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Review

The culture of sturgeons in Russia: production of juveniles for stocking and meat for human consumption

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Abstract − Culture of sturgeons in Russia began in the second half of the 19th century. During the first part of the 20th century, a significant research effort was devoted to the control of reproduction and the rearing of larvae mostly for stock enhancement purpose in rivers. Large-scale construction of hatcheries began in the 1950s after the damming of rivers, and by the 1980s over 130 million 1–3-g juveniles per year were being produced from wild broodstock. Presently, the production is 100 million juveniles. Emphasis is now on optimising stocking results through consideration of fish-specific factors (e.g. behaviour, fitness, size, balance between species) as well as environmental variables (food availability, release sites, salinity, precipitation regime). Food fish production of sturgeon (market size is 1.5–2.0 kg is just beginning using captive broodstock and new growing technologies. In 2000, farm production was about 1 650 t, which was higher than sturgeon landing from wild fisheries (1 500 t declared in 2000).

aquaculture / food fish / Russia / stocking / sturgeon

Résumé – L'élevage des esturgeons en Russie : production de juvéniles pour le repeuplement et de chair pour la consommation humaine. L'aquaculture des esturgeons en Russie a débuté dans la 2e partie du 19e siècle. Au début du 20e siècle, un effort de recherche important a porté sur la maîtrise de la reproduction et de l'élevage larvaire, principalement en vue du repeuplement des rivières. Après 1950, des écloseries « industrielles » ont été construites et ont produit, dans les années 1980, 130 millions de juvéniles par an, exclusivement à partir de géniteurs sauvages. Actuellement, la production est de 100 millions de juvéniles et la tendance est à l'optimisation du repeuplement et un nouveau schéma se met en place en prenant en compte le poisson lui-même (comportement, aptitude à survivre dans leur nouvel environnement, tailles, proportions entre espèces relâchées) et son environnement (disponibilités alimentaires dans les étangs d'alevinage, nouveaux sites pour le déversement comme des réservoirs ou des deltas lacustres, salinité, régime des pluies). La production de chair pour la consommation humaine débute avec la constitution de stocks de géniteurs en captivité et l'application de nouvelles méthodologies pour le grossissement jusqu'à la taille marchande de 1,5–2 kg. La production russe a été d'environ 1 650 t en 2000, ce qui est supérieur aux captures connues par pêche (1 500 t).

aquaculture / poisson de consommation / Russie / repeuplement / esturgeons

1. HISTORY OF STURGEON CULTURE IN RUSSIA

The origin of culture of sturgeons in Russia began in 1869 when Ovsjannikov succeeded in artificially fertilising sterlet (*Acipenser ruthenus*) eggs from the Volga river and the rearing of larvae (Milshtein, 1969). Sturgeon culture started concurrently with culture of other fish species in the northern hemisphere after the rediscovery of artificial insemination techniques used for brown trout (*Salmo trutta*) by Remy and Gehain, in France, in the 1850s (Billard, 1989). Following the success of Ovsjannikov, Russian scientists intensively studied artificial reproduction. They focused on wild spawners since it was impossible to hold large captive broodstocks. Spawning attempts with captive freshwater sterlet (whose maximum size does not exceed 2–4 kg) were unsuccessful as the fish did not mature in captivity (Grimm, 1905). In 1898, Berg also reported experiments on artificial breeding of *Acipenser stella*

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tus (Birstein and Bemis, 1997). Borodin (1898) worked with the stellate sturgeon, *A. stellatus*, and the Siberian sturgeon, *Acipenser baerii*, from several rivers and he developed the first procedure for artificial reproduction including the use of silt to remove the sticky layer surrounding the freshly fertilised eggs. In 1912, Derjavin founded the Ichthyology Laboratory of Baku and started his work on sturgeon reproduction, later summarised in his well-known book (Derjavin, 1947). A decisive step was reached when Gerbil'skij (1941, 1951, 1962), and his collaborators, such as Barannikova (1987), succeeded in stimulating ovulation using the method of hypophysation (pituitary injection). Development of the technology of artificial reproduction was completed after the basic work on oocyte maturation (Dettlaff and Skoblina, 1969) and sperm biology, fertilisation and development (Dettlaff et al., 1993). Work was also undertaken to use planktonic organisms as food for rearing fingerlings (Bogatova, 1951) and a system for rearing crustaceans was developed by Gaevskaya (1941). Finally, an integrated technology for artificially rearing sturgeons in Russia was elaborated. It was later published in the book of Stroganov (1968). During the first half of the 20th century, basic studies were being conducted on systematics and on the biology of sturgeons (Berg, 1948).

By the middle of the 20th century, dam construction started on the main rivers (Volga, Kura, Don, Kuban, Dniepr), and blocked upriver spawning migration. However, basic technologies were available for artificial reproduction including induced spawning, artificial insemination, incubation, larvae rearing on live prey, either indoors or in outdoor small ponds (2 ha). These methods were then used in the hatcheries on dammed rivers. Eventually, the hatcheries reached an industrial scale and produced large amounts of juveniles for stocking at a size of 1–4 g, and this required about 1 month.

Meanwhile the rearing of sturgeon in fish farms for meat consumption was less successful. One reason was the difficulty in maintaining captive broodstock of such a large size. It was also assumed that broodfish must be exposed to seawater during part of their life cycle to reach maturity (later shown not to be necessary). Success came from the use of small sized species living entirely in freshwater such as the sterlet and *A. baerii* (Smoljanov, 1979). Both species were successfully reproduced and the technology to breed *A. baerii* was fully established by the 1970s in the USSR and later exported to other countries (e.g. France, USA, Italy, Japan, Germany and Poland).

Another solution to produce food fish was to use hybrids which had the characteristics of both parents. One example is the 'Bester', an intergeneric hybrid made between the sterlet *A. ruthenus* (male) which lives in freshwater and the beluga *Huso huso* (female) which grows rapidly and reaches a large size. This hybrid was created in 1952 by Nikoljukin (1964) and the rearing technology was developed throughout the 1960s (Burtzev, 1983). Many other sturgeon hybrids have been created in Russia and other countries and, as expected, hybrid sturgeon possesses a combination of traits from each parent.

The objective of the present paper is to review the recent state of sturgeon production in Russia (juveniles for stocking in hatcheries and market-sized fish in farm structures). Quantitative data were obtained from the literature, unpublished official statistics from research institutes, and from data of the lead author (M. Chebanov).

2. PRODUCTION OF JUVENILES FOR STOCKING

2.1. Importance and efficiency of stocking

The release of juveniles in Russia is mostly concentrated in the Ponto-Caspian area and in Siberian rivers (*figure 1*). North of the Caspian sea, the release by hatcheries for all species was around 100 million during the years 1970–1980 and decreased to nearly 70 million by the end of the 1990s, including the production by Azerbaijan. In the Sea of Azov area, the annual release by hatcheries was 9 million *Acipenser gueldenstaedtii* and 19 million *A. stellatus* in 1985–1990; after, the release increased for *A. gueldenstaedtii* and declined for *A. stellatus* (*table I*). Juveniles of both species were stocked at 2–3 g. In addition 500 000 50-g *H. huso* and 200 000 *A. ruthenus* were

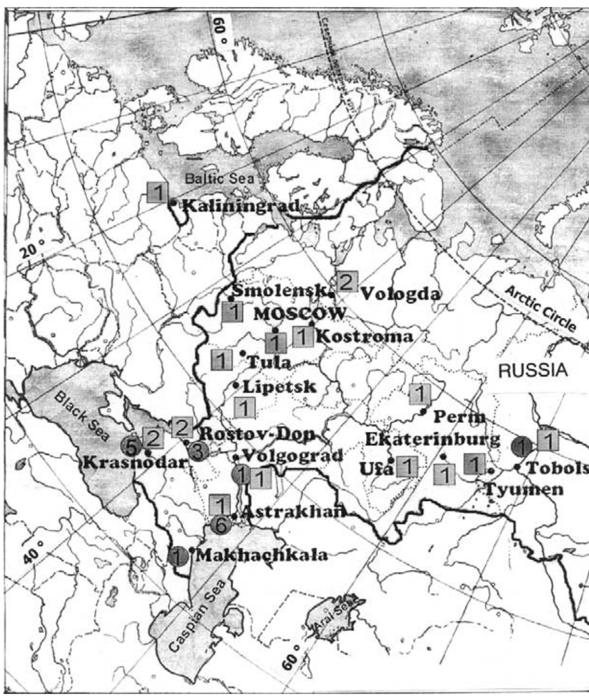

Figure 1. Geographic distribution of sturgeon State hatcheries (○) and private sturgeon farms (□) in Russia (European part). Four farms are also found in East Siberia and three in the far west and one State sturgeon hatchery is located in East Siberia. Numbers in symbols indicate the number of farms in that area.

Table I. Annual release of sturgeon juveniles in the Azov-Kuban region during 1974–1999, in millions of juveniles.

Years	*Acipenser gueldenstaedtii*		*Acipenser stellatus*		Total both species (in millions)
	Million	% of total	Million	% of total	
1974–1984	7.3	30.5	17.3	69.5	24.6
1985–1990	8.7	37.1	19.2	62.9	27.9
1991–1996	11.2	47.5	13.5	52.5	24.7
1997–1999	13.3	46.8	15.1	53.2	28.4

released in 1999 directly by the Krasnodar Research Institute and 2 million *A. gueldenstaedtii* by the Ukrainian authorities.

In the Siberian rivers, 2.5 million *A. baerii* and 0.9 million *A. ruthenus* were released in 1999, as well as 0.9 million of the local endangered population of *A. baerii* in lake Baikal. In addition, attempts were performed in the Amur river basin over the past 2 years; from 1992 to 2000, Russians have stocked, each year, 3 million 5–100-g Amur sturgeons *Acipenser schrencki* and 1 million kaluga *Huso dauricus* (Svirsky, pers. comm.).

The efficiency of stocking is not precisely known although some estimates have been established. For example in the Caspian sea from the 16 million 30–50-d-old *H. huso* juveniles released annually in the 1970s, only 0.1 % were harvested (once they reached sexual maturity) (Khodorevskaya et al., 1997). In the mid 90s the commercial return of stocked fish was 0.07 % in number for *H. huso* (Khodorevskaya, 1999). In the same area, hatcheries contributed, for the years 1991–1995, 98 % of *H. huso*, 55 % of *A. gueldenstaedtii* and 41 % of *A. stellatus* catches (Khodorevskaya et al., 2000). In the Sea of Azov basin, all rivers are dammed and there is no natural recruitment. Thus the present stocks have been, over the last 10 years, entirely supported by stocking. The average commercial return was 0.46 % of those stocked over the last 20 years. Commercial fishing is now prohibited except for a quota of 150 t spawners (males and females) allowed for the production of juveniles. The availability of females to fishermen is restricted to 12–15 d in the spring, during which the hatcheries must ensure the production of nearly 30 million juveniles (*table I*). The selection of spawners is restricted to females maturing in spring in the sea, in the mouth or in the lower course of rivers (dams are constructed not far from the sea, e.g. 150 km on the Kuban river). Late and early spawning runs are excluded from reproduction. In addition, the run-off of water has decreased to 60 % of previous levels due to agricultural usage and has changed the dynamics of the upstream migration of spawners.

2.2. Research and new technologies used in hatcheries

Research was carried out to improve the efficiency of stocking operations in hatcheries. Efforts were made to expand the period of reproduction, to make a better use of the hatcheries and nursery capacities and to have access to more genetically diversified populations taking early and late spawning runs or fish migrating far upstream (Chebanov and Savelyeva, 1999). By using captive broodstocks, it is possible to control the sexual cycle and spread the spawning time over the year. By a combination of thermal and hormonal manipulations, ovulation and spermiation can be obtained 5 months earlier or 6 months later than normal. The process of maturation can be slowed down by the exposure of females to low and slightly oscillating temperatures (average 5 °C). The critical part is the exposure to an oscillatory thermal regime when the fish are brought to the final stage of maturity (Chebanov, 1998). The spreading of the length of period of reproduction also allows the inclusion of winter spawning stock in the stocking programmes. Nowadays the traditional sturgeon pituitary injections to induce ovulation are still practised in many hatcheries but they are being replaced by synthetic analogues of the luteinizing hormone releasing hormone (LHRH). These analogues are potent at dosages as low as 1 $\mu g \cdot kg^{-1}$ (Goncharov, 1984). A technology for collecting ovulated eggs instead of performing caesarean surgery has enhanced female survival after spawning; it consists of making a small incision at the basal part of the oviducts with a scalpel introduced through the abdominal pore (Podushka, 1999). Besides permanent captive broodstock, sperm banks were established by research institutions for ex situ conservation of endangered populations (Ananiev, 1998); for instance, the federal living gene bank of the Azov and Black seas, located at the Krasnodar Institute of Fisheries, contributes to the stocking programme of the local state hatcheries.

2.3. Larvae rearing

When released directly in rivers, the survival of juveniles is only 1–3 % after a few months due to predation by other fish such as the European catfish *Silurus glanis* and the water intake for use in agriculture (including the killing of juveniles by the pumping system); this reduction of the flow rate subsequently increase salinity at the mouth of rivers (as seen in the Kuban river) (Chebanov and Saveljeva, 1999). Research was conducted by the Krasnodar Institute and the Temriuk hatchery (1992–1995) to improve the survival of juveniles for stocking by examining various cultural activities and stocking protocols (Che banov, 1998). It was shown that, in nursing ponds, the zooplankton biomass reaches 5–9 $g \cdot m^{-3}$ water within 3 to 7 d after flooding the ponds. Larvae (60–90 mg) of *A. stellatus* and *A. gueldenstaedtii* released in those ponds at the respective density of 80 000 and 70 000 per ha can reach respectively 1.0 and 1.4 g within 15 d. Beyond 15 d, the plankton density decreased and the growth and the survival of the young sturgeons were poor.

In practice, the rearing period in ponds should not be longer than 15 d at which time the juveniles are large enough to be released and the ponds can be used again for subsequent cohorts. Release of juveniles was attempted into deltaic lakes and brackish water lagoons, which show a salinity gradient from 0 to 6 parts per thousands. In lagoons, the peak of natural productivity occurred earlier than the traditional time of release of *A. stellatus* (at 15 g) and *A. gueldenstaedtii* (at 2.5 g). Release at an earlier stage, when the fish were 0.8–1.0 g for *A. stellatus* and 1.1–1.7 g for *A. gueldenstaedtii* resulted in a higher survival rate (14–20 % left in the autumn) and similar growth rate; the fish released earlier attained the same size (180–280 g) as the fish released later. Another method to improve production is to ensure better protection, once the fish are released into the lagoons, by elimination of predators and rearing in cages or enclosures for short periods to allow acclimation to the new environment. This approach is very important as we observed that the fish, once released, remained immobile for a few hours leaving them susceptible to predators. Alternatively, the culture in these semi-controlled conditions may be expanded to produce larger juveniles (100–500 g) for release.

2.4. Landlocked sturgeons

Besides river stocking, large quantities of 1–3-g *A. gueldenstaedtii* and *A. stellatus* were released into water reservoirs to establish reproductive landlocked freshwater populations. This size of juveniles is not appropriate, as they still feed on zooplankton in the water column, near the surface and are carried downstream by the current. The size of 7–10 g is more convenient as they stay on the bottom and feed on zoobenthos and trials of massive release of juveniles (200 000 each year) into the Kuban water reservoirs are presently in progress. The utilisation of reservoirs is promising because (1) of the presence of high quality live food for sturgeons in most of the south-east water reservoirs of Russia, (2) of the absence of other fish-competitors for food, (3) all anadromous sturgeon species can undergo the complete reproductive cycle in freshwater using the original sturgeon spawning beds and (4) this stocking programme can utilise the expertise and availability of the largest state sturgeon hatchery in the Sea of Azov basin which has a large capacity of production (12 million juveniles annually), presently under-utilised.

3. PRODUCTION OF MARKET SIZE FISH IN RUSSIAN FARMS

The production of sturgeon for meat has been increasing recently in Russia with the production of 1–2-kg live fish for restaurants and other live fish markets. Estimates of the total sturgeon meat potential market now in Russia is around 10 000 t. At present, there is no caviar production from farmed females in Russia due to the lack of captive mature sturgeons. When females do become mature, the farmers plan to produce fertilised eggs for growing fish in farms or even for stocking because the price of meat is 10 times higher than the price of eggs, processed in the form of caviar.

From 1994 to 1999, the number of sturgeon farms increased from 19 to 70 in Russia and the gross annual production increased 6 times (200 to 1 200 t) while the total production of other farmed freshwater fish species has decreased nearly 3 times. Sturgeon production consists roughly of: *A. baerii* 30 %, *A. gueldenstaedtii* 30 %, *A. ruthenus* 5 %, Bester 10 %, and *A. gueldenstaedtii* × *A. baerii* nearly 20 %. The culture of other species has started and Krylova (1999) listed three additional species (*H. huso*, *A. nudiventris* and the paddlefish *Polyodon spathula*) and eight hybrids (Bester × *H. huso*, Bester × *A. ruthenus*, *H. huso* × *A. nudiventris*, *A. ruthenus* × *A. nudiventris*, *A. gueldenstaedtii* × *A. ruthenus*, *A. gueldenstaedtii* × *H. huso*, *H. huso* × *A. stellatus* and *A. stellatus* × *A. medirostris*). There are several reasons for this sudden increase in farmed sturgeons. One is the increase in the demand for farmed sturgeon, due to the collapse of the Ponto-Caspian fisheries (sturgeon is a traditional food in Russia, particularly during holidays). Currently, carp production in heated waters is becoming unprofitable, due to the high costs of feed and some of these intensive rearing facilities could be converted to sturgeon farming, especially in central Russia and Siberia, as well as within the existing region of sturgeon fisheries. Several production systems could be used: industrial waste-heat effluent, traditional ponds for carp culture, raceways or cages in freshwater or brackish waters in the Volga delta and Kuban rivers (*table II*).

3.1. Culture in heated waters

More than 80 % of the sturgeons used for meat were produced in heated waters, in intensive systems with a

Table II. Production of sturgeon in Russia according to different production systems in 1999 (in % of the total production which amounted to 1 200 t).

Production system	%
Cages	41
Tanks	30
Ponds	24
Deltaic lakes	5

Table III. Ranges of individual weight (kg) of different sturgeon species and hybrids during 5 years at the warm water fish farm of the Krasnodar Research Institute (Chebanov unpubl. data).

Species and hybrids	Age (years)				
	1	2	3	4	5
Acipenser gueldenstaedtii	1.2–2.2	2.4–3.8	4.0–6.5	6.8–9.2	9.0–14.0
A. stellatus	0.7–1.2	1.5–2.6	2.7–4.6	4.0–6.7	6.0–9.0
A. baerii	1.0–1.7	2.1–3.4	3.4–5.8	4.8–8.0	7.5–12.0
A. ruthenus	0.1–0.3	0.3–0.8	0.4–1.2	0.7–3.0	0.8–3.1
Huso huso	1.9–3.2	4.7–6.9	7.0–10.2	11.3–19.0	17.0–29.0
A. gueldenstaedtii × *A. baerii*	1.5–2.7	2.8–5.3	4.1–8.9	8.5–13.5	11.0–17.0
H. huso × *A. stellatus*	1.7–3.2	4.3–6.3	7.5–11.1	–	–
H. huso × *A. ruthenus*	1.2–2.3	2.2–4.5	4.8–7.4	7.1–10.1	10.0–15.0

fish biomass density of 40–100 $kg^{-1} \cdot m^{-3}$. Under these conditions, the market size 1.5–2.0 kg is reached in 12–18 months. Under intensive culture in warm water from power stations, the growth of sturgeon shown in *table III* is faster than at ambient temperature, and sexual maturation is reached in about half the time of that of wild fish (*table IV*).

Vdovchenko and Rozhdestvensky (1999) reported that *A. baerii* cultured in geothermal brackish water in Siberia reached up to 2 kg in the first year. Abramenko (1999) described an example of this production system with the rearing of sturgeons in the waste-heat effluent of a pulp and paper plant in Arkhangel'sk. Among the various trials reported, one was carried out with cages placed in heated water. *A. baerii* and *A. gueldenstaedtii* and various hybrids showed an increase of weight between 1 and 2 kg and 100 % survival (*table V*). Pelleted feed was given at 3–6 % of body weight daily and the food conversion ratio (FCR) was relatively high at 4.5–5.0, likely generating a high load of wastes. At temperatures of 21–23 °C, market size (1.0–1.3 kg) was attained in 12 months.

Table IV. A comparison of age at first sexual maturation (years) of several sturgeon species and hybrids cultured at the warm water fish farm of the Krasnodar Research Institute and that of wild fish (Chebanov unpubl. data).

Species and hybrids	Female		Male	
	farm	wild	farm	wild
Acipenser gueldenstaedtii	6	11	3	8
A. stellatus	5	11	3	6
A. baerii	6	16	4	11
A. ruthenus	3	6	2	4
Huso huso	9	16	6	11
Hybrids:				
A. gueldenstaedtii × *A. baerii*	5	–	3	–
'Bester'*	6	–	3	–

* Bester: hybrid mode between the sterlet *Acipenser ruthenus* (male) and the beluga *Huso huso* (female).

3.2. Production of sturgeon in ponds

Sturgeons (mostly Bester) are produced in monoculture, either in small ponds (a few hectares) in intensive feeding systems (market size in 24 months) or in larger ponds (100 ha) in a ranching system without extra food (market size in 30–36 months). The rearing density is 20–40 $kg \cdot m^{-2}$ in intensive culture and 10 $g \cdot m^{-2}$ for ranching in large ponds. Sturgeons are also produced in polyculture in ponds. An example of production in a modified 16-ha carp pond has been reported in the Volga delta by Khoroshko et al. (1999). The pond was made deeper (2.5 m) and received 15 $t \cdot ha^{-1}$ organic fertiliser. It was stocked with 12-g *H. huso* and 12-g Bester at the density of 3 100 juveniles per ha and 31 200 silver carp juveniles. Additional feed (minced fish) was distributed. The water temperature reached 28 °C and the O_2 concentration decreased to 3.5 $mg \cdot L^{-1}$. In autumn, weight was respectively 54 g (28 % survival) for *H. huso*, 56 g (63 % survival) for Bester and 26 g (28 % survival) for the silver carp. The performance after wintering and a

Table V. Growth of several sturgeon species or hybrids (over a period of 1 year during the second growing year) in cages in industrial waste-heat effluent (Abramenko, 1999).

Species	Initialweight (g)	Density ($ind \cdot m^{-2}$)	Finalweight (g)	FCR*
Acipenser baerii	440	10	2 360	4.5
A. ruthenus	490	5	2 315	5.0
A. gueldenstaedtii	222	10	1 481	4.9
A. gueldenstaedtii × *A. ruthenus*	225	2	1 100	4.8

* Feed conversion rate.

Table VI. Performances of sturgeon production in polyculture in a carp pond in the Volga delta (after Khoroshko et al., 1999).

Species	Stocking		Harvest		
	Average weight (g)	Ind·ha^{-1}	Average weight (g)	% Survival	kg·ha^{-1} net
'Bester'	53.5	1 450	120–716**	76	115
Huso huso	80.7	320	691	34	50
H. molitrix	25	750	700	75	394
*Cyprinus carpio**	?	?	20–100	?	188
Divers	?	?	5–20	?	31
Total					778

* Accidental introductions.
** For Bester, two size classes were found.

second year of culture are shown in *table VI*. Survival rates increased for all species. In some cases, polyculture systems substitute paddlefish, *Hypophthalmichthys molitrix*, for silver carp.

3.3. Cage culture in freshwater or brackish waters in the wild

H. huso of 150–200 g were adapted with no mortality to heated power plant water at a salinity of 9–13, pH 8.1–8.2, O_2 6.3–8.5 mg·L^{-1}. After 2 years, 10 % of the fish had reached 3.2 kg, 54 % had reached 2.4 and 35 % reached only 1.4 kg (Rezanova and Tikhonova, 1999). In a trial, taking place in April, *H. huso* weighing 250 g were placed in cages (12 ind·m^{-3}) in the Gulf of Yergorlystsk in the Black sea. The mean temperature and dissolved O_2 were 21.5 °C and 6.6 mg·L^{-1}, respectively, during the summer and in the autumn all fish had survived and weighed on average 1 048 g (Strautman and Tolokonnikov, 1991).

3.4. Culture in deltaic lakes and brackish lagoons

Sturgeon ranching in deltaic lakes and brackish lagoons (up to 1 000 ha) open promising opportunities and require limited investments and not much artificial feed. Using 3–5-g juveniles, commercial size (1.5–2 kg) can be attained within 24–26 months with a survival rate of up to 34–38 %. Yields of 100 kg·ha^{-1} have been obtained with stocked sturgeons at 50 individual·ha^{-1} in water reservoirs, with biomass of food benthos of 4.5 g·m^{-2} and with the additional introduction of crayfish as food (collected from the coastland area of the Sea of Azov) (Chebanov et al., 1999).

4. CONCLUSION

Technologies for the commercial culture of various sturgeon species have been established over the last 20–30 years and are now available to fish farmers. The biotechnologies in use in hatcheries (induced spawning, egg incubation, first larvae rearing) are now in use in sturgeon farms and the technology for rearing broodstock in captivity have also been established. Some fish farms have established permanent captive broodstocks, sometimes for the purpose of ex situ conservation. The egg production of all sturgeon farms in Russia was 30 million fertilised eggs in 1999, of which 20 % were exported to Germany, Poland, Italy, Hungary, Spain, China and even Ecuador, and the rest stocked into growing ponds. This has required a broodstock biomass of 7 500-kg fully ripe females (about 700 specimens).

In the past, the culture of sturgeons in Russia focused on mass production of juveniles for stocking wild waterways. The traditional simultaneous mass release of 1–3 g standard sized fish is now questioned because these juveniles may not have the appropriate level of fitness for release in the wild. New stocking methods have been investigated which take into account the food availability in the rearing ponds and in the sites where the juveniles are to be released. The production of sturgeon meat for human consumption has begun more recently. The state hatcheries contribute to the development of sturgeon farming by providing the farm with fertilised eggs for growing fish and wild breeders for the constitution of captive broodstock.

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References

Abramenko, M.I., 1999. Sturgeon production trials in the waste-heat effluent of a pulp and paper plant in Archangelsk, Russia. J. Appl. Ichthyol. 15, 214–219.

Ananiev, V.I., 1998. Research results and perspectives of the program: 'Low temperature gene bank of marketable, rare and endangered fish and aquatic invertebrate species', Proc. Int. Workshop, Vancouver, Canada, 16-18 February 1998, Action before Extinction, pp. 147–161.

Barannikova, I.A., 1987. Hormones in aquaculture. Bull. Acad. Serbe Sci. Arts 96, 91–102.

Berg, L.S., 1948. Freshwater Fishes of the USSR and Adjacent Countries. Nauka Publ. Moscow and Leningrad (in Russian) [English translation IPST Jerusalem 1962, pp. 52-111].

Billard, R., 1989. Éléments de réflexion sur l'aquaculture en France, 100 ans après la création de la société centrale d'aquaculture et de pêche. Cybium 13, 303–310.

Birstein, V.J., Bemis, W.E., 1997. Leo Semenovich Berg and the biology of Acipenseriformes: a dedication. Environ. Biol. Fish. 48, 15–22.

Bogatova, I.B., 1951. Experience of plankton food rearing for fingerlings of sturgeon fishes. Proc. Saratov Department of the Caspian Branch of the Academy of Sciences USSR vol. 1. (in Russian).

Borodin, N.A., 1898. Experimental artificial insemination of sturgeons eggs and other biological observations constructed on Ural River in Spring 1897. Vestnik Rybopromyschelennosti St. Petersburg vol. 6-7. (in Russian).

Burtzev, I.A., 1983. Hybridization and selection of sturgeons during full cycle breeding and domestication. In: Kirpichnikov, V.S. (Ed.), Biological Foundation of Fish Culture. Nauka Press, Leningrad, pp. 102–113.

Chebanov, M.S., 1998. Conservation of sturgeon genetic diversity: enhancement and living gene banks. In: Action before Extinction. Proc. Int. Conf. Vancouver, Canada, 16-18 February 1998, pp. 163-173.

Chebanov, M.S., Savelyeva, E.A., 1999. New strategies for brood stock management of sturgeons in the Sea of Azov bassin in response to changes in patterns of spawning migration. J. Appl. Ichthyol. 15, 183–190.

Chebanov, M.S., Savelyeva, E.A., Galich, E.V., Chmyr, Y.N., 1999. Ecological-biotechnological problems of sturgeon culture in the Sea of Azov Basin, Proc. First Int. Symp. Fisheries Ecology, Trabzon, Turkey, pp. 199–207.

Derjavin, A.N., 1947. Reproduction of Sturgeon Stocks. Acad. Sci. Press, Baku (in Russian).

Dettlaff, T.A., Skoblina, M.N., 1969. The role of germinal vesicle in the process of oocyte maturation in Anura and Acipenseridae, Ann. Embryol. Morphol. 1, 133–151.

Dettlaff, T.A., Ginsburg, A.S., Schmalhausen, O.J., 1993. Sturgeon fishes. Developmental Biology and Aquaculture. Springer Verlag.

Gaevskaya, N.S., 1941. About methods of rearing live food for fishes. Proceedings of the Moscow Fishery Highest Technical Educational Centre, Issue 3. (In Russian).

Gerbil'skij, N.L., 1941. Metod gipofizarnich in'ekcij i ego rol' v rybovodstve. Metod Gipofizarnich In'ekcij i ego Rol' v Vosproizvodstve Rybnich Zapasov. Izd. Leningradskogo Gos. Univ., Leningrad, pp. 5–36. (in Russian).

Gerbil'skij, N.L., 1951. Intraspecific biological groups of Acipenserines and their reproduction in the lower regions of rivers with regulated flow. Syst. Zool. 4, 86–92.

Gerbil'shij, N.L., 1962. The theory of biological progress of Acipenserids and its application for sturgeons management practice. Leningrad Univ. Uchenii Zapisky 311, 48.

Grimm, O.A., 1905. Survey on Nikolskij fish farm work after 50 years of its activity. Iz Nikolskogo ribovodnogo zavoda, St. Petersburg.

Goncharov, B.F., 1984. Synthetic analogue of luteinizing hormone-releasing hormone as a new promising stimulator of gamete maturation in Acipenseridae. Dokl. Acad. Nauk. SSSR 276, 1002–1006. (in Russian).

Khodorevskaya, R.P., 1999. Formation of commercial stock of *Huso huso* in the Volga-Caspian region by hatchery reproduction. J. Ichthyol. 39, 807–810.

Khodorevskaya, R.P., Dovgopol, G.F., Zhuravleva, O.L., Vlasenko, A.D., 1997. Present status of commercial stocks of sturgeons in the Caspian Sea Basin. Environ. Biol. Fishes 48, 209–219.

Khodorevskaya, R.P., Krasikov, Ye.V., Dovgopol, G.F., Zhuravlev, O.L., 2000. Formation of the commercial stock of Caspian Acipenserids under present-day conditions. J. Ichthyiol. 40, 602–609.

Khoroshko, A., Sokolsky, A., Elovenko, V., Mikouiza, A.S., Mednaya, L., Krutshikov, V., 1999. Rearing sturgeons in unspecialised reservoirs on the Volga Delta. J. Appl. Ichthyol. 15, 327–328.

Krylova, V.D., 1999. Development of an universal methodology for morphological analysis of sturgeons (Acipenseridae). J. Appl. Ichthyol. 15, 281–282.

Milshteyn, V.V., 1969. 100th anniversary of sturgeon farming. J. Ichthyol. 9, 271–273.

Nikoljukin, N.I., 1964. Hybrid of beluga × sterlet. Ribovodstvo i Ribolovstvo 6, 8–11. (in Russian).

Podushka, S.B., 1999. Egg obtaining in sturgeon with life preservation in brood fishes, Nauchno-technicheskiy Bull. Lab. Ichtiol., St-Petersburg, pp. 4–19.

Rezanova, G.N., Tikhonova, E.Y., 1999. Commercial sturgeon (Acipenseridae) culture in sea cages. J. Appl. Ichthyol. 15, 330–331.

Smoljanov, I.I., 1979. Siberian sturgeon in water ponds of Konakovskij fishfarm. In: Osetrovoe chozayijstvo vnutennich vodoyomov USSR. Astrakhan, pp. 138-239 (in Russian).

Strautman, I.F., Tolokonnikov, G., Yu, 1991. Results of experimental rearing of marketable-sized Beluga sturgeon at the Yegorlytsk farm. J. Ichthyol. 31, 55–58.

Stroganov, N.S., 1968. Sturgeon acclimatisation and breeding in ponds. Moscow State University. (in Russian).

Vdovchenko, M.A., Rozhdestvenskiy, M.I., 1999. Experiences on the Siberian sturgeon and the irtysh sterlad year-round breeding in chutes and reservoirs with running geothermal water, Second Int. Symp. Resource-Sparing Technologies in Aquaculture, Oct. 4-7, 1999. Adler, Russia, pp. 23–24. (in Russian).