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8. Pontic shad (*Alosa immaculata*) migrating upstream the Danube river and larval drift downstream to the Black Sea in 2016

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Abstract: The genus *Alosa* is present only in the northern hemisphere of the earth with four species living in North America and others five in Europe, from which Pontic shad (*Alosa immaculata*) is subject of present study. Migration of shad depends of the environmental drivers such as increasing spring water temperature and river flooding. In 2016, both factors favoured an earlier start of shad migration in February with peak of spawning run in April, and ended in mid of May. Afterwards the size of catches and market demands no longer motivated fishermen to fish and sell Pontic shads. The 2016 catch of 386 t fitted in the multiannual 10-11 years cyclical catches.
Reproduction success was estimated by Larval Abundance Index (LAI) standardized as Catch per Unit Effort (CPUE) by number of larvae per 100 m^3 filtered water volume. Relative abundance of drifting larvae in 2016 compared with other 6 previously years showed that average LAI varied widely (2-1,252 larvae per 100 m^3) with an average of 84 larvae/100 m^3 which was ranked in regular reproductive success.

Keywords: Danube River, Pontic shad, adult's migration, larva drifting in 2016

INTRODUCTION

Pontic shad is an important species in ecological system Lower Danube-Danube Delta-Black Sea with a high economic value due to large quantities fished and gustatory qualities appreciated by the people of the Lower Danube (Năvodaru 1997).
Knowledge of the species biology and stock exploitation contributes to ensuring valuable information for species conservation and fishery management.
Developing of life cycle stages in two environments (freshwater and marine), located at large distances in different time periods, requires updating of knowledge especially on the impact of new environmental conditions on the shad population (Năvodaru 1996).
The knowledge of adult migration for spawning and return of juveniles into the sea under the pressure of environmental factors can be used developing fishery management tactics. Fisheries management is achieved by integrating three key compartments species-environment-exploitation (Năvodaru & Năstase, 2014).
Spawning migration of Pontic shad occurs from south to north along the Black Sea coast of Bulgaria and Romania to the Danube River mouths. In the past reproductive shad migrated upriver to 1000 km (Teodorescu-Leonte *et al*. 1957), currently migration is restricted up to the Iron Gates II hydropower station dams (863.55 km). Migration starts in spring (February-March) at a water temperature of 5-6°C or even as low as 3°C (Năvodaru 1997) is highest in April at 9-13°C and extends until August at 22°C (Pavlov 1953) or up to 26°C (Năvodaru 1998).
Shads (*Alosa sp.),* in terms of the conservation status is classified in IUCN Red List as Vulnerable VU category B2ab (v) (Froese and Pauly 2017); Berne Convention in Annex III (European animals protected); Red List of Danube Delta Biosphere Reserve as "nt" (not threatened), as sub-endemic exceeding the border of Romania (e3) frequent and abundant (Oțel *et al*. 2000); Red List of European freshwater fish in Europe category VU, EN for EU 27 (Freyhof & Brook 2011).
Shad is listed and protected by the following regulations EU and RO in Habitats Directive 92/43 EEC (*****, 1992 updated in 2007) in Annex II - plant and animal species of community interest whose conservation requires the designation of special areas of conservation (SCI), Annex V - plant and

animal species whose harvest from the wild may be subject to management measures; OUG 57/2007 (*****, 2007), as amended and supplemented (OUG 154/2008, Law 49/2011, *****, 2011) in Annex 3 (equivalent to Annex II of the Habitats Directive), Annex 5A (equivalent Annex V of the Habitats Directive). Pontic or Danube Shad (*A. immaculata*) has a great ecological and economic importance in the Danube Delta area and is the subject of this paper, which aims to consolidate the state-of-the-art knowledge and to bring new data on the biology of the Danube shad from 2016's adult shad upstream migration and downstream larval drift.

MATERIALS AND METHODS

Adults sampling

To cover shad migration time and space the commercial catch of fisheries have been sampled at the mouth of the Danube River during the migratory season. The shads were measured with ichtiometer at a precision of 1 mm (total length = TL and standard length = SL), weighed to an accuracy of 1 g scale (TW), and for age determination from 50-100 individuals 10-20 scales were collected from the body between lateral line and dorsal fin. Each individual was assessed for its maturation degree of the gonads by direct observation by the VI scale steps (Gheracopol & Selin 1966).

Age was determined by reading the annual growth rings on scales using binocular microscope with a magnification of 1x10 (Ciugunova 1959, Vibert & Lagler 1961, Gheracopol & Selin 1966, Tesch 1968, Yilmaz & Polat 2002).

Hydrometeorological data on water level and temperature at Tulcea town were taken from Danube River Administration of the Lower Danube which records such data daily in all Romanian Danube stations. Data on catch statistics for shad in the Danube Delta have been taken from the fisheries administration, namely the Danube Delta Biosphere Reserve Authority and National Agency for Fisheries and Aquaculture.

Status of "well-being", fattening, or condition factor (K), defined as the ratio between the weight and cube standard fish length (Nikolski 1962), that was first proposed by Fulton T. (1902), and calculated after Ricker W.E. (1975): $K = (W / L3) * 100$ where: K = coefficient of Fulton; W = weight of fish body mass; L = standard length of fish body, measured from the tip of the snout to the tail base.

Larva sampling

Shad larvae drift was sampled with ichthyoplankton net (Bongo net) (Fig. 2) in water surface layer (0-0.5 m). The drifting in time and space has been studied at Ceatal Chilia (upstream of Ceatal – Mm 44 and downstream of Ceatal on Tulcea branch – Mm 42.5 and Chilia branch – km 115) and the mouth of the Danube River (St. George, Sulina and Periprava localities), as described by Năvodaru (2001).

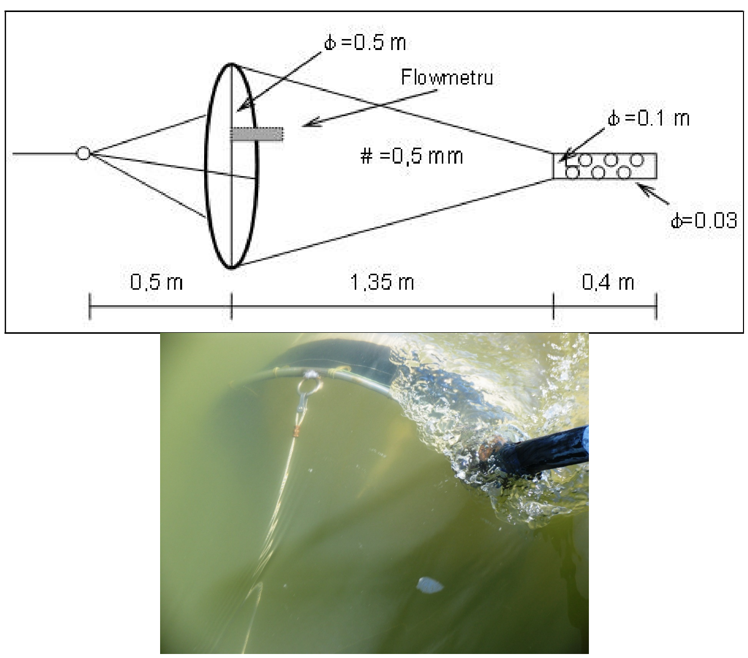

Figure 2 Schematic, dimensions and function of ichthyoplankton net (Bongo net) (after Năvodaru 1997) and photo while in function in 2016 (photo Năstase A.).

Ichthyoplankton net (Bongo net) was towed in the river water sections with a boat with 140 HP outboard engine against the current for 5 minutes per station. To determine the volume of water filtered, we used a mechanical type flowmeter 2030 (*****, 1983).

With flowmeters distance, speed and volume filtered haul, haul recording time and number of revolutions of the counter have been calculated as follows:

DISTANCE: $L = [(N2 - N1) / 999999] * K$
Where L = distance in meters
N1 = number of turns on the meter reading at the beginning hauling,
N2 = number of turns on the meter reading at the end hauling,
K = rotor constant = 26 873;
SPEED: $V = L * 100 / T$
Where V = velocity in cm / sec,
L = distance in meters
T = time in seconds;
VOLUME FILTER:
$VF = [(\pi * D^2) / 4] * L$ or $VF = 0.0053 * (N2 - N1)$

Shad larvae were counted and measured with calipers, accurate to 0.1 mm. The relative abundance was standardized at number of individuals per 100 m^3 of water filtered.
Larval development stage was determined according to the scale of Vladimirov V.I. (1953).

To study the distribution of shad larvae at Ceatal Chilia and in the two arms (Chilia and Tulcea branches), the section of Danube River upstream of Ceatal was sampled at three stations (towards both banks and in the middle) and Chilia and Tulcea arms, with each station diagonally, while all mouths (St. George, Sulina and Chilia branch near Bâstroe canal) were sampled diagonally. The time between sampling stations in the Danube River and that of the branches Tulcea and Chilia after Ceatal Chilia was about 5 minutes which was the boat travel time required between those stations, assuming the same flow larvae collection which escapes the river for the 5 stations near Ceatalul Chilia. Stations at the mouth were made on the same day but at different times.

Most important parameter to estimate the relative abundance of juvenile shad is "filtered water volume", which has been calculated and it is unaffected by water velocity and the ship's speed, encompassing these two vectors (Năvodaru & Năstase, 2014).

RESULTS AND DISCUSSIONS

Running for spawning adults

The analysis of long term shad catch statistics from Danube River (official captures from authorized institutions) in the delta area, show a cyclicality of their maximum or minimum level by the 10-11 year cycles (Năvodaru & Năstase 2014), in last almost 100 years (**Figure 3**). A possible explanation for the higher catches in the 80’ years is that the greatest Danube river foods in 1970 and 1974 has been determined the most productive period for all Danube delta fisheries and Black Sea coast because of water eutrophication, by increase of nutrients in all Danube River-Danube Delta-Black Sea system.

Changing in fishery behaviour as fishing seasonality and effort towards market demands may account for lower caches in last period, since stock estimation models do not reveal any overexploitation and length medium size of individuals do not decrease. However, overexploitation signs appear later as a mathematical model established for simulating the dynamics of the stocks under changing fishing effort developed for American shad (*A. sapidissima*) showed that the stock collapsed 20 years after the overexploitation started (Crecco & Savoy 1987).

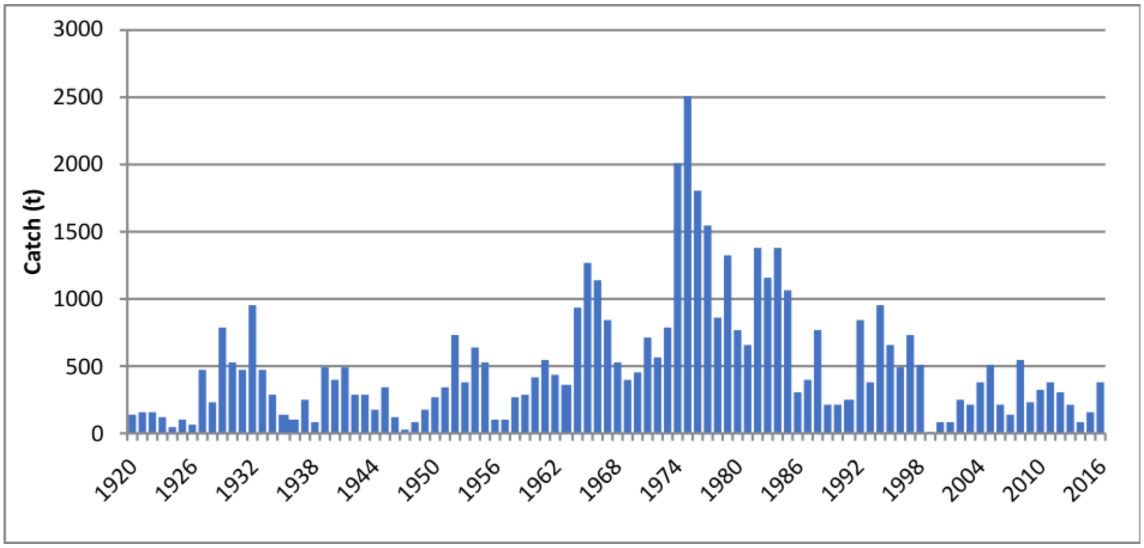

Figure 3 Cyclical evolutions of catches of Pontic shad during 1920-2016 years period

Pontic shad migration in 2016 was a typical one from the point of view of starting and running under the oscillatory influence of environmental factors (**Fig. 4**).

So, first shads appear at the mouths of the Danube as scarce individuals in February when the water temperature of the Danube River ranged between 4-5ºC and the water level rose to 200 cm. The fishery recorded the first catches on February 15, 2016 on St. George's arm.

The first substantial catches occurred at the end of February, varying until mid-March when water temperature rose above 8°C where the catch continuous increased, while water level increased to over 350 cm. After mid-March the catch trend sharply increased following the rise of the water temperature, but water level started to drop.

The peak of migration with over 233 kg/boat/day was on 1st April, somewhat earlier than usual. However, when the water temperature had risen from 10°C to 16°C and the water level dropped below 250 cm, the catch began to decrease by mid-April to less than 1 ton per day per fishery, but less fishermen actively fishing.

Beginning May 2016, in conjunction with Religious Easter and Prohibition shad time (April 28 - May 9, 2016) for 12 days in Sector 1, from Danube River mouths until Ceatal Chilia, the shad fishing was almost abandoned. Immediately after prohibition time, the fishery on shads no longer motivated the fishermen because the market demand was too low.

Following, commercial interest for shad fishing ended on 10 May 2016.

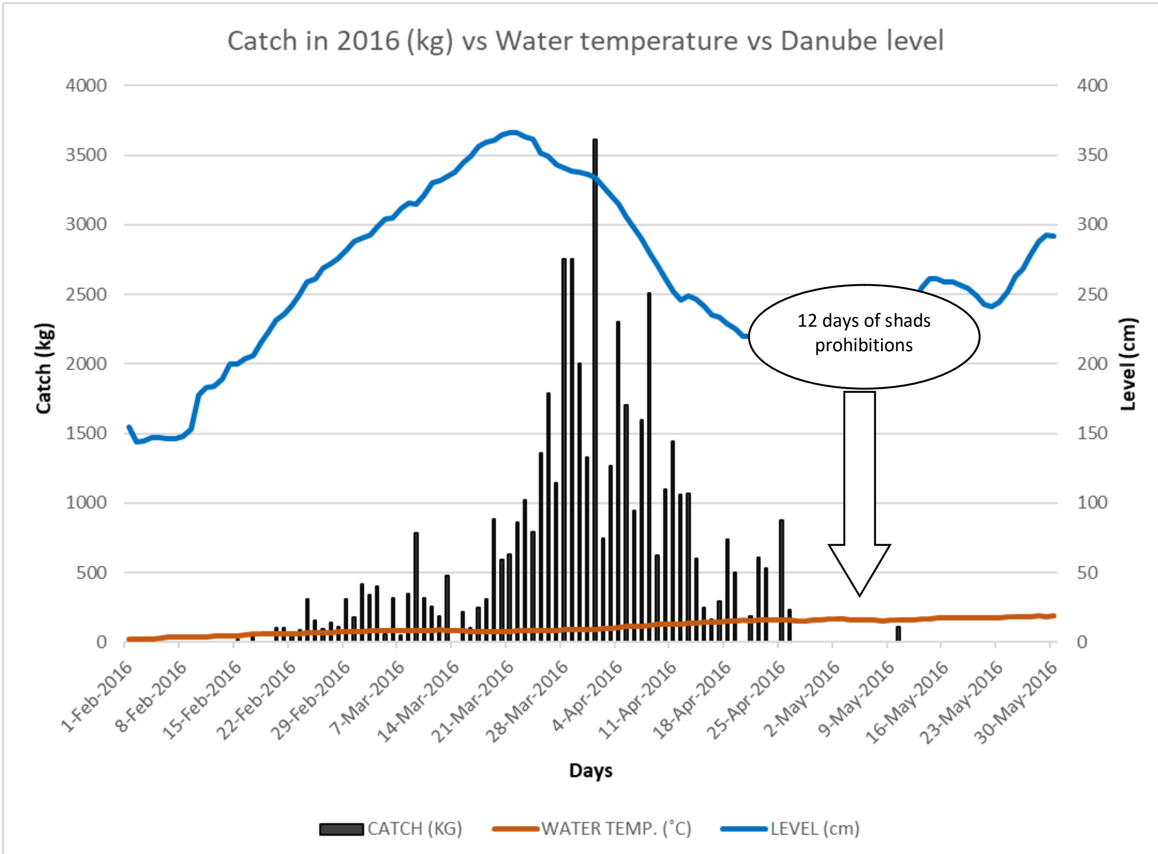

Figure 4 Evolution of the daily catch (kg=kilograms) from the St. George's mouth fisheries associated with the level and temperature of the Danube River water, measured at the Tulcea hydrological station during the migration of the Pontic shads in 2016.

The length-weight relation is an exponential function of the type $y = a{*}exp^{bx}$ demonstrating an allometric growth of the Pontic shads in 2016 (**Fig. 5**).

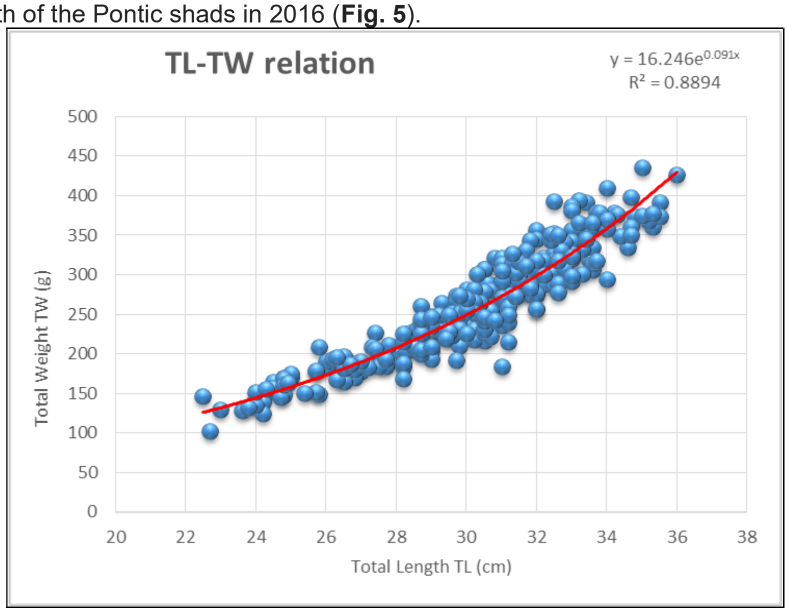

Figure 5 The length-weight relation for Pontic shads migration in 2016

The stock of migratory breeders in 2016 was made up of 4 generations from 2 to 5 years. The stock was dominated by generations of 3 and 4 years (**Fig. 6 left**). Maturity stage of Pontic shads gonads in Danube delta is more often II, sometimes III for those which go upstream for spawning, while less than 10% of very weak shads (Bănărescu 1964) is in VI stage migrating downstream to Black Sea after spawning trying to breed also next year (*****, 2016). Mostly individuals migrate in 2016 for first time (over 99 %), which could be a sign for overexploitation because the percentage individuals which spawn for 2-3 times, decreased to less than 1% (*****, 2016), with the caution that the time of sampling influences the recorded structure of the adult migrants. Also the accuracy of the scales readings can add uncertainties in the estimation of the repeated reproduction individuals.

The sex ratio in 2016 migration was M / F = 0.51 (**Fig. 6 right**). In the beginning of the migration (in April) there were relatively the most males percentage (almost 40%), with time the percentage of females increased (even up to 75%). The sex structure can vary depending on the seasonality, migration period being dominated by males at the beginning of migration, being balanced to the maximum intensity of migration and towards the end of migration dominance of the females (Năvodaru, 1997).

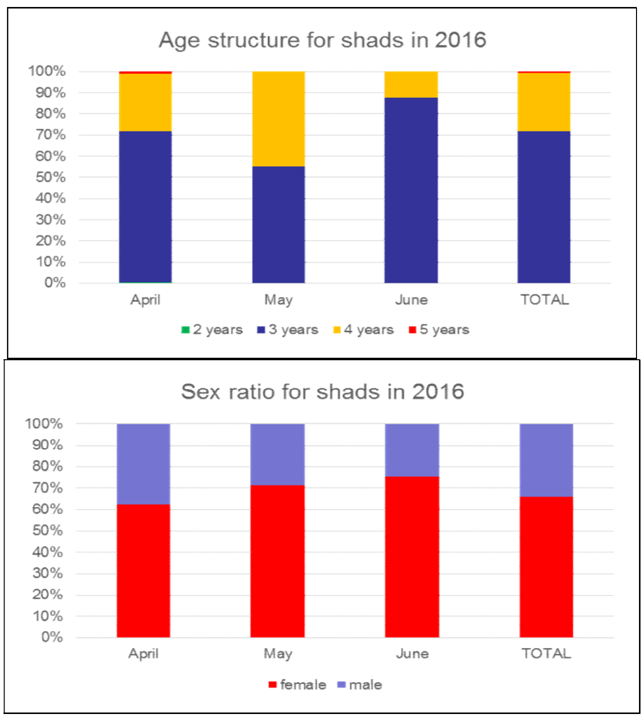

Fig. 6 Age stucture (left) and sex ratio (right) percentage (%) from Pontic shads migration in 2016

The 2016 migration was made up of shads ranging from 22.7-36 cm long and 102-435 g of biomass, respectively 28.7 cm mean total length and 236.8 g mean body weight (**Tab. 1**). The structure of the size of the shads in the 2016 migration is smaller than the structure of the last 6 migrations (2009-2014), respectively 31.2 cm medium length and 282 g individual average mass (Năvodaru and Năstase, 2014).

Tablel 1 Age structure, total length, and weight for 2016 shad migration

		Total Length (TL)		Total weight (W)	
Age	No. indiv.	Limits	Average	Limits	Average
2 years	1	22.7	22.7	102	102
3 years	209	25.5-35.5	30.2	124-376	263.7
4 years	80	30.3-36	30.4	215-426	265.6
5 years	2	35-35.2	35.1	368-435	300.5
Total	292	22.7-36	28.7	102-435	236.8

The Fulton index of shads had a fattening rate of 1.46. This was close to the average for 27 years 1988-2014 period, which was 1.42 (Năvodaru and Năstase, 2014), the Fulton coefficient of fattening for the 1988-2014 migrations varied between 1.2 and 1.7 with (**Fig. 7**).
The state of fattening depends on food availability (density-dependent factors and in particular on food competition in the Black Sea). The values of the Fulton coefficient ≥ 1 express a very good condition of fish populations. Fulton coefficient for shads decreases with migration distance to the Danube River and reproduction, due to biomass loss for the energy consumed for migration and spawning (Năvodaru, 1997).

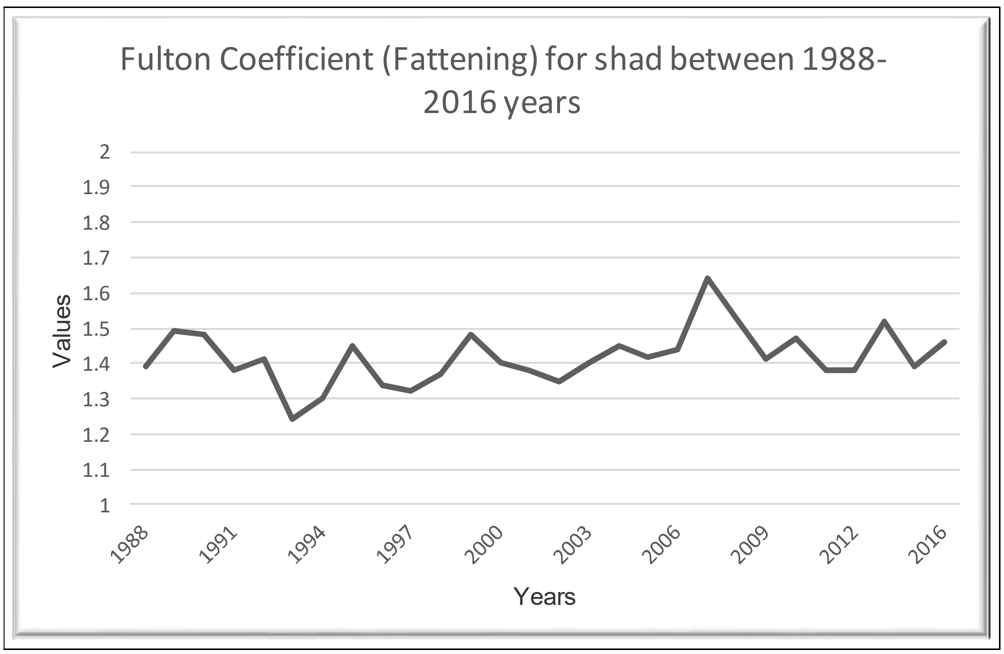

Figure 7 Fulton coefficient (fattening) values for Pontic shads (1988 – 2016).

Larva drifting

The success of the reproduction of the shads in 2016 was medium reaching an average of 84 larvae / 100 m³ of filtered water of the Danube River in the Danube Delta area (**Fig. 8, 9**), most larvae drifting in June (**Fig. 9**).

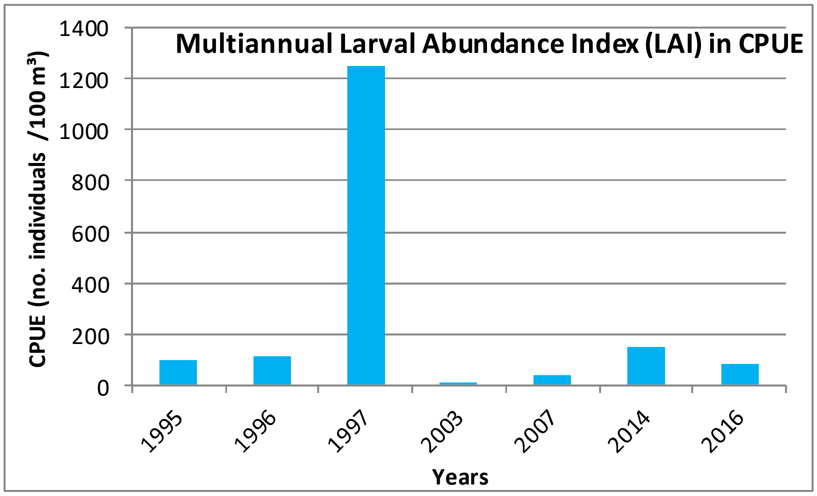

Figure 8 Multiannual Larval Abundance Index (LAI) found in 100 m³ filtered water for Pontic shads

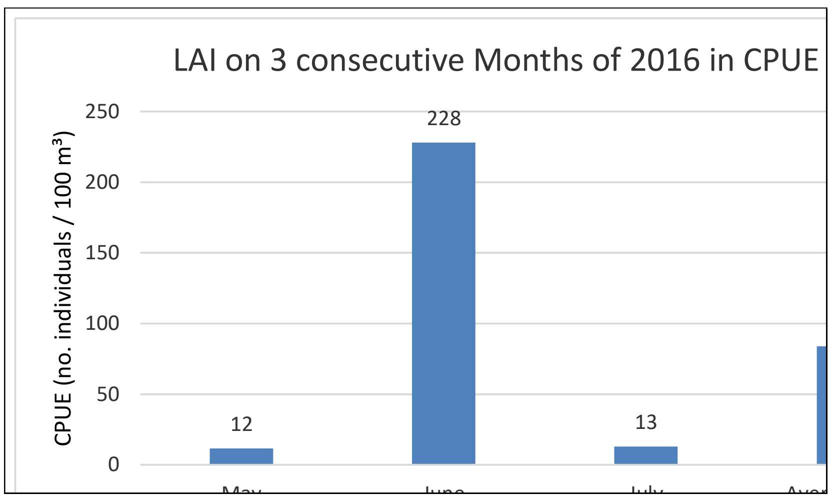

Figure 9 Larval Abundance Index (LAI) for 3 consecutive months in 2016

Regarding the lengths of the shads larvae, measured with the calipers, they vary between 5-19 mm, the majority of larvae being found in the 6-8 mm length class with a frequency over 70% (**Fig. 10**). From the point of view of the life development stage, the shads larvae are dominated by stage II, the early larval stage, with small and very small percentages in stage I (pre-larvae) and stage V-larva or fry (juveniles) (**Fig. 10**).

The hydrological drainage pattern of the Danube, in the Ceatal Chilia river bifurcation point into two arms, determines the larval distribution model. Thus, correlated with the shape of the river channel and the configuration of the water bed, we observed the drifting of the larvae predominantly where the river depth is higher with stronger current, because the water velocity in the curve increases from the shores to the middle of the stream (Constantinescu et al.1956). Consequently, the surface waters velocity pattern, transporting the larvae, will push the larvae to the outside of the curve, and thus towards to the Tulcea arm, which took more than 2/3 of total drifting larvae (**fig. 11**).
This distribution pattern also translates to the abundance of larvae in the river branches. So the largest quantities of shads larvae arrived in the Black Sea on Sulina and Sfantu Gheorghe arms, the lowest one being the Chilia branch, with small differences between the studied months (**Fig. 12**).

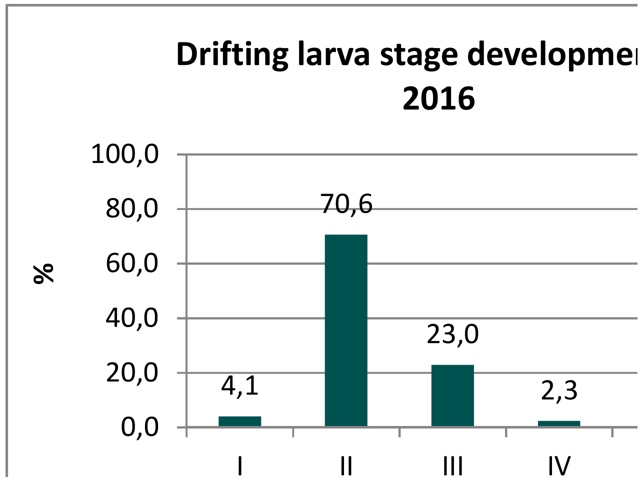

Figure 10 Stage development of shads drifting larvae in 2016

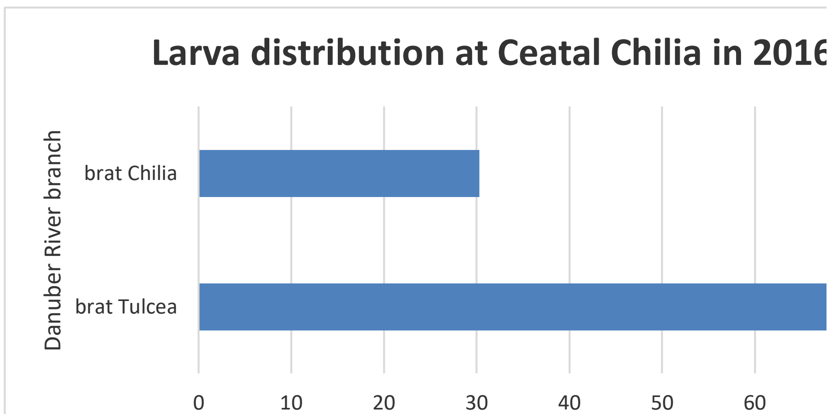

Figure 11 Distribution of shad larvae over the river branches on first bifurcation point (Ceatal Chilia) in the Danube Delta in 2016

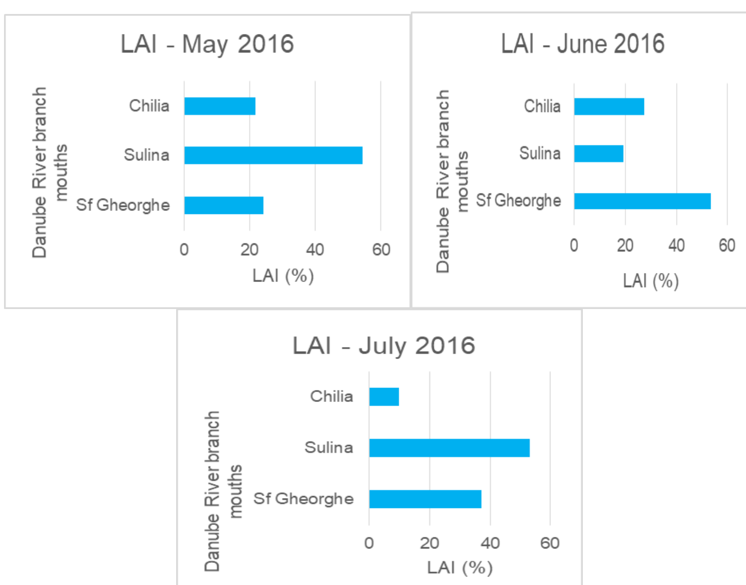

Figure 12 Percentage larval distribution over mouths of the Danube River branches in 3 consecutive months in 2016

In the studies of larvae drifting, a longitudinal-temporal relationship for survival between the abundance of larvae upstream and downstream could not be identified, because the larvae drifting is not continuous, and the likelihood of encountering the same flux at different points is minimal (Năvodaru 1997).
Consequently, it was not possible to assess the survival of the larvae on their way to the sea, although there are certainly mortalities in the larvae flowing along the Danube River to the sea.

CONCLUSIONS

In 2016 a little different than usually of running adults of Pontic shad was noticed. Migration starts earlier in February because water temperature rose quickly at 4-5°C, coupled with increase of water level to 200 cm. Intensity of migration was maximum at beginning of April at 10-14°C and 250-350 cm water level. In May, after 12 days prohibited period and decreasing in run migration, the fishermen were no longer motivated to continue to fish shads. Sporadic specimens are found up to August in occasional shad fishing.

Adults migration was dominated by the first time spawning individuals, mostly females, 3 years old class dominant, with fattening coefficient of 1.46, near than multiannual average of 1.42.
The average size structure of the shads in the 2016 migration is smaller (28.7 cm and 236 g) than the structure of the last 6 migrations (2009-2014), respectively 31.2 cm medium length and 282 g average.

Larval Abundance Index (LAI) was average ranging between multiannual limits, most abundant larvae drifted in June in 2 (II) and 3 (III) larval development stage in all Danube delta arms from Danube delta. Tulcea branch carried larger abundance of larvae than the Chilia branch, following by larger numbers in Sf. George river mouths than Chilia river mouth.

SUMMARY ON ROMANIAN LANGUAGES

Genul Alosa este present doar în emisfera nordică a globului pământesc cu 4 specii existând în America de Nord și alte 5 în Europa, din care *Alosa immaculata* (scrumbia de Dunăre) este subiectul prezentei lucrări. Migrația adulților scrumbiei de Dunăre este influențată de factorii de mediu, în special de creșterea temperaturii apei și inundațiile fluviale de primăvară care în anul 2016 au favorizat începerea migrației mai devreme decât de obicei în februarie, vârful migrației de reproducere la începutul lui aprilie, iar în luna Mai ia sfârșit, mai ales datorită faptului că piața și capturile nu mai motivează pescarii să pescuiască scrumbie. Capturile multianuale se situează între mari variabile în cadrul unui model ciclic de 10-11 ani incluse în cicluri mai mari de 35 ani. În general adulții investigați în 2016 au fost femele (depinde de perioada de eșantionare, deoarece spre sfârșitul migrației domină femelele), preponderent este vârsta de 3 ani, coeficientul de îngrășare este aproape de media multianuală, iar creșterea este una alometrică. Se observă că dimensiunile scrumbiei din 2016 au fost mai mici decât media multianuală. Succesul reproducerii a fost estimat prin Indexul Abundenței Larval (LAI), care este Captura pe Unitate de Efort (CPUE) exprimat ca număr de larve la 100 m³ volum filtrat de apă. Abundența larvelor în anul 2016 comparativ cu alți 6 ani anteriori a arătat că media LAI variază în limite largi (2-1252 larve la 100 m³) și LAI în 2016 este de asemenea inclus în aceste limite, cu o medie de 84 larve / 100 m³ care a fost clasificat în clasa medie de reproducere, ținând cont de maximul din 1997.

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