Sturgeons in the Danube River

Biology, Status, Conservation

Literature study by Ralf Reinartz

conducted on behalf of

International Association for Danube Research (IAD)
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November 2002

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Abstract

This literature study focusses on the autochthonous sturgeon species of the Danube River and the north-western Black Sea. Some basic information on the Danube River Basin as well as main anthropogenic impacts are given (2 The Danube River). The general biology of the order of Acipenseriformes (3 Sturgeons and Paddlefishes) as well as peculiarities in the ecology of these species are important for the understanding of sturgeon specific issues in the Danube River (3.1 Danubian sturgeon species / 9 Annex: Species information on Danubian sturgeons). Out of six acipenserid species that were once native to the Danube River Basin, only four still reproduce in the Lower Danube River (*A. gueldenstaedti*, *A. ruthenus*, *A. stellatus*, *H. huso*). *A. sturio* and *A. nudiventris* have possibly become extinct, while the stocks of the anadromous species *A. gueldenstaedti*, *A. stellatus* and *H. huso* have been drastically decreasing in the Lower Danube River, as documented by catches. Catch statistics in riparian countries are confusing, since different databases exist and the extent of poaching is unknown. Sturgeon fishery still subsists in the Lower Danube River, although catches have been declining since the beginning of the 20th century (4 Sturgeon catches in the Danube River and their commercial importance).

In the Upper and Middle Danube River and a number of tributaries, migratory sturgeons have become extinct, due to overfishing in past centuries, as well as by disruption of their spawning migrations into the Middle Danube River by the Iron Gate hydroelectrical dams I and II in 1972 and 1984 (5 Sturgeon conservation / 5.1 Threats to sturgeon stocks in the Danube River). A remnant population of the resident form of *A. gueldenstaedti* still exists upstream of Iron Gate dams. The location of spawning sites of migratory species in the Lower Danube River under the changed migratory conditions, the exact status of stocks and their reproduction is still unknown.

Stocks of the only true potamodromous sturgeon species in the Danube, the sterlet (*A. ruthenus*), depend on stocking in the Upper Danube River. Due to increasing water quality, temporary protection and stocking measures, sterlet stocks have been increasing in the Middle Danube. In the Lower Danube, the reserves of the sterlet have been reduced to a minimum.

Different approaches have been applied for the conservation of sturgeon stocks worldwide (5.2 Recovery and conservation measures). Stocks of migratory sturgeons in the neighboring Azov and Caspian Seas were maintained by stocking of hatchery reared juveniles. Although the release of these juveniles contributed significantly to numbers, populations could not be stabilized by stocking. Lack of hatchery funding, natural reproduction and an increase in fishing and poaching have led to a collapse of sturgeon stocks in these waters. The artificial propagation of Acipenserids is widely established in Europe and also in Danubian countries.

Stocking of sturgeons into the Danube River or the Black Sea was conducted sporadically in single countries and depends on the catch of spawners from the river.

New techniques allow the tracking of individual fish (telemetry and ultrasonic tagging) and thus the identification of key habitats. Fishpasses for sturgeons are in operation in the former U.S.S.R. and North-America. Standard solutions for passing sturgeons at dams are not available, however.

In addition new methods in sturgeon genetics allow the identification of caviar and individuals as well as the characterization of populations for management purposes (5.3 Sturgeon genetics). Possibilities for the conservation and restoration of sturgeon stocks in the Danube River are pointed out on the basis of literature and information provided by experts (6 Summary and conclusions).

1 Introduction

Sturgeons are endangered throughout the world and drastic decreases of stocks have to be observed. Especially in the Ponto-Caspian region, there is an increased demand for new knowledge of the biology and ecology of these species.

Although a lot of literature on sturgeons exists, many questions concerning Danubian sturgeons still remain unanswered. Thus, this review, conducted on behalf of IAD (International Association for Danube Research), Bezirk Oberpfalz and Landesfischereiverband Bayern e.V. was initiated in August 2001 to take advantage of synergistic effects between these organisations. The literature study is aimed at providing an overview of the historic and current status of sturgeon stocks in the Danube River, as well as their commercial value and the activities conducted for their conservation. Apart from published literature, information was obtained through researchers and the internet.

This review is a milestone for gathering further facts on the matter and providing information for anyone working on or with sturgeons in the Danube River Basin. It provides a better understanding of the biology and ecology of this ancient and fascinating group of fishes and may help to support preservation of this valuable resource for future generations living on the banks of the Danube River.

2 The Danube River

2.1 The Danube River Basin

Informations on the Danube were comprised by LIEPOLT (1967); ZINKE (1999); KHAITER et al. (2000); THE REGIONAL ENVIRONMENTAL CENTER FOR CENTRAL AND EASTERN EUROPE and ANONYMOUS e as follows.

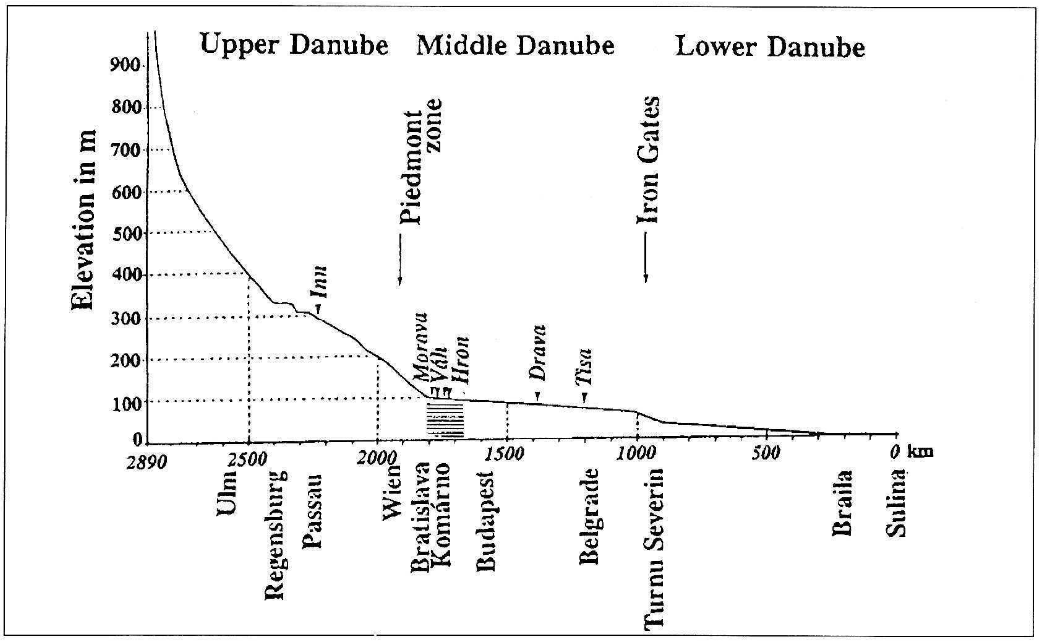
The Danube River has a total length of 2,780 kilometres and flows along or through 10 countries (Germany, Austria, Slovakia, Hungary, Croatia, Federal Republic of Yugoslavia, Bulgaria, Romania, Moldova and Ukraine). Its drainage area amounts to 817,000 square kilometres and includes large parts or entire territory of 14 states (in addition to the countries mentioned above: Switzerland, Czech Republic, Slovenia and Bosnia-Herzegovina) and touches with small areas another 3 countries (Italy, Poland, Albania). About one third of the Danube River Basin is mountainous, while the remaining two thirds consist of hills and plains. Also the climate is very diverse; influence of Atlantic climate in the western part of the upper basin, Mediterranean through Drava and Sava River Basins, while the rest has a Continental climate (from atlantic and even sub-mediterranean to continental-steppe). The annual precipitation is from about 2,000 mm per year in the high regions to 500 mm per year in the plains. Evaporation is important for the water balance in the catchments. In lower regions the mean annual evaporation varies between 450 and 650 mm. The mean altitude of the river basin is only 475 metres but the maximum differences in height between the lowland and Alpine peaks is over 3,000 metres. At its delta the discharge varies from 1,610 $m^3 s^{-1}$ to 15,540 m^3/s (average 6,550 m^3/s). The natural flow regime is strongly influenced by hydraulic structures and intensive water use in the basin.

Table 1: Key characteristics of the Danube River at different gauging stations

	Gauging station	Stream location River km	Catchment area [km^2]	Mean discharge [$m^3 s^{-1}$]
Upper Basin	Bratislava	1,869	131,338	2,020
Middle Basin	Orsova	955	576,232	5,699
Lower Basin	Ceatal Ismail	72	807,000	6,550

The river slope varies a lot: in the upper reach it is between 1 ‰ and 0.2 ‰ in the middle reach it decreases to 0.06 ‰, through the Carpathians is increased to 0.32 ‰ and then down to the delta it is less than 0.01 ‰.

Fig. 1: Gradient diagram of the Danube River with the piedmont zone (westernmost floodplain) highlighted by horizontal lines, and some main tributary entries by triangles (modified from BALON & HOLČIK 1999)



The Danube River has about 300 tributaries, of which 30 are navigable. The largest tributaries are the Inn River (at the Austro-Bavarian border, average discharge 745 $m^3 s^{-1}$), the Drava River (Croatian-Hungarian border, average discharge 578 $m^3 s^{-1}$), the Tisza River (largest sub-basin with 149,000 km^2 and an average discharge of 814 $m^3 s^{-1}$) and the Sava River (mouth at Belgrade, average discharge 1,613 $m^3 s^{-1}$).

The Danube River Basin can be divided into four sub-regions: the Upper, the Middle, the Lower basin and the Danube Delta. The Upper Basin extends from the source (Germany) to Bratislava (Porta Hungarica), the capital of Slovakia. Major tributaries here from the south are the Rivers Iller, Lech, Isar, Inn, Traun, Enns, and from the north the Rivers Altmühl, Naab, Regen, Kamp and Morava.

The Middle Basin is the largest and comprises the part from Bratislava to the Iron Gate dams on the Serbian-Romanian border. The major tributaries in this region are from the left the Rivers Vah, Hron, Ipel and Tisza (the largest tributary in the whole basin), and from the right the Rivers Leitha, Raba, Sio, Drava, Sava and Velika Morava. At Moldova Veche in the Balkan Mountains the 117 kilometres long gorge section of the Iron Gate begins which is filled by large reservoirs for hydropower and navigation.

The Lower Basin is formed by the Romanian-Bulgarian lowland and its upland plateaus and mountains. Here the Danube River flows as a wide (800 metres), slowly moving river with well developed alluvial plains. Much of the sediment load of the Danube River is deposited behind the Iron Gate dams, resulting in severe riverbank erosion in this downstream river plain. The important tributaries in this region are from the south the Rivers Timok, Iskar, Ossam and Yantra, and from the north the Rivers Jiu, Olt, Arges, Ialomita, and, most importantly, Siret and Prut.

The Danube Delta covers an area of about 600,000 hectares. It was created by the division of the river into three main branches, forming a triangle with about 70 km long sides. Almost two thirds of the delta area is seasonally submerged. The Romanian part of the delta was declared a Biosphere Reserve in September 1990 and also registered under the Ramsar Convention. Over half of the Delta area is listed under World Heritage Convention. Only about 10 % of the Ukrainian part of the delta is protected and the rest being used for agriculture.

2.2 Major anthropogenic impacts

The first efforts in river works were aimed at flood control and protection (ice flows) and at improving and securing navigation. By the end of the 19th century the Danube River had been severely changed through various river regulation works. In Bavaria, the 400 km long floodplain section was shortened by 21 % and nowadays less than 25 % of the Bavarian Danube River is still free flowing. Major changes in Austria were tow paths along the river and a 25 km long straight channel near Vienna, built after 1850. In Hungary protection works against floods were already started in the 16th century. Similar activities took place in the Yugoslavian Vojvodina and on the Drava and Sava Rivers in the 19th century.

Large-scale draining projects were conducted in Hungary, where in the 19th and 20th century some 3,700,000 ha of permanently or seasonally inundated areas were dyked in (4,000 km of dykes at a total river length of 2,800 km).

Shortcutting meanders and further straightening works reduced the length of rivers (from 494 km to 417 km in the Hungarian Danube River and 1,419 km to 966 km in the case of the Tisza River). As a result, low water levels decreased and flood peaks increased.

Intensive networks of dykes as well as drainage and irrigation systems were installed in various lowlands throughout the basin. The most important areas are the lower Tisza and Lower Danube Rivers with the Danube Delta. In Bulgaria about 72,000 ha of floodplain were dyked between 1930 and 1950, and in Romania in the 1960s and 1970s, 80 % (435,000 km^2) of floodplains were disconnected from the Lower Danube River to intensify agricultural production (agriculture as well as pond aquaculture). In the delta, the Sulina arm was made navigable for large sea vessels between 1857 and 1902.

Navigation is a traditional activity on the Danube River and supported the economic development in the riparian countries. In 1972, the Iron Gate dam I was completed, in 1984 the Iron Gate II dam was added, faciliating navigation through the gorge by way of shiplocks.

Most rivers in the Danube River Basin are developed by dams, nowadays. Only remnants of intact free-flowing sections are left today, such as the Danube River between Straubing and

Vilshofen, the Wachau and the section between Vienna and Bratislava, the Austrian Lech River, the lower Mura and Drava Rivers. River engineering works during the last decades have altered the flow and sediment regime considerably. Also furcation and meander zones were canalised resulting in:

- interrupted sediment transport, downstream of dams bed deepening and river bank erosion,
- changed hydrology,
- aggravation of flood hazards,
- reduced self-purification capabilities,
- blocking of longitudinal and lateral migrations of aquatic organisms,
- losses in biodiversity.

Table 2 provides an overview of major hydraulic structures in the Danube River and its tributaries.

The first hydropower plant on the Danube was built in 1927 at Vilshofen (Bavaria). Hydropower utilisation varies substantially from country to country (for example Hungary 28 MW = 0.6 % of national power generation; Romania 5,200 MW = 30 % of national power generation; Austria 14,200 MW = 70 % of national power generation. Iron Gate or Djerdap (Derdap) hydropower stations are the largest single hydropower dam and reservoir system along the entire Danube River. It is a peak operation system with two dams, jointly operated by Romania and Serbia (average Danube flow: 5,500 m^3 s^{-1}, overall drop: 34 m; installed capacity: 1,266 MW, annual production: 6,490 GWh).

The dams are also a non surmountable obstacle for migratory fishes. The next upstream and second largest is Gabcikovo-Nagymaros, one of the most disputed river works in Europe within the international and scientific community (SPINDLER & KECKEIS 1993; KIRKA b; NAGY 1996; CERNY & KVASZOVA 1998; GUTI 1998 a; BALON & HOLČIK 1999; STEC 1999; KERN & ZINKE 2000; HOLČIK; CARBIENER & KERN; TED CASE STUDIES d).

Table 2: Major Hydraulic Structures and Description of Rivers in the Danube Basin (from THE REGIONAL ENVIRONMENTAL CENTER FOR CENTRAL AND EASTERN EUROPE)

River (Country)	Total length of the river rkm-rkm (from source to mouth)	Total Free-flowing sections rkm-rkm	Total regulated sections rkm-rkm	Total impounded sections rkm-rkm	Total Navigable sections rkm-rkm	Number of dams/ reservoirs	Number of dams/ reservoirs > 15 m	Number of Hydropower dams
Danube D	2,780 – 2,200	183	139	332	2,411-2,200	49		27
Danube A	2,200 – 1,873				2,200-1,880	9		
Danube SK	1,880 – 1,700				1,880 – 1,700	2	1	2
Danube H	1,850 – 1,433	417	383	8	1,850 – 1,433	1		
Danube HR	1,433 – 1,300							
Danube YU	1,433 – 845	1,433-1,215	414		1,433-845	2	1	2
Danube BG	845 – 375			0	845- 374	0	0	0
Danube RO	1,075 – 0		863	212	1,075 - 0	2/2	2/2	2
Danube MD	145 – 144		1		145-144			
Danube UA	144 – 0	144	25 km	None	144 - 0	6 lakes/ reservoirsalong the main river bed		
Iller (D)	147	58	44 (diverted)			15		
Lech (A)	82	67	12 km	3 km		2		
Lech (D)	167,5	15		153,5	/	32	3	29
Naab (D)	98	98						
Isar (D)	263,3	59	86 (+ 55 diverted)	63		10	1	10
Inn (A) including Austrian-Bavarian border stretch	277	70	133 km	74 km		4		
Inn (D)	217,6	22		195,6	/	15		15
Salzach (A)						11		
Traun (A)	120 km	40	40 km	40 km	/	4		
Enns (A)	250 km	123	30 km	97 km		14		
March (A)	66 km	66	0	0				
Morava (CZ)	354-271,6	100	183		28	27	0	8
Dyje (CZ)	207	136,5	71	57	0	31	2	3
Svratka (CZ)	171	130	41	21	0	30	2	3
Raba (A, H)	211-0	200	81	11				
Vah (SK)					71-0			
Bodrog (SK, H)					65-50			
Hron (SK)								
Ipel (SK, H)	172-75; 43-0	140	77					
Sio (H)	121-0	121	92		Balaton-Danube			
Mura (A)						13		
Mura (SLO)	44	51						
Mura (HR)		46						
Mures (H)	50-0	50	25		25-0			

Table 2 (cont.): Major Hydraulic Structures and Description of Rivers in the Danube Basin (from THE REGIONAL ENVIRONMENTAL CENTER FOR CENTRAL AND EASTERN EUROPE)

River (Country)	Total length of the river rkm-rkm (from source to mouth)	Total Free-flowing sections rkm-rkm	Total regulated sections rkm-rkm	Total impounded sections rkm-rkm	Total Navigable sections rkm-rkm	Number of dams/ reservoirs	Number of dams/ reservoirs > 15 m	Number of Hydropower dams
Drava (A)	264	104	20	140		12		
Drava (SLO)		0	142		0 - 150			
Drava (HR)			95					
Drava (H)	237-228, 199-70	138	104		128			
Sava (SLO)		126	92					
Sava (HR)	207 – 725				0-593			
Tisa (RO)	79-140	19	42	-	-	-		
Tisa (H)	745 – 160	472	450	57	685 - 160			
Somes (H)	50 – 0	50	42					
Somes (RO)	0 – 376	248,5	127,5	-	-	-		
Körös (H)	138 – 0	37	126	101	115 - 0			
Crisul (RO)	0 – 234	147,5	82	0	-	-	-	
Mures (RO)	0 – 761	682	79	-	-	4		
Hernöd (SK, H)	118 – 0	104	65	14				
Sava (B & H)	563 – 207	92	264 km		356 (rkm 563 - 207)			
Drina (B & H)	346 – 0	214 km (346-290 rkm, 200-116 rkm, 92 - 18 rkm)	18 km (rkm 18 - 0)	114 km (rkm 290 - 200, rkm 116 – 92)	/	3	3	3
Vrbas (B & H)	240 – 0	197 km (rkm 240 – 136, 131 - 128, 110 - 20)	20 km (rkm ~20 - 0)	23 km (rkm 136-131, rkm 128 - 110)	/	2	2	2
Bosna (B & H)	271 – 0	264,5 (rkm 271-6,5)	6,5 (rkm 6,5 - 0)		/			
Una (B & H)	214 – 0	194 km (rkm 214 -20)	20 km (rkm 20 - 0)					
Morava (YU)								
Tarnava (RO)	0 – 246	157	80	9		4/2		
Timis (RO)	0 – 244	110,5	131	2,5		1		
Timis (YU)	0 – 118					2 in YU		
Timok (YU, BG)		Total	/	/	0	0	0	0
Jiul (RO)	0 – 339	105	211	23		7/3	3/3	
Iskar (BG)	0 – 368				0	80	8	6
Lom (BG)								
Ogosta (BG)	0 – 144				0	55	4	7
Ossam (BG)	0 – 314				0	92	3	1
Vit (BG)	0 – 188,6				0	67	3	3
Olt (RO)	0 – 615	152	463		26/26	26/26	25	
Yantra (BG)	0 – 285,5				0	178	7	2

Table 2 (cont.): Major Hydraulic Structures and Description of Rivers in the Danube Basin (from THE REGIONAL ENVIRONMENTAL CENTER FOR CENTRAL AND EASTERN EUROPE)

River (Country)	Total length of the river rkm-rkm (from source to mouth)	Total Free-flowing sections rkm-rkm	Total regulated sections rkm-rkm	Total impounded sections rkm-rkm	Total Navigable sections rkm-rkm	Number of dams/ reservoirs	Number of dams/ reservoirs > 15 m	Number of Hydropower dams
Arges (RO)	0 – 350	280	7,5	62,5		13/13	13/13	13
Vedea (RO)	0 – 224	191	33	-	-	-	-	-
Ialomita (RO)	0 – 417	212,5	192	12,5		3/3	3/3	3
Buzau (RO)	0 – 302	162,5	128	11,5		2/2	1/1	2
Siret (UA)	122,5	122,5	76					
Siret (RO)	167 – 726	230	267	62,5		7/6	5/5	6
Moldova (RO)	0 – 213	164	49					
Bistrita (RO)	0 – 283	212	13	58		10/10	8/8	8
Trotus (RO)	0 – 162	147	15					
Barlad (RO)	0 – 207	33	174					
Jijia (RO)	10 – 285	222	51	4		1/1		
Prut (UA)	0-289	289	5					
Prut (RO)	241 – 983	384	288	70	-	1/1	-	-

River works altogether led to a loss of 15,000-20,000 km^2 of Danube floodplains. Environmental impacts of dams on the river ecology (and also on sturgeon populations) are well known and have been studied extensively (BEAMESDERFER et al. 1995; NAGY 1996; STEC 1999; BERNACSEK 2000; JACKSON & MARMULLA 2000; JAGER et al. 2000; LARINIER 2000; MALIK et al. 2000; JAGER et al. 2001; TED CASE STUDIES d).

Main impacts in the Danube River Basin are:

- Disruption of the river continuum (longitudinal and lateral): barrier for the spreading of organisms (plants and animals and especially migratory fishes e.g. sturgeons and shad) resulting in loss of shelters, feeding and reproduction habitats.
- Alteration of the hydrological regime of surface and groundwaters (loss of regular soil aeration and moistening),
    - degrading a river to a “chain of ponds”,
    - degrading a river to a residual stream (at diversion sections: minimum residual flow and flash hydropeaking flow),
    - demanding of artificial wetland and back-country irrigation and drainage.
- Change of the sediment regime (balance of erosion and sedimentation processes),
    - filling-up of upstream reservoir with silt and toxic substances,
    - bed erosion of downstream river sections and subsequent drying up of surrounding landscapes (need for irrigation),
    - lowering of ground water tables,

  - loss of pioneer habitats (gravel and sand banks and islands),
  - loss of gravel banks as spawning sites, sites of embryonic development and nursing areas for juvenile fish,
  - ageing of ecosystems.
- Loss of typical and rare riverine habitat and species diversity especially in floodplains (lowlands),
- isolation of populations; spreading of monotonous landscapes and indifferent or alien species.
- Reduced flood retention capacity resulting in increased flood hazards downstream of the dam.
- Reduced self-purification capacity resulting in increased need for expensive water purification.
- Reduced economic productivity (regular free nutrient input) for forestry, agriculture and fisheries.
- Reduction of recreational value.

Anthropogenic impacts which are discussed also in literature are water pollution with nutrients of various sources, contaminations with toxic substances and petrochemicals (FLECKSEDER 1994). Problems are caused by high nutrient loads (nitrogen and phosphorus) which have increased after 1970 (NAVODARU et al. 1999; SOMLYODY et al. 1999) and contribute to eutrophication of the Danube River, its Delta and the North-western part of the Black Sea. This causes oxygen depletion in parts of the riverine / marine ecosystems, leading to a loss of biodiversity in both the Danube River and the Black Sea (COCIASU et al. 1996; AGATOVA & SAPOZHNIKOV 1998; ANONYMOUS 2000; ANONYMOUS b and f).
Water pollution by heavy metals and pesticides in the Lower Danube River is very high, affecting the entire biota (BACALBASA-DOBROVICI 1994; BACALBASA-DOBROVICI 1997). Industry and mining are responsible for most of the direct and indirect discharges of hazardous substances into the Danube River Basin (CLOVER 2000; EUROPEAN UNION 2000; KOKES 2000). Navigation is an important source of oil pollution (bilge oil) and the main source of lead into the Danube River and its large tributaries (TED CASE STUDIES b). Lately the water quality at least in the Middle Danube River improved significantly, due to the completion of waste water treatment plants (KAVKA 1997) and of the petrochemical plants in Schwechat, the decrease of oil leak from Slovnaft, the completion of the wastewater treatment plants of Vienna and Bratislava (HOLČIK) and poor economy, causing reduction of point sources by close-down of industrial plants.

3 Sturgeons and Paddlefishes

Sturgeons and paddlefishes belong to the class of bony fishes, the Osteichthyes (HUXLEY, 1880) with the subclass Actinopterygii (ray finned fishes) containing the Chondrostei and the order Acipenseriformes.

The order of Acipenseriformes contains three families of which the family Acipenseridae (sturgeons; containing the genera *Acipenser*, *Huso*, *Scaphirhynchus* and *Pseudoscaphirhynchus*) and the family Polyodontidae (paddlefishes; containing the monospecific genera *Polyodon* and *Psephurus*) are still represented by living species, whereas the family of Chondrosteidae is extinct today (DEBUS 1995).

Members of the order Acipenseriformes with 25 currently recognized sturgeon and two paddlefish species are confined to the Northern Hemisphere. Biogeographic analysis suggests that the order originated in Europe about 200 million years ago and that early diversification took place in Asia. The majority of species occurs in the Ponto-Caspian region, one third in North America and the rest in East Asia and Siberia (BEMIS et al. 1997 b; CHOUDHURY & DICK 1998).

Sturgeons migrate mostly for reproduction and feeding. More information on the occurrence of diadromy (= up- and downstream migrations) and migrations in fishes can be found in MC KEOWN (1984); MC DOWALL (1988), (1997) and (2001).

BEMIS & KYNARD (1997) defined three different patterns of migration for sturgeons:

- potamodromy (migration between key habitats in a riverine / lacustrine system),
- anadromy (spawning migrations are conducted into freshwater, most of the life cycle takes place at sea),
- freshwater amphidromy (spawning migrations are conducted into freshwater, whereas feeding and growth occur during migration to and from salt water),

Although Acipenseriformes do not have a common life history and variation within and between species is the rule rather than the exception, there are some traits that all sturgeon and paddlefish species have in common. These are summarized below.

- Almost all members of Acipenseriformes are endangered or threatened by extinction.
- All acipenseriform species reproduce in freshwater or water of low salinity although adults can migrate into brackish or even salt water for feeding (LEBRETON & BEAMISH 1998). Some even adapt to high levels of salinity during ontogenesis and migrate into full seawater, after they reach a certain size, generally staying on the continental shelf (for example the Baltic sturgeon, *A. sturio*). Some species or races spend their entire life in freshwater (*A. ruthenus*, *A. nudiventris*, resident form of *A.*

gueldenstaedti). It was found, that migratory Ponto-Caspian species mature in freshwater ponds as well.

- The life cycle of Acipenseriformes is generally quite long with puberty occurring late in life. Individuals spawn repeatedly, but most females do not spawn annually. Spawning rate is once in 2-11 years for females, and once in 1-6 years for males. Under farm conditions, WILLIOT & BRUN (1998) showed that only 25 % *A. baeri* females reproduced annually, whereas in others reproduction was either biannual (54 %) or triannual (11 %).
- The timing of spawning is highly variable. Most of the species spawn from spring to early summer over a wide range of temperatures (6 to 25° C). For several diadromous sturgeon species vernal and winter races (for some authors spring and fall races) were recognized. The winter fish spend the winter in the river or the river mouth, hibernating in holes or deeper river bends with little or no feeding. They spawn far upstream, the year(s) after entering the river. The vernal races do not hibernate and they enter the river when the temperature is rising. Vernal fish mature the same year, lower in the course of the rivers, puberty is reached earlier and they spawn later in the season. Spawning migration also depends on the flow regime of the rivers. Damming and reduction of flow rate due to agriculture irrigation occurring in the Kuban River in the early 1980s resulted in total suppression of the anadromous autumn run of *A. stellatus* (BILLARD & LECOINTRE 2001).
- Studies also indicate that the availability of suitable spawning habitat is vital for the reproductive success of Acipenseriformes. Spawning sites are characterized by hard substrates from the size of gravel to boulder size rocks, with a lot of crevices where water velocity near the bottom is typically low. These areas are typically in the mainstream of the river, or on the banks, on the bottom on hard substrates. The water depth at spawning sites varies from a few meters to 26 m and the current velocity ranges from 0.5 to 2.2 m s^{-1} in the water column, allowing a wide dispersal of fertilized eggs. Almost nothing is known about mating and spawning habits, however, considering the short duration of sperm motility for only 1-2 min, a good synchrony in the release of the gametes by the male and the female has to be presumed. The ova remain fertile after release into freshwater for up to one hour, so that erratic eggs may be fertilized by freshly ejaculated sperm. Likewise, sperm must be diluted rapidly by the high velocity of the river current; fertilization success in sturgeons and paddlefish perhaps is increased by the presence of several micropyles in eggs (BILLARD & LECOINTRE 2001).
- Eggs are adhesive and can be found immediately downstream of the spawning ground. During embryogenesis water velocities between 0.5 – 1.5 m s^{-1} have been reported.

Hatching occurs after 200-250 hours, depending on the species and water temperature. The size of newly hatched larvae ranges from 6 to 15 mm. The yolk sac larvae of several species (for example *A. baeri*, *A. brevirostrum*, *A. stellatus*) are pelagic for 2-3 days (7-8 days for *H. huso*) and are transported downstream by the currents at a velocity up to 45 cm s^{-1} or 40 km day^{-1}. After displacement from the spawning ground, the yolk sac larvae settle down, usually on coarse substrate in a much lower water velocity (1 to 5 cm s^{-1}) and start feeding on both planktonic and benthic organisms. The water velocity and substrate requirements for eggs and larvae are different for fertilization, embryogenesis, yolk-sac resorption, first feeding and active exogenous feeding. The habitat requirements for juveniles change with the seasons.

- Annual spawning success and recruitment are highly unpredictive and depend on the flow regime during the reproductive period of the female spawner. High flows can create increased bottom velocities which preclude or greatly reduce spawning success. Off-flow regime is also important for the time of egg development, hatching and downstream migration of larvae (VESHCHEV 1993; VESHCHEV & DEBOL'SKII 2000). Water level fluctuations, due to flow management by hydropower stations can also have negative effects on spawning and reproduction success (VESHCHEV 1994; KRIKSUNOV & MAMINA 1995). Year class strength is determined within the first months of sturgeon life (NILO et al. 1997). After the first year, sturgeons are usually no more subjects to predatory pressure (LUKJANENKO 1993).
- Particular spawning sites are usually frequented each year. Such site fidelity might derive either from the distinct characteristics of the site or from homing behavior. Homing fidelity has yet to be proven for sturgeons. If future studies verify that homing is as important as expected, then this might also be the explanation for the existence of different forms or races within single species, which is another common pattern particularly in members of the family Acipenseridae.
- Periods of high flow are an important trigger for the spawning migrations of many acipenseriform species (also explained by higher water levels being important for the passage of rapids and shallow river stretches). Any reduction in river discharge during the period of migratory activity of sturgeons diminishes the attractivity of the river, and thus reduces the number of spawners entering from the pre-estuarine regions. It was recorded that during initial flooding of the Tsimlyanskoye Reservoir, the current of the Don River was reduced to 0.1 m s^{-1}, while that of its tributary the Severtskiy Donets remained at 1.5–2 m s^{-1}. *A. gueldenstaedti* and *H. huso*, which hitherto spawned in the Don River above the confluence of the Severtskiy Donets, entered and spawned in the tributary, where they had not been recorded previously to spawn (PAVLOV 1989).

- Spawning populations of Acipenseriformes show a complex multi-aged structure.
- All sturgeons show a strong tendency towards hybridization with other sturgeon species, especially if suitable spawning habitats are lost and animals of different species are confined to only few suitable spawning sites.
- It is still uncertain whether anadromy or potamodromy is the plesiomorphic life history pattern for Acipenseriformes. The same species can display different life histories in different river systems (KYNARD 1997; COLLINS et al. 2000b).
- Similar habitats in one river system can also be used for different developmental stages by different species (BAIN 1997). This also suggests that diadromy is a behavioral character of dubious worth in determining phylogenetic relationships (MC DOWALL 1997).
- Acipenseriform species are genetically adapted to their river system, which is reflected by their ontogeny.

3.1 Danubian sturgeon species

Six species of Acipenseridae (shown in figure 2) are or were native to the Danube River Basin.

- *Acipenser gueldenstaedti* (Danube or Russian sturgeon),
- *Acipenser nudiventris* (Ship sturgeon),
- *Acipenser ruthenus* (Sterlet),
- *Acipenser stellatus* (Stellate or Starred sturgeon),
- *Acipenser sturio* (Common, Atlantic or Baltic sturgeon),
- *Huso huso* (Beluga or Great sturgeon).

Fig. 2: Danubian sturgeon species

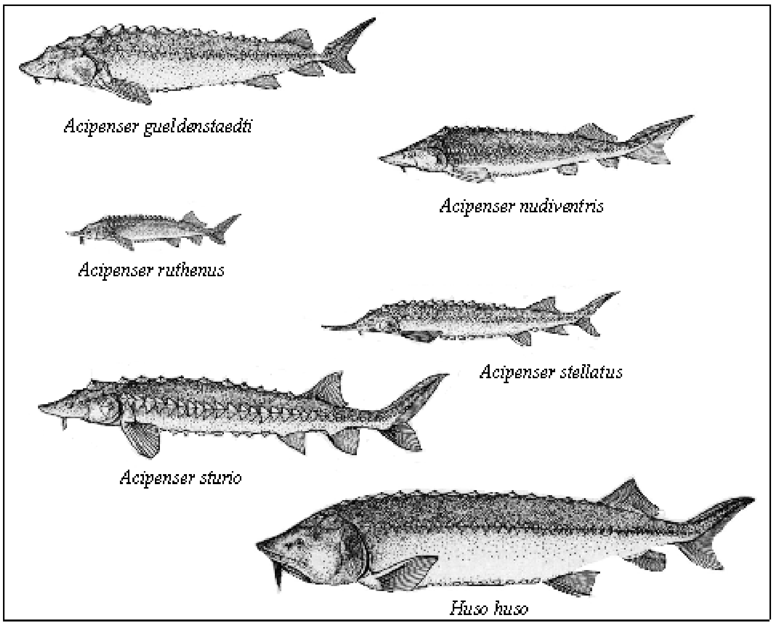
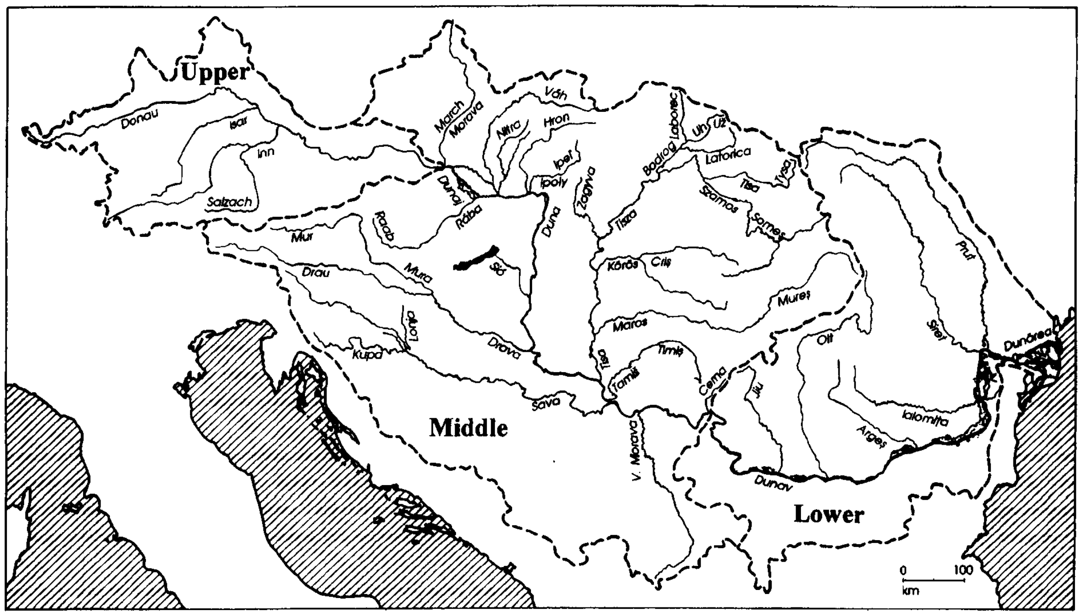


Figure 3 provides an overview of the Danube River Basin showing the rivers that are or were inhabited by these sturgeon species.

Other acipenseriform species and hybrids have been introduced into pond- and aquaculture in the Danube River catchment area, such as the North American paddlefish (*Polyodon spathula*), the Adriatic sturgeon (*Acipenser naccarii*), the Siberian sturgeon (*Acipenser baeri*) or the bester (*Acipenser ruthenus* x *Huso huso*) for the production of caviar and sturgeon meat. In the former U.S.S.R., hybrids were used in aquaculture to associate some complementary characteristics of the parents. The bester was created in 1952 for rearing in freshwater (at that time it was believed that some salinity was required in water for the growth and maturation of the anadromous sturgeons). Later it was found that most of the migratory species could be reared in freshwater and interest in hybrids has lessened. Many other hybrids were created in the former U.S.S.R. and were often exported. The export of hybrids rather than the pure species was also supposed to prevent the establishment of broodstock outside the U.S.S.R.. As for other fish hybrids, the offspring performs in between both parents and not, as often expected, better than the best parent. Thus, there is no clear-cut demonstration of the superiority of hybrids compared to parental performances (for example growth, food conversion and fecundity), and the use of hybrids in aquaculture is to be questioned considering the risks of escapement into open waters and contamination of wild sturgeon populations (BILLARD & LECOINTRE 2001).

Sturgeon juveniles of various species as well as hybrids can also be found in the aquarium or pet trade, where they are sold to hobbyists. Although not stocked into rivers on purpose, allochthonous animals are sometimes released or escape and can occasionally adapt to conditions in the wild outside of their native range (ZAUNER 1997; PAAVER 1999).

Fig. 3: Danube River Basin showing major parts and tributaries of the Danube River Basin that are (were) inhabited by sturgeons (Details on rivers and species are given in chapter 9 Annex: Species information on Danubian sturgeons). Taken from HENSEL & HOLČIK 1997, Original figure by K. Hensel



<u>Diadromy and migrations in Danubian sturgeons:</u> Out of the six native sturgeons four are or were migratory (diadromous i.e. anadromous) species, living on the Black Sea shelf and entering the estuary or the Danube River itself for spawning (*A. gueldenstaedti*, *A. stellatus*, *A. sturio*, *H. huso*). Migration of sturgeons can be observed throughout the year in the Lower Danube River. The anadromous species (*A. gueldenstaedti*, *A. stellatus*, *H. huso*), however, exhibit a two peaked migration pattern (vernal/spring and fall/winter races), where animals enter the river to spawn the same year (vernal/spring race) or overwinter in the river (in deeper stretches or holes in the river-bed) and spawn the next year (fall/winter race). The occurrence of two different races and migration patterns is explained by the longer distance, the winter races have to cover to use suitable upstream spawning sites (homing fidelity has not been confirmed as yet), as well as by the duration of migration and overwintering being

necessary for ripening of the gonads and ovulation of female spawners (AUER 1996). Spawning shoals are often accompanied by non mature males.

The two peaked migration pattern is also documented in the two peaked catching success of Romanian fishermen (spring and fall), indicating that catches might take place in the vicinity of key habitats (spawning / overwintering) (SUCIU 2001 a).

Three of the Danubian acipenserid species are either freshwater species (*A. ruthenus*), form both migratory and freshwater stocks in the Black Sea, the Danube River and its tributaries (*A. gueldenstaedti*) or are (were) present exclusively as freshwater form in the Danube River and its tributaries (*A. nudiventris*).

PAVLOV (1989) describes the downstream drift migrations of young sturgeons. The pre-larvae of most sturgeons exhibit spiralling movements, which keep them up in the water column, allowing them to drift with the current.

In later stages, the spiral/vertical movements give way to horizontal movements accompanied by a change to active feeding and manifestation of rheoreaction. By contrast the pre-larvae of the sterlet (*A. ruthenus*) appear to maintain tactile contact with the bottom so that this species does not drift into the sea. About 70 % of *A. gueldenstaedti*, 50 % of *A. stellatus* and 16 % of *H. huso* keep close to the bottom because of the different migratory ranges and the duration of migration. *H. huso* is the most pelagic of the sturgeons and its drift into the sea is rapid and quickly over. The pelagic distribution of the young is promoted not only by spiral/vertical swimming movements but also by positive photoreaction, negative tactile response, low specific gravity and their departure from shelters and near bank vegetation.

<u>Reproduction:</u> Four sturgeon species still reproduce in the Lower Danube (*A. gueldenstaedti*, *A. ruthenus*, *A. stellatus*, *H. huso*). Traditional spawning sites were situated in the middle part of the Danube River (GUTI 1993; HENSEL & HOLČIK 1997; ANONYMOUS 2000). Due to the blocking of migration routes (Iron Gates dams I and II in 1970 and 1984; river km 942 and 863), these spawning sites can no longer be reached by migratory sturgeons. The current location of spawning sites under changed migratory conditions are unknown (BACALBASA-DOBROVICI 1991; BACALBASA-DOBROVICI & PATRICHE 1999; KYNARD et al., in Press).

<u>Juvenile rearing habitat:</u> Important rearing habitats of juvenile sturgeons can be found in the Lower Danube River, the Danube River estuary as well as the shallow areas of the continental shelf in the Black Sea.

<u>Feeding:</u> Sturgeons possess tactile barbels located at the front of the mouth, which is "protactile" with thick lips. They show a digging behavior with the help of the rostrum (CARROLL & WAIN-WRIGHT 2000). Eyes are very small relative to the size of the fish and probably do not contribute much to the location and capture of prey.

Most of the species feed mainly on bottom invertebrates (insects, insect larvae, annelids and molluscs) and also occasionally on bottom fish. Some of the species reduce or stop feeding during their migration in freshwater.

H. huso is the only true predator among the six Danubian species (therefore it is also called Raptor sturgeon). In the Black Sea it preys mainly on bottom dwelling and pelagic fish, in the river it switches to freshwater species like members of the cyprinid family.

Table 3 summarizes key facts of the Danube River sturgeon species. For more detailed informations on Danubian sturgeon species see also Chapter 9 Annex: Species information on Danubian sturgeons.

Table 3: Status and characteristic traits of sturgeons from the Danube River as compiled by HOLČIK et al (1989); PIGOROVSKIĬ et al (1989); POPOVA et al. (1989); SOKOLOV & VASIL'EV (1989 a); SOKOLOV & VASIL'EV (1989 b); VLASENKO et al. (1989); BACALBASA-DOBROVICI (1991); HENSEL & HOLČIK (1997); ZAUNER (1997); GUTI (1998); BACALBASA-DOBROVICI & HOLČIK (2000). Grey areas indicate the occurrence of a species in the Black Sea – Danube River system in the given time period according to literature (-: no occurrence, ?: status is unclear; ■: depends on stocking; ▲: stocks recovered due to stocking, legal protection and improvement of water quality; ●: reserves are reduced to a minimum).

Species		*Acipenser gueldenstaedti* Danube or Russian Sturgeon (migratory form)		*A. gueldenstaedti* Danube or Russian Sturgeon (resident form)		*A. nudiventris* (Danube stock) Ship Sturgeon		*A. ruthenus* Sterlet		*A. stellatus* Stellate or Starred Sturgeon		*A. sturio* Common, Atlantic or Baltic Sturgeon		*Huso huso* Beluga or Great Sturgeon	
Distribution Status	**time period**	historic	current	historic	current	historic	current	historic	current	historic	current	historic	current	historic	current
	Upper Danube River	rare	extinct	-	-	rare	extinct		rare ■	rare	extinct	-	-	rare	extinct
	Middle Danube River		extinct		very rare		?		▲		extinct	-	-		extinct
	Lower Danube River		rare	?	?		?		●		rare	rare	extinct		rare
	North Western Black Sea		rare	-	-	-	-	-	-		rare	rare	extinct		rare
	Max. length [cm]	236		no information		221		125		218		600		800	
	Max. age [yrs.]	33		no information		36 *		24		35		48		> 100	
Reproduction	**Age at maturation [yrs.]** ♂ ♀	11 – 13 12 – 16		no information		6 – 9 12 – 14 **		3 – 5 4 – 7		5 – 6 7 – 10		7 – 9 8 – 14 ***		10 – 13 13 – 15	
	spawning season	March-November		no information		April-May**		April-May		May-June		May		April-May	
	absolute fecundity [eggs female^{-1}]	29.500 – 406.800		no information		200.000 – 1.300.000		7.000 – 108.000		70.300 – 430.000		790.000 – 1.820.000 ***		228.400 – 964.800	
Migration	**pattern**	anadromous		potamodromous		potamodromous		potamodromous		anadromous		anadromous		anadromous	
	peak / seasonal races	spring-fall		no information		no information		April-May		spring-fall		no information		spring-fall	
Feeding regime		benthic organisms (fishes and invertebrates)		benthic organisms (fishes and invertebrates)		benthic organisms (fishes and invertebrates)		benthic organisms (mainly invertebrates)		benthic organisms (fishes and invertebrates)		benthic organisms (fishes and invertebrates)		marine and freshwater fishes	

* = Ural River; ** = Kura River; *** = Rioni River - data from other river populations, as information on Danube River is lacking.

4 Sturgeon catches in the Danube River and their commercial importance

Sturgeons are fished for caviar primarily as well as for meat. They also deliver leather for bookbinding and handicrafts, isinglass (a gelatin made from the swim bladder) used in beer clarification, waterproofing materials, jellies, paint toners, and glues.

The high economic value of caviar is a main reason for endangering sturgeon stocks, and connections between overexploitation, black market, illegal trade and socio-economic problems have been thoroughly described (WALDMAN 1995; COHEN 1997; ANONYMOUS 1998; SPEER et al. 2000; CAVIAR EMPTOR; TED CASE STUDIES a and c). Especially, caviar from the Danube River is regarded as a delicacy (ANONYMOUS a).

Since April 1998 all acipenseriform species were included in the Convention of International Trade of Endangered Species (CITES), which regulates trading of species threatened with risk of extinction. Recently, the demand for meat and caviar, sport fishing, and reintroduction programmes prompted a relevant increase of aquacultural sturgeon rearing.

The development of sturgeon stocks and thus the catches in the Danube River Basin in historical times is closely related to the development of human settlements, the development of fishing techniques and the various anthropogenic impacts on the Danube River and its ecology (see chapter 2.2).

The Common or Baltic sturgeon (*A. sturio*) was always the rarest of the six species, entering the Danube Estuary only occasionally for spawning. Only single specimen were caught. Due to its scarceness *A. sturio* never gained a status of high economic importance in the Lower Danube River. The same holds true for *A. nudiventris*, which always has been the second rarest species in the Danube River Basin, although some authors suspect a confusion of this species with other acipenserids by fishermen (GUTI 1995; ZAUNER 1997).

All other species were either common or abundant in the Lower and Middle Danube River especially during spawning season. Migratory species and especially the winter races of *H. huso* and *A. gueldenstaedti* ascended into the middle and sometimes the upper part of the Danube River and some of its larger tributaries. This is documented by historical records and subfossil remains found in settlements along the river (GALIK; CHOUDHURY & DICK 1998). Because of their high economic importance, intense fishing was carried out on these fishes.

Belugas were well known in the Austrian Danube in the middle ages, for example, and a great demand existed for Beluga meat, because of its tastiness. Belugas were mentioned for the first time as a haversack ration for the troops of emperor Henry III, who marched along the Danube in 1053. According to a contemporary report, the soldiers “would most probably have starved to death had they not received 50 huge Belugas” (NATURHISTORISCHES MUSEUM WIEN).

In centuries to come, fishing pressure on the Beluga increased, when nets, rods and fishing fences (fishing weirs) were used. In this "weir fishing" the whole river was blocked by fence-like obstructions to get access to the migrating species. A decline in the occurrence of *H. huso* could already be documented for the 16th century, when such fishing methods initiated international disputes, with upstream parties complaining about downstream parties for cutting off valuable resource.

During the 18th century the fishing of migratory sturgeons in Austria collapsed, and as early as by the beginning of the 19th century, the Beluga sturgeon could only rarely be observed in the Middle and Upper Danube River (HENSEL & HOLČIK 1997; ZAUNER 1997).

Today only the sterlet and the remnants of a resident population of *A. gueldenstaedti* are still present in the Middle Danube River and the occurrence of sterlets in the Upper Danube River depends strongly on stocking measures.

Except for the sterlet in parts of the Middle Danube River as well as products from sturgeon aquaculture, sturgeons do not have any commercial importance in the Upper and Middle Danube River, due to the extirpation of the migratory wild stocks.

Data on sturgeon catches from the 20th century are somewhat confusing, since different databases are quoted and data are claimed to be inaccurate. At present, it is difficult to provide accurate figures for the size of Lower Danube River catches because of illegal or unreported fishing, which regionally can make up about half of the total catch (and up to 90 % of the sturgeon catch) (BACALBASA-DOBROVICI & PATRICHE 1999).

A great impact on Beluga catches in the Lower and Middle Danube River had the construction of the two dams of Djerdap (Iron Gate) Hydropower station in 1972 (river km 942), and thus the disrupting of sturgeon migrations into the Middle Danube River.

It was reported that catches of Beluga and Russian sturgeon (*H. huso* and *A. gueldenstaedti*) below the dam peaked during the first five years after the completion of Iron Gate Dam I, due to the mass occurrence of migrating animals below the dam. In the period from 1972 to 1976 115.7 metric tons (both species) were caught, which is 23.1 tons higher than in the five years before dam construction. After 1976 the combined catches below Iron Gate started to decrease, dropping to 37.3 metric tons during the five year period from 1980 to 1984 following the completion of Iron Gate Dam II (river km 863) (JANKOVIC 1993 and 1996; HENSEL & HOLČIK 1997).

In the Lower Danube River sturgeons have been fished since the 5th to 6th century BC by ancient Greek colonies inhabiting this area. A lack of legislation led to overfishing and a collapse of Lower Danube fisheries already at the beginning of the 19th century. Sturgeon fishery, however, was not seriously affected and annual catches remained at about 1,000 metric tons and during the first 15 years of the 20th century no change could be observed. However, by the end of the 20th century a second collapse in the fisheries in the Lower Danube River, especially for sturgeons, became obvious and a sharp decline in sturgeon catches has been observed since 1989 (BACALBASA-DOBROVICI 1997; BACALBASA-DOBROVICI & PATRICHE 1999). Apart from environmental changes (see also chapter 5.1) the authors list the following causes for this development:

- confusing and conflicting fisheries legislation,
- a lack of coordination amongst dispersed zones of fishery management,
- conflicting interests of different groups involved in the exploitation of Danubian fish,
- widespread heavy poaching on spawners and fry,
- an absence of an effective infrastructure for monitoring and surveillance.

Out of six sturgeon species, considered native to the Lower Danube River, only four are still being captured. *A. sturio* is presumably extinct in the Lower Danube River as well as the North Western Black Sea (BACALBASA-DOBROVICI & HOLČIK 2000), and no official catches of *A. nudiventris* were reported for the last 40 years. SUCIU (2001 b) reported the catch of a single specimen by a Romanian fisherman at river km 124. The fisherman described an *A. nudiventris* in detail, however, the animal was not preserved.

BILLARD & LECOINTRE (2001) suspect that governments often provide overestimates of potential sturgeon capture and caviar production to the CITES, to increase their quota for export.

However, also a considerable decrease of juvenile sturgeons, as well as changes in the species composition, could be documented by pound - net catches in the Black Sea. Whereas 30 to 40 years ago the bycatch of juvenile sturgeons (mostly *A. gueldenstaedti* and *A. stellatus*, but also *H. huso*) amounted up to 20 to 50 kg per net after overnight exposure, current catches (1999) reveal only 0 to 5 individuals (mostly *A. stellatus* and few *A. gueldenstaedti*, only rarely *H. huso*). The length of these fishes being between 15 and 80 cm (BACALBASA-DOBROVICI & PATRICHE 1999).

By the end of the 1980s, according to FAO data (HOLČIK 1989), the annual catch of Russian, stellate and great sturgeons in all countries within the Black Sea watershed did not exceed 150 to 160 tons. According to NEWCRONOS data (STATISTISCHES BUNDESAMT 2001) the annual catch for Russian sturgeons in the Danube River and the North western Black Sea (including the Ukrainian Black Sea catch) amounted to only 50 tons in 1999.

In Romania the commercial and combined catches of sturgeons dropped from around 280 tons in 1955 to about 32 tons in 1999 (STATISTISCHES BUNDESAMT (2001) / combined catches for Romanian inland waters 31 tons and Black Sea 1 ton). Not only the size, but also the structure of sturgeon populations in the Danube River has changed dramatically. The size of the spawners has decreased considerably, when compared to their size in the past, due to intense fishing (BACALBASA-DOBROVICI & PATRICHE 1999; CEAPA 2001; CEAPA et al. 2001 and in Press) and an increase in fishing effort (the number of Romanian licensed fishermen involved in sturgeon fishing has doubled over the last 10 to 15 years and mesh size of gillnets was also decreased according to BACALBASA-DOBROVICI 2001).

Sturgeons amount only to about 3 to 5 % of the combined catches in the Bulgarian Danube fisheries. Catch statistics do not contain reliable data though (especially for the beginning of the 1990s; FÜLLNER 2001). Official licenses were granted since 1995. Only since 1998, the owner of a license is obliged to collect records of his catches in Bulgaria (122 to 153 licenses for the catch of Beluga by fishing lines were granted annually between 1997 and 1999). 6 to 7 tons of sturgeons (species not given) and 30 to 35 tons of Beluga are caught each year (STATISTISCHES BUNDESAMT (2001) / combined sturgeon catches for Bulgarian inland waters: 39 tons including 27 tons of Beluga and Black Sea 12 tons including 10 tons of Beluga in 1999). The mean weights are 10 kg for *A. gueldenstaedti* and 80 kg for *H. huso* in these catches, from which about 2,200 to 2,500 kg of caviar are being exported each year. It was stated that the catch of sturgeons in Bulgaria has recently decreased by 25 %. Sturgeon fishing in Bulgaria is controlled by the NAFA (National Agency of Fisheries and Aquaculture).

The catch of *A. stellatus* in the Black Sea watershed is very small. According to the data of the Joint Commission of the International Agreement on Fishing in the Danube River (in POPOVA et al. 1989), the annual catch of this species during the period from 1958 to 1981 varied from 0.2 (in 1980) to 17.84 (in 1967) metric tons (mean 7.82 t). According to data from STATISTISCHES BUNDESAMT (2001) the annual catch for stellate sturgeons in the Danube River and the North Western Black Sea (including the Ukrainian Black Sea catch) amounted to 28 tons in 1999.

During the period from 1958 through 1981, the annual catch of Beluga in the Lower Danube varied from 19.7 to 240.4 tons and averaged 105.6 tons, according to the statistics presented at the 24th session of the Joint Commission of the International Agreement on Fishing in the Danube, Moscow 1983 (in POPOVA et al. 1989). At the beginning of the 20th century, the catch was considerably greater. In Romania, 1,042 tons were caught in 1898 and 1899 in only one section of the river, while during the 1930s, the average catch was 600 to 700 tons. According to data from STATISTISCHES BUNDESAMT (2001) the annual catch for Beluga in the Danube River and the North Western Black Sea amounted to only 45 tons in 1999.

NAVODARU et al. (1999) provide a detailed description of the current status of sturgeon fishery on the basis of a <u>R</u>apid <u>R</u>ural <u>A</u>ppraisal (RRA) applied in a program on the management of sturgeon stocks of the Lower Danube River. The sturgeon catches had decreased dramatically: in Romania from about 1144 tons in 1940 to less than 8 tons in 1995 (factor 140); in Ukraine from 114.2 tons in 1952 to no sturgeon catch recording since 1994; in Yugoslavia catch declined from 39 tons in 1975 to 5 tons in 1986. Only in Bulgaria no major changes in sturgeon catches seem to occur.

Fig. 4: Diagrams showing the development of sturgeon catches in different countries of the Lower Danube River by official data (according to a compilation from NAVODARU et al. 1999). Note the difference in scale of the y-axis (factor 10) for (A) Romania and (B) Ukraine, (C) Bulgaria and (D) Yugoslavia. Data for Ukraine, Bulgaria and Yugoslavia before 1945 were not available. Compare also to data from RRA in Fig. 6.

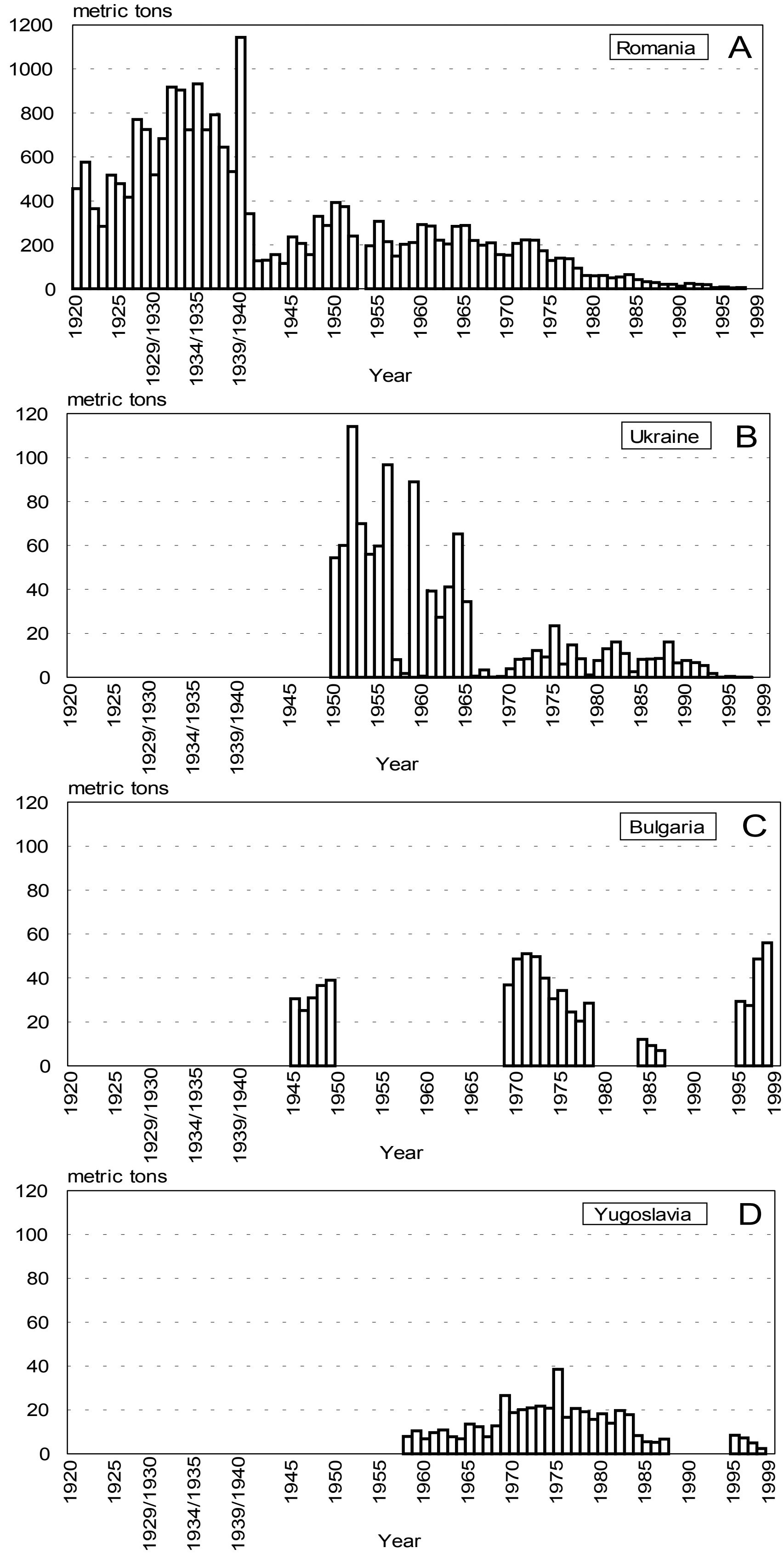


Table 4: Mean annual sturgeon catches from the Serbian section of the Danube River (from NAVODARU et al. 1999)

Period	*Huso huso*		*A. gueldenstaedti*		*A. stellatus*		Total
	kg	%	kg	%	kg	%	kg
1958-1969	6,306	56	4,488	40	374	4	11,168
1970-1983	10,847	54	8,899	44	494	2	20,240
1984-1987	4,427	68	1,913	30	148	2	6,488

Sturgeon meat is sold on national markets and caviar on international markets. Prices received by fishermen at point of landing are 4–5 USD / kg for meat and 60-100 USD / kg for caviar (Beluga caviar even up to 180 USD / kg) (no date or reference for currency is given / NAVODARU et al. 1999). According to FITZE (2001 a and b) a Beluga female with a weight of 400 kg is as valuable as a family home in Romania. There are flourishing black markets in Romania and Ukraine and to a lesser extent in Yugoslavia, favored by the centralized political system. There are no signs for a black market in Bulgaria since the licensed fishermen have the permission to trade fish and caviar. All countries on the Lower Danube River have signed the CITES convention.

Table 5 provides an overview of CITES quotas in riparian Danube countries.

Only few professional fishermen depend specifically on sturgeon fishing. There are no uniform fishing regulations for sturgeons in the riparian Danube countries:

- closed fishing seasons (in spring) and area, timely from Black Sea to spawning zone, all countries
- legal size, all countries
- gear regulation - banned the use of unbaited hooks in the Danube River, only Romania and Ukraine
- Fishing prohibition - *Huso huso*, only Ukraine

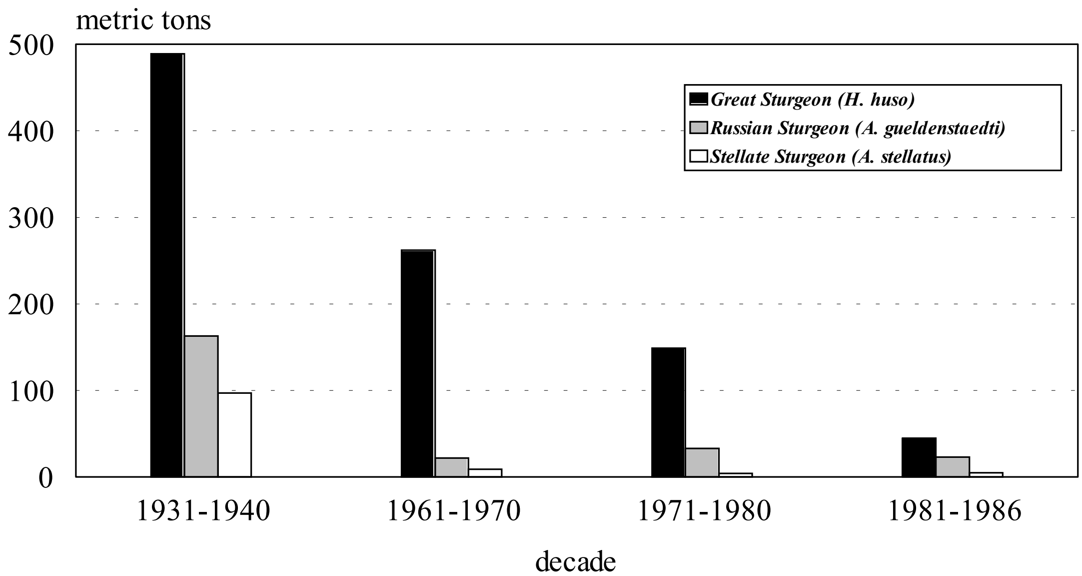
The licensing system in Romania is in transition from state fishery to private enterprise. The fishing rights and licensing system vary from a strong state control system (Yugoslavia) to an entirely private one (Bulgaria) (NAVODARU 1998 b; NAVODARU et al. 1999 and 2001).

By a comparative analysis of the statistical data of the sturgeon catches from Bulgaria, Romania, former U.S.S.R. and Yugoslavia including the period beginning with 1931 through 1940, it could be shown that in the later period (1981-1986), the Beluga catches were reduced by 10.7 times compared to the period from 1931 through 1940, the Russian sturgeon by 7.2 times and the stellate sturgeon, by 21.5 times (see figure 5).

Table 5: CITES quotas for sturgeon products in riparian countries from the Lower and Middle Danube (from www.cites.org)

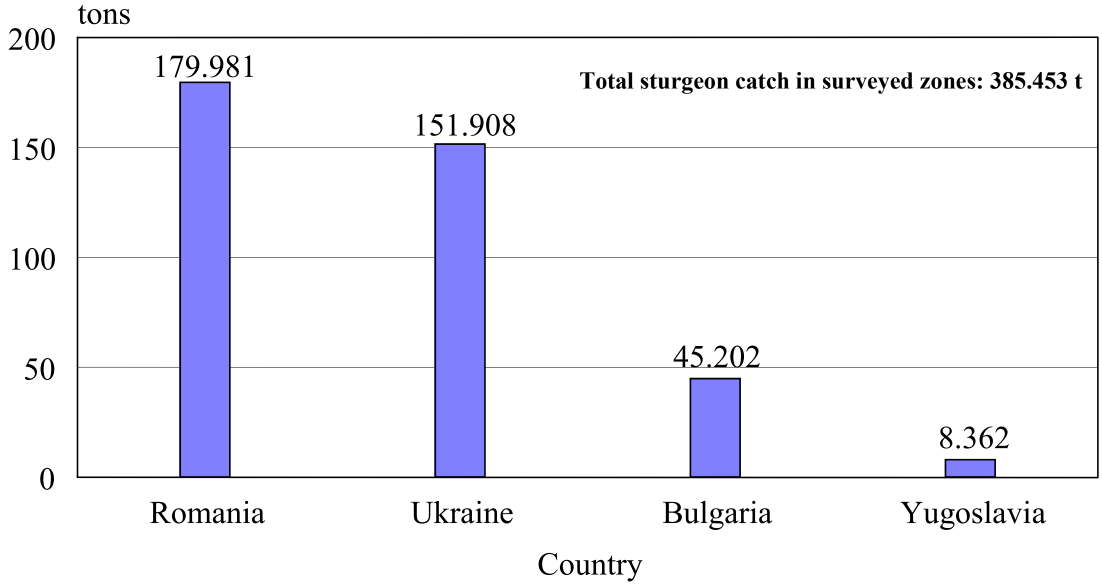
Species	Year	Country	Product	Quota (per country)
A. gueldenstaedti	2001	Bulgaria	meat	100 kg
			caviar	50 kg
		Romania	meat	19,000 kg
			caviar	1,750 kg
			fertilized live eggs for aquaculture	25 kg
	2000	Romania	meat	20,000 kg
			caviar	1,800 kg
	1999	Bulgaria	caviar produced after 1. April 1998	70 kg
		Romania	meat	3,500 kg
			caviar	1,250 kg
A. stellatus	2001	Bulgaria	not provided	-
		Romania	fertilized live eggs for aquaculture	25 kg
			meat	25,000 kg
			caviar	2,050 kg
	2000	Romania	caviar	2,100 kg
			meat	23,000 kg
	1999	Romania	meat	4,000 kg
			caviar	2,000 kg
A. ruthenus	2001	Bulgaria	not provided	-
		Hungary	live fish	4,000
	1999	Bulgaria	caviar produced after 1. April 1998	30 kg
H. huso	2001	Bulgaria	meat	5,000 kg
			caviar	2,450 kg
		Romania	meat	35,000 kg
			caviar	3,100 kg
			fertilized live eggs for aquaculture	50 kg
	2000	Bulgaria	caviar	2,500 kg
		Romania	caviar	3,200 kg
			meat	35,000 kg
	1999	Bulgaria	caviar produced after 1. April 1998	400 kg
		Romania	caviar	1,750 kg
			meat	2,500 kg

Fig. 5: Development of sturgeon catches in the Lower Danube River by species (modified from NAVODARU et al. 1999)



Catch size estimates from key areas surveyed in 1997-1998 confirmed that a major sturgeon fishery still exists with an important yield in the 20th century of between 300-400 tons per year on average, with the following percentages: 47% Romania, 39% Ukraine, 12% Bulgaria and 2% Yugoslavia. Official data (Fig. 4) seem to be a lot lower than the actual catch as documented by RRA (see figure 6) and thus have to be regarded critically.

Fig. 6: Sturgeon catch of the Lower Danube River estimated by RRA 1997-1998 (modified from NAVODARU et al. 1999). See also official data in Fig. 4.



Caviar production estimation was about 31 tons with the same percentage distribution between countries as sturgeon production. According to NAVODARU et al. (1999) the fishing effort since 1990 has been increasing because there is no entry limit regulation (except Yugoslavia). In 1998 the overall fishing capacity was about 2,584 fishing units (2,584 boats and more than 5,168 licensed fishermen), from which 54 % are Romanians, 39 % Bulgarians, 6 % Ukrainians and less than 1 % Yugoslavians.

The Romanian and Ukrainian fishermen fish sturgeons with unbaited hook & line in the Black Sea and trammel nets in the Danube River. Bulgarian and Yugoslavian fishermen use unbaited hook & line in the river as well. A new fishing method has been developed by Bulgarian fishermen that catch sturgeons with baited hooks in the Black Sea. In all countries sturgeons (adults and fry) are caught as by-catch in trammel nets targeting freshwater fish or migratory Pontic shad.

Genetic studies on Beluga from the Lower Danube River also confirmed a recent decline in the number of spawners and especially females of *H. huso* (SUCIU et al. 2000).

The sterlet (*A. ruthenus*) is also a very important commercial fish. In the past, the size of the catch was considerable. In the years 1935 through 1939, the world-wide sterlet catch amounted to 750 to 800 tons annually, of which about 700 tons were taken in the former U.S.S.R.. Most of the sterlets captured at the end of the 1980s originated from the Danube River System. From 1958 through 1981, the sterlet catch in these waters ranged from 36 tons in 1979 to 117 tons in 1963 and averaged 63.5 tons annually, according to data compiled by the Joint Commission of the International Agreement on Fishing in the Danube River. The sterlet catch was largest in former Yugoslavia. In other countries of the Danube River watershed the catch was considerably less. The fishery management that was practiced was basically irrational since catches consisted primarily of three-year-olds, i.e. individuals that are not yet mature or those that have just reached ripeness for the first time (SOKOLOV & VASIL'EV 1989 c).

According to data from STATISTISCHES BUNDESAMT (2001) the annual catch of sterlets in the Danube River watershed amounted to 37 tons in 1999 (35 tons in Hungary due to the improvement of stocks). It is hard to believe, that sterlets are fished mainly in Hungary, other catch data on sterlet were not available, however. BACALBASA-DOBROVICI (1991) states, that the reserves of sterlets in the Romanian Danube River have been "reduced to a minimum".

5 Sturgeon conservation

5.1 Threats to Sturgeon Stocks in the Danube

Most species of sturgeons and paddlefishes are endangered (KINZELBACH 1987; LELEK 1987; BIRSTEIN 1993; LEPAGE & ROCHARD 1995; KIRCHHOFER & HEFTI 1996; LUSK 1996; BEAMESDERFER & FARR 1997; BEMIS et al. 1997 a; BIRSTEIN 1997; BIRSTEIN et al. 1997; GRAHAM 1997; KEENLYNE 1997; KINZELBACH 1997; KRYKHTIN & SVIRSKII 1997; THUEMLER 1997; WIE et al. 1997; ZHOLDASOVA 1997; XIN & ZHONGLIN 1997; LAPATRA et al. 1999; LUK'YANENKO et al. 1999; NOAKES et al. 1999; VESHCHEV 1999; JENNINGS & ZIGLER 2000; SECOR et al. 2000 a; VECSEI & PETERSON 2000; VECSEI 2001; AMSTISLAVSKY; IUCN a and b; KARAPETKOVA et al.; KIRKA a and b; PRODANOV et al.; RADOVIC & STEFANOVIC; TRAFFIC a and b). It is difficult, however, to relate the threatened status of a given sturgeon species to a single cause or change in the environment (BILLARD & LECOINTRE 2001). Major threats for sturgeons in the Danube River can be summarized from literature as:

- Overexploitation,
- habitat loss and habitat degradation.

5.1.1 Overexploitation

Sturgeons and paddlefishes exhibit unusual combinations of morphology, habits and life history characteristics, which make them highly vulnerable to impacts from human activities, particularly fisheries (BOREMAN 1997).

Sturgeons are very susceptible to overfishing because of the following traits:

- The migrations of sturgeons are predictable and the animals are easy to catch,
- stocks depend on the high fecundity of individual spawners (which do not spawn annually),
- the animals mature late, thus taking a long period for the spawning population to recover from fishing mortality,
- due to these traits, effects of overexploitation are masked in the short to medium term,
- being the source of caviar, female spawners are subject to intense fishing and poaching; the animals are killed for/by the extraction of the ovaries; males are killed also due to a lack of sexual dimorphism in most species.

BILLARD & LECOINTRE (2001) state: „Presently, overfishing, accidental by-catch of juveniles, and poaching due to the high demand for sturgeon caviar remain major problems. It is obvious that most of the highly endangered stocks are located in international waters, either in seas or in rivers. Some multi or bi-lateral agreements may exist for the management and protection of the stocks but they do not work well and the tendency of nations is to catch all the fish they can. In Eurasia, in the Caspian and Black Sea, in the Lower Danube or in the Amur River, the state of endangered species is recognized by scientists for most sturgeon populations but the riverine governments do not take the appropriate measures of protection and still allow some fishing."

It is obvious that migratory sturgeons have definitely suffered from overfishing, in the Danube River, documented by the decline of stocks in the Upper and Middle Danube even before the construction of the Iron Gate dams I and II.

Stocks (represented by catches, see also chapter 4) in the Lower Danube have been decreasing drastically as well, due to confusing fisheries legislature and the lack of fishing regulations as well as an unknown extent of poaching. NAVODARU et al. (1999) provide the following proofs for overexploitation of sturgeons in the Lower Danube:

- decrease of catch size
- increase of fishing effort
- decrease of length size of landed (caught) fish
- decrease of Catch Per Unit Effort
- by-catch of younger fish

CEAPA (2001), (in press) and CEAPA et al. (2001) deliver proof for overexploitation of *A. stellatus* in the Romanian Danube River by a 4 years biometry study conducted on catches from the river. Compared with the age frequencies from 1965 to 1968 a significant shift in the proportion of the age classes towards a rejuvenation of the population was observed. Also the average total length (*Tl*) for the period from 1997 to 2000 (mean *Tl*=119.73 cm) decreased, compared to data from 30 years ago (mean *Tl*=131.16).

Apart from the overexploitation of spawners, stocks also suffer from the by-catches in other fisheries. Young sturgeons feeding in shallow areas are often caught in Black Sea pound nets, although these catches have drastically decreased over the last 40 years, due to the scarceness of juveniles. Even in deeper waters of the Black Sea young sturgeons are threatened by gillnets used for sprat-fishing. Anadromous sturgeon species are also threatened by the fisheries on pontic shad with drift nets, since the spawning run of this species occurs about the same time as the peak of sturgeon migration in spring (BACALBASA-DOBROVICI 1991; BACALBASA-DOBROVICI & PATRICHE 1999). COLLINS et al. (2000 a) state, that by-catch primarily in riverine / estuarine gillnets and estuarine / marine trawl fishery appears to be the second major source of mortality for sturgeons. The impact on sturgeon populations by marine fisheries is also documented. Temporary recovery of sturgeon stocks could be observed after the implementation of the 1962 moratorium on sturgeon harvests in the Caspian Sea (KHODOREVSKAYA & NOVIKOVA 1995; SECOR et al. 2000 a).

5.1.2 Habitat loss and habitat degradation

Sturgeons suffer from habitat loss and from degradation of their habitat due to river modification. Stocks are affected most severely by the disruption of spawning migrations (KYNARD 2001 b). This was demonstrated in the case of the Volga River, where about 80 % of the spawning sites for *H. huso* were lost after the construction of the Volgograd dam (SECOR et al. 2000 a). For the Danube River and Black Sea populations of migratory sturgeons the completion of Iron Gate (or Djerdap) dams I + II meant the loss of important spawning sites in the Middle Danube as well. Also changes in the water flow regime through damming and massive irrigation schemes are detrimental for anadromous sturgeons (VESHCHEV 1993; VESHCHEV et al. 1993; VESHCHEV 1994; KRIKSUNOV & MAMINA 1995; BACALBASA-DOBROVICI 1997; KYNARD 1997; VESHCHEV 1998; ZHURAVLEVA & IVANOVA 1999; VESHCHEV & DEBOL'SKII 2000). After damming the breeders are constricted to the remaining reduced spawning sites. Enclosed sturgeon populations can also experience allele effects caused by inbreeding depression and loss of genetic variability (GILPIN & SOULE 1986). Therefore a lot of research especially in North America focusses on sturgeon spawning migration, -sites and -behavior (MC CABE & TRACY 1993 and 1994; PARSLEY & BECKMAN 1993; CARR et al. 1996; VAN EENENNAAM et al. 1996; PARAGAMIAN et al. 2001).

Currently, the spawning sites of migratory sturgeons in the Lower Danube River under the changed migration patterns, due to the construction of Iron Gate hydropower plants, are unknown (BACALBASA-DOBROVICI 1991; BACALBASA-DOBROVICI 1997; BACALBASA-DOBROVICI & PATRICHE 1999; KYNARD et al. in Press).

River modification can also result in the loss or changes in macroinvertebrate fauna and disrupts the connectivity of rivers and their floodplains. Other anthropogenic impacts, such as water pollution and siltation, can impact negatively on the functionality of spawning sites, the development of embryos and can also reduce the abundance of benthic invertebrates found in the diet of most sturgeons, in rivers, estuaries and in the sea (BILLARD & LECOINTRE 2001).

Water quality in the Lower Danube is degraded by point and non-point sources such as industry and respectively agriculture (for further reading on point and non-point sources as well as nutrient budgets see ICPDR; BRUNNER 1997; FLECKSEDER 1999 and SOMLYODY et al. 1999). In Romania, water abstraction for irrigation land of three million hectares decreases river flow and increases pollution by fertilizers and pesticides. The resulting eutrophication now impacts on the northwestern part of the Black Sea. Irrigation pumps kill fish larvae and juveniles (PAVLOV 1989). Brackish water areas in the mouth of the Danube River and the northwestern part of the Black Sea depend primarily on flow in the Danube River, but natural flow is decreased by dams and irrigation. Other projects, such as shipping canals and junctions between different river branches in the delta, threaten to further alter the flow of the Lower Danube.

Competition for available water is a serious problem in the regions of the Danube River Basin. A lack of integrated planning and water management further stresses the problem. Irrigation is the largest user for water, and industrial enterprises also use water in large amounts in the Danube countries. The Danube Delta is an essential biofilter for the entire region (SUCIU et al. 2002). It is also the contact zone of fresh riverine water with the salt water of the Black Sea. Poorly planned aquaculture and agriculture projects added negative impacts on the biofilter capacity of the delta. As a result of these changes, eutrophication and turbidity increased, while oxygen concentrations and biodiversity decreased, which in turn adversely affected the shelf area of the Black Sea. The shelf being crucial for the sturgeons of the Danube River during their marine life periods in the northwestern part of the Black Sea (BACALBASA-DOBROVICI 1991 and 1997; NAVODARU 1998 b; BACALBASA-DOBROVICI & PATRICHE 1999; NAVODARU et al. 2001).

ZOLOTAREV et al. (1996), in contrast, found in an investigation on the state of bottom communities in the north-western Black Sea that no more than 7 % of produced food benthos was used by Acipenseridae, implicating that food shortage is not a major threat for sturgeons in the north-western part of the Black Sea. According to the authors, the mussel *Mytilus provincialis* is the most important food of *A. gueldenstaedti* in the north-western Black Sea, while *A. stellatus* consumed mostly Polychaeta: *Melinna palmata* (summer) and *Terrebellidis shoemi* (spring).

DUBININA & KOZLITINA (2000) state that water diversion through irrigation also has negative effects on the sturgeon populations of the Azov and Caspian Seas. In the North Caspian Sea, sea level variations also affect the juvenile sturgeons in nursery areas on the continental shelf (SHAGAEVA et al. 1993) (for habitat degradation see also chapter 2.2).

Sand and gravel exploitation is another threat to sturgeon habitats. Thus, gravel extraction for construction purposes destroyed sturgeon spawning sites near Calarasi (river km 373) (BACALBASA-DOBROVICI 1997). The negative consequences of gravel extraction on sturgeon spawning sites have also been reported from France (LEPAGE et al. 2000).

Another threat to sturgeon populations can be the alteration of the physiology of fish, and especially the breeders, by toxic substances accumulated in the sediments in rivers and at sea in where most feeding sturgeons are affected. AKIMOVA & RUBAN (1996) describe the effects of anthropogenic impacts on the quality of gametes in sturgeons. They concluded that hermaphroditism, degeneration and absorption of gametes as well as amitoses in oocytes can lead to the reduction of reproductive potential of populations. Alterations of oogenesis were identified as early as 1964 in some females of *A. baeri* (Lena River population), which increased in 1987 to a total of 77 -100 % of the females in the Indigirka River (RUBAN 1997). BICKHAM et al. (1998) describe the acute and genotoxic effects of Baku harbor sediment on *Acipenser gueldenstaedti*, while EVGEN'EVA (1996) reported of abnormal changes in the nervous system of *A. gueldenstaedti* under the influence of toxins. Problems with toxic substances have also been reported from North America (SMITH & CLUGSTON 1997). In the St. Lawrence River the PCB concentration in the flesh of Atlantic sturgeon exceeded the limit of the FDA guidelines for human consumption (2 mg l^{-1}) and in the Hudson River PCBs were found in a range of 0.15 - 1.70 mg l^{-1} (with 7.92 mg l^{-1} in the sturgeon brain). In samples of Beluga caviar from the Black Sea, concentrations of DDT and PCB were 3.6 and 0.4 mg kg^{-1} (wet weight), respectively (WIRTH et al. 2000).

5.2 Recovery and conservation measures

Different approaches have been used worldwide to protect or restore endangered sturgeon stocks. Recovery plans include the legal protection of species and habitats, trade regulations (CITES) and management measures, efforts to restore key habitats (migration routes, spawning sites), programs for artificial propagation and stocking as well as research. BILLARD & LECOINTRE (2001) state: "the experience from studies conducted in North America have shown that restoration efforts, which do not address habitat degradation have generally failed to restore the health of sturgeon populations. First, good knowledge of the habitat used by juveniles and adults in freshwater rivers, lakes, backwater and estuarine areas is required at various stage of the life cycle (migration, foraging, spawning, nursing, overwintering)".

General approaches for the conservation of biodiversity and models for restoring river and floodplain ecology have been established and also for the Danube River Basin (HEILER et al. 1995; SCHIEMER 1995; SCHIEMER et al. 1999; BOGDANOVIC 2000; KHAITER et al. 2000; NACHTNEBEL 2000; BLOCK et al. 2001; GALAT & ZWEIMÜLLER 2001; WARD & TOCKNER 2001; BERLYANT et al.; MINISTRY OF WATERS, FORESTRY AND ENVIRONMENTAL PROTECTION / ROMANIA; PROTECTED AREAS PROGRAMME; BLACK SEA WEB).

5.2.1 Artificial propagation of sturgeons

Knowledge about the biology of Acipenseriformes was already available at the end of the 19th century and in 1869 the first artificial reproduction of sturgeon was done in Russia. Nowadays, methods for the artificial propagation of sturgeons have been widely established throughout the world and complete guidelines are available for many species on the basis of hatchery research (STEFFENS 1981; POHLHAUSEN 1989; REICHLE et al. 1991; BRÄMICK 1992; REICHLE 1992; HOCHLEITHNER 1996; CUI et al. 1997; DOROSHOV et al. 1997; GISBERT & WILLIOT 1997; PROKES et al. 1997; REICHLE 1997; REICHLE & BERGLER 1998; WILLIOT 1998; JÄHNICHEN et al. 1999; GISBERT et al. 2000; REICHLE 2001 a and b). These also include rare species as well as incidentally caught individual and extremely rare animals (WILLIOT et al. 2000; VAN EENENNAAM et al. 2001). PATRICHE et al. (1999) developed a method for artificial propagation and development of *A. stellatus fry* in mobile cages in the Lower Danube River. Sturgeons and sturgeon hybrids are cultured for the production of caviar, meat and offspring for either the further use in aquaculture or the stocking into rivers. According to BILLARD & LECOINTRE (2001) two different systems of sturgeon farming have to be distinguished:

1. Farming systems based on captive broodstock,
2. Systems using a combination of farming and stocking.

One major problem in sturgeon aquaculture based on captive broodstock, is the long time the animals need to mature. Depending on catches of sturgeon broodstock in the river in the combinatory farming and stocking system is always risky, however, since catching and thus propagation success depends on a lot of unpredictible factors (and has often failed in the past also with Danubian sturgeon species, see below). In Europe the artificial propagation of sturgeons is a rather recent activity which started about a decade ago (HOCHLEITHNER 1991), although intensive cultivation for ranching purposes has a long tradition in Russia.

There are no specially designed systems for sturgeon culture. Most systems in Europe have therefore been adapted and modified from conventional fish farming systems and range from extensive pond farms (polyculture in combination with other fish groups, in Europe mainly Cyprinids), raceways, circular tank systems for intensive culture, sometimes in combination with heated water (for example waste heat from power plants) and / or incorporated into recirculation systems, as well as indoor hatcheries combined with grow-out ponds (BRONZI et al. 1999). Also the culture in cages has been tried in a few cases. New successful techniques were developed for the sexing of sturgeons and the extraction of ovaries by surgery (STECH et al. 1999; KYNARD et al., in press). Dietary problems for adult and juvenile sturgeons under hatchery conditions could also be solved (HOCHLEITHNER 1993; MC KENZIE et al. 1997; PROKES et al. 1997; XIN et al. 1998; GEORGIADIS et al. 2000).

Research is also underway to provide caviar of high quality from aquaculture sources as a new economic niche for aquaculture, as well as to lessen the fishing pressure on wild sturgeon stocks (BILLARD 1999 a and b; BILLARD & FEVRIER 1999; BEYER 1999; WILLIOT & SABEAU 1999; WIRTH et al. 2000). Minor problems concerning the taste of caviar from aquaculture origin still do occur (CARDINAL & CORNET 1999), but caviar produced in this way contains less pesticides than wild caviar (KIRSCHBAUM et al. 1999).

In Germany, sturgeon culture started with test programs in the former eastern part in the late 1960s. In the Federal Republic of Germany several entrepreneurs had been involved in sterlet culture and the first successful artificial propagation was achieved in 1987. After the unification several companies developed culture systems for some species on either trial or commercial scales (BRONZI et al. 1999).

The first stocking of sterlets into the Danube River in Germany was conducted in Bavaria near Regensburg with fingerlings of Hungarian origin. Later the sterlet was propagated artificially in the hatchery at Wöllershof (Bezirk Oberpfalz, see also table 6).

In Hungary rearing trials focussed mainly on sterlet and on hybrids, including the bester, and sterlets were stocked into the Danube River (GUTI 1998 b). In Romania, culture techniques presently rely on wild mature fish for reproduction and focus on extensive systems in natural ponds. Ongrowing juveniles is done with *A. stellatus* and *A. gueldenstaedti* in polyculture ponds with conventional pond fishes (Cyprinids). Trials are also underway to acclimate the North American paddlefish (*Polyodon spathula*) and to develop appropriate culture technologies for this species. The release of allochthonous species or stocks has to be regarded critically since the introduction of exotic species usually has negative effects on the ecosystem (ANONYMOUS c).

A "genetic contamination" of native sturgeon stocks has also to be considered, looking at the given potential for hybridization in Acipenseriformes.

Initiatives for artificial sturgeon propagation were also started by exporters of wild caviar from the Danube River as well as private investors, to preserve sturgeons as a valuable resource (BERGLER 2001; SCHRÖDER et al. 2001). Thus, 68,000 specimen of 30 days old *A. stellatus* (1–2 g) were released into the Danube River on June 19, 2000. All costs were covered by the companies which obtained sturgeon fishing quotas and those authorized to process and export caviar (EASTFISH NEWS 2000).

Recent programs in Danubian countries for sturgeon recovery through artificial propagation are outlined by BACALBASA-DOBROVICI & PATRICHE (1999). Artificial spawning of sturgeon in Romania was performed by various hatcheries: Gura Garlutei at Braila, Gura Saltavei at Harsova and in the Litcov hatchery in the Danube River Delta. The Fisheries Research Centre of Galati also started controlled reproduction of *A. stellatus*, beginning in 1991 followed by *A. gueldenstaedti*. Efforts to obtain fry of *H. huso* began in 1996. There were difficulties in obtaining spawners, especially of *A. gueldenstaedti* and *H. huso*. Using the fry obtained from artificial propagation, the Danube Delta Institute stocked the St. George Branch with 4,000 *A. stellatus* in 1994 and with 10,000 *A. gueldenstaedti* in both 1995 and 1996. The Fisheries Research Centre of Galati can raise 200,000 larvae and about 10,000 were released annually into the Danube River during a program on artificial propagation of sturgeons which started in 1991. In 1993, 46,000 sturgeon fingerlings were released (no species given). The broodstock was caught in spring. Four years after the beginning of the programme the subsidies for sturgeon reproduction and rearing were cancelled (ANONYMOUS d).

After construction of the Iron Gate I dam, the Romanian Electrical Organisation financed the Cetate-Dolj hatchery, for sturgeon restocking into the Danube River. Up to 15 years ago, this hatchery restocked small quantities of sterlet fry and fingerlings into the Danube River. The Yugoslavian (now Serbian) hydroelectrical organisation at the Iron Gates contributed to the building of Kladovo hatchery, and financed annual restocking activities in the Danube River. The hatchery restocked *H. huso* fry in particular, but encountered difficulties with the survival of fry, which were stocked too young.

In Bulgaria a new enterprise for the propagation of sturgeons was started recently (Oscietra Comerce in Boliarze; TSAIKOV 2001).
Table 6 provides a list of facilities culturing sturgeons in Danubian countries, which were mentioned in literature respectively by researchers, thus this list may not be complete (ANONYMOUS d; ANONYMOUS 2001; BACALBASA-DOBROVICI & PATRICHE 1999; CAKIC et al. 2000; EASTFISH NEWS 2000; BERGLER 2001; TSAIKOV 2001).

Table 6: List of facilities for artificial propagation of sturgeons in riparian countries (selection)

Country	Facility	Sturgeon Species propagated (including non mature broodstock)
Germany	Bezirk Oberpfalz / Teichwirtschaftlicher Beispielsbetrieb Wöllershof	*A. baeri* *A. gueldenstaedti* *A. naccarii* *A. ruthenus* *A. stellatus* *H. huso* *P. spathula*
Hungary	TEHAG in Szazhalombatta	*A. ruthenus*
	Rideg & Rideg GmbH	*A. ruthenus*
	HAKI (Research facility)	*A. baeri* *A. gueldenstaedti* *A. ruthenus*
	FORUS GmbH in Komadi	*A. baeri* *A. gueldenstaedti* *A. ruthenus*
Serbia	Djerdap Fishing Enterprise in Kladovo	no detailed information / depends on catches of broodstock from the Danube *A. stellatus* *H. huso*
Bulgaria	Oscietra Comerce in Boliarze	*A. baeri* *A. gueldenstaedti* *A. naccarii* *A. ruthenus* *A. stellatus* *H. huso*
Moldova	Fish farming Research Station in Chisinau	*P. spathula*
Romania	Centre of Research for fishing, fish culture and fish processing (CCPPPIP) in Galati	no detailed information / depends on catches of broodstock from the Danube *A. gueldenstaedti* *A. stellatus*

Sturgeon Ranching Programme (SRP) in the former U.S.S.R. was initiated in 1950 (SECOR et al. 2000 a). Nowadays the sturgeon stocks of the neighboring Caspian and Azov Seas depend almost exclusively on the stocking of juveniles from hatcheries (KHODOREVSKAYA 1999). Several authors consider that stocking of juveniles contributed significantly to the sustained populations. From 1980 – 1983 the numbers were 20 – 40 million Russian sturgeons being released into the Caspian Sea. This did not stabilize the population, however, and the numbers of released juveniles were increased to 40 – 60 million annually from 1986 – 1990 (fishes of hatchery origin contributed 25 – 30 % of the total catch). Currently, 29 to 32 million juveniles (1-3g) are released into the Azov Sea (CHEBANOV & SAVELYEVA 1999). The success of stocking effort is difficult to assess, but population dynamics works showed, that in the Volga River the proportion of hatchery propagated Beluga in the captures was 9.3 % in 1971 – 1975, 77 % in 1981 – 1985 and 96 % in 1991 – 1995 (KHODOREVSKAYA et al. 1997). According to BILLARD & LECOINTRE (2001), changes in release technologies occurred, too. In 1992 only 15 % of the juveniles were transported and released directly onto their feeding grounds in the Caspian Sea, compared to 40 – 50 % at the end of the 1970s. Rearing time in ponds is limited to 15 days nowadays. Afterwards juveniles are released into lagoons with enough benthic and planktonic food supply (and with a gradient of salinity from 0 to 5 ‰). Before release, juveniles are placed in large enclosures for about one day to acclimatize to their new environment. This is due to the fact that young fish remain immobile for a few hours after release, which leaves them very susceptible for predation.

Massive stocking and the introduction of exotic and genetically not adapted stocks into river systems by the import of fertilized eggs or juveniles from other watersheds also had negative effects on sturgeon stocks (TSVETNENKO 1993), such as the loss of genetic variability (LUDWIG et al.), or the disappearance of whole stocks as described for the fall or winter races in the Azov Sea by CHEBANOV & SAVELYEVA (1999). The authors state also that shortened spawning migrations (by damming) as well as artificial selection of the ripest fish have lead to high functional maturity of sturgeon spawners in the sea near the river mouth. The authors postulate that artificial propagation must preserve genetic heterogeneity of sturgeon populations. This was thought not to be possible without developing a genetic collection of the fish under controlled culture regime. Guidelines were worked out for the artificial propagation of sturgeons in response to changed patterns of migration. These guidelines included the following measures:

- long term holding of sturgeons at various but constant prespawning temperature regimes, depending on species and biological groups (seasonal forms),
- transition of sturgeons to a spawning temperature regime based on a system of variable temperatures,
- seasonal use of combined hatchery systems: warm water fishery facilities – ponds at hatcheries – for long term holding of broodstock at low temperatures,
- improved schedule of hormonal induction of fish for final gonadal maturation, dependent on dates of capture and seasonal use of broodfish,
- programming of temperature regimes for egg incubation and larvae production during non-traditional season dates,
- automatic control of water temperature regimes, water supply, and monitoring of water quality parameters.

Statistical analysis of the results of the experiments on the physiological state of broodstock permitted the establishment of consistent holding regimes for each species and seasonal form, which, in turn, depended on desired dates for obtaining mature gonadal products from sturgeons.
It was also claimed that stocked juveniles from hatchery origin are not adapted to the conditions in the natural surroundings (FREYHOF & SEROV 2000).
The dangers of conserving sturgeon populations by stocking are documented by the recent events in Russia. For many years, stocking of artificially reared juveniles has been used to maintain populations of Acipenserids in the former U.S.S.R., however, populations could not be stabilized by stocking (a similar phenomenon was observed in the United States; KHODOREVSKAYA et al. 1997; GRAHAM 1997). Since the late 1980s fewer hatcheries were operated, due to a lack of funds and broodstock (catches in the rivers also proved difficult because the spawners were becoming scarce). Due to economic and political changes as well as a decrease in funding, the artificial propagation of sturgeons and stocking in the former U.S.S.R. faces a crisis today. This, together with a lack of natural reproduction, increased harvesting and poaching, leads to a severe decrease of sturgeon stocks in the Caspian Sea.
ARTYUKHIN et al. (1999) identified overfishing, poaching and the decline of natural reproduction as main causes for the decline of sturgeon stocks in the former U.S.S.R.. According to the authors, hatchery releases have declined since the early 1990s, particularly in the Caspian Sea Basin, one of the reasons being a chronic shortage in broodfish. They also stress the need for appropriate management of fall and winter races of migratory species. ST. PIERRE (1999) developed a breeding and stocking protocol to address genetic concerns and to provide guidance for aquaculture programs. TSVETNENKO (1993) investigated the effective and genetic consequences of the introduction of the stellate sturgeon, *A. stellatus* into the Azov Basin from the Caspian Sea on the basis of identification of morphometric characters of the head. The data indicated the ineffectiveness of introducing Caspian Sea stellate sturgeon into the Azov Sea Basin, since the introduced stocks displayed a less successful reproduction.
BIRSTEIN et al. (1997) resumed that even the best stocking programs can only provide short-term solutions unless they are coupled to plans for protecting and increasing levels of natural reproduction.
A combined and coordinated stocking effort for sturgeons has not been conducted in the Danube River Basin. Sterlets (*A. ruthenus*) were stocked into the Danube River and its tributaries in Germany, Austria and Hungary (GUTI 1995; HOCHLEITHNER 1996; HENSEL & HOLČIK 1997; REICHLE 1997; ZAUNER 1997; HONSIG-ERLENBURG & FRIEDL 1999). Occasional stocking with sterlet and migratory species was conducted by Serbia, Bulgaria (into the Black Sea) and Romania. In the case of Serbia and Romania stocking depended on catches of broodstock

from the river, which proved not always successful in recent years (BIRSTEIN et al. 1997; BACALBASA-DOBROVICI & PATRICHE 1999; BERGLER 2001; TSAIKOV 2001).

The establishment of broodstocks for artificial propagation in captivity and stocking (live gene banks) is proposed by ARTYUKHIN et al. (1999) for the ex-situ conservation of sturgeon species. This raises the issue of the minimum critical number of males and females participating in the reproductive effort. BILLARD & LECOINTRE (2001) advise that a minimum of 100 fish should equally contribute to prevent inbreeding fitness depression. The fish should also come from the same population (drainage basin). If such large numbers of captive spawners are not available, a genetic screening of individuals (microsatellites) should be conducted for the optimization of hatchery crosses and the maximization of genetic diversity (WIRGIN et al. 1997).

5.2.2 Protection and habitat restoration

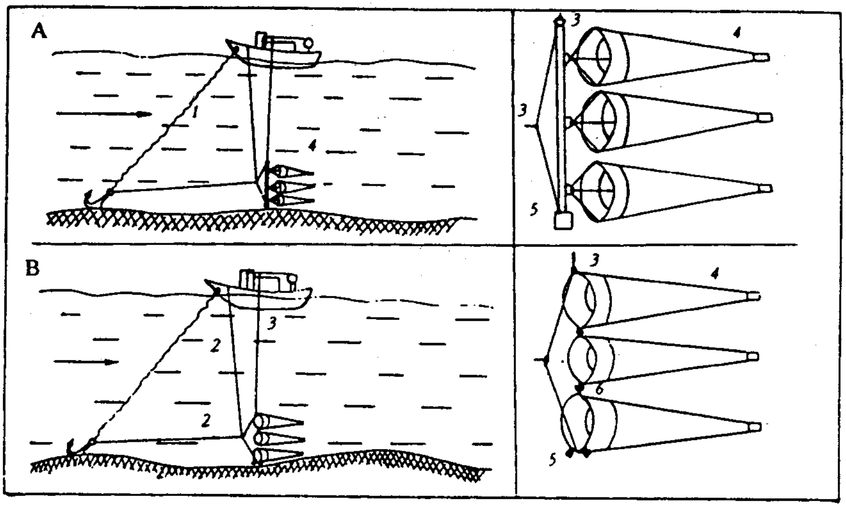
Major concerns in sturgeon conservation are the assessment of stock status, the identification and enhancement of critical habitats and the environmental conditions determining reproductive success (WILLIOT et al. 1997; COLLINS et al. 2000a).

The problem of assessing stock and reproductive status of sturgeon populations was tackled differently in literature. GUTI (1998 b) comments that the status of anadromous sturgeons in the Danube River above Iron Gate dams is impossible to determine, due to the scarceness of animals. Also, in a six year survey, *A. gueldenstaedti*, *A. stellatus*, *A. nudiventris* and *H. huso* could not be found in Hungary, according to KERESZTESSY (1996). KHODOREVSKAYA & KRASIKOV (1999) determined sturgeon abundance and distribution in the Caspian Sea by trawl catches. RASPOPOV (1993) and RASPOPOV & NOVIKOVA (1997) estimated numbers of Beluga spawners and studied the size and age composition of larvae and spawners *of H. huso* in the Volga River.

NOVIKOVA (1994) studied the densities of eggs on 7 different spawning sites of *H. huso* in the Volga River (in a ten year survey), as well as the migration of larvae from these sites.

RASPOPOV et al. (1994) were able to provide evidence of the reproduction success of *A. gueldenstaedti* in the Volga River by catching and counting migrating larvae from the spawning sites. VESHCHEV et al. (1994) and VESHCHEV (1995) studied the reproductive success of *A. stellatus* in the Volga River by counting migrating larvae, with conical IKS-80 nets (see figure 7) as best and most objective method.

Fig. 7: Conical nets for counting migrating sturgeon larvae in the river. Placement of nets with pole (A) and without pole (B). (1) Anchor chain; (2) tether (capron rope); (3) cable; (4) conical nets; (5) weight; (6) connecting bolts. (from VESHCHEV et al. 1994)



Different approaches have been used to identify sturgeon habitat as well. PARSLEY & BECKMAN (1994) estimated spawning and rearing habitat for *A. transmontanus* by combining computer based habitat simulation systems and GIS. KELLY deployed a suitability model for the determination of habitat quality for *A. fulvescens* in the Mississippi.

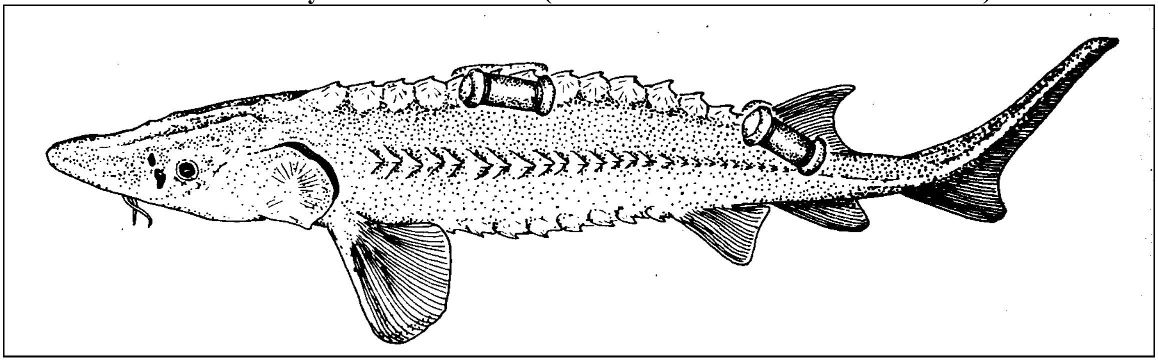
MARCHANT & SHUTTERS (1996) used artificial substrates (circular polyester floor buffing pads) for collection of eggs (*A. oxyrinchus desotoi*) and to determine the approximate spawning time and locations.

With the development and progress in devices for telemetry and hydroacoustics it became possible to study the individual movements as well as habitat use of adult sturgeons. In combination with additional measures, for instance egg collection and different catching methods, some researchers were able to identify habitats such as spawning sites. KIEFFER & KYNARD (1993 and 1996) and KYNARD et al. (2000) tagged shortnose sturgeons with ultrasonic pingers and tracked individuals to identify timing and location of spawning as well as for the characterization of spawning sites and habitat use. CURTIS et al. (1997) used radio-telemetry in the Upper Mississippi River to determine movements of shovelnose sturgeons and their response to unusually low water conditions. SCHAFFTER (1997) used radio-transmitters to follow spawning migrations of *A. transmontanus* and for the identification of spawning sites, using artificial substrates for egg collection. Radio-telemetry was conducted by MC KINLEY et al. (1998) to evaluate seasonal migratory behavior and reproductive pattern of lake sturgeon in a riverine system, where flow is regulated by hydroelectric power plants.

COUNIHAN & FROST (1999) studied the influence of externally fixed transmitters on swimming performance of juvenile *A. transmontanus* (see figure 8). They resumed that results

from biotelemetry have to be regarded critically since the size and weight of transmitters had an influence on the swimming performance of juveniles and small animals.
An overview of current methods for studying spatial behavior of freshwater fishes in their natural environment is given by LUCAS & BARAS (2000).

Fig. 8: Fixation of ultrasonic transmitters (pingers) on a juvenile white sturgeon (*A. transmontanus*). Fish in an experiment to determine the influence of externally fixed transmitters carried only one such device. (from COUNIHAN & FROST 1999)



COLLINS et al. (2000 b) used a combination of pit-tagging and radio-tagging as well as acoustic transmitters on *A oxyrynchus oxyrynchus* to determine movements and habitat use in two South Carolina rivers. SECOR et al. (2000 b) conducted biotelemetry on 32 individuals as well as internal-coded-wire-tagging on a great number of *A oxyrynchus oxyrynchus* in Chesapeake Bay for the identification of habitats as well as habitat use. Internal-coded-wire-tags showed a retention of more than 95 %. KYNARD et al. (in press) conducted telemetry and tag return studies on sturgeons of the Lower Danube River between 1998 and 2000. Studies began in the St. George branch, where only *A. stellatus* could be obtained by gill net fisheries (three in spring and seven in fall with a fishing mortality of 20 %). The animals were tagged with external acoustic transmitters at the base of the dorsal fin (offering also a reward for the return). Two fall migrants could be tracked moving upstream at a rate of 18 km day^{-1} ground speed. Two other tagged animals did not resume migration after tagging and moved downstream. Three of eight tagged fish (38 %) were returned by fishermen, one from Sulina on the Black Sea. Telemetry (tracking and upstream loggers) did not detect the missing sturgeons, so they were likely harvested, moved downstream, or both. Fall migration of *A. stellatus* ceased in early October at a temperature of 16 °C. In 1999 the studies were conducted in the mainstem Danube River to gain access to more sturgeons. During spring 1999, forty-one stellate and three Russian sturgeons were obtained from drift-net fishermen, sexed with a bioscope, and again externally tagged with acoustic transmitters offering a reward for their return. The animals were caught at Isaccea, transported to the work-boat, and released at Galatz (river km 150). Data-logging receivers were installed at Grindu (river km 140), Harsova (river km 238), and Oltenita (river km 430). Data on thirteen stellate (32 %) and one

Russian sturgeon (33 %) were collected. The Russian sturgeon was detected moving downstream by the Grindu logger. The authors summarize the results for stellate sturgeons as follows: one harvested at release site, one detected moving upstream by Harsova logger then harvested within one day, two detected moving downstream by Grindu logger, and nine moving downstream undetected and being harvested. Thus, fishermen returned tags from eleven out of forty-one (27 %) stellate sturgeons. Eleven stellate sturgeons moved downstream after release and the actual number was higher because the downstream Grindu logger missed nine fish that passed undetected. All data indicated that harvest and downstream movements removed most tagged fish from the study area. Telemetry indicated upstream migrant stellate sturgeons moved 6 – 7 km day^{-1} ground speed in the mainstem river. Downstream migrants moved at speeds between 10 – 20 km day^{-1} ground speed. Telemetry as well as the monitoring of 5 potential spawning sites between river km 258 and 600 did not reveal the location of sturgeon spawning sites in the Lower Danube River.

Sturgeons are especially affected by the disruption of their migration routes through damming and the construction of hydropower plants, therefore the restoration of river continuity and thus the implementation of passing solutions are also major points, which have to be adressed concerning sturgeon conservation and restoration of populations. This holds true especially for the anadromous migratory species, which are cut off from their spawning grounds upstream. Thus, restoration of the migration routes as well as fish-passing technology at dams is considered as one of the major tasks in sturgeon conservation. PARAGAMIAN & KRUSE (2001) developed a predictive model for sturgeon migrations (*A. transmontanus*) under different environmental conditions.

Some factors influencing the type, size and position of a passing solution are the River itself (size, morphology, hydrology, floodplain- and valley morphology etc.), type and size of the obstruction (e.g. hydropower-plant, dam, weir etc.), targeted species and the amount of available water and land.

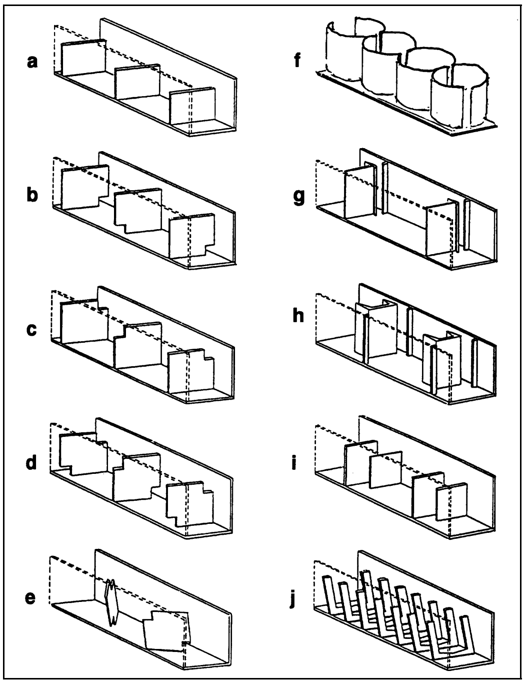
General requirements for the functioning of passing solutions can be summarized as follows (PAVLOV 1989; DVWK 1996; VERBAND DEUTSCHER FISCHEREIVERWALTUNGS-BEAMTER UND FISCHEREIWISSENSCHAFTLER E.V. (VDFF) 1997; LARINIER 2000):

- Passing respectively connectivity solutions should support the passage of all components of the „mobile“ river ecology meaning all species, sizes and developmental stages of the aquatic fauna present in the riverine system.
- Passing solutions must comprise provisions for the upstream and downstream passage of all species, sizes and developmental stages of the aquatic fauna in the riverine system.
- Passing solutions must be in function the whole year round.

- The size of passing facilities has to be adapted to the size of the targeted species as well as the expected amount of passing biomass during phases of peak-migration.
- Passing solutions must provide possibilities for the control of functioning as well as melioration measures and ensure the access to migrating animals for research purposes.

Fish-passes have to be considered as only part of the whole passing solution. The type of barrier and characteristic traits of up- and downstream riverine sections and last but not least the migrating species determine the function of a passing solution as well. Nature-like fish-passes comprise bypasses and ramps, technical passes include pool and weir fishpasses (a.k.a. fish ladders or pool and traverse fishpasses), vertical slot fishpasses and Denil fishpasses (see figure 9). Special fish-passes constitute fish-sluices and fish-lifts.

Fig. 9: Variations of technical fish-passes (a): partition wall without orifice and submerged, (b):like (a) with bottom orifice, (c): like (a) with top chute, (d): like (a) with bottom orifice and top chute, (e): like (d) with rhomboid partition walls, (f):pass with circular pools, (g): one-sided vertical slot pass, (h):double-sided vertical slot pass, (i):like (a) with double partition wall and vertical slot every other wall, (j): Denil pass (from VERBAND DEUTSCHER FISCHEREIVERWALTUNGSBEAMTER UND FISCHEREIWISSEN-SCHAFTLER E.V. (VDFF) 1997)



Major characteristics and advantages as well as disadvantages of different common fish-passes can be summarized as follows (PAVLOV 1989; DVWK 1996; VERBAND DEUTSCHER

FISCHEREIVERWALTUNGSBEAMTER UND FISCHEREIWISSENSCHAFTLER E.V. (VDFF) 1997; LARINIER 2000).

Ramps are either integrated in existing dam- or weir-constructions or span the whole width of the river. In the latter case, usually no problems with the attracting currents or the detection of the down- and upstream entrances for migrating animals occur. Low water levels can disrupt the function of this passing solution, though. The passage for the whole fauna is possible in both directions. Ramps have good self-cleaning capabilities during periods of high discharge.

Bypasses consist of an artificial stream bypassing the migration barrier (sometimes in combination with technical components and/or natural floodplain water bodies e.g. oxbows or tributaries). This passing solution almost always requires the purchase of additional land and the construction of additional bridges and culverts. However, it allows the passage of the whole fauna and functions as secondary habitat for rheophilic species. It is the only passing solution which also allows the bypassing of stagnant water bodies in upstream impounded sections. The detection of the upstream entrance into the pass can pose problems for descending animals which migrate with the main current.

Pool and weir passes (a - f and i, in figure 9, see also table 7) only tolerate relatively small water discharges, resulting in weak attraction currents at the downstream entrance of the pass. Because of their tendency for the congestion with flotsam and debris, this type of fish-pass requires a considerable amount of maintenance and cleaning. The detection of the upstream entrance into the pass can pose problems for descending animals which migrate with the main current.

Table 7: Recommended sizes of components of orifice-weir (pool and weir) type fish-passes for sturgeons (according to SNiP 1987 quoted in DVWK 1996)

pool size [m]			size of orifice [m]		water discharge in pass [m^3 s^{-1}]	Water level fluctuation in pass (permissable maximum) Δ h [m]
length	**width**	**Water depth**	**width**	**height**		
5 – 6	2,5 - 3	1,5 - 2	1,5	1	2,5	0,2

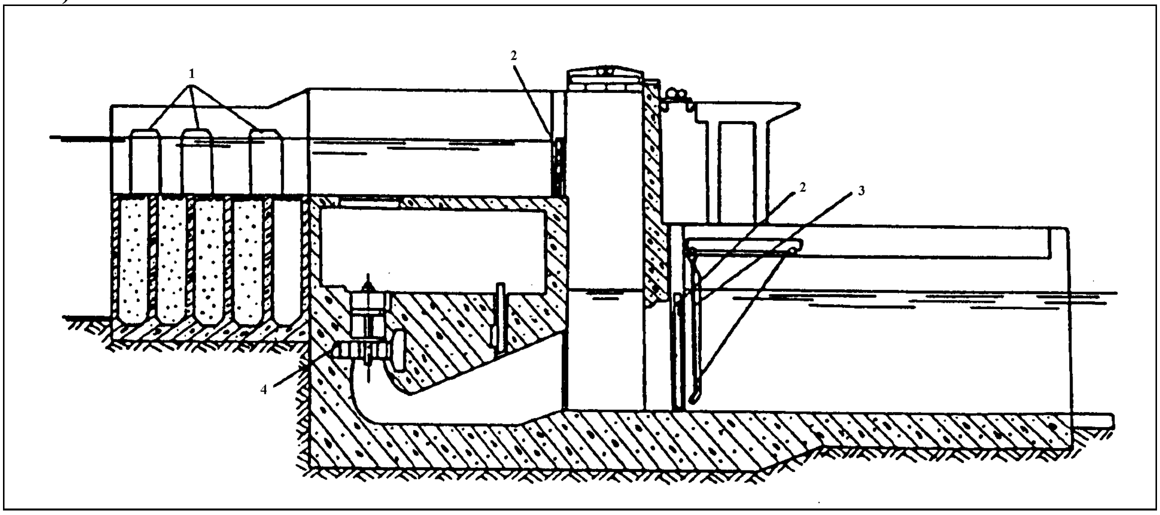
Denil passes (j in figure 9) are suitable solutions for small obstructions and for the subsequent integration into existing small dams and weirs. They do not work well for small species, bottom-oriented fish and animals with only limited swimming performance. The detection of the upstream entrance into the pass can pose problems for descending animals which migrate with the main current.

Vertical slot passes (g and h in figure 9) tolerate changing upstream water levels as well as high water discharges (up to several $m^3 s^{-1}$ depending on the size of the pass) resulting in strong attraction currents for the downstream entrance of the pass. Vertical slot passes show less tendency for the congestion with flotsam and debris than conventional pool and weir passes. The detection of the upstream entrance into the pass can pose problems for descending animals which migrate with the main current. According to current knowledge the vertical slot pass is the best technical solution, which functions well for all fish species and also macroinvertebrates if suitable bottom substrates are applied.

Fish-sluices and –lifts belong to the so-called special fish-passes. Fish-sluices are installed, when the available water and space for the passing solution is limited, for instance. Because of their usually large size, sluices are considered advantageous for the passing of large species (like sturgeons). Fish-lifts often constitute the only passing solution at obstructions of higher than 10 m. Lifts do not support the migration of descending animals, though. Both kinds of passes require a high technical and construction-work effort as well as high levels of supervision and maintenance. They work well with Salmonids and species with only limited swimming performance. They do not function very well for bottom-oriented species and macroinvertebrates. Hydraulic and mechanical fish lifts have been used to assist the migration of Acipenseridae in the former U.S.S.R. as well as in North America (PAVLOV 1989; KYNARD 1997). Examples for hydraulic systems are the Tsimkyanskij (Don River) and the Volgogradskij (Volga River) fish lifts. About 200,000 to 700,000 Acipenseridae spawners approached the Volgogradskij dam from the Caspian Sea annually, and an average of 20,000 passed each year with a maximum of 60,000 in 1967. The Saratovskiy (Volga River) and Krasnodarskiy (Kuban River) mechanical fish lifts were also constructed to allow the passage of Acipenseridae, however, no numbers for fish passage are given by PAVLOV (1989). It was estimated that Kochetovskij sluice fish-pass (Don River) allows the passage of up to 67 % of approaching Acipenseridae. A similar type, the Fedorovskiy fish-pass (Kuban River) passes up to 1,000 spawners of *A. gueldenstaedti* and *A. stellatus* annually.
BILLARD & LECOINTRE (2001) resume that fish elevator technology is not very effective for sturgeon. They cite studies conducted on the Krasnodar dam fish lift on the Kuban River where the passage of only 22 breeders between 1991-1995 was reported (instead of 63,000 expected). KYNARD (1997) recorded only 81 shortnose sturgeons lifted from 1975 to 1995 at the Holyoke dam on the Connecticut River. According to BILLARD & LECOINTRE (2001) such levels of

passage do not contribute much to the total reproduction, but ensure some gene flow within the population above the dam.

Fig. 10: Fish lock of the Volzhskaya hydroelectric dam on the Volga River: 1. outlet orifices, 2. operational gates, 3. crowding device, 4. hydroelectric unit (from PAVLOV 1989)



Considering the main traits in the biology and ecology of sturgeons the following fish-passes of those mentioned above have to be taken into consideration for connectivity solutions also working for Acipenseridae.

Ramps would probably be suitable for sturgeons, since Acipenseriformes are known to also surcome rapids. Detection of up- and downstream entrances would be supported as well as the up- and downstream migrations of pre-spawning and spent fishes as well as larvae and juveniles at different developmental stages.

Bypasses would have to be adapted to sturgeons. Although sterlets could not be ascertained in the nature-like bypass at the Freudenau – hydropower plant in Vienna (their presence downstream was observed by means of gill-net catches, EBERSTALLER et al. 2001), sturgeons are known to ascend into tributaries given the right attracting current and river-bottom topography (during the initial flooding of the Tsimlyanskoye Reservoir, the current of the Don River was reduced to 0.1 m s^{-1}, while that of its tributary the Severtskiy Donets remained at 1.5 – 2 m s^{-1}, causing *A. gueldenstaedti* and *H. huso* to ascend into the tributary, PAVLOV 1989).

Technical fish-passes would have to be adapted to the size of mature spawners on the one hand (see table 7), but should also support the migration of immature individuals and other targeted species present in the riverine ecology. Vertical slot passes should be preferred because of the superior possible attraction currents.

Fish-sluices can also be taken into consideration, if provisions for suitable attraction currents are made. Pure fish-lift solutions should be ruled out, since this technology has proven not to be very effective in the passing of sturgeons and does not support downstream migrations (BILLARD & LECOINTRE 2001).

Some authors investigated the swimming performance of Acipenseridae. Swimming speeds of bottom fishes, and notably Acipenseridae, are typically slower than those of pelagic species. WILGA & LAUDER (1999) studied the function of the pectoral fins in different phases of locomotion in juvenile white sturgeon (*A. transmontanus*) and LIAO & LAUDER (2000) the function of the heterocercal tail. Accounts of the swimming performance of sturgeons are often contradictory, however. HOLČIK et al. (1989) mention investigations by NINUA in the Rioni River, where migrating sturgeons (*A. sturio*) were observed moving against swift currents of 1.4 to 2.2 m s^{-1}. MOHR (1952) also describes *A. sturio* as a strong swimmer with high jumping ability, capable of surcoming currents of up to 2.2 m s^{-1}. SNiP (1987 quoted in DVWK 1996) on the other hand describes sturgeons as „fishes with only humble swimming performance, already avoiding currents exceeding 0.8 m s^{-1}“. PEAKE et al. (1997) created a model to relate swimming performance of lake sturgeon (*A. fulvescens*) to fishway design. They measured the endurance at sustained and prolonged (maintained for more than 20 s) swimming speeds. ADAMS et al. (1999) studied swimming endurance of juvenile pallid sturgeon *Scaphirhynchus albus*. In a laboratory tunnel, sturgeons used their pectoral fins and overall body morphology to be stationary against velocity without swimming. The fish typically swam in contact with the ventral body surface to the tunnel bottom during tests, rarely swimming in the water column. Swimming speeds were found comparable to those of similar sized species. Juvenile pallid sturgeons take advantage of low velocity microhabitats in high velocity rivers.

The spawners of Acipenseridae have high threshold velocities (18-25 cm s^{-1}), and the velocity of the attracting flow of a fish-passing device must lie between the threshold velocity and a point somewhat less than the critical velocity for the species to be attracted. Usually the attracting velocities are taken as 60 to 80 % of the critical velocities, which amounts to 0.7 – 0.9 m s^{-1} for Acipenseridae (*A. gueldenstaedti*, *A. stellatus*) (PAVLOV 1989). According to this author, there are two ways to increase the area of attraction for a fish-pass. (A) The velocity of the attracting flow can be varied. Initially the discharge flow velocity is increased to several times the critical velocity to ensure a large area of attraction, then it is gradually decreased to provide suitable conditions for fish to enter the mouth of the fish-pass. (B) An additional current at the inlet of the fish-pass is created. The current in the fish-pass itself should be the same as the cruising speed of the fish. Maximum velocities are created at the inlet, but as the fish spend only short time there (1 – 20 min) they do not become fatigued.

A more complete knowledge of swimming performance is required for calculating attracting flow velocities and periods of attraction (PAVLOV 1989). For example, the maximum time period for *A. gueldenstaedti* to swim against a flow velocity of 0.95 m s^{-1} was measured 40 minutes; for *A.*

stellatus it was 30 minutes and 10 minutes at a flow velocity of 1.1 m s^{-1}; for *A. ruthenus* and a flow velocity of 0.95 m s^{-1} 30 minutes were measured. The swimming performance also decreases sharply before spawning.

The question of suitable passage solutions for sturgeons at obstructions cannot be reduced to swimming ability, though. At least of the same importance are the identification of migration routes, areas of attraction and aggregation below and above migration barriers as well as the role of river bottom topography for the migration and/or guiding of sturgeons in the vicinity of barriers as well as passing solutions. GERTSEV & GERTSEVA (1999) developed a mathematical model of water velocity distribution in the tailwater of a hydropower plant. On the basis of this model, another model for sturgeon distribution below the dam of hydropower plants was created. The latter model was analyzed numerically in conformity with the largest hydropower plant on the Volga River in Volgograd. The results allowed a theoretical estimation of sturgeon passage. PAVLOV (1989) stresses the importance and superiority of biotelemetry (in contrast to electrofishing and netting) in studying the movements of sturgeons in the vicinity of hydropower plants and for determining the location of fish-passes.

The topography of the river bed plays an important role in determining the path traversed by bottom-dwelling fish, such as Acipenseridae, migrating along the bottom or steep banks, following the contours of slopes but avoiding areas of low relief. Observations near Balakovo before and after the construction of the Saratovskiy scheme revealed that Acipenseridae moved upstream in the reservoir by the same routes as they used before impoundment. Thus, the behavioural stereotype had not changed. Acipenseridae also tend to avoid flat surfaces and to follow the contours round the sides of mounds and slopes. The topography of the bottom, together with the current velocities, thus plays a significant role in determining the distribution of Acipenseridae, not only in rivers, but also in the tailwaters of dams. When yearly variations in the bottom topography and the hydraulic conditions of the tailwater prevail, distinct changes in the paths by which fish approach dams can be observed. Telemetric data from the tailwater zone of the Fedorovskiy hydraulic scheme revealed three main different paths of approach in three consecutive years (1969 – 1971). This complicates the choice of location for fish-passing devices, and requires the stabilisation of the bottom of the tailwater.

Different structures are used as fish guiding devices e.g. tactile ways like ditches, bottom rapids, and ledges placed obliquely from bank to fish-pass. Tactile ways consist of large stones laid on the bottom to facilitate orientation of bottom fish. Ditches are hollows cut into the bottom to guide Acipenseridae, as they respond strongly to changes in relief. Bottom rapids and ledges are especially constructed prominences on the bottom, and are in wide use in hydro-engineering practice as devices to manage deposits at water intake heads. Also different patterns of currents can be good guides for near bottom fish and have been investigated under laboratory conditions for a number of young fish including Acipenseridae.

PAVLOV (1989) provides a description of sturgeon migratory behavior in rivers, in the vicinity of dams and in fishpasses. According to this author, *A. stellatus* exhibits a 24-h-pattern of migration, but with a maximum at night. Moonlight can reduce the intensity of migratory movement in this species. This is supported by the fact that *Acipenser stellatus* and also *Acipenser gueldenstadti* were observed in fish-passes only during darkness.

One can resume, that standard passing solutions for sturgeons at migration barriers are not available and every particular migration barrier needs a particularly adapted passing solution. This calls for additional research on general topics (e.g. the role of submerged guiding structures) as well as in situ investigations to optimize passing solutions in any given case.

The identification of habitats for juvenile sturgeons (migration paths and rearing areas) poses problems, since this size of fishes is practically not observable in the river (except migrating larvae, see above). It was also stated that the migrating behavior of young sturgeons is genetically determined and that it is adapted to the riverine system inhabited by a certain stock, thus leading to different migration patterns of juveniles of the same species in different rivers. Laboratory experiments were conducted to determine the behavior and habitat preferences for larvae and juveniles of different species and stocks (duration of drift and migration, presence in different strata of the water column, diurnal patterns, etc.). Results of such laboratory experiments are considered useful for the identification of juvenile in-situ habitats as well as for the catch of juveniles for research purposes in the natural environment (KYNARD 2001 a).

LEVIN (1992) studied spatio-temporal distribution of YOY (=Young-Of-the-Year) *A. gueldenstaedti* in the estuary and the western part of the Caspian Sea by catches and found significant differences in growth in different habitats. RICHMOND & KYNARD (1995) were able to document ontogenetic changes in the behavior of *A. brevirostrum* during the first 66 days after hatching. CHIASSON et al. (1997) conducted similar studies on the potamodromous *A. fulvescens* in northern Ontario. CHAN et al. (1997) conducted laboratory experiments on juvenile *A. oxyrinchus desotoi* concerning habitat preferences. LOEW & SILLMAN (1997) investigated the light dependency of swimming behavior in newly hatched *A. transmontanus*. GISBERT et al. (1999) investigated the behavioural modifications in early life stages of *A. baeri*. PEAKE (1999) determined substrate preferences of juvenile hatchery-reared *A. fulvescens*. STAAKS et al. (1999) studied the thermal behaviour and diurnal activity rhythms of juvenile *A. sturio*. SCHUBERT & STEIN (2002) found that juvenile sterlets (4,1 cm mean *Tl*) preferred temperatures of 24 to 25º C.

Sometimes, restoration of degraded, or construction of new habitat, has been attempted. Construction of artificial spawning sites made of stones and gravel were located below the Federowskaya dam on the Kuban River, but it was entirely silted after few years and was replaced by a new spawning bed on the side of the river in which the mature spawners were attracted by the appropriate water flow regime (BILLARD & LECOINTRE 2001). In the 1980s, 48 ha of spawning beds were established in the Volga River with 2-6 cm gravel at depth of 2-6 m (floodable) or 6-12 m (in the river bed) and the density of eggs found was highly variable, from 60 to 4,000 per m^2 (POPOVA et al. 1989; VLASENKO et al. 1989). Spawning channels with a large variety of substrates and appropriate water velocity have also been used in the USA (KYNARD 1997).

5.2.3 Biotechnology

Aside from habitat restoration and artificial propagation also biotechnology has been proposed to help conserve extremely rare species, especially incidentally caught individuals by means of androgenesis (BERCSENYI et al. 1998; BERCSENYI 2001), as well as the conservation of genetic variability through the preservation of gametes (VDSF 2001).

With the technique of androgenesis, eggs of a closely related species are irradiated in order to suppress the female pronucleus, and these eggs are then fertilized with the spermatozoa of a rare male individual to produce an animal whose phenotype is that of the male species. Mitochondrial or non-nuclear DNA remains that of the “mother” species, though. Diploidy is etablished by dispermic fertilization (GRUNINA et al. 1995; GUTI 1998 b; BERCSENYI 2001). Meiotic gynogenesis was induced in shovelnose sturgeon by MIMS & SHELTON (1998).

Cryopreservation of gametes in fishes is, as a method for the ex-situ preservation of the species, currently only possible for sperm. BILLARD et al. (2000) experienced some recovery of sperm motility and some fertilisation, not exceeding 30 – 40 % of the controls. New cryoprotectants were explored and methanol was used, resulting in 47 – 64 % post thaw motility and 96% fertilisation versus controls. Sturgeon sperm banks are now established in Russia, one at Rybnoe near Moscow, and another at Krasnodar. Cryopreservation of Danubian sturgeons sperm is also conducted in Hungary (BERGLER 2001).

5.3 Sturgeon genetics

The karyotypes of the Acipenseriformes are uncommon for vertebrates (FLAJSHANS & VAJCOVA 2000; LANFREDI et al. 2001). The basic chromosomic complement consists of 10 pairs of large sized metacentric chromosomes, 22-25 pairs of small meta-, submeta- and acrocentric chromosomes and 60 microchromosomes. This makes the determination of an exact chromosomal amount in octoploid species almost impossible. The karyotype may thus be better characterized by chromosome banding, in situ hybridization with DNA probes and analyses of synaptonemal complexes (FONTANA 1994; FONTANA et al. 1998 and 1999). Three groups of chromosome configuration can clearly be distinguished; (A) a number of chromosomes close to

2n=120 (60 macro and 60 microchromosomes and 3.2-3.8 pg DNA); (B) an octoploid with approximately 4n=240 and twice as much DNA; (C) measurements of DNA (14 pg) suggest a 16 n ploidy and 500 chrosmosomes (for example in *A. mikadoi* and *A.brevirostrum*).

Data on nuclear DNA and enzymatic polymorphism suggest that the present Acipenseriformes originated from a tetraploid ancestor which had a 120 macro- and micro-chromosomes and DNA content of 3.2-3.8 pg nucleus^{-1}. This was interpreted as the result of the diploidization occurring twice from a common extinct ancestor which had 60 chromosomes (BIRSTEIN et al. 1997; BILLARD & LECOINTRE 2001). For FONTANA et al. (1999), however, the possibility of grouping silver stained NOR chromosomes into pairs and quadruplets in, respectively, 120 and 240 chromosomes karyotypes would support a diploid-triploidy condition in Acipenseriformes.

The small level of heterozygosity, the existence of polyploid states and the presence of a very high microchromosome proportion in association with chromosomes of large size are characteristics usually found in ancient groups such as lampreys and suggests that the Acipenseriformes are genetically "living fossils".

Acipenseriformes are also characterized by a high capacity for hybridization. In sympatric distribution nearly all species will hybridize. Usually the hybrids 2n x 2n or 4n x 4n (interspecific or intergeneric) are fertile, while the interploid crosses 2n x 4n are triploids sterile (no oocyte formation in females). In interploid crosses the number of chromosomes is in between those of the parents, for instance 160-180 in the hybrid *A. gueldenstaedtii* (2n=240) x *A.ruthenus* (2n=120). Reproductive barriers which prevent hybridization may be altered by drastic changes in the environment. This is likely due to the reduction of spawning grounds and the concentration of different species on the same spawning areas (BILLARD & LECOINTRE 2001).

Recent work using enzymatic polymorphism and molecular analyses of mitochondrial or nuclear DNA delivered an idea of the genetic variability of some sturgeon populations. In general the variability is low and concerns numerous more or less structured populations of limited size for most species.

Methods for species identification are a basic prerequesite for any program of species conservation (AVISE 1989; KING & BURKE 1999). This is even more important in species which are harvested commercially (BAKER & PALUMBI 1994). Furthermore, the traditional methods for species identification of acipenseriform individuals by morphometric characteristics often prove not to be sufficient to meet the current demands or regarding the identification of sturgeon hybrids (BIRSTEIN & BEMIS 1997; GARRIDO-RAMOS et al. 1997; ARTYUKHIN & VECSEI 1999; HERNANDO et al. 1999; CAMPTON et al. 2000; DOUKAKIS et al. 2000; RINCON 2000; ENE & SUCIU 2001).

Methods for the identification of different species, different units within species or individuals in modern research always depends on the identification of specific “markers”. Both biochemical (expressed genes) and genomic markers (e.g. nuclear, mt DNA or microsatellite DNA) are used. The latter having the advantage, that small sample sizes are sufficient in most cases (markers can be copied and amplified), great numbers of samples can be obtained during field work (e.g. through fin clipping) and stress for the sampled individual can be reduced to a minimum (in contrast to blood extraction, for example).

Major current aims in sturgeon molecular genetics research are:

- Species identification,
- identification of origin for sturgeon products (country and/or river) for determining the trade ability and to enforce legislature concerning Acipenseriformes (CITES),
- identification of individuals and their offspring for determining the fitness of different life history traits, as well as the influence of stocking on sturgeon populations,
- to provide information and tools for management and/or conservation programs for sturgeon stocks, by the identification of different "reproduction units" within a species, for example. Several populations or races are described for different species in the literature. They may inhabit the same river system and can be recognized only by their season of migration or different spawning sites. From a management point of view it is essential to know if these populations show reproductive isolation, how much of broodstock is involved, to what extent genetic flux between populations takes place, and what is the degree of homing fidelity.

JENNECKENS (1999) tested different biochemical and molecular markers for the discrimination of different sturgeon species as well as hybrids and summarized different approaches in genetic research on sturgeons under the following topics:

- Identification of caviar,
- identification of individuals,
- identification and characterization of populations.

5.3.1 Identification of caviar

Apart from the traditional species (*A. gueldenstaedti*, *A. stellatus*, *H. huso*), also other acipenseriform species are used for caviar production (DESALLE & BIRSTEIN 1996; BIRSTEIN et al. 1998 b). False declaration of caviar could be proven in different cases (AMERICAN MUSEUM OF NATURAL HISTORY 2001). One study (BIRSTEIN et al. 1998 b) revealed that 32 % of the examined samples were falsely declared. The reason for this being the drastic decrease in wild sturgeon populations of the species mentioned above, combined with an increase in the demand for caviar. The researchers stated that identification of caviar sources is also of great importance for the conservation of other, formerly non "caviar delivering species", which are now exploited and thus endangered (FAIN et al. 2000). Furthermore, consumers, caviar trade and customs could be protected from fraud by methods of species identification in caviar.

JENNECKENS (1999) provides an overview on the development of methods for species identification in caviar. The identification of caviar traditionally was conducted on the basis of egg-size, -appearance, texture, colour and smell.

Biochemical research on proteins (sodiumdodecylsulfate-polyacrylamidelectrophoresis) first allowed the identification of non acipenseriform caviar (for example salmon or trout), but delivered no results for the identification of caviar from different sturgeon species. By means of isoelectric focussing (IEF) the acipenseriform origin of caviar could be proven. This method could even distinguish between caviar of the closely related species *A. gueldenstaedti* and *A. persicus*. The observed banding patterns were constant within one species, differentiation between species, however, was based on the intensity of the observed patterns. The major disadvantage of this method was its demand of large quantities of samples and the lack of potential to distinguish between a lot of species.

Recent research on the origin of caviar was based on two different methods, depending on Polymerase Chain Reaction (PCR). With this technique, species-specific amplifications within the mitochondrial cytochrom b (mt Cyt b) can be conducted, and the caviar of *A. gueldenstaedti*, *A. stellatus*, *H. huso* could be identified. Species-specific differences in potentially conserved nucleotids of this gene represented the basis for identification. Comparisons of nucleotid sequences between 21 of 27 extant species were conducted in preliminary studies.

The identification of additional species (apart from *A. gueldenstaedti*, *A. stellatus*, *H. huso*) was done by means of comparisons of nucleotid sequences. Differentiation was also done by means of Single Strand Conformation Polymorphism (SSCP).

WOLF et al. (1999) were able to distinguish between 10 species of *Acipenser* and *Huso* using the mitochondrial $tRNA^{Glu}$/cytochrome *b* using PCR and Restriction Fragment Length Polymorphisms (RFLP) on a 462 bp sequence.

FAIN et al. (2000) conducted studies on a 270 bp segment of the mt Cyt *b* in *Scaphirhynchus.* Interspecific variation was found too low for species identification. Thus, the forensic identification of caviar from shovelnose sturgeon (*S. platorhynchus*) to the exclusion of pallid sturgeon (*S. albus*) and Alabama sturgeon (*S. suttkusi*) still remained elusive. TRANAH et al. (2001), however, studied the reproductive isolation of *S. albus* and *S. platorynchus*. Data from five nuclear DNA microsatellite loci indicated that pallid and shovelnose sturgeon were genetically distinct.

JENNECKENS et al. (2001) were able to identify the black caviar producer *A. stellatus* on a genomic level on the basis of the sturgeon microsatellite LS-39, because a fixed allele of 111 bp occurred in *A. stellatus* only.

5.3.2 Identification of individuals

The classic method of species identification for sturgeons is the determination by morphometric characteristics as compiled by HOLČIK (1989); KUZNETSOV et al. (1995); DEBUS (1999) or ELVIRA & ALMODOVAR (2000).

Individuals of two subspecies of the American Atlantic sturgeon (*A. oxyrinchus oxyrinchus* and *A. oxyrinchus desotoi*) displayed 15 different nucleotid-polymorphisms in a 203 bp fragment of the mitochondrial control region (D-loop), of which three allowed a differentiation between the two subspecies (WIRGIN et al. 1997).

GARRIDO-RAMOS et al. (1997) used satellite DNA (characterized on the basis of *A. naccarii*) as a probe for the differentiation of *A. sturio*.

BIRSTEIN et al. (1998 b) identified the species of six different wild stocks on the basis of sequence comparisons. Partial fragments of the mt Cyt b were amplified and the individual sequence information was then compared with a formerly established data base, containing partial sequences of mitochondrial genes of 22 acipenseriform species. This method also worked for the traditional caviar producing species (*A. gueldenstaedti*, *A. stellatus*, *H. huso*).

BIRSTEIN et al. (1998a) revealed considerable genetic differences between *A. sturio* specimen from different catch localities on the basis of mt Cyt *b*. Therefore, and to avoid confusion of *A. sturio* with *A. gueldenstaedti*, *A. baeri* and *A. naccarii*, the authors recommend a careful genetic evaluation of each captured putative *A. sturio* individual, which potentially can be used for breeding in restoration programs.

LUDWIG & KIRSCHBAUM (1998) identified seven distinct conserved nucleotids in a fragment of the mitochondrial 12S rDNA, of which two produced species-specific Restriction Fragment Length Polymorphisms (RFLPs). CONGIU et al. (2001) were able to identify interspecific sturgeon hybrids by amplified fragment length polymorphism.

Another method for the differentiation of sturgeon species is the use of Random Amplified Polymorphic DNA (RAPD) (COMINCINI et al. 1998; ZHANG et al. 2000).

JENNECKENS (1999) found that two of 40 primers used for RAPD produced species-specific banding patterns for *A. baeri*, *A. ruthenus*, *A. stellatus*, and *H. huso*. A discrimination of sturgeon hybrids was not possible.

5.3.3 Identification and characterization of populations

The classic procedure to characterize populations within different fish species depended on the use of biochemical markers (DOBROVOLOV & DOBROVOLOVA 1983; JENNECKENS 1999). Populations could be identified by the frequencies of alleles in polymorphic loci. A differentiation on the basis of biochemical markers proved successful for the eurasian species *A. baeri*, *A. gueldenstaedti*, *A. stellatus* and *H. huso* (PIROGOVSKII 1989; POPOVA et al. 1989;

SOKOLOV & VASIL'EV 1989 a; VLASENKO et al. 1989; SUBBOTKIN & SUBBOTKINA 1999) as well as Asian species (ZHANG et al. 1999). A differentiation of different populations of *A. nudiventris* in the Caspian Sea using the same method proved difficult, however (SOKOLOV & VASIL'EV 1989 b). JENNECKENS (1999) investigated 13 different markers occurring in the blood of *A. baeri*, *A. gueldenstaedti*, *A. ruthenus*, *A. stellatus* and *H. huso*. Of these, solely the allozyme system phosphoglucomutase (PGM) was characteristic for *A. stellatus*.

In recent studies the research on populations within Acipenseridae was done by means of mitochondrial and/or genomic DNA.

JENNECKENS (1999) cites studies conducted on American species of the genus *Acipenser*. The mitochondrial genome of these species has a size of 16.1 to 16.7 kb (deducted from RFLP data). Within the studied species, a high level of variation of length polymorphisms of the mitochondrial DNA-molecule could be observed, resulting from different copy numbers of a 78 – 82 bp repeating unit within the control region (D-loop). Furthermore, a high degree of mitochondrial heteroplasmy in RFLP-analyses was found in the species *A. transmontanus*, *A. medirostris*, and the subspecies *A. oxyrinchus desotoi*.

BIRSTEIN et al. (1998a) found considerable differences between different populations of *A. sturio* on the basis of mt Cyt b. DOUKAKIS et al. (1999) conducted research on the subspecies of *A. baeri* and *A. stellatus* using mt DNA (D-loop, Cyt b and ND 5/6 genes) to determine whether traditionally defined subspecies correspond to taxonomic entities and conservation management units. No fixed diagnostic differences could be found between any of the subspecies, though. Geographical structuring of haplotypes could be found within *A. baeri*. No intraspecific subdivisioning could be found for *A. stellatus*, however. The authors conclude that the morphologically and geographically based subspecies designations within Acipenseridae may not directly correspond to the biological entities appropriate for management and should not be used for conservation programs without genetic support.

JENNECKENS et al. (2000) were able to provide evidence for the "genetic" contamination of the Volga stocks of *A. gueldenstaedti*. Eleven of 34 morphologically classified *A. gueldenstaedti* were identified as *A. baeri* from sequence analysis of the mt Cyt b, proving crosses and backcrosses with *A. baeri* or *A. baeri* hybrids probably introduced into the Volga River System by unintentional release.

SUCIU et al. (2000) studied the genetic variation in anadromous sturgeon species of the Lower Danube River. Substantial polymorphism was observed at the microsatellite loci in *A. gueldenstaedti*, *A. stellatus* and *H. huso* with up to 19 alleles in *A. stellatus*. The mean heterozygosity (0.84) observed for *A. stellatus* is at the higher end of the distribution of such values in fish species, suggesting substantial large effective population sizes for this sturgeon species. This was also supported by studies on the mt DNA.

The further results of this study can be summarized as follows:

- All species were identifiable on the basis of genetic patterns,
- substantial microsatellite variability were found for all species except *H. huso*,
- genetic heterogeneity among *A. stellatus* individuals suggests more than one population in the Danube River Basin,
- a grouping of the genetic relationships of *A. stellatus* individuals revealed three major groups,
- comparisons of nuclear and mt DNA suggest a recent decline in *H. huso* numbers (and especially females).

TRANAH et al. (2001) studied the reproductive isolation of *S. albus* and *S. platorynchus*. Data from five nuclear DNA microsatellite loci indicated that pallid and shovelnose sturgeon were genetically distinct.

WALSH et al. (2001) found that morphological and meristic characteristics differed in shortnose sturgeons (*A. brevirostrum*) from different river systems. The existence of distinct populations was also supported by sequencing of mt DNA from the control region.

Methods for population characterization have proven successful for other fish species as well. HANSEN et al. (2001) provide an overview to using microsatellite markers for the assignment of individual fish to populations. CHENUIL et al. (2000) were able to track movements of adult fish in a hybrid zone (*Barbus barbus*, *Barbus meridionalis*) by combination of microsatellite genetic analysis and capture-recapture data. KAEWSANGK et al. (2000) evaluated the contribution of stocked ayu (*Plecoglossus altivelis*) to wild populations using allozyme markers.

6 Summary and conclusions

6.1 Abstract of sturgeon performance in the Danube River Basin

Out of six acipenserid species that were once native to the Danube River Basin, only four still reproduce in the Lower Danube River (*A. gueldenstaedti*, *A. ruthenus*, *A. stellatus*, *H. huso*). *A. sturio* and *A. nudiventris* have possibly become extinct, while the stocks of the anadromous species *A. gueldenstaedti*, *A. stellatus* and *H. huso* have been drastically decreasing in the Lower Danube River, as documented by catches. In the Upper and Middle Danube River and a number of tributaries, migratory sturgeons have become extinct due to overfishing in past centuries, as well as by disruption of their spawning migrations into the Middle Danube River by the Iron Gate hydroelectrical dams I and II in 1972 and 1984. A remnant population of the resident form of *A. gueldenstaedti* still exists upstream of Iron Gate dams. The location of spawning sites of migratory species in the Lower Danube River under the changed migratory conditions, the exact status of stocks and their reproduction is still unknown.

Stocks of the only true potamodromous sturgeon species in the Danube, the sterlet (*A. ruthenus*), depend on stocking in the Upper Danube River. Due to increasing water quality, temporary protection and stocking measures, sterlet stocks have been increasing in the Middle Danube. In the Lower Danube, the reserves of the sterlet have been reduced to a minimum.

Stocks of migratory sturgeons in the neighboring Azov and Caspian Seas were maintained by stocking of hatchery reared juveniles. Although stocking contributed significantly to numbers the populations could not be stabilized. Lack of hatchery funding, natural reproduction and an increase in fishing and poaching have led to a collapse of sturgeon stocks in these waters. The artificial propagation of Acipenserids is widely established in Europe and also in Danubian countries. Stocking of sturgeons into the Danube River or the Black Sea was conducted sporadically in single countries and depends on the catch of spawners from the river.

Catch statistics in riparian countries are confusing, since different databases exist and the extent of poaching is unknown. Sturgeon fishery still exists in the Lower Danube, although catches have been declining since the beginning of the 20th century.

New methods in sturgeon genetics allow the identification of caviar and individuals as well as the characterization of populations for management purposes. In addition new techniques allow the tracking of individual fish (telemetry and ultrasonic tagging) and thus the identification of key habitats. Fishpasses for sturgeons are in operation in the former U.S.S.R. and North-America and the number of passed animals varies. Standard solutions for the up- and downstream passage of sturgeons at dams could not be found in literature.

The information on Danubian sturgeons given so far, was presented by main relevant topics. The amount of information, however, calls for a summary of important events in sturgeon performance in chronological order. Therefore, table 8 provides an overview of important events in the history of sturgeon species in the Ponto-Caspian region and especially the Danube River.

Table 8: Important events for Danube River sturgeon species

Date	Event
200 million years ago	The order of Acipenseriformes (sturgeons and paddlefishes) appears in Europe. Subsequently the early diversification takes place in Asia, from where the order spreads over the Northern Hemisphere.
65 million years ago	Dinosaurs vanish from Earth's Biosphere, sturgeons still linger on.
5th to 6th century B.C.	Sturgeons in the Lower Danube River are fished by inhabitants of the Greek colonies in the area.
1053	Beluga sturgeons are mentioned as important haversac rations for troops, marching along the Upper Danube River in Austria.
Beginning of the 16th century	Catches in the Beluga fishery in the Middle Danube River decrease rapidly, as a result of overexploitation of the large winter race of this species.
18th century	Fishing on migratory sturgeons in the Austrian Stretch of the Danube River is abandoned, due to the scarceness of animals.
Beginning of the 19th century	A lack of legislation leads to overfishing and subsequently the fishery in the Lower Danube collapses. Sturgeon fishery is not seriously affected and catches remain at about 1,000 metric tons.
19th century	Occasional catches of sterlets in the Danube between Regensburg and Passau in this part of the Upper Danube River document the remnants of a dying population of this species.
1869	The first artificial propagation of a sturgeon species is performed in Russia.
1926	The last known specimen of *A. stellatus* from the Slovakian section of the Danube River is caught on February 20, at Komarno.
1950	A Sturgeon Ranching Program (SRP) is initiated in the former U.S.S.R. for the neighboring Caspian and Azov Seas, where sturgeon stocks are decreasing, due to the degradation of water quality and damming of rivers.
1962	The implementation of a moratorium on commercial sturgeon fishery in the neighboring Caspian Sea provides some relief for sturgeon stocks. The collapse of the U.S.S.R. and thus a lack of legislation and an increased extent of poaching takes a heavy toll on sturgeon stocks, which still decrease and nowadays depend heavily on stocking. A stabilization of stocks was not achieved till the current day.
1965	The last known specimen of *A. stellatus* from the Hungarian section of the Danube River is caught at Mohacs.

Table 8 (cont.): Important events for Danube River sturgeon species

Date	Event
1972	Iron Gate Dam I is completed, confining migratory sturgeons to the 942 Kilometers of Danube River from the Black Sea to the Iron Gate gorge and cutting off important spawning sites in the Middle Danube River.
1972-1976	During the 5 consecutive years after the completion of Iron Gate Dam I, Serbian catches of migratory sturgeons peak significantly below the dam.
1980	Iron Gate Dam II is completed reducing the available Danube River length for migratory sturgeons to 863 kilometers between the Black Sea and the dam.
1987	The catch of a single Beluga sturgeon at Paks, Hungary (300 cm in *Tl* and 181 kg in weight; river km 1526-1528) on May 16, proves the occasional passage of migratory sturgeons at the Iron Gate ship locks.
1989	A second major collapse in Lower Danube River fisheries occurs, this time affecting especially sturgeon fishery. A sharp decline in sturgeon catches can be observed.
1998	Since April 1, all acipenseriform species are listed in C.I.T.E.S., implementing trade regulations and a system of quotas for sturgeon products.
1998 – 2001	NAVODARU et al. (1999) conduct a survey on Lower Danube sturgeon fishery. Results indicate that a major sturgeon fishery still exists in the Lower Danube River amounting to 300 metric tons per year (average). A number, that is ten times higher than official estimates. NAVODARU et al. also provide evidence for overexploitation of sturgeons in the Lower Danube River, with an estimated extent of poaching of up to 90 percent. SUCIU et al. (2000) study the genetic variation of anadromous sturgeon species in the Lower Danube River, delivering the following results: • All species were identifiable on the basis of genetic patterns, • substantial microsatellite variability was found for all species except *H. huso*, • genetic heterogeneity among *A. stellatus* individuals suggests more than one population in the Danube River Basin, • a grouping of the genetic relationships of *A. stellatus* individuals revealed 3 major groups (populations?), • comparisons of nuclear and mt DNA suggest a recent decline in *H. huso* numbers (and especially females). CEAPA et al. (in press) conduct a four years biometry study on *A. stellatus* brood fish from experimental and commercial fisheries in the Lower Danube River, revealing a considerable shift towards younger animals and a decreasing size of the fish (mean *Tl*) as classical signs of overfishing. KYNARD et al. (in press) use ultrasonic tags to comprehend the movements of migratory sturgeons in the Lower Danube River (mostly *A. stellatus*) and for the identification of spawning sites. Most of the tagged animals are harvested or do not resume their migration after tagging, thus leaving the location of spawning sites in the Lower Danube River still undiscovered and also giving proof for a severe overharvest of *A. stellatus*.

6.2 Gaps in knowledge

Although considerable information could be collected in this study, the following questions still remain unanswered:

Stock status:

1. What is the current status of sterlet (*A. ruthenus*) in the Upper Danube River after restocking was conducted in Austria and Germany (numbers, migrations, extent of reproduction), and which factors have caused its extinction in the past?
2. What is the current status of sterlet in the Lower Danube River under the influence of heavy (respectively over-) exploitation of sturgeon stocks?
3. Is *A. nudiventris* still present in the Danube River system?
4. What is the current status of migratory sturgeon stocks in the Lower Danube River, documented by numbers, sizes, weights and sex ratios in commercial fisheries (some information, however, is given on *A. stellatus* by CEAPA 2001, CEAPA et al. 2001 and CEAPA et al., in press)?
5. What is the current reproduction status of migratory sturgeons in the Lower Danube River?

Sturgeon habitats:

1. Which key habitats can be identified for sterlets in the Upper, Middle and Lower Danube? (respectively: What are the habitat preferences of sterlets in the Danube River during ontogeny?)
2. Which key habitats for migratory sturgeons in the past (spawning and overwintering sites) can be identified in the Middle Danube River, where were they located and how have they been modified by anthropogenic impact?
3. Which key habitats are currently used by migratory sturgeons in the Lower Danube River and the Black Sea? (respectively: What are the habitat preferences of migratory sturgeon species in the Lower Danube River during ontogeny?)

6.3 Remarks on literature and information sources

The literature in this review was obtained mainly through library sources and the internet. The book on Acipenseriformes edited by HOLČIK (1989) was purchased through the book trade (as well as the books of HOCHLEITHNER, REICHLE and STEFFENS) and has to be regarded as the "basic literature" for anyone working with Eurasian sturgeon species. A lot of essential and also old literature has herein been compiled by different species-specific working groups.

Journal articles took between 2 weeks and 8 months to be delivered. Internet articles on the matter often did not contain the exact information or were not of a scientific character, apart from the difficulties of quoting them, due to changing Uniform Resource Locators (URLs) and missing references. Important literature was also supplied by researchers themselves (e.g. by the following authors: BACALBASA-DOBROVICI, BILLARD, CEAPA, GUTI, KYNARD, NAVODARU, SUCIU).

A problem in this study was the retrieval of current and objective informations and data on the stock status of migratory species especially in the Lower Danube River. Reliable data are scarce (CEAPA et al., in press) and official data by government agencies (which could not be acquired during the course and duration of this study) often do not reflect the actual situation (NAVODARU et al. 1999; BERGLER 2001; SIMONOVIC 2001).

Two hatcheries in Serbia and Romania, which were contacted by e-mails and ordinary mail in the beginning of this review did not answer till the current day. Also the cooperation with a Romanian consulting company, which had offered a large database of Eastern European sturgeon literature as well as their potential for translation and reviewing was not accomplished, due to unknown reasons since e-mails by the author of this review remained unanswered at a certain point of negotiations.

Unreliable computer hardware and internet connections posed another problem in communications since e-mails obviously got lost on their way to the Danube Delta Institute.

Further "potential" especially with regard to hatchery techniques and ontogenetic studies most probably lies in literature from the former Eastern Block countries and U.S.S.R., of which only a fraction is presented in this review. Problems here are the language barrier and missing English, French or German abstracts. The same holds true for some literature from China. Another potential information source are governmental institutions and organizations, non-governmental organizations and universities in the riparian countries with a lot of unpublished "grey reports" and / or dissertations.

The sturgeon literature used in this review is by far not complete, however, it contains the most important key literature on Danubian species as well as the latest results of scientific research on migratory sturgeons of the Lower Danube River.

6.4 Recommendations for the conservation of sturgeons

6.4.1 General recommendations by the IUCN

According to the available information and data, sturgeon stocks are critically endangered in the Danube River Basin and action for their conservation has to be taken quickly. Due to the situation, a combined international approach of the riparian countries is necessary. Experts of the IUCN have outlined the following general recommendations for the conservation of endangered sturgeon stocks throughout the world:

- Control poaching and illegal caviar trade through:
    - development and implementation of regional trade and law enforcement agreements;
    - improvement of social and economic conditions of people in the sturgeon range states;
    - improved enforcement of existing laws.

- Improve efficiency in aquaculture, stock assessment and re-stocking through:
    - development of a unified method for stock assessment and monitoring;
    - formulation of a „code of conduct“ for each species that will increase the effectiveness of re-stocking programmes.

- Improve regional and international co-operation for sturgeon conservation through:
    - regional agreements for sturgeon conservation and management particularly for the Amur River, the Black Sea, Azov Sea, and the Caspian Sea;
    - identification of potential protected areas in sturgeon habitat;
    - national level action stimulated by NGOs, the United Nations Food and Agriculture Organization (FAO), conventions and other organizations;
    - funding support for sturgeon conservation from major financial and economic mechanisms such as the Global Environment Facility and World Bank as well as the private sector;
    - increased public awareness of the threats facing sturgeon and opportunities for their conservation;
    - an information exchange network involving all parties involved in sturgeon conservation including FAO, Convention on Biological Diversity, Sturgeon Specialist Group, Convention on Migratory Species, and IUCN's European Sustainable Use Specialist Group.

6.4.2 Recommendations for the conservation and restoration of Danubian sturgeon stocks

In addition to the general recommendations given by the IUCN experts, specific measures for the Danube River Basin can be proposed. A recovery program for Danubian sturgeons has to be planned and conducted on a long term basis (30-50 years). The assessment of stock and habitat status (for both migratory and potamodromous species/stocks) is essential for determining any further measures. Because of the long maturation periods, especially in migratory sturgeons, recovery measures will take 15 to 20 years to show first effects and to be evaluated.

Experience from North America and the former U.S.S.R. has shown, that apart from artificial propagation and stocking, also management and habitat restoration issues have to be addressed. Stocking of sturgeons should therefore be considered a partial and temporally limited remedy. The main aim of any conservation and restoration measures must be the establishment of self-sustaining and reproductive stocks. It is obvious though, that stocks of migratory sturgeons in the Lower Danube River are overfished and a collapse of stocks is almost inevitable.

This review has also shown that no standardized or “off-the-shelf” solutions and techniques for problems in sturgeon conservation exist. In spite of similar problems, researchers have handled problems differently in different sturgeon rivers.

With regard to the identified research priorities, the gaps in knowledge on Danubian sturgeons and their fisheries, and the encountered problems in gaining relevant information, the following actions are considered important for the conservation and restoration of Danubian sturgeon stocks:

1. The establishment of a reliable information data network and data base on the status of fish species (including sturgeons) for the Danube River Basin (also as an early warning system for major environmental changes), in accordance with the European Water Framework Directive. A reliable information network is a basic prerequisite for any multinational research and should also allow quick access to informations. The available information should be included in subdatabases connected to Geographic Information Systems (GIS; e.g. results of research projects, fishery yields, management measures, reproduction status). The information should be published in either annual or biannual reports and/or should be accessible through the internet, respectively. It would also be essential to provide reliable hardware and access to the internet for all participating institutions and organisations.

2. The creation of legal foundation through

- the establishment of international legal instruments for a basin-wide management of migratory fish species and their protection as well as tools for their enforcement,

- the protection of key habitats in the Danube River, its Delta and the Black Sea from catches or by-catches (a complete ban of sturgeon fishery has also to be considered, until stock status and exploitability have been assessed).

Laws and management measures can only be effective if they are enforced. Therefore, the implementation of a multinational "river police" has to be considered.

3. An assessment of habitat through

- the identification of critical habitats, such as overwintering, spawning, nursing habitats and feeding areas, migration routes for adult spawners (telemetry, ultrasonic tagging) as well as migrating larvae and juveniles (standardized catches) in the Lower Danube River,
- laboratory investigations on the ontogenetic behaviour of sturgeon larvae and juveniles to determine the importance and location of habitat structures in the field,
- assessment of potential habitat on the basis of the above items (identification of potential migration routes, weir survey and connectivity assessment e.g. fish-passes, and the structural inventory of formerly inhabited rivers) in the Middle Danube as well as tributaries of the Middle and Lower Danube to assess the potential for restoration of stocks.

The identification of habitat in the Lower Danube River is essential for the legal protection of key sites. The assessment of potential habitat in the Middle Danube River is decisive for the future prospects of restoration of migratory sturgeons in this part of the riverine system. Another prerequisite is the passage of Iron Gate dams I and II for migratory sturgeons, which has to be solved. "Off-the-shelf"-solutions with a guarantee for success do not exist. Passage solutions around dams must include all kinds of aquatic organisms (target organisms) present in the particular riverine ecosystem.

4. An assessment of stock status through

- the determination of age composition in spawning shoals (or in catches and by-catches), genetic screening (genetic variability, homing and identification of management units in populations),
- the assessment of reproductive success through egg densities on spawning sites and/or numbers of migrating larvae and juveniles,
- standardized catches of juveniles in riverine / estuarine / marine nursing and feeding areas.

A basic prerequisite is the assessment of stock status of sturgeons in the Danube River system. This includes *A. nudiventris* as well as sterlets in the Upper Danube River and migratory sturgeons in the Lower Danube River. If adult fish cannot be obtained an assessment has to be done by means of assessing the extent of reproduction (e.g. juvenile index).

5. Melioration of artificial propagation through

- the use of ovaries of wild spawners for artificial propagation instead of producing caviar (this also takes advantage of the still existing genetic variability in wild stocks); caviar can be produced in aquaculture with domesticated broodstock,
- an increased effort to catch wild broodstock for restocking,
- developing schemes for the artificial propagation of offspring from wild broodstock, under consideration of management units, seasonal races and genetic variability,
- a genetic screening for the characterization of adult broodstock and the assessment of stocking contribution to populations (ratios of stocked and wild individuals in standardized catches conducted in key habitats could possibly allow an estimation of natural reproduction as well).

Stocking has to be considered an emergency measure against extinction of sturgeons in the Lower Danube River and will not result in a commercially exploitable stock, if applied solely. The stocking of yearlings into suitable habitats would make sense though, because the high natural losses occurring in the river during the first year could be avoided under sheltered hatchery conditions.
Stocking has to be performed with sturgeons of Danube River origin only, because of the high potential of hybridization in Acipenseriformes and the risk of importing alien “genes”, which are not adapted to the Danube River system. The same holds true for accidental or non-accidental introductions of alien acipenseriform species (e.g. paddlefish), which must be avoided by all means. Experience from the former U.S.S.R. has shown that attempts to acclimatize sturgeons from the Caspian Sea in the Sea of Azov were not successful.
Sexing and the extraction of ovaries is possible without killing the animal. Spent animals should be released in or close to the Black Sea, rather than into the river, where they are subject to an increased fishing pressure. One will have to take into consideration that wild broodstock for artificial propagation will have to be bought, maybe also offering some extra reward to fishermen.
Rather large facilities would have to be provided for the sole use of captive broodstock. Following the recommendations given in the text (see 5.2.1 Artificial propagation of sturgeons) this would be 100 adult animals per population to avoid inbreeding. In the case of *A. stellatus*, where preliminary genetic research suggests the presence of at least 3 different “reproduction units” this would be 300 animals. In species with a spring and fall race this could easily amount up to 600

animals, which have to be kept separately for each reproduction unit. These facilities would also have to be guarded against poaching or abduction of animals. Confinement of large numbers of animals increases the risk for diseases, resulting also in an increased need for veterinary treatment or medication. Last but not least, one would need more than one facility per species to avoid total losses by unpredictable or stochastic impacts.
Stocking of migratory sturgeons in the Middle Danube River is considered not to be urgent and should not be performed until the situation at Iron Gate dams has been solved.
For the Upper Danube River only restocking with sterlet has to be considered. Stocking has already been conducted in Austria and Germany which raises the question what has happened to these animals. Further stockings must be accompanied scientifically to provide further knowledge on the habitat use of sterlets in the Danube River and especially in large hydropower reservoirs. Genotypes of broodstock and offspring would have to be characterized by genetic fingerprinting for further characterization of the reproductive population and to assess the success of stocking.

6. Since fishing is a traditional and important commercial activity in the Danube River system (HOLČIK 1996 a) also

- "sturgeon-friendly" fishing techniques should be developed and implemented to avoid or minimize sturgeon bycatches in other fisheries,
- the possibility of lessening fishing pressure on wild sturgeons by farming sturgeons for caviar and meat has to be assessed (including the possibilities for a socially acceptable dissemination of the resulting profits through employment and enterprises of professional local fishermen, respectively) see also item 5.

Fishery is a traditionally and commercially important activity in the Danube River system. It is also a sustainable use of the aquatic resources, if practiced with the right equipment and management tools.

The following schedule for conservation and restoration activities of sturgeon stocks in the Danube River system is suggested on the basis of this review:

Next 5 –10 years:

1. A moratorium on commercial sturgeon fishery and caviar production in the Lower Danube River and the North Western Black Sea has to be enforced and implemented until a sound scientific determination of stock status and exploitability has been accomplished (e.g. through the establishment of a "juvenile index").
2. Key habitats of migratory and non-migratory sturgeons in the Lower Danube River have to be identified (telemetry, ultrasonics, GPS) and protected.

3. A weir and/or connectivity survey has to be conducted in the mainstem Danube River and its major tributaries (Upper, Middle and Lower Danube River), already offering solutions for the restoration of river continuity.
4. A survey of potential habitat for migratory sturgeons in the Middle Danube River has to be conducted on the basis of historical sources and experience from habitat identification from the Lower Danube River as well as ontogenetic studies on sturgeon larvae and juveniles (see also item 3).
5. A search for *A. nudiventris* in the Danube River system has to be conducted.
6. Ontogenetic studies on sturgeon larvae and juveniles of both migratory and potamodromous stocks/species should provide useful hints for the identification of nursery habitats as well as to locate young developmental stages of sturgeons in the field.
7. In the case of lacking natural reproduction, stocking with yearlings should be conducted (see also item 5).
8. Genetic research (fingerprinting) must be used to identify the reproduction units of sturgeons in the Lower Danube River and to create a database of genetic information on broodfish for artificial propagation as well as their offspring.
9. For the restoration of sterlet in the Upper Danube River, threats for this species have to be identified (also the reasons for extinction in the past) and careful stocking (with fishes of Danubian origin) under scientific guidance has to be conducted.
10. Telemetry studies on sterlet in the Upper Danube River should reveal habitat use as well as the location of key habitats.

Next 10 –20 years:

1. If migratory sturgeons from the Lower Danube River can pass at Iron Gate gorge, these animals will have to be tracked (telemetry, ultrasonics, GPS) and a survey of potential spawning sites in the Middle Danube has to be conducted.
2. Collections of larvae or juveniles below spawning sites or at Iron Gate gorge should provide information about the status of reproduction upstream of the dams.
3. Aside from passing sturgeons upstream past dams, provisions also have to be made for downstream-passing, respectively, guiding of juvenile sturgeons and adults around hydropower dams and turbines.
4. In the Lower Danube River the first stocked animals may return to the river for spawning and can possibly be identified by genetic fingerprinting (also through their offspring) and deliver proof of the efficiency of stocking.
5. The success of sterlet stocking in the Upper Danube will have to be assessed. Stocking would have to be considered successful, if self sustaining populations were established.

7 Acknowledgements

The author thanks the participants of the sturgeon specialist workshop held in Vienna, June 11-12, 2001, and the following researchers for sharing their expertise, supplying literature and information (in alphabetical order): Nicolae Bacalbasa-Dobrovici (University of Lower Danube Galatz, Romania), Miklos Bercsenyi (PATE University, Keszthely, Hungary), Hans Bergler (Bezirk Oberpfalz, Wöllershof, Germany), Roland Billard (Muséum Nationale d'Histoire Naturelle, Laboratoire d'Ichtyologie, Paris, France), Cornel Ceapa (Dunarea de Jos, University of Galatz, Fishing and Aquaculture Department, Romania), Andrew Ferguson (School of Biology and Biochemistry, The Queen's University of Belfast, Medical Biology Centre, Belfast, Northern Ireland), Jörn Gessner (Society To Save The Sturgeon (*A. sturio* L.), Inst. for Freshwater Ecology and Inland Fishery, Berlin, Germany), Gabor Guti (MATAV, Danube Research Station, Goed, Hungary), Thomas Hilbrich (Fisheries consultant, Gießen, Germany), Boyd Kynard (Conte Anadromous Fish Research Center, Turners Falls, MA, USA), Ion Navodaru (Danube Delta National Institute for Research and Development, Tulcea, Romania), Radu Suciu (Danube Delta National Institute for Research and Development, Tulcea, Romania), Predrag Simonovic (University of Belgrade, Yugoslavia), Angel Tsekov (Agriculture College, Plovdiv and Athanas Complet – Oscietra Comerce, Boliarze, Bulgaria) and Gerald Zauner (BOKU - Vienna, Dept. of Hydrobiology, Fisheries and Aquaculture, Austria).
This literature study was reviewed thoroughly by Jürg Bloesch (EAWAG, Dübendorf, Switzerland), Joachim Lehmann and Thomas Ring (Bezirk Oberpfalz, Regensburg, Germany) and Herbert Stein (✝)(Dept. of Fish Biology, TU München, Germany).
The realization of this study was made possible through funding by Bezirk Oberpfalz, EAWAG and Landesfischereiverband Bayern e.V..

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9 Annex: Species information on Danubian sturgeons

The following abbreviations are used in the following text (see also figure 11):

Au: unbranched rays [spinous rays, spines] of anal fin

Du: unbranched rays [spinous rays, spines] of dorsal fin

SD: number of dorsal scutes

SL: number of lateral scutes

SV: number of ventral scutes

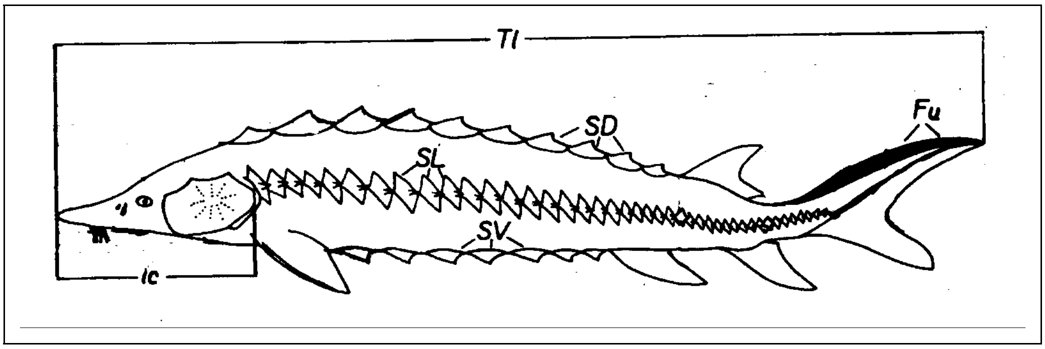
Sp. br.: branchial spines [gill rakers]

Tl: Total length

lc: length of head

Fu: fulcrae

Fig. 11: Descriptive characteristics in Acipenserids used in the text. (modified from HOLČIK 1989)



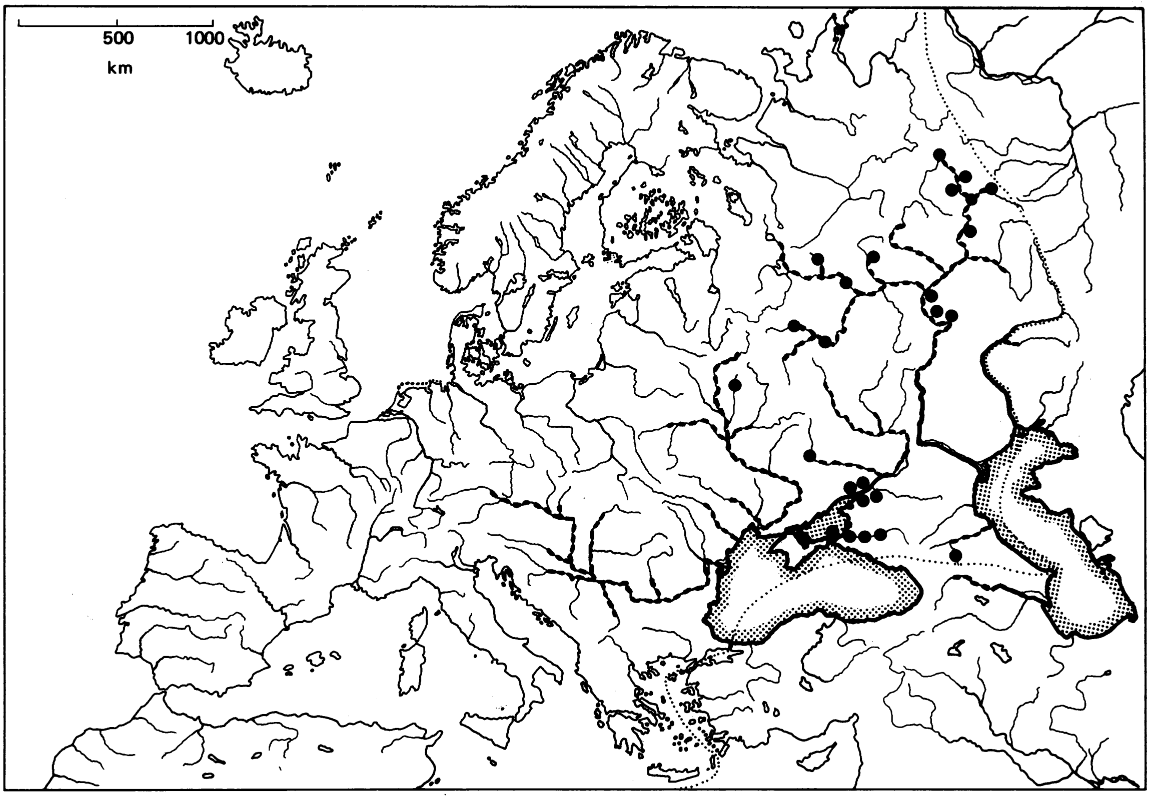
9.1 *Acipenser gueldenstaedti* Brandt, 1833

The following informations on *A. gueldenstaedti* are given on the basis of a compilation of relevant literature by VLASENKO et al. (1989).

9.1.1 Distribution

Acipenser gueldenstaedti occurs in the Black, Azov and Caspian Sea and their tributaries discharging into them. Besides the main diadromous form, a freshwater form has been reported from various rivers that does not migrate downstream to the sea (Rivers Volga, Ural and Danube). From the Black Sea most of the Russian sturgeons enter the Rivers Danube, Dniester, Yuznyi Bug and Dnieper Rivers for spawning. In the Danube River, it regularly ascended to Bratislava and rarely as far as Vienna and Regensburg. In the past this species was encountered in the following Danube tributaries: the Vah, Drava, Sava, Tisza and Morava Rivers.

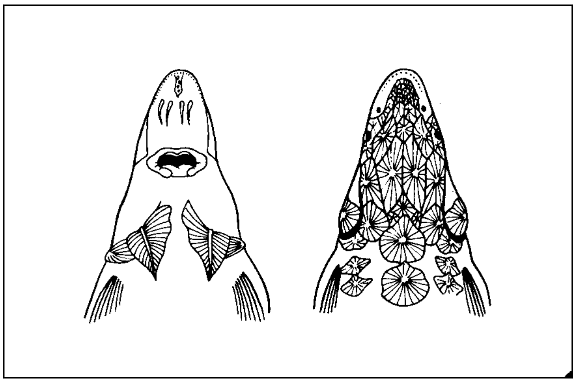
Fig. 12: Former (dotted line) and present (solid line) geographical distribution of the Russian sturgeon (*Acipenser gueldenstaedti*). Dots indicate the location of subfossil remains. Stippled area indicates the supposed coastal habitat of this species during its stay in the sea. (from VLASENKO et al. 1989)



9.1.2 Species description

Du 27-51, *Au* 18-33, *SD* 8-18, *SL* 24-50, *SV* 6-13, *Sp. br.* 15-31

Fig. 13: Ventral (left) and dorsal view of the head of *A. gueldenstaedti* (from PECL 1989)



Between the rows of scutes, there are numerous bony plates. In the Caspian Sea these fishes reach a length of 215 cm and a weight of 65 kg. In the Black Sea, specimen with a length of up to 236 cm and 115 kg weight have been documented. There are also reports that in the Black Sea and the Danube River, Russian sturgeons may reach a length of 4 m. These reports are doubtful, though, and may refer to the larger Atlantic or Baltic Sturgeon (*Acipenser sturio*) which used to be present in the lower part of the Danube River and probably still is present in the Black Sea watershed (BACALBASA-DOBROVICI & HOLČIK 2000). Analyses of subfossil fish remains from archaeological excavations revealed that the maximum size of sturgeons from the Caspian Sea and Volga River in the past was 235 cm, while those from the Black Sea reached 300 cm (SOKOLOV & TSEPKIN 1996).

The Russian sturgeon differs from the stellate sturgeon (*Acipenser stellatus*), the Atlantic or Baltic sturgeon (*Acipenser sturio*), and the Persian sturgeon (*Acipenser persicus*) in having a considerably shorter blunt snout. It usually has less than 30 gill rakers (less than the number in Adriatic sturgeon, *A. naccarii*), and can be distinguished from the Siberian sturgeon (*Acipenser baeri*) by its simple gill rakers, which are not fanshaped; from the ship sturgeon (*Acipenser nudiventris*) by its divided lower lip; and from the sterlet (*Acipenser ruthenus*) by the lower number of scutes (less than 50) in its lateral rows and and its unfimbriated barbels.

The body is elongate and spindle shaped. Its height averages 12 to 14 % of *Tl*. The head length is 17 to 19 % of *Tl*. The snout is short, blunt, and somewhat rounded. Its length in specimens from the Kura River ranges from 4 to 6.5 % of *Tl*, while in specimens from the Volga and Ural Rivers it averages 5.2 % of *Tl*. The barbels are attached closer to the tip of the snout than to the mouth. The mouth is transverse, protrusive, and comparatively small. The lower lip is divided in the middle. The coloration varies from greyish black, dirty green or dark green dorsally. Laterally, it is usually greyish brown, and, ventrally, grey or rarely a lemon yellow color. The juveniles are blue dorsally and white ventrally. *A. gueldenstaedti* does not display sexual dimorphism.

The Russian sturgeon forms separate stocks inhabiting the Black, Azov, and Caspian Seas and their tributaries, into which they migrate for spawning. Several authors have recognized a northern Caspian (Volga) stock and a southern Caspian (Kura River) stock, while in the Sea of Azov and Black Sea, a Black Sea-Caucasus (Rioni River), a Black Sea-Ukraine (Dnieper River), and an Azov (Don River) stock have been described. Comparisons of the individual antigenic composition of the serum proteins of the northern (Volga) and southern (Kura) Caspian, the Don, and two Black Sea stocks of the Russian sturgeon showed that these stocks can be distinguished by their antigenic characteristics. There was an especially high degree of antigenic difference between the Volga and the Danube sturgeon. The differences between them are also manifested in their morphology. The Volga sturgeon differs from the Azov and Black Sea populations in the greater height of its head, its wider snout, and its greater number of dorsal and lateral scutes.

There are seasonal races of the Russian sturgeon, referred to as summer and winter forms. In the middle course of the Volga River a non migratory or resident form of the Russian sturgeon was discovered. These fishes always remain in the river and differ from the migratory form in their retarded growth rate. This form (called sedentary) is also known from the Danube River.

Two varieties of the Russian sturgeon among those inhabiting the Black Sea were recognized: the Azov sturgeon (*Acipenser gueldenstaedti var. tanaica*) and the Black Sea-Caucasian variety (*Acipenser gueldenstaedti var. colchica).* The latter was elevated into the rank of a subspecies (*Acipenser gueldenstaedti colchicus*), which contains all populations of this sturgeon inhabiting the Black Sea and Sea of Azov. Placed within this subspecies were a number of lower taxonomic groups, each classified as a natio, including *tanaicus* in the Sea of Azov, *colchicus* in the Caucasian rivers and *danubicus* in the Danube and Dnieper Rivers. Besides these, several non-geographical taxa were described as “morphs” or “variations”. These include *longirostris* and *acutirostris*, distinguished according to the form of the snout; *aculeatus*, recognized by the structures of its scutes; and *golis* and *scobar*, established from the features of the bony plates between their scute rows. However, considering the great variability of these features, the presence of both migratory and resident forms as well as the spring and winter races of the migratory form, and the occurrence of hybrids between this species and all other species of sturgeons in the Black Sea watershed, the validity of these lower taxonomic units is dubious, and they are mentioned here only for the sake of completeness. It was also discovered that the sturgeons from the eastern part of the Black Sea, including the Rioni, Inguri and several other

rivers, are identical with the Persian sturgeon (*Acipenser persicus*) from the Caspian Sea in a whole series of characters.
The Russian sturgeon apparently interbreeds most frequently with the sterlet (*Acipenser ruthenus*). These hybrids may account for 46 % of all crossbred sturgeons in the Volga River. Other hybrids more rarely encountered are *Acipenser gueldenstaedti x Acipenser stellatus* and *Acipenser gueldenstaedti x Huso huso.*
The hybrids with the sterlet are characterized by an elongated body and snout, an increased number of lateral scutes and slightly fimbriate barbels not too far from from the mouth. The lower lip is deeply divided. The hybrids show a tendency to remain in the rivers. The cross between the Russian and the stellate sturgeon (*Acipenser stellatus*) has an elongated and flattened snout, which is covered by small spines in the juveniles. The barbels are situated approximately halfway between the tip of the snout and the cartilaginous arch of the mouth.
In the hybrid between the Russian and great sturgeon (*Huso huso*) the branchiostegal membrane is attached to the isthmus. There are no bony plates between the rows of scutes. It can be distinguished from the Russian sturgeon by the large size of its mouth opening.
Hybrids have also been reported between *Acipenser gueldenstaedti* and *Acipenser sturio* as well as between *Acipenser gueldenstaedti* and *Acipenser nudiventris*.
Experimental introductions of the Russian sturgeon have been carried out on a very limited scale. During the years 1964 through 1966, 277 young sturgeons in the 1+ and 2+ year classes were introduced into Lake Ladoga (situated in Russia close to the Finnish border), but positive results could not be reported as no population of this species was established. From 1962 through 1965, Russian sturgeon fingerlings were introduced into the Baltic Sea. The individual weight of these fishes was 2 to 5 g. The capture of several sturgeons was reported not far from the place of their release and also off the coast of Finland and Sweden.

9.1.3 Ecology

During the period of life in the sea, the Russian sturgeon inhabits shallow waters on the continental shelf, staying mainly in brackish water, with large concentrations of invertebrates, mainly molluscs, and small benthic fishes (mainly gobiids).
According to the season, these sturgeons remain at depths from 2 to 100 m or sometimes deeper. In the northern Caspian Sea the young sturgeons spend the summer in waters 2 to 5 m deep, mainly above sandy bottom. During the night, they frequently move out of their daytime habitat and ascend into the upper water layers.
In the rivers, *Acipenser gueldenstaedti* remains at depths from 2 to 30 m. The larvae are also found at considerable depths and in rapid currents, which contribute to their rapid downstream movements. As growth progresses, the young sturgeons move from deeper to shallow stretches of

the rivers, which are more rich in food. In the Danube River, the young sturgeons remain in deep water for a long time.

The anadromous migrations of the Russian sturgeon in the Caspian and Black Sea watersheds are similar in many ways. As an example the informations concerning the spawning run for the Russian sturgeon into the Volga River are given. Usually the spawning run of this species into the rivers begins in early spring, reaches its peak in mid or late summer and ceases in late autumn. Information from the literature on this matter is fairly diverse. Some authors state a two peaked spawning run with either the spring or the fall run being the largest. Subsequent studies on the sturgeon movements in the Volga River employing continuous fishing during all seasons revealed that the spawning migration has the characteristics of a single run with a maximum intensity in June. Under present conditions the spawning migration of the Russian sturgeon in the Volga River usually begins at the end of March or beginning of April at a water temperature of 1 to 4° C. There is a progressive increase in the spawning run activity with increasing outflow of freshwater into the sea and with the warming of fresh and sea water. The intensity increases in June and reaches its maximum in July. The mass migration of the Russian sturgeon in the Volga River is observed during the period of falling water levels and at the highest water temperatures. Thereafter, when the water temperature has decreased again to between 6 and 8° C, the spawning migration gradually declines, and by November has practically ceased. The Russian sturgeons in the Volga River migrate at an average speed of 18.1 to 22.6 km day^{-1}. The majority of the population entering the Volga River for spawning at the present time consists of the less mature winter sturgeons. These fishes generally do not spawn the same year they enter the river, but rather distribute themselves in various river sections during the winter and reproduce in the following spring.

The spawning migration of the Russian sturgeon in the rivers of the Azov and Black Sea watersheds has much in common with the runs in the Caspian drainage area. The sturgeon spawning runs in the majority of these rivers also display the characteristics of a single peak, and the migration lasts from spring to autumn. In the Lower Danube River there is a single sturgeon spawning run, which reaches its maximum intensity during July through September. Evaluation of fishery data from the former Yugoslavian stretch of the Danube River provided evidence that the spawning migration exhibits the characteristics of two peaks, however.

The Russian sturgeon is a euryhaline fish that spends its life travelling back and forth between fresh water and the sea, where the salinity is 18 ‰. It requires high oxygen concentrations in the water: at least 6 or 7 mg l^{-1}. However, the sturgeon larvae are not very sensitive to the oxygen content of water. The minimum oxygen concentration for these larvae at 20° C is 1.56 mg l^{-1}. According to the temperature, the limiting oxygen concentration for juvenile sturgeons 10 to 50 days old is 2.2 to 2.5 mg l^{-1}. The most favorable temperature for the development of eggs of the

Black and Azov Sea sturgeons is between 15 and 21° C. Temperatures between 21 and 23 to 24° C are less favorable, and at 25 to 26° C many deformities appear.

Russian sturgeon eggs are sensitive to mineral oils in the water. At an oil concentration of 0.5 to 1.0 mg l^{-1} the development of embryos is interrupted, and above 1.0 mg l^{-1} the lethal threshold is reached.

According to its feeding habits the Russian sturgeon may be characterized as a bottom-dwelling mollusc feeder. On their feeding grounds in the sea, they eat 24 h without considerable interruptions but with two peaks during the hours at sunset and sunrise.

The main food of the Russian sturgeon in the north-western part of the Black Sea are molluscs of the genera *Corbulomya*, *Abra*, *Cardium* and *Nassa*. They also readily consume crustaceans such as shrimps and crabs, and fishes including gobiids, anchovies (*Engraulis encrasicholus*) and sprat (*Sprattus sprattus*). The diet of the juveniles differs from that of the adults. Their main food items are crustaceans, including mysids and corophiids and polychaetes. In the Danube and Dnieper Rivers, the stomachs of juveniles also contained the larvae of mayflies (Ephemeroptera), caddisflies (Trichoptera), and midges (Chironomidae).

The maximum age reached by Russian sturgeons from the Black Sea is 33 years in the Danube region and 37 years in the Dnieper region. The analysis of archaeological material has shown that the life span of the Russian sturgeon from the Sea of Azov (Don River) and the Caspian Sea (Volga River) could exceed 50 years.

The Russian sturgeon, like other migratory acipenserids, is characterized by a complex, multi-aged population structure. Most of the Russian sturgeons caught in the part of the Black Sea near the Danube Delta at the beginning of the 1950s were young individuals aged between 12 and 16 years, which accounted for about 70 % of the catch. In this region, the fishery is not reasonably regulated. The average weight of the sturgeons in the catch during those years was 13.4 kg. An especially large proportion of immature individuals and those ready for spawning for the first time were found in Karkinitsk Bay, where sturgeons came to feed and spend the winter from all parts of the north-western Black Sea. In recent years, there has been an increasing proportion of old fishes in the catch due to extraordinarily poor recruitment in the north-western part of the Black Sea. From 1966 through 1968, 58 % of the catch in the Danube River consisted of 14 to 20-year-old individuals. The total number of the Russian sturgeons that were feeding in the north-western part of the Black Sea in the period from 1966 to 1974 is estimated to be 209,000. At present, the stock of this species in the Danube River includes individuals up to 290 cm long and 30 years old; about 20 % of them are included in the spawning population.

In the sturgeon catch from the region of the Black Sea near the Danube River, the males were predominant at the beginning of the 1950s, accounting for an average of 58.7 % of all the individuals examined.

9.1.4 Reproductive Biology

The Russian sturgeon is in third place among the acipenserid species, behind *Acipenser ruthenus* and *Acipenser stellatus*, for earliness in reaching sexual maturity. Rarely, individuals become sexually ripe at an age of 7 to 9 years and a length (*Tl*) not less than 100 to 110 cm. However, the great majority of the males begin to reproduce at an age of 11 to 13 years, while the equivalent age of the females is 12 to 16 years. Maturity is reached at different ages in the different river systems and also in different rivers within a single system. After spawning, the females of the Danube population are ready to spawn again after five to six years.

The number of eggs laid by a Russian sturgeon varies over a very wide range and depends primarily on the size of the female. According to different findings, Volga sturgeon produce a total of 50,000 to 1,165,000 eggs. Those in the Ural River contain from 26,000 to 1,065,000 eggs, and those in the Danube produce 29,500 to 406,800 eggs.

The temperature range in which the spawning of the Russian sturgeons takes place is fairly wide. In the Danube, the spawning sites are distributed throughout very large areas, and the Russian sturgeon run continues for a long time. Since spawning begins at a temperature of 8° C, it was assumed that the reproductive season lasts from March through November.

Due to the regulation and damming of the rivers, there has been a sharp decrease in the natural reproduction of the Russian sturgeon. For example, the dam of the Volgograd Reservoir has reduced the area of the spawning grounds by about 80 %, and presently, the spawning of all biological groups of the Russian sturgeon in the Volga River is limited to a total area of 415 ha remaining downstream from the dam. At these sites sturgeons reproduce on gravel or stony beds at depths of 4 to 25 m, where the current velocity is 1 to 1.5 m s^{-1}. Most of the reproduction takes place on the riverbed of the main channel, while a minority of the fishes lay their eggs in flooded regions along the river. To improve the spawning conditions for sturgeons in the Volga River artificial spawning sites were established. These artificial structures were accepted and used for spawning by the animals. In the Danube River, a small number of the spawning shoal reproduces near the mouth, but the great majority migrate a considerable distance upstream before spawning.

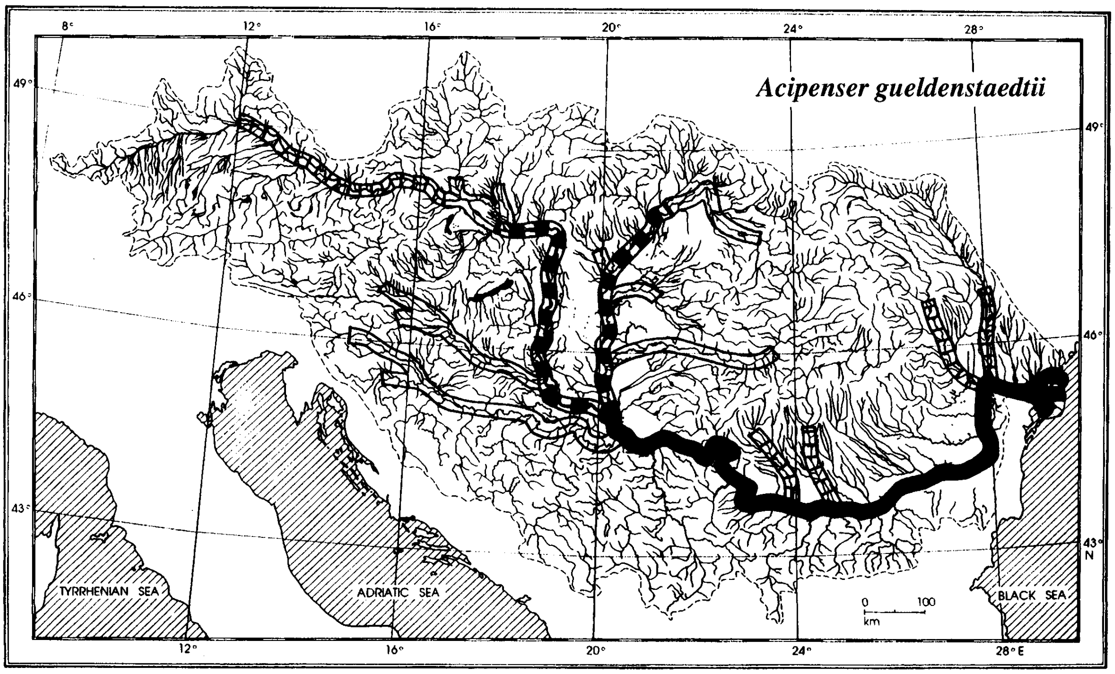
9.1.5 Historic range, stock development and current status in the Danube River Basin

The Danube or Russian sturgeon was the most widely distributed anadromous sturgeon species in the Danube River. Russian sturgeons regularly migrated upstream to Bratislava (river km 1,869) and spawned in this stretch of the Middle Danube in May and June. They rarely ascended up to Vienna (river km 1,925) and Regensburg (river km 2,381). Russian sturgeons occurred in the following left bank tributaries of the Danube: the Morava (at Suchohrad), Vah River, the Tisza River (up to Versenyi) and its tributaries, the Szamos, Zagyva River, Körös River and the Mures River (up to Mihalt). It also occasionally entered tributaries of the Lower Danube, including the

Olt River, the Jiu River (up to Transsylvania) the Prut River and the Siret River. Frequented right hand tributaries were the Drava River (and its tributary, the Mura River, as far inland as Austria), the Sava River (up to Litija as well as its tributary, the Kupa River, up to Karlovac) (HENSEL & HOLČIK 1997). Besides the migratory stock a resident form of Russian sturgeon is still present in the Middle and Lower Danube. This species is extremely rare in the Middle Danube, though. It is occasionally caught by anglers in the Hungarian and Slovakian stretches (GUTI 1997; HENSEL & HOLČIK 1997; GUTI 1999).

The status of *A. gueldenstaedti* is vulnerable throughout its range (LELEK 1987). The Russian sturgeon is critically endangered in the Danube River Basin (HENSEL & HOLČIK 1997). The four migratory *Acipenserids* are extinct from Germany and Austria (BAYERISCHE LANDESANSTALT FÜR FISCHEREI 2000; SPINDLER 1995). The migratory form of *A. gueldenstaedti* is extinct and the resident form critically endangered in Slovakia (HOLČIK 1996 b). Migratory sturgeons are considered endangered in Hungary (GUTI 1995). According to the Red List 2000 of IUCN b the Black Sea stock of *A. gueldenstaedti* is endangered.

Fig. 14: Distribution of the Russian sturgeon, *Acipenser gueldenstaedti*, in the Danube drainage system. Regular (continuous black) and occasional (black and white area) occurrence at present; regular (continuous white) and occasional (striped white area) occurrence in the past. (from HENSEL & HOLČIK 1997 Original figure by K. Hensel)



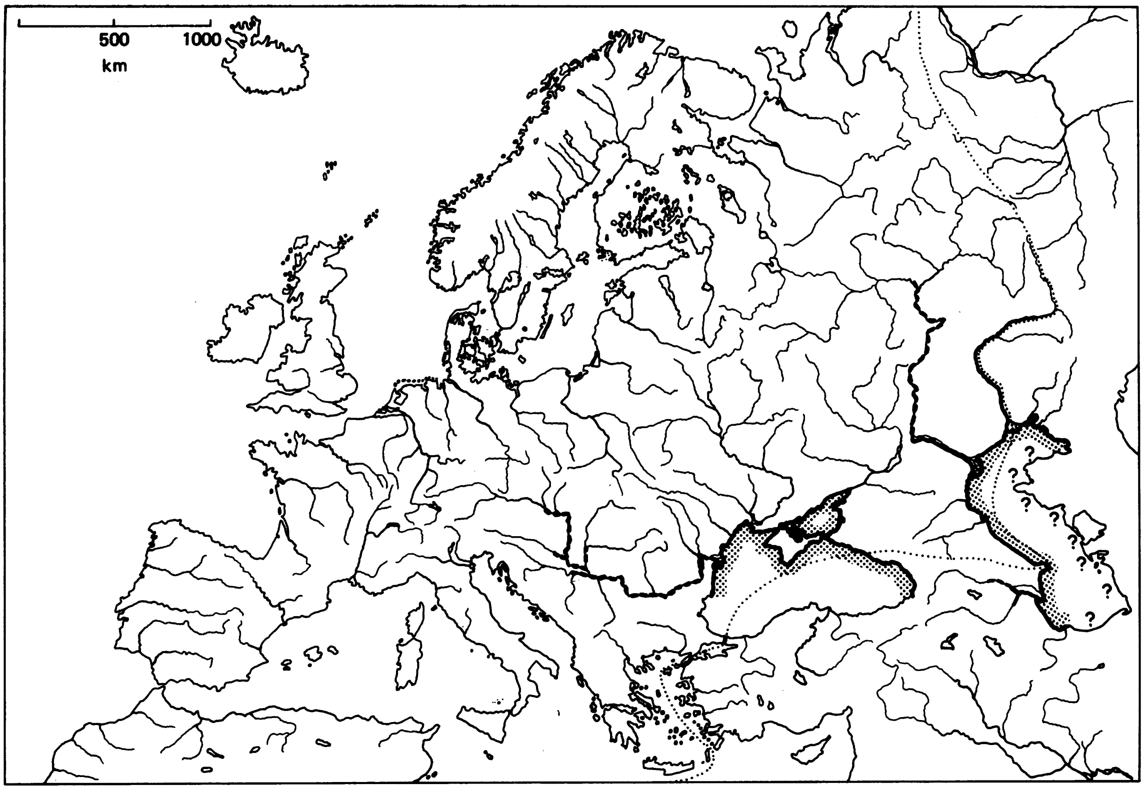
9.2 *Acipenser nudiventris* Lovetsky, 1828

The following informations on *A. nudiventris* are given on the basis of a compilation of relevant literature by SOKOLOV & VASIL'EV (1989 b).

9.2.1 Distribution

The ship sturgeon (*Acipenser nudiventris*) inhabits the Black, Azov, Caspian and Aral Seas, from which adults ascend the rivers to spawn. In the Black Sea and the Sea of Azov they are only rarely found. They are known from the Danube River system in which they formerly ascended as far as Komárno, 1,766 km from the river mouth and even Bratislava, at km 1,869. Occasional specimens were taken in the following Danube tributaries: the Rivers Váh, Tisza at Szeged, Sava and Drava, and in the lower sections of River Prut and Siret. A general predilection for freshwater is one of the biological characteristics of the ship sturgeon. A freshwater resident form is known from the Danube River.

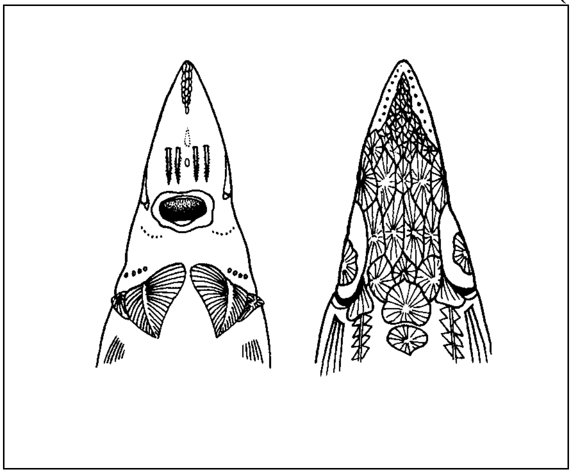
Fig. 15: Former (dotted line) and present (solid line) geographical distribution of *Acipenser nudiventris*. Stippled area indicates the coastal habitat of this species during its stay in the sea. (from SOKOLOV & VASIL'EV 1989 b)



9.2.2 Species description

Du 39-57, *Au* 23-37, *SD* 11-17, *SL* 49-74, *SV* 11-17 (in large specimen, these may be partially or completely absent), *Sp. br.* 24-45.

Fig. 16: Ventral (left) and dorsal view of the head of *A. nudiventris* (from PECL 1989)



The first dorsal scute is the largest and forms an obtuse angle with the profile of the head. The barbels are fimbriate. There are no small bony plates between the rows of scutes. In Europe this species reaches a length of 221 cm and weight of 80 kg. This species is easily distinguished from the other members of the genus *Acipenser* by its thick lower lip, which is not split in the middle. Exceptional specimens with split lower lips have been observed rarely in the Aral Sea.

The body is elongated; its depth equals 12.3 to 16.1 % of *Tl*. The head length is 19.1 to 22.2 % of *Tl*. The snout is smoothly rounded and has an almost perfect conical shape. Its length is 32.2 to 43.6 % of *lc*. The mouth is fairly large. The dorsum is greyish green, becoming lighter on the sides. The ventral surface is yellowish-white, and the fins are greyish. No valid subspecies of *A. nudiventris* have been described this far.

Acipenser nudiventris produces hybrids with *Huso huso*, *Acipenser gueldenstaedti*, *Acipenser persicus*, *Acipenser stellatus*, and *Acipenser ruthenus*. Crosses are more frequently produced with *Acipenser stellatus* and they can be recognized by their extremely elongated snout and the lack of an interruption in the lower lip. There is great interest in the commercial culture of experimentally bred hybrids between *Acipenser nudiventris* and *Huso huso*, which inherit hardiness and the ability to live in freshwater from the ship sturgeon and the predatory feeding habits and rapid rate of growth from the great sturgeon.

Ship sturgeons were successfully introduced to the Ili River-Lake Balkhash system.

9.2.3 Ecology

Because of their feeding habits, the ship sturgeons in the sea remain in relatively shallow water, above 50 m, where the bottom is muddy. They are most abundant in the vicinity of river mouths. As mentioned before, a general predilection for freshwater is one of the biological characteristics of the ship sturgeon.

Acipenser nudiventris is basically a diadromous species; it produces a non-migratory race, though, which continuously remains in fresh water. The stocks of this species in the Danube River also belong to the freshwater race.

Experiments have shown that the eggs of the ship sturgeon do not become fertile at temperatures below 10° C. At 10° C, only 42.5 % of the eggs are fertilized, and many of them show malformations during development. At 22.1° C, 58.8 % of eggs are fertilized, but all of them die by the gastrula stage. The greatest rates of fertilization, 91 to 92 %, and normal development are observed at temperatures between 12 and 17.1° C. The young fishes are very sensitive to contamination of the water with petrochemicals. At a concentration of soluble petroleum fractions of 0.03 mg l^{-1}, they cease to feed and grow, and up to 40 % of them die.

Acipenser nudiventris in the Danube River feeds on mayfly (Ephemeroptera) larvae, other insects, molluscs and crustaceans. Adult ship sturgeons from the Caspian Sea also prey on fishes. During spawning migrations, feeding almost ceases. While in rivers, the juvenile ship sturgeons feed on larvae of midges (Chironomidae), caddisflies (Trichoptera) and mayflies, as well as mysids and corophiids. Juvenile ship sturgeons tend to display more predatory habits than those of *Acipenser gueldenstaedti* and *Acipenser stellatus*.

There is little information available on the longevity of this species. Animals from the Aral Sea and the Ural River reached ages of up to 36 years.

The ship sturgeon also displays a complex multi-age population structure.

9.2.4 Reproductive Biology

Acipenser nudiventris is a fish with delayed maturation. Individuals from the Kura River attained maturity at the age of 12 to 14 years for females and 6 to 9 years for males. There are no data available for the Danube River. The gonads ripen again after more than one year, but the time interval between spawnings is not known. Females spawn every two to three years.

Absolute fecundity depends on the size of the fish. In the Danube River it is 200,000 to 1,300,000 eggs. Spawning takes place in the Danube River at water temperatures between 10 and 15° C.

Spawning sites in the Kura and Amu-Darya Rivers consist of gravelly or stony bottoms or along sections with firm, clayey sediments at water velocities between 1 and 2 m s^{-1}.

It was reported, that the early ontogeny of the ship sturgeons in the Kura River lasts five days at water temperatures between 17.7 and 21.9° C. In an experiment at water temperatures of 12, 15.5

and 17.1°C, development required 152.6, 137.5 and 102 hours. The optimum temperature range for development is believed to be between 11 and 15° C. The YOY ship sturgeons reach a mean *Tl* of 38.6 mm and a mean weight of 336 mg within 47 days.

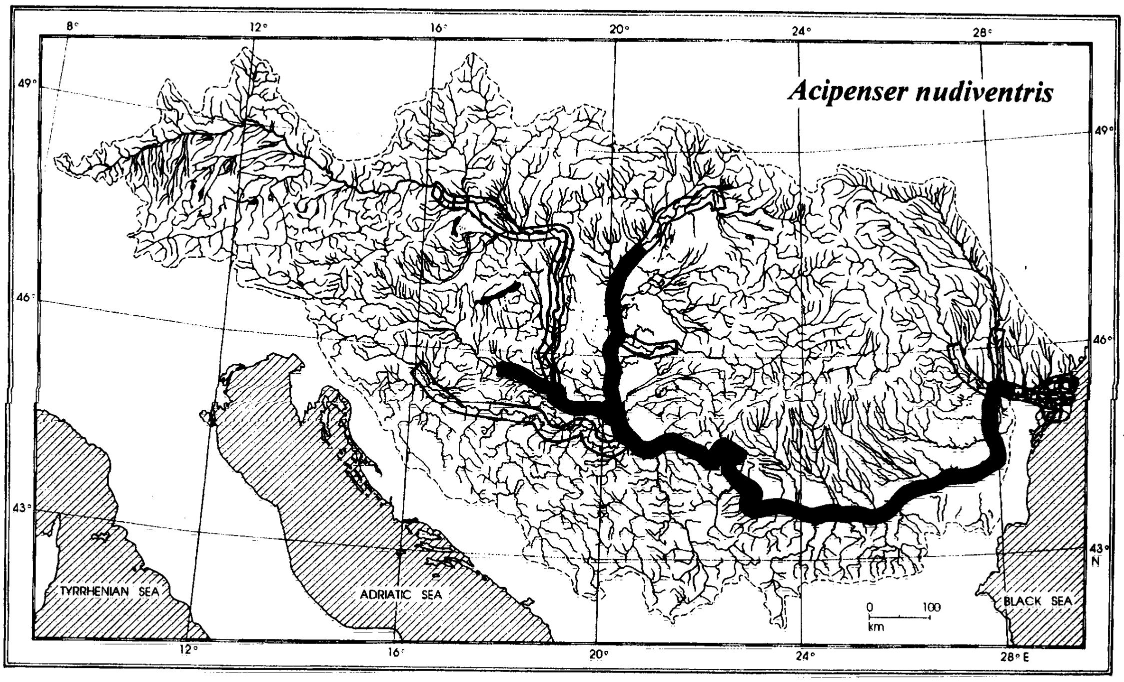
9.2.5 Historic range, stock development and current status in the Danube River Basin

The ship sturgeon forms both anadromous and potamodromous (freshwater) populations throughout its distribution area. For the Danube River, only the non migratory or resident freshwater form has been reported. It was recorded in the Lower Danube (occasionally in the delta) and in the Middle Danube upstream to Bratislava. Rarely it entered the Austrian section of the Danube (ZAUNER 1997). Ship sturgeon also occurred in some tributaries: the lower course of the Vah River, the Tisza River at Mandok, the Sava and Drava Rivers, the Maros River and also in some tributaries of the Lower Danube, the Prut and Siret Rivers (HENSEL & HOLČIK 1997). Ship sturgeons were never abundant in the Danube Basin. Verification on the basis of historical documents is difficult, however, since small ship sturgeons can easily be confused with sterlets (*A. ruthenus*) and larger specimen with Russian sturgeons (*A. gueldenstaedti*), and fishermen often did not distinguish between these species (GUTI 1995).

The ship sturgeon is very rare in the Danube River Basin nowadays and found only occasionally in the catches of Romania and Serbia (HENSEL & HOLČIK 1997). This species completely disappeared from the Austrian and Slovak stretch of the Danube River, and in the Hungarian section it is extremely rare. From tributaries of the Middle Danube it has only been reported from the Tisza and Drava Rivers. The status of *A. nudiventris* is vulnerable to endangered throughout its range (LELEK 1987). The ship sturgeon in the Danube River Basin is critically endangered (HENSEL & HOLČIK 1997). *A. nudiventris* is extinct in Slovakia (HOLČIK 1996 b).

A. nudiventris has not been recorded in the Lower Danube in Romania for 30 to 40 years (BACALBASA-DOBROVICI 1997). According to the Red List 2000 of IUCN b the Black Sea stock of *A. nudiventris* is endangered.

Fig. 17: Distribution of the ship sturgeon, *Acipenser nudiventris*, in the Danube drainage system. Regular (continuous black) and occasional (black and white area) occurrence at present; regular (continuous white) and occasional (striped white area) occurrence in the past. (from HENSEL & HOLČIK 1997, Original figure by K. Hensel)



9.3 *Acipenser ruthenus* Linnaeus, 1758

The following information on *A. ruthenus* is given on the basis of a compilation of relevant literature by SOKOLOV & VASIL'EV (1989 c).

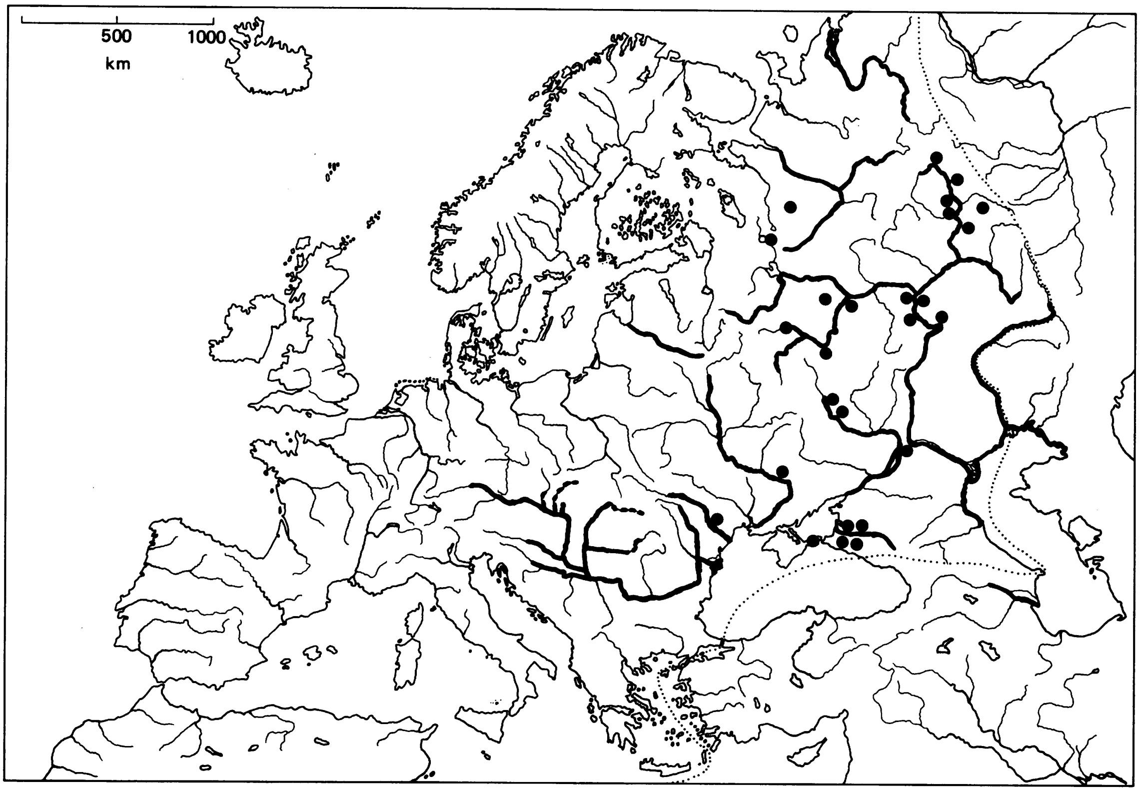
9.3.1 Distribution

The sterlet (*Acipenser ruthenus*) is an Eurasian species inhabiting rivers flowing into the Caspian, Black, Azov, Baltic, White, Barents and Kara Seas. The natio *marsiglii* Brandt, 1833, inhabits only the Ob, Irtysh and Yenisei Rivers in the Kara Sea watershed. The main sterlet river is the Volga, in which it is encountered throughout nearly the entire course, including the reservoirs.

It has been found in the lower courses of Danube tributaries such as the Rivers Prut, Olt, Arges, Siret and Jiul. In the Danube River, sterlet was formerly encountered regularly as far upstream as Passau and very rarely as far as Regensburg and Ulm (OBERPFÄLZER KREIS-FISCHEREI-VEREIN 1893). A synopsis of historical sources suggests that there was an autochthonous population of considerable size in the Danube between Regensburg and Passau and that occasional catches in the 19th century in this part of the river were rather the remnants of a dying population than accidental migrants (KINZELBACH 1994).

From the Danube River sterlets formerly ascended the Salzach River as far as Laufen and the Isar River as far as Landshut, but they are no longer known from these rivers. In the Tisza River the sterlet occurred upstream to the town of Szeged and specimens have been reported from its tributaries, the Rivers Körös, Mureşul, Someşul, Zagyva, and Bodrog. The sterlet is still known to occur in some Danube tributaries, namely the Sava River as far as the town of Sevnitsa, the Drava River as far as Maribor, the Raba River and the lowland section of the Ipel River. It is also known from Lake Balaton. In the Morava River, sterlets occurred as far as Suchohrad, in the Váh River, to the town of Trnovec and occasionally as far as Trenčín. In the Hron River, the sterlet travelled upstream as far as the Kamenitsa region. Since the 1980s the range of sterlets has again been increasing due to improved water quality. Thus, in 1980, sterlets reappeared in the Morava River as far as the Suchohrad region. They have also begun to appear in the lower reaches of the Váh River, and now the sterlet regularly occurs even at the Slovakian capital, Bratislava. An increasing abundance of the sterlet in the Slovakian and Hungarian sections of the Danube River is not only the result of improved water quality, but also due to the efforts of artificial propagation of this species in Hungary.

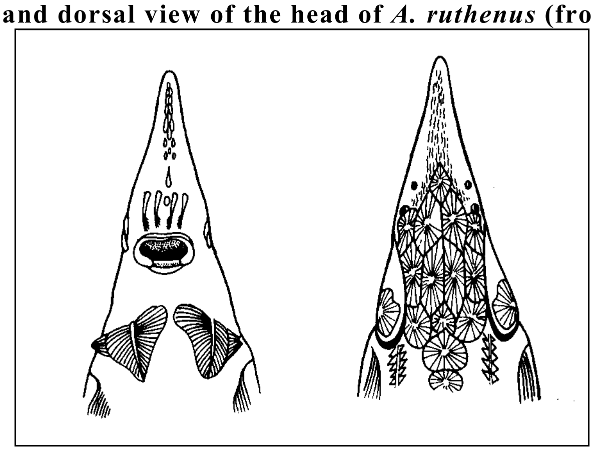
Fig. 18: Geographical distribution of *Acipenser ruthenus* in Europe. Dots indicate location of subfossil remains. (from SOKOLOV & VASIL'EV 1989 c)



9.3.2 Species description

Du 32-49, *Au* 16-34 (39), *SD* 11-18, *SL* 56-71, *SV* 10-20, *Sp. br.* 11-27, *Fu* 25-45.

Fig. 19: Ventral (left) and dorsal view of the head of *A. ruthenus* (from PECL 1989)



Between the rows of scutes are numerous bony plates. In exceptional cases, these fishes reach a length of 125 cm and a weight of 16 kg, but normally they do not grow beyond 100 cm and 6 to 6.5 kg. The sterlet can easily be distinguished from *Acipenser nudiventris* by the lower lip, which is clearly split in the middle. From other *Acipenser* species, the sterlet can be distinguished by its greater number of lateral scutes, generally more than 50, and by its fimbriate barbels.

The body is elongated, and its greatest height is 5.9 to 16.6 % *Tl*. The snout length is highly variable and is one of the least constant characteristics. In sterlets from different watersheds, its range of variation is 27.8 to 63.5 % *lc*. The small transversal mouth has a width equalling 12 to 26.9 % *lc*. The color varies greatly, but the dorsum is usually dark greyish-brown, and the belly is yellowish-white. The fins are grey and the scutes dirty white.

It is reported that in most of the inhabited water bodies, two forms of sterlet occur. One with a typical long snout and another with a short blunted one. The pointed snout sterlet was considered to be the spring form, and those with blunt snouts, the winter form. According to other researchers, these two forms of the sterlet are, in fact, two distinct genetic groupings of individuals, which are characterized by a series of differences. Other authors, however, deny the existence of two particular forms among sterlets.

Sterlets from various water bodies within the range display both meristic and morphometric differences. The most distinctive is the length of the snout and other measurements that depend directly on this length. In European rivers individuals from the north-western part of the Black Sea and especially the Rivers Danube and Dnieper have the longest snouts.

Sterlets hybridize most frequently with *Acipenser gueldenstaedti*. The hybrids are distinguished by their greater number of lateral scutes, usually numbering more than 50 and their tendency to remain in the rivers. *Acipenser ruthenus x Acipenser nudiventris* hybrids and the reciprocal cross are known. Artificially propagated intergeneric hybrids of *Huso huso* (♀) and *Acipenser ruthenus* (♂), are known as “bester”. These animals are produced for aquaculture purposes. In Siberia the sterlet also hybridizes with the Siberian sturgeon (*Acipenser baeri*).

9.3.3 Ecology

The sterlet is a potamodromous freshwater fish inhabiting the lowland and foothill zones of rivers. It usually stays in the current in deep depressions of the riverbed, over stony, gravelly or sandy bottoms. When the water level rises in spring, the sterlets move onto the flooded lowlands to feed. Small individuals are often encountered in sandy shallows. In reservoirs, the sterlets usually stay at the upstream end where there is a current and the conditions are similar to those in free-flowing rivers. They seldom occur in large lakes. The sterlet generally behaves as a resident fish and does not undertake long migrations. During the spring floods, they do swim upstream in the rivers for spawning. During strong floods they swim far upstream in large numbers for 4 to 5 weeks, as long as the water level does not decrease and until reaching the spawning ground. As in other acipenserid species, some immature individuals may accompany the spawners on their migration. After spawning, the spent fishes (= fishes after the release of their gametes during spawning) move slowly downstream to bays, sandy shoals or channels with muddy bottoms, where they feed intensively. Sometimes they may even reach brackish regions of the sea to feed, but here they do not descend to depths below 8 m. Larvae and juvenile sterlets remain at the spawning sites among rocks and stones during their early development, but later the juveniles disperse to feeding grounds. As the water temperature decreases the sterlets form large shoals in the deepest sections of the river or in depressions in the river bed to overwinter without feeding. By tagging sterlets in the Danube River System, it was found that this species usually did not travel beyond 200 km from the place of tagging, and they rarely appeared 300 km downstream. The majority of the tagged sterlets migrated 7 to 23 km downstream per day.

The sterlet, like other sturgeons, is a fish that prefers well oxygenated water. Below an oxygen concentration of 7 to 7.5 mg l^{-1} at a water temperature of 0.2 to 0.3 ° C, sterlets begin to attempt accelerated respiration and 3.5 mg l^{-1} is their tolerance threshold. The optimum pH for the development of the eggs and juveniles in natural waters is in the range of 6.8 to 7.2. Under experimental conditions, all eggs died at pH values of 3.9 to 4.0 and 8.4 to 8.5 within three to four days. Juvenile sterlets died within nine to ten hours at pH levels of 5.1 and 8.2 to 8.4. Sterlets are tolerant of salinity. Young fishes growing for 13.5 months in locations where the salinity is 12.7 ‰ are capable of maintaining a salt equilibrium within their bodies.

The main food of the sterlet in all rivers are benthic organisms. The most important of these are insect larvae, such as Chironomidae, Trichoptera, Ephemoptera and Simuliidae. Also included in the diet are larval Plecoptera and Heleidae; small molluscs of the genera *Sphaerium*, *Pisidium* and *Viviparus*; Oligochaeta, Polychaeta, Hirudinea and other benthic invertebrates. Especially lowland rivers and downstream sections of reservoirs, with a substantial occurrence of zooplankton (Cladocerans and Copepods), play a significant role in the nutrition of sterlets. During the spawning periods of other fishes, the sterlets may prey on their eggs, including those of other Acipenserids. During spawning season, these eggs can account for more than half of the stomach contents. Sometimes, during massive emergences of insects, such as mayflies (Ephemoptera) and stoneflies (Plecoptera), the sterlets leap out of the water to snap them up in flight. There are differences in the diets of young and mature sterlets. For instance, the young individuals that have completed six months of growth in the Danube River depend mainly on Trichopteran and Chironomid larvae. With increasing size, the role of the chironomids in the diet decreases, while that of Trichopterans increases, but as growth proceeds, there is practically no further change in diet. In the stomachs of large specimens, exceeding 45 cm, fishes are encountered on rare occasions. The primary competitors of the sterlet for food are the ruffe (*Gymnocephalus cernuus*), the bream (*Abramis brama*) and the white bream (*Abramis bjoerkna*).

The sterlet is the species with the shortest life span in the genus *Acipenser*. The oldest fish known from the catches in different rivers were 22 and 24 years old. Among archaeological remains a 26 year old specimen was identified. In the Kuibyshev Reservoir and the Yenisei River the maximum age reached by sterlets was 26, respectively, 27 years. All authors state, that females live considerably longer than the males.

The age structure of the sterlet populations in different rivers varies. However, the predominant classes are generally those of the four to seven-year-olds. A historical review of various time periods indicates that the average age of populations has considerably decreased due to anthropogenic factors. The numerical proportions of the sexes vary in different rivers and according to the season. At the spawning sites the males are usually predominant, accounting for about 60 to 70 % of all spawning participants. Among the fishes on the feeding grounds, the proportions of the sexes are equal, while among the individuals spending the winter in deep water, females are often observed to be predominant. In general the ratio of the sexes among the sterlets evidently approximates 1:1. With the transition to life in reservoirs and due to the disturbances of the conditions affecting sterlet reproduction, a considerable increase in the number of older fishes that do not take part in spawning has been observed.

9.3.4 Reproductive Biology

The sterlet matures early compared to other acipenserids. The males reach sexual maturity, as a rule, one to two years earlier than the females. In the Middle Danube sterlets are 3 – 5 years (♂), respectively, 4 – 7 years (♀) at lengths of 40 cm (*Tl*) by their first time of spawning. The question of the spawning periodicity of sterlets has yet to be answered. Some investigators state that they spawn every year, while others tend to believe that the gonads may become ripe again only after a one or more years' pause, the recovery period being shorter for males. One researcher found that in the Danube River, males and young females up to the age of seven years spawn every year. Older females, however, become ripe only after an interval of two years.

The absolute fecundity of sterlets from the Middle Danube ranges from 7,000 to 108,000 eggs (in individuals ranging from 52.2 – 77 cm *Tl*).

Sterlets generally spawn during the high water periods in spring. Spawning is first initiated when a suitable water temperature is reached. The time and conditions of sterlet reproduction in the Middle Danube range from April to May at water temperatures between 8 and 19° C at water depths of up to 10 m. The optimal temperature for reproduction ranges from 12 to 17° C. When the water temperature increases to 20 or 21° C, spawning ceases, and below 9.4° C, it is discontinued.

There are two types of spawning sites for sterlets. Floodplain areas that are flooded by the rising spring water and sites on the river bed. Spawning on the river bed occurs at a depth from 7 to 15 m. The eggs are laid on pebbles 1 to 7 cm in diameter, and rarely on gravelly-sand bottoms. The current velocity ranges from 1.5 or 2 to 5 m s^{-1}. The oxygen concentration on these spawning sites ranges from 6.8 to 8.3 mg l^{-1}. Usually the depression in the river bed in which the sterlets spend the winter is located near the spawning grounds. In impoundments, sterlets usually reproduce in the region farthest upstream, where there is still a water current.

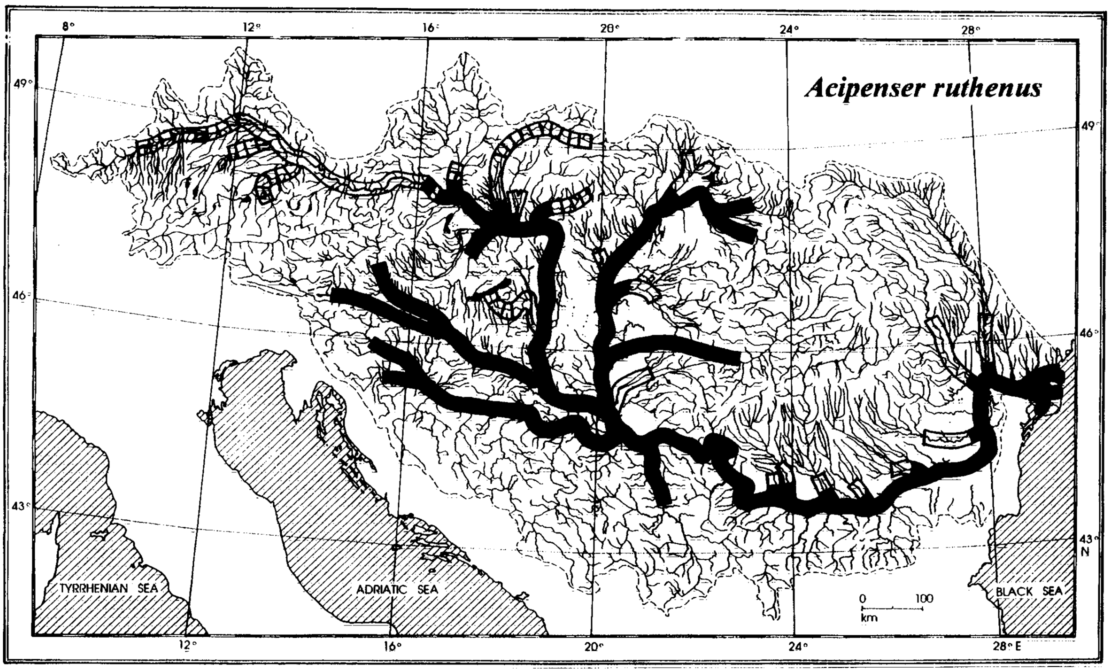
Males appear at the spawning sites before the females at water temperatures of 9 to 11° C. The females reach the spawning grounds, when the water temperature has risen to 12 to 13° C. Fertilized eggs stick to the substrate. Spent females immediately leave the spawning grounds downstream, but the males remain for some time to participate in the fertilization of eggs from other females. During the period of reproduction almost no food intake can be observed in sterlets. At a temperature of 13° C, the eggs require four to five days to develop, while at 10 to 11° C, the period is extended to seven to nine days. The incubation of sterlet eggs requires 1,920 degree-hours at 16 to 18° C, 2,300 degree-hours at 13 to 16° C and 2,140 degree-hours at 13° C. At the end of incubation, 83 to 99 % of the larvae hatched from the eggs and 78 % to 85 % survived until the onset of feeding activity. The development until hatching of the free embryos of sterlets from the Volga River at 10° C requires more than 320 hours, but at 20° C, it takes less than 80 hours. The hatchlings of the Volga sterlet are 6 to 7 mm long and the yolk is digested within six to ten days after hatching. After one month, the juveniles are 3 to 4 cm long, and YOY sterlets in August and September have already reached 8 to 18, or exceptionally 25 cm. The average weight of Danube sterlets at hatching is 0.65 g. After one month, their weight can amount to 6.8 g, which was further increased to 88.5 g in autumn (October). A detailed description of the early development of sterlet is provided by KRUPKA et al. (2000).

9.3.5 Historic range, stock development and current status in the Danube River Basin

The sterlet is best described as a typical lowland river species. It is a potamodromous species never leaving freshwater and only occasionally moving into the brackish water of the estuaries for feeding. Tagging experiments revealed a maximum migration distance in the Danube River of 322 km. Sterlets regularly occurred up to Ulm in Germany. Near Bratislava they were very abundant. The large sterlet population in the Upper Danube between Regensburg and Passau has to be considered autochthonous and not as the result of upstream migrations from downstream stretches (OBERPFÄLZER KREIS-FISCHEREI-VEREIN 1893; KINZELBACH 1994). Sterlets also ascended or occurred in the following right hand tributaries: Isar River (up to Landshut), Inn River (and its tributary Salzach River up to Laufen), Sio River (Lake Balaton), Raba River, Drava River (up to Maribor), Mura River (up to Graz), Sava River (up to Sevnica and its tributaries Lonja River and Kupa River up to Karlovac.) Left hand tributaries include: the Morava River (up to Moravka Nova Ves), Vah River (up to Trencin, exceptionally up to Liptovsky Svaty Mikulas and its tributaries Nitra River (up to Landor) and Zitava River. Hron River (up to Kamenica and Hronom), Ipel River, Tisza River (up to Sighetul Marmatie and its tributaries Bega River, Mures River up to Auid, Zagyva and Bodrog Rivers, the latter up to Brehov with the tributaries Latorica

River, Laborec River, Uh River, Somes River and Tamis River) (HENSEL & HOLČIK 1997). The sterlet is the most widely distributed sturgeon species in the Danube River Basin nowadays. Although it has been almost extirpated from the Upper Danube (the occurrence in Germany (Bavaria) and Austria strongly depends on stocking (REICHLE 1997; ZAUNER 1997)), stocks in the Middle Danube (Slovakia and Hungary) seem to recuperate. This is due to stocking measures conducted in Hungary as well as the improvement of water quality. At the beginning of the 1980s, Slovak fishermen could easily catch up to 300 sterlets in a single haul of a 300 m beach seine. Increases in sterlet catches in the Hungarian part of the Danube River started in 1971 probably due to the damming of the Tisza River, thus causing sterlets to emigrate from their spawning grounds. In the Serbian stretch of the Danube River the most abundant population of sterlets occurs near Belgrade and in the upstream sections near Vojvodina as well as in the lower parts of the Sava and Tisza Rivers (HENSEL & HOLČIK 1997). The status of *A. ruthenus* is endangered throughout its range (LELEK 1987). The Djerdap (Iron Gate) dams are also blamed for a decrease in sterlet catches, preventing migrations of this species from the lower parts of the Danube River past the Iron Gates gorges (GUTI 1995). One contemporary autochthonous population is documented for the Austrian part of the Danube near Engelhartszell (ZAUNER 1997). *A. ruthenus* is threatened by extinction in the Bavarian Danube (BAYERISCHE LANDESANSTALT FÜR FISCHEREI 2000). Stocking of sterlet into the Carinthian Drava was conducted since 1983 within the impoundments below the town of Villach. Evidence of natural reproduction could be provided (HONSIG-ERLENBURG & FRIEDL 1999). *A. ruthenus* is extinct in Slovenia (POVZ 1996). *A ruthenus* has to be considered rare in Hungary (GUTI 1995). According to HOLČIK (1996b) the status of *A. ruthenus* is susceptible in Slovakia. *A. ruthenus* is endangered in the Morava River in the Czech Republic and could not be documented recently (JURAJDA & PENAZ 1996). BACALBASA-DOBROVICI (1991) states, that the reserves of sterlets in the Romanian Danube have been “reduced to a minimum”. *A. ruthenus* is considered endangered throughout its range (LELEK 1987). *A. ruthenus* is not listed in the Red List 2000 of IUCN b.

Fig. 20: Distribution of the sterlet, *Acipenser ruthenus*, in the Danube drainage system. Regular (continuous black) and occasional (black and white area) occurrence at present; regular (continuous white) and occasional (striped white area) occurrence in the past. (from HENSEL & HOLČIK 1997, Original figure by K. Hensel)



9.4 *Acipenser stellatus* Pallas, 1771

The following information on *A. stellatus* is given on the basis of a compilation of relevant literature by POPOVA et al. (1989).

9.4.1 Distribution

The stellate sturgeon inhabits the Caspian, Azov, Black, and Aegean Seas, from which it migrates into the rivers. Within its ranges, it is represented only by a migratory form. The largest populations of stellate sturgeon are concentrated in the Caspian Sea. From there, they ascend the Volga, Ural, Terek, Sulak, Samur, and Kura Rivers. They also enter the Sefid-Rud and Gorgan Rivers along the southern Caspian coast.

From the Sea of Azov, the stellate sturgeons ascend the Don and Kuban Rivers. Recently, the stellate sturgeon has been found only in the lower sections of the Don and Kuban Rivers.

From the Black Sea, the stellate sturgeon enters the Danube River. Along the Bulgarian Black Sea Coast, only isolated individuals have been caught.

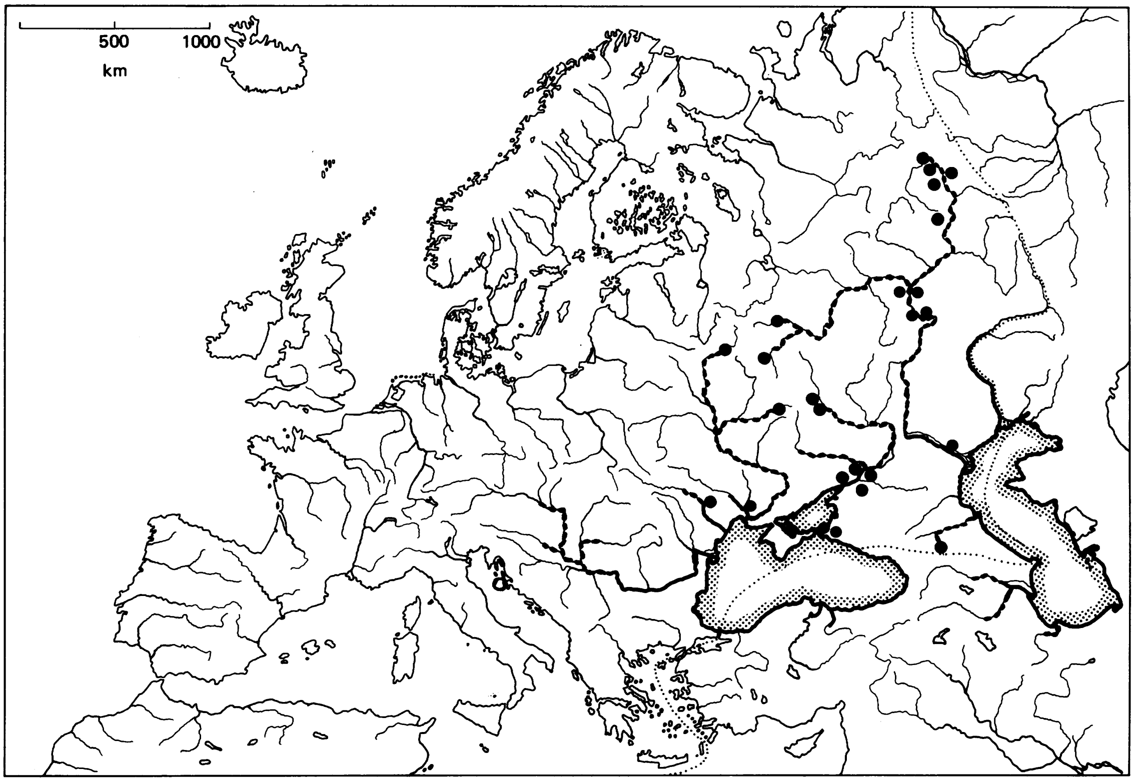
In the Dniester River, it was encountered at the mouth of the Zbruch River and farther upstream. It formerly ascended the Dnieper River as far as the city of Smolensk. It is also encountered in the Seim River, a tributary of the Desna River. Now, the great bulk of the stellate sturgeon population is concentrated in the bay at the mouths of the Dnieper and Bug Rivers, from which they ascend the latter. Only occasionally do any of these fishes occur in the Dnieper Delta. From the Black Sea, they also enter the Kizil-Irmak, Yesil-Irmak, Chorokhi, and Rioni Rivers. This species is also known from the Bosporus and Sea of Marmara.

In the Adriatic Sea, isolated individuals of this species have been caught at Zadar. The stellate sturgeon has been reported in the watershed of the Aegean Sea, particularly in the Struma (Strymon) and Maritsa (Evros) Rivers, however this has been doubted.

At present, as a result of construction and damming of the rivers, the range of the stellate sturgeon in the Caspian, Azov, and Black Sea watersheds has decreased considerably. Thus, the stellate sturgeon has become rare in the Sefid-Rud and Gorgan Rivers, in which its migrations are hindered by impoundments and the water control facilities at the river mouths. Most stellate sturgeons ascend the Danube River only as far as the dam at the Iron Gate and the Djerdap Reservoir at river km 863. The last stellate sturgeon found in the former Czechoslovakian section of the Danube River was caught at Komarno in 1926.

During 1933 and 1934 and again from 1948 through 1956, *A. stellatus* was introduced into the Aral Sea, and since 1950, this species has sometimes been caught there. For instance, in 1956, a ripe, sperm producing male was caught near the mouth of the Syr-Darya River. However, a commercially exploitable stock did not develop.

Fig. 21: Former (dotted line) and present (solid line) geographical distribution of *Acipenser stellatus* in Europe. Dots indicate location of subfossil remains. Open circle represents a single record from the Adriatic coast at Zadar. Stippled area indicates the supposed coastal habitat of this species during its stay in the sea. (from POPOVA et al. 1989)

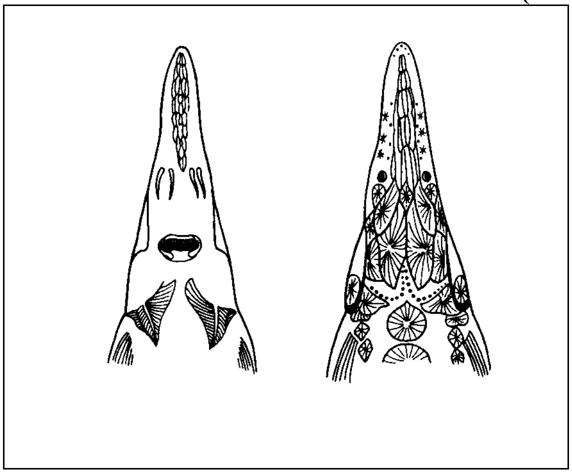


9.4.2 Species description

The specific name *stellatus* is a Latin word meaning covered with stars. This name was given to the stellate sturgeon because the plates covering its body have a starlike shape.
Du 40-54, *Au* 22-35, *SD* 9-16, *SL* 26-43, *SV* 9-14, *Sp. br.* 24-29

The snout is long, narrow, and dorsoventrally compressed, its length varying from 59 to 65 % of *Ic*. This character distinguishes the stellate sturgeon from all other members of the genus *Acipenser*. Between the rows of scutes, the body is covered by star-shaped plates. The barbels are short and not fimbriate. The lower lip is interrupted in the middle. The gill membranes are attached to the isthmus. The first ray of the pectoral fin is weak.

Fig. 22: Ventral (left) and dorsal view of the head of *A. stellatus* (from PECL 1989)



The fishes reach a maximum length of 218 cm and a maximum weight of 54 kg, but they usually range from 100 to 120 cm and 6 to 8 kg. The average length and weight of stellate sturgeons caught in the Volga River in the years 1967 through 1974 ranged from 126 to 152 cm and 6.2 to 12.7 kg.

The body is elongate and spindle-shaped. Besides the rows of scutes and small star-shaped plates, the body has a covering of pectinate grains. These grains sometimes become the predominant body covering, in which case the plates tend to be arranged in longitudinal rows. The dorsal scutes have radial stripes and strongly developed spines with the tips directed towards the caudal end of the animal.

The highest of the dorsal scutes is the third or one of the following as far back as the seventh. The dorsal fin is notched; the anal fin is blunt or slightly indented. The mouth opening is transverse and moderately long. The body has a deep blackish-brown colour dorsally and laterally. The belly is light, and the ventral scutes are a dirty white colour. Often, specimens are cinnamon brown, ashen grey, or sometimes nearly black dorsally, but the colour becomes lighter laterally. They are yellowish white near the lateral scutes. Specimens from the sea are darker than those from rivers.

The stellate sturgeon can be distinguished from the great sturgeon and the Russian sturgeon by its more elongated, streamlined body shape and smaller cross-sectional area, as well as by its smaller size and weight. In utilizing its energy resources, the stellate sturgeon compensates for its small size by its ideal hydrodynamic form, which allows swimming at relatively high speeds, compared to other sturgeon species.

The differences between the sexes are slight. Females are larger than males of the same age. Among the 14 to 16 age groups of the stellate sturgeon in the Ural River, the females were 1.3 to 1.6 times larger than the males.

Differences in the meristic characters have not been observed. It has only been noted that the numbers of dorsal, and ventral scutes, as well as gill rakers, varied over a wider range in females than in males.

There are two ecological forms of the stellate sturgeon in the Caspian Sea. One is the North Caspian or typical form, *Acipenser stellatus stellatus*, and the other is the South Caspian or the so-called Kura form, *Acipenser stellatus stellatus natio cyrensis*. The two differ in biological features. The South Caspian sturgeons mature later, their growth rate and fecundity are lower, and they spawn at a different time than the North Caspian sturgeons. Intrapopulation immunochemical analyses of North Caspian stellate sturgeons revealed that two subpopulations or local stocks do exist: the Volga and the Ural stock.

As in the case of other sturgeons, there are biological groups of the stellate sturgeon that differ among themselves in the timing of their migrations in the rivers, spawning time, water temperature at spawning, spawning grounds, and ripening of the gonads. In almost all of the rivers in the Caspian watershed which are utilized for spawning, there are both a spring and a winter form of the stellate sturgeon. The spring sturgeon run in the Volga River occurs during April and May, while that of the winter form takes place in August and September.

In the Ural River, there are also spring, both early and late, and winter stellate sturgeons, the spring form being predominant. The spring and winter forms are also known from the Terek and Kura Rivers, although the latter is inhabited predominantly by the summer form. The same situation has been observed in the Azov and Black Sea, where the spring and winter forms of the stellate sturgeon are found in the Kuban, Don and Danube Rivers.

The stellate sturgeon easily produces hybrids. In its natural habitats, *A. stellatus* is known to interbreed with *Huso huso*, *Acipenser nudiventris*, and *Acipenser gueldenstaedti*.

The following are the most frequently encountered hybrids:

Acipenser nudiventris x *Acipenser stellatus*

This crossbreed can be distinguished from the stellate sturgeon by its shorter snout. The bony plates between the rows of scutes are lacking, and only granules are in their place. Its body has a tapering cylindrical shape.

Acipenser ruthenus x *Acipenser stellatus*

The characters that distinguish this hybrid from the stellate sturgeon include a greater number of scutes in the lateral rows (40 to 60 rather than 30 to 36) and a shorter snout (54 to 61 % of *Ic* rather than 62 to 65 %, on the average). Sometimes the form of the dorsal scutes and the texture of the skin between the scutes are also different, and the first scute may be the largest, as in *A. ruthenus*.

Acipenser gueldenstaedti x *Acipenser stellatus*

This hybrid is externally similar to *A. gueldenstaedti*, but its snout is longer and thicker. It can be distinguished from the stellate sturgeon by the shape of its body, character of its skin armament, the larger dimensions of its mouth, and its less elongated snout.

In addition to these hybrids, a crossbreed of *Huso huso* x *Acipenser stellatus* has been described. Its snout is intermediate between those of its parents. The bones of its skull are similar to those of the great sturgeon. Its mouth is crescent-shaped, and the barbels are cylindrical. On the skin, there are small star-shaped plates.

9.4.3 Ecology

The stellate sturgeon, like most other acipenserids, is a typical benthic inhabitant of coastal waters in seas and the lowland sections of rivers, but unlike other sturgeon species, it can also be found in the middle and upper water layers. During the day, they are often encountered in the upper layers, while at night, they are generally found at the bottom. The distribution of the stellate sturgeons depends mainly on the water depth and the bottom properties, and particularly on the distribution of their food organisms.

In the Caspian Sea, they are widely distributed in the coastal zones at depths from 100 to 300 m, with the exception of very turbid or muddy bays. In the northern Caspian Sea, they mainly inhabit depths from 3 to 15 m. The largest concentrations of mature individuals are observed between 3 and 4 m, while the juveniles remain at about 5 m. In the central and southern Caspian Sea, they usually do not descend below 100 to 130 m, although along the southern coast, they may go deeper. In these waters, the bulk of the stellate sturgeon population prefers depths to 50 m, with the largest individuals usually remaining at the greatest depths. The largest groups of these sturgeons are typically found in waters where the depth increases gradually, the hydrological conditions remain stable, and the bottom deposits consist of small-sized particles. During the winter, they move into deeper regions of the sea, and in the spring and summer, they migrate back to shallow waters of the continental shelf.

It was found that in the Caspian Sea, the stellate sturgeons usually inhabit regions with clayey or sandy and clayey sediments in the western and south-eastern parts of the sea. However, a number of them stay at feeding grounds with sandy or shell sediments along the eastern shores. There is also a concentration of these fishes in the eastern coastal waters of the central Caspian Sea, where the bottom includes silty sand.

During the warm season, the stellate sturgeons occur throughout the entire Sea of Azov. In the winter, they move into the western and southern parts of the sea. While in the rivers, the juveniles under 9 cm remain near the mouths or in the Don Delta and congregate at depths from 6 to 18 m above a sandy bottom. The larger juveniles usually stay above clayey sediments at depths from 7 to 10 m, but they occasionally descend as deep as 17 m.

The stellate sturgeon is a migratory fish that travels considerable distances in the sea, in which it feeds and spends the winter, and in rivers, where it spawns. The damming of some rivers in the

Caspian, Azov, and Black Sea watersheds has reduced the extent of the spawning grounds and changed the time and route of the migrations.

There are two types of spawning migrations. The movement in the sea to the river mouths and the upstream run along the river bed. In the sea, the stellate sturgeons move onto the shelf, closer to the shore. The direction of the migration in the Caspian Sea during this stage is determined to a great extent by the constant influence of the cyclonic current. Along the river bed, the flow of the water serves as the main basis of navigation.

When the water temperature decreases to between 4 and 6° C, the stellate sturgeons congregate in the deep furrows and ditches in the northern part of the Caspian Sea. In the autumn and winter, the juveniles move into the deep zones of the Northern and Central Caspian Sea. A considerable proportion of the adults spend the winter in the Central Caspian Sea, where feeding can continue in spite of water temperatures descending to between 0.9 and 1.4° C. Those individuals that mature sexually in winter were found to move to depths of 1.8 to 3.6 m in the Northern Caspian Sea. The spawners which do not enter the Volga River in autumn, spend the winter not far from the migration routes.

The stellate sturgeon prefers warmer habitats. Its spawning runs in the rivers occur at water temperatures higher that those prevailing during the migrations of *Huso huso* and other sturgeons. The migration of the stellate sturgeon from the Caspian Sea into the Volga River begins during the first half of April after the water has warmed to between 6 and 9° C. The peak period of the run is usually in May, when the water temperature reaches 10 to 15° C and the water level in the river is rising rapidly. The migration occurs in very rapidly flowing, turbid water. The run decreases in June. Its intensity increases insignificantly as the water cools during August, September, and October. The migration in the rivers ceases in December. In the Ural River, the run begins when the water warms up to between 5.4 and 7.2° C in April or May and reaches its maximum intensity in mid-May at a water temperature of 12 to 14° C. A mass migration coincides with the highest water level, the greatest turbidity, and the highest current velocity. In June, stellate sturgeons nearly cease to occur in the river. Their autumn migration in the Ural River takes place from end of August to the second half of October. Its maximum intensity is reached in September, but it is not significant.

The stellate sturgeon runs in the Volga, Terek, and Sulak Rivers take place under more severe conditions than those in the Kura and Sefid-Rud Rivers. Thus, they are shorter and postponed until summer. Migration in the Kura River can be observed throughout the year, and its intensity also shows two peaks. In winter, there is only insignificant activity by stellate sturgeons in the rivers. The dynamics of the stellate sturgeon runs in the Kura River are influenced not only by temperature, but also by the water level in the river during the course of the year.

In the rivers, the stellate sturgeons avoid rapid currents and remain in shallow places. The swimming strength depends mostly on the size of the fish. Small individuals generally move along the banks, while large ones wander near the main channel. During the period of low water, the current velocity is reduced to 0.5 to 0.7 m s^{-1}, and most fishes migrate in the center of the main channel. In the Volga River at a current velocity of 0.94 m s^{-1}, the migration speed averages 110 km day^{-1}, but in relation to the bank line, the progress amounts to only 17.6 km day^{-1}. In terms of specific power per unit of body mass, the stellate sturgeon is the best swimmer among the sturgeons.

Although the stellate sturgeon runs in the Don River can be observed during the whole year, there are two peak runs, from April through June and from September through November, and two periods of minimum intensity, December through March and July through August. The schedule of the migration in the Kuban River is quite different. The run occurs from April through August with a single peak in June. The fewest stellate sturgeons migrate in September and October, and the run ceases at the end of October. In both the Volga and the Kuban Delta, the mass migration coincides almost exactly with the high water period in May and June. All main stages of the spawning run of the Azov and Volga stellate sturgeons occur at higher temperatures than those of other sturgeons, including *Huso huso*.

The Azov stellate sturgeons migrate into the western and southern parts of the sea to spend the winter. In spring and summer, they move to all parts of the sea during spawning or feeding migrations. They range widely along the entire sea coast in search of better feeding places after hard winters, when their benthic prey is scarce, or after summer mortalities of their prey, due to hypoxia. After entering the sea in September and October, the YOY juveniles stay near the rivermouths. The shoals of older juveniles spend the winter in the western and southern parts of the Sea of Azov, and in May and June, they spread throughout the sea and enter the Taganrog Bay. In November, they return to those parts of the sea where they spend the winter.

The stellate sturgeon spawning migration in the Danube River takes place immediately after those of *Huso huso* and *Acipenser gueldenstaedti*. It is characterized by two peak periods. It begins in March at a water temperature of 8 to 11° C, reaches its peak intensity in April, and continues through May. A second, more intense migration begins in August and lasts until October. A two-peaked run of stellate sturgeons could also be observed in the Yugoslavian section of the Danube River, with 52 to 74 % of individuals caught from January through March downstream the Iron Gate dam. The stellate sturgeon, like other Acipenserids, enters the Danube River to spawn throughout almost the entire year, but two peak periods are evident.

A. stellatus is an oxyphilic fish with a positive relationship between the intensity of oxygen consumption and the early development of this species. The threshold oxygen concentration averages 2.27 mg l^{-1} at a water temperature of 20 °C. At higher temperatures, the critical oxygen concentration increases. At a water temperature 25 to 27° C, a reduction of respiration was observed among juveniles held at oxygen concentrations from 5.0 to 6.0 mg l^{-1}. The threshold oxygen concentration for stellate sturgeon larvae undergoes no change in the temperature range from 11 to 25° C. At higher temperatures, the oxygen conditions become critical.

The stellate sturgeon does not display a dependence on any particular salinity. In the Caspian Sea, both the adults and juveniles are encountered over a wide range of salinity, from 0.1 to 13.5 ‰. In the bays at the mouth of the Kuban River, juveniles inhabit waters with salinities from 0.01 to 8.72 ‰. The osmoregulating capacity of *A. stellatus* increases with the age and body weight. In experiments on large juveniles averaging 15.2 cm in length and weighing 4.1 g, almost 100 % survived the transfer from fresh to brackish water with a salinity of 12.5 ‰. The survival of small juveniles, 10.6 cm and 2.6 g, was 72 % under the same conditions.

The stellate sturgeon is an eurythermal species. In the Caspian Sea, it inhabits regions with a wide range of water temperatures, from 4 to 27° C. An even wider temperature range, from 2 to 30° C was also reported. However, water temperatures below 6° C during the feeding period are suboptimum.

The pH range at which stellate sturgeon eggs can survive lies within the range of 6 to 10. The strongest influence of the hydrogen ion concentration was noted during the early stages of development; excessive acidity or alkalinity for two to three hours can evoke numerous deformities.

The diet of the stellate sturgeon depends on its specific biological characteristics as well as on the specific features of the water bodies. In the Caspian Sea during the 1930s, its main diet consisted of crustaceans and fishes. The younger individuals feed primarily on crustaceans, while fishes become more important in the diet as individuals grow older.

During subsequent decades, however, the diet changed significantly. The role of fishes decreased, while that of worms and molluscs increased. The main food items of the stellate sturgeon are now crustaceans and worms. These changes are correlated with a general change in the benthic community in the Caspian Sea. As a result of intentional and accidental introductions of *Mytilaster lineatus*, *Abra ovata* (Mollusca), *Nereis diversicolor* (Polychaeta), and other allochthonous invertebrates, the stellate sturgeon started to use these new resources as food. A seasonal change in the diet is typical for this species. It was found that in spring these sturgeon feed along the entire Caspian Sea coast. The small individuals from 40 to 80 cm feed mainly on *Nereis diversicolor* and Cumaceans along the west coast of the central Caspian Sea. Those larger than 80 cm consume Corophiids, *Clupeonella sp*., and *Nereis diversicolor* along both coasts of the Central Caspian Sea. In August, the main feeding grounds are in the Northern Caspian Sea. The smaller individuals consume *Nereis diversicolor*, Corophiids, and Gammarids in the middle and eastern regions, while the larger ones feed mainly on *Abra ovata* and *Nereis diversicolor* in the western regions.

The diet of the stellate sturgeons in the Sea of Azov comprises 19 species of organisms. Steady components of the diet in 1951 were worms. The percentages of preferred items consumed were 35 to 60 % worms, 30 to 50 % fishes, and 15 to 30 % molluscs. In spring, the preferred fish species were *Gobius syrman* and *Gobius melanostomus*. In autumn, both *Gobius* species were consumed. The anchovy (*Engraulis encrasicholus*) is very important in the stellate sturgeon diet during autumn. The molluscs consumed include *Corbulomya sp*., especially in spring, and *Abra ovata*, mainly in summer and autumn. Preferred crustaceans are *Ampelisca sp*., mainly in spring, and crabs, only in autumn. The highest stomach fullness indices were recorded in autumn, during the period of intensive feeding on fishes. In winter, fishes account for 50 % of the total food consumed in the Sea of Azov, while mysids constitute 38 %, and smaller quantities of worms and molluscs are also eaten.

The main food of adult stellate sturgeons in the north-western part of the Black Sea is the polychaete worm *Mellina*. Sometimes, they prey on *Abra ovata* and other organisms, as well. It was reported that the stomachs of stellate sturgeons from the north-western part of the Black Sea contained organisms inhabiting the "*Phyllophora* field of Zernov", such as *Crangon crangon* and *Venus gallina*.

There are differences between the diets of this species in the rivers and in the sea. Juveniles in the rivers during transition to active feeding consume benthic and bentho-nektonic organisms, including Gammarids, Chironomid larvae, Mysids, and Oligochaetes. Planktonic organisms apparently play a role in the nutrition only in the early larval period. In each of the various rivers, the main food of the juveniles is different. Thus, in the Volga River, the main prey is Gammarids; in the Kura River, Gammarids and Chironomid larvae; in the Don River, Mysids; and in the Danube River, Oligochaetes and Gammarids.

In the sea, the main foods of stellate sturgeons 40 to 80 cm long and from one to over six years old are *Nereis diversicolor* and crustaceans, especially Corophiids. Specimens longer than 80 cm prey almost exclusively on *Nereis*, making up from 53.2 to 98.6 % of the total food intake.

The daily ration as a percentage of the body weight, calculated for individuals from 40 to 80 cm and longer than 80 cm by different methods, was found to range consistently from 2.5 to 4.0 % and 1.5 to 2.2 %.

The Acipenserid species in the Caspian Sea differ greatly in feeding activity and selectivity, as well as in their success in competition with other species of fish. The food items consumed by *A. stellatus* are the same as those taken by *A. gueldenstaedti*, *Rutilus rutilus*, and *Abramis brama*. The greatest dietary similarity is with *A. gueldenstaedti*.

The maximum age of stellate sturgeons, reached by specimens caught in the Caspian Sea during 1962 and 1963 was 27 years, and in the catch from 1976 to 1978, it was 35 years. Among subfossil fishes from the Caspian Basin, a 41-year-old stellate sturgeon was found. A few stellate sturgeons in the catch from the Don River between 1929 and 1932 reached the greatest age of 17 years. Among those caught from 1946 to 1963, the oldest fish was 28 years old. During earlier periods, the oldest age was 18 years. The maximum age of stellate sturgeons from the Kuban River between 1924 and 1928 was 26 years. In Kazantipskii Bay in the Sea of Azov, a 29-year-old specimen was caught. There was a 23-year-old stellate sturgeon in the catch from the north-western part of the Black Sea.

The stellate sturgeon, like other sturgeons, is characterized by multi-age structured populations. The catch from the Volga River contained individuals aged from 7 to 24 years. The females are predominantly 11 to 15 years old, while the age of most males ranged from 9 to 14 years. The age structure of the spawning populations in the Ural River tends to be more dominated by younger age groups than that in the Volga River.

Among the stellate sturgeons caught in the Don River during 1962, 9 to 10-year-olds were predominant, while 7 to 14-year-olds dominated the catch from the Kuban River. Among the juveniles, males are usually more numerous, while females are predominant among the older age groups. In recent years, the age structure of the Azov stellate sturgeons has undergone an enjuvenation.

The age structure of the stellate sturgeon population in the north-western part of the Black Sea from 1965 through 1968 included 5 to 23-year-old females and 3 to 20-year-old males.

Palaeoichthyological data indicate that since historical periods the minimum, maximum, and average ages of the stellate sturgeon have all decreased. The age of the individuals in the catches from the Volga River in ancient times varied from 8 to 41 years, while at the end of the 1980s, the age range was from 7 to 24 years.

The sex ratio may be different in the various water bodies and during different periods of time. During the 1930s, males were predominant (63 %) in the Volga catch. In the period from 1961 through 1963, their percentage had decreased to between 37 and 43 %. At the feeding grounds in the Caspian Sea, the females are predominant among the 16th and 17th year classes. The sex ratio in the Sea of Azov approximates 1:1. However, among the 10-year-olds, the percentage of males was between 27 and 38 %, indicating a decrease from the period of 1931 through 1934.

9.4.4 Reproductive Biology

Sexual maturity is reached sooner by the stellate sturgeon than by most other Acipenserid species (except *A. ruthenus*). The population in the Sea of Azov is the earliest to mature, its members becoming ripe three to four years sooner than the stellate sturgeon in the Caspian Sea. The males in the Kuban River mature especially early. Occasionally, they begin to mature during their fourth year, while most reach maturity at an age of five or six years. Generally, the females require two to three, but sometimes even five years more than males to mature. The average age of females at maturity in the Sea of Azov is 9.7 years. The sturgeons of the Kura River population take the longest time to mature.

The stellate sturgeon does not spawn each year. The fishes from the Sea of Azov rarely spawn more than three times in their lives. The period between spawnings is shorter for males than for females. The interval between reproduction periods by members of the Caspian population is not less than three to four years.

Stellate sturgeons in the Kuban River attain high fecundity. The absolute fecundity is lower than that of the Volga, Ural, and Terek populations but higher than that of the groups in small rivers along the southern Caspian coast. The stellate sturgeon displays a considerable amount of individual variability in fecundity, proportional to the length, weight, and age of the fish. The fecundity of females weighing 10 to 15 kg varies from 80,000 to 180,000 eggs, and that of 15 to 20 kg females is 150,000 eggs.

In accordance with its preference for warmer temperatures, the stellate sturgeon begins spawning later than *Huso huso* and *Acipenser gueldenstaedti*. The success of spawning depends on the amount of discharge, the conditions during the springtime floods and those of the low water period in summer. The stellate sturgeon is more sensitive than *Acipenser gueldenstaedti* to fluctuations in the water level and current velocity. Even a small decrease in discharge causes them to cease releasing eggs and move into deeper sections of the river with more stable conditions. Thus, spawning takes place only under relatively constant hydrological conditions, when the daily water level fluctuations do not exceed 0.2 to 0.5 m. The stellate sturgeons of the Danube River spawn from May to June at temperatures between 17 and 23° C.

This species spawns on river banks inundated by spring floods and above the stony bottom of the river bed at relatively fast currents of 0.7 to 1.8 m s^{-1} at the bottom and 1.1 to 1.9 m s^{-1} at the surface. The eggs are laid on beds of scattered stones, pebbles, and gravel mixed with shell fragments and coarse sand. The optimal spawning conditions include a high velocity of water flow from 1.2 to 1.5 m s^{-1}, and a clean gravel bottom. When the preferred substrate is not available, the stellate sturgeons can also deposit their eggs on other material, such as shifting sand mixed with clay. A decrease in current velocity can lead to increased mortality of embryos.

As a result of the regulation and damming of large rivers used for spawning in the Caspian, Azov, and Black Sea watersheds, the spawning conditions for the stellate sturgeon have deteriorated. To improve the conditions for the reproduction of this species, artificial spawning grounds were established along the Volga and Kuban Rivers. Sediments of gravel and pebbles 3 to 10 cm in diameter were provided, and these proved effective.

Males arrive at the spawning grounds earlier than females. The mass tagging of this species have shown that the males remain at the spawning sites no longer than six weeks, while females stay only 10 to 12 days. After release and fertilization, the eggs stick to the substrate and remain firmly bound to it for the entire period of early development until hatching. These sturgeons consume almost no food at the spawning site. Unlike *Acipenser gueldenstaedti*, they use up to half of their fat reserves on the trip from the sea into the rivers. Therefore, after spawning, the spent females immediately migrate downstream to their feeding places in the sea. The speed of downstream migration varies from 70 to 80 km day^{-1}.

Virtually nothing is known about the spawning habits of this species. At the moment of spawning, sturgeons display a strong shaking of the lower body surface against the bottom, which has an effect on the condition of the scutes and skin of the fishes that have spawned, evident from scratches and bruises on the underside.

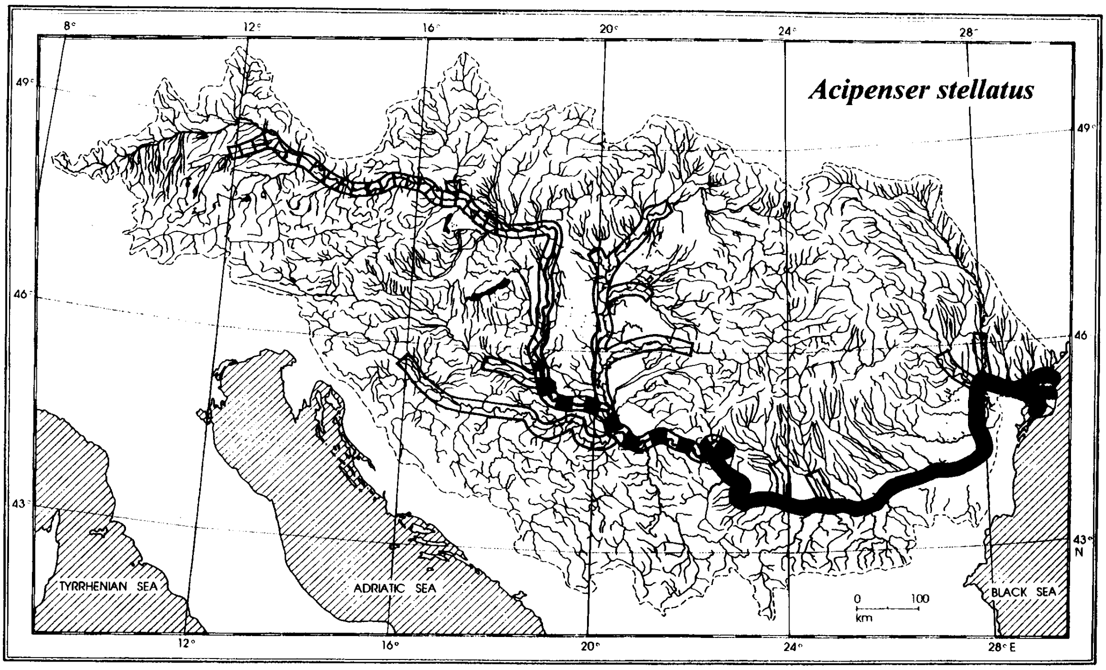
The development of Volga stellate sturgeon eggs from activation to the hatching of the larvae requires 2 to 6.5 days, depending on the temperature. The early development of the stellate sturgeon eggs from the Kura River lasts 44 to 88 hours. Experiments revealed that at constant temperatures of 16 and 23.1° C, hatching occurs after 132 and 67.5 hours, respectively. The stellate sturgeon early development occurs at the highest temperatures of all species of the genus *Acipenser*.

The juveniles of *A. stellatus* are phototropic. Thus, during the initial period of life, the larvae inhabit not only the lower and middle water layers in the rivers but also occur at the surface. They drift downstream, and during subsequent development, their capability of active movement increases. The downstream migration of juveniles in the Volga River occurs later than that of *A. gueldenstaedti*. It occurs only while the water level is decreasing and lasts from June or July to October and November. Most juveniles migrating seaward weigh from 1.0 to 7.5 g. In years when there is much outflow through the rivers, the percentage of juveniles near the minimum weight increases. In the Ural River, the seaward migrants include larvae. The most intensive migration is observed at the end of May and the first third of June. The total length of the migrating larvae ranges from 5 to 17 mm, and that of juveniles having started active feeding averages from 31.2 to 43 mm. Their average weight is 150.7 mg. At the end of downstream migration, the mean weight of the juveniles is 11.6 g, but sometimes they reach 31.0 g. In the Don River, the length of juveniles during their most intensive migration in the second half of May and June varies from 25 to 87 mm, and their weight from 0.18 to 3.25 g. In the Kura River, the juveniles that migrate downstream reach the sea 12 to 15 days after hatching, but some of them stay in the river for three months. In the Kuban River, where food supply is limited, the larvae remain only one month. It was found, that in the Danube River, the distribution of juveniles on the river bed is influenced by the food supply, current and turbidity. Juveniles migrate downstream at depths of 4 to 6 m. The life span in the rivers lasts from May to October. Active feeding begins when the larvae reach 18 to 20 mm.

9.4.5 Historic range, stock development and current status in the Danube River Basin

The stellate sturgeon was always rare in the Middle and Upper Danube, seldomly ascending upstream to Komarno, Bratislava, the Austrian stretch or even occasionally the Bavarian Danube near Straubing and even the Isar River. During their spawning migrations stellate sturgeons also entered tributaries of the Lower Danube like the Prut, Siret, Olt and Jiul Rivers. In the Middle Danube it ascended the Tisza River (up to Tokaj) and in the lower courses of its tributaries the Maros and Körös Rivers, the mouth of the Zagyva River, the lower courses of Drava and Sava Rivers and the mouth of the Morava River. The stellate sturgeon today is extirpated from the Upper Danube and the upper stretch of the Middle Danube (Hungarian-Slovakian stretch). The last known specimen from the Slovakian section was taken at Komarno on February 20, 1926, and the last stellate sturgeon caught in the Hungarian stretch was reported from Mohacs in 1965. Djerdap dams at Iron Gates gorge block the migration of stellate sturgeons into the Middle Danube and only few individuals succeed in passing through the ship-locks (HENSEL & HOLČIK 1997). The status of *A. stellatus* is vulnerable throughout its range (LELEK 1987). The four migratory Acipenserids are extinct from Germany and Austria (SPINDLER 1995, BAYERISCHE LANDESANSTALT FÜR FISCHEREI 2000). *A. stellatus* is extinct in Slovakia (HOLČIK 1996 b). Migratory sturgeons are endangered in Hungary (GUTI 1995). According to the Red List 2000 of IUCN b the Black Sea stock of *A. stellatus* is endangered. KYNARD et al. (in press) conducted telemetry and tag return studies on *A. stellatus* in the Lower Danube (Romania). The stellate sturgeon tag returns of 38 % in 1998 and 27 % in 1999 (plus a likely large unreported return) demonstrated that there is a severe overharvest of stellate sturgeon, particularly by the Galati fishery. The authors predict a soon collapse of stellate sturgeon stocks in the Lower Danube, if the present rate of harvest is continued.

Fig. 23: Distribution of the stellate sturgeon, *Acipenser stellatus*, in the Danube drainage system. Regular (continuous black) and occasional (black and white area) occurrence at present; regular (continuous white) and occasional (striped white area) occurrence in the past. (from HENSEL & HOLČIK 1997, Original figure by K. Hensel)



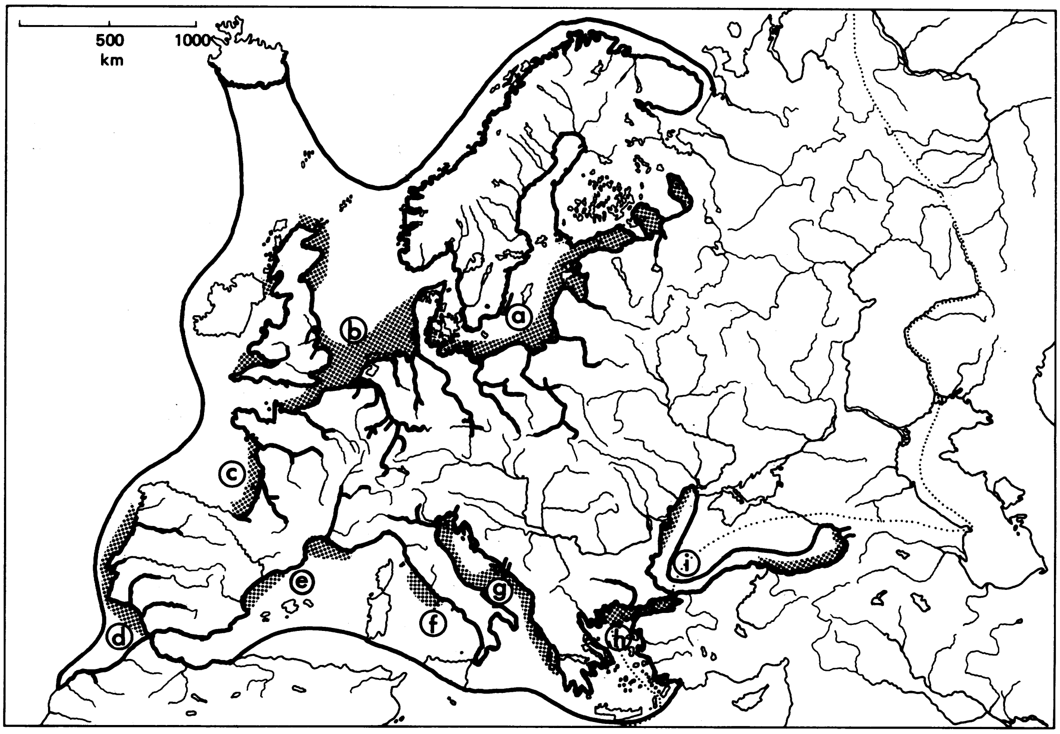
9.5 *Acipenser sturio* Linnaeus, 1758

The following information on *A. sturio* is given on the basis of a compilation of relevant literature by HOLČIK et al (1989).

9.5.1 Distribution

Acipenser sturio is living exclusively in Europe and West Asia. This species is confined to the Northeastern Atlantic Ocean, especially to the shallow parts of the North and Baltic Seas and some coastal water bodies in the Mediterranean and Pontic region, including the Ligurian, Tyrrhenian, Adriatic, Ionian, North-Aegean, Marmara and Black Seas. According to some historical sources, the sturgeon may once have occurred near Crete and Rhodes. *Acipenser sturio* was also occasionally reported from Iceland and the North African coasts of the Atlantic and the Mediterranean Sea, respectively. The available data indicate that its reproduction is confined to European and West Asian waters, though, where it ascended all major river systems to spawn. In the Black Sea watershed, sturgeons ascended into the Danube Estuary, the Inguri (Dzhvari), the Rioni (regularly to Samtredia and rarely to Akhalsopeli and Bashi), the Yesil Irmak and the Kizil Irmak. Today the Atlantic or Baltic sturgeon is close to extinction. In the Lower Danube it is believed to be extinct today (BACALBASA-DOBROVICI & HOLČIK 2000).

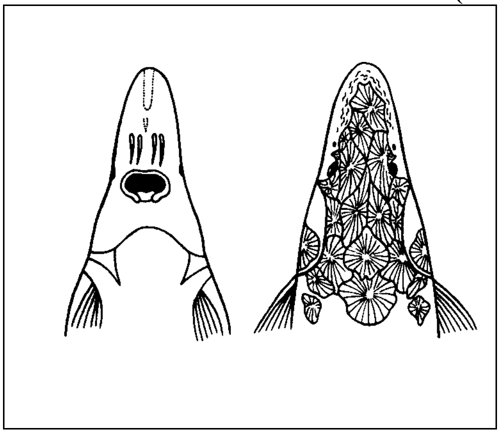
Fig. 24: Geographical distribution of *Acipenser sturio*. Dotted areas indicate isolated findings, while letters denote the main regions of distribution. a) Baltic watershed b) Southern North Sea and English Channel drainage area c) Bay of Biscay drainage area d) Iberian Atlantic watershed e) Ligurian watershed f) Tyrrhenian watershed g) Adriatic and Ionian watershed h) North Aegean and Marmara watersheds i) Black Sea watershed. (modified from HOLČIK et al. 1989)



9.5.2 Species description

Du 30-50, *Au* 22-33, *SD* 9-16, *SL* 24-40, *SV* 8-14, *Sp. br.* 15-29

Fig. 25: Ventral (left) and dorsal view of the head of *A. sturio* (from PECL 1989)



Dorsal, lateral and ventral scutes are large and stout, more than twice as large as the scutes of the Russian sturgeon (*A. gueldenstaedti*) of the same size. Their surface is covered with small spines, and they are radially striated. Between the dorsal and lateral scale rows, there are many patches of rhombic denticles. The first ray of the pectoral fin is transformed into a strong spine. The snout is broad, but more pointed than in *A. gueldenstaedti*. The base of the barbels of adults is closer to the mouth than to the snout apex. The lower lip is distinctly interrupted. Large diadromous fish attain lengths (*Tl*) of 5.5 to 6 m and a weight of 1,000 kg. A landlocked population has been described from Lake Ladoga in Russia.

The body is elongated and low, its maximum height being 10.0 to 13.5 % of *Tl*. The snout is pointed and slightly turned up. Its length ranges from 52.6 to 65.8 % of head length. The distance between the base of the barbels and the snout apex ranges from 65 to 76 % of the snout length. The colour of adults varies from greyish-green and greyish brown to bluish-black on the dorsum and head. It is paler laterally with hazy dark blotches of variable intensity. Ventrally it is silvery white, whitish or yellowish. The pectoral fin is yellowish, the others greyish. The scutes are dirty-looking to vivid white. Large specimen are golden-green. The eye is small and slightly oval with a brazen yellow iris and a black pupil with a greenish tint. *A. sturio* is darker in colour than *A. gueldenstaedti*. The males of this species are generally smaller than the females.

No subspecies of *A. sturio* have been described as yet, although genetic research implies a high degree of relationship between *A. sturio* and *A. oxyrhinchus*.

A. sturio rarely interbreeds with *A. gueldenstaedti*. The hybrid has a longer snout than *A. gueldenstaedti.* The shape of its dorsal and lateral scutes is intermediate between those of the parental species, and its skin is covered by rather large rhombic denticles.

9.5.3 Ecology

All available data indicate that during its stay in the sea, *A. sturio* is a littoral species limited mainly to estuaries with muddy bottoms. Younger specimens, 50 to 100 cm in *Tl*, usually stay within a radius of more than 100 km (60 miles) of the river mouth, and in the sea, the majority are caught at depths of 20 to 50 m. Rarely, they are taken as deep as 70 m at salinities below 32 ‰. Large specimens occur at depths exceeding 100 m and to 200 m in the Adriatic Sea. Most young-of-the-year sturgeons stay in rivers close to the spawning grounds where they hatched, but some of them move downstream to the estuaries during their first summer.

A. sturio is basically an anadromous species. In spring, mature individuals leave the sea and enter freshwater to spawn. Sturgeons enter the rivers from January to October, and the peak migration usually occurs from the beginning of April to the end of May, during periods of high water. The exact dates depend on the geographic location of the river. Southern populations begin to appear in the rivers sooner than the northern populations. For instance, in the Guadalquivir River from 1934 to 1942, almost 83 % of the total sturgeon catch was taken between the beginning of March and April 10. Historical records show that 85 % of the sturgeon catch in the Rhine River upstream from Bonn was taken from May to July. It is of interest that in the Rhine River and probably also in the Vistula River, a few sturgeons were also caught while migrating upstream in August, September and October. These fishes probably stayed in the river during the winter and spawned during spring of the following year. This weak late summer and autumn migration suggests that there is a winter race of *A. sturio*, analogous to those of other diadromous sturgeon species. Sturgeons caught in the lower course of the Guadalquivir River in January probably also belonged to the winter race as their gonads were relatively well developed.

Collected data show that the peak migration of the males occurs about two or three weeks before that of the females. This indicates that males enter the rivers sooner than females. Historical sources reported that sturgeons migrated in small groups consisting of one female and one to three males.

A. sturio migrates in the main river channel at depths of 2 to 8 m and water temperatures from 12 to 17.5 °C. Migrating individuals are able to move against a swift current of 1.4 to 2.2 m s^{-1}, as observed in the Rioni River. They easily pass rapids, such as the Binger Loch rapids in the Rhine River. The moving *A. sturio* leave wakes at the surface of smooth-flowing water, and they are even able to jump like salmon.

The distance of the spawning migration seems to be positively correlated with water discharge or water level, and a distance of 1,000 km or more may be covered during years of high water. The distance of migration probably also depends on the population density during the spawning run in the estuaries or in the lower courses of the rivers. From historical records, the following maximum distances of migration were compiled: the Vistula River system, 831 km (San River at Przemysl) and 982 km (Dunajec River at Niedzica); the Elbe River system, 820 km (Ohfe River at Kadan) and 810 km (Vltava River at Prague); the Oder River system, 503 km (Oder River at Wroclaw) and 575 km (Warta River at Konopnica); the Rhine River system, 850 km (Rhine at Rheinfelden) and 837 km (Main River at Schweinfurt). It appears that the inland migration of this species is limited at elevations 200 to 300 m a.s.l.. In other river systems the migration routes are much shorter, such as 110 to 115 km in the Rioni River and about 300 km in the Elbe River.

Spent fishes immediately return to the sea in which *A. sturio* may migrate as far as 1,000 km or more from the spawning sites. The young *A. sturio* usually migrate downstream at the age of two years in Lake Ladoga and the Tiber River, three years in the Po River, and four in the Gironde River. The young *A. sturio* that migrate downstream are about 60 cm in *Tl* and weigh 0.4 to 3.0 kg. They occur at depths of 7 to 12 m. The young sturgeons migrate downstream at the end of summer and in autumn.

The occurrence of various age groups of *A. sturio*, including young fishes, in Lake Ladoga suggests the existence of a non-migrating form in this water body. In this respect, *A. sturio* is similar to other species of this genus that are known to form landlocked populations, such as *A. nudiventris*, *A. baeri*, and *A. gueldenstaedti*.

Little is known about the hardiness of this species. It was suggested that this species does not tolerate low oxygen concentrations, but there are some reports indicating that it is actually very tolerant to oxygen depletion. Three examples of sturgeons caught in the Bohemia section of the Elbe River from 1889 to 1900 were given, ranging from 40 to 200 kg in weight, which were kept alive in barrels for 14 days and exhibited to the public. This was also a common practice along the Rhine River. The fact, that sturgeons live in slow flowing estuaries under eutrophic conditions suggests a certain amount of resistance to oxygen depletion. (Adaptations to increase survival under widespread or prolonged environmental hypoxia have also been reported for *A. transmontanus* by CROCKER & CECH 1997).

The distribution of this species in the sea, suggests a higher tolerance to high salinity than with other European sturgeons. Two-year-old *A. sturio* survived in 3 to 8 ‰ concentrations of NaCl, but they died shortly after being transferred into sea water.

Only specimens older than four years tolerate a 33 ‰ salinity and are able to live in the ocean; seven-year-old specimens easily adapted themselves after being transferred from fresh to salt water or vice versa.

There is little information on the diet of this species. When in fresh water, the juveniles feed on larvae of aquatic insects, worms, Crustaceans and Molluscs. Also fresh and brackish water invertebrates (Gammaridae, Mysidae, Chironomidae, Oligochaeta, and Crangonidae) were found in young *A. sturio* inhabiting the estuary of the Rioni River. Two young *A. sturio* from Lake Ladoga, 430 mm in *Tl*, were found to have fed on *Pontoporeia affinis*, *Gammaracanthus* *loricatus*, and *Pallasea quadrispinosa*. Stomachs of young individuals from the same lake were also filled with *Mysis oculata relicta*.

Adult *A. sturio* feed on benthic invertebrates, such as Molluscs, Polychaete worms, Isopods and shrimps, as well as on small fishes, including sand eels (*Ammodytes*) and Gobiids. *Echinogammarus berilloni* and Chironomid and Trichopteran larvae were found in the stomachs of *A. sturio* from the Gironde River. Specimens caught at the mouth of this river had fed almost exclusively on Polychaetes, especially *Nephthys hombergii* and *Stylaroides monilifer*, while the stomachs of those caught in the sea contained Polychaetes, Mysids, and shrimps. In the Black Sea, however, adult sturgeons feed mainly on fishes, and almost exclusively on the European anchovy (*Engraulis encrasicholus*). Adults do not eat during migration and spawning, but there is a report from the Bohemian section of the Elbe River that one *A. sturio*, 250 cm in *Tl* and 150 kg in weight, swallowed a barbel (*Barbus barbus*) caught on an angler's line. Feeding does not cease during winter.

The maximum age documented is 48 years for a specimen of 360 cm in *Tl*. Among the remains of *A. sturio* found, in the 8th to 9th century human settlements along the Volkhov at Staraya Ladoga, specimens ranging from 1.7 to 3.1 m in *Tl* were encountered. Some of them were 35 or 36 years old, and one female from the Gironde River was even 42 years old and 255 cm long. The life span of males is considerably shorter than that of females. No males older than 19 years were found in the Guadalquivir River, while the oldest female was 25 years old. Males older than 25 years are very rare in the Gironde River.

Very little information is available about the population dynamics of the Baltic sturgeon. The spawning population in the Rioni River consisted of males in six age groups, 7 through 12, and females in ten age groups, 11 through 20. Females predominate over males by 1.3:1. The average length of males ranges from 110 to 140 cm, and their average weight is 10 to 15 kg. The respective figures of the females are 170 to 200 cm and 30 to 50 kg. In the Guadalquivir River population, the sexually mature males fell into 10 age groups, 9 to 18-year-olds, and the females, into 13 age groups, 13 to 25-year-olds. In this population, females predominated over males at a 3:1 ratio. The average length and weight of the males ranged from 135 to 160 cm and 17 to 23 kg, respectively, and those of the females, from 170 to 210 cm and 35 to 55 kg. The total numbers of *A. sturio* in the populations from the Gironde and the Rioni Rivers at the beginning of the 1960s were estimated at 1,000 each. At present, however, the Rioni population consists of only 300 specimen. In the Po River, *A. sturio* was formerly more abundant than *A. naccarii*, but now it is less numerous.

9.5.4 Reproductive Biology

Members of the southern populations reach sexual maturity two to six years earlier than those in the northern populations. The first spawning of females occurs one to five years later than that of the males. The females are larger during the first spawning. Adults survive and spawn more than once. The males are able to spawn annually, while there is a one year interval between each spawning of the females. It was suggested that the minimum spawning frequency is two or three times during the total life span of *A. sturio*. However, this does not seem to be correct. In the Guadalquivir River the sexual activity of males lasts an average of 8 years, while that of the females continues 30 years or more. The reproductive ability is retained for a long time of up to over 40 years.

Absolute fecundity is reported to be 0.2 to 5.7 million eggs per female. In nine females from the Rioni River the absolute fecundity varied from 0.79 to 1.82 million, and the relative fecundity from 18,100 to 34,300 eggs per kg of live weight. In 107 females from the Guadalquivir River weighing 25 to 85 kg, the number of eggs ranged between 0.289 and 1.412 million. The relative fecundity calculated for this population seems to be lower. It varies from 11,600 to 16,700 eggs per kg live weight. The fecundity of *A. sturio* is generally higher than that of congeneric species and approaches that of *Huso huso*.

The spawning period is reported to continue from March to August. It is obviously later for the northern populations and those spawning at sites farther from the estuaries. In the Baltic Sea watershed, spawning occurs from June to August, while in the Black Sea drainage area, most *A. sturio* spawn in May. Spawning occurs at water temperatures of 7.7 to 22 °C.

Spawning takes place in deep pools with swift currents over a rocky or pebble bottom, either in the main channel or in lotic branches. The following characteristics of the spawning grounds in the Rioni River were determined: current velocity, 1.5 to 2.0 m s^{-1}; dissolved oxygen, 7.4 to 9.5 mg l^{-1}; pH 7.4 to 7.6.

Only one observation has been reported on the mating habits of this species, indicating that one female spawns with several males.

The incubation period depends on the water temperature, reported to vary from 3 to 14 days at 22 and 7.7 °C. It requires from 56 to 108 day-degrees. The total length of the larvae at hatching is 9.3 to 11.0 mm; their mean *Tl* is 12, 13.2, and 16.5 mm at ages of 5, 7 and 13 days. The yolk is resorbed when, 11 to 14 days after hatching, the larvae have reached 16 to 18 mm. Juveniles have well developed scutes by the time they have reached 70 to 80 mm.

9.5.5 Historic range, stock development and current status in the Danube River Basin

The Atlantic or Baltic sturgeon was always the rarest Acipenserid species occurring in the Black Sea watershed. Its presence in this region has been recorded quite late in the beginning of the 20th century, due to its scarcity. Single specimen were then recorded in the catches of fishermen in both the Danube River and the Black Sea. It seems likely that this species also spawned in the Lower Danube since YOY animals as well as hybrids with other species have been described in the 1930s, suggesting the simultaneous spawning with other Acipenserids on the sand banks off the Danube estuary. Reports on the upstream occurrence of this species in Bulgaria and Serbia are contradictory. Further occurrences along the Anatolian coast could not be confirmed in recent studies. Nowadays it seems likely that this species has disappeared from the western part of the Black Sea and the Lower Danube and that the only inhabited area in this watershed remains in the eastern coast of the Black Sea and the Rioni River, its sole current spawning ground. *A. sturio* is endangered (close to extinction) throughout its range (LELEK 1987). According to the Red List 2000 of IUCN b the stocks of *A. sturio* are critically endangered throughout their range. *A. sturio* is extinct in the Danube River-Black Sea system (BACALBASA-DOBROVICI & HOLČIK 2000).

9.6 *Huso huso* Linnaeus, 1758

The following information on *Huso huso* is given on the basis of a compilation of relevant literature by PIROGOVSKIĬ et al. (1989).

9.6.1 Distribution

The great sturgeon inhabits the Black, Azov, Caspian, and Adriatic Seas. Within its range, only diadromous forms occur.

In the Adriatic region only solitary individuals have been reported. These occurred in the northern part near Venice, the lower and middle sections of the Po River, and rarely along the coast of Albania. Reports of its occurrence along the North Aegean Sea coasts are doubtful. In the Black Sea region, the great sturgeon formerly congregated in considerable numbers for spawning in the large rivers, including the Danube, Dniester, Southern Bug, Dnieper, and rivers along the eastern coast of the sea.

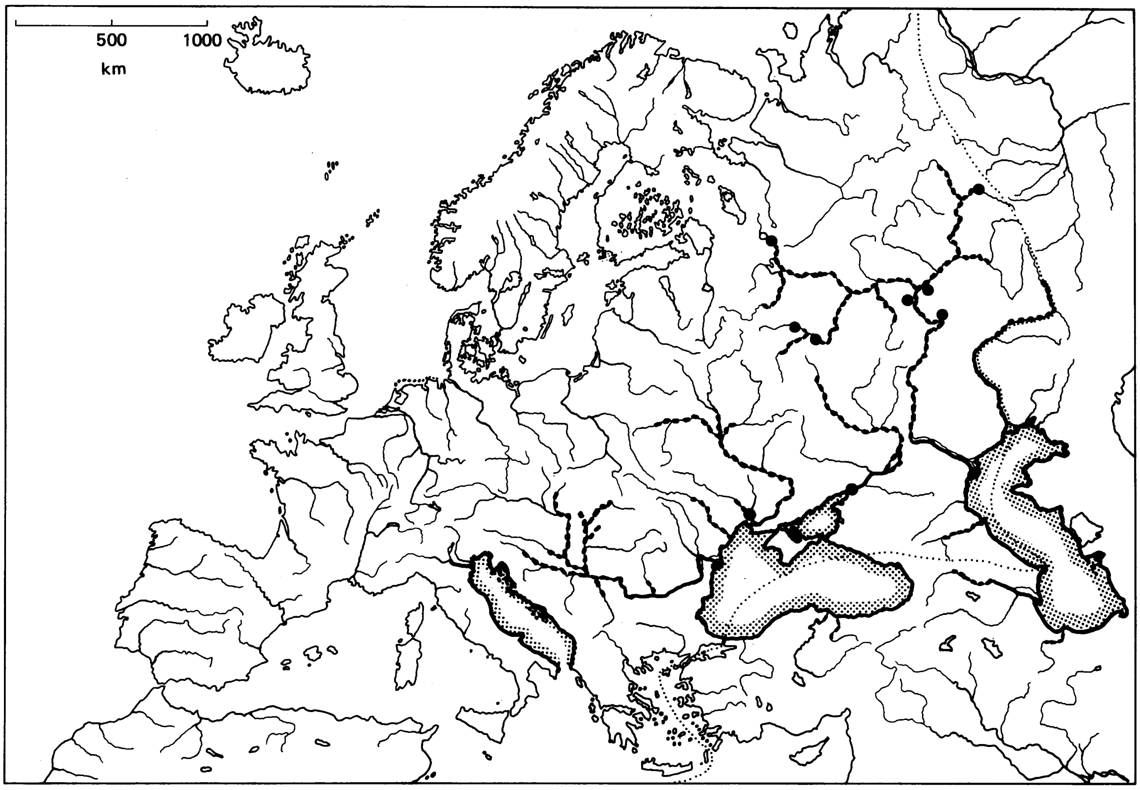
During the middle ages a fishery was conducted in the middle stretches of the Danube River for a large winter race that spawned as far as Komarno (1,768 to 1,810 km from the sea), but the catch decreased rapidly by the beginning of the 16th century. In the Danube River, the great sturgeons nowadays reach only the impoundment of Iron Gate, 863 km from the sea.

These fishes were never numerous in the Dniester River. In the Dnieper River, they travelled upstream farther than Kiev and entered many of its tributaries. A few individuals still enter the rivers along the Black Sea Coast bordering the Caucasus, including the Rioni River. Great sturgeons are also infrequently encountered in the Yesil Irmak and Kizil Irmak Rivers along the Anatolian coast. From the Sea of Azov, great sturgeons enter the Don River for spawning and formerly swam very far upstream. Very few individuals enter the Kuban River.

In the Caspian watershed, the main spawning river for the great sturgeon was the Volga River, where 90 % of their stock reproduced. A second river in the Caspian watershed known to be inhabited by the great sturgeon is the Ural River. Great sturgeons also inhabited the Gurgen and Sefid Rud Rivers in Iran.

Due to the extensive river modifications (damming, irrigation, bank construction and channelisation) carried out during the past few decades that have changed the conditions in the rivers within its range, the great sturgeon has suffered a sharp decline, and presently, its movements are confined by dams. The great sturgeon lost practically almost all of its natural spawning grounds, and its stock is now maintained by numerous fish farms.

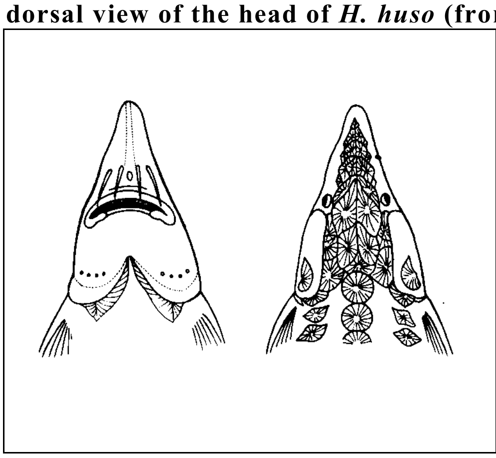
Fig. 26: Former (dotted line) and present (solid line) geographical distribution of *Huso huso* in Europe. Stippled area indicates the supposed coastal habitat of this species during its stay in the sea. Dots represent locations of subfossil remains. (from PIROGOVSKIĬ et al. 1989)



9.6.2 Species description

Description Du 48-81, Au 22-41, SD 9-17, SL 37-53, SV 7-14, Sp. br. 17-36

Fig. 27: Ventral (left) and dorsal view of the head of *H. huso* (from PECL 1989)



Dorsal scutes are oval and provided with a longitudinal denticulate comb; in sexually mature specimen they are covered with a soft skin. Lateral scutes are smooth, the ventral scutes hidden beneath the skin. Between the scute rows are numerous small bony plates and grains. The scute rows never merge on the tail, and the caudal peduncle is not laterally compressed. The protrusible mouth is crescent-shaped and extends horizontally beyond the ventrolateral edges of the head. The branchiostegal membranes are joined together to form a fold free from the isthmus. The gill rakers are rodshaped. The barbels are long, laterally compressed, and bear foliate appendages. These fishes grow to a length of about 6 m and a weight exceeding 1,000 kg. In exceptional cases, lengths of 8 m and weights of 3,200 kg have been reported.

The great sturgeon differs from the closely related kaluga, *Huso dauricus* (Georgi, 1775), which inhabits the Amur River, in that the first scute of the dorsal row is the smallest, the barbels possess foliate appendages, and the dorsal fin usually contains more than 60 rays.

The body is massive, spindle-shaped, and narrows toward the tail. Its height varies from 9.0 to 22.0 % of *Tl*. The head length is about 23 % of *Tl*. The snout is short, conical, cartilaginous, and soft. Its length varies widely, between 7.0 and 12.5 % of *Tl*. Dorsally and laterally, the fishes are ashen gray or sometimes black, gradually transitioning to white toward the underside. They are white ventrally, and the snout is yellowish.

Within the individual watersheds, the great sturgeon appears to have formed distinct groups adapted to the regional conditions. Two races (natio) of the Black Sea great sturgeon were described: in the western part, the darker coloured *H. huso ponticus natio occidentalis*, which is found in the Black Sea as far east as Feodosia and undertakes spawning migrations into the Danube and Dnieper Rivers; further eastward, *H. huso ponticus natio orientalis*, which occurs along the eastern and southern coasts of the Crimean Peninsula and spawns in rivers draining the Caucasus, including the Rioni, Chorokhi, Inguri, and Khopi Rivers. The geographical races display a series of morphological differences. On the basis of antigenic studies of the blood serum proteins, three subpopulations of the Caspian great sturgeon were identified: those of the Volga, the Ural, and the Kura.

Material that is suitable to determine differences among populations from different water bodies is extremely scarce. Research on the morphological peculiarities of the Danubian great sturgeon revealed that it differs manyfold from the Caspian population. The most important of these differences are the greater number of rays in the dorsal and anal fins, and the larger gill rakers, but also height of body and head are different. However, these data are too scarce to support any conclusions on the validity of a great sturgeon subspecies.

Natural hybrids are known between *H. huso* and *A. ruthenus*, *A. nudiventris* (known as the beluzhii ship), *A. gueldenstaedti*, *A. persicus*, and *A. stellatus*. Hybrid specimen have rather large mouths and a somewhat greater number of lateral scutes. In comparison with the parental species, hybrids show a tendency to remain in a river for a longer time. The artificial hybrid, *H. huso* x *A. ruthenus* is called "bester" after the parent species and used for aquaculture purposes.

Attempts to acclimatize the great sturgeon to habitats outside of its natural range have not been made. Due to the alarming condition of its population in the Sea of Azov, fertilized eggs have been brought there from the Caspian watershed in recent years to improve the fishery yield in the Don and Kuban Rivers.

9.6.3 Ecology

During the life period in marine waters, the great sturgeon mainly inhabits the pelagic zone. Its vertical distribution depends on the presence of its food organisms. In the Black Sea region, the great sturgeons are capable of descending as deep as 180 m, where hydrogen sulfide, originating from deeper layers, can already be detected. In the Caspian Sea, they are found between 100 m and 140 m. It has been noted that the great sturgeon is confined to sea regions with muddy bottoms. Apparently, the depth at which they stay does not depend upon the size and age of the fish. Only during the first year of life, the juveniles remain in shallow, well warmed habitats on the continental shelf. During both the seaward and the spawning migration, the great sturgeon normally travels in the deepest parts of the riverbed, but it frequently ascends into the upper layers of the water bodies.

There are basically three kinds of long distance displacements during the life of the great sturgeon. (A) The anadromous spawning migrations of the adult fishes from the sea into the rivers, (B) the catadromous movement of spent adults after the completion of spawning, and (C) the drift of larvae and migration of juveniles in the rivers after hatching. The anadromous migration period begins at the end of January or during February and ends at the end of November or in December. Throughout its whole range, the great sturgeon developed winter and spring races (fall and summer races). The members of the spring race reproduce in the same year during which they enter the rivers, while those of the winter race spend the winter in fresh water and reproduce in spring of the next year. In the Danube River, spawning migrations can be observed almost all year round; nevertheless, two peak periods have been noted, one for the winter and one for the spring race. The spring run is observed from January through April, beginning soon after thaw at a temperature of 4 to 5° C. The autumn run is beginning in August and reaching its peak in October and November. The winter race is apparently more numerous, since an evaluation of the fishery records from the years 1969 and 1977 showed that 41 to 57 % of the great sturgeons were caught from September through November, while only 7 to 15 % were taken in the period from February through April (data presented by Romania at the 12th and 20th sessions of the Joint Commission of the International Agreement on Fishing in the Danube in Moscow in 1971 and in Sofia in 1979, respectively (POPOVA et al. 1989)).

The migrations of the Caspian great sturgeon are more clearly defined, the spring run occurring in March and April, and the autumn migration during September and October. The winter race is dominant in the Volga River, while the spring race predominates in the Ural River accounting for

about 70 % of all the individuals. Within these races, smaller biological groupings occur, differing in the degree of their gonad ripeness, the places and timing of spawning and other features.
Spent adults and, shortly thereafter also the newly hatched young move downstream in the rivers to the feeding grounds in the sea, where they remain until they reach maturity. The basic factors determining in which parts of the Black Sea the great sturgeon will occur are the thermal regime and the availability of food, particularly anchovies (*Engraulis encrasicholus*), red mullet (*Mullus barbatus ponticus*), gobies (Gobiidae), shad (*Alosa spp.*), Black Sea whiting (*Merlangius merlangus euxinus*), and flounder (*Platichthys flesus luscus*). In winter, they descend in search of prey to a depth of 160 m, but in spring, they return to the upper layers, where they remain during the warm seasons. Seasonal migrations of the great sturgeon in the Black Sea occur along the northern shelf, where the depth does not exceed 200 m. In the Sea of Azov they do not migrate great distances but remain fairly evenly distributed whithin the basin. However, they are most abundant in the southwestern part, which is the main feeding ground for this sturgeon species. In the Caspian Sea most of the great sturgeons remain during summer at their feeding grounds in the northern part. At the end of summer or beginning of autumn, they are encountered at their feeding grounds in the central Caspian Sea, which is along the western coast. When the water temperature decreases below 10° C, they descend to depths between 100 m and 140 m. In early spring, they return to shallow water, and as the water becomes warmer, they gradually move toward the northern part of the sea. During feeding migrations, they move at a speed of 10 to 13 km per hour. Individuals of different ages share the same feeding ground, and only in the Black Sea are particular size and/or age groups confined to certain regions of the sea. The individuals encountered in Karkinit Bay are almost exclusively immature 3 to 13-year-olds, while older age groups stay in the region near the mouth of the Danube River.
Great sturgeons are oxyphilic fishes, inhabiting water with high oxygen concentrations, averaging about 14 mg l^{-1}. However, they spend the winter at great depths, where the oxygen concentration is quite low. In the Black Sea, this is only 2 to 3 mg l^{-1}, and the presence of hydrogen sulfide in concentrations up to 0.5 mg l^{-1} can often be detected. Great sturgeons are euryhaline and can survive at salinities as high as 22 ‰. During the downstream movement, the juveniles fairly rapidly adapt to increasing salinity. The development of the osmoregulatory apparatus is already completed in their second month of life, and they are capable of enduring salinities as high as 12 ‰. During the course of their first year of life, they develop the ability to survive in all parts of the sea. Great sturgeons are characteristically eurythermal to a great degree. In summer, they do not cease feeding until the temperature has risen to 30°C, and in winter, until it has decreased to 0.5°C. The temperature range for the spawning migrations varies from 6° to 21°C. In spring, the great sturgeons arrive at their feeding grounds in the northern Caspian Sea when the water temperature has reached 4°C.

The great sturgeon begins preying on vertebrates at a very early age, consuming shad (*Alosa spp.*), vobla (*Rutilus rutilus m. migratorius*), and other fishes. Larger individuals consume aquatic birds and even baby seals. In the stomachs of specimens captured off the Romanian Black Sea Coast, the primary food items were shad (*Alosa*), anchovy (*Engraulis*), and Cyprinids (*Cyprinus, Leuciscus, Scardinius*, and *Aspius*), but birds were also present, and from one individual, even the jawbone of a horse could be recovered. The main food of juveniles are the larvae of aquatic insects, especially the Ephemeropteran, *Palingenia longicauda*, and also Gammarids, Mysids, Copepods, and Cladocerans. After attaining a length of only 2 to 3 cm, they begin to feed on fishes consuming larval Acipenserids, Cyprinids, and other species. Fishes are the primary diet when the great sturgeon has reached a length of 9 cm. In the Sea of Azov, the piscivorous feeding habits are generally more active and adopted earlier than in the Caspian Sea, and therefore the growth rate is faster. In the Lower Danube River, they begin piscivorous feeding at a length of 24 cm, although individuals as small as 5 cm may consume fishes in exceptional cases. In the Black Sea, 80 % of the diet consists of fishes, 15 % Crustaceans, and 4 % Molluscs and insect larvae. Algae and other marine plants could be found in the stomachs, as well.

Both pelagic and benthic fishes are taken as prey. The diet of the great sturgeon is variable during the course of a year. The seasonal changes in the food items consumed were most clearly shown in the Black Sea. In the northwestern part of the sea from April through June, they prey on shad, *Alosa spp.*, which are migrating into the Danube River. Semi-migratory fishes like *Vimba vimba*, *Cyprinus carpio*, *Abramis brama*, *and Stizostedion lucioperca*, are included in the diet from June through September, while gobies (Gobiidae) are consumed from May through November. Marine fishes, such *as Scomber scombrus*, *Trachurus mediterraneus ponticus*, and *Sprattus sprattus*, also play an important role in the diet when the great sturgeons are congregating near the coast prior to entering the rivers, between May and September. During autumn and winter, from November through March, they descend into the deep regions of the sea, where red mullet (*Mullus barbatus ponticus*), Black Sea whiting (*Merlangius merlangus euxinus*), flounder (*Platichthys flesus luscus*), and anchovy (*Engraulis encrasicholus*) are included among the food items. The diet in the Sea of Azov is poorly known, but the great sturgeons are distributed throughout this drainage system according to the behavior and migration patterns of their main food species, the anchovy, *Engraulis encrasicholus*. Also known to be components of the diet in the Sea of Azov are gobies (Gobiidae) and tadpole gobies (*Bentophilus spp.*). The quantities of food consumed by mature great sturgeons in the Caspian watershed differ widely. The individuals travelling upstream in the Volga River to spawn actively hunt pikeperch (*Stizostedion lucioperca*) and sterlet (*Acipenser ruthenus*). Thus, the stomach of one individual weighing 365 kg contained six large pikeperches, and in the stomach of another weighing 74 kg, 23 sterlets from 13 to 22 cm were found. The prey in the freshwater stretches of the large rivers also includes several Cyprinids, e.g. vobla (*Rutilus* *rulilus m. migratorius*), and kutum (*Rutilus frisii kutum*). In the Caspian Sea, the main items in the diet are gobies (Gobiidae), "kilka" herrings (*Clupeonella spp*.), and shad (*Alosa spp.*). Along with fishes, the diet of the great sturgeon in the Caspian watershed includes a small quantity of invertebrates, including large Crustaceans and Molluscs. As in the case of other fishes, the feeding intensity of the great sturgeon depends primarily on the water temperature. During the cold seasons, they consume at most 1 to 3 % of their own weight, which is similar to other piscivorous fishes. In spring and summer, there is a sharp increase proportional to the water warming. Thus, from April to June, these predators consume food amounting to about 21 % of their own weight. From June to August, the great sturgeons consume over 50 % of their annual ration. A feeding coefficient of 2.7 was calculated for Caspian great sturgeon under the age of 5 years. For fishes from 5 to 13 years old, the coefficient was 8.3, and for 13 to 28-year-olds, it was 9.3. The average feeding coefficient in the Sea of Azov is 7.8.

The great sturgeon is a very long-lived fish with a life span that can exceed 100 years. Unfortunately, the exact ages of the giant specimens found were rarely determined. Thus, a female with an absolute length of 490 cm and weight of 1,004 kg that was caught in the northern Caspian in 1937 was estimated to be 91 to 101 years old. The age of a male caught in the northern Caspian in 1940 (400 cm and 725 kg), was similarly estimated to be 107 to 118 years. At present, the highest age recorded for great sturgeons is 36 years in the Black and Azov Seas, and 60 years in the Caspian Sea.

The great sturgeon, like other Acipenserids, is a species of fish in which carry-over of mature individuals considerably outcompetes the recruitment of first time spawners to the spawning population. Such populations are characterized by an intricate multi-age structure. Thus, the spawning population of the Volga River great sturgeon in 1936 included 50 age groups: the females ranged in age from 15 to 61 years, and the males, from 12 to 30 years. The bulk of the breeding population consisted of 21 to 26-year-old females and 15 to 17-year-old males. In 1933, the main portion of the migrating spawners in the Kura River, as determined from data on both sexes, consisted of 16 to 22-year-olds. In the Volga River during 1964, the spawning population included 28 age classes: the females ranging from 15 to 36 years, and the males, from 9 to 34 years. The bulk of the females were 20 to 27 years old, while most of the males were in the 14 through 19 year classes.

The bulk of the Black Sea great sturgeon catch in the Danube River at the beginning of the 1950s consisted primarily of 10 to 15 year classes, that is, fishes actually on their way to their first spawning. There was a total of 28 age classes in the Danube population. By the end of the 1960s, there was a decrease in the catch, and in parallel a considerable increase in the age of spawners. This is explained by an extremely weak recruitment due to the low efficiency of the natural reproduction and a lack of work on the artificial propagation of this species. The main age groups within the reproductive population in the north-west part of the Black Sea, which spawns in the Danube River, were 20 and 21 years for the females and 17 to 20 years for the males. Generally, the total number of age groups has been reduced to 24. The average total length of the fishes in the catch increased from 189 cm in 1951 and 206 cm in 1952 to between 232 and 253 cm during the period from 1965 through 1968. The average weight also increased from 54.3 kg in 1951 and 1952 to between 76.9 and 85 kg in the years 1965 through 1968. By the end of the 1960s, the great sturgeon fishery in the Black Sea utilized only the remains of the productive generations of 1942 through 1944.

In the Black Sea at the beginning of this century, the males were predominant over the females in the spawning populations, accounting for 86.8 % to 88 % of the total number of fishes in 1903 and 1904. As a result of a reduction in the number of young individuals and general aging of the population, there was a shift in this relationship in favour of the females. At the beginning of the 1950s, there was still a predominance of males, which accounted for an average of 62.1 % of the fishes in the years 1951 and 1952. However, by the years from 1966 through 1968, females showed a 59.8 % majority. In 1981, they still accounted for 52 % of the spawning population.

9.6.4 Reproductive Biology

Sexual maturity is attained by the great sturgeon very late. The males of the Volga population can first reach maturity in their eleventh year of life, but many of them mature even later at the age of 14 to 16 years. The females can become sexually mature during the sixteenth year of life, but most of them first reach this stage at 19 to 22 years. Among great sturgeons from the Kura River, maturity is reached after 13 years by the males and 18 years by the females. The same approximate ages also apply to the group that reproduces in the Ural River. In the Sea of Azov, males reach maturity after 12 to 14 years, and females after 16 to 17 years. In the Danube River and north-western part of the Black Sea, very precocious individuals mature at an age of 6 to 7 years old, but such cases are very rare, affecting only about 0.35 % of the population. Most of the male Black Sea great sturgeons undertake their first spawning migration at 10 to 13 years old, while the females begin migrating at the age of 13 to 15 years. Thus, the process of attaining sexual maturity is considerably protracted and lasts for many years. For example, the sexual maturation of males and females from one generation of the Volga population required 11 and 12 years, respectively. Subsequent spawning by great sturgeons from the Volga River apparently begins at least 5 years later.

On May 11, 1922, a female great sturgeon was captured in the Volga River Delta, weighing about 1,220 kg and containing 146.5 kg of eggs. In 1924, a 1,228 kg specimen, captured in the northern Caspian region, was found to contain 246 kg of eggs. On the average, every ton of female great sturgeon mass includes 161 kg of eggs.

The great sturgeon is the most prolific of all sturgeons. The number of eggs laid depends primarily on the size of the female. The larger fishes have a greater fecundity. In general, females from the Caspian Sea produce a significantly greater quantity of eggs than those of comparable weight from the Black Sea. The absolute fecundity of great sturgeons from the Danube stock varies from 228,400 to 964,800 eggs and averages 574,400. For females of the Azov great sturgeon, the range is 499,000 to 1,638,000 eggs. The individuals on which these determinations were made weighed from 141 to 350 kg. For females from the Caspian Sea, taken in the Volga River, the absolute fecundity ranged from 224,300 to 2,853,400 eggs and averaged 855,000. In exceptional cases, the fecundity of the Volga great sturgeon can reach 7,729,700 eggs. There can be differences within the great sturgeon stocks in individual watersheds. Thus, those that reproduce in the Kura River are somewhat less productive than those in the Volga River. The relative fecunditiy of the great sturgeon, according to weight, also varies over a considerable range, from 3,300 to 13,100 eggs per kg of live weight. Its average is about 6,000 to 7,000 eggs kg^{-1} body weight.

Regardless of the season they have entered the rivers, the great sturgeons breed during the period of high discharge in spring. In the Volga and the Ural Rivers, the main spawning season is in May and June, and in the Kura River, during April and May. In the Don River, the spawning peak is recorded in May, and in the Danube River, it is in April and May.

The great sturgeon spawns at a lower temperature and within a narrower temperature range than other migratory sturgeon species, particularly the Russian (*A. gueldenstaedti*) and the stellate (*A. stellatus*) sturgeons. The spawning time of the great sturgeon usually coincides with a flood peak. Spawning begins at a water temperature of 6 to 7° C, and it ceases when the temperature reaches 21° C. The optimal temperature lies within the range of 9 to 17 °C. It was reported that an autumn spawning also occurs in the Danube River during October and November at water temperatures near those that prevail in March and April, but this information requires confirmation. The hatchlings do not remain very long in the rivers, and at an early age, while still larvae, they travel to the sea. The total length of the larvae drifting downstream in the Lower Volga ranges between 11.4 and 14.3 mm with a weight from 17 to 32 mg. They were 2 to 3 days old. The downstream migration progresses at a speed of about 50 to 60 km day^{-1}.

The location of the sturgeon spawning sites in the rivers does not depend on the distance from the mouth but rather on the presence of conditions conducive to reproduction, such as the proper kind of bottom and a suitable current velocity. In general, the great sturgeons spawn farther upstream in all rivers than any other anadromous migratory sturgeon, and therefore the regulation of the water flow and construction of dams have the greatest impact on the natural reproduction of this species. For spawning, the great sturgeons seek a section of the river with a hard, stony or gravelly bottom and only very rarely with one of sand or clay. The spawning usually takes place at a depth of 4 to 12 or 15 m, but it also occurs as deep as 40 m. The current velocity at the spawning site is about

1.5 to 2 m s^{-1}, and oxygen saturation of the water needs to exceed 80 %. The main spawning sites are in the river bed, but temporary sites in floodplains may also be utilized for reproduction. A limited amount of spawning may also occur in the lower courses of the river. For instance, it was reported that there are spawning sites in the Kilia Arm of the Danube River Delta, in a stretch of river where an especially strong current exposes a stony bottom that can be used by sturgeons for depositing their eggs. Spawning of great sturgeons has also been noted just below the dam of the Volgograd hydropower plant. Reproduction occurred on scattered stones during the second half of May at depths from 3 to 9 m and at water temperatures from 7.5 to 12 °C. The density of eggs was 670 eggs m^{-2} in 1979, 50 eggs m^{-2} in 1980, and only 2 to 5 eggs m^{-2} in 1983.

As in the case of other sturgeons, the males are the first to arrive at the spawning sites. The females arrive later, after the water has warmed to 7 or 8° C. During the period of the spawning run, and possibly during the actual spawning itself, the fishes frequently jump out of the water. The females release the eggs gradually, according to their rates of ovulation. Fertilized eggs sink to the bottom and adhere to the substrate. The spawning habits of the great sturgeon are unknown.

The embryonic development of the various sturgeon species is very similar. The larval period of the Azov great sturgeon is completed when a length of about 40 mm is reached. At the age of one month, the great sturgeon juveniles have grown to a length of between 52.5 and 58 mm. The five rows of scutes are well-developed, and the fins are completely formed with clearly distinguishable fin rays. Dermal bones covering the head appear. The gill covers almost completely conceal the gill lamellae. The juveniles are dark or almost black in colouration.

9.6.5 Historic range, stock development and current status in the Danube River Basin

Vernal (spring) and winter (fall) races of this species ascended the Danube River each year. Two peak periods of migration could be observed. Upstream movement of the winter race usually started in August and culminated in October or November. Migration of the vernal race lasted from January until April. While the vernal race spawned in the river the same year of entering it, the winter race overwintered in deeper stretches of the river and spawned in the following spring. Winter Beluga regularly ascended up to Bratislava in Slovakia (river km 1,860 – 1,870) and rarely also up to the Austrian and even the German (Bavarian) stretch up to Straubing (river km 2,320). The main spawning grounds for Beluga sturgeons in the Middle Danube were situated in Zitny Ostrov reach below Bratislava (river km 1,766 – 1,866 the contemporary Slovak-Hungarian border), as well as between Budapest and Szentendre (ANONYMOUS 2000). The main fishery on Beluga sturgeon was conducted in the so called Little Danube (the northern branch of the Danube) near the mouth of the Vah River at the village of Kolarovo, and in the Danube River, between Komarno and Sap (HENSEL & HOLČIK 1997).

Beluga also entered the lower Morava River (one reported catch at Lanzhot), the Vah River (up to Trnovec nad Vahom and exceptionally up to Trencin), the Zitava River (up to Nesvady), the Drava River, the Tisza River (up to Trakany and its tributaries Zagyva, Körös and Maros Rivers), the Sava River (up to Zagreb, and its tributary the Kupa River), the lower courses of the Velika Morava River and the Olt River (HENSEL & HOLČIK 1997).

The Beluga was among the most abundant of the Danubian migratory sturgeons. It was also the most valuable. Due to overfishing of the adult spawners, the catches of Beluga in the Middle Danube started to decline already after the 16th century. Belugas were caught by means of special nets, fishing lines equipped with particular hooks called "samolov" and most effectively by means of the catching weir. Since the majority of the caught individuals were first-time spawners, and since this species has a long life span and a late sexual maturation, mortality surpassed recruitment and the Danube population of *Huso huso* declined rapidly.

Weir fishing was abandoned in the Middle Danube at the end of the 16th and from the Tisza River at the end of the 17th century. It was used by Serbian fishermen at the Iron Gate gorge till World War I, however. Exploitation of Beluga stocks continued through the 17th and 18th century, and in the 19th century only few Belugas could be caught in the foothills and the Lower Danube. The last Beluga recorded in the Slovakian-Hungarian stretch of the river was a female (3.1 m / 150 kg) taken near the town of Sturovo in 1925.

A great impact on Beluga stocks as well as all other migratory species of fishes (and especially sturgeons and shad) in the Danube River had the construction of the two dams of Djerdap (Iron Gate) hydropower station (BACALBASA-DOBROVICI 1991 and 1997; HENSEL & HOLČIK 1997; NAVODARU 1998 a; BACALBASA-DOBROVICI & PATRICHE 1999).

It was reported that catches of Beluga and Russian sturgeon (*A. gueldenstaedti*) culminated during the five year period after the completion of Iron Gate Dam I in 1972 (river km 942) due to the mass occurrence of migrating animals below the dam. In the period from 1972 to 1976 115.7 metric tons (*H. huso* and *A. gueldenstaedti*) were caught which is 23.1 tons higher than in the five years before dam construction. After 1976 the combined catches below Iron Gate started to decrease, dropping to 37.3 metric tons from 1980 to 1984, following the completion of Iron Gate Dam II (river km 863).

Migratory sturgeons only occasionally pass both of the Iron Gate dams through the shiplocks. One documented catch of a Beluga male (3 m / 181 kg) was at Paks in Hungary (river km 1,526 – 1,528) on May 16th in 1987.

H. huso is considered vulnerable to endangered throughout its range (LELEK 1987). The Beluga or great sturgeon is currently extirpated from the Upper Danube, critically endangered in the Middle Danube and vulnerable in the Lower Danube (HENSEL & HOLČIK 1997). The four migratory Acipenserids are extinct from Germany and Austria (SPINDLER 1995; BAYERISCHE

LANDESANSTALT FÜR FISCHEREI 2000). Migratory sturgeons are endangered in Hungary (GUTI 1995). *H. huso* is extinct in Slovakia (HOLČIK 1996 b).

According to the Red List 2000 of IUCN b the Black Sea stock of *H. huso* is endangered.

Fig. 28: Distribution of the great sturgeon or Beluga, *Huso huso*, in the Danube drainage system. Regular (continuous black) and occasional (black and white area) occurrence at present; regular (continuous white) and occasional (striped white area) occurrence in the past. (from HENSEL & HOLČIK 1997, Original figure by K. Hensel)