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# RESEARCH STATE OF *ALOSA IMMACULATA* (BENNETT, 1835) STOCKS FROM ROMANIAN SECTOR OF DANUBE – SHORT OVERVIEW

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***Abstract***

*Shad (Alosa spp.) is an important fish species and has high economic value. Commonly, it is found in the Black Sea basin and is represented by four species and one subspecies: Alosa maeotica, Alosa tanaica, Alosa immaculata, Alosa caspia, which are distributed in the Black Sea. For the Romanian fishery sector, the Pontic shad (Alosa immaculata) is an important fishery resource. The attractiveness of the Pontic shad fishery, both in the sea and especially in the Danube River (during the migration period), depends on the seasonal nature of this activity but also the interest of consumers for these species. Consumers' interest for Pontic shad is due to both the flavor of the meat and its nutritional qualities. According to IUCN, Pontic shad is estimated as a vulnerable fish species, stocks being affected by the construction of the Iron Gates I and II hydroelectrical dams. In this context, this paper aims to present an overview of the current stocks state of the Pontic shad in the context of environmental and exploitation conditions in Romania.*

***Key words**: exploitation, fish catch, migratory fish species, shad.*

## INTRODUCTION

The generally called “shads” include types of fish that differ very little in terms of external appearance. Clupeids are ancient, tertiary forms that inhabited the ancient Sarmatian Sea, which is why among them some are migratory freshwater species (potamodromous Clupeids) and marine migratory species (anadromous Clupeids) (Niculescu-Duvăz, 1959).

Despite their commercial importance, there are many unknown aspects regarding their phylogenetic bonds within the genus *Alosa*, leading to systematic and taxonomic uncertainties, that can make it harder to establish appropriate conservation measures (Faria et al., 2006).

*Alosa* species occur in the northern hemisphere of the Earth, inhabiting the Atlantic Ocean and the Mediterranean, Black, and Caspian Seas.

The Pontic shad is the most widespread species from the *Clupeidae* family that inhabits the Black Sea area (Kottelat & Freyhof, 2007). Along with the *Alosa tanaica* and *Alosa maeotica* species, the Pontic shad migrate for reproduction in the Black Sea and Azov Sea tributary rivers (Kolarov, 1991; Navodaru & Waldman, 2003). If in the past some specimens of Pontic shads migrated up to Budapest (Danube river, 1650 km) (Bănărescu, 1964), nowadays fishes barely reach km 864, migration route distance being shortened by the construction of the Iron Gates II Hydropower Plant (Navodaru & Waldman, 2003).

In Romania, the Pontic shad commercial fishing catch has a commercial value of about 1.5 million euros, with an average annual catch of 200-500 tons. But the bigger is the interest in the exploitation and commercialization of the *Alosa* stocks, the greater the danger of causing a drastic decline of the populations from the Danube and the Black Sea regions. In the last decades, the population of Pontic shads are rapidly declining, according to the IUCN Red List of Threatened Species, *Alosa immaculata* is classified as vulnerable specie (VU) (Freyhof, 2010). Some of the major current threats for this species are represented by overfishing, pollution, climate changes and dams construction, threats that have led to a big reduction of reproduction and feeding in large areas, and implicitly a decrease in shad stocks (Kottelat & Freyhof, 2007).

Numerous studies have highlighted the influence of medial factors and climate change on the migration of Pontic shad and implicitly on commercial catches. For example, Smederevac-Lalić et al. (2018) analyzes the influence of water level oscillations in the Danube river, especially of the spring floods upon the *Alosa immaculata* catches, as a key to predicting future fluctuations in catches and the influence of solar activity on shad stocks. The influence of temperature on the migration of Pontic shad was also underlined, a migration that generally begins during the February – March period, when the water temperature gets close to 5-6°C, reaching maximum potential in April, at 9-13°C water temperatures (Năstase et al., 2018) and ending in June-July when temperatures are within 22-26°C interval (Năvodaru 1996, 1998).
This research aims to generally present the current state of Pontic shad stocks, analyzed in the context of environmental factors and the exploitation state of Romania.

## MATERIALS AND METHODS

The Danube is the most important river in Romania. Targeted areas are parts of the Romanian Danube river that represent a central point of wetland with particular importance for fish populations (Ibănescu et al., 2016). A long large stream, like the Danube, the second river in Europe, is an extremely variable and complex environment. Its multiple uses set up the foundation of numerous arguments for long-term systematic research which can help us understand the seasonal variation of physico-chemical and hydrological parameters, factors that have extremely important consequences on the structure and dynamics of fish communities (Calin Sandu et al., 2013).
Data regarding the hydrological and physical parameters of the water (water level and temperatures) were daily collected from the Galati Lower Danube River Administration website (Administrația Fluvială a Dunării de Jos RA Galați, n.d.) (Figure 1). These data were processed using MS Excel 2021 package.
The dynamics of the reported catches from 2010 to 2021 were presented with the use of the official data obtained from the National Agency for Fisheries and Aquaculture (www.anpa.ro). The Total Allowable Catch (TAC) data regarding our in-study species were collected from the legislation 2010-2021 TAC Orders.

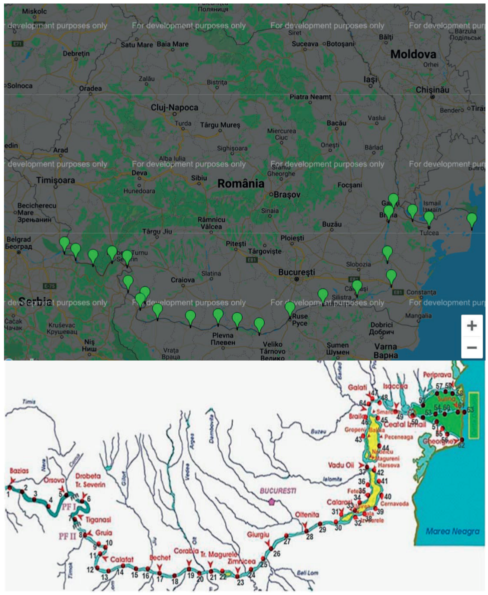


Figure 1. Sampling stations along the Danube river (Galati Lower Danube River Administration, n.d.)

## RESULTS AND DISCUSSIONS

Numerous researches state that upstream migration and reproducing of European *Alosa* spp. are triggered by water temperature, water flows and water levels (Cassou-Leins et al., 2000; Mennesson-Boisneau et al., 2000; Aprahamian et al., 2003; Acolas et al., 2006, Esteves & Andrade, 2008).
Recently, the current research taken over the Danube riverine countries does not sufficiently address the influence of environmental factors on the migration of the Danube shad, nor on the state of stock-exploitation. Ciolac (2004), describes the migration of the Danube shad during the 2000 years and concludes that its migration began in March when the water level was rising and the water temperature stabilized at about 6°C, with a maximum intensity of migration during April, and an ending point in July. Năstase et al. (2018) describe the shad migration as typical and directly influenced by environmental factors, especially the water temperature increase on a side and elevated water levels (spring floods) on the other side,

which in 2016, favored the start of migration earlier than usual, in February, with a peak of reproduction migration in early April and ending time in May, mainly because to the lack of data, given by the fact that the market and catches no longer motivated the fishermen to catch and report this species. A general analysis of the average annual temperatures of Danube River water in 2020-2021 period is presented in Table 1.

Table 1. Temperatures (°C) from the Gruia, Calafat, Giurgiu, Brăila, Tulcea and Sulina stations

| Years | Calculated indices | Registered temperatures (°C) / Stations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Gruia | Calafat | Giurgiu | Brăila | Tulcea | Sulina |
| 2010 | Average±S.D. | 13±7.9 | 13.4±8.2 | 13.7±8.2 | 13.5±8.3 | 13.6±8.4 | 13.5±8.4 |
| | Min. | 1 (Feb/Dec) | 0.8 (Feb) | 0.5 (Feb) | 1 (Feb) | 0.5 (Jan) | 0.5 (Jan) |
| | Max. | 26.5 (Jul) | 27 (Jul) | 27.4 (Jul) | 28 (Aug) | 28 (Aug) | 27 (Aug) |
| 2011 | Average±S.D. | 13.3±8.9 | 13.6±8.8 | 14±8.9 | 13.9±9.1 | 13.8±9.2 | 13.7±9.2 |
| | Min. | 0.5 (Jan) | 1 (Jan) | 1.1 (Jan) | 1 (Jan) | 1 (Jan) | 1 (Jan) |
| | Max. | 25.8 (Jul) | 26.2 (Jul) | 26.8 (Jul) | 28 (Aug) | 28 (Aug) | 28 (Jul) |
| 2012 | Average±S.D. | 13.4±9.1 | 13.8±8.8 | 14.3±9 | 14.4±9.3 | 14.3±9.3 | 14.4±9.4 |
| | Min. | 0.2 (Feb) | 0 (Feb) | 0 (Feb) | 0.1 (Feb) | 0.3 (Feb) | 0.2 (Feb) |
| | Max. | 28 (Jul) | 27.2 (Jul) | 27.8 (Jul) | 29 (Jul) | 28 (Jul) | 28 (Jul/Aug) |
| 2013 | Average±S.D. | 13.1±8.3 | 13.6±8 | 13.6±8.2 | 14±8.4 | 13.8±8.4 | 13.8±8.4 |
| | Min. | 1.3 (Jan) | 3 (Jan/Dec) | 1.7 (Jan) | 1.5 (Jan) | 2 (Jan) | 2 (Jan) |
| | Max. | 26.9 (Aug) | 27 (Aug) | 26.8 (Aug) | 29 (Sep) | 27.5 (Aug) | 27.5 (Aug) |
| 2014 | Average±S.D. | 13.6±7.7 | 14.1±7.3 | 14±7.5 | 14.1±7.8 | 13.9±7.9 | 13.9±8 |
| | Min. | 1 (Feb) | 1.8 (Feb) | 1.4 (Feb) | 1 (Feb) | 1 (Feb) | 1 (Feb) |
| | Max. | 26 (Aug) | 26 (Aug) | 26.5 (Aug) | 27 (Aug) | 27 (Aug) | 27 (Aug) |
| 2015 | Average±S.D. | 13.6±8.5 | 14.4±8.2 | 14.4±8.4 | 14.6 ±8.5 | 14.5±8.5 | 14.4±8.5 |
| | Min. | 1.2 (Jan) | 1 (Jan) | 1.6 (Jan) | 1.5 (Jan) | 1.5 (Jan) | 1.5 (Jan) |
| | Max. | 27.4 (Aug) | 31 (Jul/Aug) | 28 (Aug) | 28 (Aug) | 28,5 (Jul) | 28 (Jul/Aug) |
| 2016 | Average±S.D. | 13.8±8.2 | 14.2±8.3 | 14.3±8.2 | 14.3±8.4 | 14.3±8.5 | 14.3±8.5 |
| | Min. | 1 (Jan) | 1.2 (Jan) | 1.2 (Jan) | 1 (Jan) | 1 (Jan) | 1 (Jan) |
| | Max. | 27.2 (Aug) | 35 (Jul) | 27 (Aug) | 27 (Aug) | 27.2 (Aug) | 27.2 (Aug) |
| 2017 | Average±S.D. | 14±9 | 14 ±9 | 14±9 | 14.2±9.1 | 14.1±9.1 | 14.1±9.1 |
| | Min. | 0 (Jan) | 0 (Jan) | 0 (Jan/Feb) | 0 (Jan) | 0 (Jan/Feb) | 0 (Jan/Feb) |
| | Max. | 28.5 (Aug) | 28.2 (Aug) | 28 (Aug) | 28 (Aug) | 28.2 (Aug) | 28 (Aug) |
| 2018 | Average±S.D. | 14.3 ±9.3 | 14.7±9 | 14.8±9 | 14.6±9 | 14.7±9 | 14.6±9 |
| | Min. | 1 (Mar) | 2 (Jan/Feb/Mar) | 2 (Mar) | 1 (Mar) | 0.4 (Mar) | 0.3 (Mar) |
| | Max. | 27.5 (Aug) | 27.5 (Aug) | 31 (Aug) | 27 (Aug) | 26.8 (Aug) | 26.8 (Aug) |
| 2019 | Average±S.D. | 14.9±8.4 | 15±8.1 | 15.1±8.1 | 15.1±8.2 | 14.9±8.3 | 14.7±8.3 |
| | Min. | 2 (Jan) | 2 (Jan) | 1.8 (Jan) | 1 (Jan) | 1.2 (Jan) | 1.2 (Jan) |
| | Max. | 27.5 (Jul/Aug) | 27 (Aug) | 27.2 (Aug) | 27.5 (Aug) | 27.5 (Aug) | 27.2 (Aug) |
| 2020 | Average±S.D. | 14.5±8.2 | 14.7±8 | 14.9±8 | 14.9±8 | 14.9±8.1 | 14.8±8.1 |
| | Min. | 3 (Jan) | 3 (Jan) | 3.1 (Jan) | 3 (Jan) | 2.6 (Jan) | 2.6 (Jan) |
| | Max. | 27 (Aug) | 26.8 (Aug) | 27 (Aug) | 27 (Aug) | 26.7 (Aug) | 26.7 (Aug) |
| 2021 | Average±S.D. | 14.2±8.2 | 14.1±8.1 | 14.2±8.1 | 14.3±8.2 | 14.2±8.3 | 14.2±8.3 |
| | Min. | 3 (Jan) | 3 (Jan) | 3.4 (Jan) | 3 (Feb) | 2.5 (Feb) | 2.5 (Jan/Feb) |
| | Max. | 29 (Jul) | 28 (Jul/Aug) | 28.5 (Aug) | 28.5 (Jul) | 28 (Jul/Aug) | 28 (Jul/Aug) |

The average annual temperatures of the Danube river water show an increasing trend from year to year, for the 2010-2021 period.

It can be observed that since 2010, for example, in Gruia station, the average annual temperature of the Danube river water increased from 13 ± 7.9°C registered in 2010 to 14.2 ± 8.2°C, in 2021. Also, the minimum and maximum temperature of the Danube river water show increasing trends from year to year, as can be seen in Table 1.

This phenomenon of increasing the average annual temperatures leads to changes in the migration behavior and also in variations regarding the reproduction and pre-development of the *Alosa immaculata* species.

In this regard, researches upon the shad population migration in the context of global climate changes are suitable to be conducted. The water levels of the Danube river in the springtime display significant variations from year to year, but in the 2010-2021 period it can be seen a clear increasing trend as observed in the following graphs (Figures 2-7).

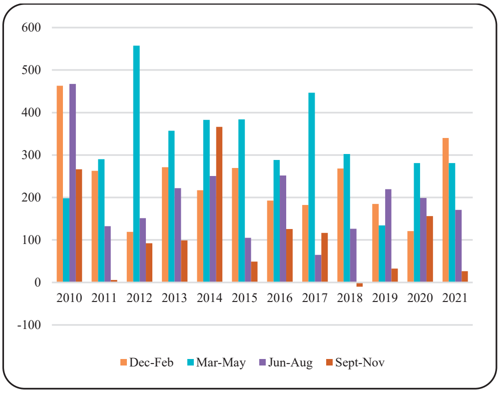


Figure 2. Water level fluctuation at the Gruia station

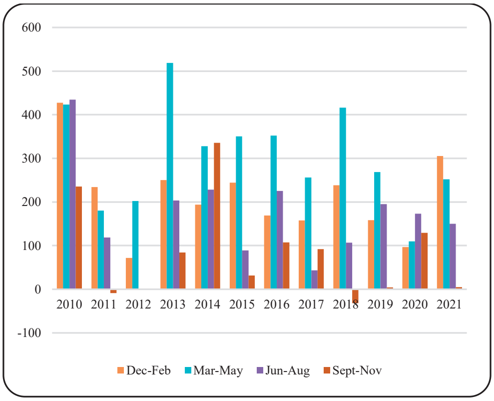


Figure 3. Water level fluctuation at the Calafat station

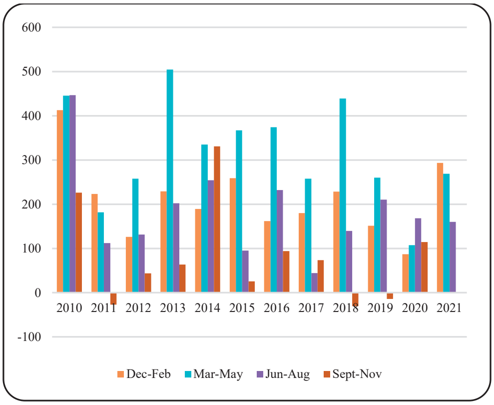


Figure 4. Water level fluctuation at the Giurgiu station

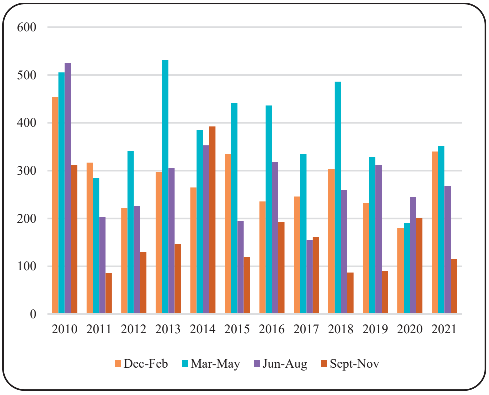


Figure 5. Water level fluctuation at the Brăila station

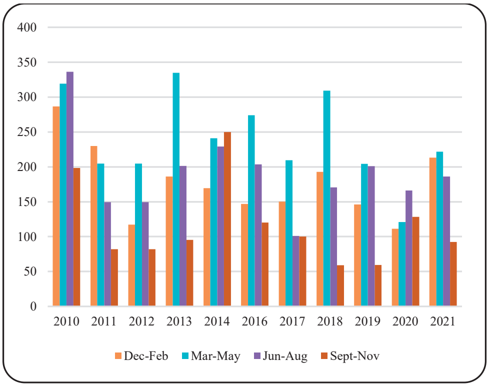


Figure 6. Water level fluctuation at the Tulcea station (*no data available for 2015)

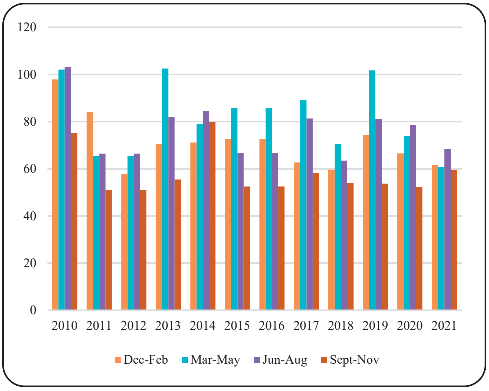


Figure 7. Water level fluctuation at the Sulina station

This phenomenon appears due to abundant rainfall or melting of the ice, specific to the spring season, which influences shad migrations.

Năstase et al. (2018) report substantial catches during the 2016 year, that were registered at the end of February, varying until mid of March, correlated with the increase of the Danube water level from 200 cm to 350 cm. On the other side, a decrease in catches was reported at the same time with the decrease of the water level below 250 cm and the increase in the water temperature. For Romania, Ukraine and Bulgaria, the Danube shad stock supports an important activity of integrated fishing.

The egg spawning takes place between 180 and 500 kilometers of the Danube river. The eggs are pelagic and the larvae swim passively toward the Black Sea (Năvodaru & Năstase, 2014). Shad fishing is estimated at a commercial value of about 1.5 million euros, with average annual catches of 200-500 tons (Mocanu et al., 2020).

In an analysis performed by Ibănescu et al. (2020), on the species structure part of commercial catches in Romania during the 2008-2018 period, it was highlighted that shad represents 10.54% of the total catch of our country. According to Năvodaru and Năstase (2014), *Alosa immaculata* has a cyclical evolution of catches, with minimums or maximums at 10-11 years, for example during the period 1960-1998, the absolute minimum was 200 tons, and the maximum was 2,400 tons. In the period 2010-2021, the catches varied between a minimum of 174.6 tons in 2015 and a maximum of 634.5 tons in 2019 (Figure 8).

At the same time from the Figure 8 it can be observed that in the 2010-2021 period, there were only 3 years (2016, 2019, 2021) with exceeded catches (related to the total allowable catch orders reports), a fact that indicates that the *Alosa immaculata* specie was overfished.

In the rest of the years, there were reported lower catch values than the calculated total allowable catch. If a comparison of the quantities in the annual orders (TACs) and the quantities reported by fishermen is made, it can be seen that reports are sometimes even lower - less than 50% of the TAC (e.g. 2013, 2018, 2020) therefore, it can be concluded that in this case, we face the non-reporting of shad catches, that are traded illegally (IUU - Illegal, unreported and unregulated fishing).

This trend is also indicated by Ibănescu et al. (2020), in a study that analyzed the dynamics of commercial catches in Romania during the 2008-to 2018 period. It should be noted that recent studies indicate concerning values over the exploitation index of the species *Alosa immaculata* (Mocanu et al., 2021).

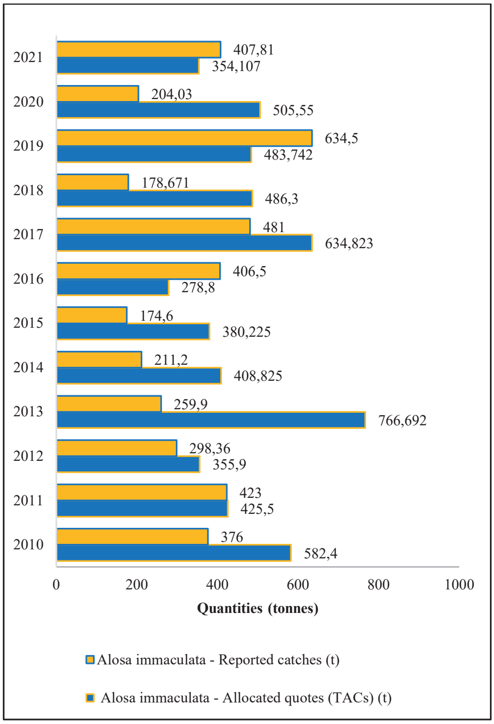


Figure 8. Allocated and reported quotes for *Alosa immaculata*

## CONCLUSIONS

Even though migration, reproduction and the conservation status of Danube shad stocks are currently clearly important, it is obvious that overexploitation is the most concerning cause of stock declining stocks of this species. Regular research that overseers the migratory population of A. *immaculata* in the Danube River must be carried out annually in order to be able to notice and take action in case of occurred changes regarding the conservation status of the species. Additional research is needed to quantify any changes concerning the number of individuals, their age structure and their state of welfare and to validate whether there is an upward trend in abundance. Also, with the help of the obtained annual data resulting from the research, it is necessary to make predictions about the state of the shad stocks and to elaborate a common plan of measures for the protection of the species, at the Danube riverine countries level.

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