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Additional Fisheries Data on Pontic Shad (Alosa Immaculata) one of the Main Fish Resources of the Danube-Black Sea System

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Abstract

The latest data on the Pontic shad fishery of the Danube-Black Sea system comes from the year 2024, based on a sequence of steps including field studies, analyses for over 1100 adult migratory individuals from commercial catches, scales taken from significant number of individuals for age structure and observations of sex structure, gonad maturity and IAL (index of larval abundance) as an indicator of reproductive success. The most important fish stock parameters are growth, recruitment, natural mortality and fishing mortality for the deltaic fisheries including the Pontic shad fishery. Spatially, the population of Pontic shad is interpreted as a system with two main compartments: the stock in the western and south-western Black Sea and the cycling compartment, represented on the one hand by sexually mature individuals migrating to the Danube to spawn and on the other hand by juveniles, the result of reproduction, entering the stock. As this is a migratory stock, for practical reasons and due to the uncertainties caused by the different results of the assessment models, it is not recommended to intensify the fishery or to reduce the mesh size, but only to fish in a way that avoids catches below the minimum allowable size, even if the results of 2024 are much better than those of the last three years.

Keywords: Pontic Shad, Fisheries Stock Parameters

Introduction

The most recent classifications of bony fishes place them in the following taxa: kingdom Animalia, phylum Chordata, infraphylum Vertebrata, superclass Osteichthyes, class Actinopterygii, subclass Neopterygii, infraclass Teleostei, and in Table 1, two variants of the classification of fishes of the order Clupeiformes, family Clupeidae (which includes the genus Alosa, from our study) are presented.

Table 1: Different Classifications of Bony Fish Included Alosinae

Classification after Nelson, 2006 [1]	Classification after FishBase 2025 / www.calacadademy.org 2025
kingdom Animalia	kingdom Animalia
phylum Chordata	phylum Chordata
subphylumCraniata	infraphylum Vertebrata
superclass Gnathostomata	superclass Osteichthyes
class Actinopterygii	class Actinopterygii (Actinopteri)
Subclass Neopterigii	Subclass Neopterygii

division Teleostei	infraclass Teleostei
subdivisionOstarioclupeomorpha	orderClupeiformes
Superorder Clupeomorpha	Suborder Clupeoidei
Order Clupeiformes	Family Clupeidae
suborder Clupeoidei	Subfamily Alosinae
family Clupeidae	
subfamily Alosinae	

The genus Alosa is present only in the northern hemisphere of the Earth and comprises a total of 24 valid species: 18 species in Europe and the East Atlantic coasts and 6 species in North America [2].

The genus Alosa is represented by several species, the most important of which are widespread in the Atlantic, Mediterranean, Black and Caspian Seas. The best known are: an American species, Alosa sapidissima (Wilson, 1811), two European species, Alosa (Linnaeus, 1758) and Alosa fallax (Lacepede, 1803), found off the coasts of the Scandinavian peninsula, southern England, western Europe and the Mediterranean Basin, and three other valuable species found in pontic waters, the Danube and the Black Sea: Alosa immaculata (Bennett, 1835) (Danube shad), Alosa tanaica (Grimm, 1901) (Azov shad), synonymized with the subspecies Alosa caspia nordmanni and Alosa maeotica (Grimm, 1901) (Black Sea shad or Kercishad) [2, Năvodaru & Năstase, 2014) [3, 4]. In the Danube-Black Sea system the most economically and ecologically important species is Alosa immaculata (Pontic shad), which is also the subject of the present study, providing new complete data on the species' fishery under the climatic conditions of 2024 in the Danube Delta Biosphere Reserve (DDBR).

Materials and Methods

The material and methods selected are a sequence of steps including field studies, analyses, simulations that the DDNIRD uses in a standardized way for estimating fish stocks.

The "unit stock" hypothesis was assumed for stock estimation. The stock is a part of the population of a fish species, with a particular migration pattern, specific spawning areas and subject to a distinct fishery, for which the parameters of growth, recruitment, natural mortality and fishing mortality are the only significant factors determining population dynamics, and immigration and emigration are insignificant; the stock refers to juveniles and adults in numbers or biomass.

Steps in the Estimation of the Status and Exploitation of Fish Stocks

1. Sampling of catch by species from the commercial fishery in the main fisheries in the spring fishery
2. Collection of catch statistics by species, area and user
3. Assessment of the quality of catch statistics (black market and poaching)
4. Collection of data on fishing capacity
5. Assessment of stock status and exploitation by analytical methods
6. Identification of measures for sustainable enhancement, i.e. optimization of exploitation by modifying fishing effort and/or mesh size
7. Estimation of short-term sustainable yields through stock assessment methods using recorded catches.

Migration of Spawning Adults of the Pontic Shad Adult

Spatially, the population of the Pontic shad is interpreted as a system with two major compartments: the stock confined to the western and south-western Black Sea and the cycling compartment, represented on the one hand by sexually mature individuals that migrate to the Danube to spawn, and on the other hand by juveniles, the result of reproduction, that enter the stock [5-7]. Samples are taken from adult individuals migrating to the Danube from commercial fisheries.

In order to cover the spatial migration, samples are extracted at the fishery landing points: Isaccea, Mahmudia, Sf. Gheorghe, Crișan, Sulina, Chilia, and Periprava. The migration over time is analyzed by collecting samples during the migration period, i.e. April-July.

Samples are extracted from commercial catches (Fig. 1). The Pontic shad are measured (total length=TL or LT and standard length=SL), weighed (W). 1108 exploitable spawning migratory adult were measured, from 574 individuals scales were taken to determine the age of the individuals and how many migrations the individual is on, mostly from the St. George's Branch the main transition route to the spawning grounds (Table 2).

The data files, are entered into a tabular computer database in the tabular calculation program EXCEL, and into the database used by the Fish Stock Estimation Program (ESP), a program created in Turbo Pascal by DDNIRD Tulcea [8].

Larval Seaward Larval Run-off (Drifting)

The 2024 Pontic shad runoff study is carried out in April, May, June and July, with several sites covering the Danube Delta Biosphere Reserve (DDBR) as follows: at Chilia Split (upstream of the split in the Danube - Mm 44 and downstream of the split, on the Chilia - km 115 and Tulcea - Mm 42.5 branches) [9], at the mouths of the Danube (Sfântu Gheorghe, Sulina and Chilia km 8, downstream the Bâstroe channel), and within the present project sampling was also carried out on the Danube at Isaccea (Mm 54) and Reni (Mm 68), as well as on the branches, cuts or meanders.

All stations are sampled in one station per diagonal, from bank to bank where possible, except on the Danube and the Chilia branch where the diagonal holds up to half of the channel (the other half belonging to Ukraine).

For sampling fishery, the ichthyoplanktonic or Bongo net with the mesh size of 0.5 mm (500 microns) is used (Fig.1), the trawling time is 5 minutes for each station in the water layer 0-0.5 m from the water surface so that the whole circle of the net is submerged in the water [9].

The ichthyoplankton fillet is towed against the water current with a 135 hp speed boat. To determine the volume of filtered water, mechanical flowmeter type 2030 or ***Hydro-Bios flowmeter is used, which is mounted on the diameter of the circle at 1/3 of the attachment point on the edge and 2/3 on the other edge, regardless of the angle with the horizontal [10]. The flowmeter can be used to calculate the distance traveled, the velocity of the drawdown and the volume filtered, recording the time of the drawdown and the number of revolutions on the meter [11].

Hydrological data (water level) and water temperature are recorded on the Danube at Tulcea (http://www.afdj.ro/ro/cotele-dunarii Hydrometeorological bulletin published by AFDJ Galați). Pictures were taken with Canon camera or Samsung camera.

The field data sheets are entered into a tabular database on computer in EXCEL spreadsheet program. The data files, were organized in a computer database, representing the samples taken in 2024, when a total number of 40 ichthyoplankton samples were sampled for the investigation of the outflow of Pontic shad larvae to the sea which forms the basis for further analyses. Data on physico-chemical parameters were also collected from the sampling points were extracted using Hach multiparameter with sensors for: pH, water temperature (°C), water conductivity (µS*cm-¹), water oxygen (mg*L-¹), water oxygen saturation (%). Water depth (cm) and transparency (cm) were identified using Secchi disk with 10 in 10 cm step. GPS coordinates to identify the sampling location was done using the OsmAnd program downloaded to mobile phone or Garmin in GPS. Results are compared with previous results in Năvodaru and Năstase, 2014, Năstase et al., 2018, Țiganov 2017, Țiganov et al., 2023.

Table 2: Sampled Effort During the Study Period (Spring-Summer 2024)

Site		No. of adult shad for ESP			No. of adults exemplars for age			No. of ichthyoplankton larvae samples						
Date/Place	TOTAL	Sf Gheorghe	Sulina	Chilia-Periprava	Sf Gheorghe	Sulina	Chilia-Periprava	Chilia Split	Chilia branch	Tulcea branch	Sf Ghe. branch	Sulina branch	Chilia-Periprava	Canal Mila 36
27.03.2024	182	182	0	0	0	0	0	0	0	0	0	0	0	0
28.03.2024	361	317	0	0	44	0	0	0	0	0	0	0	0	0
1-24.04.2024	565	35	0	0	530	0	0	0	0	0	0	0	0	0
24.04.2024	0	0	0	0	0	0	0	0	0	1	2	2	0	0
09.05.2024	0	0	0	0	0	0	0	1	1	2	1	1	0	1
30.05.2024	0	0	0	0	0	0	0	1	1	2	2	1	0	0
03.06.2024	0	0	0	0	0	0	0	1	1	2	1	1	0	0
20.06.2024	0	0	0	0	0	0	0	1	1	2	1	1	0	1
04.07.2024	0	0	0	0	0	0	0	2	1	2	1	1	0	1
Total	1108	534	0	0	574	0	0	6	5	11	8	7	0	3

Figure 1: Scientific Activity (Left-capturing Drifting Larva, Middle-binocular Studying, right–adults Measuring)

Results and Discussion

Adult Contranatant Migrants

Age and sex demography

The age and sex demography of the Pontic shad sampled at landing points, the legal collection points of the fishery resource for the year 2024, is consistent with the theory formulated over time that males mature faster and start migrating earlier from the age of 2 years, and females are larger and dominate older ages such as 4 and 5 years, but the lack of 6 and 7 year olds can be interpreted as a negative result of constant overfishing in this species (spawning fish very rarely migrate for a second exceptionally a third time), although in the past fish older than 5 years were present, but also rare. Dominant during migration are 4-year-olds, followed by 3-year-olds (Fig. 2). At 4 years of age there is some sex balance with slight dominance of females (Fig. 3). Overall, the sex ratio is about 1 or in the case of 2024 it is about 1.1 in favour of females, indicating a needed balance in the population.

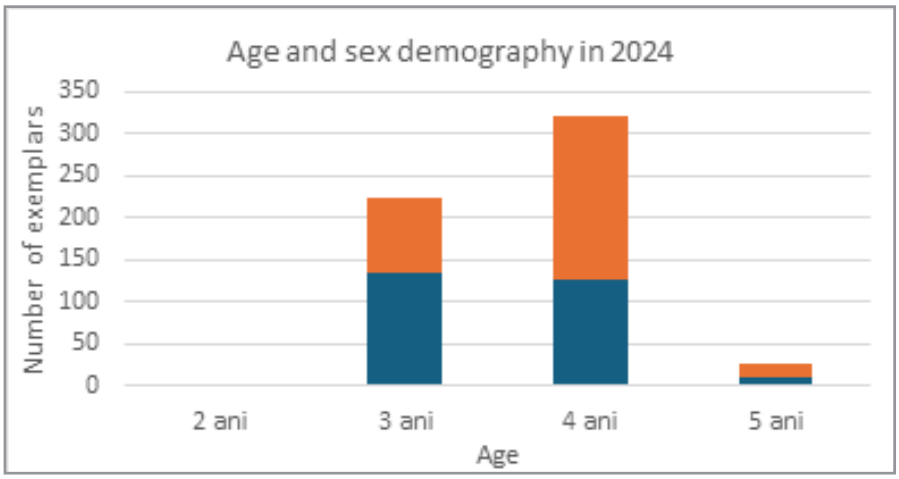


Figure 2: Demography by Age and Sex for the Year 2024 for Exploitable Specimens (Male – Blue, Female – Red) Between 2 – 5 Years Observed Age

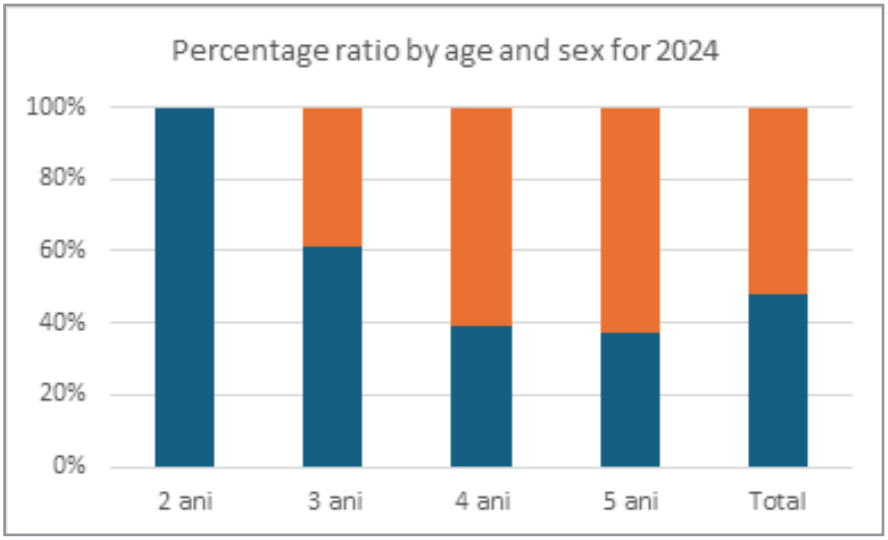


Figure 3: Percentage Ratio by Age and sex for the year 2024 on Exploitable Specimens (Male – Blue, Female – Red) Between 2 – 5 Years Observed Age

Estimates of the state and exploitation of Pontic shad stocks (2024)

Length-weight frequency

For the estimation of the status of the migrating stocks of Pontic shad in 2024, were sampled 1108 specimens weighting 278.6 kg from the Danube inlets, more specifically only from Sfântu Gheorghe branch other two branches without func-tional official landing points in 2024 (Table 3).

Table 3: Structure of the samples taken according to length-weight frequency from Pontic shad gillnets fishing tools (a=30 mm) (No ex. = number of exemplars, TL=total length, W=weight, L.c.m.f.=most frequent total length, E=state of exploi-tation, F=fishing mortality, Z=total mortality)

Sampling area	State of exploitation E=F / Z	No. ex.	Mass (kg)	TL average (cm)	W average (g)	Limits of TL (cm)	L . c . m . f . (cm)	% Below the permitted limit
Sf. Gheorghe	0.46	1108	278.6	30.4	251	20-35.5	30	0.50%
branch	On balance							
Sulina		0	0					
branch								
Chilia		0	0					
branch								
Total		1108	278.6					

The length-weight relationship, has o great value in research practice, in the sense that after several length-weight measurements of individuals are made, this relationship is established, and then only length measurements are made, and then the biomass is determined by calculation, with a known and accepted degree of error in the study of fisheries.

The length-weight relationship has been calculated for 2024 for Alosa immaculata (Fig. 4) and a very high degree of positive correlation is found. Graphical representation and mathematical expression of the length-weight relationship are useful tools whose accuracy is accepted in fishery survey.

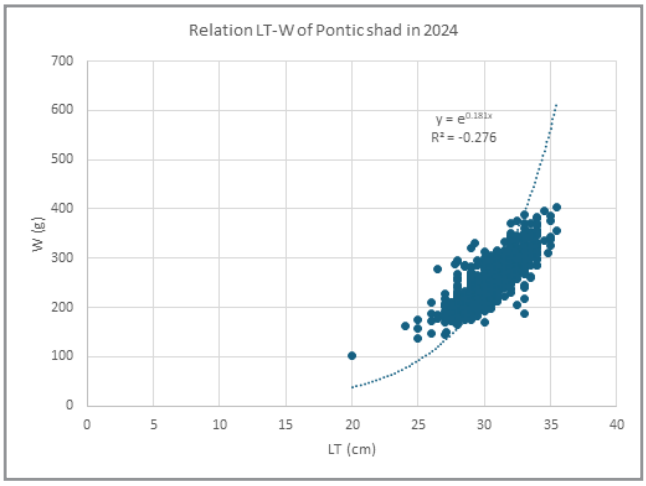


Figure 4: Length-weight Relationship of Pontic Shad in 2024

Growth and Exploitation Parameters

Based on the length-frequency structure samples of the commercial catches, the growth and exploitation parameters of the migrating stock of the Pontic shad were estimated by analytical methods (Table 4), observed appropriate values for Pontic shad to the values obtained from marine area, but with significant differences against 1990s in Danube [12, 13] .

Table 4: Growth, exploitation parameters and length-weight relationship L= maximum total length (cm) that individuals can reach, at which growth ceases, k = curve parameter that determines how quickly the fish approaches L, to = theoretical age at which length is '0', Lr = length at first recruitment, Lc = length at which 50% of the fish in the gear are retained, M = natural mortality, F = fishing mortality, Z = total mortality, W = a x TL^b is the length (TL)-weight (W) relationship, where a and b are the coefficients of the equation) for gillnets a=30 mm fishing tool

Species	L	K	to	Lr	Lc	M	F	Z	W = a x Lb	
Pontic shad	36.5	0.394	-0.2	20	28.8	0.667	0.58	1.25	0.04454	2.52769

Stock and Exploitation Estimation

The state of exploitation of the Pontic shad stocks was analyzed by positioning the current point of exploitation (Pc) using the coordinates expressing the length at which the fishing selectivity has the value Lc=28.8 cm and 0.58 the intensity of exploitation

(Fc) and 1.34 for Fo on the Y/R isopleth diagram resulting from the application of the Beverton - Holt model (Fig. 5 and Fig. 6).

Fishery optimization was achieved by modelling exploitation by changing fishing effort (F), and recalculating the optimal biomass and sustainable catch (MSY) by VPA and Thomson-Bell analytical model (Table 5 and Fig. 5).

Table 5: Assessment of the exploitation condition and measures to optimize the current condition (Fc=Current effort, Lc=Length at first catch, Cc=Current catch, Bc=Current biomass, Fo=Optimum effort, Co or MSY=Optimum catch or sustainable catch, Bo=Optimum biomass, Y/Rc=Production per recruit current, Y/Ro=Production per recruit optimum) for gillnets a=30 mm fishing tool

Species	Fc	Lc	Cc tons	Bc tons	Fc→Fo (Fo/Fc)	Fo	Y/Rc	Y/Ro	Bo tons	Co MSY tons	α
Pontic shad	0.58	28.8	10	51.09	2.2	1.34	25.1	45	43.73	13.53	1.35

Estimated Sustainable Catches of Pontic Shad in 2025

The length structure of the Pontic shad sample taken from the Danube inlets includes specimens in the length range 20-35.5 cm with an average weight of 251 g/ex. and an average length of 30.4 cm.

The dominant length classes are in the range 29-32 cm representing 60.6% of all specimens sampled. The specimens below the minimum size allowed for fishing represent 0.5% of the total specimens in the sample taken from the commercial catches (only on St. Gheorghe branch).

The state of exploitation assessed by the production per recruit model is characterized by equilibrium, balanced compared to previous years when it was constantly overexploited, given the selectivity of the gear used (a = 30 mm), resulting in a length at first catch Lc = 28.8 cm.

Being a migratory stock, for practical reasons and the uncertainties given by the different results of the assessment models, it is not recommended to intensify fishing or to reduce the mesh size, but only to fish in a fishery that avoids catches below the minimum allowable catch.

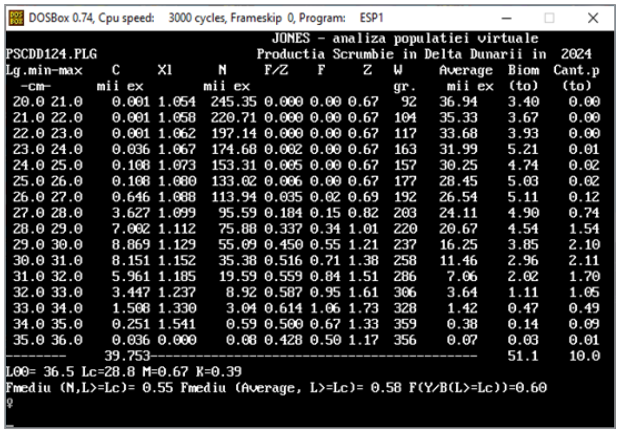


Figure 5: Assessment of current status through virtual population analysis and fishery optimization using the Thompson-Bell model for the species of Pontic shad, 2024 (10 tonnes reference)

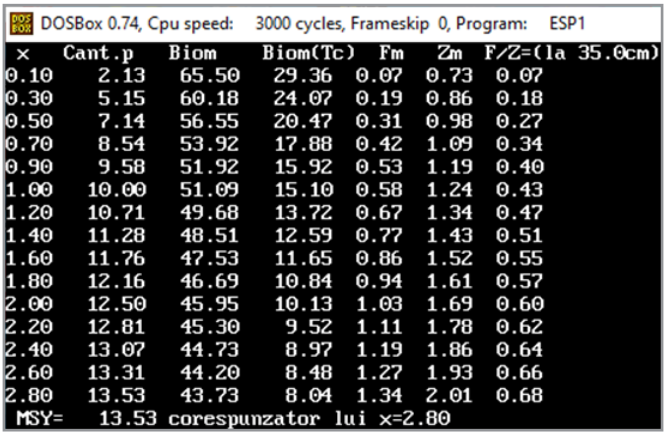
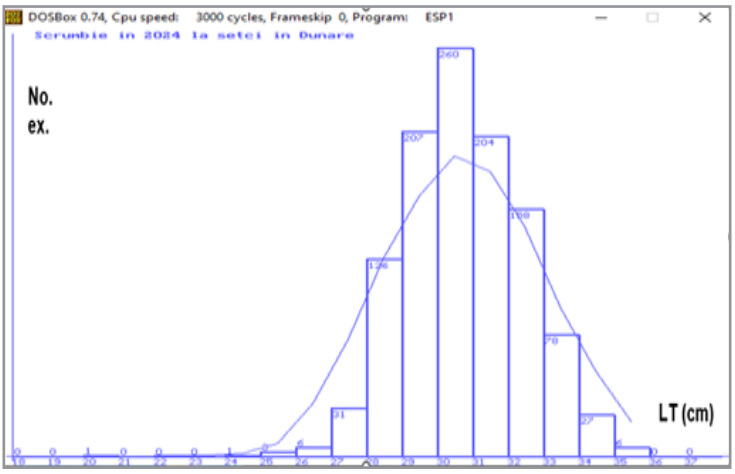
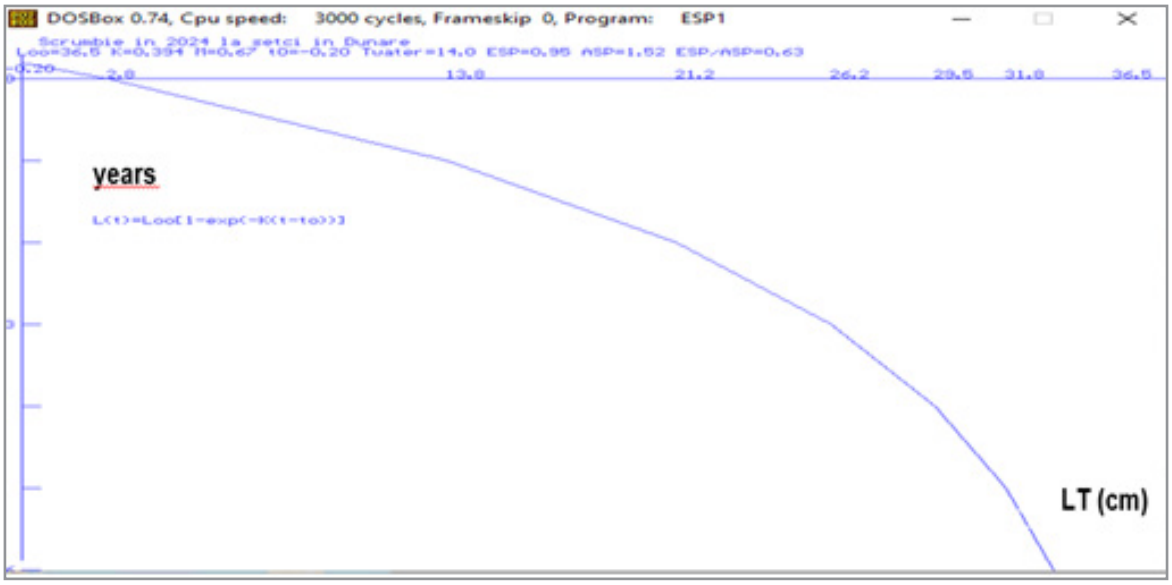
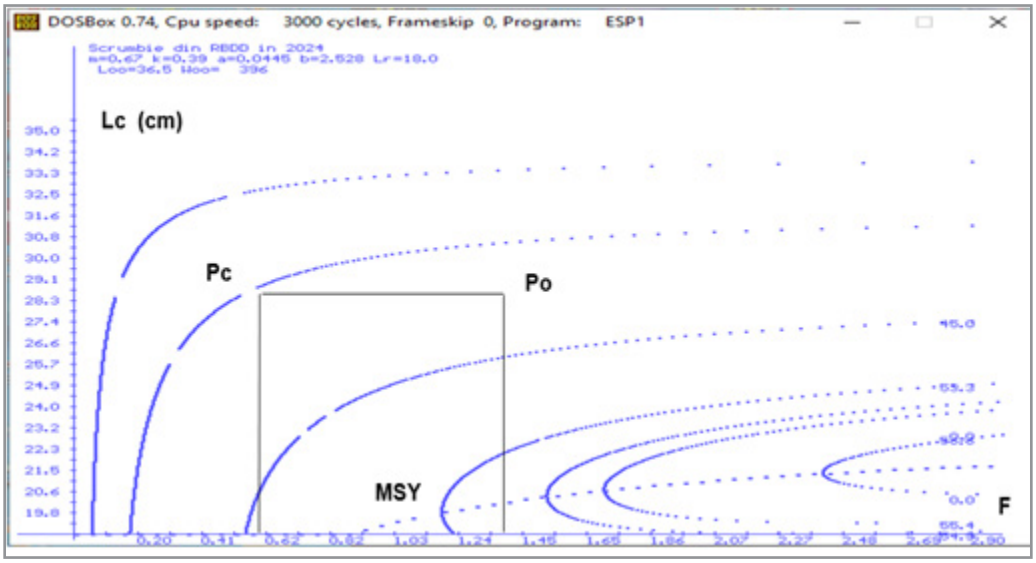


Figure 6: Length Frequencies (up), Growth Curves (Middle) and Exploitation Analysis by Beverton - Holt Model of Production per Recruit (Y/R) of Pontic Shad (down), 2024







Larvae Drifting Toward to the Sea

Return of Larvae to the Sea

The year 2024 was not at all beneficial for larval abundance, with the LAI (Larval Abundance Index) index having a low but slightly increasing value compared to 2022 and 2023 (Fig. 7).

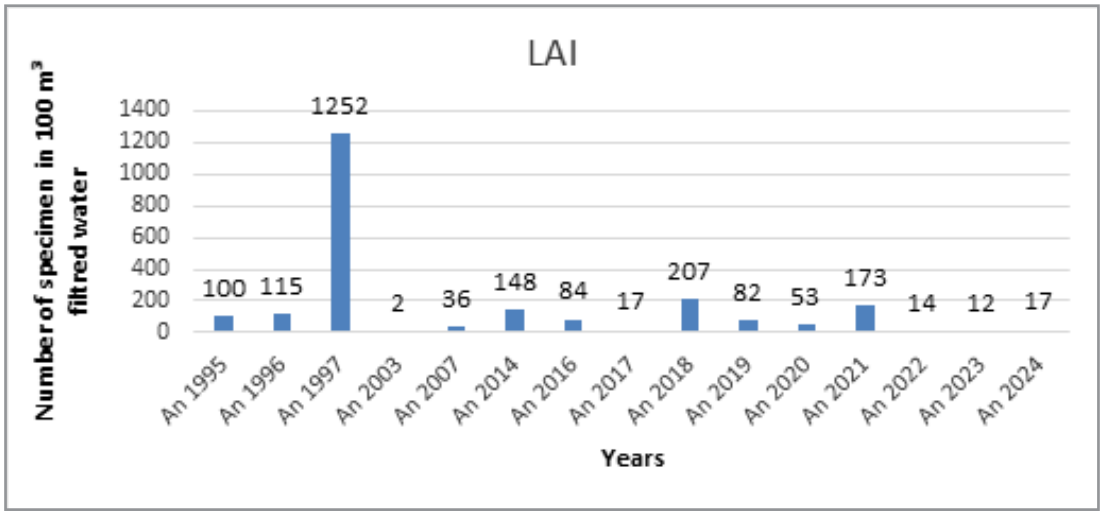


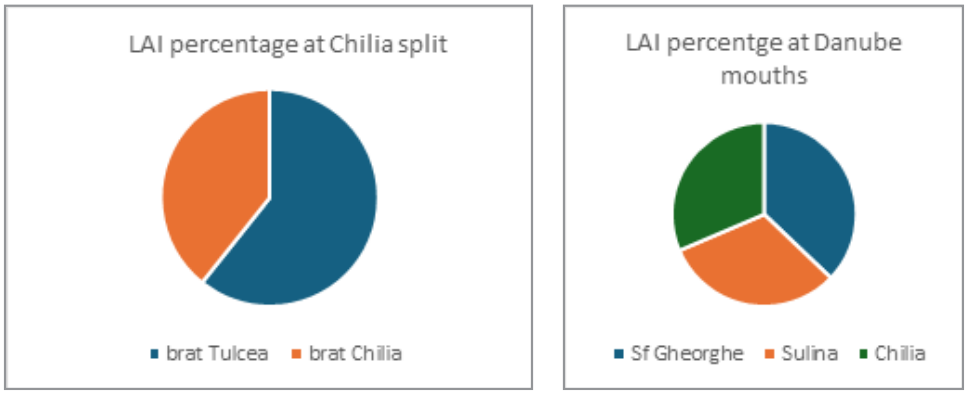
Figure 7: LAI (Larval Abundance Index per 100 m³ filtered water) of the Pontic shad (Alosa immaculata) in multiannual dynamics

It can be observed that the maximum LAI in 2024 is in the second half of May, and the drifting larvae ends in early July, but interesting thing is the starter of drifting larvae in second period of April (Table 6), earlier than in the 1995-2014 period when it started in May and maximum was in May in 2024 earlier than June in 2016 [14, 15]. However, overall, 2024 has values closer to the quantified historical minimum (2individuals/100 m³ filtered water), with the average annual value being 16.69 individuals/100 m³ filtered water (Fig. 7 and Table 6).

Table 6: LAI (Larval Abundance Index per 100 m³ filtered water) of the Pontic shad (Alosa immaculata) for each month in 2024 (I - first half of the month, II - second half of the month)

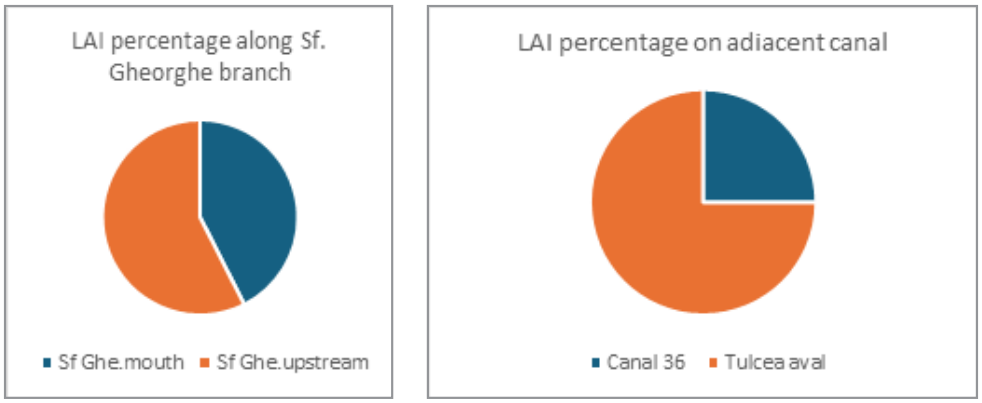
Month	2024	Periods	2024
March	0.0	II March	0.0
April	5,2	I April	0.0
		II April	5,2
May	25,21	I May	23,9
		II May	26,5
June	7,53	I June	7,33
		II June	7,70
July	0,72	I July	0,72
		II July	0,00
Annual average	16.69		

Although the Tulcea branch takes up a higher number of larvae of the Pontic shad (Fig. 8a), due to the fact that they drain with the higher current on the Romanian shore due to the outward curve towards the Romanian shore upstream of Chilia Split. At the mouth of the Danube the abundance of larvae reaches a balanced equilibrium (Fig. 8b). The most likely reason for the rather low number of larvae on the Sf. Gheorghe and Sulina branches is due to the fact that more than a quarter of the percentage larvae get lost on adjacent or dead branches/meanders, most obviously on the Tulcea and Sf. Gheorghe branches (Fig. 9 a and b).



a. b.

Figure 8: Larval Abundance Index Per 100 m³ Filtered Water (LAI) of Pontic Shad, on the Branches and Mouths of the Danube in 2024



a. b.

Figure 9: Larval Abundance Index Per 100 m³ of Filtered Water (LAI) for Pontic Shad Along Course on the Tulcea and Sf. Gheorghe Branches and Compared to Adjacent Canals/Meanders in 2024

Developmental Stages of Larvae Drifting to the Sea

Overall, after Vladimirov 1953 larval stages recognition, in the DDBR in 2024 larval stage II (early larvae) dominates, as in Fig. 10 probably due to the different hydrometeorological conditions in spring and summer [16].

Over annual time they are observed to be abundant in the months May-June, thus in the spring months early larvae are dominant, after which towards summer the percentage of old larvae increases slightly, but is not a rule (Fig. 11).

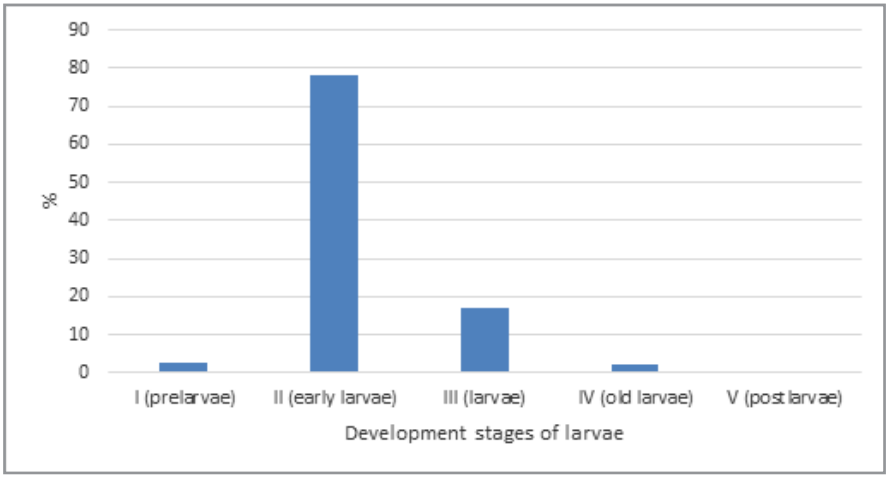


Figure 10: Larval Stages Percentage Abundance of Pontic Shad from Danube in DDBR in 2024

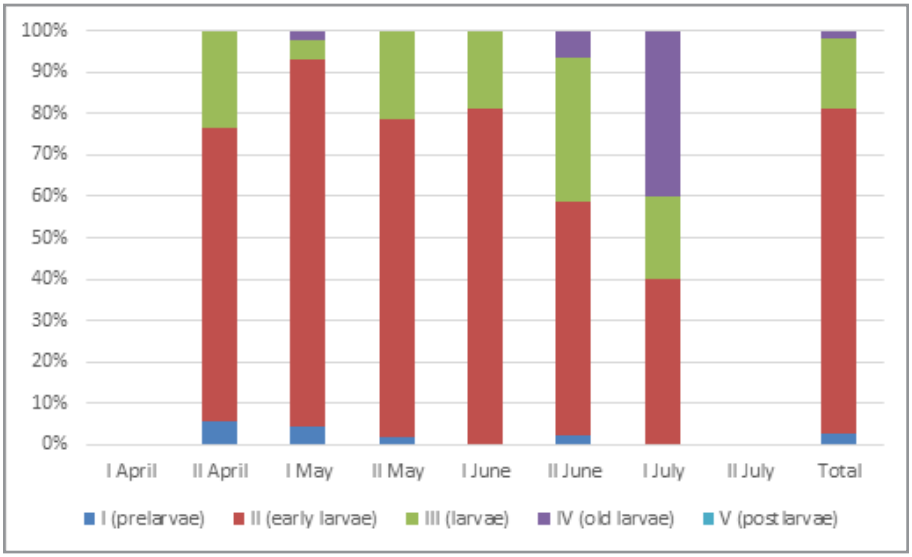


Figure 11: Larval Stages Percentage Abundance of Pontic Shad from Danube in DDBR in 2024 on Months (I - First Half of the Month, II - Second Half of the Month

Conclusions

The age and sex demography show that males mature faster and start to migrate earlier from the age of 2 years, and females are larger and dominate at older ages such as 5 years, but the absence of ages 6 and 7 can be interpreted as a negative result of constant overfishing of this species since spawning fish rarely migrate a second exceptionally third time. During migration, 4-year-olds dominate, followed by 3-year-olds, and there is a gender balance at age 4.

The dominant length classes are in the 29-32 cm range, representing 60.6% of all sampled individuals. The specimens below the minimum size allowed for fishing represent 0.5% of the total specimens in the sample taken from the commercial catches (all from the St. Gheorghe branch). The state of exploitation assessed by the production per recruit model is characterized by equilibrium, or even slight under-exploitation after several years of intense overexploitation, given the selectivity of the gear used (a = 30 mm), resulting in a length at first capture (Lc) of 28.8 cm.

It is not recommended to intensify the fishery or to reduce the mesh size, but only to avoid fishing below the minimum allowable size for Pontic shad [17].

A low number of Pontic shad larvae with a quarter loses in adjacent canals or meanders, consists mostly of early larvae (II or III stages), indicating that spawning success in 2024 is close to a historical low. This requires further legislative corrections for Alosa immaculata (Pontic shad) in the coming years, correlated with climate change impacts.

The influence of climate change can be observed in the breeding migration behaviour of the Pontic shad adults, which seems to reproduce earlier, as evidenced by the appearance of larvae earlier in April compared to May as was before 10 years ago, however more extensive studies in time and space could confirm the hypothesis by reporting daily not only monthly catches by commercial fishermen to the DDBR Administrator as a legislative obligation especially for consistent scientific data of migratory fish species [18, 19].

Acknowledgement

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