STURGEONS AND CAVIAR

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Summary

The Acipenseriformes includes 2 families: Polyodontidea (paddlefish, 2 extant species), and Acipenseridae (sturgeon, 25 extant species). They exist since 200 MY (Lower Jurassic) and live in the Northern Hemisphere. Half of the species are in Europe mostly in the Ponto-Caspian Region, one third in North America, and the rest in East Asia and Siberia. Their phylogeny is now well augmented, both by morphological, and molecular data, which are in general congruent. Most of the Acipenseridae live on the bottom and eat benthic organisms, and demersal fish at the adult stage. One representative of the Polyodontidea the American paddlefish living in freshwater feeds exclusively on plankton and suspended particles in the water column. Acipenseriformes reproduce in freshwater and most of them migrate to brackish waters (Caspian, Azov and Black seas), sometimes in full seawater in the ocean continental shelf. Usually puberty occurs late (5–30 years of age) and adult females do not spawn annually. Adults continue to grow and some species such as the beluga have reached 100 years and 1000 kg. in historical times. The stocks of sturgeons are dramatically decreasing particularly in

Eurasia; the world sturgeon catch was near 28 000 t. in 1982 and less than 4000 in the year 2000. This was the result of: 1) Damming rivers preventing upstream migration to the spawning grounds and regulating the water flow which become unfavorable to migration and reproduction; 2) Over fishing, often via poaching, due to the high demand of caviar (production of 260 t. in 1998); and 3) The effects of pollution of water and sediment, which is severe for sturgeon due to their benthic feeding behavior resulting in alteration in the structure of gonads and muscles. As a result all of the species are threatened and several are on the verge of extinction. Several protection measures have been taken. Juveniles stocking was intensively practiced in the former USSR and still continue now but to a less extend. All of the sturgeons are on the 1996 IUCN red list of threatened animals and all of the sturgeon products, including caviar, are now under the CITES regulation. Attempts are presently made to produce caviar from farmed sturgeons.

1. Introduction

A strong interest is now focused on Acipenseriformes, *i.e*. sturgeons (Acipenseidea), and paddlefish (Polyodontidea) as they are endangered species, and also for their breeding for meat, caviar, and occasionally for aquariums. Presently 27 extant species are recognized; they all live in the Northern Hemisphere (see Appendix 1 and Table 1). Most of the Acipenseriformes in the world are now endangered due in large part to overfishing (particularly because of the strong demand for rare and highly priced caviar), alteration of habitat (damming and changes in the water regime in the rivers), pollution, and no strict regulation (see *Adjustment of Institutions and Allocation of Use Rights*). There is now some evidence that females at their first reproduction and even at an immature stage are captured in most of the European sturgeon distribution area. One preservation approach widely used in the former Soviet Union was the stocking of juveniles produced in hatchery from wild brood fish but their efficiency has never been measured precisely. It is clear that a way to prevent, at least partly, this over fishing is to set up, and implement, international regulations such as the recently established CITES listing and even a total ban on fishing for critically endangered species, and on caviar trade (see Appendix 2). This would be acceptable if alternative ways of caviar production are offered; one of them is to produce caviar of satisfactory quality from cultivated sturgeon species as already achieved in several countries (USA, Italy, and France). Non-gastronomic uses of the sturgeon exist such as ichtyoglues (this name of ichthyoglue was attributed to *H. huso*). There are reports that the Russians and the Tartars dry the skin of *H. huso* and use it as windows' glass.

There has been during the last few years a strong development of research; four international conferences were held since 1990, and numerous reviews of the literature were published. Significant contributions were also made on systematics as well as on the needs for conservation. It should be pointed out that the knowledge on the sturgeon was already vast at the end of the nineteenth century; several memoranda published at that time reported the available information for the North American continent with data on the techniques of artificial reproduction and processing (fillets, flaying the skin, and caviar processing). The first artificial insemination of a sturgeon occurred in 1869 in Russia.

Species	Ref (1)	Synonyms	Geographic distribution	Environment (2)	Sub-species, populations	maximum length (m)	maximum weight (kg)	Status (3)	Stocking
A. baerii	(100)	10	Siberia, Arctic	f b	*A. b. baicalensis;*	3	200	EN/VU	++
					A. b. stenorrhynchus				
A. brevirostrum		6	From Florida to	f		1.5	45		+
			New-Brunswick						
A. dabryanus		0	China	f			750	CR	
			Yang Tse, Korea						
A. fulvescens		28	Great Lakes and	f b		2.4	140	VU	++
			Lakes of South Canada						
A. gueldenstaedtii	(240)	7	Caspian, Black	s d f	*A. g. tanaica; A. g.*	2.3	100	EN	+++
			and Azov Seas		*colchicus*				
A. medirostris		6	N.E. Pacific	s		2.0	160	VU	
A. mikadoi			N.W. Pacific	s		2.0		EN	
A. naccarii	(29)	0	Adriatic, Pô	f s				VU	(+)
A.nudiventris	(65)	6	Caspian, Black and Azov (Aral) Seas	s	isolates in Caspian Sea	2.0	127	EN(5)	+++
A. oxyrinchus		12	Gulf of Mexico	s	*A. o. desotoi;*	4.2	367	LR/VU	+
			Hamilton/Fundy		A. o. *oxyrinchus*				
A. persicus	(70)	5	Caspian Sea	s	*A. p. persicus,*	2.4	70	VU/EN	
			Black Sea		*A. p. colchicus*				
A. ruthenus	(130)	15	Europe, ex USSR	f b	*A. r. n marsigli;*	1.1	16	VU	
			Caspian, Black, Azov		*A. primigenius*				
A. schrenckii		3	Amur River,	f b		2.9	200	EN	
			Okhotsk & Japan Seas	(b)					
A. sinensis		0	Yang Tse, Min Lia-	s		>2	550	EN	
			ho, Korea, Japan						
A. stellatus	(180)	9	Black, Caspian,	ss	Ural Volga,	2.2	80	EN/VU	+++
			Azov Seas		Kuhn, Don, Danube				
A. sturio	(120)	6	Europe (North Africa)	s (f)	Biscaye, Cadix ?	5.0	500	CR	(+)
A. transmontanus		I	N.E. Pacific	s b	autumn race	6.1	816	LR/EN	+

				f	spring race				
H. dauricus		3	Amur Riv., Japan	f b	freshwater ;1/2 anadromous morphs	5.6	1000	EN	
H. huso	(140)	10	Black, Caspian, Azov, Adriatic Seas	s	Several geographic races	8.5	1300	EN/CR(4)	
P. hermanni		0	Aral,Amu-Darya	f (s)		0.27		CR	
P. fedtschenkoi		0	Syr-Darya	f (s)	3 morphs	0.27		CR	
P. kaufmanni		0	Aral, Amu-Darya	f (s)	Common & dwarf forms	0.37	2.5	EN	
S. albus		0	Mississippi, Missouri	f		1.8	3.0	EN	
S. platorynchus		0	Mississippi,Missouri	f		0.9	2.5	VU	
S. suttkusi			Alabama, Mississippi			0.8	2.3	CR	
Polyodon spathula		0	Mississippi basin	f		2.5	100	VU	
Psephurus gladius		0	Yangtse	f		4		CR	

(1) Number of references quoted for European species in Holcik (1989),
(2) f: live entirely in freshwater, a/s : amphyhaline with growth phase in the sea in full sea water (s) or in brackish water (b),
(3) IUCN listing 1996 proposal, Birstein 1997 EX : extinct, CR : critically endangered, EN : endangered, VU : vulnerable, LR : low risk, T : treathened, SC : special concern,
(4) Extinct in the Adriatic Sea,
(5) Exctint in the Aral Sea

Table 1. The extant species of the Acipenseriformes.

The sturgeon appears in art. A sturgeon was identified on the mosaic of the temple of Fortune in Penestre (Ancient Greece) and a sculpture representing a fisherman carrying a sturgeon on his back is reported in the church of Saujon in Saintonge (France); this fact is interesting to point out because fish are rarely represented in church sculptures. Sturgeons are also found on coins and appear in paintings and pictorial art; D. Cordelier from the Louvre Museum showed interest in a drawing of Pisanello (1395–1445) representing a fish whose head is one of a sturgeon but the body is one of another fish.

Sculptures of sturgeons are also found in public areas. Naturalized sturgeons exist in most of the Science Museums of towns located on rivers where the sturgeon lived or still does live.

A lot of stories, myths, and legends exist about the sturgeons, for instance stories on their abundance as on salmon that the farm-servants didn't want to eat more than twice a week. It was said, that in the Hudson River, it was difficult to row without hitting a sturgeon or that just one head of a sturgeon can give a ton of oil.

2. General Morphology

The main characteristics of the Acipenseriformes are a skeleton, which most parts are cartilaginous, the persistence of a notochord, a spiral intestinal valve, and a skull, which is cartilaginous but covered by bony plates. The caudal fin is mostly heterocercal, (which means asymmetrical, generally with a continuation of the spinal cord in the most developed superior lobe). A spiracle or a vent-hole (orifice at the upper part of the pre-opercular bone from which the water is expelled) is generally well developed, and associated with pseudo-branchiae (not found in every group).

The form of the vertebra doesn't show, on the central part, any deformities, and the hemispherical projections found in teleosts. The pre-maxilla and the maxilla bones are joined together but the upper jaw is not attached to the skull. The body is long, spindle shaped; the pelvic-abdominal region is without a true spine; notochord persistent, extending to the upper lobe of the tail; and the gaz bladder, when present, is connected to the pharynx.

Sturgeons, which live on the bottom, have a ventral flat base; they mostly eat benthic organisms as well as fish and they are provided with tactile barbels located in front of the mouth, which is "pro-tactile" with thick lips. Their "digging" behavior furthers the existence of a rostrum. The section of the body is pent-angular; it is characterized by the frequent presence of bony dermic plates (scutes), in 5 rows.

Paddlefish, which live in the water column, eat plankton, and substances in suspension found in mid-water, and show a large mouth without anterior barbels. They have a very long snout dorsoventrally flattened to a paddle shape. No row of bony scutes. Some of these characters can be considered as primitive but they are rather the result of regression: reduction of ossification, absence of teeth and branchiostegal rays. At the same time highly specialized characters (rostrum, ventral mouth, barbels) are present. Sturgeons, because of their peculiar morphology, their large size, for most of them, and wide distribution range were identified, and named in many languages.

3. Systematics

The sturgeons' form the group of the Chondrostei gathered up in several families of the Acipenseriformes. They have existed at least since the Lower Jurassic (200MYBP) in England and in Germany (Chondrosteidae) and the Upper Jurassic/Lower Cretaceous in China (Peipiaosteidae). The Acipenseriformes are routinely divided into two main families, the Polyodontidea and the Acipenseridae and the number of species that are most commonly recognized is seventeen *Acipenser*, three *Pseudoscaphirhynchus*, three *Scaphirhynchus*, two *Huso*, one *Polyodon*, and one *Psephurus* (see Table 1). A phylogenetic tree is shown in Figure 1.

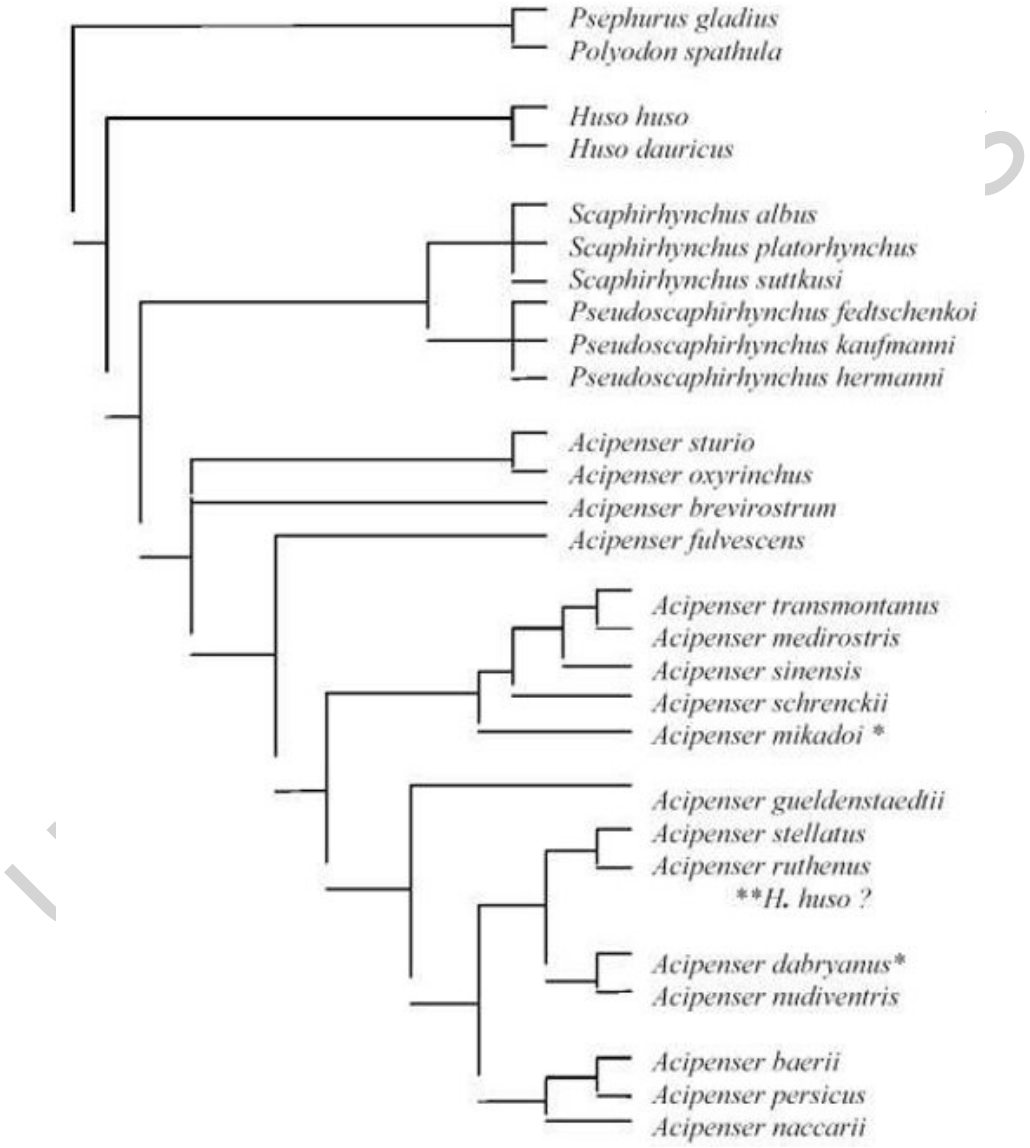

Figure 1. Consensus tree showing possible relationships among Acipenseriformes by Bemis and Kynard in Birstein et al. 1997. When possible, multifurcations were resolved following statistically supported nodes from the molecular analysis of Birstein and DeSalle (1998). * Alterations made from recent molecular data by G. Lecointre. ** Molecular data show that *Huso huso* falls in the group *A.S./A.R.*

The Polyodontidea (paddlefish) do not show rows of shields but are totally covered by small scutes and have a long rostrum (spatula), which flattens itself and widens at its extremity. The Polyodontidea family has two genera: *Polyodon* with only one species, the American paddlefish *P. spathula* living in fresh water in the eastern region of Northern America (Mississippi), and *Psephurus* with the Chinese paddlefish *P. gladius* living in the Chang Jiang (Yangtse) River in China. The gill rakers of the Chinese paddlefish are shorter and less numerous than those of the *American paddlefish.*

The Acipenseridae (sturgeons) have a rostrum, but it is shorter than that of the Polyodontidea; they are provided with 5 longitudinal rows of well-developed scutes, one dorsal, two lateral, and two ventral; spikes on the scutes are sharp in the young, and blunt in the adults. The number of scutes is discriminating for certain species. The skin is also covered with bony plates; the first ray of the pectoral fin is transformed into a spine. The lower jaw is protractile, and the adults have no teeth; it is surrounded by thick lips and has a row of 4 barbels in front of the mouth. The number of gill rakers is reduced; the branchiostegal bone (located under the lower jaw in teleost fish) is absent. The gills are covered by a thick bone; the sub-operculum, and the classic opercular bones of bony fish are, either diminished (pre-operculum), or absent (inter-operculum or operculum).

The Acipenseridae are divided into two sub-families. The Scaphirhynchines have a rostrum slightly flattened into a spatula with sharp edges, they do not have any vent-hole (spiracle) and a long and thin strand extends the upper lobe of the caudal fin. Two genera have been identified *Scaphirhynchus* and *Pseudoscaphirhynchus*. *Scaphirhynchus* is characterized by fringed barbels and by its long caudal peduncle entirely mailed or armored (which means totally covered with bony plates), with a long anal fin whose extremity reaches the caudal base. Three species of this genus exist: the Shovelnose sturgeon *S. platorynchus*, the pallid sturgeon *S. albus*, and the Alabama sturgeon *S. suttkusi*. *Pseudoscaphirhynchus* shows a caudal peduncle not entirely covered by shields, a short anal fin that doesn't reach the base of the caudal fin, and either smooth barbels or partly fringed. The Acipenserines have a conical rostrum more or less pointed with rounded edges, a well-developed spiracle, and a caudal fin with no strand. Two genera are acknowledged: *Huso* having a large mouth that opens up towards the back with the shape of a crescent, a branchial membrane unattached to the lower jaw and *Acipenser* having a smaller mouth, transversal, and rectilinear, and whose branchial membrane is attached to the isthmus.

4. Biogeography and Way of Life

Acipenseriformes live exclusively in the northern hemisphere (paddlefish are only found in North America, and in Asia) (see Figure 2). Certain species stay in fresh water all their life, others migrate in brackish water, some, less numerous, go up to full seawater whilst staying on the continental shelf; paddlefish are primarily freshwater animals.

All Acipenseriformes reproduce in freshwater. Their life cycle is generally quite long with a late puberty. Certain species can reach up to 100 years of age and, up to one ton of weight (sturgeons are among the biggest fish encountered in fresh water). Specimens

of one tone do not exist anymore but fish of more than 100 kg. are still found. Some ichthyologists like Belon and Artedi have recognized the European catfish *Silurus glanis* as a large sturgeon. Also the European sturgeon *Acipenser sturio* was named *Silurus* in Egypt in the Nile. It should be mentioned that the general term "Silure" meant large fish in Greek and roman times. Such big size and continuous growth (see Figure 3) allows them to live in the waters of large rivers, which represents an original ecological niche; not used by smaller sized species. Also considering their size and the niche, large sturgeons have no predator with the exception of man. Even the fertilized eggs flowing at high speed in the strong current in the middle of large river cannot be caught by other fish or predators.

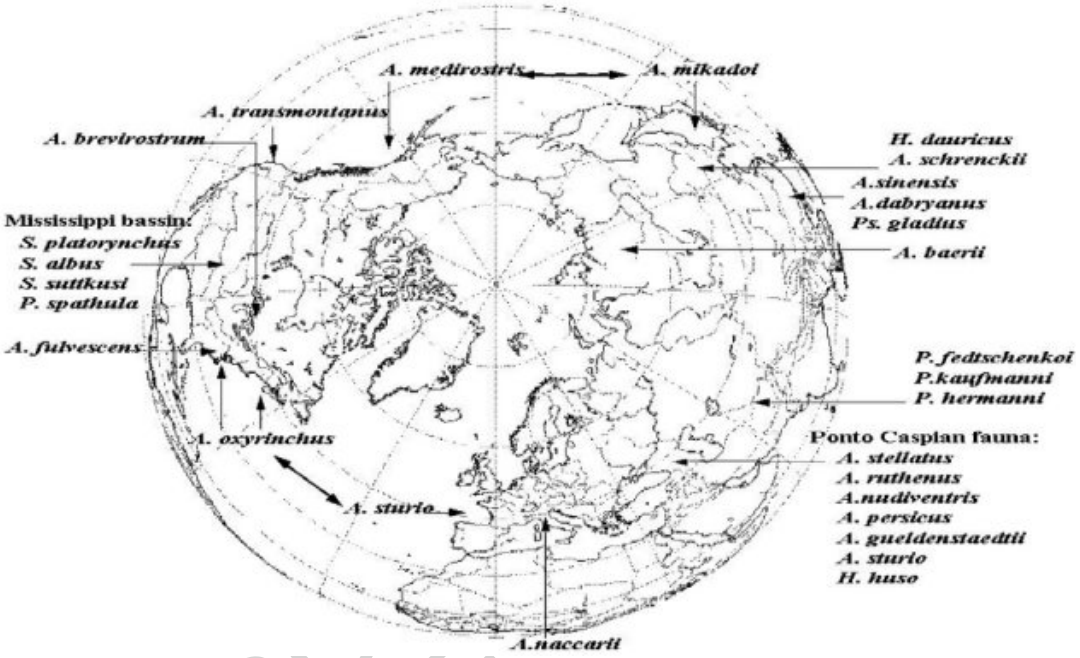

Figure 2. Geographic distribution of extant sturgeon species.

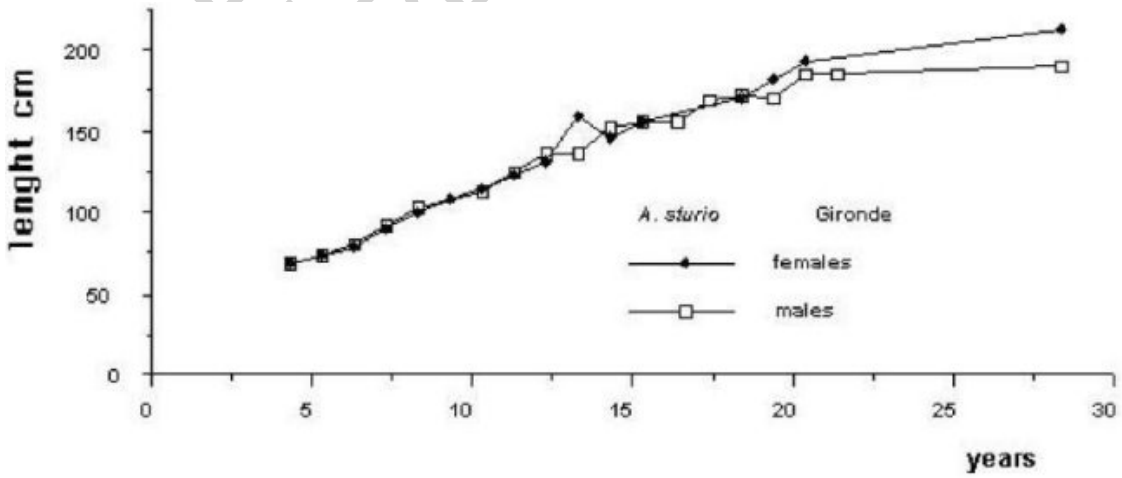

Figure 3. Growth in length of the European sturgeon *Acipenser sturio* in La Gironde, France(After Magnin 1962).

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Biographical Sketch

Roland Billard was born in 1934 in France, and graduated from Lyon University in 1965. He received his Doctorat d'Etat at the Paris P & M. Curie University. He has worked as Assistant and Director of research at the National Institute of Agronomic Research (INRA) and was Director of the Fish Physiology Laboratory in this institute from 1970 to 1984. Since 1986 he is Professor at the Muséum National d'Histoire Naturelle in Paris and Director of the Laboratory of General and Applied Ichthyology. His main research interest is fish reproduction, spermatogenesis (structural and quantitative aspects, endocrine regulation) and physiology of spermatozoa with application to the control of reproduction and spawning, gamete preservation and artificial insemination. He also showed interest on the production systems in aquaculture. He has published more than 300 scientific articles and 200 technical papers and published or edited a dozen books. He is a member of the French Academy of Agriculture, foreign member of the Romanian Academy of Agriculture, and a member of the Academia Georgofilli (Italy).