IUCN Species Survival Commission

Sturgeon Stocks and Caviar Trade Workshop

Proceedings of a workshop held on 9-10 October in Bonn, Germany by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Agency for Nature Conservation

Vadim J. Birstein, Andreas Bauer and Astrid Kaiser-Pohlmann

Editors

Occasional Paper of the IUCN Species Survival Commission No. 17

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The meeting was chaired by Dr Vadim J. Birstein, Chairman of the IUCN/SSC Sturgeon Specialist Group, and organized by Astrid Kaiser-Pohlmann, Ministry for the Environment, Nature Conservation and Nuclear Safety, and Andreas Bauer Federal Agency for Nature Conservation.

Vadim J. Birstein, Andreas Bauer and Astrid Kaiser-Pohlmann

Editors

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Foreword

The situation regarding the worldwide stocks of sturgeons used for caviar production is alarming. Many of the stocks are in decline and some species are in danger of extinction. The economic changes and financial problems in the former Soviet Union (FSU) have led to uncontrolled exploitation of sturgeon stocks. Previously successful breeding programmes have been curtailed because of financial problems and falling numbers of mature females needed for breeding. The FAO estimates that the sturgeon population has recently been reduced by 50% in the FSU (FAO, 1994). The quality of caviar has also worsened. With repackaging, bartering and smuggling, the caviar trade is increasingly affected by crime. Other factors which are jointly responsible for the sturgeons' decline include the destruction of their spawning grounds, the building of migration barriers and water pollution.

The common sturgeon (*Acipenser sturio*) is now virtually extinct in Northern, Western and Central Europe. In the FSU, however, it is still possible that sturgeon populations can be saved and thereby guarantee the long-term production of caviar.

Germany has long been one of the world's leading consumers of caviar. In 1994 its imports of caviar exceeded a record 100 tonnes. Germany is therefore particularly interested in preserving sturgeon stocks and indeed has become actively involved in this. However, international measures are required if the sturgeon is to be saved. The aim of this workshop is to collect the necessary information to achieve this.

Sturgeon and caviar experts involved in research, nature conservation and trade were invited to this workshop by the German Ministry for the Environment, Nature Conservation and Nuclear Safety.

30 May 1996

From the Editor

The workshop "Sturgeon Stocks and Caviar Trade" was an international meeting of specialists concerned about the future of sturgeon species currently threatened by tremendous overfishing. Five Russian sturgeon experts (Drs Yu. V. Altuf'ev, E. N. Artyukhin, I. A. Burtsev, A. V. Levin, and V. G. Svirsky), two specialists from Germany (Dr L. Debus and Ms S. Taylor), the Chairman of the IUCN/SSC Sturgeon Specialist Group, (Dr V. J. Birstein, USA), a representative of the World Conservation Monitoring Centre (Mr. N. Cox, UK), as well as representatives of the German Ministry for the Environment, Nature Conservation and Nuclear Safety, and the Federal Agency for Nature Conservation attended this workshop. The scientists and a specialist on the international caviar trade—Ms. S. Taylor (Dieckmann & Hansen Caviar, Hamburg, Germany)—gave presentations in the fields of their expertise.

These proceedings include the edited texts of presentations and of the discussions which followed each presentation. All footnotes to the articles were written by the Scientific Editor, Dr V. J. Birstein.

All foreign participants are very grateful to the German Ministry for the Environment, Nature Conservation and Nuclear Safety and its representatives Dr G. Emonds and Ms A. Kaiser-Pohlmann, for their kind invitation to attend the workshop and for their hospitality.

Dr Vadim J. Birstein
Chairman of the Workshop
and Scientific Editor

Overview: Economic importance and conservation of sturgeons

Overview: Economic importance and conservation of sturgeons

A. Bauer, Federal Agency for Nature Conservation, Bonn, Germany

keywords: sturgeons, Acipenseridae, Polyodontidae, caviar, uncontrolled fishery, extinction, conservation, CITES, overfishing.

abstract: The situation regarding the worldwide stocks and present use of sturgeons is alarming. The causes of the present situation are briefly explained, with particular reference to the caviar trade. An overview is given of the biology of sturgeons, their endangered status and economic significance. As Western countries are traditionally among the largest consumers of caviar, they are particularly interested in protecting sturgeons as the source of caviar and have taken on much of the responsibility of this. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety therefore organised a workshop for experts, involving international representatives from trade, science and nature conservation.

Kurzfassung: Die weltweite Bestandssituation und die derzeitige Nutzung der Störe ist besorgniserregend. Die Ursachen für die derzeitige Situation werden insbesondere im Hinblick auf den Kaviarhandel kurz dargestellt. Es wird ein Überblick über die besondere Biologie der Störe, ihren Gefährdungsstatus und ihre wirtschaftliche Bedeutung gegeben. Die westlichen Staaten gehoren zu den traditionell größten Verbrauchern von Kaviar, so daß hier ein besonderes Interesse aber auch eine besondere Verantwortung für den Schutz und die Bestandserhaltung der Störe liegt. Dies war Anlaß des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit einen Experten-Workshop mit internationalen Vertretern aus Handel, Wissenschaft und Naturschutz zu veranstalten.

Sturgeons and paddlefishes

Sturgeons and paddlefishes belong to the order Acipenseriformes, the last remaining group of the Chondrosteans. There are about 27 living species (25 sturgeons and 2 paddlefishes), most of them are endangered, threatened by extinction, or, in the case of some species and populations, already extinct (Birstein, 1993). For example, the common sturgeon (*Acipenser sturio*), which inhabits the Northern European coasts and rivers, is extinct in large parts of its range due to overfishing at the beginning of the 20th century.

The commercial value of some sturgeon species is extremely high because of their caviar and excellent meat. In recent decades, many species have become the subject of aquaculture or ranching programmes aimed at supporting targeted stocks by artificial propagation. At this conference, most of the discussion will focus on the following commercially important species: the beluga (*Huso huso*), stellate (*Acipenser stellatus*) and Russian sturgeon (*A. gueldenstaedti*) of the Caspian Sea, and the kaluga *(H. dauricus)* and Amur sturgeon (*A. schrencki*) of the Amur River.

Increasing overfishing (mainly in the Caspian Sea), water pollution (from pesticides and heavy metals), river damming, the loss of spawning grounds, and the destruction of water regimes (as demonstrated by the drying out of the Aral Sea) all contribute to the dire situation confronting sturgeon species today. At the first World Conservation Congress in October 1996, members of IUCN - The World Conservation Union passed a resolution urging Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to regulate international trade in sturgeon products by including all species of sturgeons in the Appendix II of the Convention.

Biological characteristics of sturgeons

Sturgeons are extremely vulnerable to overfishing because of their late maturity (between 6 and 25 years) and their dependence on repeated spawning over several seasons. They are either anadromous (i.e. they spawn in freshwater, then the juveniles migrate out to sea to mature on the coastal shelf, and the mature specimens return to the rivers to spawn) or they live their whole life in freshwater. Some species have anadromous and freshwater forms, e.g. *A. sturio* with extinct populations in the Ladoga and Onega lakes. The survival of anadromous sturgeon species is severely threatened by river damming and the loss of spawning habitats. Sturgeons are relatively opportunistic feeders, feeding mainly on benthic invertebrates, but also consuming fish as well. Two paddlefish species are exceptions in that they are filter feeders.

Fisheries

The Community of Independent States (CIS) of the former Soviet Union is the major producer of sturgeon products with nearly 90% of the world catch originating in its waters. In economic terms, the beluga, stellate and Russian sturgeons are the most important species, representing 90% of the world's total sturgeon catch. According to the FAO fisheries statistics yearbooks (FAO, 1993, 1994), sturgeon production from catches and aquaculture decreased from 28,616 tonnes in 1982 to 9,603 tonnes in 1992, and the production of sturgeons in the FSU fell during the same period from 25,704 tonnes to 5,564 tonnes. This trend reflects the decline in natural stocks at a time when illegal catches have increased drastically. The Caspian Sea is the most important area for sturgeon fisheries, and strict fishery regulations existed there until the collapse of the Soviet Union in 1991. No agreement on the new catch quotas has been signed between the FSU republics bordering the Caspian Sea (Russia, Azerbaijan, Turkmenistan, Kazakhstan and the two autonomous Russian republics Dagestan and Kalmykia).[1] In addition, the sea fishery, which was banned in the FSU from 1962, has come back into operation resulting in an increased harvest of young and immature specimens. This will cause a rapid depletion in natural stocks. According to the information from the Russian Ministry (now Committee) for Protection of the Environment and Natural Resources, the commercially exploited stocks of sturgeons have declined over recent years and the production of the Caspian Sea in 1994 was only 4,800 tonnes (compared with between 20,000 and 25,000 tonnes from 1974 to 1985). Due to the economic problems in the region, sturgeons are regarded as a swimming currency and caviar ('black gold') is an important source of income. As there is no effective fishery control, poaching and smuggling of sturgeon caviar are increasing. Statistics of caviar imports into Germany from the CIS (Warenverein der Hamburger Börse e.V., 1994) show a remarkable increase as a result of the intensive fishing operations there. Despite the decline of natural stocks, imports of caviar more than doubled between 1989 and 1992.

Sturgeon hatcheries

The purpose of hatcheries is to produce juveniles for release into the river or sea. In recent decades production of sturgeon juveniles has become increasingly important. Because of the depletion of natural stocks, stock enhancement and ranching programmes have been organised in the Caspian, Azov and Black Seas. Estimates of the total number of sturgeon juveniles produced in the former Soviet Union range from 80 million to 140 million annually (mainly *A. gueldenstaedti*, *A. stellatus* and *Huso huso*). According to information from the Russian Ministry for Protection of the Environment and Natural Resources, 23 Russian enterprises produce around 90 million

[1] On 14 November 1996, Russia, Azerbaijan, Kazakhstan, Turkmenistan and Iran signed an agreement to ban all sturgeon fishing in the Caspian Sea in 1997. Under the agreement, sturgeon fishing will only be allowed in the deeper waters of the Volga and Ural rivers.

juveniles each year. Due to the economic situation and the difficulties in getting enough females for reproduction, it is unclear how many hatcheries are still in operation and how many juveniles are still being released annually. Because of high levels of pollution, it has been estimated that 100% of the eggs from *A. gueldenstaedti, A. stellatus* and *Huso huso* caught in the lower reaches of the Volga River in 1990 were anomalous and that embryos of these species were not viable (Birstein, 1993).

Besides Russia, Iran is another important range state of the Caspian Sea. In the 1960s, Iran was still sea fishing for sturgeons, at a time when the spawning grounds in Iranian rivers had been completely destroyed by damming. Currently, Iran has a hatchery which produces about 8 million juveniles each year.

Sturgeon aquaculture

Sturgeon farms produce meat and caviar from sturgeons raised in ponds, basins or net cages. Since the first captive breeding programmes, which began in Russia, the aquaculture industry has expanded. About 19 species have been bred artificially so far (Steffens *et al.,* 1990; Steffens and Janichen, 1992; Steffens and Rosenthal, 1992). Hybrids between various species play a very important role in aquaculture; 'bester' *(Huso huso* x *Acipenser ruthenus*), for example, is the most important aquaculture 'species' in Russia. Hybrids have several advantages: they are easy to manage, fast growing and mature relatively early. In 1993, at least 4,000 tonnes of sturgeon meat were produced through aquaculture (Steffens, 1994). In France, 300,000 juveniles of the Siberian sturgeon (*A. baeri*) are produced annually and production is predicted to reach 500 tonnes per year in the next two years.

As a result of aquaculture production, the release of non-indigenous sturgeon species and hybrids has taken place. For example, eight individuals of *A baeri* x *A. gueldenstaedti* hybrids and non-identified sturgeons were captured in 1992 and 1993 in Dutch waters. The intentional introduction of *A. baeri* and *A. gueldenstaedti* into the Baltic Sea took place in the 1960s but was unsuccessful.

Artificial breeding for conservation

According to various authors, artificial breeding may be the only way to save and maintain populations of the most endangered species (Birstein, 1993; Rosenthal and Gessner, 1992; Steffens and Jahnichen, 1992). According to Birstein (1993), *A. sturio, A. mikadoi, A. baeri baicalensis, A. nudiventris* and *Pseudoscaphirhynchus kaufmanni* are the most endangered species. Because only a few specimens of some of the species exist (e.g. in public aquariums), urgent action is required. Other species like *P. fedtschenkoi* have already completely disappeared from their habitats, or, in the cases of *A. nudiventris* and *A. sturio,* have lost their species diversity. Another way of maintaining genetic diversity is through the creation of cryobanks. A cryobank for the Russian sturgeon species operates successfully in St Petersburg (Russia).

Status of the common sturgeon, *Acipenser sturio*

The common (European) sturgeon (*A. sturio*) only exists in very small numbers and only a few subpopulations may still be reproducing (Kinzelbach, 1990). It is extinct in the main area of its former distribution. The main cause of its decline has been the massive overfishing during the past century. In recent years, there have been a few records of catches of *A. sturio* from the Lower Rhine and the North Sea (Voltz and De Groot, 1992), but these captured specimens represent the last survivors of the North European sturgeon population. In October 1993, a female European sturgeon was caught near the island of Helgoland (Timmermans and Melchers, 1994). It measured 2.85m in length, 142kg in weight; and had 12kg of roe. There are plans in Germany and other countries to catch some of the last *A. sturio* for the purposes of artificial propagation to maintain the species' genetic diversity. It is hoped that eventual reintroduction will be possible.

International conservation of sturgeons

Only four species of sturgeons are protected by CITES: *A. sturio* and *A. brevirostrum* are listed in Appendix I, and *A. oxyrinchus* and *Polyodon spathula* are listed in Appendix II. The most endangered species are not protected by international law and include: *Pseudoscaphirhynchus kaufmanni, P. fedtschenkoi, P. hermanni,* and the Aral Sea population of *A. nudiventris* which became endangered due to the destruction of the water regime of the Syr and Amu Darya rivers and the Aral Sea, which has dried out (Birstein, 1993). *Acipenser dabryanus, A. sinensis* and the Chinese paddlefish *Psephurus gladius* which inhabits the Yangtze River face extinction because of damming and water pollution. The economically important species *A. gueldenstaedti, A. stellatus, A. schrencki, Huso huso* and *H. dauricus* are threatened by the rapid expansion of commercial and illegal fishing. According to Birstein (1993) and Russian fishery biologists, the overfishing will result in a decline of all sturgeon species of the Caspian Sea.

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Workshop Proceedings

The current status of commercial sturgeon species in the Volga River-Caspian Sea Basin

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keywords: sturgeon, *Acipenser gueldenstaedti, Acipenser stellatus, Huso huso,* overfishing, poaching, caviar, Caspian Sea, Volga River, Ural River.

abstract: The Volga is the most important river for spawning of the three commercially harvested Caspian Sea sturgeons: Russian sturgeon (*Acipenser gueldenstaedti*), sevruga or stellate sturgeon (*A. stellatus*), and beluga (*Huso huso*). During the 1970s and 1980s, between 12,000 and 18,000 tonnes of sturgeons were caught annually in the Volga River Delta. In 1994, the legal catch dropped to 3,100 and in 1995 to 1,500 tonnes. Due to poor ecological conditions in the 1970s and 1980s, the natural reproduction of sturgeons in the Volga River fell to 3,800 tonnes. Sturgeon poaching has increased dramatically since the early 1990s. Sturgeon stocks in the Caspian Sea have been supported by the annual release of about 80 million artificially raised sturgeon juveniles since the 1960s. Currently, the number of the released juveniles is much smaller, mainly due to the lack of sturgeon spawners in the Volga River. It might take 40-45 years for the stocks to improve.

Kurzfassung: Im Wolga-Kaspi Gebiet hat der Störfang und die Gewinnung von Kaviar große Tradition. Die Wolga ist das wichtigste Laichgewässer für Störe. In den 70er und 80er Jahren wurden laut offizieller Fangstatistik 12.000 bis 18.000t Störe pro Jahr gefangen. Der Fang setzte sich wie folgt zusammen: Russischer Stör (*Acipenser gueldenstaedti*) 60-70%, Sternhausen (Sevruga, *Acipenser stellatus*) 30-35% und Hausen (Beluga, *Huso huso*) 5-7%. Im Jahre 1994 wurden noch 3.100t angelandet. Eine Verbesserung der Bestande würde nach Schatzungen etwa 40-45 Jahre dauern. Die Stützung der Bestände erfolgte durch den jahrlichen Besatz mit etwa 80 Millionen Jungstören. Aufgrund des Mangels an laichreifen Weibchen werden heute weniger Jungfische ausgesetzt.

Introduction

The Volga River-Caspian Sea has always been of great importance to the following three sturgeon species: Russian sturgeon (*Acipenser gueldenstaedti*), stellate sturgeon (*A. stellatus*) and beluga (*Huso huso*). Almost 90% of all Russian sturgeon, 40% of stellate sturgeon and 50% of beluga hatch in the Volga River. About 75-78% of the total sturgeon landings occur in this area. During the 1970s and 1980s, 12-18,000 tonnes of sturgeon were caught annually in the Volga River delta. Commercial catches of Russian sturgeon were double those of stellate sturgeon, and the catch of beluga only accounted for 5-7% of the total catch.

From 1959 to 1963, the annual natural reproduction in the Volga River stood at 12,400 tonnes (Raspopov et. al., 1995). From 1966 to 1985, more than 1.5 million sturgeons migrated into the Volga River to spawn (Khodorevskaya et. al., 1995). In the 1970s and 1980s, the sturgeon hatcheries released about 80 million sturgeon juveniles each year. During this period, up to 80% of Russian and stellate sturgeons and 75% of beluga sturgeon caught had been bred and raised artificially. Unfortunately, these numbers have since sharply declined.

Present situation

The total number of adult sturgeons has fallen from 142 million in 1978 to 43.5 million adults in 1994. The total catch in the Volga River fell from 16,450 tonnes in the 1980s to 3,100 tonnes in 1994 (Malutin, 1995). According to official statistics, the legal catch in 1995 was only 1,500 tonnes.

From 1988 to 1993, it is estimated that between 189,000 and 240,000 spawners reached the spawning grounds in the Volga River. Over the next few years, when their hatchlings are incorporated into the catch, sturgeon catches will be less than 2,000 tonnes per year.

The decline in population size of sturgeons and in the number of individuals is due to several factors. Poor ecological conditions from 1978 to 1989 resulted in a decline in replenishment from natural reproduction of sturgeons in the Volga River. In the 1980s, the harvest of sturgeons fell to 7,900 tonnes, compared with 12,400 tonnes in the 1960s(Raspopov *et. al.*, 1995). In the early 1990s, natural reproduction fell to 3,800 tonnes while, from the early 1990s, sturgeon poaching increased tremendously.

During the past few years, less than 100,000 sturgeons migrating into the Volga River have reached the spawning grounds. The number of spawning females has dropped to 20-25%. Even sturgeon poaching in the areas around the sturgeon spawning grounds below the Volgograd Dam is now unprofitable due to the dearth of sturgeons. The Volgograd Hatchery has not been able to release juveniles in recent years because not enough breeders have been caught. For comparison, in the 1970s, the number of sturgeons wintering in this region of the Volga River was more than 300,000.

There is no international agreement on the regulation of sturgeon catches between countries bordering the Caspian Sea (Russia, Azerbaijan, Kazakhstan, Turkmenistan, and Iran). Because of this, overfishing continues in the Caspian Sea.[2]

The number of *A. gueldenstaedti* harvested has fallen drastically over the past decade, a fall caused by inadequate regulation of the catch. During these years, Russian sturgeon were caught during the summer, when individuals belonging to the winter race (85% of the whole population of Russian sturgeon in the Volga River-Caspian Sea basin) migrated into the river. Most of the migrants were harvested, and very few individuals could reach the spawning grounds. As a result, natural reproduction of *A. gueldenstaedti* dropped precipitously, while the caviar market was overwhelmed by Russian sturgeon caviar of a very poor quality comprising the roe of immature females. Prior to this, Russian sturgeon which migrated for spawning for the first time, second time, and older individuals constituted 27%, 53% and 20% of the population, respectively. Now these numbers are 11%, 39%, and 50%, respectively. Therefore, the level of natural reproduction has decreased considerably at the same time as the population size has also dwindled.

Poor regulation of catches does not appear to be the cause of the changes in *A. stellatus's* population structure. In the past, individuals which migrated for spawning for the first time, second time, and older sturgeon constituted 12.4%, 73% and 13% of the population, respectively. In the early 1990s, the population structure showed a marked change with 15%, 45% and 40%, respectively.

The situation with *Huso huso* is a little better. At present, individuals which migrate for spawning for the first time, second time, and older fish constitute 47.7%, 44% and 8.3% of the whole population of migrants (Khodorevskaya *et al.*, 1995). But because of poaching, there can be little hope that the catch of beluga will increase in the near future.

Conclusions

Three possibilities should be considered:

1. The present situation in the Volga River-Caspian Sea basin will continue. In this case the natural reproduction of sturgeons in the Volga River will

[2] See footnote 1.

come to an end because of poaching. Populations of all three species will have to be maintained by the work of hatcheries. In the 21st century, the sturgeon catch in the Caspian Sea will be about 1,000-1,500 tonnes as it is in the Sea of Azov now.

2. If the agreement on sturgeon catches between the countries bordering the Caspian Sea is signed soon, poaching will be stopped. In this case restoration of sturgeon stocks will take 25-30 years. The future harvest will then be as large as it was in the 1970-1980s.

3. More probably, the process of improving the current situation will take a long time, with a return to high catches taking some 45-50 years.

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Discussion

Blanke: What is the function and significance of the government-owned hatcheries for young fishes?

Artyukhin: The government hatcheries are financed by the Russian State Fishery Committee. The number of juveniles released there accounted for around 30% of total juvenile stocks. The artificial breeding of sturgeons and releasing of juveniles is now becoming more significant, as natural reproduction is in decline and illegal fishing is increasing.

Blanke: There is a fish lift in the Volgograd Dam. How does it work?

Artyukhin: The Volgograd Dam has a lift which worked very well for some time. In the 1970s, around 60,000-70,000 sturgeons migrating upriver were transported by the lift each year. Other fish, such as carp, also used the lift. At present, unfortunately, the lift does not work because of a second dam located upstream of the city of Volgograd, which was built in 1968 near the city of Saratov. This second dam prevents the fish from ascending any further. There are very few spawning grounds between the two dams. Currently, the spawning grounds below the Volgograd Dam are the most important for sturgeons.

The distribution and migration of sturgeons in the Caspian Sea

Dr A. V. Levin, Caspian Fisheries Research Institute, Astrakhan, Russia

keywords: sturgeon, *Acipenser gueldenstaedti, Acipenser stellatus, Huso huso,* spawning migration, restocking, poaching, juvenile, caviar, Volga River, Caspian Sea.

abstract: The largest populations of sturgeons in the world are in the Volga River-Caspian Sea basin. In addition to the three main commercial species -Russian sturgeon (*Acipenser gueldenstaedt*), sevruga or stellate sturgeon (*A. stellatus*) and or beluga sturgeon or beluga (*Huso huso*) — two other species (ship sturgeon, *A. nudiventris*, and Persian sturgeon, *A. persicus*), inhabit the Caspian Sea. The distribution, migration and reproduction of the main commercial species are described. Since the 1950s, natural reproduction has been supported by the artificial breeding and releasing of juveniles into the Volga River and Caspian Sea. At present, the number of juveniles released annually from the hatcheries is falling significantly.

Kurzfassung: Das weltweit größte Vorkommen von Stören liegt im Wolga-Kaspi-Gebiet. Neben den drei kommerziell bedeutsamen Arten Russischer Stör (*Acipenser gueldenstaedti*), Sternhausen (sevruga, stellate sturgeon, *Acipenser stellatus*) und Hausen (beluga, *Huso huso*) kommen dort weitere Arten vor. Das Vorkommensgebiet, die Wanderungen und die Reproduktion der wirtschaftlich wichtigen Arten werden beschrieben. Bereits seit den 50er Jahren wird die natürliche Reproduktion durch das Aufziehen und Aussetzen von Jungfischen unterstützt.

Introduction

The Caspian Sea populations of sturgeons are the largest in the world. Three most abundant species form the bulk of commercial catches: the Russian sturgeon (*Acipenser gueldenstaedti*), sevruga or stellate sturgeon (*A. stellatus*) and beluga (*Huso huso*). Also, smaller populations of the Persian sturgeon (*A. persicus*) and ship sturgeon (*A. nudiventris*) inhabit the Caspian Sea *Acipenser gueldenstaedti* and *A. stellatus* always dominated in the Caspian Sea and Volga River, whereas *H. huso* and *A. nudiventris* were far less numerous. In recent years, the Caspian Sea population of *A. nudiventris* has decreased markedly. All these species are anadromous. A relatively large population of the sterlet (*A. ruthenus*) also lives in the Volga River and its tributaries. *Acipenser ruthenus* poses some threat to the other sturgeon species spawning in the Volga River because sterlets prey on their eggs. Sturgeon hybrids also occur sporadically in the Volga River.

The largest commercial catch of sturgeons in the Caspian Sea basin this century - some 27,300 tonnes - was in 1977. Large catches of sturgeons in the Volga River (almost 17,000 tonnes per year) were made in 1976, 1981 and 1983. The Russian sturgeon was the most abundant species in the catch, comprising 79% (at maximum), followed by stellate sturgeon (17%), with beluga making up the remainder. By 1995, the legal harvest in the Volga River had fallen by a factor of 8. Since the fall of the Soviet Union in 1991, poaching has increased dramatically.[3]

[3] For more details, see Barannikova *et al.* (1995) and Khodorevskaya *et al.* (1995, 1997).

Sturgeons are caught mainly in the wider branches of the Volga River delta. From 1962, fishing of sturgeons in the Caspian Sea was strictly prohibited in the Soviet Union. With the collapse of the Soviet Union in 1991, the Caspian Sea coastline was split between five states: the Russian Federation, Kazakhstan, Turkmenistan, Azerbaijan and Iran. All these countries are now catching sturgeons and the sea harvest has started again. Iran has approximately 60 fishing sites off the coast.

In this presentation I will describe the reproduction of sturgeons in the Volga River-Caspian Sea, the spawning migration of sturgeons into the Volga River, and the downstream migration of juveniles into the Caspian Sea.

Natural and artificial reproduction of sturgeons

The Volga River has always been of great importance to sturgeon reproduction and stock enhancement. After construction of hydroelectric power station dams (the first Volgograd Dam built in 1958-1960 is located 700km upriver from the Caspian Sea), *A. stellatus* maintained a high level of natural reproduction on 60-70% of its spawning grounds. The rate of reproduction of *A. gueldenstaedti* and *H. huso* has decreased several times, particularly in recent years. Natural reproduction of sturgeons still occurs in the Ural River (Kazakhstan) and to a lesser extent in the Kura River (Azerbaijan). The number of sturgeon entering the Terek and Sulak rivers (Autonomous Republic of Dagestan within Russia) is minimal. Some reproduction occurs in the rivers of Iran.

For forty years, the stocks of these three species have been enhanced through a combination of natural reproduction (though this is now considerably reduced) and an artificial hatchery programme (restocking or ranching). There are 14 sturgeon hatcheries in the basin. At the beginning of the 1990s, eight hatcheries in the lower reaches of the Volga River produced and released approximately 60-67 million juveniles of the Russian, beluga and stellate sturgeons.[4]

Spawning migration

The anadromous migration of *A. gueldenstaedti* from the Caspian Sea to the spawning grounds in the Volga

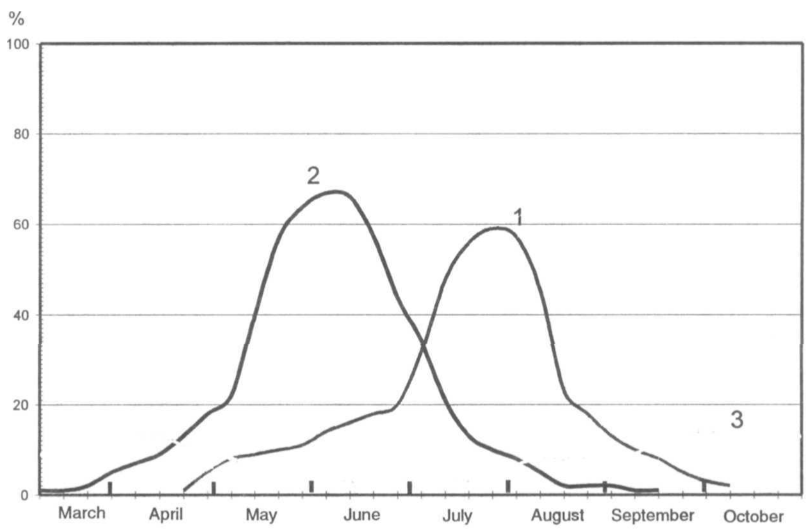

Figure 1. The dynamics of the spawning migration of the Russian sturgeon (1), stellate sturgeon (2) and beluga (3) into the Volga River.

[4] See also Barannikova (1995) Barannikova *et al.* (1995) and Khodorevskaya *et al.* (1997).

River usually begins in April (Figure 1). The so-called early spring race (or run) of sturgeon enters the deepest branch of the Delta, the Volga River-Caspian Sea Canal (VCC), in April-May, and migrates upriver for 600-700km. These fish spawn in May-June at a water temperature of 12-15°C (Titarenko and Ulezko, 1955; Barannikova, 1957). This population is not large.

In May-June, the late spring sturgeon race migrates to the spawning sites. Spawning occurs in July-August of the same year at a water temperature of 19-22°C. In June-July, the winter sturgeon race, which will migrate upriver next summer, enters the delta, and from August through October the late winter sturgeon race moves up. The winter races spend winter in the deep parts of the river (wintering areas) and below the Volgograd Dam. They spawn at the end of the following April and May at a relatively low water temperature of 9-13°C. The majority of these fish come from the western part of the Caspian Sea and move upstream along the VVC. Downstream migration is more intensive along the eastern branch of the delta (the River Buzan), in June-August with the maximum in July.

Acipenser gueldenstaedti spawns between the ages of 8 and 35 years (Khodorevskaya *et al.*, 1993). In general, females are some 6 to 8 years older than males. Their average weight is 26-29kg with a maximum length of between 136 and 163cm. The average weight of males is 12.0-14.5kg, and their average length is 130-134cm. Females reach maturity at the age of 10 years (two or three years later than males). There are roughly equal numbers of males and females in the spawning population. In recent years the number of Russian sturgeons reaching the spawning grounds has declined from 500,000-600,000 to 120,000-150,000, and the efficiency of breeding has declined several-fold. For spawning, *A. persicus* tends to enter the Kura River and rivers of the Iranian coast (especially the Sefid-Rud River), and also the Terek, Sulak, Volga and Ural rivers. Spawning takes place at a water temperature of 17-23°C.

Like *A. gueldenstaedti,* stellate sturgeon begin their migration into the Volga River in March-April, during the spring flood (Barannikova, 1975). The spawning migration peak is in May (Figure 1). During this period a single commercial catch could consist of 70-80 fish. Migration can continue until October-November.

The age of the *A. stellatus* spawners ranges between 6 and 28 years (on average, 11 to 16 years). The average length of females is 150-152cm, and the average weight is 11-12 kg. Male spawners are smaller than female ones, they are of 128-130cm in length and of 6-7 kg in weight. Females constitute 40-48% of the spawning population. The spawning population is comprised mainly of 10-14-year-old fish. The spawning temperature is 16-22° C.

In recent years, the number of spawning *A. stellatus* has decreased. In 1993, about 500,000 stellate sturgeon were expected to enter the Volga River, but only 273,000 did so, of which approximately 116,000 reached the spawning grounds. The number of downstream migrating fish has declined considerably mainly due to the rampant poaching.

The Volga River population of *Huso huso* consists of the winter and summer races. Rare beluga spawners enter the Volga River in the autumn, between August and October (Figure 1), and breed after the winter hibernation. Other spawners enter the river in the winter and spring, from December to May. The peak of migration is from February to March, and the peak of spawning is in May. Beluga spawning grounds in the Volga River are located below the Volgograd Dam. After spawning, fish migrate downstream to the Caspian Sea from June to September. The schedule of the beluga's spawning migration into the Ural River is the same as for the Volga. The Kura River beluga population is almost extinct.

Over the past ten years, the average length of beluga female spawners migrating into the Volga River has ranged between 236 and 261cm, and their weight between 106 and 160kg. Individuals longer than 400cm are extremely rare. Males are considerably smaller than females, with an average length of 199-204 cm and a weight of 48-55kg. Females comprise 20-24% of the spawning population. Beluga sturgeon spawn at a water temperature of 9-11°C. The spawning population consists of 17-21-year-old females and 11-18-year-old males. In recent years, only 8,000-9,000 beluga sturgeon have been entering the Volga River. The commercial catch of beluga has decreased to 100,000kg per year and the proportion of young fish in the catch has increased.

The entire area used by sturgeons for spawning can be divided into the upper, middle and lower zones along the Volga River. Stellate sturgeons spawn mainly in the lower zone. The downstream migration of the stellate sturgeon larvae starts in June and is the shortest compared with that of beluga and Russian sturgeon larvae. The migration of the stellate sturgeon larvae continues until mid-August, with a peak during the first twenty days of July.

The downstream migration of the beluga larvae takes place between the second half of May and beginning of June. For many years, beluga larvae originating from wild stocks were rare. The Russian sturgeon larvae usually leave their spawning sites between the second half of May and the end of June, with a peak of migration at the end of May-beginning of June.

Since the early 1990s, the spawning grounds below the Volgograd Dam have not been fully utilised (Raspopov *et al.*, 1993). The density of beluga and Russian sturgeon batches of eggs has decreased 40-50 times, and the number of larvae has decreased 10-20 times.

The function of the hatcheries and the migration of young sturgeons

The rearing of young sturgeons at the hatcheries built in the Volga River delta began in 1955. The numbers of beluga, Russian and stellate sturgeon juveniles released each year from the hatcheries grew until 1989. The Russian sturgeon was the main species reared, making up between 36% and 75% of all juveniles released in various years. Each breeding season started with the raising of beluga and Russian sturgeon juveniles, followed later by the stellate sturgeon juveniles. A complete biotechnical cycle lasts 45-65 days.

After 28-45 days in ponds, the beluga and Russian sturgeon juveniles attain an average weight of 2.5-3g, and the stellate sturgeon juveniles a weight of 1.8-2.5g. The beluga juveniles are usually released into the Volga River in the middle of June, followed by the sturgeon juveniles. Since 1963, some of the juveniles have been transported from their hatcheries to the western part of the north Caspian Sea aboard vessels equipped with special tanks and released into the brackish water zone over the feeding grounds.

All sturgeon hatcheries in the Volga River delta are located on its main and deepest branch (VVC, see above) or not far from it. Therefore, the hatchery-raised juveniles migrate downstream into the western part of the sea like their wild counterparts. The duration of this migration varies from year to year, but it was longer in the 1970s. Starting in the last week of June, it reached a peak in the third or fourth week of July and ended in late August or in September. In 1989-1990, no juveniles were seen in the mouth of the canal in late August. In 1991 and 1992, sturgeon juveniles could not be found even in mid-August. In 1995, the last Russian sturgeon juveniles were caught at the end of July, and stellate sturgeon juveniles, in mid-August. Half of the stellate sturgeon larvae migrate from the spawning sites not along the main branch of the Volga River Delta, but along its eastern branch, the Buzan River (Lagunova, 1976). Possibly, the change in the migration route of sturgeon juveniles occurred because of a decline in juvenile numbers.

During the summer, the largest concentration of that year's young sturgeons is in the north-western part of the Caspian Sea on the feeding grounds (Figure 2). The distribution, concentration and absolute number of these young fish on the feeding grounds during the summer and autumn vary from year to year. The distribution depends on the total number of naturally migrating juveniles and the number brought by vessels from the hatcheries.

The beluga juveniles of 6-11cm in length appear at the mouth of the canal and adjoining areas at a depth of 3-5m at the end of June. Due to the water current in the canal, the majority of them migrate quickly towards the western shelf in the middle part of the Caspian Sea. Hatchery-raised juveniles released from vessels also move quickly (up to 24km per day) to the south. At the beginning of August, one or two beluga fry per trawl can be caught in the Northern Caspian Sea. By the end of August, all juvenile beluga sturgeon are on their way to the central part of the sea, migrating along the western coastline.

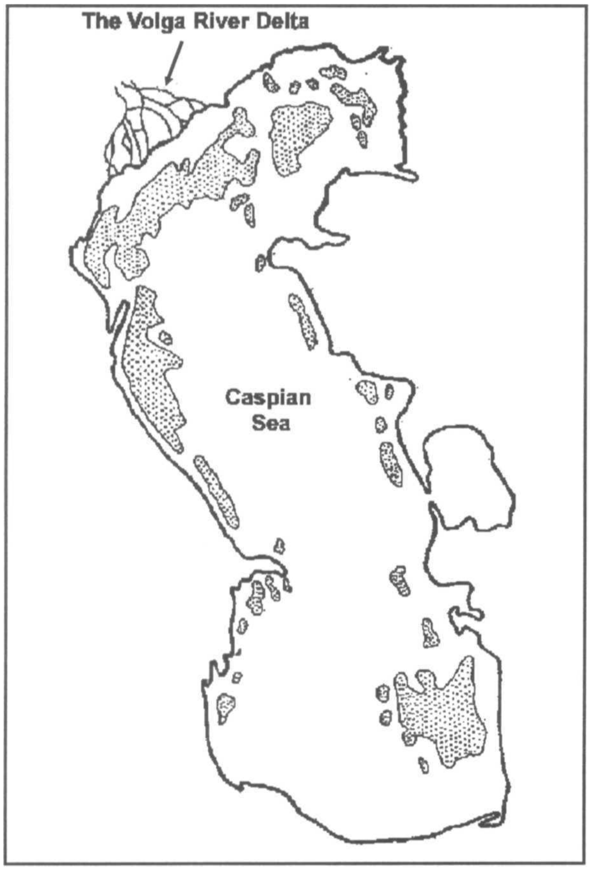

Figure 2. The summer distribution of sturgeons in the Caspian sea

The Russian sturgeon juveniles also migrate southwards. Some of them feed in the brackish waters ofthe northern Caspian Sea (with a salinity up to 4-6‰) until September and even until October. Due to large-scale restocking in certain years (e.g. 1990), the maximum catch of young sturgeon during August and September reached 29-40 per trawl at the Zhemchuzhnye Banks at a depth of 2-3.5m. The pond-raised juveniles released into the ecologically favourable shallow waters over the feeding grounds near the islands and banks remain there for 2-3 months. The sturgeon raised that year grow quickly on the feeding grounds and their survival rate increases two- or three-fold. During the past few years, hatchery-produced juveniles have not been released into the sea. The special vessels designed to transport them are no longer seaworthy and new ones have yet to be built.

Stellate sturgeon juveniles remain in the estuary for a short time to feed but then migrate to the central Caspian Sea. They never congregate in the shallow waters of the northern part of the Caspian Sea.

Seasonal migrations and the feeding grounds

The rapid migration ofjuveniles, particularly those of the Russian sturgeon, to wintering grounds located on the western shelf occurs in September and October when the water temperature drops to 22-23°C. In December, that year's young sturgeons and most of those from other age groups concentrate on the western shelf of the central and southern parts of the Caspian Sea. Juveniles from the Ural River and fish of various age groups from the north eastern part of the Caspian Sea also migrate in autumn to the central and southern parts of the sea, moving mainly along the eastern coastline.

During the winter, Russian sturgeon concentrate mostly on the western shelf of the Caspian Sea, from Chechen Island to the Azerbaijan coast. In some years, concentrations of the Russian and stellate sturgeons congregate in the south-western part of the sea near Ogurchinsky Island. When wintering, sturgeons remain at depths between 5 and 24m. At this time, the average water temperature at the bottom of the central part of the sea is 2-5°C and in the southern part of the sea it is 8-10°C. The salinity is around 12.0-13.3‰. During the 1970s and at the beginning of the 1980s, the maximum sturgeon catch at the wintering sites was 87-90 sturgeon per trawl, but in recent years it has decreased to an average of 0.5-0.7 fish per trawl. Stellate sturgeon winter mostly in the southern part of the Caspian Sea along its eastern coast, and only some fish winter along the western coast. In the spring and summer, the Russian and stellate sturgeons move vertically from the deep water up to the surface.

Beluga sturgeon do not congregate like Russian and stellate sturgeons and remain dispersed both in winter and in summer. Beluga sturgeon tend to swim in the middle depths: they prey on sprats, which are pelagic fish, whereas the Russian and stellate sturgeons are mainly benthophagous.

In the spring, the three species move to the shallow waters of the northern Caspian Sea. The mature fish enter the rivers, while the others spread widely throughout the northern part of the Caspian Sea. During the summer (Figure 1), ecological factors (the nature of benthic silt, water temperature and benthos distribution) largely determine their distribution. The young Russian and stellate sturgeons gather above sandbanks and around islands, where there is a high concentration of crustaceans. The adult Russian sturgeon feed at sites rich in the mollusc *Avra ovata.* Stellate sturgeon prefer polychaets and chironomids on the silt/sandy grounds. The maximum catch for Russian and stellate sturgeons (35-65 fish per trawl) occurs in June at depths of 2.5-3.5m near Zhemchuzhny Island.

In recent years, the sturgeon stocks have been redistributed throughout the Caspian Sea and sturgeons have been found in the eastern shallow part of the Northern Caspian Sea more frequently than before (Palgui, 1991). Possibly, the redistribution is a consequence of the ecological change in the area caused by the rising level (since 1978) of the Caspian Sea.

At present, we are investigating the migration of sturgeon juveniles from the Volga River into the Caspian Sea. This study will allow us to explain why the number of sturgeons is decreasing and, possibly, will help us to find measures to improve the survival rate of young sturgeons.

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Discussion

Blanke: What is the reason for the decline in natural reproduction? What is your interpretation?

Levin: There are several reasons for this. From the middle 1970s until 1987, the water level in the Caspian Sea was falling. Through the 1980s, natural reproduction declined and the number of released juveniles dropped sharply. According to our data, a large proportion of young fish can survive their first year only if they are released at the feeding grounds in the northern part of the Caspian Sea. Another factor is water pollution. A combination of these factors caused a sharp decline in sturgeon populations. Between 1985 and 1990, the status of sturgeon stocks improved. The water level was higher and the conditions for natural reproduction were better. Unfortunately, since then, the number of the released juveniles has substantially decreased.

Artyukhin: 1 would like to add that the official catch statistics do not include the illegal catch and the theft from commercial catches, which may account for up to 50% of the total catch. Therefore, the actual catch is approximately 2-3 times higher than that indicated by the official statistics.

Taylor: How long does it take before the juveniles can be released?

Levin: They need about 45 days.

Blanke: How do you explain the loss of and decline in the number of artificially raised juvenile sturgeons?

Levin: There are undoubtedly cases of cannibalism. However, the main cause is the decline in the number of spawners which can be caught for artificial breeding. Females in particular have become less common. Moreover, the fecundity of females has decreased because their average size decreased.

Artyukhin: This year only 83 beluga females were caught in the northern part of the Caspian Sea. For comparison, in the late 1980s, the average figure was 1,500 sexually mature females harvested each year.

Bauer: How many sturgeon hatcheries are still producing juveniles, and how efficiently do they operate?

Levin: There are eight hatcheries in the Volga River area and another six hatcheries on the Kura, Terek and Sulak and Iranian rivers. There are no hatcheries on the Ural River. There are two hatcheries in Azerbaijan, and another one in Dagestan. In Azerbaijan, the efficiency of the hatcheries has declined drastically. Dagestan has never produced many young fish. Hatcheries on the Volga River continue to operate more or less as before, but production has failed to increase. The main problem is a bad financial situation, which makes modernisation of the hatcheries impossible. Above all, a new vessel specially designed for the transportation of juveniles to the Caspian Sea must be built. This project started ten years ago. The construction work at the Astrakhan shipyard has stopped because of financial troubles. The current economic situation in Russia makes the improvements impossible. At present, a joint research project is being carried out by our Institute and Iran, which is also endeavouring to increase its sturgeon stocks. The aim of the project is to promote commercial fish farming, as well as to improve the sturgeon stocks.

Morphofunctional abnormalities in the organs and tissues of the Caspian Sea sturgeons caused by ecological changes

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keywords: sturgeon, *Acipenser gueldenstaedti, Acipenser stellatus, Huso huso,* spawning migration, caviar, histopathological abnormalities, fertility, lamination, water pollution, pollutants, Volga River, Ural River, Caspian Sea.

abstract: Until 1990, each year approximately 7.9 billion cubic metres of polluted waste water have been discharged into the water bodies of the Caspian Sea basin. Between 1981 and 1994, tissue and organ samples were taken from the three commercial species of sturgeons *(Acipenser stellatus, A. gueldenstaedti* and *Huso huso)* caught in the Volga and Ural rivers and in the Caspian Sea. A detailed histological study of samples demonstrated different types of histopathological abnormalities in the gonads, liver and muscles, presumably caused by the high level of toxic pollutants both in the sea and rivers. From 1985 to 1990, a specific pathology of muscles (lamination of muscle tissue or muscular dystrophy) was observed in sturgeons both in the Volga River and Caspian Sea. In the period 1989-1991, the environmental conditions in the basin started to improve because of socioeconomic changes in Russia (industrial activity virtually ceased). In 1991-1993, oil and pesticide pollution in the northern part of the Caspian Sea diminished considerably. It is likely that these changes will result in the improvement in the status of sturgeon populations in the Caspian Sea basin.

Kurzfassung: In der kaspischen Region der ehemaligen UDSSR finden sich über 220 größere Stadte und 250 industrielle Direkteinleiter. Von dort gelangen verschiedene Schadstoffe in das Wasser. Bis 1990 hat sich die Umweltsituation verschlechtert. Pro Jahr gelangten etwa 7,9 Milliarden Kubikmeter Abwasser in die Gewasser des kaspischen Bassins. Durch die sozio-okonomischen Anderungen in den GUS-Staaten verbessert sich momentan dort die Umweltsituation. Von 1981 bis 1994 wurden Gewebe- und Organproben der drei kommerziell wichtigen Störarten (*Acipenser stellatus, A. gueldenstaedti* und *Huso huso*) entnommen und auf Abnormitäten untersucht. Es wurden chronische Auswirkungen der Schadstoffe festgestellt. Zu den gefundenen Schädigungen gehörten: 1. Störungen bei der Gonado- und Gametogenese: Weibchen bildeten zum Beispiel mehrkernige Oocyten und die Fruchtbarkeit geht zurück. Diese Beobachtungen deckten sich mit der Zunahme von Schadstoffen wie DDT und Organochlorverbindungen in anderen Geweben. 2. Bei alien drei Störarten wurden 1985 erstmals Laminationen des Muskelgewebes entdeckt. 3. Die Leber der Störe wies Degenerationen wie zum Beispiel verstSrkter Fettgehalt und Pigmentstörungen auf. Durch die Abnahme der industriellen Produktion gehen die Schadigungen zurück. Die Reduktion der Fruchtbarkeit bleibt jedoch bestehen.

Introduction

It is estimated that more than 220 large towns and over 250 industrial enterprises have been discharging 7.9 billion cubic metres of polluted waste water into the Caspian Sea basin each year for the past 20 years. Toxic chemicals and mineral fertilizers have also been flushed from the fields into the rivers of the basin. As a result of the waste discharges in 1979 and 1986, water pollution in the northern part of the Caspian Sea increased three-fold. Since 1990, the environmental conditions in the basin have started to improve because of the socioeconomic changes in Russia (the majority of industrial enterprises stopped working after the break up of the Soviet Union in 1991) and perhaps also because of rising water levels in the Caspian Sea.

Progressively deteriorating ecological conditions had a profound impact on all three main commercial sturgeon species inhabiting the Caspian Sea basin (the Russian sturgeon, *Acipenser gueldenstaedti*, stellate sturgeon, *A. stellatus,* and beluga, *Huso huso*). This paper presents results of long-term research (1981-1994) on abnormalities found in various organs and tissues (gonads, muscles, liver) of sturgeons, which were presumably caused by water pollution.

Materials and methods

During 1981-1994, tissue samples from gonads of 6,113 sturgeons captured in the Volga and Ural rivers and in the northern, middle and southern parts of the Caspian Sea were collected and analysed using standard histological methods (Romeis, 1954;Merkulov, 1969). Also, samples of muscle and liver tissues from 395 Russian, 255 stellate, and 245 beluga sturgeons caught in the sea, as well as from 327 Russian, 256 stellate and 227 beluga sturgeons caught in the Volga River were studied. Stages of gonadal maturity were determined using Trusov's scale (Trusov, 1964). Histopathological changes in muscles and liver were described according to Logunov and Arunin (1964), Lesnikov and Tchikareva (1987), Altuf'ev (1989), and Romanov *et al.* (1990).

Results

I. Histopathological changes in gonads

First of all, 1%-3% of multinuclear oocytes appeared in sturgeon females as a response to the presence of toxic pollutants. In 1981-1983, amitotic divisions occurred in the oocytes of 16.8 % of all females of the three species.

Oocyte cytoplasm fragmentation was observed in females aged 6-8 years of all three species with gonads at stage II of maturity captured in the sea. Also, necrosis of oocytes was noticed. In 5 % of the Russian sturgeon females caught in the vicinity of the village of Kilazi (which is located at the boundary between the middle and southern parts of the Caspian Sea) the disturbances were found in 100% of oocytes. Possibly, these changes were also caused by a prolonged exposure of fish to toxic pollutants.

In 1987-1988, oocytes without cytoplasm or nuclei and deformed oocytes were observed. These abnormalities were characteristic in females captured in the sea with gonads at stage II of maturity and those migrating for spawning whose gonads were at stages III and IV of maturity. Thus, in April-May of 1988,5% of the Russian sturgeon females examined had 11% of the deformed oocytes, 13% of the stellate sturgeon females had 18 % of the deformed oocytes, and 1.5% of the beluga sturgeon females had 0.8% of the deformed oocytes. The changes in oocytes could be a result of genetic mutations induced by some mutagenic pollutants (Auerbach, 1969).[5]

In 1988, disturbances in the egg membranes have increased drastically in females with gonads at the final stages (III and IV) of maturity. There were about 50% of the deformed oocytes in 24% of the stellate sturgeon females and far fewer in the females of the two other species. Females caught in the river had an increased number of oocytes in a process of resorption; 22% of the examined Russian sturgeon females had this anomaly. During the same period (1988-1989), the total resorption of oocytes was observed in females in the sea. These disturbances might have caused failure of the females to spawn. In addition to the disturbances in gametogenesis, both females and males also

[5] See Hose *et al.* (1996), Kocan *et al.* (1996) and Norcross *et al.* (1996) on the mutagenic effect of oil and its compounds on teleost eggs, embryos and larvae, and Hose *et al.* (1987) on the mutagenic effect of chloro-organic pesticides on teleosts.

displayed disturbances in gonadogenesis. Some individuals caught in the northern and middle parts of the Caspian Sea had the ovary-testicle complexes consisting of the testicular tissue attached to ovaries with asynchronously developed cells.

Extensive proliferation of the connective tissue in gonads was found mostly in males. The replacement of generative tissue by connective tissue could have resulted in a partial sterilisation of males. Proliferation of the striated muscle tissue in ovaries was observed in females of all three species. Such neoplasms were well developed in 3.8%, 1.6% and *2%* of beluga, Russian and stellate sturgeons, respectively.

Tumors, cysts and other kinds of neoplasms on the surface of gonads occurred in 8-10% of the females and males examined. Before 1981, these abnormalities were observed in Russian sturgeon aged between 27 and 35 years. More recently, similar abnormalities have appeared in younger (6-10-year-old) fish and in first-time spawners (16-20 years old), mainly females. Apparently, the growth of neoplasms was caused by an exposure to a high concentration of pollutants.

II. Histopathological changes in muscle tissue

In 1985 sturgeons with a distinctive disease, which can best be described as lamination of the muscle tissue, were observed for the first time in the Volga River and Caspian Sea. This phenomenon was revealed on a mass scale in 1987-1989. In 1987, the histological analysis of the cross-striated muscles of the Russian sturgeon showed that so-called 'muscle tissue lamination' is a local muscular dystrophy characterised by replacement of muscle cells by the lipoid and connective tissues. The disruption of fibres, vacuole dystrophy of sarcoplasm and hyaline degeneration of fibres were the most frequent histopathological changes. More recently observed muscles have been losing their striation structure. The destruction of muscle fibres looks similar to the morphological abnormalities in human muscle tissue which have been described as myopathy by Bozhinov and Gilyabov (1977) or progressive muscular dystrophy-myopathy by Martynov (1988).

The beluga and Russian sturgeon females captured both in the river and in the sea were more affected by the disease than males. In the stellate sturgeon, on the contrary, the dystrophy was more pronounced in males than in females.

A detailed study of sturgeons captured in the Volga River and in different parts of the Caspian Sea showed the following (the data for the Russian sturgeon are given as an example):

1. In the Volga River sturgeon affected by disease were observed mainly in the spring (April, May), while in the sea they were affected mostly in the late summer (August).

2. Fish from different parts of the sea were affected by the disease to different degrees. The manifestation of the dystrophy was different in individuals caught along the western coast of the middle and southern parts of the Caspian Sea (near Chechen Island, near the village of Kilazi and the mouth of the Kura River) and captured in the south-eastern part of the northern Caspian Sea (near Ogurchinskiy Island).

3. In the Volga River, sturgeon of all age groups (from 16 to 25 years old) were affected by the disease to the same extent, while in the sea, muscular dystrophy was more pronounced in the old individuals.

Since 1988, all three species have shown signs of improvement in the structure of muscles and the percentage of normal fish has increased both in the river and the sea. For Russian sturgeons taken from the sea, this trend was as follows: 2.90% of fish with dystrophy in 1988, 2.30% in 1989, 2.30% in 1990, 2.07% in 1991, 2.15% in 1992, 2.21% in 1993 and 2.00% in 1994.

III. Histopathological changes in the liver

The liver of most individuals of all three sturgeon species examined in 1987-1994 had an increased content of lipids and lipofuscin. Lipid and albuminoid degeneration, pigment exchange disturbances, monocellular necrosis and fibrosis were the most frequent types of liver pathology. No specimen with the normal structure of liver tissue was found. The livers of those sturgeons which were considered 'normal' were in the stage of recovery from the disease: binuclear hepatocytes were observed, which is evidence of mitotic activity of cells. In the Volga River, the maximal level of histopathological changes in the liver of Russian and stellate sturgeons was noticed in July, and the minimal level was observed in June. In the Ural River, the maximal level of histopathological changes in the liver of beluga sturgeon was in February, and the minimal in May.

Discussion

We studied the consequences of the effect of unfavourable environmental conditions on the anadromous sturgeon species in the Caspian Sea basin. Sturgeons, which spawn many times during their life, have developed a highly plastic mechanism of maintaining their homeostasis (Gerbilskii, 1962). Spawning is considered to be a natural physiological stress (Polenov, 1975). Unfavorable environmental conditions cause changes in the physiological-biochemical characteristics of sturgeons (Altuf'ev *et al.,* 1987, 1989; Bal *et al.,* 1989; Geraskin, 1989; Shleifer *et al.,* 1989; Sukhoparova, 1989). If some important organs are affected at the beginning of the spawning migration, a considerable number of morphological disturbances in the tissues and organs will result (Altuf'ev *et al.,* 1989; Romanov and Altuf'ev, 1989; Romanov *et al.,* 1989). The results described in this paper and the data published recently (Altuf'ev *et al.,* 1989, 1992; Kornienko *et al.,* 1989; Romanov and Altuf'ev, 1989; Romanov *et al.,* 1989,1990; Evgen'eva, 1989; Altuf'ev, 1994) demonstrate that during the last decade profound disturbances in the gameto- and gonadogenesis and tissue structure of internal organs occurred in sturgeons inhabiting the Volga River-Caspian Sea basin.

The disturbances in sturgeon tissues were definitely caused by the presence of pollutants in the water bodies of the Caspian Sea basin. The presence of pesticides and herbicides in the water decreases ovarian activity and causes disturbances in the liver parenchyma of sturgeons (Davlet'yarova *et al.,* 1989; Semenova *et al.,* 1989). Increased levels of organochlorine and organophosphorous pesticides and heavy metals were observed in the organs and tissues of sturgeons with a typical manifestation of muscular dystrophy (Kirillov *et al.,* 1989). Finally, one of the main groups of pollutants in the Caspian Sea, oil and oil products, have a serious impact on sturgeons. Both crude oil and its emulsion causes a reduction in sturgeon growth rate, fecundity and reproduction, as well as histopathological changes in the liver and gonads (Altuf'ev, 1994). As a result of all these effects, the mortality of sturgeons in the Volga River in 1988 and 1989 was very high.

Histopathological changes in sturgeon tissues seem to have appeared in two stages. Between 1981 and 1994, sturgeons were exposed to different pollutants from the early stages of their ontogenesis in the rivers and, later, during their feeding in the sea. This contamination caused the disturbances in gonado- and gametogenesis and abnormalities in the liver and muscles.

At the second stage, because of a change in metabolism (which resulted from a switch to the endogenous feeding), some muscle proteins started to disappear from the tissue. Certain protein fractions composing muscle cells have disappeared from the muscle tissue of individuals with the maximal manifestation of muscular dystrophy (Bal *et al.,* 1989).

Possibly, in the riverine period of a sturgeon's life the effect of pollutants is even stronger than in the sea. Prolonged exposure of young sturgeons to the dissolved organochlorine pesticides combined with oil compounds have a maximum destructive effect on sturgeon tissues (Altuf'ev, 1994).

In 1991-1993, oil pollution in the northern part of the Caspian Sea diminished by a factor of three or four, while pesticide pollution (DDT and organochlorine compounds) decreased between 6 and 13 times compared with 1987-1988. This indicates an improvement in and stabilisation of the ecological conditions in the area which, hopefully, will eventually result in the improvement of the status of sturgeon populations.

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Discussion

Artyukhin: Allow me to add a few words to this presentation. Despite a certain improvement in the environmental conditions in recent years, the sturgeon gonad remains in unsatisfactory shape. At the beginning of this April and the end of May [1995] my colleagues working at two Volga River hatcheries found that 60% of beluga females have serious disturbances in gonads, whereas at the beginning of May, almost 90% of stellate sturgeon females have these disturbances. There were abnormalities in the membrane structure of many eggs in these females. Only 50% of embryos obtained from the eggs of these females survived. In other words to produce the same number of juveniles as before, twice the number of females are now required.

Birstein: The decline in the quality of roe and the presence of abnormalities in the egg membranes also mean a reduction in the quality of caviar.

Altuf'ev: Perhaps I have not made myself quite clear. The fact that now only six types of tissue abnormalities instead of twelve can be identified in sturgeons points to the improvement in the environmental conditions of the Caspian Sea basin. The unsatisfactory quality of eggs, of course, is very disturbing.

Taylor: In recent years, there have been changes in the colour of Russian sturgeon caviar. Could this be caused by the pigment disorders in the liver you mentioned?

Altufev: I do not think so. The liver excretes pigments into the blood and these pigments do not reach eggs. The color of caviar depends on the location at which sturgeon females have been caught, the time they had spent at certain feeding grounds and the food they had consumed there. Sturgeon females naturally exhibit different colouration of roe. The variations in the colour of the Russian sturgeon caviar depend mostly on the females' diet. Possibly, the abnormal colour of caviar is the result of resorption of eggs in the ovaries.

Artyukhin: During the degeneration of the oocyte membrane the pigment layer becomes thinner. As a result, the roe becomes lighter or has light patches.

Taylor: What causes the stickiness of caviar, which is increasingly becoming a problem in processing?

Altuf'ev: In addition to the problem of muscular dystrophy, we also have the problem of egg membrane destruction. The deterioration in the caviar quality (its stickiness) is a result of abnormalities in the egg membrane characteristics.

Bauer: Do these problems affect caviar sales? Also, can you give some more details about the large scale deaths of sturgeons?

Altufev: There is no problem with caviar sales. All caviar can be sold on the domestic market in Russia. Storage and transportation conditions do affect caviar quality. As for the high mortality of sturgeons migrating into the Volga River, this phenomenon was observed in 1988 and 1989. The percentage of normal individuals has increased in recent years. This creates an impression that the state of the whole population has improved. But remember that fish already dead could not be taken into account.

Birstein: How would you assess the improvement in the environmental conditions and the decline in the level of water pollution, which are a reflection of declining industrial production? What is your forecast for the future?

Altufev: The improvement in the environmental conditions can be ascribed to the decline in industrial production and in the use of mineral fertilizers. If industrial production resumes in the near future, environmental conditions will deteriorate again. Therefore, restocking efforts should be intensified. However, I know nothing about such efforts in the other states of the former USSR except Russia.

Burtzev: The main question is: Where do the fish accumulate the pollutants, in the sea or in the river? We do not have this problem with our females. We keep sturgeons in ponds supplied with water from the Don River. That is why I think that most of pollutants accumulate in the Caspian Sea.

Birstein: But as far as I am aware, oil pollution in the Caspian Sea has increased without a drastic effect on sturgeons. On the other hand, perhaps we have not been accurately monitoring the situation for long enough to notice this effect.

Altufev: We observed the maximal number of abnormalities in the structure of muscle and liver tissues of individuals caught in the central and southern parts of the Caspian Sea, where the chemical and oil pollution is maximal. The eastern coast is less affected. After fish have lived in the sea for 16 years and then migrate into a river, they are especially sensitive to the effects of pollutants in the river, and many die as a result.

Taylor: Iran catches sturgeons in the southernmost part of the Caspian Sea, but the quality of Iranian caviar is often superior to that of Russian caviar. Is this due to the lower level of pollution in the Iranian rivers?

Altufev: Currently, pollution is very high along the western coast of Dagestan and Azerbaijan. The rivers are cleaner in Iran because there is less industry there.

Birstein: As far as I am aware, the current level of caviar production in Iran is quite low and Iran cannot fulfil the contracts signed with Western countries. We cannot exclude the possibility that a portion of Iranian caviar originates from Russia.

Artyukhin: We should not forget that Iranian caviar is produced from sturgeons, the majority of which mature outside Iranian waters. They are mainly sturgeons from the waters of Azerbaijan and Russia. The sturgeon stocks in Iran and Azerbaijan have declined significantly. The natural reproduction of sturgeons in Iran is very low now, and cannot sustain the volume required for the extensive industrial harvest. The proportion of the Russian caviar sold by Iran will continue to rise in the near future. This primarily concerns the beluga. So, if you see white caviar from Iran, it is from the beluga females which have matured in the Ural or Volga rivers in Kazakhstan or Russia.

I would like to say a few more words about the colour of caviar. The beluga caviar eggs are pale and large. The Russian sturgeon caviar eggs are slightly darker and smaller. The stellate sturgeon caviar eggs are very dark and small. It is extremely unlikely that the very pale caviar originates from albino sturgeons, as the latter are extremely rare. The yellow caviar known as Tsar's caviar is very rare.

Sturgeon catch and the current status of sturgeon stocks in the Amur River

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keywords: kaluga, Amur River sturgeon, *Huso dauricus, Acipenser schrencki, Acipenser* spp., legal and illegal overfishing, caviar, Amur River, Okhotsk Sea, Sea of Japan.

abstract: Both the kaluga *(Huso dauricus)* and the Amur River sturgeon *(Acipenser schrencki)* are commercially important. They are endemics of the Amur River, which is over 4,000 km long. At the end of the 19th century, the commercial fishery in the Amur River region reached its maximal level, when the annual catch of kaluga was 595 tonnes. There are several kaluga and Amur River sturgeon populations in the Amur River basin. Strict regulation of the catch was introduced in the Soviet Union in 1976 in order to prevent overfishing of the sexually mature sturgeons in the river. In 1981, 1,000 tonnes of sturgeon were caught in the Russian part of the river. Since then, the annual legal Russian catch has dropped to 40-50 tonnes per annum, while the illegal catch has increased. In the Chinese part of the Amur River, sturgeons are caught both legally and illegally. At present, the proportion of sexually mature individuals within kaluga and Amur River sturgeon populations is very low (around 2-3 %), and the fish are maturing now at a younger age. In the Zeya and Bureya rivers, the kaluga and Amur River sturgeon populations are on the verge of extinction.

Kurzfassung: Im über 4000km langen Fluß Amur kommen die wirtschaftlich wichtigen Störarten Kaluga *(Huso dauricus)* und der Amur-Stör *(Acipenser schrencki)* vor. Die kommerzielle Fischerei erreichte Ende des vergangenen Jahrhunderts Rekordwerte. Damals wurden bis zu 959t Kaluga pro Jahr gefangen. Der Kaluga kommt in verschiedenen Populationen im Amur vor, deren Nahrungsgründe im Delta, im küstennahen Brackwasser aber auch im Ochotskischen Meer und vor der japanischen Kuste liegen. Sowohl Rußland als auch China betreiben im Amur Fischerei. Der Einfluß und die Tendenzen der Fischerei beider Lander werden kurz beschrieben. Um die Überfischung von laichreifen Tieren zu verhindern, wurden 1976 in der UDSSR strenge Regelungen getroffen, die, würde auschließlich eine kontrollierte kommerzielle Fischerei stattfinden, zu einer Erholung der Bestände beitragen wurden. Im Jahre 1981 wurden l000t Stör gefangen, mittlerweile sind es 40-50t pro Jahr an legalen Fängen. Durch die spate Geschlechtsreife und die geringe Reproduktionsrate ist die Vermehrung der Störe jedoch geringer als bei anderen Fischen des Amur. Einige Populationen des Kaluga und der Amur-Stör sind daher durch die Uberfischung besonders gefahrdet und stark im Rückgang begriffen. Auch in China gibt es kontrollierte und unkontrollierte Störfänge im Amur. Unter dem Einfluß der Fischerei ändert sich die Anteil der laichreifen Störe, der etwa 2-3 % beträgt, das Alter der Laichfische wird immer geringer.

Introduction

The Amur River is formed by the confluence of the Argun and Shilka rivers. It enters into the Amur River estuary of the Tatar Strait (Figure 1). The Amur River estuary is 48km long and 16km wide. The Amur River is 4,092km long if its longest tributary, the Shilka River, is included. The total size of its basin is 1,856,000km . For much of its length, it forms the border between Russia and China.

According to the structure of its valley, bed and flow characteristics, the Amur River can be divided into three parts. The upper reach extends down to the city of

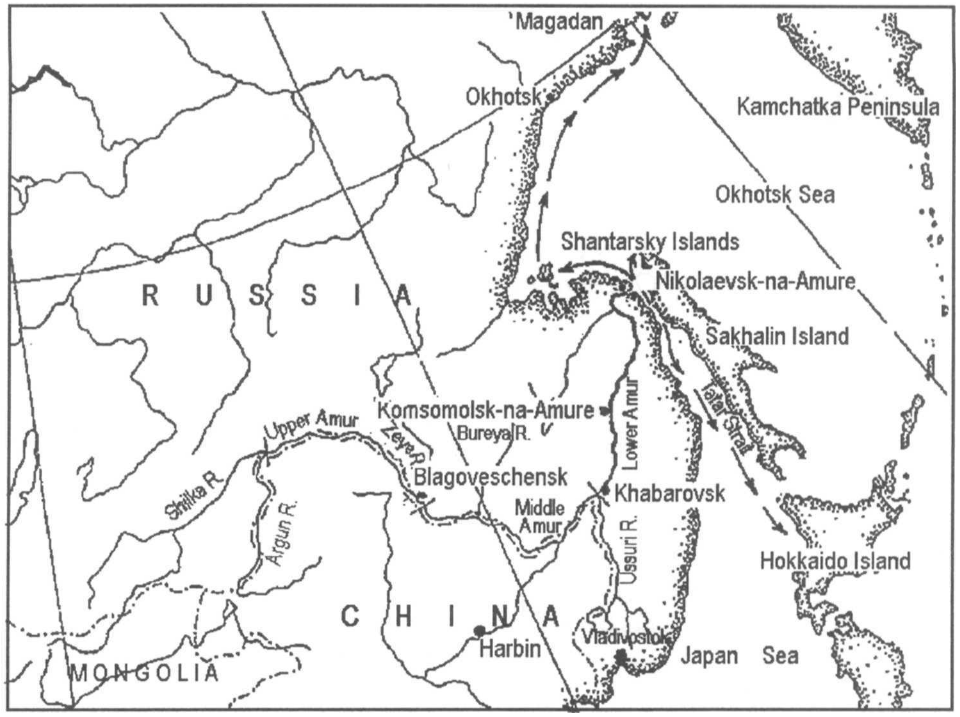

Figure 1. The Amur River and the migratory paths of kaluga

Blagoveshchensk (upper Amur, 883km); the middle section continues down to the mouth of the Ussuri River (middle Amur, 975km); and the lower reach continues down to the estuary (lower Amur, 966km). During the Quaternary, there were times when the Amur River bed was either elongated 1.5-2.0 times, or sea water penetrated deeply into the continent reaching the present middle Amur (Svirsky, 1968).

There are two endemic sturgeon species in the Amur River; the kaluga, *Huso dauricus*, and the Amur River sturgeon, *Acipenser schrenckii* (Berg, 1948; Nikolskii, 1956; Svirskii, 1971; see Figure 2). Their biological characteristics are given in detail in Krykhtin and Svirskii (1997) and Wei *et al.* (1997). In this presentation we will discuss only some general characteristics of these species and the current status of their stocks.

Kaluga sturgeon *Huso dauricus*

The kaluga is one of the largest freshwater fish reaching more than 5.6m in length, more than 1 tonne in weight and an age of more than 80 years. It inhabits the Amur River basin from its estuary to the upper reaches,

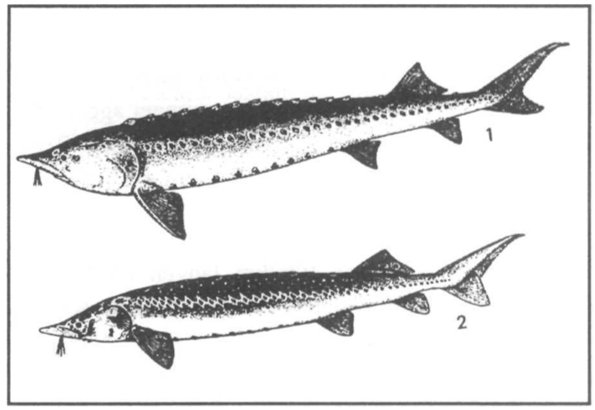

Figure 2. The kaluga, *Huso dauricus* (1) and Amur River sturgeon, *Acipenser schrenckii* (2)

including several of its large tributaries and lakes (Nikolskii, 1956). Young kaluga have been caught during summer in the coastal waters of the Sea of Okhotsk (Kostarev and Tyurnin, 1970), near the north-eastern part of Sakhalin Island (Gritsenko and Kostyunin, 1979), in the northern part ofthe Tatar Strait (Krykhtin, 1984), and in the Sea of Japan near the islands of Hokkaido (Amaoka and Nakaya, 1975) and Honshu (Honma and Itano, 1994). During recent decades, the number of young fish has increased considerably in coastal waters of the northern part of the Tatar Strait and in the south-western part ofthe Gulf of Sakhalin.

There are four kaluga populations in the Amur River basin. The first lives in the coastal brackish waters of the Sea of Okhotsk and Sea of Japan, the second inhabits the lower Amur, the third in the middle Amur, and the fourth in the lower reaches of the Zeya and Bureya rivers. Two ecological morphs exist in the estuary population, known as the freshwater and saltwater forms (Lukyanenko *et al.*, 1979; Krykhtin, 1985).

The kaluga populations have decreased considerably since the turn of the century. At the end of the 19th century, when the highest catches were recorded (more than 595 tonnes per year), the middle Amur population was the largest. At that time, fish from the middle Amur population constituted 87% of the annual kaluga catch in the Amur River basin, fish from the estuary population constituted 2% of the catch, and fish from the Zeya and Bureya population constituted the remaining 11 %.

At present, the estuary population is the most abundant. Due to restrictions on the harvest introduced in 1976, the total number of kaluga in this population has increased by 35% since the early 1970s, and the number of fish of more than 100kg in weight has increased by 2.5 times (Krykhtin, 1979). At the end of the 1980s, the estuary population consisted of about 70,000 fish that were more than one year old. Of these, approximately 5,000 fish weighed more than 100kg and were potentially sexually mature. However, by 1993 because of the illegal fishery in the lower Amur during the spawning migration, the number of mature fish in the estuary population was reduced by 30-35%. The current population consists predominantly of young fish, with only 2-3% of mature adults.

The number of individuals older than two years in the lower Amur population is approximately 40,000, and in the middle Amur population, 30,000. The decline in kaluga populations, which started at the end of the 1960s, continues. The middle Amur population is especially vulnerable. The size of the Zeya and Bureya population, if estimated on the basis of the very low catch in the Amur River within the Amur district (0.09-1.03 tonnes), is extremely small and is on the verge of disappearing.

The efficiency of natural reproduction in the kaluga is very low, as can be seen from the slow recovery rate of the estuary population: from the 1970s until the beginning of the 1990s, its size increased by only 35%, or less than 2% per year.

Amur River sturgeon *Acipenser schrenckii*

Similar to kaluga, the Amur River sturgeon, *Acipenser schrenckii,* is represented by populations in the delta and in the lower, middle and upper Amur. The delta sturgeon population is currently quite small and consists of approximately 3,000 fish more than two years old. Historically, it was also small at the turn of the century, when the largest catches were recorded. In 1891, when the catch of the Amur River sturgeon in the Amur basin reached 607 tonnes, only 3% of the total annual catch was from the lower reaches and the estuary (Kryukov, 1894), with the greatest number (89%) of the fish being caught in the middle Amur. Differences in the catch were mainly due to regional differences in the abundance of sturgeons. At present, the lower Amur population consists of about 95,000 fish older than two years, and the Zeya and Bureya population is on the verge of extinction.

The current situation and the harvest

The decline in kaluga and Amur River sturgeon populations, especially in the middle Amur, started at the end of the 1960s and still continues.The legal catch in the Russian waters of the Amur River is only 100 tonnes of kaluga and Amur River sturgeon per year. However, since the fall of the Soviet Union in 1991, the illegal catch of sturgeons in the Amur River has increased enormously. The trend in the level of poaching during the last decade is given in Table 1.

In 1995, in the lower reaches of the Amur River (Russian territory), individual poachers were replaced by organised criminal groups which have excellent equipment (boats, motors and nets) for the sturgeon catch.

During the same period, the legal and illegal catch of sturgeons in the Chinese waters of the Amur River also intensified (Table 1). In 1985 the legal sturgeon catch was 175 tonnes of sturgeons; in 1987 it was set at 200 tonnes; in 1989-1993 at 400 tonnes; and in 1994-1995 at about 170 tonnes. At present, the Chinese part of the Amur River is strewn with nets which Chinese fishermen check many times during the day. The intensity of the sturgeon catch in the Chinese waters is six times higher than in the Russian waters.

Both legal commercial fishing and poaching cause profound changes in the population structures of kalugas and Amur River sturgeons. The number of potentially sexually mature fish has decreased to 2-3%, and the spawners have become younger. All these alarming facts show that the populations of both species are in a bad shape and that control of the harvest is needed urgently.

Country and catch	Years and trend
Russia, illegal	1985=1986=...1989<1990<1991<<1992<1993<<1994<<<1995
China, legal	1985<1986<1987<1988<1989=1990=1991>1992>1993>1994=1995
China, illegal	1985=1986=1988<1989<1990«1991<1992>1993>1994>1995

Table 1. Trends in the illegal and legal catch of sturgeons in the Amur River in 1985-1995

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Discussion

Blanke: Do you cooperate with the Chinese?

Svirsky: Over the past two or three years, our relations with China have improved. Now we have contacts for a future exchange of experts, and the preconditions for cooperation exist.

Birstein: Please tell us about the efforts made by the Chinese.

Svirsky: As far as I am aware, the Chinese specialists have been involved in sturgeon farming since 1957. Artificial breeding was practised at small hatcheries. According to my information, one of the hatcheries produces 100,000 sturgeon juveniles each year.

Bauer: The Amur River is a very large river, approximately four times the length of the Rhine. Which parts of it were studied in order to obtain population data?

Svirsky: We have two research stations on the river. Until 1993, experimental fishing was practised in the lower Amur, for which we have reasonably good data. We do not have data for the upper and middle reaches, where sturgeons are less abundant.

In the future we hope to use mathematical modelling for the estimation of sturgeon populations. My colleague and I have already worked with mathematical models of other fishes of the Amur River. In this way we can analyse the current situation and calculate the number of juveniles needed for the support of natural populations.

Bester in aquaculture

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keywords: sturgeon, *Huso huso*, *Acipenser ruthenus*, *Acipenser* spp., bester, aquaculture, hybridization, caviar production, ranching, conservation, illegal fishery, Don River, Sea of Azov.

abstract: Aquaculture of sturgeons dates back to the 19th century, when the first artificial breeding took place. Today, the aquaculture of sturgeons offers commercial opportunities as well as the means of conserving endangered sturgeon species. In 1952, Nikolyukin and Timofeeva obtained the first hybrids between the beluga sturgeon (*Huso huso*) and the sterlet (*Acipenser ruthenus*). These hybrids were named 'bester'. Bester are now bred in aquaculture programmes. Backcross hybridisation with the parental species is also practised. Sturgeon aquaculture offers an opportunity for producing fish with the required properties, such as rapid growth and early maturation. Moreover, it is possible to ease the pressure on the wild stocks by producing juveniles, caviar and sturgeon meat at aquaculture farms.

Kurzfassung: Die Aquakultur von Stören reicht bis ins letzte Jahrhundert als man erste künstliche Befruchtungen herbeiführte, zurück. Heute bietet die Aquakultur von Stören sowohl wirtschaftliche Möglichkeiten als auch Möglichkeiten zur Arterhaltung der Störe. Im Jahre 1952 wurde erstmals von Nikolukin und Timoveeva aus dem Hausen (*Huso huso*) und dem Sterlet (*Acipenser ruthenus*) der Hybride Bester erzeugt. Mittlerweile werden Bester in vollcyclischer Aquakultur gehalten. Die Weiterzucht und Rückkreuzung mit den Elter-Arten wird praktiziert. Die Aquakultur von Stören bietet die Moglichkeit, Fische mit den gewünschten Eigenschaften wie rasches Wachstum, fruhe Fruchtbarkeit und gute Futterverwertbarkeit zu produzieren. Daruberhinaus kann durch die Produktion von Jungfischen, Kaviar und Störfleisch der Druck von Wildbestanden genommen werden.

The history of the captive breeding of sturgeons extends over more than a century. In 1869, the Russian Academician F. V. Ovsyannikov successfully fertilized sterlet eggs (*Acipenser ruthenus*) using the milt of the Russian sturgeon (*A. gueldenstaedti*) and stellate sturgeon (*A. stellatus*) (Ovsyannikov, 1872, 1873). He predicted a great future for sturgeon hybrids in the fish industry. The year 1870 is considered in Russia to mark the official start of sturgeon propagation. In fact, V. P. Vrassky, the founder of the first hatchery in Russia, had offered to breed sterlet artificially and raise them in ponds even earlier.

In the Soviet Union, the enhancement of anadromous sturgeon species was studied intensively in the 1930s through to the 1950s in connection with the construction of dams on the main Russian rivers. In the late 1940s, sturgeon-raising experiments were undertaken in tanks and ponds in a bid to acclimatise them to conditions in captivity (Stroganov, 1968).

Experimental sturgeon hybridisation was initiated by Professor N. I. Nikolyukin in 1949 (Nikolyukin, 1973). Many species were used for the crosses: Russian sturgeon, sterlet, beluga (*Huso huso*) and stellate sturgeons. The results were unpredictable because of the distant relationships between the species (Nikolyukin and Timofeeva, 1953). The crosses between a very large, carnivorous beluga and a small, benthophagous sterlet appeared to be extremely successful. The hybrids were not only viable but also fertile. This hybrid was named 'beste' (Nikolyukin and Timofeeva, 1953). At first, bester and other sturgeon hybrids were raised in ponds at the Teplovsk Hatchery near the city of Saratov (on the Volga River), but since

1963, the farming has been continued at the Aksai Fish Farm located on the Don River near the city of Rostov-on-Don (southern Russia).

Bester inherited a high growth potential from beluga, but this potential could only be realised if the fish raised in ponds on natural food resources were provided with supplementary artificial food. Feeding the bester on natural food alone delayed maturation of the juveniles. Bester's growth potential became evident when fingerlings were released into the brackish water of the Proletarskoe Reservoir near the city of Rostov-on-Don and Taganrog Bay in the Sea of Azov. By the end of the first summer, the bester juveniles gained 400-500g, by the end of the second summer they weighed 1.5-2.0kg, and by the end of the fifth summer their weight was up to 13kg (Nikolyukin, 1973). The hybrids were caught by fishermen in these waters. Later, because of the danger of crosses with the wild species, especially beluga, the release of bester into natural water bodies was prohibited. Mature bester have been kept in captivity since hatching (Burtzev, 1967).

The goal of further studies was to elaborate intensive methods of bester aquaculture. Numerous Russian fishery research institutes participated in developing sturgeon aquaculture technology. For many years the bester was the main species raised at sturgeon farms. Total production of bester quickly reached 150-200 tonnes per year and at that time it was the highest yield of fish in aquaculture. Later other countries used the Russian experience and developed sturgeon farming. In Russia in the late 1950s, part of the facilities were dedicated to restocking sturgeons into the Caspian and Azov seas.

Our group of researchers at the Russian Federal Research Institute of Fisheries and Oceanography (VNIRO) has performed genetic research on bester and other sturgeon hybrids, as well as investigating their potential for reproduction and selection. The karyotypes of beluga, sterlet and other sturgeon species were studied. The karyotypic similarity of beluga and sterlet may explain the reproductive ability of the bester (Serebryakova, 1960,1970; Arefjev, 1988). We noticed some genetic imbalance in the second generation of hybrids (F2) (Burtsev and Serebryakova, 1980). These data were kept in mind during our selection of offspring from the best spawners obtained for the broodstock. The spawners were selected on cytological criteria and the viability of offspring. Perhaps, due to our selection, the karyotypic characteristics stabilised in the third generation of hybrids (Arefjev, 1989). Reproduction of bester has also been studied for many years at the Institute of Ecology of Fresh Water and Fish Fanning in the former German Democratic Republic which received first generation (F_1) bester fingerlings in 1972-1974 and produced the third generation 1991 (Steffens and Jahnichen, 1982, 1995).

In 1958, N. I. Nikolyukin and T. V. Shpilevskaya obtained backcross hybrids between bester males and the parental species (Nikolyukin and Shpililevskaya, 1959). We repeated these experiments in 1965 (Burtsev, 1969) and in 1969-1973. Both backcross hybrids were raised in ponds until maturation and then they were crossed again (Burtsev *et al.*, 1987). Also, triple hybrids between bester, stellate, ship sturgeon (*A. nudiventris*) or Russian sturgeon were produced (Nikolyukin, 1973). At present, the following forms of bester and its hybrids exist in our collection of live fishes:

1) the main hybrid (usually called BS or SB) with the genomes inherited from both parental species (B+S, Figure 1);

2) the backcross hybrid bester x beluga (usually called B.BS; Figure 2);

3) the backcross hybrid bester x sterlet (usually called S.BS).

The main hybrid can be simply called the 'bester'. The first backcross hybrid, B.BS (e.g., beluga x bester) can be called the 'big bester' and the second one, S.BS (e.g. bester x beluga), can be called the 'small bester'. These names correspond to the most characteristic morphological feature of the hybrids, i.e. their size. Some of the biological characteristics of the hybrids are given in Table 1. Krylova (1980a, b) studied the inheritance of the main morphometric and biological characteristics such as the final size, age of maturation, fecundity, growth rate, etc., in hybrids of the first and second generations.

Figure 1. A bester F_2 (a hybrid of the second generation) aged 10 years with a weight of 10-15kg.

Figure 2. A backcross hybrid B.BS (a hybrid between bester and beluga) aged 30 years with a weight of 60kg.

Character	Bester (main hybrid)	Backcross hybrid with beluga (B.BS)	Backcross hybrid with sterlet (S.BS)
1. Genetic structure (numbers of beluga (B) and sterlet (S) genomes)	1B + 1S	1.5B + 0.5S	0.5B + 1.5B
2. Age of maturation (years):			
males	3-5	6-10	3-4
females	8-11	12-18	5-8
3. Weight of spawners at the first spawning (kg):			
males	2-5	10-15	1-2
females	6-10	20-40	2-4
4. Fecundity (thousands of eggs per female)	100-250	200-400	30-50

Table 1. Some biological characteristics of various forms of bester

The meat of sterlet is the most delicious of that of all sturgeons. Bester and its hybrids inherited this characteristic, especially the hybrid S.BS (the small bester). The protein and fat content in sturgeon muscles gradually increases in the following sequence of species and hybrids:

beluga Ò**B.BS** Ò**BS**Ò**S.BS**Òsterlet raised in ponds (Nikolaev, 1984). Apparently, the taste of sturgeon and hybrid meat depends on the protein and fat content in their muscles.

A different growth potential, morphological characters as the shape and size of the mouth, and behavioural patterns are conditional for the ecological specificity of different bester hybrids. These forms differ in their ability to live in ecologically different water bodies: reservoirs with highly productive brackish water and abundant food organisms are suitable for the beluga, bester and big bester, whereas the relatively nutrient poor freshwater lakes and rivers are suitable for the sterlet and small bester. Bester and its backcross hybrids with beluga can adapt to the brackish water with a salinity of 16-18‰ at the age of 1.5-2.0 months. Bester backcross hybrids with sterlet and sterlet itself can be maintained in freshwater only (Burtsev *et al*., 1989).

Historically, bester was the first sturgeon introduced into aquaculture and was used for raising (ranching) under different conditions in natural reservoirs, in ponds of different size, in net cages in fresh (including warm-water farms) and brackish water bodies, in tanks, and, finally, in modern facilities. The main use of the bester, undoubtedly, is its full-cycle cultivation at farms using intensive aquaculture methods which guarantee a reasonable profit.

Bester propagation was a good example for the introduction of many other sturgeon species into aquaculture. Ranching sturgeons in reservoirs separated from waters inhabited by wild sturgeon species can also be a good method for commercial purposes. It is necessary to create hatcheries producing stocking material and adopt special fishing regulations prohibiting the catch of juveniles throughout the ranching area.

Aquaculture is the only conservation method for saving the endangered sturgeon species. This is particularly so for the common European sturgeon (*A. sturio*), Sakhalin sturgeon (*A. mikadoi*) and Italian sturgeon (*A. naccarii*). The ship and beluga sturgeons have recently become endangered because of uncontrolled fishing and water pollution in the Caspian Sea and the Sea of Azov.

The large decline in sturgeon populations in these seas has affected the production of black caviar. Our long-term experience in maintaining bester brood-stocks and in production of fertilized eggs for fish farming may help to improve this situation because we have shown that it is possible to produce black caviar at aquafarms. First, we developed a surgical method allowing us to obtain over ten times the number of eggs from the same sturgeon female (Figure 3). So far, during the lifespan of a female, we can obtain roe weighing two or three times her own body weight (the amount of eggs produced by every female weighs from 15 to 25% of her total body weight). Second, shortening the maturation period and the duration of recurring maturation cycles allows for highly efficient caviar production (due to the exclusion of long upstream and downstream migrations of spawners and corresponding energy expenditure). The most effective caviar production can be achieved at fish farms with modern technological units which provide optimal year-round conditions for the growth and maturation of sturgeons; by excluding an unproductive winter period.

Taking into consideration the above-mentioned possibilities and observed tendencies of rapid development of sturgeon aquaculture in many industrial countries, we predict that in the very near future sturgeon meat and caviar production will increase not only in Russia, but in many countries which invest substantial sums in this industry.

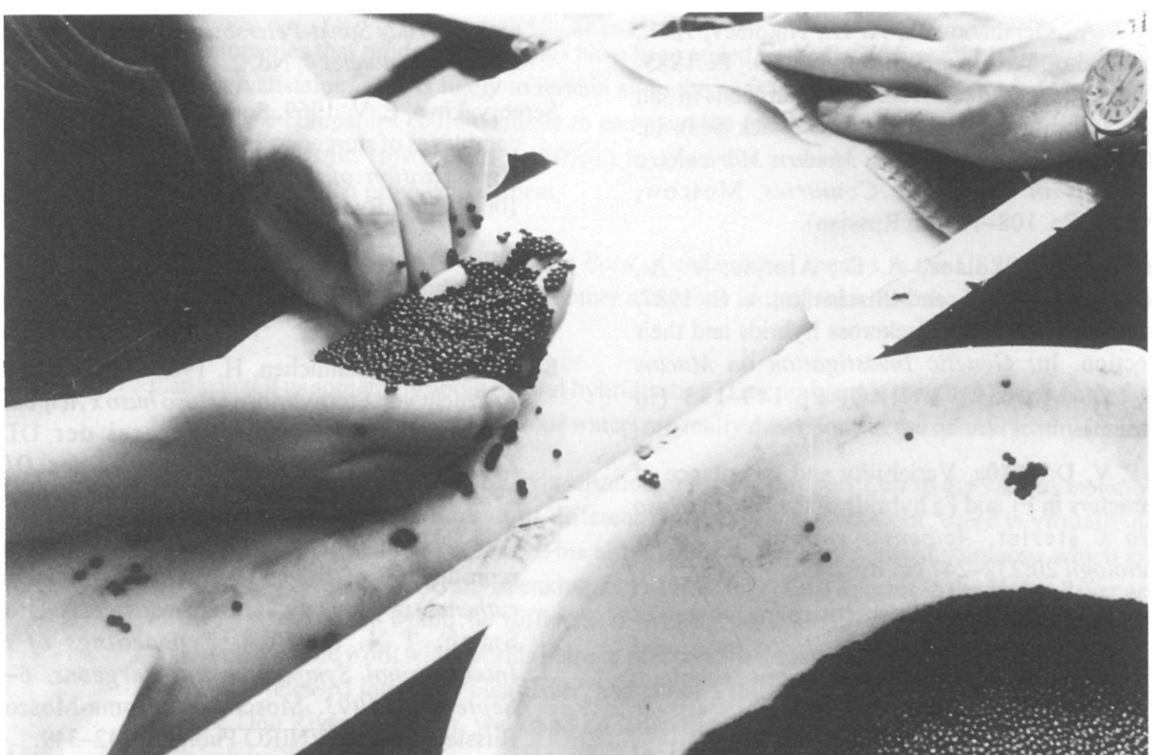

Figure 3: The release of ovulated eggs by special surgery.

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Discussion

Bauer: How are the procedures you described implemented? Which is more commonly produced, fmgerlings or caviar? There are still problems concerning the quality and processing of caviar produced at fish farms. To what extent is the caviar produced from aquacultured sturgeons marketable?

Burtsev: We produce primarily young fish. But we do obtain a large quantity of juveniles and caviar. Both are sold. In recent years, we have developed a special salting technique for our caviar. Our caviar needs to be processed differently to common caviar, due to fermentation activity and we have patented this method. However, the quality of our caviar still needs to be improved and we are working on this problem. The French, Italian and American aquaculturists are also working in this direction. So, we have a future in this area.

Birstein: This is a particularly important direction of research. In 1994, at the sturgeon conference in New York, we tried caviar from the aquafarmed white sturgeon. This caviar is already being produced in small quantities in California.

Burtsev: There are also some German firms which plan to produce bester and are cooperating with the VNIRO. I believe that Germany has an opportunity to restore the common sturgeon.

Bauer: We have some farms rearing and producing different species of sturgeons but not the common sturgeon. Are the aquafarms in Russia government-owned, or have some of them already been privatised?

Burtsev: All companies that produce fmgerlings have been added to the list of firms which are excluded from privatisation. This is likely to remain so in the near future. Privatisation would be useful because the companies could continue to carry out the orders from the government, and could also make a profit. However, it is difficult to solve this problem now. There are some stock corporations which produce fish meat.

Artyukhin: In Russia, we have the *USSR Red Data Book* of endangered species in the USSR, but not that for the CIS states yet. The beluga and other sturgeons in the Black Sea should be protected in particular.

Blanke: Can you tell us something about natural hybridisation? Our problem is that the hybrids and other species of sturgeons which occur in our waters are really distortions of the natural ichthyofauna.

Burtsev: I discussed the problem of natural hybridisation in my dissertation. Due to the various isolation mechanisms, probably as a result of different morphology or behaviour, there is virtually no hybridisation between wild species. This also applies to the aquacultured sturgeons which are released into the wild. Generally speaking, only 1% or less of the hybrids in the Volga River are fertile. The situation would be different if hybrids were released en masse, which I find unacceptable. The work with hybrids helps to preserve the other species. Several thousand bester have been released into the Volga River, and about 1 million of their juveniles were released into the Don River. However, we found no indication of the backcross hybridization of bester with beluga.

Svirsky: I would like also to comment on this point. According to our experiments on hybridisation of the Amur River sturgeon with kaluga, only 40-50% of hybrids hatch after the incubation period if the female is a sturgeon. Consequently, it is better to use a kaluga female and a sturgeon male for artificial hybridisation. Hybridisation also occurs in the wild. However, like Dr Burtsev I believe that hybrids should be kept in closed systems and under no circumstances should they be released into the wild. Stocking may be useful for certain hybrids and regions, but this is not the direction we wish to take. I started to work on the industrial production of sturgeons in the 1960s. In our studies, we found out that the proportion of natural hybrids was 0.5-1%, and this figure rose to 2% in the following years. Increased fishing favours natural hybridisation, but the number of hybrids in the wild remains rather low. I believe there are hybrids wherever there are several species of sturgeons. However, to release hybrids into the wild would be a time bomb.

Levin: I have no doubts that it is expedient to produce caviar and sturgeon meat artificially. However, substantial investments are needed, for example, for the technical equipment and food. The most economical production site is nature itself. We should observe what happens in the wild. It is difficult to replace the productive power of the vast seas and rivers by building ponds.

Birstein: In our discussion, we do not wish to imply that natural and artificial reproduction are mutually exclusive.

Burtsev: At the beginning, Dr Birstein argued that we aim to ease the pressure on wild stocks by means of industrial production. The numbers taken from the wild stocks would then be lower. This does not contradict the other essential endeavours. Of course, investments are needed which the Russian government cannot provide alone. But there is also the opportunity for non-government investments. I know of five industrial facilities with closed-cycle systems which are stock corporations and which operate successfully. I believe that private investment and governmental subsidies in this area can contribute towards protection of sturgeons.

Birstein: The French, the Italians and the Americans all use Russian technology and employ Russian experts for their aquaculture efforts. This is the result of many years of work by Russian colleagues, some of whom are represented here today. Currently, there is no French caviar without Russian experts. At present, we are experiencing a crisis with sturgeon species. It is quite obvious that if the situation continues, we shall have no caviar left in ten years. We must take action, such as the advancement of aquaculture to obtain sturgeon meat and caviar. We need a precise understanding of artificial breeding for the restocking of juveniles into the wild. This knowledge can be obtained from the developments achieved in aquaculture. I see no contradictions between the aquaculture methods and other efforts to save sturgeons. In the future, we should bear in mind various aspects of sturgeon survival: the caviar trade, government obligations and challenges, and the requirements of international conservation organisations. I believe that we can solve various sturgeon problems as colleagues working in different fields, but not rivals.

Burtsev: I would like to comment on Dr Blanke's question about the problem of natural hybridisation. Hybrids have no advantages over the natural species in terms of natural selection. If we consider the situation of the common sturgeon in Europe, there is a risk of foreign species or hybrids reaching the same spawning grounds. However, this is very unlikely.

Birstein: I see no risk in hybridisation. However, it is necessary to discuss the pros and cons. I believe that hybridisation is not the main threat to the survival of sturgeon species. Currently, the principal threat to sturgeons is the illegal and uncontrolled overfishing of sturgeons in the rivers and seas.

Levin: If the environmental situation in the Caspian Sea area continues to deteriorate, we will be confronted with the necessity of organising conservation areas for sturgeons. We will then have to think seriously about how the artificial and natural reproduction can be harmonised with one another.

Burtsev: We must use our power to ensure that a high rate of natural reproduction of sturgeons is preserved. Sturgeons are now being farmed in South America and are becoming more widespread.

The historical development of the caviar trade and the caviar industry

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keywords: sturgeon, *Acipenser* spp., *Huso huso*, *Polyodon spathula*, caviar, crime, illegal production, caviar quality, overexploitation, poaching, SHILAT, Caspian Sea, Germany, China, USA.

abstract: At the turn of the century, about 100 tonnes of caviar were exported each year from Russia. At present, the caviar trade is changing as a result of the political and economic upheavals in the former USSR. In recent years, the unblemished reputation of Russian caviar has suffered some damage. As a result of so-called barter transactions, smuggling and falsifying the declarations on low-grade caviar, the caviar trade has become criminalised. In 1993, approximately 100 tonnes of caviar were smuggled out of Russia. As a result of the price drop, global market demand has risen from 300 tonnes to between 450 and 500 tonnes per annum. Regrettably, the standards of quality and processing of caviar often fail to satisfy market requirements. Measures for the improvement of the trade situation and the sturgeon stock status in the Caspian Sea are discussed.

Kurzfassung: Die Geschichte des Kaviarhandels in diesem Jahrhundert bis hin zur heutigen Situation wird kurz beschrieben. Bereits zur Jahrhundertwende wurden etwa 100 t Kaviar pro Jahr aus Russland exportiert. Durch die politischen und wirtschaftlichen Anderungen im Gebiet der ehemaligen UDSSR änderte sich auch der Kaviarhandel. Der tadellose Ruf des russischen Kaviars erlitt in den letzten Jahren Schaden. Der Kaviarhandel erfahrt durch sogenannte Bartergeschäfte, Schmuggel und Umdeklarieren von minderwertigem Kaviar eine allmähliche Kriminialisierung. Im Jahre 1993 wurden etwa l00t Kaviar aus Russland geschmuggelt. Durch den Preisruckgang stieg der Weltmarktbedarf von 300t jährlich auf 450 bis 500t jährlich. Bedauerlicherweise genügen die Qualitäts- und Aufbereitungsstandards oft nicht den Markterfordernissen. Oft muß Kaviar verworfen werden. Es werden Vorschläge zur Verbesserung der Handels- und der Bestandsituation der übernutzten Störbestände gemacht.

History of the caviar trade and the present situation

By the end of the 19th century, the amount of Russian caviar being exported already exceeded 100 tonnes. Even then, Hamburg was the main trans-shipment port for Russian caviar. From Hamburg, caviar was exported to Paris, New York, Rome, London and Stockholm. Most of the caviar was produced from sturgeon females caught in the northern part of the Caspian Sea, some from the Baku region (the capital of Azerbaijan), and an even smaller number captured in the rivers of eastern Siberia. After the Russian Revolution of 1917, the Soviet Union owned all the fishing rights in the Caspian Sea. Only in 1953, Persia (Iran) obtained the right to fish in the southern part of the Caspian Sea. The Iranian state-owned fishing industry employed Russian scientists to organise caviar production until the Iranian Revolution in 1979-1980. Even several years after the Revolution, the Soviet Union was still buying caviar from Iran in order to meet its own very high domestic demand.

As the Western countries became more affluent from the 1950s onwards, the demand for caviar grew considerably. During the First and Second World Wars, sturgeon fishing had had to be halted and as a result fish stocks increased. The Soviet Union traditionally exported only 10% of its produced caviar. The total amount of caviar producd in the USSR in the 1980s was over 2,000 tonnes a year, 140 tonnes of which were of export quality. In Iran, the sturgeon catch increased greatly after 1981. Almost the entire amount of caviar produced (about 300 tonnes) was exported. Although sturgeon fishing and caviar production are still under the control of the Iranian state-owned fishery (SHILAT), caviar started to be smuggled out of Iran in the 1980s; the illegal trade reached its peak (70 tonnes) in 1983. This so-called 'bazaar caviar' was produced from the roe of the illegally caught sturgeons. Roe processed at 'home kitchens' in unhygienic conditions reached Western countries through unusual channels in extremely primitive tins with rubber ring seals made from old tires. In the Western countries, this caviar was sold by Iranian refugees who had fled the revolution. The reputation of Iranian caviar suffered from this poor quality, and hence its price was low. Draconian measures conducted by the Iranian government over ten years eventually brought smuggling back to its pre-revolution levels of about 2-4 tonnes annually. At about the same time, however, sweeping changes began in the Soviet Union, and by the time the country had collapsed, caviar was starting to be smuggled from there. This trade reached about 100 tonnes in 1993, even though caviar was on the Russian list of strategic export commodities (or precisely because it was on the list).

By 1994, mainly the Poles, along with citizens from the other countries of the former Eastern block smuggled caviar out of Russia. They repacked it into their own tins and jars which imitated the original packaging. So, the old caviar was sold as the 'new catch'. This, in turn, not only damaged the previously more or less spotless reputation of Russian caviar, but also caused a sharp decline in caviar prices on the world market (Tables 1 and 2). The decline in prices caused an increase in worldwide demand in caviar outside the producing countries from approximately 300 tonnes per year (which had until then been 'a normal level') to about 450-500 tonnes. Two international markets have developed: one for so-called 'people's caviar', and another one, 'top-class caviar', for expensive hotels and restaurants. The 'people's caviar' was sometimes sold for a third of the price of the 'top-class caviar'. The demand from individual airlines rose to 18 tonnes a year and supermarkets, especially in France, were buying up to 8 tonnes a year to be sold as a special offer during the Christmas season, mostly in 50g tins costing DM12 per tin, or DM240 per kg net weight, duty paid and tax paid. In Germany, the customs duty alone accounted for 30% of the price (today 28%), and in France, for 18% of the price. The quality of the caviar was (and still is) below any acceptable level!

From the early 1950s and until the 1970s, there were about ten caviar trade companies in the Western countries; Dieckmann and Hansen GmbH is the oldest of them. The caviar trade was strictly regulated. Only experienced companies with the necessary expertise were involved in the business. For decades, the Soviet Union had one or two general importers in the Western countries: two in Germany, one in France, one in Britain and one in Japan. For political reasons, the USA was not supplied directly, but traditionally mostly via Germany. Also, there were shipments of caviar from Iran every five years to the United States, South American countries, Europe, Japan and the Middle East countries until the 1979/80 revolution. The total amount of caviar exported from Iran was 115 tonnes per year, and the Soviet Union bought 30-70 tonnes of caviar annually from Iran. Dieckmann and Hansen GmbH was the only general agent for both the Russian and Iranian caviar. After the revolution, the management of SHILAT was replaced by religious fanatics. The despised "traders" were disposed of or had already emigrated. The Persian businessmen who had emigrated set up the cheap trade in exile, just as Russian emigrants became caviar importers in various countries (primarily the USA) after the collapse of the USSR.

Table 1. Purchasing price trends over a period of 13 years (from 1983 to 1995) in DM per kg net weight, duty unpaid

Year	Origin (USSR or CIS and Iran)	Type of caviar[1]			
		Beluga	Osetra	Sevruga	*"bazaar" (approximate price)*
1983	USSR Iran	432 540	350 408	292 341	200[2]
1984	USSR Iran	525 600	354 424	318 400	180
1985	USSR Iran	630 675	418 465	356 404	180
1986	USSR Iran	688 650	360 460	325 345	200
1987	USSR Iran	655 650	356 414	291 325	180
1988	USSR Iran	622 1,630	315 445	298 31-0	180
1989	USSR Iran	1,394 2,600	468 510	332 345	220
1990	USSR Iran	1,250 1,596	420 432	300 304	220[3]
1991	USSR Iran	914 1,600	415 450	305 337	80[4] 180
1992	CIS IRAN	850 1,600	451 470	305 345	90 160
1993	CIS IRAN	800 950	335 435	270 345	120[5] 160
1994	CIS IRAN	658 950	350 500	260 355	140 80

[1] *Beluga* means caviar made of the beluga sturgeon *(Huso huso)* roe, osetra is the name of caviar made of the Russian sturgeon (*Acipenser gueldenstaedti*) roe, and sevruga is the name for caviar made of the stellate sturgeon or sevruga *(A. stellatus)* roe. The 'bazaar caviar' is the illegally produced and smuggled caviar from Iran (see the text).

[2] At their peak, illegal exports amounted to approximately 70 tonnes per year or about 50% of legal exports from Iran.

[3] After approximately ten years of illegal caviar exports, the Iranian authorities had 'pushed down' the level of illegal exports to about 4 tonnes.

[4] Large-scale smuggling from the USSR started in 1991, primarily via Poland. The annual quantity is estimated at approximately 50 tonnes.

[5] The peak of the illegal catch and export from the CIS countries occurred in this year (about 100 tonnes in 1993).

[6] At the same time the production figures continue to drop dramatically as the export licenses are no longer mandatory. The same applies to the caviar quality. The export through smuggling is at a level of about 40-50 tonnes, half of which comes from Azerbaijan, and the other half is from Astrakhan and the bordering areas.Table 2. Caviar import, export and consumption statistics for Germany

Table 2. Caviar import, export and consumption statistics for Germany

Year	Imports (tonnes) from country of origin					Exports (tonnes)	Consumption (tonnes)	Price per kg (DM)
	USSR/CIS	Iran	China	Others[1]	Total			
1987	24.3	50.0	8.6	5.4	88.3	30.6	57.7	292.0
1988	27.1	42.4	8.9	2.9	81.3	39.7	41.6	306.0
1989	20.9	29.1	8.4	0.2	58.6	28.0	30.6	371.0
1990	23.5	32.9	5.1	0.7	62.3	27.9	34.3	339.0
1991	50.1	29.2	6.3	1.4	87.0	52.2	34.9	295.0
1992	72.2	20.5	3.1	1.2	97.0	47.7	49.3	270.0
1993	80.9	12.0	2.7	3.9	99.4	30.4	69.0	211.0
1994	68.8	30.0	2.3	2.1	104.1	27.3	76.8	222.0
1995 Jan-Apr	17.0	5.4	2.2	1.4	26.0	5.4	20.6	242.5

[1]Other countries (USA, Romania and Turkey) and false declarations

Caviar trade and crime

As a result of developments, particularly in the CIS, the caviar trade gradually became a victim of organised crime. Many former Persian smugglers and Russian and Polish emigrants and caviar dealers organised caviar shipments from the large former Soviet companies in Astrakhan and Guryev (Kazakhstan), which were then, however, not paid for. These activities were partly run as barter transactions. For example, a German construction firm in Kazakhstan signed a contract to build 40 houses in return for 24 tonnes of caviar. These 24 tonnes were never paid for, i.e., the houses were never built. A barter transaction in Astrakhan (road construction in return for caviar) ended up with the caviar being exported to Alaska, where it was received, without the road construction ever being started. Altogether, bartering totally ruined the caviar trade as there was, and still is, fraud and deception on all sides. The Iranian company SHILAT has never traded caviar in barter transactions but only in return for direct payment in hard currency.

In the CIS, caviar is today only supplied after 100% prepayment. Trade is continuing to suffer due to the privatisation of caviar production in the CIS. The vast majority of producers are interested only in earning 'quick bucks' through the export trade. The World Bank's requirement of embracing the market economy has almost inevitably led to privatisation of the caviar industry; it remains unclear whether the bank's loans to caviar producers were used properly or not.

Present quality of caviar

The fact that producers in the CIS have no knowledge of the regulations and standards by which the caviar business is conducted in the importing countries does not help in the international caviar business. More than ever, production today is not geared to world market requirements, but still follows the old Soviet quality and packaging standards This means that the importers need to repack caviar themselves which is very expensive and, moreover, further damages the already inferior quality of the caviar.

At present, properly packed caviar of export quality is available in small quantities only in Kazakhstan. Russia, with its main caviar production centre in the city of Astrakhan, no longer produces any caviar of acceptable quality. In Azerbaijan, the amount of legally and illegally produced caviar has increased significantly since 1991. However, due to very poor conditions in the production, packaging and transportation stages, almost 80% of the Azarbaijan caviar is fit only for disposal. During the past few years, smuggling on a large scale and the export of caviar from Azerbaijan via Turkey and Dubai, as well as Germany and the USA, have developed. These processes are depleting the already extremely scarce sturgeon stocks in the Caspian Sea.

The prices at which caviar is sold by legal and illegal producers in their home markets have risen considerably too. The smugglers, however, have an important advantage over Western buyers of exported goods: in the old Soviet Union and now in Russia, the *beluga*, *osetrova* or *sevruga* caviars[6] are sold for the same price. However, because of the terrible quality of the Russian caviar, especially that coming from Astrakhan (in particular, the *osetrova* from the Russian sturgeon caught in summer), the smugglers could barely make a profit in 1995 since the importers refused to pay more for *osetrova* than for *sevruga* (which is cheaper on the international market) due to its poor quality. The price of *osetrova* will probably soon reach the same low price as that of *sevruga*. As the selling price for *beluga* has already been very high for years, the demand for this caviar has sharply declined in the Western countries, and now the world traders buy only the tiniest quantities of it in Russia and Iran. The estimated demand for each type of sturgeon caviar in overall trade in the Western countries in shown in Table 3.

The situation in China

For about 12-15 years, approximately 15 tonnes of *kaluga/osetrova* caviar have been produced annually in China, mainly in the Amur River area.[7] About half of the Chinese production goes to Japan (Table 4), and another half to the United States. Despite the concern of the Chinese authorities about the requirements of and prices at the world market, the caviar quality is still not suitable for the European market, at least not for the catering sector. The eggs in the Chinese caviar have very little fluid and a relatively hard shell (the shell is "chewy"). Nevertheless, this caviar is definitely better and more reliable than caviar from sturgeons caugh in the CIS during summer and autumn. In 1995, the export price for Chinese caviar was about $195.00 per kg net weight CIF at the receiving end. The sturgeon catch in China is also not high, about 10 tonnes in 1995.

[6] The term *beluga* is used as a commercial name for the caviar made of the beluga sturgeon, (*Huso huso*) roe, and the term *sevruga* is used for the caviar made of the stellate sturgeon or sevruga, (*Acipenser stellatus*) roe. The word *osetrova* makes no sense in Russian. It is better to use the word *osetra* for the caviar made of the Russian sturgeon, (*Acipenser gueldenstaedti*) roe. The term *asetra* in Table 3 (see below) is a synonym of *osetra* and *osetrova*.

[7] See Krykhtin & Svirsky (1997a; 1997b, this workshop).

The situation in the USA

Over the past few decades, several rivers in the United States have become much cleaner and production of caviar started again about 15 years ago. American caviar is produced primarily from the roe of the American paddlefish, *Polyodon spathula,* which belongs to the family Polyodontidae, not Acipenseridae.[8] The American paddlefish caviar has an unpleasant, very salty aftertaste (this has nothing to do with the quality of salt used during processing) and cannot be kept for a long time. The USA produces about 15 tonnes of caviar from this and other sturgeon species,[9] which so far has mostly been consumed within the country. From 1994 onwards, however, it has also been exported and sold, as well as mixed with the Russian caviar by a number of irresponsible European traders, primarily to French supermarkets and airlines. American caviar is duty free. It costs only about US$55 per lb., or about DM170 per kg net weight.

Table 3. The demand from Western markets for different types of caviar (the total requirement equals 450 tonnes)[1]

Type of caviar	Demand in tonnes	Approximate supply in tonnes
Russian *beluga*	3.5	10.0
Iranian *beluga*	0.2	2.0
Iranian *asetra* I. A	2.0	0.5
Iranian *asetra* I. B	60.0	40.0
Iranian *asetra* II.	15.0	10.0
Russian *osetrova* (spring catch)	25.0	0.5
Russian *osetrova* (summer catch)	3.0	60.0
Russian *osetrova* (autumn catch)	3.0	20.0
Russian *sevruga*	140.0	30.0
Iranian *sevruga* I	100.0	30.0
Iranian *sevruga* II	100.0	25.0
Total	451.7	228.0

[1]Requirements= Demand (dependent upon quality and price); Supply = approximate total production in 1995.

[8] See Krykhtin and Svirsky (1997a; 1997b, this workshop).

[9] Both families Acipenseridae and Polyodontidae belong to the order Acipenseriformes. There are 25 extant sturgeon species within the Acipenseridae, and two extant paddlefish species within the Polyodontidae.

Figure 4. Caviar import statistics for Japan (in tonnes)[1]

Year	Russia	Iran	China	Other	Total
1990	34	17	7	0	58
1991	32	24	14	0	70
1992	36	12	5	2	55
1993	35	12	3	2	52
1994	22	25	7	2	56

[1]Thesestatistics do not contain the following: any quantities destined for storage at a free port (Hamburg) and shipped from there unaltered to a third country. Hamburg is traditionally the most important place of trans-shipment for sturgeon caviar. The figures clearly show that Japan is affected very little by smuggled caviar compared with Germany, but that Japan pays attention to quality and price in its purchasing policy.

Preservation of sturgeon caviar

According to the traditional Russian method of caviar processing,[10] salt was added to the eggs for caviar preservation. Over the past few decades, a mixture of salt with borax has been used for this purpose in order to reduce the salt content in caviar.[11] Borax is the salt of boric acid, and its use in caviar has been made legal again in Europe since February 1995, although its maximal content should be less than 4g/kg. The United States and Japan continue to prohibit the addition of borax, allowing only caviar with salt to be imported. Since the Soviet Union produced caviar according to its old GOST standards, it was clear which caviar contained salt and which contained an admixture of borax. Currently, every second shipment contains either too much or too little borax. This creates another difficulty for the importers, who now more than ever must comply with the European laws and regulations governing foodstuffs. As the imported goods have to be paid for in advance, importers are now buying 'a pig in a poke'. Any hope of retrieving money paid to the CIS countries is so illusory that no attempt has even been made.

European hygiene regulations

The European hygiene regulations relating to caviar production have been in force since July 1993. They stipulate the conditions required in the processing of fish and fish products in order that exporters are eligible to export their products to member countries of the European Community (EC). Despite numerous efforts made by the caviar industry (including efforts at the political level), it has not been possible to enforce these regulations. Even where the factories are in relatively good shape (as in Astrakhan, for instance), health and safety conditions throughout the CIS are still disastrous by European standards. According to the provisional regulations, a state from which a processing factory

[10]See Sternin and Dore (1993).

[11]The caviar producers in Astrakhan started to use borax and salycilic acid for caviar preservation in 1870 (Sternin & Dore, 1993; p.22).

may export its fish production over a certain period of time must use a health certificate issued by the local authorities. This practice has been undermined by the fact that every stamp and every signature in the CIS and such 'transit countries' as Dubai, Turkey and Poland can be bought. It is virtually impossible for importers and the EC authorities to determine which stamps are genuine and which are not. At present, the provisional regulations will apply for another two years. After that every factory in a third country must be licensed by the EC authorities before it will be allowed to export its production to the EC countries. It is doubtful that there will be any improvement in the conditions of caviar production in the CIS and China within these two years.

Conclusions

I would like to make the following recommendations for the improvement of the sturgeon situation and international caviar trade, even though it may already be too late:

1. Sturgeon fishing quotas should be introduced in the countries bordering the Caspian Sea and they should be rigorously monitored by the governments of these countries.

2. In Russia, caviar production and trade should be nationalised for at least 5 years.

3. The rigorous monitoring of caviar processing and its quality according to international standards should be imposed in all CIS countries producing caviar.

4. Better payment for fishermen and caviar producers should be introduced.

5. Barter transactions with caviar should be prohibited.

6. The caviar-producing factories should be modernised.

7. The amount of caviar produced in all countries should be based on the current demand of the world caviar market.

8. A commission consisting of international experts from the spheres of politics, science and industry (no more than 12 people in all) should be organised for annual discussions of problems relating to the sturgeon and of future opportunities for the caviar industry.

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Discussion

Taylor: I would like to ask the experts a question. Iran catches sturgeons in the sea four weeks prior to spawning. I believe this allows them to produce caviar of superior quality. Is this true? Caviar from the Volga River sturgeons is often of an inferior quality.

Burtsev: When the roe is removed from sturgeon females early, it does not contain many nutrients.

Artyukhin: The roe should never be removed more than two months before spawning.

Altuf'ev: In recent years, caviar has often been obtained from the females caught in the lower reaches of the Volga River because their migration had been prevented by the Volgograd Dam. However, the quality of caviar depends more on the quality of marine feeding grounds on which females feed than on the distance they cover during migration. The storage and transport conditions can also affect the quality of the caviar.

Levin: The reasons for the low quality of caviar from the Volga River sturgeons are clear. Currently, the Russian sturgeons, which reside in the lower reaches ofthe Volga River during the summer, are numerous. Their spawning period is several months away from that time. Nevertheless, the fish are caught. Their meat is OK, but the roe is not yet ripe, although there are plenty of eggs. If the fish were caught later, the quality of caviar would be better.

Burstev: In principle, the fishing industry has facilities (for example, small ponds) for keeping the fish until spawning. Maturation could be stimulated by hormone injections. This would be a way to solve this problem. But it needs investments, and this will make caviar more expensive.

Taylor: I would like to stress that the quality is the prime criterion for caviar. It should be consistently good.

Sturgeons in Europe and causes of their decline

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keywords: sturgeon, *Acipenser sturio, Huso huso, Acipenser* spp., spawning migration, conservation, overfishing, extinction, Baltic Sea, North Sea, Mediterranean Sea, Black Sea, Caspian Sea, Atlantic Ocean, Volga River, Gironde River.

abstract: A brief overview of the distribution of the European sturgeon species and of the current threats to sturgeon survival is given. The data on the common sturgeon, *Acipenser sturio,* are used for the reconstruction of the historical fluctuations in the size of its populations. The anthropogenic factor is the major cause of the stock size fluctuations and depletion. Other factors, such as construction of dams, chemical pollution caused by industrial and agricultural discharges, affect natural reproduction of sturgeons. Recommendations for the improvement of the current situation regarding sturgeon stocks are given.

Kurzfassung: Einleitend wird eine kurze Übersicht über die ehemalige Verbreitung der Europäischen Störarten und ihren aktuellen Gefährdungsgrad gegeben. Anhand des historischen und rezenten Fangaufkommens wird am Beispiel des Gemeinen Störs *Acipenser sturio* ein Bild starker Bestandsschwankungen nachgezeichnet. Die unterschiedlichen, zu Bestandsrückgängen fuhrende Bedingungen, werden differenziert beurteilt. Vor dem Hintergrund der natürlichen klimatischen Umweltveranderungen wird als wesentlichste Ursache für Bestandsschwankungen der anthropogene Einfluß herausgearbeitet. Sowohl die Überfischung, welche vermutlich schon in prähistorischer Zeit lokale Populationsveränderungen bewirkte und heutzutage durch Raubfischerei ihren aktuellen Ausdruck findet, als auch indirekt wirkende Faktoren (zunehmender Schiffsverkehr, die chemische Belastung der Flüsse durch industrielle und landwirtschaftliche Einträge), die eine Verschlechterung oder gar Verhinderung des Reproduktionserfolges nach sich ziehen, werden erlautert. Abschließend wird das zur Zeit in Deutschland anlaufende Programm mit dem Ziel der Wiederbelebung des fast erloschenen Bestandes des Gemeinen Störs *Acipenser sturio* vorgestellt.

Introduction

Currently, a continuous loss of the biodiversity of fauna and flora occurs on a large scale. Even sturgeons (Acipenseridae), which are the largest freshwater fishes, are classified as highly endangered or even extinct in the European *Red Data Books.* A large number of records and data confirm the catastrophic situation (Luk'yanenko, 1992; Bacalbasa-Dobrovici, 1993; Birstein, 1993; Boyle, 1994; Barannikova *et al*., 1995). At present, it is possible to take action at an international level to restore the north European sturgeon species and to provide protection to the south European species. This presentation illustrates the distribution of the European sturgeon species, the historical decline in their stocks (in particular that of *Acipenser sturio)* and the causes of their decline.

Recent distribution of the European sturgeon species

Eight of the 25 extant species of the family Acipenseridae live in Europe. This group includes *Huso huso, Acipenser sturio, A. nudiventris, A. naccarii, A. persicus, A. gueldenstaedti, A. stellatus,* and *A. ruthenus* (see reviews in Holcik, 1989). Until the middle of the 19th century, sturgeons were widely distributed throughout the European continent. The distribution of the recent European fauna (including sturgeons) originated from colonisation during the post-glacial period and had been influenced by geological and climatic factors for only several thousand years.

The analysis of archaeological material shows that the ranges of the European sturgeon species remained more or less unchanged until the 17th or 18th century (Tsepkin and Sokolov, 1979).[12] Even the upper reaches of such big rivers as the Dnieper, Don, Volga, and Ural (the territory of the former Soviet Union or FSU) were inhabited by sturgeons. Of all fish bones found during excavation of old villages and towns in the Volga River basin and dated from the 6th to 14th century, 65-70% belonged to sturgeons. Very large sturgeons were common in the past: according to the size of bones, one fifth of all beluga sturgeon were of 4-6 metres in length. In the 20th century, such giants have become extinct.

In the 18th century, sturgeon stocks in the Caspian Sea comprised 50,000 metric tonnes, while in the 20th century, they did not exceed 10,000-15,000 tonnes despite the increased fishery (Figure 1). Currently, the range of all species has become smaller and some species are virtually extinct. The decline in populations of the common sturgeon, *A. sturio*, is a good example of this trend.

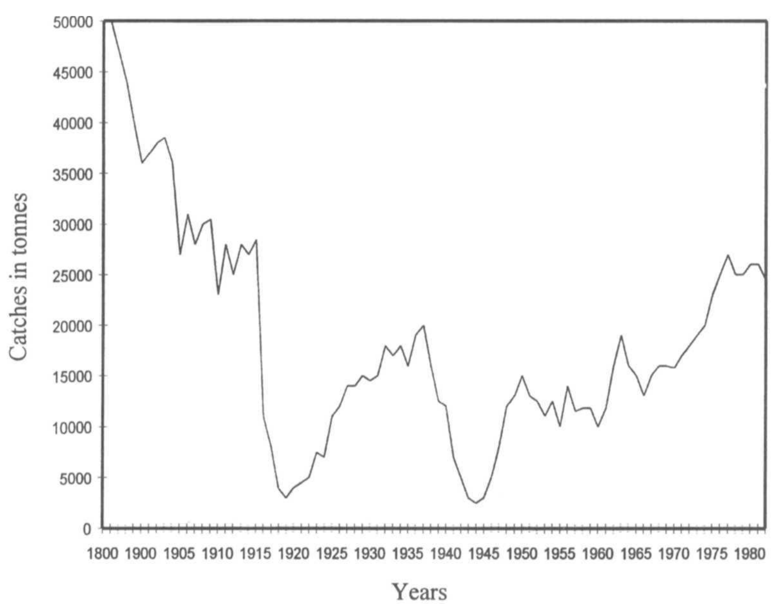

Figure 1. Catches (tonnes) of the Russian sturgeon (*Acipenser gueldenstaedti*) in the Caspian Sea (1800-1980)

[12]Detailed information on the archaeological material can be found in two recent reviews (Tsepkin, 1995; Sokolov and Tsepkin, 1996).

Historical changes in the distribution of *Acipenser sturio* and its population size

1. General characteristics

There are several English synonyms for *Acipenser sturio:* the Atlantic, Baltic, German or common sturgeon (Holcik *et al.,* 1989). In the past, this species showed the widest distribution of all European acipenserids (Figure 2).

The colonisation of the Baltic Sea by *A. sturio* has not yet been fully reconstructed. Duncker (1960) assumes that the species moved from the Black to the Baltic Sea via the Dnieper-Vistula bridge 6,000 years ago. The New Stone Age people discovered the sturgeon in the Baltic Sea over 5,000 years ago: there are pictographs of sturgeons on the rocks surrounding the Onega Lake in Russia (Ravdonikas, 1936).

Two forms differing in some morphometric and meristic characters (e.g., the number and texture of scutes), were described within *A. sturio* (review in Holcik *et al.,* 1989; Debus, 1994; 1995a). Historically, the first form inhabited the Atlantic Ocean, the Mediterranean and Black seas, and the second lived in the Baltic Sea. At the beginning of this century, the Baltic Sea form spawned in all large rivers between the White and Black seas (Figure 2, black lines). At present, *A. sturio* spawns only in two river systems, the Gironde (France) and the Rioni (Georgia) (see Figure 2, the circled river systems). The Gironde population consists of a few thousand individuals (Lepage and Rochard, 1995). In 1994, French researchers caught several juvenile sturgeon in the Gironde (P. Williot, pers. communs.).[13] The presence of juveniles shows that the natural reproduction of *A. sturio* still occurs in this river.

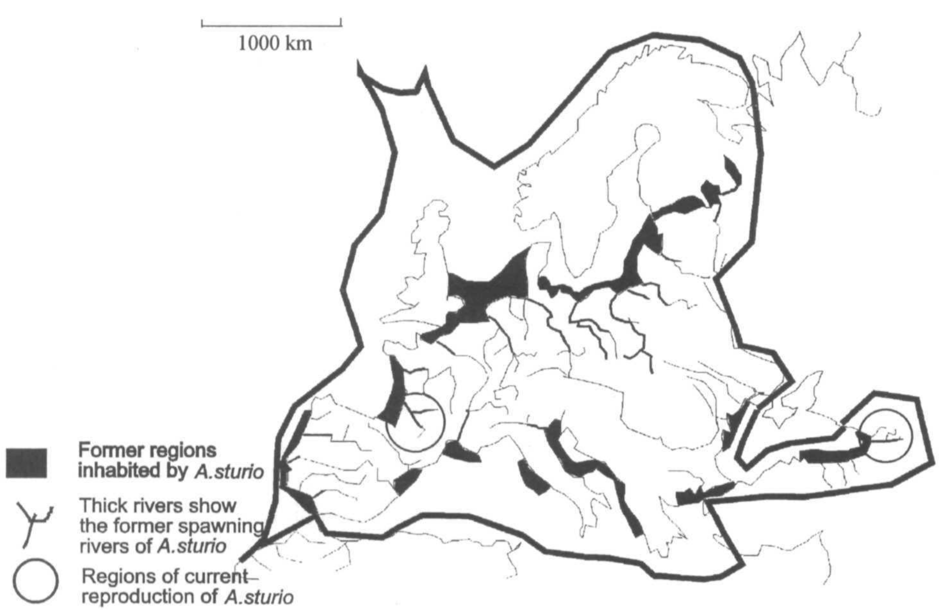

Figure 2: Historical range of *Acipenser sturio*

[13] For more details, see Williot *et al* (1997).

The Red Data Books of Russia, France, Spain, Poland and Germany and the IUCN list A. sturio as endangered or even extinct (Lelek, 1987; Holchik et al., 1989).[14] The species is protected under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

sturgeon bones was decreasing over the course of several centuries and that finally the sturgeon bones disappeared from the archaeological sites completely. Apparently, the absence of bones can be interpreted as the end of sturgeon fishery due to the decline in the stock.

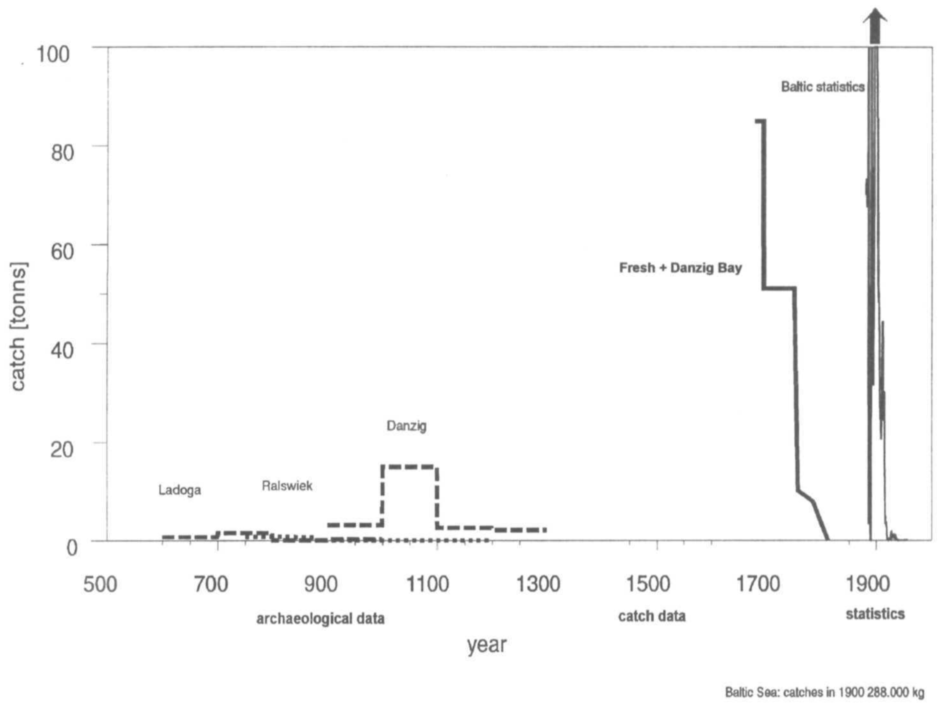

Figure 3. Sturgeon catches in the Baltic Sea

2. *The history of* A. sturio *decline*

a) The Baltic Sea basin

Figure 3 shows the decline in *A. sturio* stock in the Baltic Sea. On the basis of archaeological findings it is possible to reconstruct the catches of the species beginning from the 7th century. Excavations at three different locations near the Ladoga Lake (Lebedev, 1960), the city of Gdansk (Urbanovich, 1965) and near Ralsviek (Benecke, 1986) showed that the number of

There are no data on sturgeon catches from the 13th to the 15th centuries. Sturgeon fishing in the Gdansk area started again around 1530 (Muhl, 1933). As a result, around 1750, the fishery declined again. A similar development was observed in the Frisches Haff (Fresh Bay) between 1700 and 1812 (Debus, 1995b). Seventy years later, sturgeon fishing started once again in the same two areas. This time it ended after an even shorter period of time, within 50 years.

[14] In the last edition of the *IUCN Red List of Threatened Animals* (IUCN, 1996) *A. sturio* is listed as Critically Endangered.

Since the 1920s, *A. sturio* has lost its economic importance (Holcik *et al.*, 1989). The last sturgeons were caught in the Baltic Sea near the Rügen islands in 1931,Oderhaffin 1950, Gotland in 1967, in the Gdansk bay in 1971, and in Lake Ladoga in 1984 (Podushka, 1985; Debus, 1995b; Figure 3). In 1994 and 1995, there were reports of a catch of sturgeons in the Volkhov River near city of Leningrad (Russia), but these specimens were not clearly identified (A. Neelov, pers. communs.,1995).[15]

Figure 4. The historic and recent sites of the catch *of A. sturio* in the Baltic Sea

[15]The last specimen of A. sturio was captured in the Estonian Waters of the Baltic Sea on May 24, 1996 (Paaver, 1986).

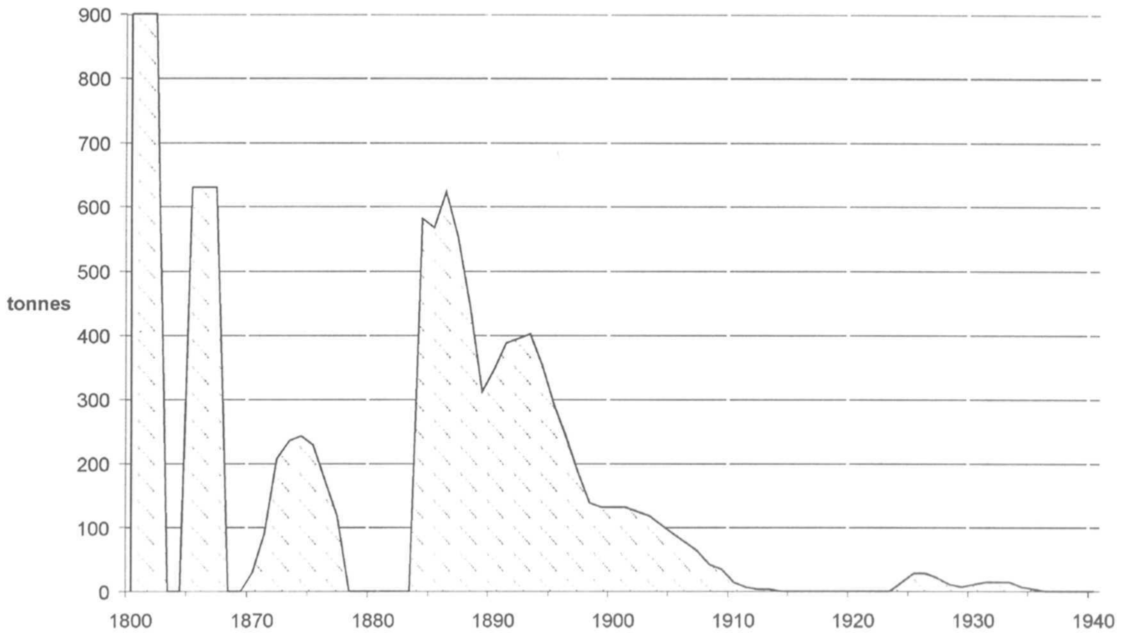

Figure 5. Sturgeon catches in the North Sea from 1800 to 1940.

b) The North Sea basin

Detailed information on the history of the decline of the Rhine population of *A. sturio* is given in Verhey (1949, cited in Mohr, 1952) and Kinzelbach (1987).[16] Between 1920 and 1970, only one or two sturgeon were caught each year near the Dutch coastline (Mohr, 1952). The decline in sturgeon fishery during the 19th century is presented in Figure 5. The last specimen was caught in September 1993 (Timmermanns and Melchers, 1994).

c) The Atlantic Ocean area

France. The decline of populations in the Gironde River system is given in Table 1. In France, the catch of *A. sturio* was banned in 1984 (Rochard *et al.*, 1990). Currently, a population of *A. sturio* still exists near the West European coast of the Atlantic Ocean (Figure 1).

Year	Number of sturgeon caught
1947	4,000
1963	195
1980	0

Table 1. The decline in sturgeon catch in the Gironde River from 1947 to 1980

[16] The last common sturgeon was caught in the Dutch part of the Rhine in January 1992 (Volz and De Groot, 1992).

Spain. Elvira and Almodovar (1993) reported the last sturgeon catch in the Gulf of Cadiz near the estuary of the Guadalquivir River on 14 September 1992.

Italy. Rossi *et al.* (1993) present brief information on the *Huso huso, A. naccarii* and *A. sturio* catches along the entire Italian coastline. *Acipenser sturio* had been commercially harvested until 1920 when 100 tonnes of sturgeon were caught; in 1950 the catch was only 15 tonnes. The main fishing areas included the Po River basin and the northern part of the Adriatic Sea. A small population of *A. sturio* still existed in 1980 in the Po River and its tributaries. Since then, *A. sturio* has practically disappeared from Italian waters.

Georgia. A population of *A. sturio* in the Black Sea is estimated at about 300 specimens (Pavlov *et al.*, 1994).

Causes of the sturgeon stock decline

Both climatic and geological processes affect fish stocks, but human activity has the most destructive impact. The main factors which cause changes in fish populations are described below.

1. Fishing

Fishing is the main anthropogenic factor that historically reduced and continues to reduce sturgeon stocks. Overfishing in different basins has had a devastating effect on sturgeon populations.

a) In the Baltic Sea

The fluctuations in catches during the Middle Ages, reconstructed on the basis of archaeological data, were described above. Catches in the different fishing areas of the Baltic Sea did not decrease simultaneously (Figure 3). On the contrary, climatic changes have possibly caused simultaneous fluctuations in fish stocks known as herring periods (Lepiksaar and Heinrich, 1977).

Until the 19th century, sturgeons were primarily caught in the rivers of the Baltic Sea basin. In 1880, fishing was extended to the coastal areas of the Elbe and in 1885, to the Vistula rivers (Blankenburg, 1910). With the development of diesel engines, fishermen started to trawl *A. sturio* in the open sea (Steiner, 1918).

During the 19th century, the fishing industry was not alarmed by the decline in sturgeon catch. Although experts predicted the destructive impact of overfishing on sturgeons (Heckel and Kner, 1858; Anonymous, 1895; Sterner, 1918), the intensive fishery continued. As a result, the harvest of subadult *A. sturio* with a minimal length of lm intensified (Debus, 1995b).

b) In the Danube River

The overfishing of the autumn race of *A. nudiventris* and other sturgeon species *(A. gueldenstaedti, A. stellatus* and *H. huso)* in the upper and middle Danube River followed a similar pattern (reviews in Pirogovskii *et al.*, 1989;[17] Sokolov and Vasil'ev, 1989; Vlasenko *et al.*, 1989). The Danube River sturgeon populations had started to decline in the 16th century, i.e. a long time before severe pollution and changes in the habitat affected the stocks.

c) In the Caspian Sea

The Caspian Sea is the most important area for the future survival of the main European sturgeon species (Rochard *et al.,* 1990). The situation after the collapse of the Soviet Union 1991 and the subsequent legal and illegal overfishing in the basin are discussed in the other presentations at this workshop (Artyukhin, 1997; Levin, 1997).[18] The current level of overfishing threatens the survival of sturgeons in the Caspian Sea.

2. Destruction of spawning grounds

Agricultural development, including deforestation, along riverbanks is the primary cause of changes in

[17]For detailed information, see Bacalbasa-Dobrovici (1997) and Hensel and Holcek (1997)

[18]See also Khodorevskaya *et al.* (1997).

river flow and the destruction of fish spawning grounds. The extraction of sand, gravel and rocks from the spawning sites in the Danube, Guadalquivir and Garonne rivers for construction purposes was particularly devastating. This activity also reduced the benthic biomass which is the main food resource of sturgeons.

3. Obstructions to migration

The regulation of river systems by dams and other hydrotechnical facilities prevents the anadromous fish from reaching their spawning grounds and restricts their natural reproduction, sometimes even preventing it completely. The spawning migration of *A. sturio* in the rivers Elbe, Eider, Oder, Rhine and Vistula is restricted by the construction of dams, flow regulation, embankment, and deepening of the channel (Voigt, 1870; Kinzelbach, 1987). After the construction of the Volgograd Dam on the Volga River, beluga sturgeons were prevented from reaching the spawning sites in this river (Barannikova, 1995). The spawning grounds of the Russian sturgeon in this river have been reduced by 85%, and those of the stellate sturgeon by 40%. The Guadalquivir River population of *A. sturio* experienced a similar fate after the Alcal de Rio dam and reservoir were built (Rochard *et al.,* 1990). The passages arranged in the dams for migrating sturgeons are ineffective (Rochard *et al.,* 1990).

Dams also prevent the downstream migration of sturgeons. The passage of juveniles through the hydroelectric power turbines is usually lethal for them. In addition, flow regulation causes considerable fluctuations in the water level. As a result, the spawning sites dry out from time to time. During the winter, water fluctuations force hibernating sturgeon of the winter race to move downstream. This movement causes egg resorption in females.

4. Deterioration of the water quality

Industrial pollution affects both the water quality and the amount of benthic and planktonic organisms important as fish food resource. The chemical pollution in the large rivers of the CIS countries is the best example. The death of sturgeons in the Volga River on a mass scale was caused by a waste discharge from the large installations near the town of Krasnoarmeisk in 1965 (about 350,000 dead sturgeons) and by a discharge of petroleum waste in the lower reaches of the river in 1988 (Pavlov *et al.,* 1994). In 1987, high concentrations of pesticides were found in dead juveniles obtained at the Volga River hatcheries. The effect of contaminants on sturgeons in the Volga River-Caspian Sea basin is described in Altuf'ev (1997, this workshop).

5. Biological causes

The introduction of species outside their natural range can have a devastating effect on the endemic fauna. The introduction of *A. stellatus* from the Caspian into the Aral Sea caused a mass death of the endemic ship sturgeon *(A. nudiventris)* which became infected with *Nitzischia sturiones,* a gill parasite of *A. stellatus* (Pavlov *et al.,* 1994).[19]

The introduction of the beluga from the Black Sea population into the Sea of Azov was also destructive (Pavlov *et al.,* 1994). The competition between the introduced form and the endemic Sea of Azov beluga sturgeon form (sometimes described as a subspecies, *Huso huso maeoticus)* resulted in a disappearance of the endemic form.

These examples show the potential danger to the existing *A. sturio* population of introducing an alien species into the North and Baltic seas. In the past few years, the uncontrolled releases of various sturgeon species into the coastal waters of the Baltic Sea were reported (Koli, 1966; Otterlind, 1970). These fish may endanger the limited number of the endemic *A. sturio.*

Another danger is the genetic depletion of species caused by the artificial breeding of only certain

[19] For more details, see Zholdasova (1997).

ecological forms of the same species in aquaculture and releasing them into the wild.

6. Other factors

Since the middle of the 19th century the increase in waterborne traffic has had a fatal impact on spawning sturgeons and larvae. Waves produced by ships have caused juveniles and spawning adults to be pushed onto shores and has led to the mechanical destruction of the benthic communities.

The effect of electromagnetic fields created by the high voltage electric lines located above rivers is another factor affecting the sturgeon migration (Pavlov *et al.*, 1994). Sturgeons interrupt their migration at such sites.

Measures to counter the decline of sturgeon stocks

1. Regulation of mesh size

In Germany the protection of sturgeons started in the 16th century. Edicts on the necessity of sturgeon protection were included in laws of the city of Hamburg in 1594 and in Gdansk legislation in 1717 (Benecke, 1881). The use of nets with a small mesh size was prohibited by these documents. However, these measures were ineffective because of the difficulty in policing their implementation (Blankenburg, 1910; Zimdars, 1941). Similar protective measures for *A. sturio* introduced in France in 1890 were more effective (Rochard *et al.*, 1990).

2. Regulation of fishing

France introduced a temporary prohibition on sturgeon fishing in 1939, and a complete ban in 1982 (Rochard *et al.,* 1990). The ban on sturgeon catches in the northern part of the Caspian Sea introduced in the Soviet Union in 1940 and between 1958 and 1961 was extremely effective (Barannikova *et al.,* 1995; Khodorevskaya *et al.,* 1995). The number and the biomass of the sturgeon populations increased and the commercial catch reached its peak in the 1970s. In 1977, a considerable fine was imposed on the beluga poachers and the illegal caviar producers.

3. Sturgeon lifts

During the construction of dams on the Volga River, special lifts were installed for migrating sturgeons. They appeared to be inefficient since only 10-20% of the ascending sturgeon were transported by the Volgograd Dam lift.[20]

4. Reconstruction of spawning grounds

Artificial spawning grounds were constructed in Russia below the Fedorovsk Dam on the Kuban River and below the Volgograd Dam on the Volga River (Barannikova *et al.*, 1995). These grounds were mainly used by the stellate sturgeon. Since 1981, gravel excavations in the lower reaches of the Dordogne River in France (the spawning sites of *A. sturio)* have been prohibited (Rochard *et al.,* 1990).

5. Artificial breeding and stocking

a) Germany

Artificial breeding and stocking of *A. sturio* started in Germany in the late 19th century. However, these efforts were not very successful. Numerous experiments on the stocking of the sterlet *(A. ruthenus)* in the Baltic Sea basin were also conducted in Germany (Munter, 1871; Borne, 1886; Mohr, 1952).

b) France

Long-term studies by French scientists of *A. sturio* in the Dordogne-Garonne-Gironde river system were primarily focused on sturgeon biology and migration patterns (CEMAGREF, 1987). In the 1980s, the

[20] See discussion after Artyukhin's paper (1997, this workshop).

experimental breeding was partly successful only twice, and the larvae died after hatching (Rochard *et al.*, 1990). Only during the experiments conducted in 1995 did the larvae survive. This time the eggs and sperm were obtained from two adults caught in the Gironde River (P. Williot, pers. communs).[21]

c) Italy

Since 1977, the Adriatic or Italian sturgeon *(A. naccarii)* has been artificially propagated in Italy for both conservation (restocking) and commercial purposes (Arlati and Bronzi, 1995). In 1988, the efficiency of breeding and propagation considerably increased due to the use of hormonal stimulation of breeders.

d) The USSR and Russian Federation

Ten sturgeon hatcheries built in the late 1950s and early 1960s are operating in the lower reaches of the Volga (Barannikova *et al.*, 1995.[22] They released into the rivers approximately 90 million juveniles of *A. gueldenstaedti, A. stellatus,* and *H. huso* annually.[23] On average, around 36% of the Russian and stellate sturgeon and 76% of beluga catches in the Caspian Sea basin originate from the artificially stocked juveniles.

No attempts to save *A. sturio* from the Baltic Sea and the Ladoga Lake by artificial breeding were made. Also, it was not possible to catch breeders for supporting the Rioni River population of *A. sturio* in the Black Sea (Barannikova, 1987). Attempts to introduce the Siberian sturgeon *(A. baeri)* in the Ladoga and Onega lakes have not succeeded (Kuderskii, 1983). Experiments on the introduction of the Russian sturgeon *(A. gueldenstaedti)* in these lakes were also unsuccessful. The main cause of the failure was the small size of spawning sites and the regulation of the rivers' flow.

5. Public awareness

Public awareness is extremely important for species protection. According to the experience of French researchers, the information campaign about *A. sturio* resulted in a reduction of illegal fishing and in an increase in reports of accidental sturgeon catches (Rochard *et al.*, 1990). In Germany, on 1 July 1994, a Society for the Conservation of the Common Sturgeon (*Acipenser sturio*) was created (Hochleithner, 1995). The main aims of the society are to save and to protect the last specimens of *A. sturio* and to build a reasonable stock for artificial propagation (Elvira and Gessner, 1996). Germany also participates in an initiative to reintroduce *A. sturio* into the Rhine. The Netherlands, Spain and Italy are planning similar efforts (Holcik *et al.*, 1989).

Conclusions

Summarising the data described above, the following measures can be recommended to stop the decline in sturgeon stocks:

1. adopt legal regulations to prevent poaching and legal overfishing of mature sturgeons;
2. increase treatment of polluted water;
3. improve the former spawning grounds and eliminate the obstructions to sturgeon migrations;
4. intensify information campaigns;
5. intensify the artificial breeding and propagation of sturgeons from various stocks for restocking and conservation purposes;
6. develop methods of caviar processing from live sturgeon females; and
7. improve the social conditions of fishermen.

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[21] See Williot *et al.* (1997).

[22] The beginning of artificial breeding in Russia is mentioned in Burtsev (1997, this workshop).

[23] For more details, see Levin (1997, this workshop).

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Discussion

Birstein: All recent cases I know of in which common sturgeons were caught met with the same fate - in the pot. But joking aside.

Svirsky: I was intrigued by Dr Debus' statement that sturgeon periodically disappeared and reappeared in the Baltic Sea. How should we interpret these fluctuations?

Debus: The periodic fluctations in the size of *A. sturio* populations in the late Middle Ages can be interpreted as a result of overfishing.

Birstein: I think that it would be very interesting to compare the data on the historical fishery in the Baltic Sea basin with those from other sea basins - for instance, with data on the historical sturgeon fishery in the Danube River - in a bid to understand the pattern in fluctuations in the size of populations of different sturgeon species.

Final discussion

Burtsev: The restocking of the common sturgeon will take a long time. Would it not be worth considering using the other species of sturgeons for introduction into the north European rivers? Would it be successful more rapidly?

Bauer: We should concentrate our efforts on the formerly indigenous species, which means the common sturgeon. The introduction of foreign species entails ecological risks.

Blanke: We have the expression 'Faunenverfalscher' [translated as 'distorting nature']. This refers to the release of non-indigenous species into the wild. There are state regulations in Germany governing this in the Federal Directive on the Protection of Species.

Birstein: We cannot exclude the possibility that the restoration of the common sturgeon will take a long time. But I am absolutely against the introduction of new species. I'd like to remind you about an introduction of the stellate sturgeon into the Aral Sea, when a gill parasite was introduced with the stellate sturgeon. This resulted in an epizootic among the indigenous ship sturgeon. We should consider other ways of improving the situation.

Levin: Discussions like this rarely take place, even though they are very important. One of the reasons for sturgeon depletion is that there is still no agreement on the size of sturgeon catches between countries bordering the Caspian Sea. The governments of certain countries are probably incapable of enforcing any effective controls over fishing. This cannot be done without an international agreement. But our task as scientists is to continue our research work in order to preserve these wonderful fish.

Birstein: As chairman, I would like to summarise our discussion. The main problem with sturgeons in Russia (in the European part, in the Far East and Siberia), and many other countries is the illegal fishing of sturgeons and government inability to stop it. The Russian government does not have the political power and financial resources to do so. Let's consider the situation in Siberia. According to the official statistics, 200 tonnes of sturgeon used to be caught each year in Siberia. This year (1995), officially 4-9 tonnes were caught in the Ob River basin, whereas the illegal total catch was around 300 tonnes. This is just in one river system, and rivers in Siberia are numerous. The poachers are imaginative in the techniques they use. This makes natural reproduction and artificial breeding of sturgeons and restocking them into the Caspian Sea almost impossible. Illegal fishing causes extreme overfishing.

What options do we have? One of them is the advancement of aquaculture methods for various purposes, including the production of caviar. This approach could help to ease the pressure on the natural stocks. But the quality of caviar from aquacultured sturgeons needs to be improved.

Some efforts should be focused on the preservation of sturgeon species in the form of collections of live individuals. In this way we will save those species which become extinct in the wild. There is a collection of sturgeon species from the Sea of Azov in Krasnodar, in south Russia, and a cryobank for sturgeon sperm has been established in Russia (St Petersburg).

International legal measures are another possibility. It is very important to include sturgeons in the Appendices to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

International cooperation is also needed in research work. Scientific studies in Russia have become difficult because of the lack of government funding. We do not know whether our colleagues will receive their salaries next year and will be able to continue their work or not. Direct international financial support of individual researchers or teams would be the best way to give sturgeon scientists an opportunity to continue their work.

Dr Levin mentioned one more issue: the need to build a special vessel for releasing sturgeon juveniles in the Caspian Sea. It is impossible to build this vessel in Russia without international financial support.

Blanke: No caviar should be wasted and discarded in the future. Opportunities are afforded by improving the processing and marketing of caviar. The protection of sturgeons and the caviar industry have the same objective: optimal sustainable utilisation. Inclusion of sturgeons in Appendix II of CITES will provide a legal basis for the international control of the caviar trade.

Concluding remarks: The current status of sturgeons, threats to their survival, the caviar trade and international legal actions needed

Concluding remarks: The current status of sturgeons, threats to their survival, the caviar trade and international legal actions needed

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keywords: sturgeons, paddlefishes, *Acipenser sturio*, *Acipenser* spp., *Psephurus gladius*, overfishing, pollution, damming, juveniles, restocking, caviar, international market, poaching, legal actions, CITES.

abstract: Sturgeons and paddlefishes are the most numerous group of living fossil' fishes. Unfortunately, since the mid-1980s, many of these species have become endangered and some are on the verge of extinction. Historically, there are three main causes of sturgeon and paddlefish decline: overfishing, river damming and water pollution. In 1991, a new threat to the survival of the beluga (*Huso huso*), Russian sturgeon (*Acipenser gueldenstaedti*) and stellate sturgeon (*A. stellatus*) inhabiting the Caspian and Black seas, appeared: a completely uncontrolled illegal and legal overfishing by the countries of the former Soviet Union. The illegal production and export of caviar from Russia from the beginning of this period has been in the hands of organised criminal groups now operating internationally. There are two ways to decrease the pressure of current overfishing on wild sturgeon populations: production of caviar from aquacultured sturgeons (which will not produce significant quantities for at least five years), and international legal action, such as CITES listing of all sturgeon species which will provide some control of caviar imports.

Introduction

Sturgeons and paddlefishes are ancient fishes which can be called 'living fossils'. They make up the most numerous group of 'living fossil' fishes: 25 species of sturgeons and 2 species of paddlefishes live in the Northern Hemisphere. Unfortunately, during the last decade many of these species became endangered and some are on the verge of extinction (Birstein, 1993, 1996; Bemis and Findeis, 1994; Waldman, 1995; Birstein *et al.*, 1997). Last year members of the IUCN/SSC Sturgeon Specialist Group, evaluated the threatened status of sturgeon and paddlefish species worldwide (IUCN, 1996). Sturgeons are threatened throughout all parts of their range: in Western and Central Europe, in the Black and Caspian sea basins, in Central Asia, in Siberia, in the Amur and Yangtze rivers in Far Eastern Asia, and in the Missouri-Mississippi river system in North America (Table 1).

Historically, there are three main causes for the decline in sturgeon and paddlefish stocks: overfishing, river damming and water pollution. The exploitation of the common European sturgeon, *Acipenser sturio*, especially the commercial overfishing at the turn of the century, resulted in the disappearance of this species from almost all European rivers (Holcik *et al.*, 1989; Debus, 1997, this workshop). Only a tiny population of *A. sturio* still exists and reproduces in the Gironde river system in France (Williot *et al.*, 1997). There are signs of recent recovery of this species. Since 1990, common sturgeons have been captured in different areas of Western Europe: in 1992 the Gulf of Cadiz (the Atlantic Ocean) near Spain's coast (Elvira and Almodovar, 1993); the same year in the Dutch part of the Rhine (Volz and De Groot); in 1993, in the North Sea near the Dutch coast (Timmermanns and Melchers, 1994); and in 1996, in the Estonian waters of the Baltic Sea (Paaver, 1996). It is necessary to mention that sometimes individuals which are reported as *A. sturio*,are in fact members of other sturgeon species (Birstein *et al.*, 1997).

Table 1. Threatened status of acipenseriforms

Species[1]	English name	Distribution	Status (national listing or according to the latest studies): Status[2]	Status (national listing or according to the latest studies): References	IUCN listing 1996[3]	CITES 1996
Family Acipenseridae						
Acipenser baerii	Siberian sturgeon	Main Siberian rivers			VU	
A. baerii baerii	Siberian sturgeon	Ob River basin	EN	Ruban, 1996, 1997	EN	
A. baerii stenorrhynchus	Lena River Sturgeon	Basins of the East Siberian rivers: Yenisei, Lena, Indigirka, Kolyma, and Anadyr	Ruban, 1997	VU		
A. baerii baicalensis	Baikal sturgeon	Lake Baikal (Siberia)	VU	RSFS Red Data Book, 1983, Pavlov *et al.*, 1994	EN	
A. brevirostrum[4]	Short-nose sturgeon	Rivers, estuaries and ocean along east coast of North America from Indian River (Florida) to Saint John River (New Brunswick)	T (Canada) and USA V (Canada)	USFWS, 1967, DOI, 1973, Williams *et al.*, 1989, Manci, 1993, Campbell, 1991	VU	Appendix I
A. dabryanus	Yangtze or Dabry's sturgeon	Yangtze River system	EN (category I of state protection)[5]	Wei *et al.*, 1997	CR	
A. fulvescens	Lake sturgeon	Great Lakes and lakes of southern Canada	T (Canada and USA)	Williams *et al.*, 1989, Manci, 1993	VU	
A. gueldenstaedtii	Russian sturgeon	Black, Azov, Caspian seas and rivers entering into them	VU	Lalek, 1987	EN	
		Caspian Sea population	H	Khodorevskaya *et al.*, 1997	EN	
		Black Sea population			EN	
		Danube River population, Hungary	EN	Guti, 1995		
		Danube River population, Romania	VU	Banarescu, 1995		
		Dnepr River population (Black Sea)	EN	Gringevsky, 1994		
		Sea of Azov population	VU, H	Volovik et al., 1993; Chebanov and Savel'eva, 1995	EN	

Species[1]	**English name**	**Distribution**	**Status (national listing or according to the latest studies)**		**IUCN listing**	**CITES**
			Status[2]	**References**	**1996**[3]	**1996**
A. medirostris	Green sturgeon	Pacific coast of North America from Aleutian Islands and Gulf of Alaska to Ensenada, Mexico	V (Canada) T (USA)	Campbell, 1991 Moyle *et al.,* 1994	VU	
A. mikadoi	Sakhalin sturgeon	Pacific Ocean from Amur River to northern Japan, Korea, and Bering Sea, Tumnin (Datta) River	EN	USSR Red Data Book. 1984, Pavlov *et al.,* 1994	EN	
A. naccarii	Adriatic sturgeon	Adriatic Sea, Po and Adige rivers	VU	Lelek, 1987	VU	
A. nudiventris	Ship sturgeon	Aral, Caspian, Black seas and rivers entering into them			EN	
		Caspian Sea and rivers entering into it	EN	Lelek, 1987; Pavlov *et al.,* 1994		
		Black Sea and rivers entering into it	EN	Pavlov *et al.,* 1994		
		Danube River population			CR	
		Danube River population, Hungary	EN	Guti, 1995		
		Danube River population, Romania	Ex	Banarescu, 1995		
		Aral Sea (Central Asia)	Ex	Zholdasova, 1997	Ex	
A. oxyrinchus desotoi[5]	Gulf sturgeon	Gulf of Mexico and northern coast of South America	T	Williams *et al.,* 1989, USFWS, 1990b, Manci, 1993	VU	
A. o. oxyrinchus	Atlantic sturgeon	Rivers, estuaries and ocean along east coast of North America from the St. Johns River (Florida) to Hamilton Inlet (Labrador)	SC (USA)	Williams *et al.,* 1989	LR (nt)	Appendix II
A. persicus	Persian sturgeon	Caspian and Black seas and rivers entering into them	EN	Lelek, 1987	EN	
		Caspian Sea population			VU	
		Black Sea population	R	Pavlov *et al.,* 1994	EN	
A. ruthenus	Sterlet	Drainages of main rivers entering the Caspian and Black seas (Volga, Danube)	EN	Lelek, 1987	VU	
		Volga River population			LR (lc)	
		Danube River population			VU	

Species[1]	English name	Distribution	Status (national listing or according to the latest studies)		IUCN listing	CITES
			Status[2]	References	1996[3]	1996
		Danube River population, Hungary	VU	Guti, 1995		
		Danube River population, Romania	VU	Banarescu, 1995		
		Dnepr River population	EN	Gringevsky, 1994		
		Northern Dvina river system				
		Ob, Irtysh, Yenisey rivers (Siberia)			VU	
A. schrenckii	Amur River sturgeon	Amur River system (Siberia)	T	Manci, 1993	EN	
			EN	Krykhtin and Svirskii, 1997		
A. sinensis	Chinese sturgeon	Yangtze River system (China)	EN, H (category I of state protection)[4]	Wei *et al.*, 1997	EN	
A. stellatus	Stellate sturgeon or sevruga	Caspian, Azov, Black and Aegean seas and rivers entering into them			EN	
		Caspian Sea population			VU	
			H	Khodorevskaya et al., 1997		
		Black Sea population			EN	
		Dnepr River population (Black Sea)	EN	Gringevsky, 1994		
		Danube River population, Hungary	EN	Guti, 1995		
		Danube River population, Romania	EN	Banarescu 1995		
		Sea of Azov	VU, H	Volovik et al. 1993; Chebanov and Savel'eva, 1995	EN	
A. sturio	Atlantic (Baltic) sturgeon	Baltic, Eastern North Atlantic, Mediterranean, and Black Sea	EN[7]	USSR Red Data Book, 1984, Lelek, 1987, Holcik *et al.*, 1989	CR	Appendix I
A. transmontanus	White sturgeon	Rivers and Pacific coast of North America from the Gulf of Alaska to	V (Canada)	Campbell, 1991	LR (nt)	
		Baja California	V (California, USA)	Moyle, 1994		
		Kootenai River and Kootenai Lake in Idaho, Montana, and British Columbia downstream of Libby Dam in Montana	EN	USFWS, 1994[8]	EN	
Huso dauricus	Kaluga sturgeon	Amur River system	EN	Krykhtin and Svirskii, 1997, Wei et al., 1997	EN	
H. huso	Giant sturgeon or beluga	Caspian, Black, and Adriatic seas and rivers entering into them	VU	Lelek, 1987	EN	

Species[1]	English name	Distribution	Status (national listing or according to the latest studies) Status[2]	References	IUCN listing 1996[3]	CITES 1996
		Caspian Sea population			EN	
			H	Khodorevskaya *et al.*, 1997		
		Black Sea population			EN	
		Dnepr River population (Black Sea)	EN	Gringevsky, 1994		
		Danube River population, Hungary	EN	Guti, 1995		
		Danube River population, Romania	VU	Banarescu, 1995		
		Azov Sea population	EN	Pavlov et al., 1994	CR	
			H	Savel'eva and Chebanov, 1995		
		Adriatic Sea population			Ex	
Pseudoscaphirhynchus fedtschenkoi	Syr-Dar shovel-nose sturgeon	Syr-Darya River (Kazakhstan, Central Asia)	EN	USSR Red Data Book, 1984	CR	
				Pavlov et al. 1985, 1994	Ex	
P. hermanni	Small Amu-Dar shovel-nose sturgeon	Amu-Darya River (Uzbekistan, Central Asia)	EN	USSR Red Data Book, 1984	CR	
			CR	Salnikov *et al.*, 1996		
			Ex	Pavlov *et al.*, 1994		
P. kaufmanni	Large Amu-Dar shovel-nose sturgeon	Amu-Darya River (Turkmenistan, Uzbekistan and Tadjikistan, Central Asia)	EN	USSR Red Data Book, 1984; Salnikov et al., 1996	EN	
			CR	Zholdasova,1997		
Scaphirhynchus albus	Pallid sturgeon	Missouri and Mississippi river basins	EN[9]	Williams *et al.*, 1989, USFWS, 1990b, Manci, 1993	EN	
S. platorynchus	Shovel-nose sturgeon	Missouri and Mississippi river basins	E	Williams *et al.*, 1989	VU	
S. suttkusi	Alabama sturgeon	Mobil basin in Alabama and Mississippi	EN[10]	Williams *et al.*, 1989, Williams and Clemmer, 1991 Manci 1993, 1994	CR	
Family Polyodontidae						
Polyodon spathula	American paddlefish	Mississippi River system, particularly Missouri and its tributaries	SC (USA and Canada)	Williams et al., 1989	VU	Appendix II
Psephurus gladius	Chinese paddlefish	Yangtze River system	EN (category I of state protection)[5]	Wei et al., 1997	CR	

[1] For spelling see Birstein and Bemis (1997)

[2] Categories are given in the new IUCN system (IUCN Red List Categories, 1994): Ex, Extinct; CR, Critically Endangered; EN, Endangered; VU, Vulnerable; LR, Low Risk; LR(nt), Near Threatened; LC(lc), Least Concern; or in the US Office of Endangered Species system: E, endangered; T, Threatened; SC, Special Concern. H (Hatcheries) designates species whose natural reproduction is limited; such species are artificially bred and juveniles obtained are released into their natural habitat.

[3] IUCN (1996).

[4] All populations of *A. brevirostrum* along the east coast of the USA and Canada are listed as endangered by the USFWS, Title 50, parts 17.11, 17.12 (USFWS, 1967; DOI, 1973).

[5] A list of wild animals by the state's special protection in category I and II. 14 pp. (in Chinese).

[6] Populations of *A. oxyrinchus desotoi* are listed as endangered in al., FL, GA, LA, and MS by the USFWS, Title 50, parts 17.11, 17.12; federally threatened status from September 30, 1990 (USFWS, 1990b).

[7] According to the IUCN Red List (1994), the status *of A. sturio* is different in different countries: Albania (EN?), Algeria (EN), Belgium (Ex?), Finland (Ex?), France (EN), Germany (Ex?), Greece (EN), Iceland (Ex?), Ireland (Ex?), Italy (EN), Morocco (E), Netherlands (Ex?), Norway (Ex?), Poland (Ex?), Portugal (EN), Romania (EN), Russia (EN), Spain (Ex?), Switzerland (?), Turkey (EN), Ukraine (EN), United Kingdom (EN), Yugoslavia (Ex?). The status of *A. sturio* for Spain and Netherlands should be considered as E since in 1992 sturgeons were caught in both countries (Volz and DeGroot 1992, Elvira and Almodovar 1993). In 1996, a female of *A. sturio* was caught in the Estonian waters of the Baltic Sea (Paaver, 1996).

[8] Kootenai River population of *A. transmontanus* is listed as federally endangered from September 6, 1994 (USFWS 1994)

[9] Populations of *S. albus* are listed as endangered in 13 states (AR, IA, IL, KS, KY, LA, MO, MS, MT, ND, NE, SD and TN) by the USFWS, Title 50, parts 17.11, 17.12; federally endangered status from September 6, 1990 (USFWS, 1990a).

[10] Proposed listing of *S. suttkusi* as endangered has been withdrawn (Federal Register 59, No. 240 :64794-6409 (1994)). For the present, USFWS has placed this species in Category 2 (those species for which insufficient information is available to determine whether to proceed with a proposed rule to list or to consider the species extinct). At its meeeting in Edmonton (Canada), 15-19 June 1995, the American Society of Ichthyologists and Herpetologists urged USFWS to list *S. suttkusi* as an endangered species (Anonymous 1995a; see also Mayden and Kuhajda, 1996).

A similar decline in sturgeon populations occurred at the turn of the century in the New World. In the 17th century, when the first English emigrants reached New England, the American Atlantic sturgeon *(A. o. oxyrinchus)* were so numerous in the rivers that it was 'hazardous for canoes and the like small vessels to past too and again' (J. J. Gent, 1675, cited in Smith, 1985). The native Indian population used to catch and feed on sturgeons (Van der Donck, 1841). In the second part of the 19th century, it was not Russia but the United States which exported black caviar to Europe (Ryder, 1890). Fifty tonnes of caviar made of the *A. o. oxyrinchus* roe caught in the Delaware River and Bay were sent to Germany in 1888. No wonder the catch of sturgeons in the rivers of the east coast declined precipitously about 1900 and had virtually collapsed by 1905 as the populations of *A. o. oxyrinchus* declined (Brundage and Meadows, 1982).

But the United States also provides us with an example of successful measures to restore the depleted populations of sturgeons. The Hudson River population of the shortnose sturgeon *(A. brevirostrum)* considerably exceeded that of the sympatric Atlantic sturgeon *(A. o. oxyrinchus)* in the 1990s (Bain, 1996). This increase in the *A. brevirosrum* population was due to the ban in 1967 on the *A. brevirostrum* fishery after it was listed as a federally endangered species (USFWS, 1967). A restatement of the species' endangered status was made in 1973 (USDOI, 1973) and after this *A. brevirostrum* was included in Appendix I of the Convention on the International Trade in Endangered Species of Wild Fauna and Flora.

The intensive fishery at the beginning of the 20 century in the Caspian Sea basin, the main location of the world stocks of sturgeons, did not result in any serious depletion in their numbers. Traditionally, three sturgeon species were targeted by the commercial fishery in the Caspian Sea: the Russian sturgeon (*Acipenser gueldenstaedti*), stellate sturgeon (*A. stellatus*) and beluga sturgeon (*Huso huso*). Both sturgeon meat and roe were used: meat was smoked and the roe was processed for caviar (Sternin and Dore, 1993).

From 1896 to 1914, the annual sturgeon catch in the northern Russian part of the Caspian Sea, as well as in Azerbaijan and Turkmenistan, reached 350,000-390,000 tonnes (Korobochkina, 1964). The pressure of the harvest on the populations was too high: in 1914-1915, the catch decreased to 277,000-287,000 tonnes. Evidently, the disruption to commercial fishing in the Caspian Sea during World War I (1914 -1918) and the Russian Civil War (1918-1921) saved the sturgeon stocks at that time from overfishing. During the Soviet period, the catch was never as high as it was at the beginning of the century (Korobochkina, 1964; Barannikova *et al*., 1995).

The sturgeon fishery in the other Russian area, the Amur River region, followed the same trend. At the end of the 19th century, about 1,200 tonnes of kaluga sturgeon (*Huso dauricus*) and Amur River sturgeon (*A. schrencki*) were harvested in that river (Kryukov, 1894). The sturgeon fishery in that area never reached such a high level again (Nikol'skii, 1956; Krykhtin and Svirsky, 1997a; 1997b, this workshop).

The damming and other constructions on the European rivers which began at the beginning of the 19th century partly destroyed the spawning sites of *A. sturio* and cut off migrating populations from these sites (Nicola *et al.,* 1996; Debus, 1997, this workshop; Williot *et al.,* 1997). As a result, only one or two populations of this species currently still exist (see above). Caviar production from the roe of *A. sturio* which started in France in the Gironde basin in the 1930s, ended in the 1980s: in 1950, 3,000kg of caviar were produced, in 1963,250kg, and in 1980, only 25kg of caviar were produced (Anon., 1995b). The same happened in the main rivers of the Atlantic coast (Smith, 1985) and Pacific coast (Beamesderfer *et al.,* 1995) of North America. The damming of rivers used by sturgeons for spawning together with overfishing at the beginning of the 20th century resulted in a sharp decline in populations of the main American black caviar producers, *A. o. oxyrinchus, A. brevirostrum* and *A. transmontanus* (white sturgeon).

The construction of dams in 1970 and 1984 in the lower reaches of the largest river of the Black Sea basin, the Danube, caused a collapse in the natural reproduction of sturgeons (*H. huso, A. gueldenstaedti* and *A. stellatus*) in this river and of the sturgeon industry in all countries of the area (Bacalbasa-Dobrovici, 1991; 1997; Jankovic, 1995, 1996; Birstein, 1996a). The riverine form of the ship sturgeon (*A. nudiventris*) became extinct in this river (Banarescu, 1994).

The Tsimlyanskaya Dam built in 1953 on the Don River and the Krasnodar Dam built in 1974 on the Kuban River (southern Russia) largely ended the natural reproduction of the main commercial populations of sturgeons in the Sea of Azov: *A. gueldenstaedti, A. stellatus* and *H. huso* (Chebanov and Savelieva, 1995). An even more devastating effect on the Caspian Sea sturgeon populations was brought about by the damming of the Volga River. The construction of a series of dams from the 1940s to the 1960s, especially of the Volgograd Dam in 1958-1960, caused a considerable reduction in the natural reproduction of the three main commercial species (Barannikova *et al*., 1995; Khodorevskaya *et al*., 1997; Artyukhin, 1997, this workshop; Levin, 1997, this workshop). The beluga, *H. huso,* suffered the most: it was cut off completely from its natural spawning sites in this river (Khodorevskaya and Novikova, 1995).

Unfortunately, new dam construction still threatens the survival of other sturgeon species. This year (1997) the gigantic Three Gorges Dam will be finished on the Yangtze River in China (Hoh, 1996). Its completion will destroy the spawning grounds of the three endemic species of the river: the Chinese sturgeon (*A. sinenis*), the Dabry's sturgeon (*A. dabryanus*) and the Chinese paddlefish (*Psephurus gladius*) (Wei *et al.,* 1997). The paddlefish lost access to its spawning grounds after the construction of the Gezhouba Dam in 1981 and is now on the verge of extinction (Mims, 1996). Without spawning grounds, the two Yangtze River sturgeon species will also disappear in a few years. A revival of another large Chinese project, the Khinganski Dam, which the Chinese authorities are planning to build on the Amur River (Matthiessen, 1993), will threaten the survival of two more species, the kaluga (*H. dauricus*) and the Amur River sturgeon (*A. schrencki*).

Foreseeing the catastrophic consequences of the damming of the Volga, Don and Kuban rivers, ten hatcheries were built in the late 1950s and early 1960s in the Caspian Sea basin, and seven hatcheries in the Sea of Azov basin (Barannikova, 1995; Barannikova *et al.,* 1997; Levin, 1997, this workshop). The main purpose of these hatcheries was to artificially breed *H. huso, A. gueldenstaedti* and *A. stellatus* and release their juveniles into the rivers and seas to support wild populations whose natural reproduction had declined. Until the fall of the Soviet Union, hatcheries located in the Volga River basin (mainly in the lower reaches and in the delta), released up to 90-100 million juveniles annually. As a result, virtually the entire spawning population of beluga in the Volga River consists of hatchery-produced fish (Khodorevskaya and Novikova, 1995).

After 1991, because of the economic depression in the former Soviet Union (FSU), the number of hatcheries operating in the lower Volga River has twice been halved, as has the number of juveniles released (Khodorevskaya *et al.,* 1997; Artyukhin, 1997, this workshop; Levin, 1997, this workshop). Two hatcheries located below the Volgagrad Dam have effectively closed down due mainly to the lack of breeders (Artyukhin, 1997, this workshop). Two hatcheries in Azerbaijan built on the Kura River are also no longer operating because of the lack of breeders and the rising waters of the Caspian Sea (the hatcheries are almost under water). The only five facilities which still continue to operate successfully in Russia are located on the Kuban River. During the 1990s, they released annually into the Sea of Azov about 24 million Russian and stellate sturgeon juveniles and in 1993, also 116,000 beluga juveniles (Chebanov and Savel'eva, 1995; Savel'eva and Chebanov, 1995).

Besides the decline in the number of juveniles released from the Volga River hatcheries, there are two more problems concerning these juveniles. At present the juveniles are released into the Volga River. However, only the release of juveniles into the shallow waters of the northern part of the Caspian Sea is efficient (Levin, 1997, this workshop). Juveniles released into the river are too vulnerable to the biological and abiotic factors. The viability of juveniles released into the sea is much higher. In the 1980s, specially designed vessels were used for the transportation of juveniles from the hatcheries to the sea. These vessels are now too old and are no longer operational. Russian authorities do not have the money to subsidise the construction of a new ship (Levin, 1997, this workshop). Unfortunately, the future of the whole

Russian restocking program is now under threat. The Russian government cannot continue to finance the program, and the European Community experts have not recommended financial support for it (H. Dumont, pers. communs.) Recently, Iran started its own small restocking program for the same three species.

The second problem concerns the biological viability of the juveniles released from the Volga River hatcheries. During the late 1980s and early 1990s, the quality of eggs of spawning sturgeon females decreased drastically, and in 1990-1991 the number of eggs with several histopathological abnormalities reached 100% (Shagaeva *et al*., 1993, 1995). This increase correlated with the abnormalities in larvae development which caused mass-scale mortality of the larvae. A comparison of these abnormalities with those obtained experimentally in the larvae raised in the presence of different toxic chemicals (Tikhonova and Shekhanova, 1982; Markov, 1990; Dettlaff *et al.*, 1993) allowed Shagaeva *et al.* (1993, 1995) and Akimova and Ruban (1996) to conclude that the abnormalities in the eggs and larvae must be caused by different water pollutants in the Volga River.

Pollution is the third main threat to the survival of sturgeon species throughout the world. In recent years, the level of pollution in the Black Sea basin has been very high; however, some improvement in water quality in the Danube River has been observed (Bacalbasa-Dobrovici, 1997). In 1990, following a discharge of toxic substances into the Sea of Azov, approximately 55,000 sturgeons died there (Volovik *et al.,* 1993). High levels of pollution cause numerous anatomical and histological abnormalities in the gonads of Siberian sturgeon (*A. baerii*) inhabiting most Siberian rivers (Akimova *et al.,* 1995a, 1995b; Ruban, 1996). Although the use of DDT, other pesticides and PCBs has been banned in the United States for more than ten years, the level of water pollution in the Mississippi-Missouri river system is still so high that organs of sturgeons living in those rivers are highly contaminated with these pollutants and heavy metals (Welsh and Olson, 1992; Ruelle and Henry, 1994). Apparently, the pollution causes disturbances in the sturgeon reproductive system in this area (Ruelle and Keenlyne, 1993).

During the last decade of the existence of the Soviet Union, in the late 1980s, the pollution in the Volga River and northern part of the Caspian Sea was very high(Luk'yanenko, 1990; Pavlov *et al.*, 1994). In 1988, the concentration of chloro-organic pesticides in the waters of Volgograd Reservoir was lg/l, and in the waters of the northern Caspian Sea about 2g/l. No wonder that at that time the concentration of these compounds in the organs of sturgeons was from 0.23 to l,68g/g and the concentration of mercury was from 0.046 to 0.149mg/kg wet weight (Luk'yanenko, 1990; Pavel'eva *et al.*, 1990). Apparently, a high level of pollution caused numerous anatomical abnormalities in sturgeons, known as 'muscle dystrophy' and the death of affected sturgeons on a large scale (Altuf'ev, 1997, this workshop).

Since then, at the beginning of the 1990s, the environmental conditions in the Volga River-Caspian Sea area seem to have improved, mainly because of the economic depression in Russia (Altuf iev, 1997, this workshop). But this does not mean that the conditions will be better in the near future. The main problem is the increasing oil pollution in the Caspian Sea.

The coastal waters of Azerbaijan (especially near the city of Baku, the capital of Azerbaijan) have already been polluted by oil to the extent that many areas have become 'dead zones' without any fauna (Pavlov *et al.*, 1994). This pollution is the result of a hundred years of oil exploitation on the sea shelf. Currently, because of the rise of the water level in the Caspian Sea (by 1992, it had risen some 2m above the 1977 level; Rodionov, 1994), the sea water has already started to cover industrial 'lakes' of crude oil and oil products located along the shore of Azerbaijan (Rodionov, 1994; Dumont, 1995). The effect of such mass oil pollution on sturgeons will be especially devastating because sturgeons winter not far from the Azerbaijan coast.

There is a potential threat of radioactive contamination of the central part of the Caspian Sea. The Gur'evskaya nuclear reactor near Akatau in Kazakhstan uses water from the Caspian Sea for cooling and desalination and discharges liquid waste into a natural depression located only about 8m above the current water level of the Caspian Sea (Dumont, 1995).

Table 2. The dynamics of the legal import of caviar from the countries of the Caspian Sea region to the countries of the European Union (in metric tonnes)[1]

	USSR or Russia	**Kazakhstan**	**Iran**	**Total**
1988	55		112	167
1989	43		101	154
1990	42		97	139
1991	63		142	205
1992	111	9	95	195
1993	105	10	197	312
1994	51	25	102	178
1995	42	10	52	104

[1]Data from De Meulenaer and Raymakers (1996)

Another potential threat to the survival of sturgeons is the rapid development of oil fields in Kazakhstan, especially the Tengiz oil field on the northern shore of the Caspian Sea (Sagers, 1994). Sturgeons will be especially affected by pollutants from this developing industry because the main spawning rivers, the Volga and Ural, and the main feeding grounds of young sturgeons are located in the Northern Caspian Sea. Possibly, the pollution from these fields will be minimal because of the use of Western technology and the involvement of Western oil companies in the exploitation (P. Dumont, pers. communs.).

In 1991, a new threat to the survival of the three main commercial species of the Caspian and Black seas suddenly appeared: a completely uncontrolled illegal and legal overfishing in the countries of the FSU (Artyukhin, 1997, this workshop; Levin, 1997, this workshop; Krykhtin and Svirsky, 1997, this workshop; Khodorevskaya *et al.,* 1997). Azerbaijan which had previously been strictly prohibited from catching sturgeon in the sea started an official harvest. The main catalyst for this increased overfishing and poaching was the ease of selling caviar on the international caviar market for 'quick bucks'. In 1991-1993, the European caviar market increased 1.5-2.0 times (Table 2), and caviar imports to the United States have increased by 100% from 21 tonnes in 1991 to 41-44 tonnes in 1994 (De Meulenaer and Raymakers, 1996; Taylor, 1997, this workshop). All the new republics of the FSU started an uncontrolled legal harvest of sturgeons.

The illegal production and export of caviar from Russia from the beginning of this period has been in the hands of organised criminal groups which started to operate internationally. Thus, in 1992 such FSU countries as Armenia and Lithuania, as well as Poland, Sweden and Turkey (which do not have sturgeons), suddenly became exporters of black caviar to Western Europe and the United States (De Meulenaer and Raymakers, 1996). Supermarkets in Germany were overwhelmed with very cheap caviar of a poor quality (Taylor, 1997, this workshop). Denmark started to export more caviar than it imported. At the same time, poaching intensified even in Iran with its extremely strong political regime. Dubai became a third country used for the export of legal and illegal caviar from Iran to the United States. Poaching and illegal caviar production increased also in the Black Sea basin, i.e. in Romania (Birstein, 1996a) and Ukraine (Zolotarev *et al.*, 1996).

In Russia poaching and illegal caviar production increased enormously due to the weakness of government structures and the police. However, on 14 November 1996, the countries bordering the Caspian Sea (Russia, Kazakhstan, Azerbaijan, Turkmenistan and Iran) signed an agreement on the banning of sturgeon catches except those in the Volga and Ural rivers (Anonymous, 1996), but it is not clear how this agreement will be implemented. At present, it seems that the Russian caviar mafia controls the catch (Scott, 1996).

The extreme overfishing of sturgeons in the Caspian Sea has already resulted in a high depletion of stocks. The total quantity of caviar imported to Europe in 1994 and 1995 was lower than in previous years (Table 2). Only one advertisement for caviar sales appeared in *The New York Times* over Christmas 1996 whereas over the previous three years there were numerous advertisements published each day during the Christmas period. According to one of the oldest European caviar trade companies, Dieckmann and Hansen, the annual international market requires 450 tonnes of black caviar, but total legal production in 1996 was only 155 tonnes: about 40 tonnes in Russia, 20 tonnes in Kazakhstan and 95 tonnes in Iran (Taylor, 1997, this workshop, and pers. communs.)

The dearth of caviar from commercial species has already resulted in a high level of mislabelling in the shops of New York City. Our investigation of more than 30 caviar samples purchased in different shops showed that 17% of samples were mislabeled (Birstein, 1996; Birstein *et al.*, 1997c). Species identification was carried out using a PCR-based molecular method which allowed detection of the species using a single caviar egg (DeSalle and Birstein, 1996).

Results showed that it is not only the traditionally harvested species from the Caspian Sea (*A. gueldenstaedti*, *A. stellatus* and *H. huso*) that are threatened by the caviar trade (Birstein *et al.*, 1997c). It is alarming that caviar of the Siberian sturgeon (*A. baerii*) was used as a replacement for beluga caviar since this species has not been used before for caviar destined for the international market. The caviar of ship sturgeon (*A. nudiventris*) originated apparently from Kazakhstan, because the Ural River is currently the only river in which this species continues to spawn (Avetisov, 1992). *Acipenser nudiventris* is endangered and commercial catches of the ship sturgeon in Kazakhstan will wipe this species out very soon. The white sturgeon (*A. transmontanus*) has been used as an illegal replacement for the beluga (Cohen, 1997). Also, it is alarming that the caviar of the Amur sturgeon (*A. schrencki*) is sold in New York (Birstein *et al.*, 1997c). Krykhtin and Svirsky (1997, this workshop) described a tremendous level of poaching of this species.

There are two ways to decrease the pressure of the current overfishing on wild sturgeon populations: caviar from aquacultured sturgeons (Burtsev, 1997, this workshop) and international legal actions to control caviar imports in different countries. Although the quality of caviar produced from aquacultured sturgeons is considered to be much poorer than that produced from wild sturgeons, this caviar has potential. A group of businessmen in France have already started to produce caviar from aquacultured Siberian sturgeon (*A. baerii*). In California, another group of businessmen have started to work on the caviar from aquacultured white sturgeon (*A. transmontanus*). They plan to produce 10 tonnes of caviar annually within six years.

But the most urgent need is for legal protection. At present, there is no legal document which would allow European, American or Japanese (the three main international caviar markets) authorities to control caviar imports. Inclusion of all sturgeon species in the Appendices of CITES would allow regulation and control of caviar trade. The World Conservation Congress at its First Session in Montreal, 14—23 October 1996, adopted a special resolution (CGR1.82-rev 1) appealing for inclusion of 'commercially exploited sturgeon species in the Appendices of CITES'. Presently, CITES listing is the most urgently needed international action for saving sturgeons from extermination.

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The SSC's mission is to conserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats. A volunteer network comprised of nearly 7,000 scientists, field researchers, government officials and conservation leaders from 188 countries, the SSC membership is an unmatched source of information about biological diversity and its conservation. As such, SSC members provide technical and scientific counsel for conservation projects throughout the world and serve as resources to governments, international conventions and conservation organizations.

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