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Polyodon spathula – a review on its biodiversity, meat quality, and environmental impact in Romania

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Abstract. The sturgeon and caviar trade limiting as a result of Convention of International Trade in Endangered Species of Wild Fauna and Flora (starting with 1st of April 1998), as well as the increased human demand for fish consumption, made necessary the paddlefish (*Polyodon spathula*) monoculture rearing system development, or in association with Romanian or imported and acclimated common fishes such as *Cyprinus carpio*, *Ctenopharingodon idella* and *Hypophthalmichtys molitrix*. Besides its increased productivity, the *P. spathula* rearing is recommended by its high meat nutritional values, which are in close relationship with its high protein, unsaturated fat, vitamin, and mineral contents. *P. spathula* pisciculture may bring economic benefits to its growers, and could have a positive impact on sturgeons protection and conservation in their natural areas. The events so far shown that *P. spathula* present a minimum ecological risk in different Romanian fish populations; its planktonofag feeding make it a non competitor for the native fishes. Moreover, the genetic distance with indigenous acipenseride make impossible the introgression process. In order to obtain a high quality fish meat, and to improve the economical value of Romanian fish meat production, *P. spathula* might be recommended to be used in different aquaculture farms, at the present time being no conclusive data regarding its negative impact on the autochthonous ichtyofauna, and its role into another fish extinctions or dramatically decreasing of their number.
Key Words: Romanian pisciculture, native fishes, imported fishes, risks.

Introduction. Paddlefish - *Polyodon spathula* is a sturgeon fish spread in North America, which eat zooplankton filtered from water. In its natural areas, the paddlefish population is in a dramatic regress due to the overfishing and habitat changing. It has a higher development potential, compared to other freshwater species, but only when feed is not a limitative factor (Jennings & Zigler 2009).

P. spathula pisciculture rearing system became necessary if the human increased interest for the paddlefish meat and caviar, and its decrease number in natural populations are considered. Furthermore, in agreement with Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the fish and caviar trade is strictly limited (Costache et al 2004).

The aim of this paper is to briefly present some literature data with respect to *P. spathula* biodiversity and environmental impact in Romania. The events so far shown that *P. spathula* present a minimum ecological risk in different Romanian fish populations; its planktonofag feeding make it a non competitor for the native fishes; moreover, the genetic distance with indigenous acipenseride make impossible the introgression process (Costache et al 2004; LeBreton et al 2004).

Life in the wild. *P. spathula* is a sturgeon fish naturally located in the North of America, being the only representative of Polyodontidae family in this area. It may reach at 1.5 up to 2 meters and 50-70 kilograms at its maturity, being a planktonofag fish with a quite fast growing. It's a "long life" fish, the determined ages on the dental bones sections discovering many individuals from 15 to 30 years old-aged (Epifanio et al 1996; Russell 1986).

Females are sexually mature at the age of 7-8 years and males few years later. A part of the males from the Mississippi river are sexually mature at the age of 4-9 years, while in the Missouri river, males are sexually mature at the age of 8-10 years. Females reproduce once at every three years but the time required for oocyte maturation is over one year for each female (Graham 1997). *P. spathula* female lays about 100 000 eggs in two to 10 meters deep water, with 11 to 14^{o}C, and high speed water flow, the eggs substrate adhesion being one of the most important factor which ensure their survival. Larvae hatch at seven to ten days after fertilization, rostrum develops after their first ten to 14 days of life, and after their first 30 days of life, the offsprings are bigger that ten centimeters in length, and look like their parents. The growing is fast in the first year of life (up to 65-80 centimeters), and occurs even in winter (Pasch et al 1980; Mims & Shelton 2005). After the first year of life, and up to the age of five years, the growing became slower, the length growing rate being by five centimeters per year. In the next five years after the age of five years, the growing is really fast, *P. spathula* doubling or even tripling its weight (Costache et al 2004).

Generally, the lake *Polyodon* populations have a faster growth than those from rivers, because of feed abundance and its availability (Southall & Hubert 1984; Crance 1987; LeBreton et al 2004).

***Polyodon spathula* genetics**. There are few knowledges about *P. spathula* genetics. There are known three strains in U.S.: the upper Missouri river basin in Montana and North-Dakota, the Missouri and Mississippi river basins in the South-Central and Central U.S., and the Alabama river system (Cosewic 2008).

The genetic variability on the level of different *P. spathula* populations could be studied using molecular markers of protein polymorphism and mithocondrial DNA, some studies already shown a very low level of variability on *P. spathula* populations (Epifanio et al 1996; Szalanski et al 2000).

The increased demand for meat and caviar led to *P. spathula* wild populations decreasing, their genetic monitoring being vital for the species conservation success. The dams built on the length of rivers lead to a reproductive isolation and a higher rate of inbreeding with effects in loss of important genes in populations. All of these effects could be limited by a better *P. spathula* wild populations management, and an increase of its rearing in fish farms (AAFS 2011).

***Polyodon spathula* aquaculture in Romania**. *P. spathula* was added to Romania in 1992 when there were imported the first larvae from U.S.A. The lot arrived at the Nucet, Dâmboviţa Piscicultural Station on May 8th, 1992. Since then new lots of larvae were imported every spring until 1999, all of them being brought and bred in Nucet (Vizitiu et al 1997, cited by Gavriloaie 2007). Around 40 older specimens were also brought in 1992 from the Moldavia Republic to S. C. Acvares S.A. in Iaşi. In the spring of 2002 the successful artificial reproduction of the species took place in Nucet by using grown-up specimens from the first lot brought in Romania in 1992. The piscicultual material that came out was disseminated in several fish farms throughout the country and the results obtained at the breeding during summer I were good both as far as the average weight was concerned and as for the living standard. During 2002–2003, few individuals of paddlefish were caught in some lakes in Argeş river basin by the anglers (Gavriloaie 2007; Gavriloaie & Berkesy 2013; Iacob & Petrescu-Mag 2008).

This fish adapted well both in mono-fish farms and poly-fish farms, in associations with usual fishes such as carp (*Cyprinus carpio*), white amur (*Ctenopharingodon idella*) and silver carp (Hy*pophthalmichtys molitrix*). There were reported productions of 300-500 kilograms per hectare and weights of 1000-2500 grams per individual up to the age of two years or 4000-5000 grams per individual up to the age of three years, and associated productions of 1000-1400 kilograms per hectare for carp (1000-1500 grams per individual up to the age of three years), and of 150-300 kilograms per hectare for white amur (1000-1500 grams up to the age of three years) (Costache et al 2004).

The rearing of *P. spathula* in fishing farms require the fulfillment of some technological conditions:

- an optimal oxygen level ensuring: according to 4706/1988 Romanian Quality Standard, the minimum oxygen concentration of water required for fish breeding is ranged from 4 to 5 mg L^{-1}. The optimal values for carp is ranged from 6 to 8 mg L^{-1}, a concentration of 0.5 mg L^{-1} of water being deadly. *P. spathula* requires for its survival at least 4 mg L^{-1} (Costache et al 2004);

- water transparency: there is an optimum of 25 cm on the water collumn height for zooplankton growing, and this is for the second quality of fishery waters (4706/1988 Romanian Quality Standard). It could be recorded a bigger water transparency in May, and a lower one in August and September;

- water temperature: Rosen & Hales (1981) estimates a decreasing of *P. spathula* feeding when water temperature is over 26^{o}C for a long period of time;

- water pH: the extreme pH values could be enough stressful for aquatic creatures. The pH variations could be dangerous by modifying the toxicity of many pollutants. There is an optimum ranged from 6.5 to 8, pH values under 4.8 and over 11 being able to produce mortality (Diudea et al 1986).

- Ca^{2+} and Mg^{2+} content: according to 4706/1988 Romanian Quality Standard calcium si magnesium optimal values are 200 and 100 mg L^{-1}, respectivelly, any changes to these could lead to the decreasing of some zooplankton species, being affected the fish feeding and growing.

***Polyodon spathula* meat – an argument for its rearing and consumption**. Our previous researches shown the *P. spathula* meat has special qualities conferred by high protein, unsaturated lipid, vitamin, and mineral contents. It is considered that 100 grams *P. spathula* meat might cover almost 4% of daily energy requirement, and 21% of protein ones (Simeanu et al 2011, 2012).

But which are the basis of these findings? Mims & Shelton (2005) appreciated *P. spathula* meat as firm, white, boneless, and tasting, as the meat of another sturgeons. Fifty-seven percent (57%) of its boby may be carcass processed (beheaded, eviscerated, and without fins), and 27% as fillé (red meat, skinless) (Melchenkov et al 1996; Lou et al 2000).

Although its appearance suggests a significant head proportion (maybe due to the rostrum which represent 1/3 of the total body length), the meat proportion is 55.28% at the age of one year, 56.12% at the age of two years, 57.36% at the age of three years, and 57.78% at the age of four years. The older *P. spathula* individuals are, the bigger is the meat proportion, which also could be shown by slaughter yield (Simeanu et al 2010).

The acidity of Polyodon spathula meat is in a straight relationship with sensorial, hygienical, and technological quality; this is reflected in the chemical compounds status, tenderness, consistency, flavor, and taste, influencing the water retention capacity, and the meat shelf-time (Savu 2008). Generically, the pH values at different times after fishing are higher comparative to mammals due to smaller amounts of lactic acid (Banu & Dumitraş 1978). The fish meat pH ranges from 7 to 7.3 soon after catching, but the full stiffness install at 5.4 up to 5.8, or maybe more (6.2 up to 6.5).

The fillé water content (*P. spathula* lateral muscles) is higher at early ages, and lower at aging. In our previous research (Simeanu et al 2011), we found a *P. spathula* fillé water content ranged from 75.41-78.37% in their first summer of growing, results which were in agreement with those of Lou et al (2000) findings. Besides a lower nutritional value, a fillé higher water content accelerates microorganisms development, reducing the shelf-time.

The water-protein ratio (w/p) is a criteria which classifies fishes in five classes (Usturoi et al 2009):

- fishes with a higher nutritional value, in which the w/p ranged from 2.5 to 3.5;
- fishes with a good nutritional value, in which the w/p ranged from 3.5 to 4.2;
- fishes with a medium nutritional value, in which the w/p ranged from 4.2 to 4.7;
- fishes with a lower nutritional value, in which the w/p ranged from 4.7 to 5.2;
- fishes with a state of starvation, in which the w/p is bigger than 5.2.

Our previous investigations shown that sturgeons from their first three summers of life fits to the third classe depending on w/p content, and ones from their fourth summer, in the second one (Simeanu et al 2011).

The nutritional value and the meat digestibility are influenced by the muscles structure, and their chemical composition. The protein which determine the meat structure have a different digestibility, the sarcoplasmatic ones have a better digestibility compared to collagen and elastin (Zara et al 2005). Feeding *P. spathula* with a commercial food based on 32% proteins and four point five lipids, Onders et al (2005) recorded a better growing yield, and a better fillé protein content compared to the feeding with another commercial food based on 45% proteins and 16% lipids. Our investigations shown that sturgeons in their first fourth summers of life offered a fillé protein content ranged from 18.08% to 19.89% (Simeanu et al 2011). The protein levels of the investigated *P. spathula* fits this fish on the class of proteic fishes, with 15-20% protein yields (Ionescu et al 2006). Generally, the protein contents in fish meat range from 12.3% to 28.0%, the amount of protein being positive correlated with water content (Ionescu et al 2006; Usturoi et al 2009). Lou et al (2000) shown that the meat from 7.7 kilograms fish bodyweight contains 79% water, 17.5% proteins, 3.1 % lipids, and 1% minerals. The lipid contents is 3.1% higher than Decker et al (1991) found it at 0.5 kilograms fish body weight. At fish with more than eight kilograms bodyweight, the lipid contents was almost 4.6%. However, based on this results, *P. spathula* may be classified as a fish wih a lower lipid content (Pigott & Tucker 1990). The red muscles on *P. spathula* have a higher lipid content than the white ones, and the lipid content of *P. spathula* white muscles is lower compared to another sturgeons (Singer & Ballantyne 2004). However, the lipids in fish meat widely varies (from 0.0 to 28%), based on this being known: fat fishes (more than 8% lipids), medium fat fishes (from 4 to 8%), and poor fat fishes (lower than 4% lipids) (Paltenea et al 2006).

Our results shown a lipid *P. spathula* fillé content ranged from 2.45 to 3.96%, typical values for poor fat fishes (Simeanu et al 2011). These findings confimed Decker et al (1991), Lou et al (2000), and Onders et al (2005) results.

The nutritional value of *P. spathula* meat increase with aging and body development, especially due to the fat accumulation (97.39 kilocalories/100 grams – 114.31 kilocalories/100 grams, from the first year of life up to the fouth one) (Simeanu et al 2011, 2012). Comparing the another sturgeons meat nutritional value (105 kilocalories/100 grams) (Badiani et al 1997), our obtained values are close, which could demonstrate the genetic influence of the layout shown.

The fat fish degrees of assimilation are better compared to those from another animals, due to its mono, and polyunsaturated fat acids higher content (linoleic, linolenic, arahidonic, eicosapentaenoic, docosapentaenoic, docosahexaenoic). Our findings on *P. spathula* meat shown 25.45-25.97% saturated fats, 53.93-54.78% monounsaturated fat acids, and 19.48-20.61% polyunsaturated fat acids, higher from 4.18 to 5.31% saturated fats, lower from 1.32 to 2.17% monounsaturated fat acids, and lower from 2.53 to 3.05 % polyunsaturated fat acids than the findings of Singer & Ballantyne (2004).

***Polyodon spathula* environmental impact assessment in Romania**. New fish introductions might lead to the occurrence of unwanted developments. Therefore, the small size of the larvae and finding a suitable aquatic environment, may conduce to a rapid spread of new fishes, and of their pathogens. Moreover, the introgression up to the family level it is also possible (Semmens & Shelton 1986).

A new fish introduction into a country aquaculture may sometimes result in irreversible changes in ecosystems they get (Tendron 1997). First, their number decreases, but later there is a numerical „explosion" of the allochtonous fish, followed either by an invasion or by a stabilization and an optimum level recording at which the introduced fish could normally develop besides autochthonous fish (Lever 1994 cited by Costache et al 2004).

P. spathula is a plankton consuming fish, either by animal or vegetal origin. The phylogenetic distance between *P. spathula* and Romanian Acipenseridae makes the hybridization impossible, therefore the introgression could not happen. Its kinship with

these fishes is very weak and its nearest relative, the *Psephurus gladius* fish live just in China (Birstein & DeSalle 1997; Birstein et al 1997). *P. spathula* occasionally eat the other fishes larvae, but only in an accidental way (Rosen & Hales 1981; Hageman et al 1986; Hoxmeier & DeVries 1997). The performed researches on *P. spathula* already located in Romania confirm cladocerans, copepods, and less rotifers presence in its digestive tract, and more macrophytes and algae (Costache et al 2004).

An allochtonous fish introduction into a new country aquaculture might be based on economic grounds. For example, *P. spathula* fish could substitute in different Romanian aquaculture farms the Asian plankton consuming fishes, considering their lower meat qualities, and consumers lower interest (Costache et al 2004). The *P. spathula* feed competition might be real in the Romanian aquaculture only with *Aristichthys nobilis*, *Carassius auratus*, and *Abramis ballerus*. *P. spathula* could only partial substitute *A. nobilis*, and almost never other phyto-plankton consuming Romanian fishes (Costache et al 2004). In its country of origin, *P. spathula* is threatened by *A. nobilis,* and *H. molitrix* (Billard & Lecointre 2001). These threatening fishes could reach 1.5 metres in their length, ant they are very prolific (up to 1 million eggs) (Kolar et al 2005). It seems these carp fishes easily consume all of the plankton resources, which negativelly affect all autochthonous fishes, including *P. spathula* (Cudmore et al 2012). Therefore, it is difficult to consider *P. spathula* as a predator in its origin country, and even in other countries aquaculture systems (Simonović et al 2006).

In order to obtain a high quality fish meat, and to improve the economical value of Romanian fish meat production, *P. spathula* might be recommended to be used in different aquaculture farms, at the present time being no conclusive data regarding its negative impact on the autochthonous ichtyofauna, and its role into another fish extinctions or dramatically decreasing of their number.

P. spathula embryonated eggs are free from parasites and pathogens, as certified by U.S.A. Veterinary Authorithy, and the Romanian one's, as a result of their applied controls on the leaving point from U.S.A. and the Romanian board.

P. spathula is a fish which easily adapt into its new habitats, recently being identified on the Danubian Serbian bank in the area of Iron Gates II at 862–863 kilometers from the Black Sea. Its Danube existence is an accident, *P. spathula* coming from the Romanian or Bulgarian fisheries, countries in which was introduce in 1990's (Simonović et al 2006).

Conclusions. *P. spathula* is a sturgeon fish naturally located in the North of America, being the only representative of Polyodontidae family in this area. It may reach at 1.5 up to 2 meters and 50-70 kilograms at its maturity, being a planktonofag fish with a quite fast growing. *P. spathula* was introduced in Romania in 1992 when there were imported the first larvae from U.S.A.

P. spathula meat has special qualities conferred by high protein, unsaturated lipid, vitamin, and mineral contents. One hundred (100) grams *P. spathula* meat might cover almost 4% of daily energy requirement, and 21% of protein ones. The *P. spathula* meat is appreciated as firm, white, boneless, and tasting as the meat of another sturgeons. Fifty-seven percent (57%) of its body may be carcass processed (beheaded, eviscerated, and without fins), and 27% as fillé (red meat, skinless).

P. spathula meat could represent an alternative to other fish meat. This fish might be recommended to be used in different aquaculture farms, at the present time being no conclusive data regarding its negative impact on the autochthonous ichtyofauna, and its role into another fish extinctions or dramatically decreasing of their number.

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