] used for the fishing of *Alosa immaculata* on the Black Sea coast (Romania), fishing gears with a 32 mm mesh size were used and generations aged between 2 and 5 years old were reported. Also, with the same gillnets, the authors reported few catches of *Alosa immaculata* with a total length smaller than 25 cm [2]. Electrofishing, an alternative method, proves less suitable for capturing *Alosa immaculata* due to their behavioral tendencies and natural habitat. As migratory fish, *Alosa immaculata* exhibit an active swimming behavior and cover long distances within river systems like the Danube. The swift currents in their habitat render electrofishing less effective, as it struggles to capture fish in dynamic movement. Moreover, the equipment's limited coverage area reduces its efficiency in capturing *Alosa immaculata*, further emphasizing the suitability of gillnets for our study's objectives.

Năvodaru (1997) [7] conducted a comprehensive study regarding the demographic structure of the migratory population of *Alosa immaculata* in the Danube River, Romania, between the years 1987 and 1996. The author's findings revealed distinctive age structures for each migration season. This differentiation was attributed to the pronounced impact of environmental variability on each generation during their initial year of life. Moreover, the study highlighted the significant influence of variable fattening durations among individuals within the same generation. This variable duration was identified as an important factor in initiating reproductive migration. The complex interaction between the environment and individual developmental timelines highlights the intricate nature of age-structure dynamics in the Pontic shad population.

Also, data relating to the sex ratio have a great significance in comprehending the relationship between fish and the reproductive capacity of a population [40]. The sex ratio of the population in terms of gender can fluctuate based on seasonal changes and migration patterns. According to Năvodaru (1997) [7], males are more predominant in the initial phases of migration, reaching a balance at the migration peak. As the migration concludes, there is a transition in dominance, with females taking a more prominent role.

In our research, the ratio of sexes (M/F) indicates a slight domination of females (M/F = 0.89), which are prevailing in stocks in the examined period. The sex ratio is quite similar to those reported by our similar study conducted for migration in the year 2020 in the same fishing area [41]. However, our observed sex ratio is lower than those presented by Năstase et al. (2018) [42] and Mocanu et al. (2021) [37], who reported sex ratios of 0.51 and 0.34, respectively, for the Danube River. For the Black Sea Coast in Romania, ref. [39] reported a sex ratio of 0.62.

Our findings indicate that Pontic shad exhibits a negative allometric growth pattern, characterized by b-values under 3.00. This suggests that the fish experience more pronounced length growth than their weight [17]. According to Battes et al. 2008 [43], the value of "b" is a measure of the living conditions that the environment provides to fish.

The observed trend aligns with the expected characteristics of the *Alosa immaculata* species, given its typically elongated body structure. Notably, the coefficient "b" obtained in our research is higher compared to values reported by other authors (b = 2.45; b = 2.487; b = 2.19; b = 2.31) for Pontic shad in their studies in the Danube River, Romania [6,9,37,44]. For the Black Sea coast of Romania, there were reported higher values of "b" (3.134 and 2.879, respectively) [2,45]. On the contrary, some authors have noted a positive allometric growth pattern in Pontic shad (b = 3.435; b = 3.085; b = 3.134) [40,45]. However, the L-W relationship can be influenced by several factors, such as biological factors [46], the environmental temperature [47], geographic area [48], and even human activities [49].

The determination of the growth parameter constants, such as L_∞, k, and $t_{0,}$ can help in predicting the fish's body size when it reaches a certain age. In our research, the asymptotic length was found to be L_∞ = 36.75 cm, the growth coefficient k was 0.68 year^{-1}, and the calculated growth performance index (φ') was 0.67 year^{-1}.

The obtained values are comparable to those obtained by other authors. (Table 3). For example, ref. [6] found the same value for the asymptotic length of Pontic shad, with data provided from commercial fishing from the year 2022 in the Danube Delta, Sulina Branch Mm 34–18, Romania (Table 3).

The estimated instantaneous growth coefficient (k = 0.68 year^{-1}) suggests favorable growth conditions for the species. This finding aligns closely with a comparable value of 0.66 year^{-1} [6], suggesting an accelerated growth pattern for the species. On the contrary, earlier studies for *Alosa immaculata* at the Bulgarian part of the Danube River [50,51] indicated a contrasting perspective, revealing slow growth rates for the species (k = 0.27 year^{-1} and k = 0.10 year^{-1}, respectively). However, differences in the growth rates between the Romanian and Bulgarian populations may be attributed to varying environmental conditions along different stretches of the Danube River.

The natural mortality (M), calculated with Pauly's equation [24], was 0.89 year^{-1}, while the estimated natural mortality derived from growth parameters showed a higher moratlity rate (0.92 year^{-1}). Overall, the values reported by our study are almost similar to those reported by Leonov et al. (2023) [6], and much higher than those reported by Ibănescu et al. (2017) [44] for the same research area, or by Tiganov et al. (2018) [45] for the Black Sea Coast.

The total mortality (Z), mortality by fishing (F), and exploitation rates (E) were estimated as 2.76 year^{-1}, 1.87 year^{-1}, and 0.68 year^{-1}, respectively.

The natural mortality (M) together with the fishing mortality (F) contribute to the total mortality (Z) of a fish stock and play a crucial role in population biology, providing valuable insights into the intricate dynamics of populations [52,53]. According to Gulland, 1983 [54], the most favorable situation for a population is when the rate of the fishing mortality matches the rate of natural mortality. In this scenario, fishing activities target the segment of the population that would otherwise be lost due to natural mortality.

From the estimated parameters of M and F, it can be observed that the fishing mortality is greater than that reported by other authors [6,37,44,45]. Ibănescu et al. (2017) [44] reported a value of F of 0.95 year^{-1} in 2017 for the same fishing area, while Mocanu et al.

(2021) [37] reported a value of F of 1.55 year^{-1}, having observed a high increase over recent years.

Table 3. Growth parameters, mortality, and exploitation rates for *Alosa immaculata* in the Danube River.

Growth Parameters			Mortality and Exploitation Rates				Area	Reference
L_∞	k	t_0	Z	M	F	E		
36.75	0.68	−0.67	2.76	0.89	1.87	0.68	Danube River, Romania	Our study
48.10	0.2	−1.58	-	-	-	-	Danube River, Romania	[9]
43.05	0.51	−0.53	2.32	0.77	1.55	0.67	Danube River, Romania	[37]
36.75	0.66	-	1.83	0.87	0.96	0.53	Danube River, Romania	[6]
40.43	0.38	−0.08	1.54	0.58	0.95	0.61	Danube River, Romania	[44]
35.74	0.49	0.341	-	-	-	-	Danube River, Bulgaria	[1]
40.43	0.27	−0.218	-	-	-	-	Danube River	[51]
57.38	0.10	1727	-	-	-	-	Danube River	[50]
41.5	0.38	−0.35	1.71	0.58	1.13	0.66	Black Sea, Romania	[45]
41.5	0.38	−0.34	1.71	0.63	1.07	0.625	Black Sea, Romania	[45]
37.8	0.87	−0.69	3.03	1.12	1.01	-	Black Sea	[2]

The findings from our study highlight a concerning pattern of overexploitation in Pontic shad stocks. Our results show that fishing mortality surpasses natural mortality, indicating an intense exploitation of the species. Additionally, the calculated exploitation rate (E = 0.68 year^{-1}) exceeds the optimum reference (E = 0.5) proposed by Gulland and Holt (1959) [55], further pointing towards an unsustainable level of exploitation. Moreover, when the ratio Z/k exceeds one, this indicates that the stock is in a state of collapse. If the ratio equals one, the population is in a steady state, and the dominance of growth over mortality is evident when the ratio Z/k is below one [56]. On the other hand, if the proportion is significantly greater than two, it signifies the overexploitation of the stock. In our study, the Z/k ratio was determined to be 4.05, well beyond the critical threshold of two. The coherence between our observed exploitation rate and the Z/k ratio reinforces the evidence that the Pontic shad stocks are in an overexploited state, emphasizing the necessity for conservation and sustainable management measures.

The size of the first capture (Lc50) of *Alosa immaculata* in this study was estimated at 30.25 cm. The Lc50 of the present study is lower than that determined in Pontic shad stocks by Tiganov et al. (2023) [2] in the Black Sea Coast, Romania. The differences in estimations could be linked to environmental factors and prolonged fishing pressure over an extended timeframe [57,58]. This situation might have a significant impact on the size at maturity, forcing the population to mature at a smaller size as a strategy to ensure the species' survival.

The length-based virtual population analysis (Figure 7) showed that the natural losses were highest among individuals within the length range of 24 to 28 cm, while the highest fishing mortality was experienced by individuals within the interval of 28 to 35 cm.

Calculating mortality rates is important to sustain fish stocks at the desired levels and prevent the overexploitation of fisheries. In the current study, the analysis revealed an Emax value of 0.77 in comparison to the current exploitation rate (E) of 0.68 year^{-1}. This suggests that the fish stock in the Danube River, Romania, is experiencing fishing pressure.

The Virtual Population Analysis (VPA) shows that the size class of 27 to 32 cm was affected by fishing mortality, while the highest natural losses were recorded at the length range of 24 to 28 cm. In this context, fish species of a smaller size undergo a lower rate of mortality due to fishing, while larger-sized fish species face a higher fishing mortality rate. When we assess the harvesting rate, it becomes apparent that fish species belonging to smaller mid-length groups have relatively higher rates of catches compared to fish species found in larger mid-length groups.

5. Conclusions

The exploitation rate (E = 0.66) was over the optimum level of 0.5, indicating that the *Alosa immaculata* species is overexploited in the Danube River, Romania. In this context, the long-term monitoring of Pontic shad populations, considering various factors such as age and sex distribution, is essential for making informed management and conservation decisions. Consistent and comprehensive data collection over the years enables researchers to identify trends, understand population dynamics, and implement effective conservation measures if it is necessary.

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References

1. Rozdina, D.; Raikova-Petrova, G.; Mirtcheva, P. Age composition and growth rate of the spawning part of the population of pontic shad *Alosa immaculata* (Bennett, 1835) in the Bulgarian sector of Danube River. *Bulg. J. Agric. Sci.* **2013**, *19* (Suppl. S1), 118–125.
2. Țiganov, G.; Grigoraș, D.; Năstase, A.; Păun, C.; Galațchi, M. Assesing of Pontic shad (*Alosa immaculata*, Bennett 1835) stock status from Romanian Black Sea Coast. *Turkish J. Fish. Aquat. Sci.* **2023**, *23*. Available online: https://www.trjfas.org/uploads/pdf_14965.pdf (accessed on 22 January 2023).
3. Bănărescu, P. *Fauna of Romanian Popular Republic. Pisces-Osteichthyes*; Romanian Academy Publishing House: Bucharest, Romania, 1964; p. 962.
4. Lenhardt, M.; Cakić, P.; Kolarević, J. Influence of the HEPS Djerdap I and Djerdap II dam construction on catch of economically important fish species in the Danube River. *Ecohydrol. Hydrobiol.* **2004**, *4*, 499–502.
5. Năvodaru, I. Exploitation of *Alosa pontica* in the Danube Delta, Romania. In *Stock Assessment in Inland Fisheries*; Cowx, I.G., Ed.; Fishing New Books: Oxford, UK, 1996; pp. 448–453.
6. Leonov, C.M.; Stroe, M.D.; Dima, F.M.; Vidu, L.; Nicolae, C.G. Assessment of growth and mortality parameters of *Alosa immaculata* (Bennet, 1835) from the Danube Delta. *Sci. Pap. Ser. D Anim. Sci.* **2023**, *66*, 596–601. Available online: https://animalsciencejournal.usamv.ro/pdf/2023/issue_1/Art78.pdf (accessed on 5 February 2023).
7. NAFA, National Agency of Fishery and Aquaculture. Available online: https://www.anpa.ro/wp-content/uploads/2022/02/pescuit-comercial-ape-interioare.pdf (accessed on 1 February 2023).
8. Năvodaru, I.; Staraș, M.; Cernișencu, I. Influence of the hydrological regime of the Danube on the annual variation of the Pontic shad (*Alosa pontica* Eichvald). In *Analalele Științifice ale Institutului Delta Dunării*; Institutul Delta Dunării: Tulcea, Romania, 1995; Volume III/1, pp. 215–221.
9. Năvodaru, I. The Evolution of the Pontic Shad Populations in the New Ecological Conditions of the River and Measures to Maintain Them. Ph.D. Thesis, Dunărea de Jos, University of Galați, Galați, Romania, 1997.
10. Smederevac-Lalić, M.; Kalauzi, A.; Regner, S.; Navodaru, I.; Višnjić-Jeftić, Ž.; Gačić, Z.; Lenhardt, M. Analysis and forecast of Pontic shad (*Alosa immaculata*) catch in the Danube River. *Iran. J. Fish. Sci.* **2018**, *17*, 443–457. [CrossRef]
11. Freyhof, J.; Kottelat, M. *Alosa Immaculata*. The IUCN Red List of Threatened Species 2008: E.T907A13093654. Available online: https://doi.org/10.2305/IUCN.UK.2008.RLTS.T907A13093654.en (accessed on 19 December 2023).
12. Habitats Directive 92/43 EEC. Available online: https://eur-lex.europa.eu/legal-content/RO/TXT/?uri=celex:31992L0043 (accessed on 22 January 2023).

13. Emergency Government Ordinance 57/2007. Available online: https://legislatie.just.ro/Public/DetaliiDocumentAfis/83289 (accessed on 22 January 2023).
14. Allen, M.S.; Hightower, J.E. Chapter 2. Fish population dynamics: Mortality, growth, and recruitment. In *Inland Fisheries Management in North America*, 3rd ed.; American Fisheries Society: Bethesda, MD, USA, 2010; pp. 43–79.
15. Yilmaz, S.; Polat, N. Age determination of Shad (*Alosa pontica*, Eichwald, 1838) inhabiting the Black Sea. *Turk. J. Zool.* **2002**, *26*, 393–398. Available online: https://journals.tubitak.gov.tr/cgi/viewcontent.cgi?article=2563&context=zoology (accessed on 22 January 2023).
16. Bolat, Y.; Yağci, A. A comparative study on age determination of carp (Cyprinus carpio Linnaeus, 1758) in Lake Eğirdir using otolith, vertebrae and scale counts. *J. Agric. Sci.* **2018**, *24*, 199–204. [CrossRef]
17. de Moraes Vazzoler, A.E.A. *Biologia da Reprodução de Peixes Teleósteos: Teoria e Prática*; Eduem: Maringá, Brazil, 1996; 169p.
18. Ricker, W.E. Computation and Interpretation of Biological Statistics of Fish Populations. *J. Fish. Res. Board Can.* **1975**, *191*, 1–382.
19. Froese, R.; Tsikliras, A.C.; Stergiou, K.I. Editorial note on weight-length relations of fishes. *Acta Ichthyol. Piscat.* **2011**, *41*, 261–263. [CrossRef]
20. Pauly, D. Some simple methods for the assessment of tropical fish stocks. *FAO Fish. Tech. Pap.* **1983**, *234*, 52.
21. Pauly, D.; Munro, J.L. Once More on the Comparison of Growth in Fish and Invertebrates. *ICLARM Fishbyte* **1984**, *2*, 21.
22. Ragonese, S.; Vitale, S.; Mazzola, S.; Pagliarino, E.; Bianchini, M.L. Behavior of some growth performance indexes for exploited Mediterranean hake. *Acta Adriat.* **2012**, *53*, 105–122. Available online: https://hrcak.srce.hr/file/132894 (accessed on 5 February 2023).
23. Gayanilo, F.C., Jr.; Sparre, P.; Pauly, D. *FAO-ICLARM Stock Assessment Tools II (FiSAT II). Revised Version, User's Guide*; FAO Computerized Information Series (Fisheries); FAO: Rome, Italy, 2005; 168p.
24. Pauly, D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *ICES J. Mar. Sci.* **1980**, *39*, 175–192. [CrossRef]
25. Then, A.Y.; Honeig, J.M.; Hall, N.G.; Hewitt, D.A. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. *ICES J. Mar. Sci.* **2015**, *72*, 82–92. [CrossRef]
26. Gulland, J.A. *The Fish Resources of the Ocean*; Fishing News (Books) Ltd.: Chichester, UK, 1971; Available online: https://www.fao.org/3/al937e/al937e.pdf (accessed on 22 January 2023).
27. Balik, İ. Population parameters of the Pontic shad, *Alosa immaculata* Bennett, 1835 in the Fatsa coast of the south-eastern Black Sea. *EgeJFAS* **2019**, *36*, 319–324. Available online: http://www.egejfas.org/tr/download/article-file/751645 (accessed on 5 February 2023). [CrossRef]
28. Beverton, R.J.H.; Holt, S.J. *Manual of Methods for Fish Stock Assessment, Part II, Tables of Yield Function*; Fisheries Technical Paper No. 38, Review 1; FAO: Rome, Italy, 1966.
29. Basilone, G.; Ferreri, R.; Bonanno, A.; Genovese, S.; Barra, M.; Aronica, S. Age and Growth of European Sardine (*Sardina pilchardus*) in the Central Mediterranean Sea: Implication for Stock Assessment. *Fishes* **2023**, *8*, 202. [CrossRef]
30. Tah, L.; Joanny, T.G.; N'Douba, V.; Kouassi, N.J.; Moreau, J. Preliminary Estimates of the Population Parameters of Major Fish Species in Lake Ayamé I (Bia basin; Cơte d'Ivoire). *Appl. Ichthyol.* **2010**, *26*, 57–63. [CrossRef]
31. Li, P.; Liu, J.; Wang, T.; Wang, J. Estimates of the Age, Growth, and Mortality of *Triplophysa scleroptera* (Herzenstein, 1888) in the Upper Reaches of the Yellow River, China. *Fishes* **2023**, *8*, 457. [CrossRef]
32. Kolarov, P.P. Biological Characteristics and Population Dynamic of Anadromous Fish Specie. Ph.D. Thesis, Institute for Fish Resources, Varna, Bulgaria, 1985.
33. Schmutz, S. *Assessment of the Potential Transboundary Effects of the Construction of the Bystre Deep-Water Navigation Channel on Fish and Fisheries*. Report to the ESPOO Inquiry Commission Vienna. 2006, p. 56. Available online: https://unece.org/DAM/env/eia/documents/inquiry/Final%20Report%20Schmutz.pdf (accessed on 22 January 2023).
34. Available online: https://www.afdj.ro/ro/cotele-dunarii (accessed on 5 February 2023).
35. Niculescu-Duvăz, M.; Nalbant, T. Consideratii Asupra Sistematicii Scrumbiei de Dunare (Alosa Pontica Pontica Eichw.) si Asupra unor Fenomene Specifice Legate de Migratia si Prognoza Acestei Specii în Apele Dunarii. *Bul. Inst. Cercet. Pentru Pescuit Si Piscic. XXIV 1* **1965**, *24*, 15–25. (In Romanian)
36. Năvodaru, I.; Năstase, A. New data on pontic shad (*Alosa immaculata* Bennet 1835) migration and drifting larvae in Danube River, Deltaica. In *Noi Date Asupra Prezenţei Marilor Peşti Migratory Anadromi în Marea Neagră—Zona Marină a Rezervaţiei Biosferei Delta Dunării (New Data on Presence of the Great Anadroumous Migratory Fishes in Black Sea—Marine Zone of Danube Delta Biosphere Reserve)*; Torok, L., Ed.; Institutul Naţional de Cercetare-Dezvoltare "Delta Dunării"—Tulcea: Tulcea, Romania, 2014; Volume 3. [CrossRef]
37. Mocanu, M.; Oprea, L.; Cordeli, A.N.; Crețu, M. 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. *Sci. Pap. Ser. D Anim. Sci.* **2021**, *64*, 448–453.
38. Ciolac, A.; Patriche, N. Structure of Danube shad (*Alosa pontifica* Eichwald, 1838) spawner flocks migrating for reproduction in Danube River. *Appl. Ecol. Environ. Res.* **2003**, *2*, 53–58. [CrossRef]
39. Tiganov, G.; Năvodaru, I.; Cernișencu, I.; Năstase, A.; Maximov, V.; Oprea, L. Preliminary Data on the Studies of *Alosa immaculata* in Romanian marine waters. *Sci. Ann. Danub. Delta Inst.* **2016**, *22*, 141–148. Available online: https://ddniscientificannals.ddni.ro/images//22_17.pdf (accessed on 5 February 2023).

40. Trindade-Santos, I.; Freire, K.M.F. Analysis of reproductive patterns of fishes from three large marine ecosystems. *Front Mar. Sci.* **2015**, *2*, 38. [CrossRef]
41. Stroe, M.D.; Crețu, M.; Ion, G.; Mirea, D.; Savin, V.; Tenciu, M.; Patriche, N. Population structure and growth parameters of *Alosa immaculata* species, Bennett, 1835 (Pontic shad) on the Danube sector km 169–km 197 in 2020. *Sci. Pap.-Anim. Sci. Ser. Lucr. Ştiinţifice Ser. Zooteh.* **2021**, *75*, 265–270. Available online: https://www.uaiasi.ro/firaa/Pdf/Pdf_Vol_75/Desimira_Stroe.pdf (accessed on 5 February 2023).
42. Năstase, A.; Năvodaru, I.; Cernișencu, I.; Țiganov, G.; Popa, L. Pontic shad (*Alosa immaculata*) migrating upstream the Danube River and larval drift downstream to the Black Sea in 2016. *Sci. Ann. Danub. Delta Inst.* **2018**, *23*, 57–68. Available online: https://www.ddniscientificannals.ro/images/23_08.pdf (accessed on 22 January 2023).
43. Battes, K.W.; Pricope, F.; Ureche, D.; Ureche, C.; Stoica, I.; Răducanu, D.; Dogaru, N. Evaluarea stării resurselor pescăreşti şi capturilor durabile din apele interioare. In *Estimarea Stocurilor de Peşti şi Pescăriilor*; Năvodaru, I., Ed.; Ed. Dobrogea: Constanţa, Romania, 2008; pp. 275–288.
44. Ibănescu, D.C.; Popescu, A.; Nica, A. Estimation of growth and mortality parameters of the Pontic shad (*Alosa immaculata* Bennett, 1835) in Romanian section of the Danube River. *Sci. Pap.-Zootech. Univ. Agric. Sci. Vet. Med. Iași* **2017**, *67*, 285–289. Available online: https://www.uaiasi.ro/firaa/Pdf/Pdf_Vol_67/Daniela_Ibanescu.pdf (accessed on 5 February 2023).
45. Tiganov, G.; Nenciu, M.I.; Danilov, C.S.; Nita, V.N. Estimates of the population parameters and exploitation rate of pontic shad (*Alosa immaculata* Bennett, 1835) in the Romanian Black Sea coast. *Sciendo Agric. Life Life Agric. Conf. Proc.* **2018**, *1*, 162–167. [CrossRef]
46. Vieira, R.P.; Monteiro, P.; Ribeiro, J.; Bentes, L.; Oliveira, F.; Erzini, K.; Gonçalves, J.M.D.S. Length-weight relationships of six syngnathid species from Ria Formosa, SW Iberian coast. *Cah. Biol. Mar.* **2014**, *55*, 9–12. Available online: https://sapientia.ualg.pt/bitstream/10400.1/8805/1/2014%20Vieira%20et%20al_WL%20relationships%20Syngnathidae.pdf (accessed on 22 January 2023).
47. Li, Y.; Feng, M.; Huang, L.; Zhang, P.; Wang, H.; Zhang, J.; Xu, J. Weight–Length Relationship Analysis Revealing the Impacts of Multiple Factors on Body Shape of Fish in China. *Fishes* **2023**, *8*, 269. [CrossRef]
48. Wang, L.; Wu, Z.; Liu, M.; Liu, W.; Zhao, W.; Liu, H.; Zhang, P.; You, F. Length-weight, length-length relationships, and condition factors of black rockfish *Sebastes schlegelii* Hilgendorf, 1880 in Lidao Bay, China. *Thalass. Int. J. Mar. Sci.* **2017**, *33*, 57–63. [CrossRef]
49. Morado, C.N.; Araújo, F.G.; Gomes, I.D. The use of biomarkers for assessing effects of pollutant stress on fish species from a tropical river in Southeastern Brazil. *Acta Sci. Biol. Sci.* **2017**, *39*, 431–439. [CrossRef]
50. Kolarov, P. Particularities of Pontic shad (*Alosa kessleri pontica* Eichw.) in 1979 in Bulgarian aquatory. *Fisheries* **1980**, *27*, 7–19.
51. Kolarov, P. Some basic parameters of the Pontic shad (*Alosa kesleri pontica* Eichw.) population. *Hydrobiologiya* **1983**, *19*, 60–69.
52. Tsikliras, A.C.; Froese, R. Maximum sustainable yield. *Encycl. Ecol.* **2019**, *1*, 108–115. [CrossRef]
53. Santos, R.; Peixoto, U.I.; Medeiros-Leal, W.; Novoa-Pabon, A.; Pinho, M. Growth Parameters and Mortality Rates Estimated for Seven Data-Deficient Fishes from the Azores Based on Length-Frequency Data. *Life* **2022**, *12*, 778. [CrossRef] [PubMed]
54. Gulland, J.A. *Fish Stock Assessment. A Manual of Basic Method*; FAO/Wiley Series on Food and Agriculture; FAO: Rome, Italy, 1983; 64p.
55. Gulland, J.A.; Holt, S.J. Estimation of Growth Parameters for Data at Unequal Time Intervals. *ICES J. Mar. Sci.* **1959**, *25*, 47–49. [CrossRef]
56. Etim, L.; Lebo, P.E.; King, R.P. The dynamics of an exploited population of a Silurid catfish (*Schilbe intermidius*, Reupell 1832) in the Cross River, Nigeria. *Fish. Res.* **1999**, *40*, 295–307. [CrossRef]
57. Tsikliras, A.C.; Antonopoulou, E. Reproductive biology of round sardinella (*Sardinella aurita*) in north-eastern Mediterranean. *Sci. Mar.* **2006**, *70*, 281–290. Available online: https://scientiamarina.revistas.csic.es/index.php/scientiamarina/article/view/155/152 (accessed on 5 February 2023). [CrossRef]
58. Jennings, S.; Kaiser, M.J.; Reynolds, J.D. *Marine Fisheries Ecology*; Blackwell Science: London, UK, 2009; 393p.