Sturgeons and Paddlefishes: Threatened Fishes in Need of Conservation

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Abstract: *A review of endangered and threatened chondrostean (sturgeon and paddlefish) species is given. It is shown that at least three species from the territory of the former Soviet Union are the most endangered. Among them is the large Amu-Dar shovelnose* Pseudoscaphirhynchus kaufmanni, *which seems to be the last survivor of the most primitive group among sturgeons, still living in the region where it originated. These facts call for quick conservation efforts. Because of the present economic crisis in Russia, there is no hope that such effort can be made by Russian scientists alone. Saving sturgeons should be a goal of the international community.*

Esturiones y peces espátulas: Especies en peligro que necesitan conservación

Resumen: *Se presenta una revisión de especies condrósteas (esturion y pez espátula) en peligro y amenazadas. Se muestra que por lo menos tres especies del territorio de la ex Unión Soviética son las más comprometidas. Entre ellas se encuentra el gran Amu-Dar* Pseudoscaphirhyncus kaufmanni, *que parece ser el último sobreviviente del grupo más primitivo de esturiones, que aun vive en la región donde fue originado. Estos hechos claman un pronto esfuerzo conservacionista. Debido a la crisis económica actual en Rusia, no hay esperanzas de que tales esfuerzos puedan ser realizados solo por cientificos rusos. La salvación de los esturiones debería ser un objetivo de la comunidad internacional.*

Introduction

Conservation biology is a crisis discipline (Soulé 1985) that requires immediate action or recommendations (Coblentz 1990). The main question of conservation biology, what to protect, is discussed by many authors (see, for instance, Allendorf 1988; Vane-Wright et al. 1991; Rojas 1992). One extremely endangered group of animals that should be the object of conservation biology is sturgeons and their close relatives, paddlefishes. They belong to the Order Acipenseriformes, Infraclass Chondrostei. Sturgeons, the main representatives of the Chondrostei, are primarily known as producers of black caviar. A lesser known fact is that almost all chondrostean species are endangered or threatened. In this short review I wish to draw the attention of conservation biologists to this group of ancient fishes. The most endangered species of sturgeons, inhabiting the territory of the former Soviet Union, need immediate attention and can be saved only by joint international efforts.

Chondrostean Background

The order Acipenseriformes is a distinctive assemblage of fishes (Berg 1948*a*, 1948*b*; Gardiner 1984; Sokolov & Berdichevskii 1989) with some unique morphological characters: most of their endocranium is cartilagenous, the notochord is retained in the adult stage, and they have a heterocercal tail. In addition, the body of sturgeons is armed with five rows of bony scutes.

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Chondrosteans also have a few unusual genetic characteristics. All species investigated are polyploids and can be arranged as a series 4n–8n–16n (reviews in Birstein & Vasiliev 1987; Birstein et al. 1993). Their karyotypes consist of an enormously high chromosome number, 120, 240, and an estimated 500 (for the last count only the DNA content has been measured [see Birstein et al. 1993; Blacklidge & Bidwell 1993]). Chromosomes are of two types: about half of them are of "usual" size, the macrochromosomes, and the rest are very small, the microchromosomes. The karyotypes of 120-chromosome species are all similar, indicating a slow karyological evolution. This correlates with a slow rate of DNA (Kedrova et al. 1980) and protein (Carlson et al. 1982; Phelps & Allendorf 1983; Bartley et al. 1985) evolution. Apparently, unusual genetic patterns allow acipenseriforms to hybridize easily; many interspecific and even intergeneric hybrids have been found in nature (Berg 1948*b;* Carlson et al. 1985). Hybrids between the beluga *Huso huso* and the sterlet *Acipenser ruthenus* (and the reciprocal hybrids) obtained artificially are not only viable but also fertile, and they are widely used in aquaculture in Russia (Krylova 1988), Germany (Steffens et al. 1983), and Japan (Kijima & Maryama 1985).

Chondrosteans are primitive fishes and are very important in terms of vertebrate evolution (see, for example, Berg 1948*a*). Extant acipenseriforms, the sturgeons and paddlefishes, can be considered "living fossils" (Gardiner 1984), since fossil acipenseriforms are known from the Jurassic (Berg 1948*a;* Obruchev & Kazantseva 1964; Grande & Bemis 1991). In general, it is supposed that chondrosteans as a group originated in the freshwater basins of northern Asia in the early Triassic from ancient ancestors belonging to the paleoniscoid fishes (Berg 1948*a;* Schaeffer 1973; Yakovlev 1977). It seems that the acipenserids became widespread in the Northern Hemisphere in the late Cretaceous, while polyodontids diverged later (Grande & Bemis 1991).

Among all "living fossil" bony fishes the Acipenseriformes have the largest number of living species. About 25 chondrostean species are still living in the Northern Hemisphere, Eurasia, and North America (Table 1). The relationships between sturgeon species are poorly known. Unfortunately, most species are endangered or threatened.

Endangered European Atlantic Sturgeon

As an example, I wish to describe the fate of the Atlantic (Baltic) sturgeon, *Acipenser sturio,* a fate that more plentiful species could share within a few years. Atlantic sturgeons are large fishes, reaching a length of 3 m and a weight of 200 kg (Berg 1948*b;* Holčík et al. 1989). Although individuals attain maturity rather late (males at 7–15 years and females at 8–20 years), they grow faster than other acipenserids. This fish has been well known in Western Europe for at least two thousand years. According to archaeological data, the Atlantic sturgeon has been used for food since Roman times (Kinzelbach 1987). Large numbers of sturgeons were caught in the Rhine estuary, especially during the sixteenth century. By the end of the nineteenth century, *A. sturio* was commercially important in Western Europe (Holčík et al. 1989).

At the beginning of the twentieth century, *A. sturio* was widely distributed in the northeastern Atlantic Ocean, especially the shallow parts of the North and Baltic Seas and some coastal water bodies in the Mediterranean and Pontic regions (Holčík et al. 1989). It was also occasionally caught around Iceland and the North African coasts of the Atlantic and Mediterranean. During the first decade of this century the catch decreased catastrophically. In the 1970s and 1980s, only single individuals could be caught or seen in the Rhine, Po, Gironde, Danube, and Douro Rivers (Kinzelbach 1987; Almaça 1988; Holčík et al. 1989). *Acipenser sturio* is on the endangered species list in the former U.S.S.R., France, Poland, and Germany, as well as on the list of the International Union for Conservation of Nature (IUCN) (Holčík et al. 1989).

The only population of *A. sturio* still remaining is the one in the Black Sea; in the 1970s and 1980s it consisted of only 300–1000 individuals (Ninua 1976; Ninua & Tsepkin 1984). Captive breeding from this population could be the last chance to save *A. sturio* from extinction.

Endangered Species from the Territory of the Former Soviet Union and China

Of the three Central Asian *Pseudoscaphirhynchus* species, the Syr-Dar (*P. fedtschenkoi*), the small Amu-Dar (*P. hermanni*), and the large Amu-Dar (*P. kaufmanni*) shovelnoses, which thrived 30–60 years ago in the Syr and Amu Darya Rivers (Nikol'skii 1938; Berg 1948*b;* Tleuov & Sagitov 1973), only a small population of *P. kaufmanni* in the Amu Darya River still exists (Pavlov et al. 1985; Pavlovskaya & Zholdasova 1991). None of the three shovelnose species was a big fish at 0.3–0.5 m in length, and they had an unusually wide and flat snout. It seems that these ancient species survived up to the twentieth century because the native Muslim population of Central Asia did not use these fishes as food and did not catch them; commercial fishing began only after the appearance of the Russian population in this region at the end of the nineteenth century (Nikol'skii 1938). For the last 25 years there have been no reports of *P. fedtschenkoi* being caught (Dukravets & Mitrofanov 1982), and in 1989 *P. hermanni* was not found (Pav-

Table 1. Threatened status of the Chondrostean species.*

Species	*English name*	*Distribution*	*Status*	*Reference*
Family Acipenseridae				
Acipenser baeri Brandt 1969	Siberian sturgeon	Main Siberian rivers (Ob, Irtysh, Yenisei, Lena, Kolyma)	K; AP	Sokolov & Vasil'ev 1989*c*
		Indigirka River (Siberia)	E	Ruban & Akimova 1991
A. baeri baicalensis A. Nikolsky 1896	Baikal sturgeon	Lake Baikal (Siberia)	E	Pavlov et al. 1985
A. brevirostrum Lesueur 1818	shortnose sturgeon	Rivers, estuaries, and the sea along east coast of North America from the Indian River (Florida) to the Saint John River (New Brunswick)	V (Canada, U.S.A.) T (Canada, U.S.A.) V (Canada)	IUCN Red List 1988 Williams et al. 1989 Campbell 1991
A. dabryanus Duméril 1868	Yangtze sturgeon	Yangtze River system	E, close to Ex	Doroshov & Binkowski 1985
A. fulvescens Rafinesque 1817	lake sturgeon	The Great Lakes and lakes of southern Canada	V (Canada, U.S.A.) T (Canada, U.S.A.)	IUCN Red List 1988 Williams et al. 1989
A. gueldenstaedti Brandt 1833	Russian sturgeon	Black, Azov, and Caspian Seas and rivers entering into them	V AP	Lelek 1987 Vlasenko et al. 1989*a*
A. medirostris Ayres 1854	green sturgeon	Pacific coast of North America from the Aleutian Islands and the Gulf of Alaska to Ensenada, Mexico	V (Canada)	Campbell 1991
A. mikadoi Hilgendorf 1892	Sakhalin sturgeon	Pacific Ocean from the Amur River to northern Japan, Korea, and Bering Sea, Tumnin (Datta) River	I	U.S.S.R. Red Data Book 1984
A. naccarii Bonaparte 1836	Adriatic sturgeon	Adriatic Sea, Po and Adige Rivers	V	Lelek 1987
A. nudiventris Lovetzky 1828	ship sturgeon	Caspian Sea and rivers entering into it	E AP	Pavlov et al. 1985; Lelek 1987; Sokolov & Vasil'ev 1989*a*
		Black and Azov Seas and rivers entering into them	E AP	Pavlov et al. 1985; Sokolov & Vasil'ev 1989*a*
		Aral Sea (Central Asia)	Ex	this paper
A. oxyrhynchus desotoi Vladykov 1955	Gulf sturgeon	Gulf of Mexico and northern coast of South America	T	Williams et al. 1989
A. o. oxyrhynchus Mitchell 1814	Atlantic sturgeon	Rivers, estuaries, and the sea along east coast of North America from the Hamilton Inlet (Labrador) to the St. Johns River (Florida)	V (Canada, U.S.A.) SC (U.S.A.)	IUCN Red List 1988 Williams et al. 1989
A. persicus Borodin 1897	Persian sturgeon	Caspian and Black Seas and rivers entering into them	E	Lelek 1987
A. ruthenus Linnaeus 1758	sterlet	Drainages of the main rivers entering the Caspian and Black Seas (Volga, Danube)	E AP	Lelek 1987 Sokolov & Vasil'ev 1989*b*
		Northern Dvina system (northern Russia)	I	this paper
		Siberian rivers (Ob, Irtysh, Yenisei)	K	this paper
A. schrencki Brandt 1869	Amur sturgeon	Amur River system (Siberia)	V	IUCN Red List 1988
A. sinensis Gray 1834	Chinese sturgeon	Yangtze River system (China)	E	Georgi (personal communication)

Table 1. Continued.

Species	*English name*	*Distribution*	*Status*	*Reference*
A. stellatus Pallas 1771	stellate sturgeon	Caspian, Azov, Black, and Aegean Seas and rivers entering into them	I; AP	Shubina et al. 1989
A. sturio Linnaeus 1758	Atlantic (Baltic) sturgeon	Baltic, Eastern North Atlantic, Mediterranean, Black Sea, and rivers of Western Europe	E, close to EX E	U.S.S.R. Red Data Book 1984; Lelek 1987; Holčik et al., 1989 IUCN Red List 1988
A. transmontanus Richardson 1836	white sturgeon	Pacific coast of North America from the Gulf of Alaska to Baja California	V (Canada)	Campbell 1991
Huso dauricus Georgi 1775	Kaluga sturgeon	Amur River system	R	IUCN Red List 1988
H. huso Linnaeus 1758	giant sturgeon or beluga	Caspian, Black, and Adriatic Seas and rivers entering into them Azov Sea population	V to E AP Ex	Lelek 1987; Pirogovskii et al. 1989 this paper
Pseudoscaphirhynchus fedtschenkoi Kessler, 1872	Syr-Dar shovelnose	Syr Darya River (Kazakhstan, Central Asia)	E Ex	U.S.S.R. Red Data Book 1984 Dukravets & Mitrrofanov 1982; Pavlov et al. 1985
P. hermanni Kessler, 1877	small Amu-Dar shovelnose	Amu-Darya River (Uzbekistan, Central Asia)	E Ex	U.S.S.R. Red Data book 1984 Pavlov et al. 1985
P. kaufmanni Bogdanov 1874	large Amu-Dar shovelnose	Amu-Darya River (Uzbekistan, Central Asia)	E E, close to Ex	U.S.S.R. Red Data Book 1984 Pavlovskaya & Zholdasova 1991; this paper
Scaphirhynchus albus Forbes et Richardson 1905	pallid sturgeon	Missouri and Mississippi River basins	E	IUCN Red List 1988; Williams et al. 1989
S. platorynchus Rafinesque 1820	shovelnose sturgeon	Missouri and Missippi River basins	E	Williams et al. 1989
S. suttkusi Williams et Clemmer 1991	Alabama sturgeon	Mobil basin in Alabama and Mississippi	E	Williams et al. 1989; Williams & Clemmer 1991
Family Polyodontidae				
Polyodon spathula Walbaum 1792	American paddlefish	Mainly the Mississippi River system	I (U.S.A.) SC (U.S.A., Canada)	IUCN Red List 1988 Williams et al. 1989
Psephurus gladius Martens 1862	Chinese paddlefish	Yangtze River system	E	Georgi 1990

** Categories are given in the IUCN system (Ex, extinct; E, endangered; V, vulnerable; R, rare; I, intermediate; K, insufficiently Known) or in the U.S. Office of Endangered Species system (E, endangered; T, threatened; SC, special concern). AP (artificially propagated) designates species whose natural reproduction is limited. These species are artificially bred and then released into their natural habitat.*

lovskaya & Zholdasova 1991) in the region of the Amu Darya River, where it had been numerous in the 1960s (Sagitov 1983). These three species are probably the most ancient and most closely related to the ancestral forms of all the acipenserids (Schmalhausen 1991).

However, even the *P. kaufmanni* population is extremely endangered. The species has disappeared from most of its habitat; specimens could be found only upstream of the city of Chardzhou (Pavlovskaya & Zholdasova 1991). The decline of *P. kaufmanni* (as well as the disappearance of the *P. fedtschenkoi* and *P. hermanni*) in their traditional localities during the past decades has resulted from ill-planned economic activity (use of water for irrigation, blocking of migratory paths, creation of the Karakum and other canals, pesticide pollution [Sagitov 1983; Pavlovskaya & Zholdasova 1991]). At the end of the 1960s, *P. kaufmanni* young-of-the-year made up 26% of all young fishes descending the Amu Darya (Tleuov & Sagitov 1973), while at the end of the 1970s and during the 1980s, Pavlovskaya and Zholdasova (1991) found no young-of-the-year at all. In general, the species of *Pseudoscaphirhynchus* have become victims of the Aral Sea disaster—the Aral Sea drying as a consequence of the construction of an enormously large irrigation system for cotton growing (see Ellis 1990; Feschbach & Friendly 1991). This system destroyed the water regime of the Syr and Amu Darya Rivers, which fed the Aral Sea. In the past, *P. kaufmanni* was represented by two forms, the normal (the average length of adults was about 0.4 m, and weight about 0.8 kg), and the dwarf (about 0.3 m in length and 0.4 kg in weight) (Tleuov & Sagitov 1973). Now normal individuals have become extremely rare (Goncharov et al. 1991). Presently, three dwarf *P. kaufmanni* individuals live in the Moscow Aquarium.

Another victim of this disaster is the Aral population of the ship sturgeon, *Acipenser nudiventris.* This species inhabited the Black, Azov, Caspian, and Aral Seas, as well as the rivers entering their basins (Berg 1948*b;* Sokolov & Vasil'ev 1989*a*). In the Black and Azov Seas, it was always rare (Svetovidov 1964). The ship sturgeon was most numerous in the southern part of the Caspian Sea until the 1950s, when the Mingechaur Dam was built on the Kura River. The specimens from the Aral Sea population differed in meristic characteristics from those of the Caspian population. At the end of the 1960s, in the Amu Darya River, the ship young-of-the-year comprised up to 53% of the total number of young of all fish species (Tleuov et al. 1967). Now, because of Aral Sea drying, *A. nudiventris,* as well as the other inhabitants of this sea, has become extinct in the wild. There are only six individuals from the Aral Sea population alive in captivity in the Moscow Aquarium.

There is one more acipenserid species listed in the former U.S.S.R. Red Data Book (1984): the Sakhalin sturgeon, *A. medirostris.* This rare, anadromous Pacific species is distributed from the Amur River to Northern Japan, Korea, and the Bering Sea (Andriyashev & Panin 1953; Lindberg & Legeza 1965; Masuda et al. 1984; Honma 1988). For a long time this species was considered to be the same species as the American green sturgeon, also *A. medirostris* (Andriyashev & Panin 1953; Scott & Crossman 1973; Houston 1988). Other authors regarded the Asiatic form as a distinct subspecies, *A. medirostris mikadoi* (Lindberg & Legeza 1965). Recent investigations of the DNA content show that the genome size of the Asian and American forms differ considerably (Birstein et al. 1993; Blacklidge & Bidwell 1993). This means that these two forms can be considered different species. Therefore, the Asian form, the Sakhalin sturgeon, should be called *A. mikadoi* Hilgendorf, the name by which it was first described (Hilgendorf 1892). The only site in Russia where this species is known to spawn is the Tumnin (Datta) River (Berg 1948*b*). It has been successfully bred artificially only once (Artyukhin & Andropov 1990).

Two more *Acipenser* species, the sterlet, *A. ruthenus,* and the Siberian sturgeon, *A. baeri,* are threatened. The sterlet is a freshwater species that inhabited the rivers of Eurasia (Berg 1948*b;* Sokolov & Vasil'ev 1989*b*). It was widely distributed in the rivers flowing into the Caspian, Black, Azov, Baltic, White, Barents, and Kara Seas. Populations also existed in the Siberian rivers—Ob, Irtysh, and Yenisei. Individuals from the Siberian populations differed somewhat from the European ones, and that is why this form was named *A. ruthenus ruthenus* natio *marsiglii* Brandt, 1833 (Berg 1948*b*). It seems that much of the diversity of this species has already been lost. Thus, in the tenth through the fourteenth centuries, two forms of the sterlet were common in the Volga River: a rather small one, similar to the contemporary form, and a fast-growing large one of about 1.25 m in length (Tsepkin & Sokolov 1990). The large form disappeared 40–50 years ago, apparently as a result of fishing. During the last several decades the sterlet has wholly disappeared from the rivers of the Northern Dvina basin in northern Russia (Sokolov & Vasil'ev 1989*b*) because of uncontrolled logging, pollution, and other environmental changes. In Russia, the sterlet now lives mainly in the Volga River. But even there its biology has been changed considerably as a consequence of dams built in the 1930s through the 1950s: fishes grow unusually fast in large water reservoirs, but they do not mature (Lukin et al. 1981). The main commercial catch of the sterlet occurs not in Russia, but in the Danube System of Bulgaria, Romania, and the former Yugoslavia (Sokolov & Vasil'ev 1989*b*). The sterlet aquaculture maintained in warm water was created in Russia in the 1980s (Novik 1981). For many years, there has been no record of the sterlet's presence in any Siberian river.

The same can be said about different populations of *A. baeri.* The original area inhabited by the Siberian sturgeon was very wide: it included Siberian rivers from the Ob in the west to Kolyma in the east (Berg 1948*b;* Novikov 1966; Kirillov 1972). These fish enter brackish water and travel into the bays of the Arctic Ocean. Because of their wide distribution and some differences in the morphology and biology of specimens from different populations, the division of this species into subspecies has been discussed by a few authors (review in Sokolov & Vasil'ev 1989*c*). The Lake Baikal population of Siberian sturgeon is considered a distinct form, *A. baeri stenorrhyncus* natio *baicalensis* (Egorov 1961). To reproduce, these sturgeons migrate into the rivers entering Lake Baikal. The real difference between individuals from distant populations of *A. baeri* is not known, however. The main data on this species were obtained in the 1940s through the 1960s, and "it is absolutely necessary to conduct additional investigations employing modern methods" (Sokolov & Vasil'ev 1989*c*). The construction of dams and the intensive pollution of Siberian rivers resulted in a sharp decline in population size in the Ob, Yenisei, Lena, and Irtysh during the 1960s (Votinov & Kas'yanov 1974), and a recent paper indicates that the Indigirka River population is threatened (Ruban & Akimova 1991).

The aquacultures of *A. baeri* from the Lena River population are successfully propagated in Russia (Berdichevskii et al. 1983), France (Williot & Brun 1983), and Japan (Katsumi & Genjiroi 1977). In Russia the aquacultures are kept in warm-water pools in electric generating plants. Breeding and raising the Lena River sturgeons in warm water greatly changed some of their morphological and meristic characteristics (Ruban & Sokolov 1986) and shortened their reproduction period (Akimova 1985).

The beluga or the great sturgeon, *Huso huso,* inhabits the Caspian (main population), Black, and Adriatic Seas, and rivers entering them (Berg 1948*b;* Svetovidov 1964; Pirogovskii et al. 1989). *H. huso* is among the largest freshwater fishes: in the past individuals reached a length of about 6 m and a weight of more than 3200 kg (Berg 1948*b*). Fish from different seas differ in morphological and meristic characteristics, as well as in the age of sexual maturation. On the whole, *H. huso* matures late: males at 10–16 years and females at 13–22 years. Since the end of the nineteenth century, the beluga has been one of the main objects of commercial fisheries in Russia and Eastern Europe. In the Caspian Sea, the highest catch was in 1902–1907, and in the Danube in 1898–1899 (Pirogovskii et al. 1989). Besides overfishing, construction of dams on the Volga, Don, Danube, and other rivers drastically affected all populations of *H. huso.* As a result, the natural reproduction of the beluga is extremely limited. The *H. huso* population in the Sea of Azov is maintained only due to the release of juveniles by commercial sturgeon farms, and the size of the Caspian Sea population depends on the number of juveniles released (Pirogovskii et al. 1989). Lelek (1987) considers *H. huso* to be endangered.

Two more species of great commercial importance for Russia, the Russian sturgeon, *Acipenser gueldenstaedti,* and the stellate sturgeon, *A. stellatus,* seem to be threatened (Lelek 1987; Shubina et al. 1989), in spite of all measures taken by the sturgeon farms (Barannikova 1987). Both species inhabit in Caspian, Black, and Azov Seas, and river entering into them (Berg 1948*b;* Shubina et al. 1989; Vlasenko et al. 1989*a*). *A. stellatus* has been also caught in the Adriatic Sea (Berg 1948*b*). The Russian sturgeons reach 2.2–2.4 m in length, and 65–115 kg in weight. In the past these fish reached the age of 48 years, but now they do not exceed 38 years (Berg 1948*b;* Vlasenko et al. 1989*a*). Males begin to reproduce at 11–13 years and females at 12–16 years.

Although the stellate sturgeons can reach a length of 2.2 m and a weight of 54 kg, their usual size is 1.3–1.5 m, and weight 6–13 kg (Berg 1948*b;* Shubina et al. 1989). The maximum age of this fish is about 27 years, females having a longer life span than males. The stellate sturgeons mature sooner than other species, males at 5–6 years and females at 8–10 years (Shubina et al. 1989).

The flesh and eggs (caviar) of the beluga, Russian, and stellate sturgeons are considered valuable and delicious. Sturgeons have been used for food since the Neolithic period, 4,000–2,000 years B.C. (Tsepkin 1986), and commercial sturgeon fishing in the Caspian Region started in ancient times, around the second century (Korobochkina 1964). The influence of this catch, which was rather small until the end of the nineteenth century, has led not only to a shrinkage of the area inhabited by each species and to a sharp decline in the number of fish, but it has also caused changes in some biological characteristics of the main European sturgeon species. At the end of the eighteenth century, sturgeons were still so numerous in the Volga River that, during two hours near its delta, it was possible to catch about 500 great sturgeons weighing 600–1000 kg (Korobochkina 1964). An investigation of sturgeon bones found during archaeological excavations showed that the average size of the beluga, sterlet, Russian, and stellate sturgeons was bigger and their longevity was higher in the Middle Ages than at present (Tsepkin & Sokolov 1971). Apparently, this difference was caused by a slower growth rate and a longer maturation during the Middle Ages than now. Moreover, the morphological diversity of all sturgeon species that inhabited the Volga River system was much higher in the past than now (Tsepkin & Sokolov 1990). For instance, a large form of the stellate sturgeon was previously common in the Volga River basin and now exists only in a small form. Also, a small, slow-growing form of the Russian sturgeon was widely distributed in the Volga in the past. This form was nonanadromous and is now extinct.

A. gueldenstaedti has been the largest sturgeon catch since the end of the nineteenth century. In 1898–1913 it averaged 6700 tons per year in the northern Caspian, and during the 1940s through the 1970s it was about the same size (Korobochkina 1964; Vlasenko et al. 1989*a*). To compensate for the decrease in natural reproduction caused by dams beginning in 1954, 90 million juveniles have been released annually by 13 sturgeon farms into the rivers entering the Caspian Sea (Barannikova 1987). The maximum catch of the stellate sturgeon, 10,000–11,000 tons per year, was during 1899–1900, and about the same amount was achieved in the 1970s (Korobochkina 1964; Vlasenko et al. 1989*a*). In the Black Sea, the Russian and stellate sturgeons are caught mainly in the Danube Delta. The total catch of sturgeons in this region by Russian, Romanian, Bulgarian, and former Yugoslavian fisheries currently comprises 150–160 tons per year. In the Sea of Azov, the Russian sturgeon population is maintained artificially by the release of juveniles by sturgeon farms (Vlasenko et al. 1989*a*).

The Persian sturgeon, *Acipenser persicus,* which is morphologically similar to the Russian sturgeon, inhabits the southern and central parts of the Caspian Sea (Berg 1948*b;* Vlasenko et al. 1989*b*). A population of *A. persicus* seems also to exist in the Black Sea (Artyukhin & Zarkhua 1986). This species is commercially caught mainly in Iranian waters (Vlasenko et al. 1989*b*). *A. persicus* is endangered (Lelek 1987).

One more species, which might be a subspecies of the

Russian sturgeon, the Adriatic sturgeon, *Acipenser naccarii,* is threatened (Lelek 1987). It lives not in Russia but in the rivers entering the Adriatic Sea (Tortonese 1989). These fish reach 2.0 m in length and 25 kg in weight. *A. naccarii* has little commercial value: only the flesh is used as food, while "eggs are not consumed as caviar" (Tortonese 1989).

Two Siberian (Far Eastern) species, the Amur sturgeon, *Acipenser schrencki,* and the kaluga sturgeon, *Huso dauricus,* were listed as vulnerable and rare species, respectively, by the Conservation Monitoring Center of the International Union for the Conservation of Nature (1988). Both species are endemics of the Amur River basin (Berg 1948*b;* Nikol'skii 1956). The average length of the Amur sturgeons is about 1 m, and the weight 2.5–6.0 kg. Individuals living in the Amur estuary are bigger than those in the river, about 1.7 m in length. Singular individuals have appeared in the Sea of Japan and the Okhotsk Sea (Masuda et al. 1984). *A. schrencki* is similar morphologically to the Siberian sturgeons from the Lena and Kolyma River populations (Berg 1948*b;* Nikol'skii 1956). The Amur sturgeons mature at 9–10 years.

The kaluga sturgeons are large, reaching 2.9–4.0 m in length, and 660–820 kg in weight. The average size of fish in the Amur River and its estuary differs considerably: the river sturgeons are rather small, approximately 1.4 m in length, while in the estuary they are two times longer, about 2.9 m. Morphologically, *H. dauricus* is similar to the great sturgeon (beluga) *Huso huso.* The kaluga sturgeons enter the Sea of Japan (individuals have been caught near Hokkaido Island [Amaoka & Nakaya 1975]) and the Okhotsk Sea (*H. dauricus* has been found in the rivers of Sakhalin Island [Gritsenko & Kostyunin 1979]). Males attain maturity at 14–21 years, and females at 17–23 years (Krykhtin 1986). The age of the largest individuals is not less than 50–55 years (Berg 1948*a*).

The population size of both species, especially of the Amur sturgeon, was always small (Nikol'skii 1956). The catch of both species in the Amur River declined drastically at the turn of the century. In 1958 the catch was banned, but in the early 1970s the Amur sturgeon was still rare (Krykhtin 1972). Now the Amur sturgeon and kaluga face extinction; logging and chemicals from gold-mining operations, as well as from the agriculture on both the Russian and Chinese banks of the Amur River, have caused serious water pollution (Matthiessen 1993). But an even greater threat is the revival the Khinganski Dam project (originally planned as a joint Russian/Chinese venture in the 1950s), which Chinese authorities plan to build on the Amur in the near future. It will irretrievably destroy the habitat of the river's acipenserids and salmon (Matthiessen 1993). No reports on the artificial propagation of either species have been published.

Two extremely endangered chondrostean species inhabit another region of Asia, the Yangtze River System in China. They are the Yangtze sturgeon, *Acipenser dabryanus,* and the Chinese paddlefish, *Psephurus gladius.* Both have been poorly investigated (Kimura 1934; Nichols 1943; Liu & Zeng 1988) and both seem to face extinction (Doroshov & Binkowski 1985; Georgi 1990). The appearance of the Chinese paddlefish is unusual and curious, the length of the head of these fish being about half of total body length including the tail. In the past, the standard length of these fish was about 7 m. The snout is narrow and very long, up to the third of body length. It is prolonged in a flat spatulate blade, becoming flatter towards its narrow tip. In contrast to sturgeons, the body of the Chinese and American (see below) paddlefishes is naked, without scutes. Mature Chinese paddlefish migrate from the Yangtze River to the East China and Yellow Seas (Liu & Zeng 1988). Because of its delicious caviar, *P. gladius* is considered to be one of the most valuable Chinese fishes. Due to overfishing, during the last decade the number of Chinese paddlefishes decreased immensely, and now *P. gladius* is regarded as a protected species in China (Liu & Zeng 1988). One of the main dangers for *A. dabryanus* and *P. gladius* is the high level of the Yangtze River water pollution (T. Georgi, personal communication). Dr. Steven Mims of Kentucky University is working on a program of artificial propagation of the Chinese paddlefish in the United States (Mims et al. 1993).

There is no reliable information on the status of two more Far Eastern Asian species, the Chinese sturgeon, *Acipenser sinensis,* and the Japanese sturgeon, *A. multiscutatus.* The Chinese sturgeon inhabits the Yangtze River System in China and enters the China Sea and the Sea of Japan (Kimura 1934; Nichols 1943; Masuda et al. 1984). Apparently, it can be regarded as endangered (T. Georgi, personal communication). The Japanese sturgeon has been described in two prefectures of southern Japan (Masuda et al. 1984). According to the view of Artyukhin and Andropov (1990), "it seems evident that *A. multisculatus* requires revision, since it is most improbable that sturgeons absent from continental waters exist only in Japan."

North American Chondrostean Species

The status of chondrosteans in the United States and Canada seems to be better than that of the endangered species in the former Soviet Union and China. Sturgeons and paddlefishes are protected in most states and provinces where they live (Johnson 1987; Williams et al. 1989).

The American Atlantic sturgeon, *Acipenser oxyrhynchus,* almost shared the fate of its European namesake, *A. sturio.* For a long time, the American form was considered a subspecies of the European *A. sturio* because of their morphological similarity (Magnin & Beaulieu 1963). In the seventeenth century, *A. oxyrhynchus* was so numerous in the rivers of New England that it was "hazardous for canoes and the like small vessels to past too and again." (Gent 1965, cited in Smith 1985). It was even "pickled and brought for England" (Wood 1634, cited in Smith 1985). The fisheries peaked in 1880–1890 and almost collapsed in 1905 (Smith 1985). Now, only remnant stocks of the American Atlantic sturgeon exist in the areas of former abundance. The northern subspecies, *A. oxyrhynchus oxyrhynchus,* is more abundant and widely distributed, ranging from Hamilton Inlet on the coast of Labrador to the St. Johns River in eastern Florida (Scott & Crossman 1973; Smith 1985). The southern subspecies, *A. o. desotoi,* is limited to the Gulf of Mexico and the northern coast of South America (Vladykov & Greeley 1963; Smith 1985). Today, *A. o. oxyrhynchus* is of special concern in the United States, while populations of *A. o. desotoi* are listed as endangered in AL, FL, GA, LA, and MS by the U.S. Fish and Wildlife Service (USFWS), Title 50, sections 17.11 and 17.12 (Williams et al. 1989). In order to protect remaining stocks, the imposition of a total harvesting moratorium has been recommended (Smith 1985).

Another species of the Atlantic coast of North America is the shortnose sturgeon, *A. brevirostrum* (Scott & Crossman 1973; Dadswell 1979, 1984). These fish are small, about 90 cm in length after 25 years. Their maximum known size is 143 cm and their maximum eight 23 kg. Maximum age is 67 years for females and 30 years for males (Dadswell 1979). The shortnose sturgeon inhabits the eastern seaboard from the Saint John River in New Brunswick to the Indian River of eastern Florida. As a consequence of overfishing at the beginning of the twentieth century and of habitat loss, *A. brevirostrum* is now on the lists of rare and endangered species of Canada and the United States (Ono et al. 1983; Dadswell 1984; Williams et al. 1989). Doroshov and Binkowski (1985) assume that this fish is the most endangered of the American *Acipenser* species.

A similar process of overfishing at the end of the nineteenth century resulted in a fast decline of the American white sturgeon, *A. transmontanus.* It inhabits the Pacific coast of North America from the Gulf of Alaska in the north to Ensenada and Baja, California, in the south, but sizable populations of this species are limited to three river systems, the Sacramento, Columbia, and Fraser rivers (Scott & Crossman 1973; McPhail & Lindsey 1986; Lane 1991). The white sturgeons are the largest freshwater fishes in North America, some individuals can exceed 6 m in length and 600 kg in weight. The age of these individuals is unknown; it is likely that some fish live to an age of 100 years (Lane 1991). Commercial fishing started only in 1880, peaked in 1897, and was followed by a sharp decline (93.3% reduction in catch from 1897 to 1905) to practically commercial extinction; since 1913 the commercial and sports catch has been below 50 tons per year (Scott & Crossman 1973; Lane 1991). The Columbia River population also decreased after dams were built on this river (Semakula & Larkin 1968; Galbreath 1985; Lane 1991). In the last decade, methods of artificial propagation of the white sturgeon were successfully developed (Doroshov et al. 1983; Doroshov 1985). Now a wide program for study of the biology and reproduction of this species for breeding and culturing, headed by Dr. Gary Moberg, has been developed at the University of California, Davis.

About the same time, at the turn of the century, overfishing and (probably) pollution resulted in a rapid decline of the nonandromous lake sturgeon, *A. fulvescens,* in the Great Lakes and the lakes of southern Canada (Vladykov & Greeley 1963; Scott & Crossman 1973; Houston 1987). These fishes are not large, reaching 0.9–1.5 m in length and about 160 kg in weight, but they are well known for their longevity: a sturgeon caught in 1952 was reputed to have been 152 years old (Ono et al. 1983). This species is listed as threatened (Williams et al. 1989). Recently, methods of breeding, rearing, and management of *A. fulvescens* were developed (Czeskleba et al. 1985; Folz & Meyers 1985; Thuemler 1985; Threader & Brousseau 1986). This means that there is some hope that the status of this species will be improved in the near future (Holtzkamm & McCarthy 1988).

The present status of representatives of the genus *Scaphirhynchus,* the only relatives of the Central Asian *Pseudoscaphirhynchus kaufmanni* (see above), is not very clear. The pallid, *S. albus,* and shovelnose, *S. platorynchus,* sturgeons live in the Missouri and Mississippi River Basins; in Alabama, the genus is represented by a separate species, *Scaphirhynchus suttkusi* (Bailey & Cross 1954; Kallemeyn 1983; Carlson et al. 1985; Williams & Clemmer 1991). Maximum body size in *S. platorynchus* and *S. suttkusi* rarely exceeds 0.8 m in length, while *S. albus* is known to reach a length of 1.7 m. They are similar morphologically to the *Pseudoscaphirhynchus* species (the latter have longer tails). Some authors (Gardiner 1984) consider the morphological and anatomical differences between the *Scaphirhynchus* and *Pseudoscaphirhynchus* species too small to divide these five species into two genera. This conclusion seems to be the result of poor comparative data. Commercial fishing of *S. platorynchus* was intensive at the beginning of this century and reached 300,000 kg per year (Carlander 1954). Now, populations of the pallid and sturgeon are listed as endangered in AR, IA, IL, KS, KY, LA, MO, MS, MT, ND, NE, SD, and TN by the USFWS, Title 50, sections 17.11 and 17.12. The Alabama sturgeon is also endangered (Williams et al. 1989). It seems that the ease with which *S. albus* and *S. platorynchus* undergo hybridization, which became possible after reconstructions on the Mississippi and Missouri rivers, may be a threat to the survival of *S. albus* (Carlson et al. 1985).

The last American chondrostean species, the paddlefish *Polyodon spathula*, inhabits the Mississippi River system and smaller drainages that empty directly into the Gulf of Mexico (Parker 1988). It was also reported in the Great Lakes at the turn of the century (Trautman 1957). These fish are smaller than their only close relative, the above-mentioned Chinese paddlefish, *Psephurus gladius*. Their average length is about 1.5 m and average weight about 40–60 kg, but the largest individuals in the past reached 2.2 m (Scott & Crossman 1973; Parker 1988). As with the Chinese species, the American paddlefish have a very unusual, long, paddle-shaped snout. Commercial harvesting of the American species has been permitted in 12 midwestern and southern states (Parker 1988). It is now on the special concern list of fishes of North America (Williams et al. 1989). Methods of artificial propagation of this species have been successfully developed (Hicks 1983), and aquacultures of this species have been created in the United States (Mims & Clark 1991) and the former Soviet Union (Gershanovich & Nickolaev 1985).

The data on the present status of all extant chondrostean species is summarized in Table 1. The species are listed according to Rochard et al. (1991), with three exceptions. *A. kikuchii* was not included because it seems to be a synonym of *A. sinensis* (Takeuchi 1979). *A. multisculatus* was not mentioned because its taxonomic status is not clear (see above). *A. persicus* was added because it is now considered to be a valid species (Vlasenko et al. 1989*b*). The contemporary distribution of species is shown as discussed above. The status of species is given using the categories of the IUCN Red List (1988) (Ex, extinct; E, endangered; V, vulnerable; R, rare; I, intermediate; K, insufficiently known), or, for the American species, using the categories of the U.S. Office of Endangered Species (E, endangered; T, threatened; SC, special concern).

Discussion and Conclusions

From the short presentation of chondrosteans given above, it is evident that many sturgeon species are endangered. Some species inhabiting the territory of the former Soviet Union (and, possibly, China) are facing extinction. Thus, in the near future, the large Amu-Dar shovelnose, one of the oldest and most primitive "living fossils," will disappear, suffering the fate of the small Amu-Dar and Syr-Dar shovelnoses, which have disappeared recently. The ship sturgeon of the Aral Sea is already extinct in the wild, although it is possible that a small population of this form could be reared in captivity. The last small population of the Atlantic (Baltic) sturgeon still inhabiting the Black Sea could disappear very soon if action is not taken quickly. It is not clear if the Sakhalin sturgeon can survive without the help of conservation biologists. In addition, the unique infraspecific forms of at least two species with a very wide range in the past, the sterlet and Siberian sturgeon, have already disappeared.

The traditional objects of commercial fishing in Russia, such as the Russian sturgeon, *Acipenser gueldenstaedti*, the stellate sturgeon, *A. stellatus*, or beluga, *Huso huso*, are also threatened, in spite of artificial breeding and propagation (for a review, see Barannikova 1987). The Sea of Azov populations of these species are maintained only by artificial propagation and release of juveniles (see above). Moreover, since 1985 all sturgeon species in the Caspian Sea and rivers of its basin (including the Volga River) have been seriously affected by industrial pollution (Altuf'ev et al. 1992). As a result, the pesticide content in the liver and fat tissue of the commercial catch in the last few years was 2–5 times higher than the maximum concentration officially allowable in Russia, and the nickel content was 70 times higher than the maximum allowable value (Semenov et al. 1991). Now overfishing threatens the status of sturgeons in the Caspian Sea and rivers feeding it. In the past, one centralized state—the Soviet Union—did most of the fishing in the Caspian Sea basin. The level of the Iranian catch was low compared to the Soviet level. Now, after the fall of the U.S.S.R., there are four new states located on the banks of this sea. This will probably result in a rapid expansion of commercial fishing by these new states and in a decline of all sturgeon species.

Chondrosteans are a real challenge to conservation biology. Different sturgeon species need different conservation approaches. The large Amu-Dar shovelnose is a typical stream fish regarding problems of conservation (Sheldon 1988). Populations (subspecies?) of the Siberian sturgeon are comparable to the populations of the cutthroat trout, for which "preserving the genetic variation . . . entails preserving as many local populations as possible" (Allendorf & Leary 1988). There is no hope that the large Amu-Dar shovelnose or the Sakhalin sturgeon can survive in the wild, because environmental conditions in their regions will not be improved in the near future and the most endangered species can only be saved by breeding and maintaining populations in captivity. Captive breeding should be undertaken for at least the large shovelnose, the Atlantic (Baltic), Baikal, Sakhalin, and Amur sturgeons, as well as the Black Sea ship sturgeon. As for the Aral ship sturgeon, only experimental work with the few individuals living in the Moscow Aquarium will determine whether it is possible to save this form as an artificially created population.

Returning to the problem of the large Amu-Dar sturgeon, it should be noted that a part of its genetic diversity has already been lost; only a dwarf form of these species could be caught now and bred in captivity

(Goncharov et al. 1991). Possibly, the disappearance of the normal form was caused by the disconnection of the Amu Darya River and the Caspian Sea. Because of the shrinking of the Aral Sea, in 1989 the former Amu Darya River delta was about 30 miles away from the sea (Ellis 1990). For the Russian sturgeon it is known that the normal large form was represented by anadromous fishes, and the small "dwarf" form, which lived in the Volga River only and which is extinct now, was nonanadromous (Tsepkin & Sokolov 1990). It seems that the two forms of the Amu-Dar shovelnose can be compared with those of the Russian sturgeon: in the past the normal shovelnoses appeared in the brackish water of the delta (Gosteva 1953), while the dwarf form seems to live in fresh water only. With the drying of the sea and delta the normal form became extinct.

One of the main problems of management of these fishes is their late sexual maturation and the long period between spawnings. But in captivity, at least in some species, these characteristics can be changed. For example, in the wild, Siberian sturgeon males mature at 20–24 years, and females at 25–30 years (Sokolov & Vasil'ev 1989*c*). In captivity, however, males attain maturity in 3–4 years, and females in 7–8 (Berdichevskii et al. 1983; Williot & Brun 1983). Moreover, in captivity males can reproduce each year, and females every 1.5–2.0 years (Akimova 1985). In addition, the fertility of Siberian sturgeons is greater in individuals raised in captivity (Berdichevskii et al. 1983). The same can be said about the large Amu-Dar shovelnose: females, maintained in captivity became sexually mature every year after hormonal stimulation (Goncharov et al. 1991), while in the wild, females reproduce every 4–5 years (Makeeva & Sagitov 1979). Female fertility also increased during maintenance in captivity (Goncharov et al. 1991).

Captive breeding is an important temporary measure for the conservation of endangered sturgeon and paddlefish species. In spite of the negative effect of captive propagation on the genetic diversity of fishes (Allendorf & Phelps 1980; Meffe 1986), for such species as the large Amu-Dar shovelnose, Atlantic (Baltic), and Sakhalin sturgeons, or the Chinese paddlefish, the management of captive stocks is the only possible means of saving them from extinction. In the future, it is to be hoped that the polluted environment of the Amu Darya and Yangtze River will be improved to the extent that the large Amu-Dar shovelnose and Chinese paddlefish could be successfully reintroduced to their natural habitats.

In addition to breeding endangered sturgeon species in captivity, it will also be necessary to create banks of cryopreserved sperm, oocytes, and embryos (Veprintsev & Rott 1979). This is especially important for preserving genetic diversity. Methods for the cryopreservation of sperm (Stoss 1983), as well as of eggs and embryos (Whittingham & Rosenthal 1978; Harvey et al. 1983), of bony fishes have been published. Moreover, a 25% hatching rate for cryopreserved carp embryos has been reported (Zhang et al. 1987). The same methods should be explored for use in sturgeons.

Russian scientists have a great deal of experience working with sturgeons, including endangered species. Specialists from the Koltsov Institute of Developmental Biology (Moscow, Russian Academy of Sciences) succeeded in artificially breeding the large Amu-Dar shovelnose in the laboratory and in raising the offspring (Goncharov et al. 1991). A method of diploid androgenesis, which can be useful for "restoration" of the Atlantic sturgeon, is in the process of development at the same Institute (Grunina & Neifakh 1991). Scientists from St. Petersburg's Central Laboratory on the Reproduction of Fish Stocks successfully bred the Sakhalin sturgeon (Artyukhin & Andropov 1990). But since the fall of the Soviet Union and in the ensuing economic crisis, there is no money in Russia for saving endangered sturgeon species. Only the support of American and West European colleagues interested in the problem of conservation of biological diversity can help save the most endangered sturgeon species. Joint programs including expeditions, breeding, and propagation, as well as studies of ontogenesis are necessary. The results of such studies will be helpful not only for saving endangered species, but also for aquaculture of commercial sturgeons.

There is little time left for these international efforts. In a few years, we may be forced to write words similar to those of the authors of the work on African cichlids: "Unfortunately, we are losing the opportunity to study the cichlid fauna of Lake Victoria, because much of it is going or has gone extinct . . ." (Meyer et al. 1990). With the extinction of endangered acipenseriforms we will lose important links in the chain of vertebrate evolution and, at the same time, one of the best opportunities for understanding biological diversity as well as the relationships between the ichthyofauna of two continents, Eurasia and North America.

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Literature Cited

Akimova, N. V. 1985. Gametogenesis and maturation cycle of the Siberian sturgeon in the wild and in captivity. Pages 111–122 in Peculiarities of the fish reproduction cycles in the water reservoirs of different latitudes. Nauka, Moscow, Russia. In Russian.

Allendorf, F. W. 1988. Conservation biology of fishes. Conservation Biology **2**:145–148.

Allendorf, F. A., and R. B. Leary. 1988. Conservation and distribution of genetic variation in a poplytypic species, the cutthroat trout. Conservation Biology **2**:170–184.

Allendorf, F. A., and S. T. Phelps. 1980. Loss of genetic variation in a hatchery stock of cutthroat trout. Transactions of the American Fisheries Society **109**:537–543.

Almaça, C. 1988. On the sturgeon, *Acipenser sturio* Linnaeus, 1758, in the Portuguese rivers and sea. Folia Zoologica **37**:183–191.

Altuf'yev, Yu. V., A. A. Romanov, and N. N. Sheveleva. 1992. Histology of the striated muscle tissue and liver in the Caspian Sea sturgeons. Voprosky Ikhtiologii **32**:157–171. In Russian.

Amaoka, K., and K. Nakaya. 1975. First record of the kaluga sturgeon, *Huso dauricus,* from Japan. Japanese Journal of Ichthyology **22**:164–166.

Andriyashev, A. P., and K. I. Panin. 1953. Discovery of a Pacific sturgeon (*Acipenser medirostris* Ayres) in the Bering Sea. Zoologicheskii Zhurnal **32**:932–936. In Russian.

Artyukhin, E. N., and A. E. Andropov. 1990. A morphological study of the green sturgeon, *Acipenser medirostris* (Chrondrostei, Acipenseridae), from the Tumnin (Datta) River and some aspects of the ecology and zoogeography of Acipenseridae. Zoologicheskii Zhurnal **69**:81–91. In Russian.

Artyukhin, E. N., and Z. G. Zarkhua. 1986. Taxonomic status of sturgeon of the Rioni River (the Black Sea basin). Voprosky Ikhtiologii **26**:61–67. In Russian.

Bailey, R. M., and F. B. Cross. 1954. River sturgeons of the American genus *Scaphirhynchus:* characters, distribution, and synonymy. Papers of the Michigan Academy of Sciences, Arts, and Letter. **39**:169–208.

Barannikova, I. A. 1987. Review of sturgeon farming in the Soviet Union. Voprosky Ikhtiologii **27**:735–746. In Russian.

Bartley, D. M., G. A. E. Gall, and B. Bentley. 1985. Preliminary description of the genetic structure of white sturgeon, *Acipenser transmontanus,* in the Pacific North-West. Pages 105–109 in F. P. Binkowski and S. I. Doroshov, editors. North American sturgeons: Biology and aquaculture potential. Dr. W. J. Junk Publishers, Dordrecht, The Netherlands.

Berdichevskii, L. S., V. S. Malyutin, I. I. Smol'yanov, L. I. Sokolov, N. V. Akimova, and A. V. Kokarev. 1983. The results of fish acclimatization work with the Siberian sturgeon. Pages 259–270 in Biological principles of sturgeon breeding. Nauka, Moscow, Russia. In Russian.

Berg, L. S. 1948*a.* On the position of the Acipenseriformes in the system of fishes. Trudy Zoological Institute **7**:7–57. In Russian.

Berg, L. S. 1948*b.* Pages 57–109 in The freshwater fishes of the U.S.S.R. and adjacent countries. Part 1. Nauka, Moscow & Leningrad, Russia. In Russian; English translation published by National Science Foundation, Washington, D.C., 1962.

Birstein, V. J., and V. P. Vasiliev. 1987. Tetraploid-octaploid relationships and karyological evolution in the order Acipenseriformes (Pisces). Karyotypes, nucleoli, and nucleolus-organizer region in four acipenserid species. Genetica (Netherlands) **73**:3–12.

Birstein, V. J., A. I. Poletaev, and B. F. Goncharov. 1993. The DNA content in Eurasian sturgeon species determined by flow cytometry. Cytometry **14**:377–383.

Blacklidge, K. H., and C. A. Bidwell. 1993. Three polidy levels indicated by genome quantification in Acipenseriformes of North America. Journal of Heredity, in press.

Campbell, R. P. 1991. Rare and endangered fishes and marine mammals of Canada. COSEWIC Fish and Marine Mammal Subcommittee Status Reports: VII. Canadian Field-Naturalist **105**:151–156.

Carlander, H. B. 1954. A history of fish and fishing in the Upper Mississippi River. Special Publication. Upper Mississippi River Conservation Committee.

Carlson, D. M., M. K. Kettler, S. E. Fisher, and G. S. Whitt. 1982. Low genetic variability in paddlefish populations. Copeia:721–725.

Carlson, D. M., W. L. Pflieger, L. Trial, and P. S. Haverland. 1985. Distribution, biology and hybridization of *Scaphirhynchus albus* and *S. platorynchus* in the Missouri and Mississippi rivers. Environmental Biology of Fisheries **14**:51–59.

Coblentz, B. E. 1990. Exotic organisms: A dilemma for conservation biology. Conservation Biology **4**:261–265.

Czeskleba, D. G., S. AveLallemant, and T. F. Thuemler. 1985. Artificial spawning and rearing of lake sturgeon, *Acipenser fulvescens,* in Wild Rose State Fish Hatchery, Wisconsin, 1982–1983. Pages 79–85 in F. P. Binkowski and S. I. Doroshov, editors. North American sturgeons: Biology and aquaculture potential. Dr. W. Junk Publishers, Dordrecht, The Netherlands.

Dadswell, M. J. 1979. Biology and population characteristics of the Shortnose Sturgeon, *Acipencer brevirostrum* Le Sueur, 1818 *Osteichthyes:* Acipenseridae) in the Saint John River estuary, New Brunswick, Canada. Canadian Journal of Zoology **57**:2186–2210.

Dadswell, M. J. 1984. Status of the shortnose sturgeon, *Acipenser brevirostrum,* in Canada. Canadian Field-Naturalist **98**:75–79.

Doroshov, S. I. 1985. Biology and culture of sturgeon Acipenseriformes. Pages 251–274 in J. F. Muir and R. J. Roberts, editors. Recent advances in aquaculture. Croom Helm, London, England.

Doroshov, S. I., and F. P. Binkowski. 1985. Epilogue: A perspective on sturgeon culture. Pages 147–151 in F. P. Binkowski and S. I. Doroshov, North American sturgeons: Biology and aquaculture potential. Dr. W. Junk Publishers, Dordrecht, The Netherlands.

Doroshov, S. I., W. H. Clark, Jr., P. B. Lutes, R. L. Swallow, K. E. Beer, A. B. Mcguire, and M. D. Cochran. 1983. Artificial propagation of the white sturgeon, *Acipenser transmontanus* Richardson. Aquaculture **32**:93–104.

Dukravets, G. M., and V. P. Mitrofanov. 1982. Rare and endangered fish species of the Kazakhstan fauna. Pages 68–70 in Animal world of Kazakhstan and problems of its preservation. Nauka, Alma-Ata, Russia. In Russian.

Egorov, A. G. 1961. The baikal sturgeon: *Acipenser baeri stenorrhynchus* natio *baicalensis* A. Nikolski. Izdatelstvo Sibirskogo Otdeleniya Akademie Nauk U.S.S.R. Ulan-Ude, Russia. In Russian.

Ellis, W. S. 1990. The Aral. A Soviet sea lies dying. National Geographic **177**:72–92.

Feschbach, M., and A. Friendly, Jr. 1991. Ecocide in the U.S.S.R. Health and nature under siege. Basic Books, New York.

Folz, D. J., and L. S. Meyers. 1985. Management of the lake sturgeon, *Acipenser fulvescens,* population in the Lake Winnebago system, Wisconsin. Pages 136–146 in F. P. Binkowski and S. I. Doroshov, editors. North American sturgeons: Biology and aquaculture potential. Dr. W. Junk Publishers, Dordrecht, The Netherlands.

Galbreath, J. L. 1985. Status, life history and management of Columbia River white Sturgeon, *Acipenser transmonantus.* Pages 119–125 in F. P. Binkowski and S. I. Doroshov, editors. North American sturgeons: Biology and aquaculture potential. Dr. W. Junk Publishers, Dordrecht, The Netherlands.

Gardiner, B. G. 1984. Sturgeons as living fossils. Pages 148–152 in N. Eldredge and S. M. Stanley, editors. Living fossils. Springer Verlag, New York.

Georgi, T. A. 1990. An update on the Chinese paddlefish, *Psephurus gladius* (Pisces: Chondrostei). Proceedings of the Nebraska Academy of Sciences **100**:23.

Gershanovich, A. D., and A. I. Nikolaev. 1985. Results of rearing paddlefish in polyculture with sturgeon hybrids, carp, and herbivorous fish within three years. Pages 170–175 in Marine fish farming. VNIRO Publishers, Moscow, Russia. In Russian.

Goncharov B. F., O. I. Shubravy, and V. K. Uteshev. 1991. Reproduction and early development of the large Amu-Dar shovelnose (*Pseudoscaphirhynchus kaufmanni*) under artificial environmental conditions. Ontogenez **22**:485–492. In Russian.

Gosteva, M. N. 1953. Find of the shovelnose *Pseudoscabirhynchus kaufmanni* (Bodg.) in brackish water. Voprosky Ikhtiologii **1**:115–116. In Russian.

Grande, L., and W. E. Bemis. 1991. Osteology and phylogenetic relationships of fossil and Recent paddlefishes (Polyodontidae) with comments on the interrelationships of Acipenseriformes. Journal of Vertebrate Paleontology **11(supp. 1)**:1–121.

Gritsenko, O. F., and G. M. Kostyunin. 1979. The Ussuri whitefish, *Coregonus ussuriensis* Berg, and the kagula, *Huso dauricus* (Georgi), in the Sakhalin Island inner waters. Voprosky Ikhtiologii **19**:1125–1128. In Russian.

Grunina, A. S., and A. A. Neifakh. 1991. Induction of diploid androgenesis in the Siberian sturgeon *Acipenser baeri* Brandt. Ontogenez **22**:53–56. In Russian.

Harvey, B., R. N. Kelley, and M. J. Ashwood-Smith. 1983. Permeability trials of intact and dechorionized zebra fish embryos to glycerol and dimethyl sulfoxide. Cryobiology **20**:432–439.

Hicks, C. E. 1983. Artificial propagation as a management practice in maintaining paddlefish populations. Page 123 in Proceedings of the 45th Midwest Fish and Wildlife Conference, St. Louis, Missouri, December.

Hilgendorf, F. 1892. Über eine neute Stör-Art aus Nord-Japan (*Acipenser mikadoi*). Sitzungsber. Ges. naturf. Freunde. Berlin 142–144.

Holčík, J., R. Kinzelbach, L. I. Sokolov, and V. P. Vasil'ev. 1989. *Acipenser sturio* Linnaeus, 1758. Pages 366–394 in J. Holčík, editor. The freshwater fishes of Europe. vol. 1, part 2. General introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Holtzkamm, T., and M. McCarthy. 1988. Potential fishery for lake sturgeon (*Acipenser fulvescens*) as indicated by the returns of the Hudson's Bay Company Lac la Pluie District. Canadian Journal of Fisheries and Aquatic Science **45**:921–923.

Honma, Y. 1988. Records and distributional notes on the sturgeons along the coast of Japanese Archipelago. Bulletin of the Biogeographic Society of Japan. **43**:51–55 In Japanese, with English summary.

Houston, J. J. 1987. Status of the Lake Sturgeon, *Acipenser fulvescens,* in Canada. Canadian Field-Naturalist **101**:171–185.

Houston, J. J. 1988. Status of the green sturgeon, *Acipenser medirostris,* in Canada. Canadian Field-Naturalist **102**:286–290.

International Union for Conservation of Nature. 1988. 1988 IUCN Red List of Threatened Animals. The ICUN Conservation Monitoring Centre, Cambridge, England.

Johnson, J. E. 1987. Protected fishes of the United States and Canada. American Fisheries Society, Bethesda, Maryland.

Kallemeyn, L. 1983. Status of the pallid sturgeon *Scaphirhynchus albus.* Fisheries **8**:3–9.

Katsumi, S., and N. Genjiroi. 1977. Rearing of sturgeons in Japan. Pages 379–393 in Proceedings of the 5th Japan-Soviet Joint Symposium on Aquaculture, Tokyo, Japan, September 1976.

Kedrova, O. S., N. S. Vladytchenskaya, and A. S. Antonov. 1980. Single and repeated sequence divergency in the fish genomes. Molecular Biology **14**:1001–1012. In Russian.

Kijima, T., and T. Maryama. 1985. Histological research for the development of the gonad of hybrid sturgeon, bester (*Acipenser ruthenus* L., male x *Huso huso* (L.), female). Bulletin of the National Institute of Aquaculture **8**:377–381.

Kimura, S. 1934. Description of the fishes collected from the Yangtze-kiang, China, by late Dr. K. Kishinouye and his party in 1927–1929. Journal of the Shanghai Science Institute, Section III **1**:11–247.

Kinzelbach, R. 1987. Das ehemalige Vorkommen des Stvörs, *Acipenser sturio* (Linnaeus, 1758), im Einzugsgebiet des Rheins (Chrondrostei: Acipenseridae). Zeitschrift für Angewandte Zoologie **74**:167–200.

Kirillov, F. N. 1972. Fishes of the Yakutiya. Nauko Publishers Moscow, Russia. In Russian.

Korobochkina, Z. S. 1964. Main stages of sturgeon fisheries development in the Caspian Sea. Trudy VNIRO **52**:59–86. In Russian.

Krykhtin, M. L. 1972. Change in the content and number of the kaluga *Huso dauricus* (Georgi) and the sturgeon *Acipenser schrencki* Brandt populations in the Amur River basin during the period of catch prohibition. Voprosky Ikhtiologii **12**:3–12. In Russian.

Krykhtin, M. L. 1986. Rate of sexual maturation and reproductive rhythm of kaluga sturgeon *Huso dauricus* (Georgi) in the Amur estuary. Voprosky Ikhtiologii **26**:945–954. In Russian.

Krylova, V. D. 1988. Use of morphological test characteristics in diagnosis of selected forms of bester. Pages 119–137 in I. A. Burtzev, editor. Genetic analysis of marine hydrobionts. VNIRO, Moscow, Russia. In Russian.

Lane, E. D. 1991. Status of the white sturgeon, *Acipenser transmontanus,* in Canada. Canadian Field-Naturalist **105**:161–168.

Lelek, A. 1987. Threatened fishes of Europe. Pages 43–57 in The European Committee for Conservation of Nature and Natural Resources—Council of Europe, editor. The freshwater fishes of Europe, vol. 9. AULA-Verlag, Wiesbaden, Germany.

Lindberg, G. U., and M. I. Legeza. 1965. Fishes of the Sea of Japan and adjacent areas of the Okhotsk and Yellow Seas, part 2. Nauka Publishers, Moscow & Leningrad, Russia. In Russian.

Liu, C. H., and Y. J. Zeng. 1988. Notes on the Chinese paddlefish, *Psephurus gladius* (Martens). Copeia:482–484.

Lukin, A. V., V. A. Kuznetsov, N. Kh. Khalitov, N. N. Danilov, K. P. Tikhonov, and R. R. Melent'eva. 1981. The sterlet of the Kuibyshev Reservoire and the ways of its adaptation to the new environment. Kazan University Press, Kazan, Russia. In Russian.

Magnin, E., and G. Beaulieu. 1963. Étude morphométrique comparée de l'*Acipenser oxyrhynchus* Mitchill du Saint-Laurent et de l'*Acipenser sturio* Linné de al Gironde. Nature Canada **90**:5–38.

Makeeva, A. P., and N. I. Sagitov. 1979. Materials on the gametogenesis and reproduction of the large Amu-Dar shovelnose. Pages 155–159 in Biological principles of the sturgeon breeding development in the U.S.S.R. reservoirs. Nauka Publishers, Moscow, Russia. In Russian.

Masuda, H., K. Amaoka, C. Araga, T. Ueno, and T. Yoshino. 1984. The fishes of the Japanese archipelago. Tokai University Press, Tokai, Japan.

Matthiessen, P. 1993. The last cranes of Siberia. The New Yorker **May 3**:76–86.

McPhail, J. D., and C. C. Lindsey. 1986. Zoogeography of the freshwater fishes of Cascadia (the Columbia system and rivers north of the Stikine). Pages 615–638 in C. H. Hocutt and E. O. Wiley, editors. The Zoogeography of North Freshwater Fishes. John Wiley & Sons, New York.

Meffe, G. K. 1986. Conservation genetics and the management of endangered fishes. Fisheries **11**:14–23.

Meyer, A., T. D. Kocher, P. Basasibwaki, and A. C. Wilson. 1990. Monophyletic origin of Lake Victoria cichlid fishes suggested by mitochondrial DNA sequences. Nature **347**:550–553.

Mims, S. D., and J. A. Clark. 1991. Overwintering paddlefish in monoculture and in polyculture with channel catfish and rainbow trout. Journal of Applied Aquaculture **1**:95–101.

Mims, S. D., T. A. Georgi, and C. H. Liu. 1993. The Chinese paddlefish, *Psephurus gladius:* Biology, life history, and potential for cultivation. World Aquaculture **24L**46–48.

Nichols, J. T. 1943. The fresh-water fishes of China. Pages 15–16 in Natural History of Central Asia, vol. IX. American Museum of Natural History, New York.

Nikol'skii, G. V. 1938. Pages 55–74 in Fishes of Tadzhikistan. Izdatelstvo Akademie Nauk U.S.S.R., Moscow & Leningrad, Russia. In Russian.

Nikol'skii, G. V. 1956. Pages 26–49 in Fishes of the Amur River Basin. Izdatelstvo Akademie Nauk U.S.S.R., Moscow & Leningrad, Russia. In Russian.

Ninua, N. Sh. 1976. The Atlantic sturgeon from the Rioni River. Metsniereba, Tbilisi, Russia. In Russian.

Ninua, N. Sh., and E. A. Tsepkin. 1984. The Atlantic sturgeon. Page 204 in A. M. Borodin, editor. U.S.S.R. red data book, vol. 2. Lesnaya Promyshlennost, Moscow, Russia. In Russian.

Novik, N. V. 1981. Offspring obtaining from the sterlets, raised in warm water reservoirs. Pages 172–173 in Efficient fundamentals of sturgeon farming. Volgograd, Russia. In Russian.

Novikov, A. S. 1966. Fishes of the Kolyma River. Nauka Publishers, Moscow, Russia. In Russian.

Obruchev, D. V., and A. A. Kazantseva. 1964. Superorder Chondrostei. In Yu. A. Orlov, editor. Fundamentals in Paleontology, vol. 11. Nauka Publishers, Moscow, Russia. In Russian; English translation, 1967.

Ono, R. D., J. D. Williams, and A. Wagner. 1983. Pages 29–32 in Vanishing fishes of North America. Stone Wall Press, Washington, D.C.

Parker, B. J. 1988. Status of the paddlefish, *Polyodon spathula,* in Canada. Canadian Field-Naturalist **102**:291–295.

Pavlov, D. S., Yu. S. Reshetnikov, M. I. Shatunovsky, and N. I. Shilin. 1985. Rare and endangered fish species of the U.S.S.R. and principles of their inclusion in the "Red Data Book." Voprosky Ikhtiologii **25**:16–25. In Russian.

Pavlovskaya, L. P., and I. M. Zholdasova. 1991. Anthropogenic changes in the fish fauna of the Amu Darya River (based on data from sampling drift of eggs and larvae). Voprosky Ikhtiologii **31**:585–595. In Russian.

Phelps, S. R., and F. Allendorf. 1983. Genetic identity of pallid and shovelnose sturgeon (*Scaphirhynchus albus* and *S. platorynchus*). Copeia:696–700.

Pirogovskii, M. I., L. I. Sokolov, and V. P. Vasil'ev. 1989. *Huso huso* (Linnaeus, 1758). Pages 156–200 in J. Holčík, editor. in The freshwater fishes of Europe, vol. 1, part 2. General introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Rochard, E., P. Williot, G. Castelnaud, and M. Lepage. 1991. Elements de systematique et de biologie des populations sauvages d'esturgeons. Pages 475–507 in P. Williot, editor. Acipenser. Cemagref Publishers, Bordeaux, France.

Rojas, M. 1992. The species problem and conservation: What are we protecting. Conservation Biology **6**:170–178.

Ruban, G. I., and N. V. Akimova. 1991. Notes on the ecology of the Siberian sturgeon, *Acipenser baeri,* in the Indigirka River. Voprosky Ikhtiologii **31**:596–605. In Russian.

Ruban, G. I., and L. I. Sokolov. 1986. Morphological changes in the Lena River Siberian sturgeon *Acipenser baeri* Brandt caused by its propagation in warm water. Voprosky Ikhtiologii **26**:470–475. In Russian.

Sagitov, N. I. 1983. Fishes and fodder invertebrates in the middle and lower course of the Amu Darya. Fan, Tashkent, Russia. In Russian.

Schaeffer, B. 1973. Interrelationships of chondrosteans. Pages 207–226 in P. H. Greenwood, R. S. Miles, and C. Patterson, editors. Interrelationships of fishes. Academic Press, London, England.

Schmalhausen, O. I. 1991. Development of the large Amu-Dar shovelnose larvae. Ontogenez **22**:493–513. In Russian.

Scott, W. B., and E. J. Crossman. 1973. Pages in 77–116 in Freshwater fishes of Canada. Journal of the Fisheries Research Board of Canada, Ottawa, Canada.

Semakula, S. N., and P. A. Larkin. 1968. Age, growth, food and yield of the white sturgeon (*Acipenser transmontanus*) of the Fraser River, British Columbia. Journal of the Fisheries Research Board of Canada **25**:2589–2602.

Semenov, A. D., A. G. Stradomskaya, T. S. Kishkinova, and V. G. Sofer. 1991. Character and pollution level of the Caspian Sea water in connection with the sturgeon mussel myopathy phenomenon. Page 71 in Thesis Report to the 1st International Conference on the Caspian Sea problems, Baku, Azerbaidjan. In Russian.

Sheldon, A. L. 1988. Conservation of stream fishes: Patterns of diversity, rarity, and risk. Conservation Biology **2**:149–156.

Shubina, T. N., A. A. Popova, and V. P. Vasil'ev. 1989. *Acipenser stellatus* Pallas, 1771. Pages 395–444 in J. Holčík, editor. The freshwater fishes of Europe, vol. 1, part 2. General introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Smith, T. I. J. 1985. The fishery, biology, and management of Atlantic sturgeon, *Acipenser oxyrhynchus,* in North America. Environmental Biology of Fisheries **14**:61–72.

Sokolov, L. I., and L. S. Berdichevskii. 1989. Acipenseriformes. Pages 148–149 in J. Holčík, editor. The freshwater fishes of Europe, vol. 1, part 2. General introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Sokolov, L. I., and V. P. Vasil'ev. 1989*a. Acipenser nudiventris* Lovetsky, 1828. Pages 206–226 in J. Holčík, editor. The freshwater fishes of Europe, vol. 1, part 2. General introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Sokolov, L. I., and V. P. Vasil'ev. 1989*b. Acipenser ruthenus* Linnaeus. 1758. Pages 227–262 in J. Holčík, editor. Freshwater fishes of Europe, vol. 1, part 2. General Introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Sokolov, L. I., and V. P. Vasil'ev. 1989*c. Acipenser baeri* Brandt, 1869. Pages 263–284 in J. Holčík, editor. Freshwater fishes of Europe, vol. 1, part 2. General Introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Soulé, M. E. 1985. What is conservation biology? Bioscience **35**:727–734.

Steffens, W., H. Janichen, and F. Fredrich. 1983. Erffolgreche Vermehrung von Hausen-Sterlet-Hybriden (*Huso huso* × *Acipenser ruthenus*) (Pisces, Acipenseridae). Zoologischer Anzeiger **211**:55–64.

Stoss, J. 1983. Fish gamete preservation and spermatozoan physiology. Pages 305–350 in W. S. Hoar and D. J. Randall, editors. Fish Physiology, vol. 9. Reproduction, Part B. Behavior and Fertility Control. Academic Press, New York.

Svetovidov, A. N. 1964. Pages 41–59 in Fishes of the Black Sea. Nauka Publishers, Moscow & Leningrad, Russia. In Russian.

Takeuchi, T. 1979. Description of two acipenserid fishes, *Acipenser sinensis* Gray and *A. kikuchii* Jordon et Snyder, recorded from Sagamy Bay. Annual Report of the Keikuy Aburatsubo Marine Park Aquarium **10**:20–25. In Japanese.

Threader, R. W., and C. S. Brousseau. 1986. Biology and management of the lake sturgeon in the Moose River, Ontario. North American Journal of Fish Management **6**:383–390.

Thuemler, T. F. 1985. The lake sturgeon, *Acipenser fulvescens,* in the Menominee River, Wisconsin-Michigan. Pages 73–78 in F. P. Binkowski and S. I. Doroshov, editors. North American sturgeons: Biology and aquaculture potential. Dr. W. Junk, Dordrecht, The Netherlands.

Tleuov, R. T., and N. I. Sagitov. 1973. Chondrosteans of the Amu Darya. Fan, Tashkent, Russia. In Russian.

Tortonese, E. 1989. *Acipenser naccarii* Bonaparte, 1836. Pages 284–293 in J. Holčík, editor. The freshwater fishes of Europe, vol. 1, part 2. General introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Trautman, M. B. 1957. The fishes of Ohio, with illustrated keys. Ohio University Press, Columbus, Ohio.

Tsepkin, E. A. 1986. A short review of the Quatenary fresh water ichthyofauna of the Asian part of the U.S.S.R. Voprosky Ikhtiologii **26**:367–373. In Russian.

Tsepkin, E. A., and L. I. Sokolov. 1971. On the maximal size and age of some sturgeon fishes. Voprosky Ikhtiologii **11**:541–542. In Russian.

Tsepkin, E. A., and L. I. Sokolov. 1990. Main results of investigation of the Quaternary fossil ichthyofauna of the continental fresh waters of the U.S.S.R. Voprosky Ikhtiologii **30**:885–890. In Russian.

U.S.S.R. Red Data Book. 2nd edition. Vol. 1. Moscow, Lesnaya Promyshlennost. 1984. In Russian.

Vane-Wright, R. I., C. J. Humphries, and P. H. Williams. 1991. What to protect? Systematics and the agony of choice. Biological Conservation **55**:235–254.

Veprintsev, B. N., and N. Rott. 1979. Conserving genetic resources of animal species. Nature **208**:663–634.

Vladykov, V. D., and J. R. Greeley. 1963. Order Acipenseroidei. Pages 24–60 in H. B. Bigelow and W. C. Schroeder, editors. Fishes of the Western North Atlantic. Memorial Sears Foundation for Marine Research, vol. 1, Yale University, New Haven, Connecticut.

Vlasenko A. D., A. V. Pavlov, and V. P. Vasil'ev. 1989*a*. *Acipenser gueldenstaedti* Brandt, 1833. Pages 294–344 in J. Holčík, editor. The freshwater fishes of Europe, vol. 1, part 2. General introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Vlasenko, A. D., A. V. Pavlov, and V. P. Vasil'ev. 1989*b*. *Acipenser persicus* Borodin. 1897. Pages 345–366 in J. Holčík, editor. The freshwater fishes of Europe, vol. 1, part 2. General introduction to fishes. Acipenseriformes. AULA-Verlag, Wiesbaden, Germany.

Votinov, N. P., and V. P. Kas'yanov. 1974. The status of the sturgeon *Acipenser baeri* Brandt resourses in the Siberian rivers and measures for their reproduction. Voprosky Ikhtiologii **14**:796–805. In Russian.

Whittingham, D. G., and H. Rosenthal. 1978. Attempts to preserve herring embryos at subzero temperatures. Archiv für Fischereiwissenschaft **29**:75–79.

Williams, J. E., and G. H. Clemmer. 1991. *Scaphirhynchus suttkusi,* a new sturgeon (Pisces: Acipenseridae) from the Mobile Basin of Alabama and Mississippi. Bulletin of the Alabama Museum of Natural History **10**:17–31.

Williams, J. E., E. J. Johnson, D. A. Hendrickson, S. Contreras-Balderas. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries **14**:2–20.

Williot, P., and R. Brun. 1983. Résultats sur la reproduction de *Acipenser baeri* en 1982. Bulletin Francais de Pisciculture **55**:19–22.

Yakovlev, V. N. 1977. Phylogenesis of the Acipenseriformes. Pages 116–146 in: Essays on phylogenesis and systematics of fossil fishes and agnathans. Nauka Publishers, Moscow, Russia. In Russian.

Zhang, X. S., L. Zhao, and T. C. Hau. 1987. Cooling of embryos from the common carp *Cyprinus carpio* to—196°C. Journal of the Shanghai Institute of Mechanical Engineering **9**:15–23.