AGRICULTURAL BIOLOGY, 2018, V. 53, № 4, pp. 698-711
(SEL'SKOKHOZYAISTVENNAYA BIOLOGIYA)

ISSN 2412-0324 (English ed. Online)
ISSN 0131-6397 (Russian ed. Print)
ISSN 2313-4836 (Russian ed. Online)

UDC 639.371.2.03

doi: 10.15389/agrobiology.2018.4.698eng
doi: 10.15389/agrobiology.2018.4.698rus

STURGEON (*Acipenseridae*) ARTIFICIAL REPRODUCTION PARADIGM CHANGEOVER UNDER CONDITIONS OF NATURAL STOCK DEFICIT OF STURGEON IN THE VOLGA-CASPIAN BASIN

(review)

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The authors declare no conflict of interests
Received February 5, 2018

Abstract

As well known, natural populations of sturgeon (*Acipenseridae*), except sterlet (*Acipenser ruthenus*), reached critical values by the beginning of the 21st century (P. Bronzi et al., 1999; E.V. Makarov et al., 2000; L. Speer et al., 2000; G.I. Ruban et al., 2015). For the endangered species of sturgeon, artificial reproduction continues to be the main source of replenishment of their populations (M.S. Chebanov et al., 2007). This method of sturgeon breeding is the most developed in the Lower Volga of the Caspian basin (V.V. Mil'shtein, 1982; A.A. Kokoza, 2004; L.M. Vasilieva, 2011) in Russia. To increase the effectiveness of sturgeon aquaculture, existing technologies are being updated and new ones are being developed (M. Chebanov et al., 2011; S. Wuertz et al., 2018). One such is the formation of broodstock (production) herds at sturgeon hatcheries (V.V. Tyapugin, 2015; L.M. Vasilieva, 2015; A.A. Popova et al., 2002). Abroad, broodstocks of sturgeon fishes have been created in industrial farms mainly aimed at commercial activities. For the analytical study, we used our own data, literature sources and reports on sturgeon artificial reproduction of the North Caspian Basin Directorate for Fisheries and the Conservation of Aquatic Biological Resources (Sevkasprybvod). It should be noted that most of the Russian relevant papers on the issue have been published in regional periodicals with a restricted accessibility. In this review, we intend to fill the existing gap. Among the six sturgeon species habiting in the Volga-Caspian basin, beluga *Huso huso*, Russian sturgeon *Acipenser gueldenstaedtii*, the sturgeon *A. stellatus*, and the sterlet *A. ruthenus* (G.I. Ruban et al., 2011) are considered. The data on the use of sturgeon producers of different origin in artificial reproduction at six hatcheries of the Astrakhan region are analyzed for the period from 2012 to 2015. In the species composition of wild producers caught for fish breeding, Russian sturgeon predominates (85-90 %) with critically small proportions of beluga and stellate, the species which are almost on the verge of complete extinction in the natural habitat (A.A. Kokoza et al., 2014; G.I. Ruban et al., 2017). Among sturgeon producers, the number of individuals from natural populations decreased while those of broodstock increased. Production broodstocks are formed by two alternative methods, the domestication of wild adult fish and the cultivation of producers from birth (from fertilized eggs) to sexually mature stages. The domestication makes it possible to accelerate the formation of broodstocks, since it does not necessitate growing sturgeons during four periods of the life cycle (embryonic, larval, juvenile, and immature stage). The formation of brooocks by domestication method, which began in Russia in 1999, led to a decrease in the average age of reaching puberty in different species of sturgeon under captivity up to 2-9 years. The proportion of juveniles derived from sturgeon producers which were grown in artificial conditions in the Astrakhan region is dynamically increasing. Russian experts have developed scientific foundation and technologies for the formation of sturgeon broodstocks which are currently involved in artificial reproduction at federal sturgeon hatcheries in the Lower Volga. Thus, the change of the paradigm of sturgeon fish artificial reproduction is stated which in modern conditions should be based on the offspring of producers from broodstocks.

Keywords: Sturgeon, the Volga-Caspian basin, artificial reproduction, Sturgeon hatcheries, spring and winter races, sturgeon natural stocks shortage, brood stock, domestication, paradigm changeover

It is common knowledge that at the turn of the 20th century in most countries the *Acipenseridae* species had become extinct or almost extinct [15, 16]. Furthermore, in the water basins of Europe and North America the decline of their populations had occurred one and a half centuries before it happened in Russia [12]. Until now, in our country (as compared with the other countries) the total population of *Acipenseridae* has been the largest, but also close to critical [17, 18]. It has to be mentioned that the habitat of *Acipenseridae* in the Volga-Caspian basin of Russia changed so drastically overall that their natural reproduction became possible only for the species that do not have long migrations, specifically, for sterlet [16].

It was only during the last 30 years that the technologies of artificial reproduction developed in Russia (former USSR) have begun to be used extensively in the world in order to obtain young *Acipenseridae* fish as the source of restoring the natural populations and replenishing the needs of the market [19-21]. In many countries such reproduction is aimed at commercial breeding [22, 23]. The scientifically substantiated attempts to restore completely lost natural populations have been made [24-26]. The restoration of most species of European *Acipenseridae* in their natural habitat is possible due to vacant ecological niches and is performed in the context of aquaculture with the help of created broodstocks, for which in Europe they use own producers that are occasionally caught in their natural habitat or imported impregnated roe and young fish. This tendency is actively developed in Italy, Germany, France, Poland, the Czech Republic, Spain, Finland, Baltic States and Iran, Kazakhstan and Uzbekistan [27, 28]. Unlike those countries, in Russia *Acipenseridae* still exist in their natural habitat. There is also a network of federal sturgeon hatcheries established in the middle of the 20th century, where until the start of the 21st century the artificial reproduction of sturgeons was based on the usage of wild producers [16, 27]. However, catching wild producers gradually decreased, and currently domestic fish hatcheries are not supplied with the quantities of sturgeon males and females required for the reproduction of young fish.

The global problem of extinction of *Acipenseridae* in their natural habitat resulted in the signing of a Ramsar Declaration on Global Sturgeon Conservation [29]. One of the actions recommended in the declaration was broodstock development at fish hatcheries [28, 29]. Due to this, at the turn of the 21st century a new technological stage appeared in the biological engineering of artificial sturgeon reproduction. Its purpose is to establish broodstocks and use domesticated or hand-raised "from roe to roe" males and females [28].

It has to be mentioned that there does not exist such a system of artificial reproduction of sturgeons abroad similar to the Russian one; however, most articles on this subject were published in the regional periodical publications, which determines poor accessibility of the available data array in spite of their academic and practical interest. This survey aims to fill this gap by summarizing a large volume of information about the system of artificial reproduction of sturgeons in Russia.

It was our aim to analyze the activity of sturgeon hatcheries in the Lower Volga basin operating broodstocks in domestic aquaculture during the recent years, the results of which reflect the shift of paradigm of artificial sturgeon reproduction in Russia.

One of the factors that affected the size and condition of Caspian *Acipenseridae* was river control of the Volga and Kama rivers with a cascade of hydro power plants resulting in sharp decline of natural reproduction, because the migration routes of producers to spawning areas was significantly reduced. For instance, 11 hydro power plants were built during 1942-1987 on the rivers of the Volga and Kama basin, of which eight were built on the Volga River: Ivankovskaya hydro power plant in 1942; Rybinskaya hydro power plant in 1950; Uglichskaya hydro power plant in 1955; Nizhegorodskaya (Gorkovskaya) hydro power plant in 1956; Zhigulevskaya (Kuybyshevskaya) hydro power plant in 1957; Volzhskaya (Stalingradskaya, Volgogradskaya) in 1961 hydro power plant, fish ladder; Saratovskaya hydro power plant in 1970, fish ladder; Cheboksarskaya hydro power plant in 1986; three hydro power plants on the Kama River: Kamskaya hydro power plant in 1956; Votkinskaya hydro power plant in 1966; Nizhnekamskaya hydro power plant in 1987 [30]. The dam of Volzhskaya hydro power plant (the lower stage of the Volga-Kama cascade) located 600 kilometers away from the Volga Delta in 1961 quite predictably and almost completely closed the spawning route for anadromous fish of the Caspian Sea, including sturgeons (with the exception of spawning areas of the Lower Volga) [31].

A new solution was added to the design of the Volzhskaya hydro power plant to minimize the damage of the migration route of sturgeons: a fish-passing facility — a hydraulic fish ladder [31] of a pit-lifting type which was commissioned in 1961. During the first years, when 200 to 700 thousand males and females migrating from the Caspian Sea for spawning assembled on the ebb side of the dam, about 20 thousand of them were moved through the fish ladder on the average, with the maximum number of 60 thousand in 1967 [32, 33]. However, this was just 10-15% of the number of migrating fish, which cannot be deemed efficient [32, 34, 35]. A mechanical fish ladder was built at Saratovskaya hydro power plant, which was reached only by 0.46-2.0% of all fish that overcame the Votkinskaya hydro power plant. Due to the fact that subsequently sturgeons stopped approaching the Votkinskaya hydro power plant, its fish ladder was put on hold in 1999, and later the same happened at Saratovskaya hydro power plant [31]. Consequently, this method of compensation to the fishing industry failed to accomplish its task of preserving natural reproduction of sturgeons in natural breeding areas of the mid-Volga and Upper Volga regions and the Kama River region. The reproduction of long-lived beluga and Russian sturgeon in the upper spawning areas took the biggest hit, and, to a lesser extent this affected the short cycle starred sturgeon and sterlet that do not make long migrations and all spawning areas of which are located below the dam of the Volga hydroelectric complex [33].

As far back as during the stage of designing the construction of Volga-Kama cascade of the hydro power plant the experts came to the conclusion that without a wide-scale implementation of artificial reproduction of sturgeons it would be impossible to preserve their natural populations [35, 36]. Consequently, fish breeding became the second method of compensating damage to natural populations of *Acipenseridae* in the Volga-Caspian basin [37, 38]. In the mid-20th century (1955-1981), 8 fish hatcheries were built in the Lower Volga beginning with the Volgograd hydroelectric complex for *Acipenseridae* rearing: one was built in the Volgograd region (Volzhskiy fish hatchery, which was later renamed to Volgogradskiy fish hatchery, town of Volzhskiy; commissioned in 1960), seven fish hatcheries in the Astrakhan region (Kizanskiy fish hatchery, Privolzhskiy region, village of Kizan, 1955; Lebyazhiy fish hatchery, Narimanovskiy district, town of Narimanov, 1979; Alexandrovskiy fish hatchery, Iskryaninskiy district, village Trudofront, 1974; Beryulskiy fish hatchery, village Algaza, 1961; Zhitninskiy fish hatchery, village of Zhitnoye, 1981; Iskryaninskiy fish hatchery, village Iskryanoye, 1962; Sergievskiy fish hatchery, village Sergievk, 1963). The Iskryaninskiy plant was converted several times and currently acts as a scientific and experimental facility of the Caspian Research and Development Fishery Institute (CaspNIRKH), the BIOS Center with a status of a sturgeon rearing farm. The Alexandrovskiy fish hatchery became a branch of Severokaspiskiy basin administration for fishery and preservation of aquatic biological resources. Presently, 6 federal sturgeon fisheries have remained and continue operation in the Lower Volga and in the Astrakhan region [39], which are part of the Severokaspiskiy basin administration for fishery and preservation of aquatic biological resources, the first of which was commissioned before Volga became closed with a dam of the Votkinskaya hydro power plant (in 1958-1960). In the Lower Volga, Kizanskiy fish hatchery had been built first before Votkinskaya hydro power plant was commissioned but after commissioning of the Upper Volga hydro power plants (Iskryaninskaya, Rybinskaya, Uglichskaya, Nizhegorodskaya, Zhigulevskaya and Kamskaya hydro power plants). The latter blocked access to the spawning areas on the Kama River for beluga; however, in the mid-Volga Region they were still accessible until the Votkinskaya hydro power plant and Saratovskaya hydro power plant were commissioned.

The cumulative production capacity of fishing hatcheries exceeded 70 million standard young fish (3-5 g weigh) of three sturgeon species (beluga, Russian sturgeon and starred sturgeon), which were reared to viable stages and released to the water basins of the Volga-Caspian basin to replenish the natural resources [35]. This allowed restoring the natural reserves of sturgeons, and at the end of 1980-s their commercial yield amounted to 24-25 thousand tons, and production of caviar amounted to 2-2.5 thousand tons [40, 41]. Since 1956, more than 3 billion units of fishery-reared young sturgeons have been released in the Caspian Sea. At the turn of the 21st century, the percentage of reared fish in Caspian catch was 98% for beluga, 65 % for Russian sturgeon and 45% for starred sturgeon. Its has been determined that every million of standard young fish yielded 1030 tons of Russian sturgeon, up to 110 tons of starred sturgeon and 130 tons of beluga [41].

Because of the present adverse hydrological and environmental conditions and ongoing unceasing illegal fishing (illegal, unregistered and unregulated fishing; IUU-fishing) of migrating producers of sturgeons in the main water courses of the Lower Volga, the efficiency of their natural reproduction has declined [15, 16]. It turned out that natural reproduction is incapable of providing not only the legal population, but also of maintaining the biological diversity and generic heterogeneity of populations. In this context, the only option of preserving the sturgeons and their population is their rearing [38].

During the last years, the scope of sturgeon rearing in Russia has been declining, the existing fishing hatcheries in the Astrakhan region are operational only at 15-20%, and problems have been encountered with producers for industrial needs. The deficit of quality producers of natural generations increases every year. When in 1997-2004 the used fishing quotas for rearing in general for four sturgeon species amounted to 87%, in 2007-2010 this amounted to 32% [39]. In 2012-2015, this figure further declined and amounted to 46%, 21%, 7.2%, and to 25% of allocated quotas (Fig. 1).

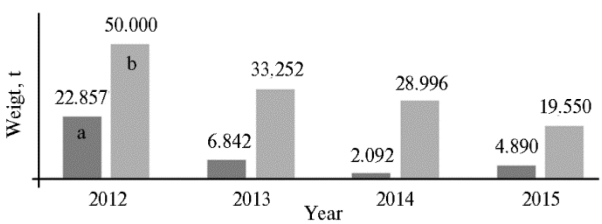

Fig. 1. Cumulative quota usage for catching of four sturgeon species for rearing purposes in the Volga-Caspian basin: a — catching, b — quota.

The comparative analysis of species composition of sturgeon producers caught in the lower Volga River for rearing indicates that the Russian sturgeon prevails in the catches (85-90%) (Table 1). Furthermore, only 0.877 tons of starred sturgeons were reared in 2012-2015 for the total allocated quota of 8.4 tones (about 10% quota usage). Particularly critical is the situation with rearing beluga producers: no single beluga was caught in four years [39].

1. Fishing quota usage (tons) **for four sturgeon species for the purpose of rearing in the Volga-Caspian basin**

Species	Year							
	2012		2013		2014		2015	
	quota	catch	quota	catch	quota	catch	quota	catch
Beluga	3.800	0.000	1.272	0.000	2.083	0.000	1.910	0.000
Russian sturgeon	38.500	21.895	31.480	6.660	26.413	1.993	17.340	4.660
Starred sturgeon	7.400	0.665	0.400	0.082	0.400	0.000	0.200	0.130
Sterlet	0.300	0.297	0.100	0.100	0.100	0.099	0.100	0.100
Total	50.000	22.857	33.252	6.842	28.996	2.092	19.550	4.890

The declining numbers of sturgeon producers entering the Volga River for spawning resulted in prolongation of the catching period for rearing purposes. Whereas previously the fish rearing process involved primarily the producers of later run, in 2012-2015 it was dominated by spawning sturgeon migrants of the summer and autumn spawning run, i.e. the early runs, whose percentage turned out to be 12 higher and amounted to 678 individuals as compared with 55 individuals of later runs [41]. The early producers of sturgeons to be spawning in the next year require protracted autumn-winter reservation in fisheries, which predicates the need for technical modernization of fisheries, and, specifically, the construction of wintering fish basins for wintering of migrant fish. In this respect fish-rearing and physiological parameters of producers of two sturgeon species need to be studied (Operational and financial performance report of Severokaspiskiy basin administration for fishery and preservation of aquatic biological resources, Astrakhan, 2015).

The morphometric (weight, length), fish-rearing and biological parameters (amount of ovulating roe, oocyte diameter, percentage of conceptions) of early run sturgeon females entering the river for the winter and spawning in the next spring turned out to be higher than those of later runs that spawn in the same year they enter the river without wintering. Which means that early run females of beluga are better prepared for spawning than later run females [42; Operational and financial performance report of Severokaspiskiy basin administration for fishery and preservation of aquatic biological resources, Astrakhan, 2015]. At the same time, the average hemoglobin content of later run females was 69 g/l, and 48.2 g/l for early run females. Identical changes were observed concerning whey protein content in blood. The hematological parameters of early run females are indicative of expressed anaemia after the winter period spent in wintering fish basins due to reduced intensity of metabolic and oxidizing processes in the body during the winter period [43, 44]. In spite of the fact that fish-rearing and biological parameters of early run sturgeon females are better than those of later runs, the young fish produced by the latter is more viable, which was confirmed by its survival and growth rate. The concentration of hemoglobin and whey protein content in blood of the offspring of later runs were higher than those of the offspring of early run fish, which allows us to establish a connection between hematological parameters of females and young sturgeons [Operational and financial performance report of Severokaspiskiy basin administration for fishery and preservation of aquatic biological resources, Astrakhan, 2015].

Presently, the dominating factor limiting the scale of sturgeon rearing is the increasing deficit of producers of natural generations [45]. At this stage of biological engineering the only option of preserving the genetic material of natural populations of sturgeons is the guaranteed delivery to fishing hatcheries of producers from broodstocks created and maintained in fish farm conditions (46).

This implies a change of tactics of rearing for such species. The usage of wild sturgeon producers for rearing was abandoned of necessity and transition to the usage of males and females from broodstocks has occurred [38, 47].

In Russia, broodstocks of sturgeons began to be established relatively recently, and 20 years ago the necessity to create them was purely speculative. For most sturgeon species this process was considered extremely complicated and economically unjustified [35]. The deteriorating situation with the catching of sturgeon producers of natural generation dictated the need for rapid transition to the establishing of broodstocks in fish farm conditions to guarantee rearing processes. There are two key methods of establishing sturgeon broodstocks: rearing to reproductive age at fish farms according to the "roe to roe" principle and domestication of wild producers [48-50]. The first method of stock formation is a long lasting process requiring more than 10 years for producers to mature, because sturgeon species belong to the long-lived species that mature late. Due to this, the sturgeon hatcheries prefer domestication of mature wild individuals. For domestication purposes they use sturgeon females that first produce roe, and subsequently are transitioned to a rearing regime of maintenance and feeding. It is a known fact that during their lifetimes sturgeon females can spawn repeatedly [51], and in farm conditions they can yield fish-rearing roe 10-12 times [52-54]. This method allows reducing the time required for maturing of beluga, Russian sturgeon and starred sturgeon by two or three times after their successful adaptation for unusual maintenance conditions, and ensures a wide genetic diversity of offspring.

The sturgeon rearing farms of the Astrakhan region commenced creating production broodstocks in 1999. By now they have created and operate commercial broodstocks of beluga, Russian sturgeon, starred sturgeon and sterlet, and their size and biomass increase annually. In 2011, the total size of the stock in sturgeon broodstocks at federal fishing hatcheries amounted to 3746 individuals with total biomass equal to 62478 kilos, and in 2015 these figures increased to 4,428 individuals (by 18.2%) and 94100 kilos (more than by 5 %), respectively. In terms of species composition, Russian sturgeon (more than 85%) dominates fish hatcheries in domesticated production broodstocks, which exceed 80% of the total amount of females. The percentage of other species is an order less, for beluga 8 %, for starred sturgeon 4 %, for sterlet 3 %. In rearing female stocks the parameters created using the "roe to roe" method constitute 72%, including 58% for females; the fish of rearing groups that have not achieved reproductive age makes 28% [53, 55, 56].

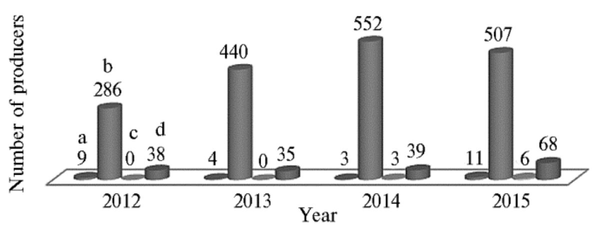

Fig. 2. The quantitative dynamics of domesticated producers of sturgeons used for breeding in fish farm conditions at six federal fish hatcheries located in the lower course of the Volga River: a — beluga, b — Russian sturgeon, c — starred sturgeon, d — sterlet.

In 2012-2015, the total number of sturgeon producers involved in fish rearing processes amounted to 2243 individuals from production broodstocks (where 2001 or 89.3% are domesticated females) and 242 individuals (or 10.7%) of the rearing female stocks completely raised and matured in fish farm conditions. During 4 years the number of domesticated sturgeon producers that matured in fish farm conditions during (Fig. 2) increased by 1.8 times, the largest share falls to Russian sturgeon (89.0%), the share for sterlet is 9.0%, for beluga 1.3%, for starred sturgeon 0.4% [35, 55].

All fish in production stocks at federal fish hatcheries of Severokaspiskiy basin administration for fishery and preservation of aquatic biological resources in Astrakhan region have individual markers (chips), which enables creating rearing and genetic passports for each fish. The study of passport data of domesticated producers allowed determining that 1025 females matured in wintering fish basins, including 914 Russian sturgeons, 89 sterlets, 18 belugas, and 4 starred sturgeons. The interval between spawning varied from 2 to 9 years, for sterlet it was 1-2 years, for Russian sturgeon it was 3-4 years, for starred sturgeon it was 4-5 years and for beluga it was 5-6 years [50]. The age of the initial maturing of females in wintering fish basin was the largest (6-9 years) for three species, which took a long time to adapt to the farm conditions of growing and feeding [52]. Furthermore, the second maturing of these species happened faster (after 3-4 years), which is indicative of high genetic flexibility and successful adaptation of female fish to farm conditions [44, 51]. Eurybiontic sterlet turned out the most easily adapting species, while beluga turned out to be the hardest to adapt. These facts can be the crucial for the fact that created production stocks will be reliable for fish rearing [45, 47].

Since 2012, the individuals of rearing generation have begun to mature in farm stocks which were used to obtain reproductive products. Between 2012 and 2015, the total population of these sturgeon females involved in fish rearing amounted to 242 individuals and, with the exception of beluga which matures late, increased from 2012 to 2014 by 18 times (Table 2). The largest number of matured fish was sterlet females which in natural habitat mature at the ages of 4-5 [47]. The population of Russian sturgeon females involved in the fish rearing process displays a stable growth every year (see Table 2). The age of the first maturing of females of Russian sturgeon, starred sturgeon and sterlet primarily corresponded to the age of maturing of natural generation fish, and beluga reached reproductive age in wintering fish basins 2-3 years sooner than in its natural habitat. The obtained findings are indicative of the fact that duly established and raised rearing sturgeon broodstocks provide the rearing process with producers of farm-reared generation.

2. The species composition and number of sturgeon females that matured in the production stock during different years and involved in farm rearing at six federal fishing hatcheries located in the lower course of the Volga River

Species	Number of females			
	2012	2013	2014	2015
Beluga	–	–	–	2 (16)
Russian sturgeon	6 (13)	11 (14)	19 (15)	28 (16)
Starred sturgeon	–	–	4 (12)	–
Sterlet	–	82 (3)	85 (4)	5 (5)
Total	6	93	108	35

N o t e. The age of fish species in years is shown in brackets. Strikethrough means that females have not matured.

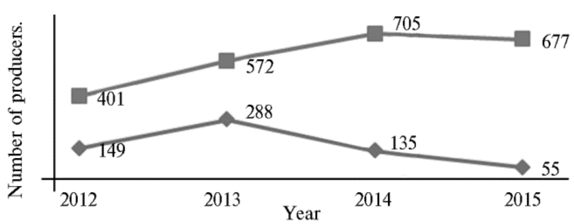

Fig. 3. Using sturgeon producers of different origin in farm rearing at six federal fishing hatcheries located in the lower course of the Volga River: ▲ — catching in a river, ■ — production stocks.

The comparative analysis of using sturgeon production of different origin indicates (Fig. 3) that during recent years, in the context of declining number of fish caught in the Volga-Caspian basin for rearing needs, the rearing process at sturgeon fisheries is maintained due to producers from the created production stocks. In 2012, the natural to fish-reared generation fish ratio was 1:2.5, in 2013 this ratio was 1:2, in 2014 1:5, and in 2015 the number of producers from the created broodstocks was 12 times higher than those caught in the natural habitat. It is fair to say that in the nearest years fish rearing will be provided with producers from fishery stocks [55, 56].

Therefore, the unique relict sturgeon species inhabiting out planet for millions of years have adapted and survived many natural and man-made disasters. Their primary natural population, which is currently concentrated in the Volga-Caspian basin, is critically endangered and at the brink of extinction [1]. The analysis of these facts leads to the analogy with the theory of G.A. Zavarzin [57], according to which prokaryotes evolve with the habitat. Presumably, this theory can apply to eukaryotes, and specifically to *Acipenseridae*. The habitat conditions of Volga sturgeons changed drastically and fast due to anthropogenic influence. The early runs of sturgeons disappeared, the conditions for spawning in breeding areas above the Volgograd hydroelectric complex became unsuitable, and population of later runs became critically endangered. In order to preserve and restore these natural resources in a context of near-complete lack of natural reproduction [54], the scope of farm reproduction of sturgeon species is maintained using different methods [47], including improvement of biological engineering technologies and increase of efficiency of farm rearing [55].

While natural reserves of sturgeon species in the southern seas of Russia started to plummet [1] their farm rearing emerged and increased. This resulted in the closing of sturgeon farm hatcheries (36). The farm rearing of sturgeon species in the rivers of the Azov and Black Sea basins in Russia continues only on account of creation of rearing female stocks. Presently, they are available in the Askaysko-Donskiy fishery, Rogozhinskiy fish hatchery and Science Center of Aquaculture Vzmorye of Azov Fishery Research and Development Institute, which are a part of the Azovo-Donskoy Center of Aquaculture (the Don River), and Grivenckiy fish hatchery, Temryukskiom fish hatchery and Achuevskiy fish hatchery – the business units of the Azovo-Donskoy Center of Aquaculture (the Kuban River) [56]. In Astrakhan region six federal fish hatcheries of the Volga-Caspian basin eluded the threat of liquidation, as well as Volgograd sturgeon fish hatchery located inside the Volzhskaya hydro power plant (Volgograd region). Due to the fact that these fisheries [58] promptly commenced creating brood (production) stocks of sturgeon species and created them, it guarantees that natural reserves of sturgeon species in the Caspian Sea will not only preserve but will also be restored using contemporary aquaculture methods.

Consequently, it can be said that at this time a significant obstacle has been removed to implementing the principles of sturgeon breeding in the lower Volga established as the concept for preservation of sturgeon species as far back as in the middles of the 20th century prior to regulation of the Volga-Kama basin rivers by the cascade of hydro power plants. This concept was based on the usage of mature sturgeon producers in fish rearing caught in the Volga River during their spawning migration. However, during that time there was still no deficit of producers of natural generations, whereas now the availability of wild producers for fisheries is not sufficient for production capacities and does not exceed 5-10% [34, 35].

The experience of last years is indicative of the fact that processing methods of sturgeon rearing in Russia have been updated [58-60] and the model of sturgeon rearing has changed because fish rearing process at fisheries is supplied by progressively larger quantities of producers contained in production (rearing female) stocks [61]. For instance, sturgeon rearing female stocks at fisheries of the Astrakhan region were formed in two ways, by domestication of adult fish from natural populations and by breeding producers from birth to spawning in farm conditions. The population and biomass of such stocks grows annually, as does involvement in breeding in the conditions of aquaculture [47]. The availability of such stocks guarantees supplies to the Russian fish hatcheries of fully-fledged males and females, which will help preserve the population of these relict fish species, at least in their natural habitat regions in the Volga-Caspian basin. The fish rearing of sturgeon species in the Volga-Caspian basin remains a unique domain of domestic aquaculture that has no analogues in the world in terms of the history of development, duration and scope [60, 61]. The new elements of intensifying sturgeon breeding [61-65] are such that when obtaining sturgeon offspring in farm conditions the tactic of fish rearing with wild producers, whose population is plummeting, is gradually replaced with the usage of females and males from brood (production) stocks [66-68] as this is performed with regard to most other species of fish aquaculture [69].

To summarize, Russia has developed scientific foundations and technologies of creating production stocks of sturgeon species involved in fish rearing at federal sturgeon fisheries of the Lower Volga. The fish rearing of sturgeon species in the Volga-Caspian basin among other things is aimed at maintaining the population of these species in natural water bodies, including that part of their natural Russian habitat, where their spawning sites still remain, and specifically, in the Lower Volga. The main paradigm of sturgeon rearing has changed 50 years after the federal sturgeon fisheries appeared in our country. The broodstocks are created at each of the six fisheries located in the Astrakhan region. Their formation is conducted via one of the following two methods, the domestication of the few wild producers and rearing of females and males at fisheries from roe obtained during fish rearing. The dynamics of this process indicates that in the nearest future the breeding will be completely supplied by producers from broodstocks.

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