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RESEARCH PAPER

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Assessing of Pontic Shad (*Alosa immaculata*, Bennett 1835) Stock Status from Romanian Black Sea Coast

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Abstract

With the growth of the human population, the need for food resources increases, so the pressure on living marine resources also increases. In addition to this aspect, the Black Sea ecosystem during recent decades suffered changes that determined the deterioration of all components of the marine ecosystem, which had direct impact on decreasing the biological diversity and productivity, affecting the quality of life and ecological balance.

The species *Alosa immaculata* (Bennet, 1835) - Pontic shad is of high commercial value and with an important role in the livelihoods of many local communities across the Black Sea coast. However, the status of Pontic shad fisheries is unknown, mainly because is a status of data-poor fish stocks. Thus, growth parameters were determined in a total of 783 individuals with a biomass of 194.5 kg from 9 fishing points of the Romanian Black Sea Coast. For the estimated parameters of length-weight relation the combined data and sexes have been used, coefficient of determination (r^2) was 0.794 and b value 2.879. A negative allometric growth has been observed for the species where b<3. The virtual population analysis (VPA) by lengths was performed using the FISAT II software. Catch data previously determined were used to apply the model: length class frequency set, coefficients a=0.0134 (2021) and b=2.879 (2021) of the length-weight relationship, natural mortality M=1.12/year, L_∞=37.8, k=0.87/year. The main aim of this paper is to provide an overview of the current status and trends of this valuable resource.

Introduction

Fisheries can effectively be managed if there is sufficient scientific understanding of the current biomasses and trends of fish stocks. However, because most stocks lack robust assessments, practical advice for them, and hence management capabilities, are impaired (Demirel et al., 2020). Thus, because the Pontic shad is an important species in the Danube - Danube Delta - Black Sea ecological system and with great economic value due to the large quantities caught and the taste qualities appreciated by the population of the lower Danube area, knowing the essentials of the biology and exploitation of the species helps to provide basic information for the conservation of the species and the management of stocks. The unfolding of the life cycle in two environments (freshwater and marine), located at great distances in different periods of time, requires knowing and updating the impact of new environmental conditions on the population. *Alosa* species are extremely vulnerable to anthropogenic changes, especially related to access and quality of their spawning

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grounds (Faria et al., 2006). Therefore, more conservation measures should be conducted to perpetuate the stocks of these species (Turan et al., 2015).

The factors that have a negative effect on stocks are pollution, overfishing and dam construction (Navodaru, 1996), also the species is classified as vulnerable (VU) (Freyhof & Kottelat, 2008). A mathematical model established for simulating the dynamics of the stocks in the change effort, developed for American shad (A. sapidissima) shows that the stock collapse to 20 years after overexploitation started (Crecco & Savoy, 1987). Also, the political goal of resource use is often a weak part of fisheries management system as conflicting objective is often found when exploiting a fish resource as to maximize sustainable biomass yield and sustainable economic yield, to increase employment in certain regions, to secure protein production, food supply and increase export income (Duzgunes & Erdogan, 2008).

Thus, the cooperation of the Black Sea riparian countries and the exchange of knowledge regarding the status of the stock of these species is extremely important for sustainable exploitation.

Materials and Methods

The assessment of Pontic shad populations has been made on length and weight data, samples have been collected from research surveys across the Romanian Coast organized between January and April 2021 in 9 fishing points from Vadu to Sulina area (Figure 1). Sampling activity was done with fixed gillnets, the constructive characteristics of these tools were: length 90 meters (m), height 2.5-3.5 m, mesh size 32 millimeters (mm). This fishing gear is highly productive during shad migration along sea coast towards the Danube River. Methodology and techniques that have been used for collection, verification, processing and analysis, as well as the assessment of fish stocks are generally accepted for the Black Sea (Bagenal & Tesch, 1978; Battes et al., 2008; Ibănescu et al., 2016) and in accordance with international methodology (Zaharia, 2013).

Specimens have been measured for its total length with a precision of 0.1 cm, for the length distribution the measurements have been grouped in 1 cm length classes. Length frequency distribution resulted was then used to estimate population parameters like growth,

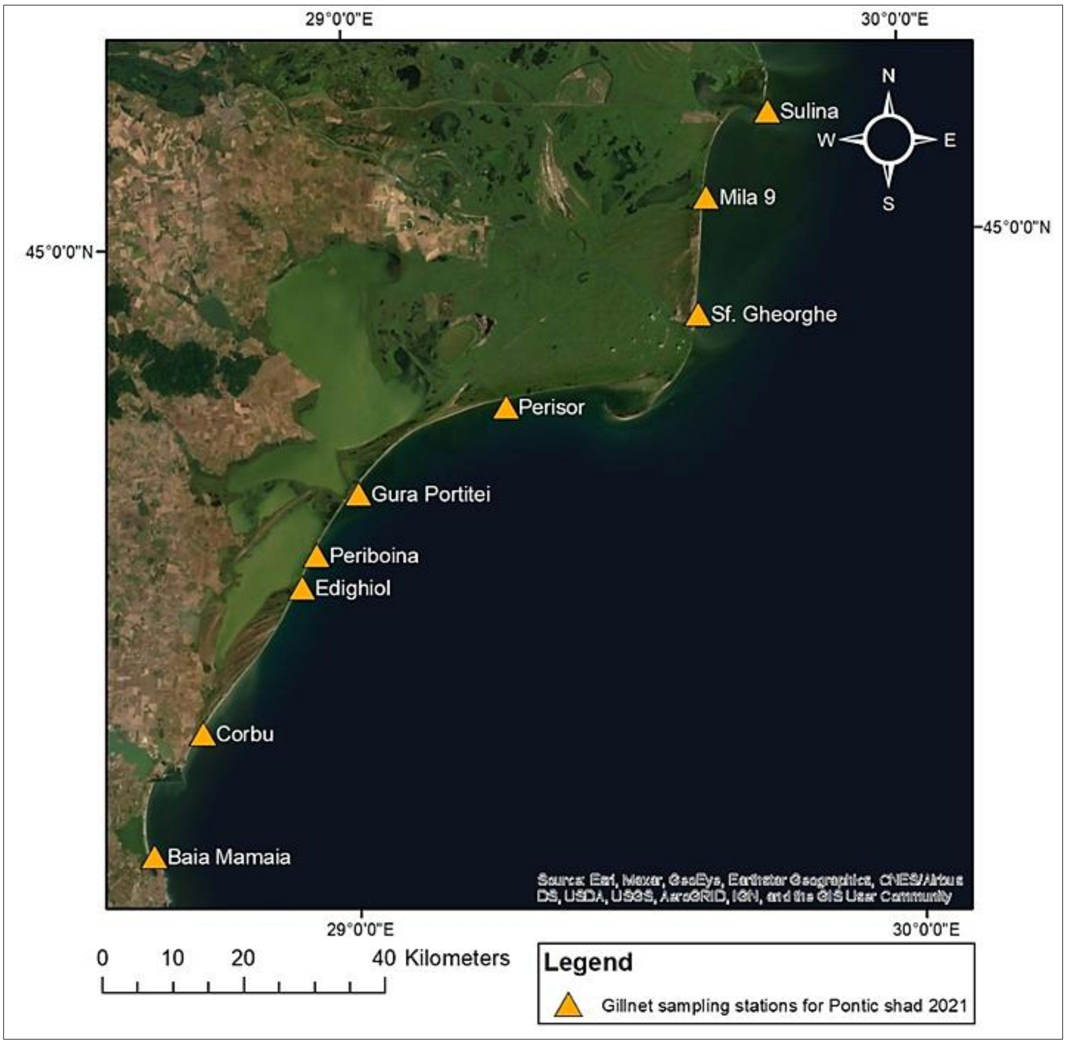

Figure 1. Gillnet sampling stations for Pontic shad in 2021.

recruitment and mortality rates. The von Bertalanffy equation and growth performance index were determined by FISAT II software, the total mortality coefficient (Z) was estimated by length converted catch curve method and natural mortality was calculated by different methods (Then et al., 2015; Hamel, 2015; Jensen, 1996, Jensen, 1997& Pauly, 1980) using The Natural Mortality Tool: Empirical Estimators of Natural Mortality (M) developed in R. Fishing mortality rate was estimated by Z-M. Length at first capture was calculated by selection Ogive method determined (Kalayci et al., 2007) by applying probability of capture to the length frequency distribution. The length structured Virtual Population Analysis (VPA) of FISAT II was used to assess the fishing pressure on different length groups and the relative yield-per-recruit model for stock predictions was computed based on Beverton & Holt (1957) model.

Results

Based on the catch resulted from experimental fishing with 32 mm mesh size gillnets, the age reading made determined that the population of Pontic shad is comprised of 4 generations (2-5 years) for the study period. The cohorts of 3 and 4 years dominated (Figure 2). The sex ratio obtained from the analysis showed a dominance of females with a 52% from the total numbers of specimens.

The growth parameters in Pontic shad were determined in a total of 783 individuals with a biomass of 194.5 kg from 9 fishing points of the Romanian Black Sea Coast. For the estimated parameters of length-weight relation the combined data and sexes have been used, coefficient of determination (r^2) was 0.794 and b value 2.879. A negative allometric growth has been observed for the species where b<3. The value of b for the studied samples is close to values recorded in Danube River in recent study wrote by Mocanu et al. (2021) but lower than the values obtained in 2012-2013 (Tiganov et al., 2018). These differences may be a reflection of growth variation, as length-weight relationship (Savaş & Nazmi, 2011) can fluctuate due to the influence of temperature, salinity, food availability and reproduction. The fish growth variation could be under the influence of temperature as for the study year 2021, the annual medium temperature recorded for the Black Sea was 14.2°C degrees, with 2 degrees higher than 2020.

The values of the a and b growth coefficients resulting from the plots are shown in (Figure 3) and the

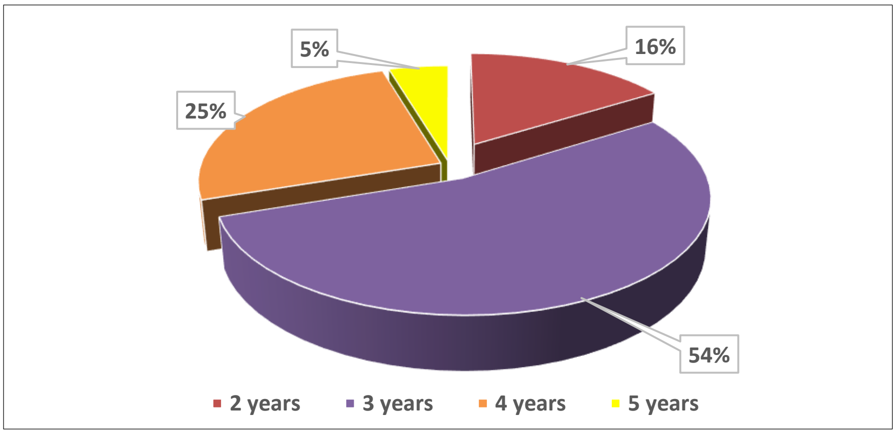

Figure 2. Age structure of Pontic shad during 2021.

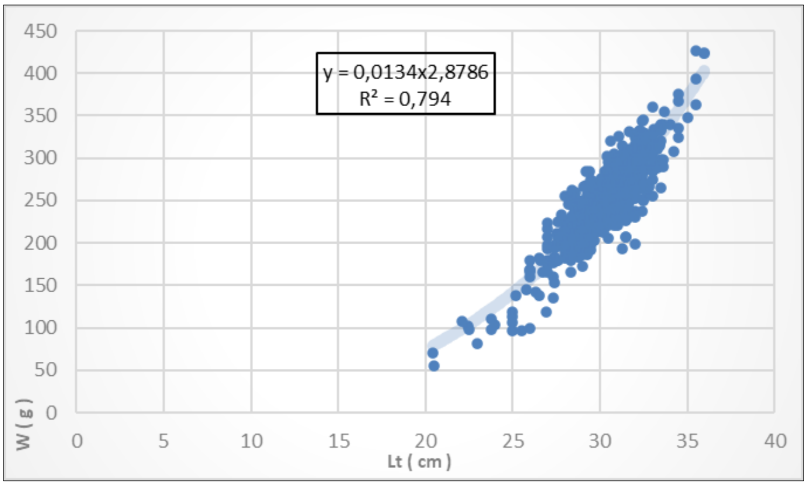

Figure 3. Length-weight relationship combined sexes in Romanian Black Sea area, 2021.

relationship between the total length and weight (Lt-W) for the Pontic shad population during the study period determined: W=0.0134 * Lt 2.879.

Length frequency data and growth curves were plotted with FISAT II software by stations, by months and by total, which resulted in a peak of individuals caught of 30 cm across the sampled areas. (Figure 4, 5).

After analyzing the samples for length frequency in experimental fish catches, the growth and exploitation parameters of the Pontic shad stock were estimated by analytical methods, using FISAT II software (Table 1).

The results obtained for introducing total length data for one studied year, the asymptotic length (L∞=L infinity) of Pontic shad generated by the ELEFAN I method was 37.8, values that is for species with high growth rates in the first years of life. The results obtained are comparable (Table 2) and in range of the values obtained in previous studies by different authors (Kolarov 1980, 1983; Prodanov & Kolarov, 1983; Rozdina et al., 2013).

The natural mortality instantaneous coefficient (M) of the entire Pontic shad population, calculated

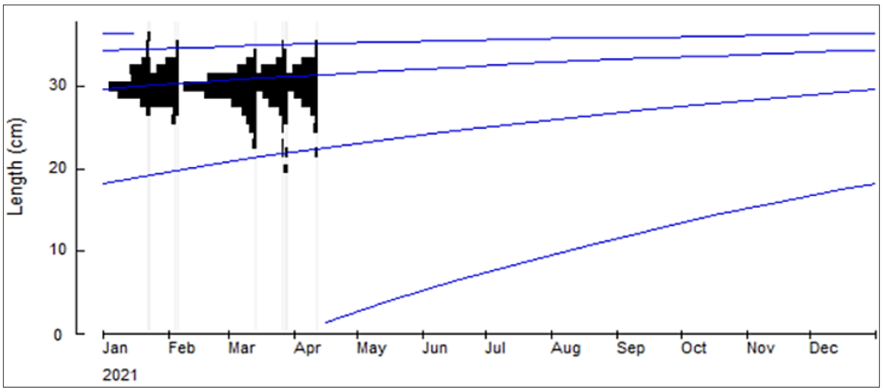

Figure 4. Length frequency and growth curves of Pontic shad by stations and months, in Romanian Black Sea area, 2021**.**

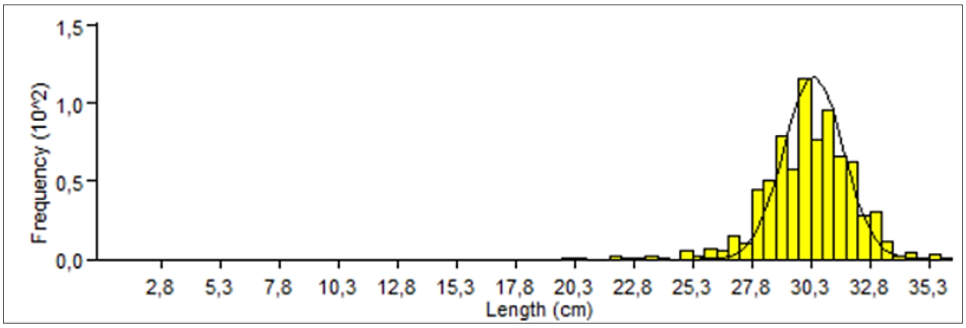

Figure 5. Length frequency by total for Pontic shad, in Romanian Black Sea area, 2021.

Table 1. Growth, exploitation parameters and length-weight relationship - migration 2021 in the Black Sea (W = a x Ltb length-weight relationship, Lt - total length, W - weight, a and b - regression coefficients).

Sampling year	Gear	L∞	K	to	Lr	Lc	M	F	Z	W = a x Lb	
2021	Gillnets a=32 mm	37.8	0.87	-0.69	14	30	1.12	1.91	3.03	0.0134	2.879

Table 2. Von Bertalanffy growth parameters for linear growth in Pontic shad.

Area and author	L ∞	K	to
Danube (Năvodaru, 1997)	48.10	0.2	-1.58
Danube (Rozdina, 2013)	35.74	0.4932	0.3411
Danube (Kolarov, 1980)	57.38	0.1067	1727
Danube (Kolarov, 1983)	40.43	0.2705	-0.218
Danube (Mocanu, 2021)	43.05	0.51	-0.53
Blak Sea (Prodanov, Kolarov, 1983)	40.43	0.27	-0.218
Blak Sea (Tiganov, 2012)	41.5	0.38	-0.35
Blak Sea (Tiganov, 2013)	41.5	0.38	-0.34
Blak Sea (Tiganov, 2021)	37.8	0.87	-0.69

according to 5 different formulas with The Natural Mortality Tool, using the growth parameters of the Von Bertalanffy formula and the mean annual temperature of one year of study of 14.2°C, recorded a mean value of M=1.12 in 2021 (Table 3).

The length at full recruitment to the exploitable phase (Lc=30 cm for 2021) was determined after analyzing gillnet selectivity in relation to the frequency of lengths within catches (Figure 6).

The calculation of the catch curve (Figure 7) used to determine selectivity led to the total mortality instantaneous coefficient (Z=3.03) for all age groups. Fishing mortality (F) was calculated according to the relationship Z=F+M, in this case F=1.91 (2021).

Additional considerations were made on the availability of food to some cohorts correlated to specimens' density, which impacts on growth, by testing the difference from 3 of the value of coefficient b in the relationship (Năvodaru, 1997). As such, good conditions and favorable densities result in accelerated growth (Figure 8), reflected by a value of coefficient b close to 3 or higher. In our case, the value of b was <3 during the year studied.

The logistic regression of the probability of capture routine values recorded for the analyzed species are presented in Figure 9. The estimated L50 was 31.65 cm. The L25 was calculated as 30.62 cm, while L75 was 32.68 cm. The Beverton Holt relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) were estimated using the selective Ogive procedure of FiSAT II. The analysis indicated that the exploitation rate, which maximizes yield per recruit, produced values of Emax=0.949; E10=0.853 and E50=0.413 for Pontic shad (Figure 10 a, b).

The virtual population analysis (VPA) by lengths was performed using the FISAT II software. Catch data

Table 3. Estimates of natural mortality (M) in Pontic shad for the year 2021.

Method	*Then_VBGF*	*Hamel_k*	*Jensen_k 1*	*Jensen_k 2*	*Pauly_lt*	*Mean_Value*
M	0.9951	1.2990	1.1115	1.1856	1.004	1.1190

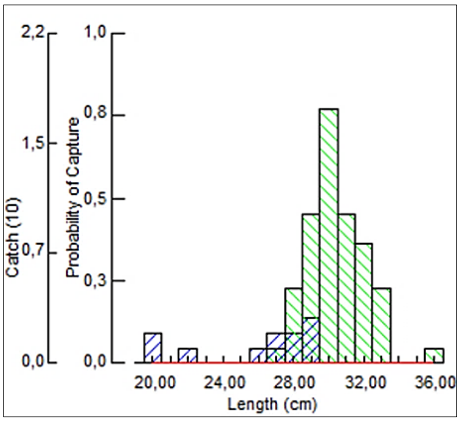

Figure 6. Gillnet selectivity in relation to the frequency of lengths in Pontic shad, Romanian Black Sea area, 2021.

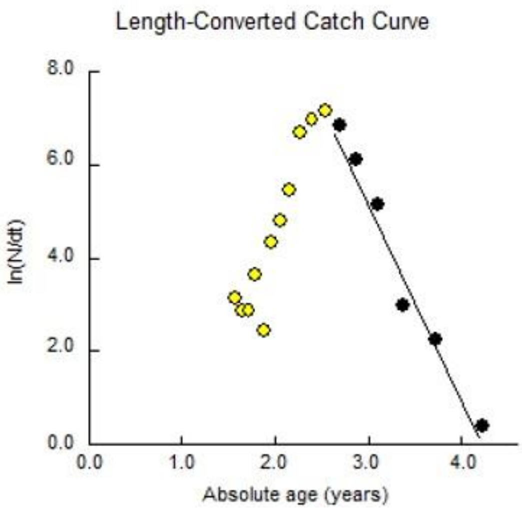

Figure 7. Length converted catch curve of Pontic shad, in Romanian Black Sea area, 2021.

previously determined were used to apply the model: length class frequency set, coefficients a=0.0134 (2021) and b=2.879 (2021) of the length-weight relationship, natural mortality M=1.12/year, L∞=37.8, k=0.87/year. Further we performed a simulation of fishing optimization by modelling recalculating the optimal biomass and the maximum sustainable yield (MSY), using the VPA analytical model for the minimum of historical catches. From the information gathered in the field work, most of the Pontic shad specimens from the Danube were fished on the St. George arm, which shows that the migration on the other arms of the delta was insignificant (without the capture of Ukraine). Relatively high productions were also fished in the Black Sea, especially in the area of the Musura bay, Perișor – Periboina, Chilia - Câşla Vadanei and on the Sulina arm and Unic Danube small amounts of shads were caught, while actually on the Chilia arm no number of shads was recorded. In space, the fisheries at the mouths of the Danube (especially at Sf. Gheorghe) are the most productive, where the fishing effort is also more intense, productivity decreasing upstream. Based on this information the catches used in the model are combined for Danube Delta and Black Sea, data from 2008 till 2021 has been used (Figure 11).

The final data obtained from this analysis are absolute estimates of the stock and fishing mortality, for each length class, graphically shown in (Figure 12) and (Table 4) for 2021.

For the first time the estimation on this stock status have been made (2422.27 tons) and also for the current MSY value of 242,2 tons for year 2021 in order to have a starting point to make further assessments and assumptions on the level of exploitation and management measures to protect the species. According to these results and the total catches made in 2021 of 364.31 tons, the stock of Pontic shad is overexploited, the same result is obtained also from the current exploitation rate E=0.63 - which is the report between fishing mortality and total mortality E=F/Z according to Ricker (1958 and 1975), from the formula that is higher than E=0.5 (Gulland, 1971). Another indicator of the overexploitation status of the stock of Pontic shad is the fishing mortality F=1.91 which is greater than the natural mortality M=1.12.

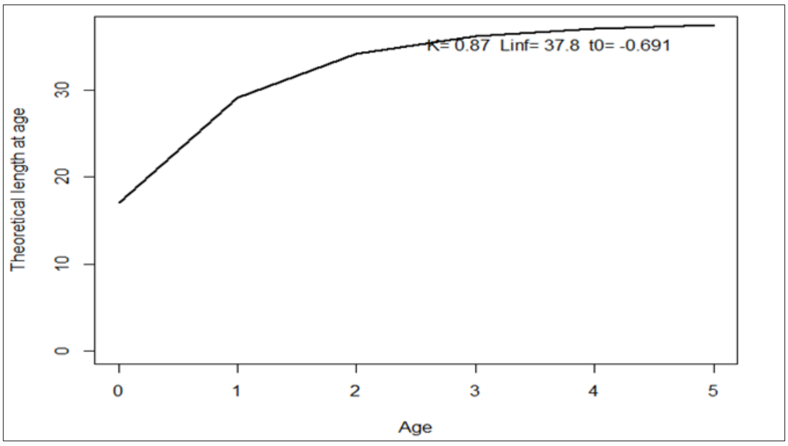

Figure 8. Von Bertalanffy growth curve in Pontic shad, in Romanian Black Sea area, 2021**.**

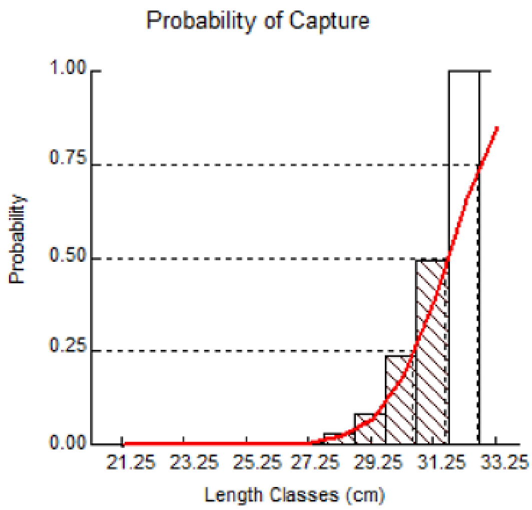

Figure 9. The probability capture curve showing the L25, L50 and L75 of Pontic shad, from Romanian Black Sea area, 2021.

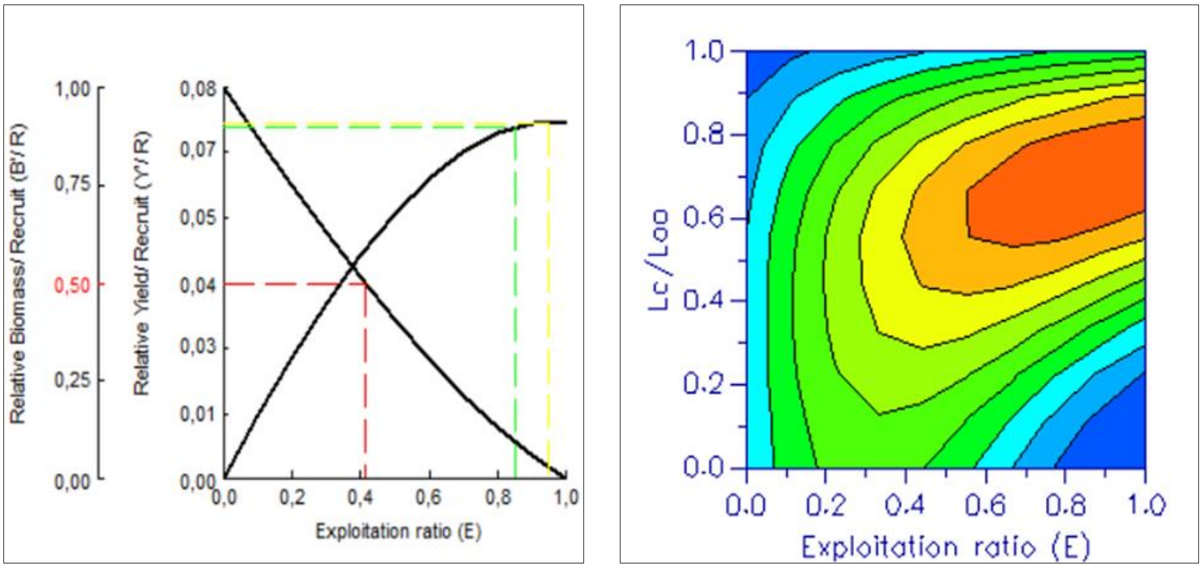

Figure 10. Beverton and Holt's relative yield per recruit and average biomass per recruit models, showing levels of yield indices of Pontic shad, from Romanian Black Sea area, 2021.

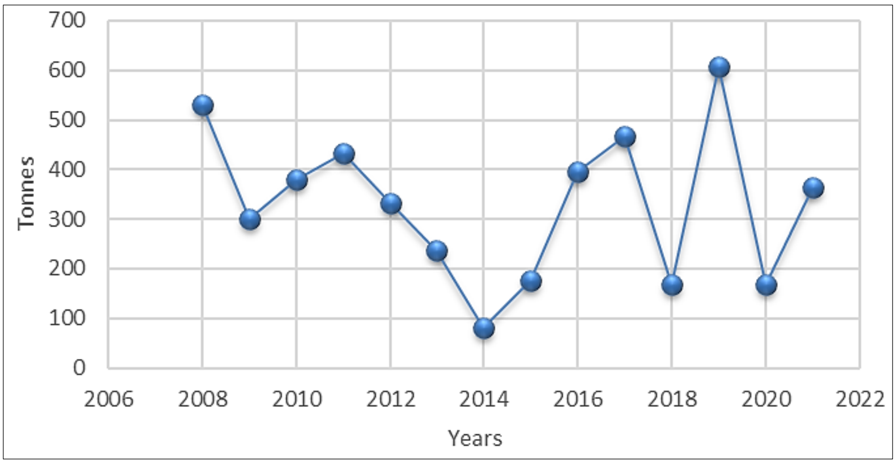

Figure 11. Total catches of Pontic shad for Black Sea and Danube Delta in the period 2008-2021.

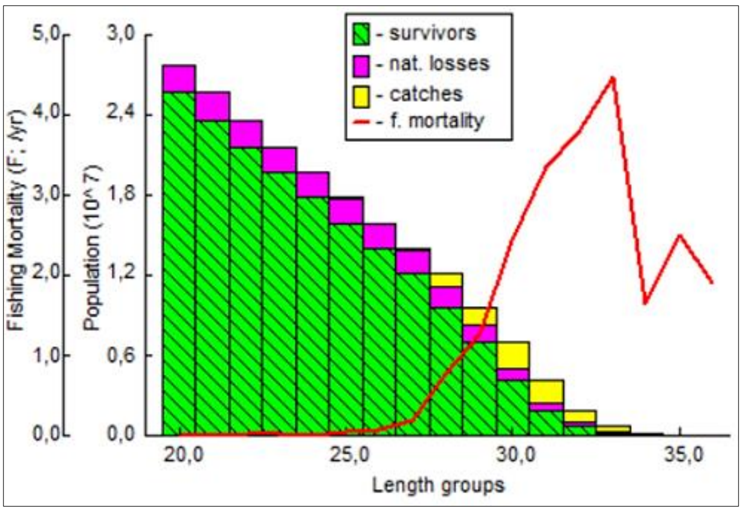

Figure 12. Assessing the current state by virtual population analysis in Pontic shad, in Romanian Black Sea area, 2021.

Table 4. Assessing the current state by virtual population analysis in Pontic shad, 2021.

Mid-Length (cm)	Catch (in numbers)	Population (N)	Fishing mortality (F)	Steady-state Biomass (tonnes)
20	20000	27730562	0.0116	128.61
21	0	25643126	0	144.73
22	30000	23621314	0.0182	161.55
23	30000	21617322	0.0187	178.85
24	10000	19664368	0.0064	196.67
25	70000	17783658	0.0463	214.46
26	120000	15899786	0.0824	231.39
27	250000	14031655	0.1799	246.09
28	960000	12113874	0.7555	249.82
29	1370000	9629108	1.2735	233.98
30	1930000	6968188.5	2.4232	190.99
31	1620000	4082435	3.3646	126.89
32	900000	1884636.5	3.7884	68.6
33	410000	699546.56	4.4638	28.98
34	60000	179326.5	1.6431	12.55
35	40000	75505.98	2.497	5.99
36	10000	16282.72	1.91	2.12
Total	7830000	201640695		2422.27

Discussion

In this study, we made, for the first time at Romanian Black Sea Coast, the estimation of Pontic shad stock status.

The results show that fishing mortality rates (F) differ according to mean length and species' character. Length classes with higher mortality rates varied considerably during the lifetime of fish. The length classes with higher fishing mortalities were 29.0 - 36.0 cm (2021).

Also, comparing the optimum E value with the E value obtained from this study shows that the Pontic shad is overexploited in the Romanian Black Sea area. Recent publication (Kozobrod et al., 2022) indicate similar aspects regarding the fishing mortality rates (F) for Pontic shad in Ukrainians Black Sea area, from F=0.29 in 2018 to F=0.38 in 2020, a trend of increasing fishing mortality above the level of target exploitation.

This fact would imply in future management measures such as size-limit regulation by gradually increasing fishing gear mesh size and longer ban periods in the migration and spawning season and cooperation at the level of the entire Black Sea basin.

Conclusion

The present study has provided information on the growth and population status of *Alosa immaculata* (Bennet, 1835), that will help in the development of efficient management and conservation strategies. The length-weight relationship results revealed an exponent of (b) values of 2.879 and the coefficient of determination (r^2) of 0.794. The length at first capture (Lc) estimated in this study showed that the selectivity of the gillnets retains individuals of medium size. Fishing mortality was greater than the natural mortality, while exploitation rate (E) was higher than 0.5, the catches from 2021 were bigger than the MSY value, the species exhibited a negative allometric growth pattern. The Pontic shad in the Black Sea is overexploited. Unless sufficient effort is taken to control the stocks, the stock may collapse as fishing develops in the future to fulfil consumer demand.

Ethical Statement

This study has been conducted in an ethical and responsible manner, and in full compliance with all relevant codes of experimentation and legislation.

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Author Contribution

ŢG, GD and PC performed samplings, MG performed the measurements in the laboratory. ŢG and GD run analysis and evaluate outputs. NA and MG reviewed literature data. ŢG conceived the first draft, all authors contributed to the final version.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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