

### **3.8 Restoration of the European sturgeon, *Acipenser sturio* L., in Germany: background, actual situation, and perspectives**

### **3.8 Wiedereinbürgerung des Europäischen Störs, *Acipenser sturio* L., in Deutschland: Hintergründe, aktueller Stand und Perspektiven**

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Key words: restoration; decline; broodstock; habitat; water management; European sturgeon

#### **Abstract**

One century ago, *Acipenser sturio* was a prevalent species of the fish communities in all major German rivers. Since then, the population sizes decreased rapidly due to overfishing, pollution, and hydroconstruction. The last remaining population was observed in the river Eider until 1968. Recently, specimens were observed in German waters very rarely. In 1994, joint activities of scientists and aquaculturists led to the foundation of the "Society to Save Sturgeon (*A. sturio* L.)" aiming at the coordination of the restoration measures of *A. sturio* in Germany. Since 1996, a federal programme was initiated, supporting several subprojects dealing with this matter. Under a scientific cooperation agreement with the French Cemagref, the Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB) received juvenile *A. sturio* in May 1996 as an *ex-situ* measure. The main scientific aspects investigated in this context are concerning general biology and autecology of the species. These are comprising rearing experiments aiming at optimal rearing conditions ideally leading to enhanced gonad maturation. Furthermore, studies on endocrine regulation of gonad development are carried out, trying to identify the mechanisms leading to vitellogenesis. Complementary experiments are performed on model species such as *A. ruthenus* and *A. baerii*, in cooperation with the Research Institute for Agriculture and Fisheries of Mecklenburg-Vorpommern. Phylogenetic and population genetic analysis of *A. sturio* were carried out using specimens from different museums based on mtDNA and microsatellites. The genetic analysis of the recent Gironde population including the specimens of the German and the French broodstocks were carried out with the Cemagref as basis for a long-term conservation of the still existing genetic plasticity. Evaluation of habitat for the restoration of *A. sturio* in the rivers Oder and Elbe are performed in part in collaboration with the Institute for Inland Fisheries of Poland.

#### **Zusammenfassung**

Der Europäische Stör, *Acipenser sturio*, war bis zum Ende des 19. Jahrhunderts ein vorherrschendes Element der Fischgemeinschaften aller größeren deutschen Flüsse, insbesondere der Elbe. Hauptgründe für den ab 1890 einsetzenden dramatischen Rückgang lagen in der Überfischung, der Gewässerverschmutzung und der Gewässerverbauung. Die letzte verbliebene Population Deutschlands in der Eider hielt sich bis 1968, danach waren nur noch Fänge einzelner Individuen zu verzeichnen. Durch gemeinsame Aktivitäten von Fischzüchtern und Wissenschaftlern wurde 1994 die "Gesellschaft zur Rettung des Störs e.V." gegründet, um die Koordination von Wiedereinbürgerungsmaßnahmen zu übernehmen. Ein Vorhaben zur Arterhaltung konnte 1996 durch die Unterstützung des Bundesamtes für Naturschutz begonnen werden. Zeitgleich wurden juvenile *A. sturio* aus künstlicher Vermehrung des französischen Cemagref für den Aufbau eines

Laichfischbestandes an das Leibniz-Institut für Gewässerökologie und Binnenfischerei (IGB, Berlin) gebracht. Die wissenschaftlichen Fragestellungen in diesem Themenkomplex befassen sich mit der Biologie und der Autökologie der Art. Hierbei stehen Versuche mit verschiedenen Naturfuttermitteln zur Sicherung maximalen Wachstums und schneller Gonadenreifung im Vordergrund; weitere Untersuchungen befassen sich mit der endokrinen Regulation der Gonadenentwicklung und der Vitellogenese. Diese Arbeiten werden u.a. mit Hilfe verschiedener Modellstörarten (*A. ruthenus*, *A. baerii*) in Zusammenarbeit mit der Landesforschungsanstalt für Landwirtschaft und Fischerei Mecklenburg-Vorpommern durchgeführt. Diese Arbeiten wurden durch Untersuchungen zur genetischen Charakterisierung der verschiedenen Populationen (Ostsee, Nordsee, Mittelmeer) von *A. sturio* als Basis für die Wiederansiedlungsprogramme ergänzt. Zudem wurden Studien zur genetischen Heterogenität des Bestandes von *A. sturio* in der Gironde sowie der deutschen und französischen Zuchtgruppe als Grundlage eines langfristigen Nachzuchtprogrammes durchgeführt. Wichtig sind ebenfalls Untersuchungen zur Identifikation geeigneter Laichhabitats für die Art in der Oder in Kooperation mit dem polnischen Instytut Rybactwa Środladowego (IRS). Analoge Untersuchungen sind auch für die Elbe und ihre Nebenflüsse in Vorbereitung. Die internationale Kooperation ist ein wichtiges Element für das Gelingen des Vorhabens.

### 3.8.1 Background

Sturgeon and paddlefish exhibit unusual combinations of size, behaviour, habits, and life history characteristics, which make them highly vulnerable to impacts from human activities: fisheries, hydroconstruction, and habitat destruction and degradation (Rochard et al., 1990; Beamesderfer & Farr, 1997; Boreman 1997). It is therefore not surprising that most of the 27 species of sturgeons are actually endangered (Birstein, 1993). However, the combination of the various anthropogenic impacts is different for each species, and also particular to each river system. The historical distribution in comparison with the actual situation of the European sturgeon, *Acipenser sturio*, are a typical example in this respect.

Historically, *A. sturio* ranged from the Black Sea via the Mediterranean and the Eastern North Atlantic to the North, Baltic and White Sea (Holcik et al., 1989). During the 19<sup>th</sup> and particularly the 20<sup>th</sup> century the stocks decreased drastically. Today there is only a relict population in the Gironde-Garonne-Dordogne basin in France (Rochard et al., 1990; Lepage & Rochard, 1995; Williot et al., 1997).

*A. sturio* played a major role in fisheries in German waters in former times (Benecke, 1881; Quantz, 1903; Blankenburg, 1910; Seligo, 1931; Ehrenbaum, 1936), especially in the lower parts of the rivers Eider, Elbe, Ems, Oder, Pregel, Rhine, Weichsel and Weser. For seventeen southern Baltic sites, archeological data demonstrated a reduction in average fish size consumed in relation to the total protein sources from 70 % of the fish consumed from the seventh up to the 13<sup>th</sup> century; in addition, during the seventh, eighth and ninth century of the total protein source consumed 70% comprised sturgeon meat; this percentage dropped to only 10 % during the 12<sup>th</sup> and 13<sup>th</sup> century (Benecke 1986, cited in: Hoffmann, 1996). In the 18<sup>th</sup> and 19<sup>th</sup> century, sturgeon fisheries were an important socio-economical factor. British trade companies owned the leases in the Gdansk and Pregel area of the Baltic (Seligo, 1931). In Northern Germany (Fig. 3.8.1) especially the rivers Eider, Elbe, and Rhine were important for sturgeon fisheries (Mohr, 1952), and trade (Kinzelbach, 1987; 1997). Until the turn of the 20<sup>th</sup> century the intensive harvest in sturgeon fishing continued, leading to a sharp decline in the catches from the Baltic Sea since 1894 (Debus, 1996). Fisheries compensated the decline in riverine sturgeon catches over 4-6 years by increased utilization of migrants in marine waters (Kraeft, 1894).

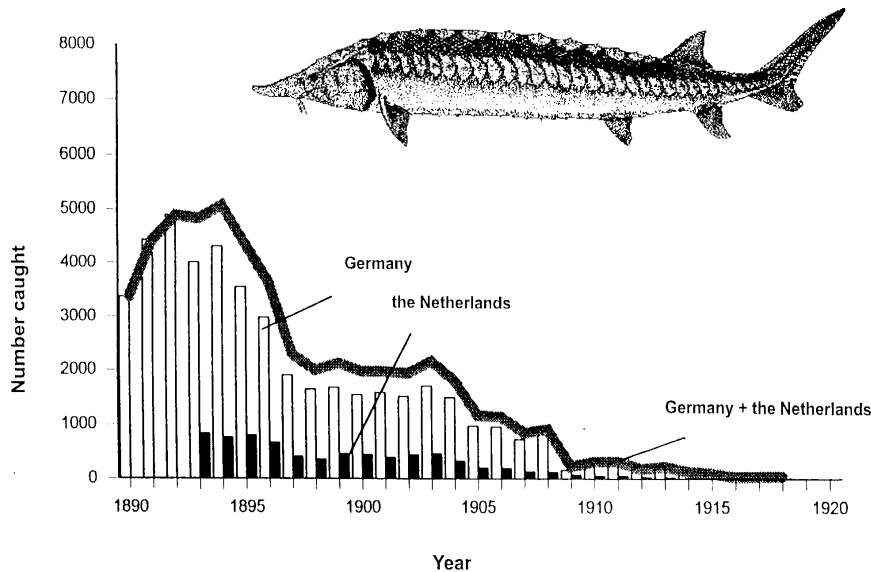


Fig. 3.8.1  
Total catch of  
*A. sturio* in  
Germany and the  
Netherlands from  
1879 to 1918  
(after Kirschbaum  
& Gessner, 2000,  
modified after  
Lozan et al., 1996).

Management attempts (see e.g. Ehrenbaum, 1916) to protect the species were enforced too late and were insufficient to avoid the disappearance of the species. The decline of *A. sturio* in Germany is caused by a combination of different impacts (Bonne, 1905; Bauch, 1958; Schirmer, 1994): overfishing, hydroconstruction, degradation of water quality, and destruction of spawning habitat are the main factors contributing to the extirpation.

If fishing pressure would have been the major impact leading to the recruitment failure in all large German rivers, it should have been obvious in the Eider River, too. The difference between the Eider and other rivers is that only small settlements and little industry were located along the river in the 19<sup>th</sup> century. Apart from damming the tributaries Sorge and Treene in the 17<sup>th</sup> and 18<sup>th</sup> century and the upper reaches of the Eider in the 1860's, no major hydroconstruction took place until 1890 (Fig. 3.8.2 ). During the 1890's, the construction of the Kiel Canal had a detrimental impact on the river habitat, eliminating approximately 35 % of the catchment area from the main river (Fock & Ricklefs, 1996). The zone of tidal influence and the sediment transport from the coastal areas into the river drastically increased due to flow reduction. This led to more frequent floods and increased sediment influx. A second, even more detrimental measure for the sturgeon of the Eider was taken in 1934: the erection of the dam at Nordfeld blocked the migration route to the spawning sites upstream (Ehrenbaum, 1923). As a consequence of the recruitment failure, the sturgeon catches declined in the 1950's to incidental catches of single individuals (Spratte, 2001). The idea in 1953 to artificially reproduce the few remaining fish arose too late. No delivery of a ripe male or female was recorded for the subsequent years. The occasional catches were killed before reporting (Spratte & Hartmann, 1992). The last sturgeon from the Eider River was caught in 1968. The decline of the Eider population demonstrated that each river system has to be analysed separately to identify reasons for the decline of the population.

In the last two decades of the 20<sup>th</sup> century, only occasional catches of *A. sturio* were reported in Northern Germany (Arndt et al., 2001). The last large sturgeons were caught in the North Sea in 1993 and in the Baltic Sea in 1996 (Paaver, 1996).

In the 1990's the rising interest in conservation of genetic diversity led to a series of international agreements on conservation of endangered species (for instance EU-Directive 42 EWG 92), leading in consequence to the protection and restoration of the required environment (Bern, Bonn conventions Flora Fauna Habitats).

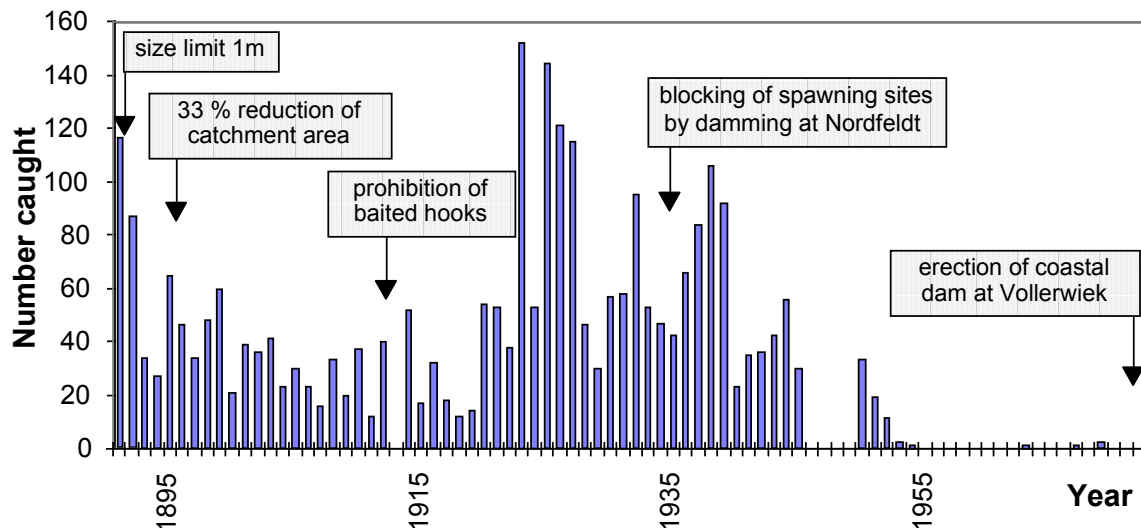


Fig. 3.8.2 Sturgeon catches in the river Eider, Northern Germany, between 1891 and 1973; arrows indicate important events (after Kirschbaum & Gessner, 2000).

The first attempts to restore migratory species to large rivers were performed with the salmon (*Salmon salar*) in the tributaries of the Elbe River (Knösche & Zahn, 1999) and the River Rhine (Schmidt, 1996; Neumann et al., 1998) comprising the joint action of the bordering countries (IKSR 1987, 1991).

The increased interest in restoration of the European sturgeon, *A. sturio*, in Germany in the early 1990's (Kirschbaum & Gessner, 2000) led to contacts with scientists working on the restoration of this species, for instance in Spain (Elvira et al., 1991), but particularly in France (Williot et al., 1997). This, together with the need to work on this subject by coordinating the various activities both nationally and internationally, led scientists, fish farmers and fishery administrators to the foundation of the "Society to Save the Sturgeon (*A. sturio* L.) e.V." in 1994. Subsequently, the Federal Agency for Nature Conservation (see von Nordheim et al., 2001) began to support these activities providing the basic funding for the current programme in Germany.

### 3.8.2 Actual situation of the restoration measures

#### 3.8.2.1 *Ex-situ* measure

The European sturgeon actually occurs with certainty only in the Gironde-Garonne-Dordogne basin in France at a very low stock size level of a few thousand specimens exhibiting irregular natural spawnings (Rochard et al., 1990; Lepage & Rochard, 1995; Williot et al., 1997). Therefore, the basis of the restoration measures in France comprises research concerning broodstock development which began in the early 1990's (Williot et al., 1997, Williot et al., 2000).

The establishment of a broodstock, is also the basis of the restoration programme in Germany as the species has practically disappeared from German waters. This *ex-situ* measure began in 1996 when on the basis of a co-operation programme the Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB) received juveniles from the Cemagref in Bordeaux originating from artificial reproduction in 1995 (Williot et al., 2000). The first experience with this species indicated (Williot et al., 1997) that this fish is difficult to maintain in contrast to many other sturgeon species.

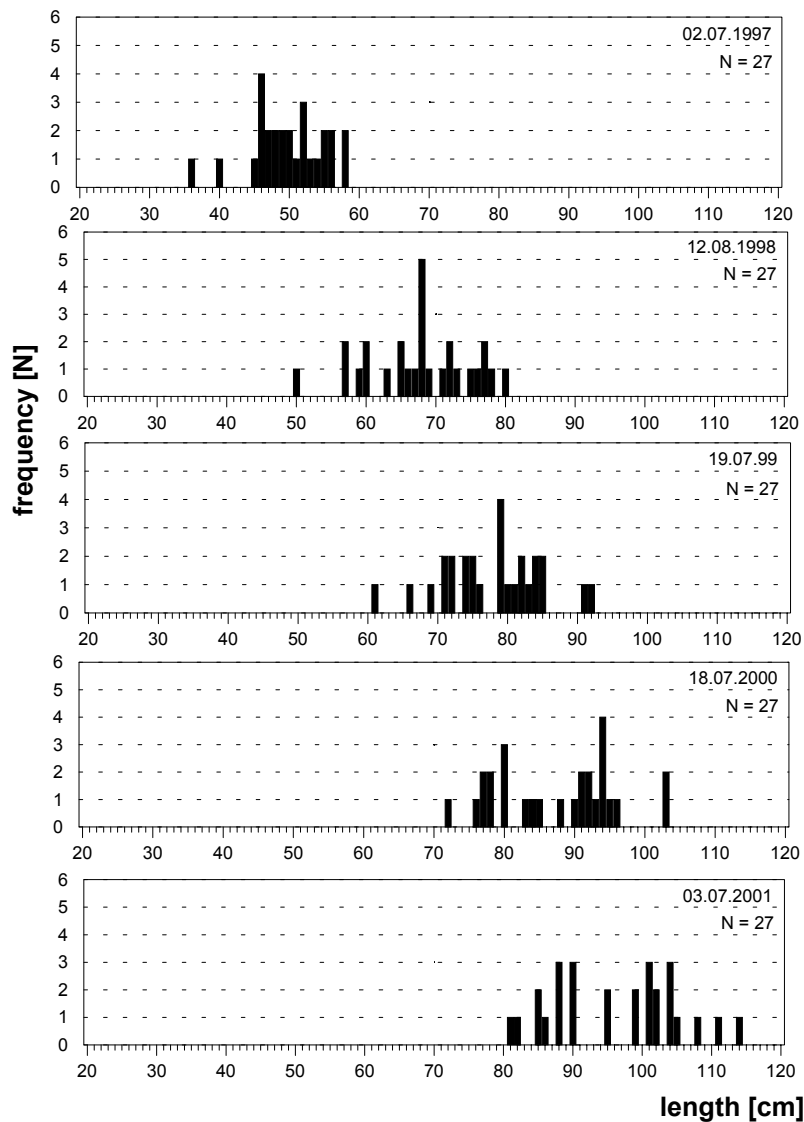


Fig. 3.8.3  
Length frequency distribution of the 27 specimens of the German *A. sturio* broodstock from 02/07/1997 upon individual tagging, to 03/07/2001 (after Kirschbaum & Gessner, 2002 subm.).

The Cemagref and the IGB therefore decided to apply different strategies during the establishment of the broodstock in order to gain as much knowledge as possible. In France, fresh, brackish and salt-water is used for raising the fish and during the breeding experiments (Williot et al., 2002), in the IGB only freshwater is applied. In France, very low light intensities are applied and an annual temperature variation between 25 and 11 °C whereas in the IGB the fish are raised at constant temperatures around 20 °C at the natural photoperiod. The weighing intervals comprise several months in France, and two weeks in the IGB. In France, the fish are fed on different species of shrimps only (Williot et al., 1997) whereas in the IGB, a variety of natural food items was tested each of which result in quite different specific growth rates when offered as single food item (Kirschbaum et al., 2000; Hensel et al., in press).

The feeding experiments aim at maximum growth in order to reach the minimum size for first sexual maturity as early as possible. The growth of the broodstock (Fig. 3.8.3), is lower than the maximum growth of this species observed in the wild (Lepage et al., 1994). The reported minimum size for reproduction in males is 1.20 m and about 1.50 m in females (Mohr, 1952). The largest fish of the IGB broodstock actually has reached a length of approximately 1.20 m (Fig. 3.8.4). The aim of future feeding trials is to determine natural and artificial feeds resulting in an improved growth performance, comparable to wild fish, but avoiding the main adverse effects observed with commercial feeds.

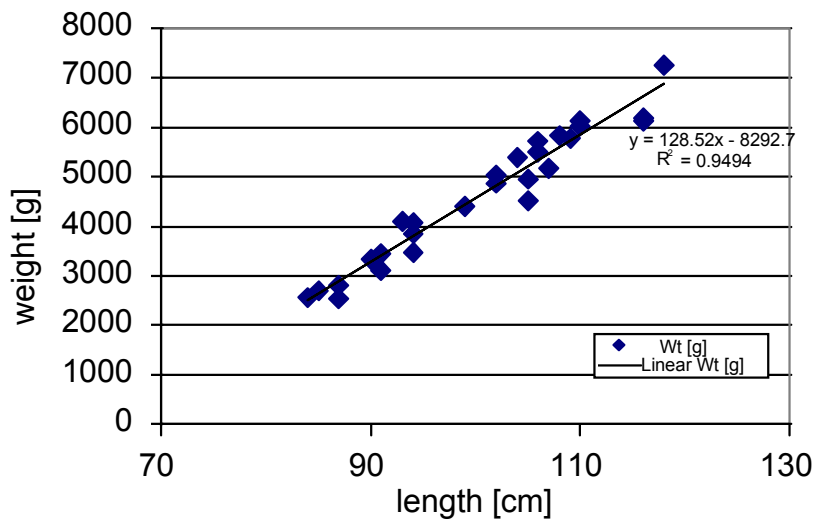


Fig. 3.8.4 Length-weight-distribution of the 27 specimen of the German *A. sturio* broodstock at 11/12/2001 (after Kirschbaum & Gessner, 2002).

### 3.8.2.2 Endocrine regulation of gonad maturation

In the past, the reproduction of sturgeon has been recognized to be one of the major concerns for conservation measures (Williot et al., 1997). In the context of a late maturity, an highly variable reproductive cycle of up to several years and observations on a delayed maturation prior to the onset of vitellogenesis, the underlying endocrine mechanisms are poorly understood. Along the hypothalamus-pituitary-gonad axis, interaction of protein hormones and steroids controls the development of the gonad, mediating the environmental stimuli of external factors such as temperature and photoperiod. Recent investigations show that, next to the involvement of sex steroids, an additional factor is involved in early vitellogenesis, priming the onset of puberty. Our work focuses on the identification of this VIF (vitellogenesis inducing factor). Due to the variability of sex steroids in the plasma of maturing sturgeon (Fig 3.8.5), the VIF is considered the most promising parameter to overcome the above mentioned problems in sturgeon reproduction. Therefore, it seems a promising indicator for the optimization of culture conditions aiming at early maturation and high yields of maturing females. Based on recent publications on the induction of puberty in fish, we investigate the role of IGF-I as the paracrine modulator of gonad maturation. First identification of IGF-I mRNA in *Acipenser* species was carried out using RT-PCR, RACE PCR-techniques and subsequent cloning of the templates. An assay for semi-quantitatively measuring IGF expression, based on real-time PCR, is developed later on. These investigations are conducted using model species at the IGB and the Research Institute for Agriculture and Fisheries of Mecklenburg-Vorpommern (Fig. 3.8.5).

### 3.8.2.3 Population genetics and genetic diversity of the broodstocks

Historically, *A. sturio* comprised several geographical races (Holcik et al., 1989) separated by variable morphological features (Holcik, 2000; Artyukhin & Vecsei, 1999), and in part by genetic differences (Birstein et al., 1997). The genetic characterization of the European Atlantic populations using both recent (Gironde fish) and museum material (North Sea) (Ludwig et al., 2000) is another prerequisite of the restoration. In addition, related species, in particular *A. oxyrinchus*, will be included into the characterization of the species. These data will be the basis for decisions concerning stocking trials in the different German rivers. Using mitochondrial DNA (mtDNA) it could be shown (Ludwig et al., 2000) that the fishes from the Gironde and the North Sea are genetically similar (Fig. 3.8.6). Both differ in a few substitutions from fish of Mediterranean and Adriatic origin.

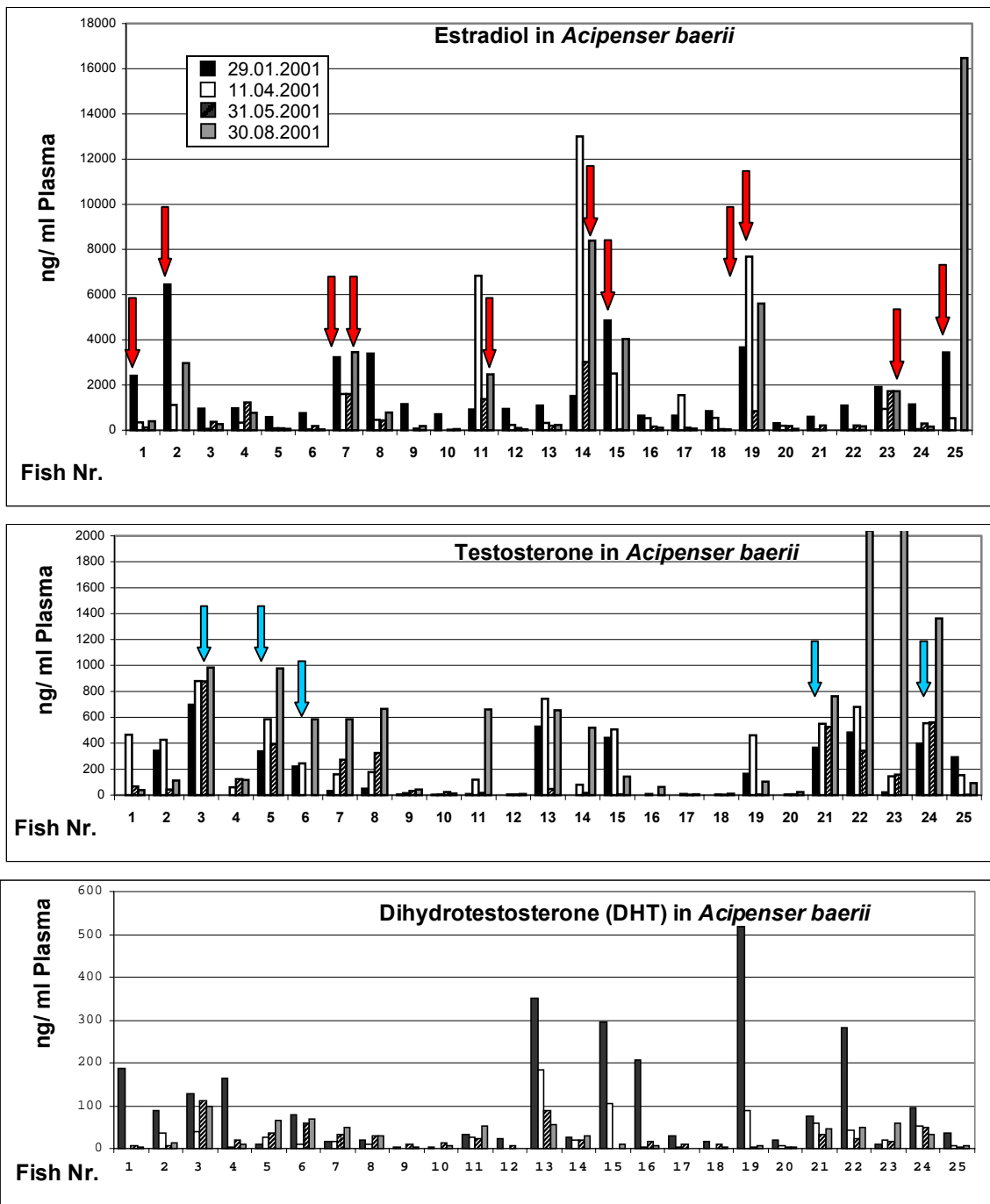


Fig. 3.8.5 Status of the sex steroids estradiol (arrows = stage IV females), testosterone (arrow = mature males) and dihydrotestosterone, showing a high variability of hormones in first maturing Siberian sturgeon, *Acipenser baerii*.

In close co-operation between the Cemagref in Bordeaux and the IGB, studies on the genetic structure of the remaining population in the Gironde and the captive broodstocks are conducted, aiming at a breeding protocol for future reproduction strategies. Thus, allowing to minimize inbreeding and to increase genetic heterogeneity in both, German and French breeding groups. Results (LUDWIG et al., 2000), based on microsatellite analysis, show (Table 3.8.1) that the fishes of the German broodstock still comprise about 40 % of the genetic variability compared to the variability of both recent and archival specimens originating from the North Sea. The genetic diversity of the IGB-broodstock will further be

increased by transfer of sperm from the French broodstock and by integration of wild fish from the Gironde population and of the single specimen presently kept at the public aquarium in Helgoland.

Tab. 3.8.1 Distribution of the alleles observed in *A. sturio* and *A. o. oxyrinchus*: The broodstock kept at the Institute of Freshwater Ecology and Inland Fisheries (Berlin) originated from artificial reproduction of two *A. sturio* individuals caught in the Gironde River basin in France (Williot et al., 1997).

Locus	<i>Acipenser sturio</i>		<i>Acipenser o. oxyrinchus</i>		
	Archival samples 1823 - 1996 n = 38	Broodstock (Berlin) n = 27	Delaware River n = 16	Hudson River n = 14	St. John River n = 60
Afu-19	118, 121, 124, 127, 130, 145	118, 145	121, 124, 127, 145	121, 127, 145	124, 127, 145
Afu-34	141, 144, 147, 150	147, 150	138, 141, 144, 150, 153	138, 141, 153	144, 147, 150
Afu-39	120, 123	123	120, 123	120, 123	123
Afu-54	180, 184, 188	184, 188	184, 188, 192	184, 188	184
Afu-68	128, 136, 140, 152	140	132, 136, 140, 144, 148 152, 156, 160	140, 144, 148, 156	140, 144, 148, 152, 156, 160
Overall loci	19	8	22	14	14

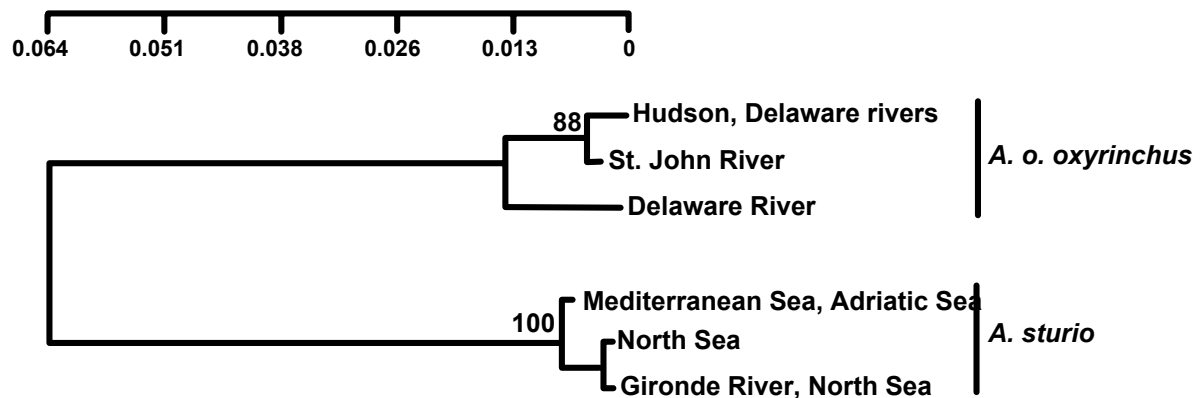


Fig. 3.8.6 Genetic distance tree using 250 bp of the mitochondrial D-loop and the tRNAPro gene basing on the different haplotypes found in this study. The tree was calculated in MEGA (Kumar, Tamura and Nei, 1993) based on p-distance values and neighbour-joining. Bootstrap values >50 are shown on the branches (after Ludwig et al., 2000).

### 3.8.3 Perspectives

#### 3.8.3.1 The aim of the restoration measures

The aim of the restoration measures comprise:

- 1) successful reproduction of the broodstock over prolonged periods of time, and
- 2) successive experimental restocking with juveniles to achieve self reproducing natural

populations. The prerequisites concerning the long-term development of the broodstock have been described (see above). Natural populations, however, can only be established if the most important factors that contributed to the decline of the species a hundred years ago are no longer present in the rivers chosen for the re-introduction measures: the Oder River, the Elbe River, and the Rhine River.

### 3.8.3.2 Ecology of “Sturgeon” Rivers Oder, Elbe, and Rhine

There are numerous recent studies on the fish communities of these large rivers indicating successful reproduction and recruitment of various species (Bischoff & Wolter, 2001a, b, c; Wolter & Bischoff, 2001; Buisje & Cazemier, 1998; Staas, 1998; Molls, 1998; Thiel et al., 1998). These results indicate ecological conditions (see for instance Prange et al., 2000) that would also allow successful reproduction and recruitment of sturgeons. Potential spawning habitats for *A. sturio* were found in the river Rhine (Schmidt, pers. comm.) and in the Oder River (Gessner & Bartel, 2000).

The habitat assessments mainly focused on spawning habitat for sturgeons because of its key role for successful reproduction of the species, since it supports the most vulnerable life stages. In the Oder River, identification of potential spawning grounds was based on historical data (Przybyl, 1976; Sych et al., 1996). To assess the status of potential spawning sites, migration obstacles and water pollution, dynamic of the discharge, water quality and profiles of the river were evaluated. Substrate composition was determined by video-picture analysis. Spawning grounds comprise river habitat with gravel substrate, sufficient water exchange in interstitial water and absence of sedimentation (Sulak & Clugston, 1999; Elie, 1997, Richmond & Kynard, 1995). Historical sturgeon distribution in Oder River is reported up to Raciborz. However, these sites have been inaccessible since the construction of a weir in Wroclaw (Breslau) in the 19<sup>th</sup> century. In the Oder River excessive sediment transport can be observed throughout the river bed in the middle and lower part of the river, thereby, excluding the main river channel as potential spawning site for sturgeons. Only very limited areas of suitable substrate could be found in groyne fields and river bank structures where sedimentation was not detectable. In the Warta River migration obstacles are solely located in the upper reaches of the river as well as in some of its tributaries (Notec, Obra, Prosna). In Warta River, at least two historical spawning sites are readily accessible. Here, the high nutrient load is the main reason for the limited suitability for natural reproduction. In Prosna River, fine sands dominate the substrate throughout the investigated river stretch of 25 km along the historic spawning sites. In Drawa River - described as sturgeon spawning habitat until 1939 - potentially suitable habitat was determined to be readily available with the substrate in the main channel dominated by clear cobbles and stones.

Comparable attempts to verify the status of historical spawning sites are prepared for the Elbe River and its tributaries (Oste and Stör Rivers).

### 3.8.3.3 Hydroconstruction

As previously discussed, hydroconstruction was a major cause that prevented spawning migrations and finally led to the disappearance of the species in the Eider River (see above). In the lower part of the Oder River, hydroconstruction presently is no problem for the restoration measures (Gessner & Bartel, 2000). In the Elbe River, the weir at Geesthacht about 150 km from the mouth does not prevent spawning migration of the large migratory salmon (Fredrich et al., 1999). However, this barrier certainly would prevent spawning migration of *A. sturio* due to its dimension. Therefore, potential upstream

spawning habitats of *A. sturio* would actually not be available for the species. However, interest for modifying this barrier has been expressed by several administrative bodies. The Rhine River (van Winden et al., 2000), actually can be used as migration route up to the barrage of Iffelsheim, 700 km upstream of the mouth of the river. Therefore, the Rhine River will be important for restoration both for Germany and the Netherlands (van Winden et al., 2000).

#### 3.8.3.4 Alien species in German waters

Recent data on sturgeon catches (Gessner et al., 1999) indicate the presence of alien species (Arndt et al., 2000). Previous studies are demonstrating hybridizations among several sturgeon species (Birstein et al., 1997; Jenneckens et al., 2001). These species represent a certain risk for the restocking measures (hybridization may occur). The non-native catches indicate that the environmental conditions allow survival and even growth of these species. Therefore, it can be concluded that they also indicate favourable ecological conditions for *A. sturio*. However, no natural reproduction of non-native fish in Baltic or North Sea waters was reported until now.

#### 3.8.3.5 Fisheries regulations

Overfishing was an important impact for the decline of the species, and it is still considered a major threat for restoration measures in the North Sea (Nellen et al., 1994). Therefore, development of adapted fisheries techniques to reduce probability of bycatch of sturgeons in the coastal waters of the Oder River will be performed in co-operation with IGB and the Research Institute for Agriculture and Fisheries of Mecklenburg-Vorpommern.

#### 3.8.3.6 Experimental restocking

The sizes of single specimens of the German broodstock (Fig. 3.8.4) indicate first successful reproduction in a few years. The offspring are to be used for first experimental stocking trials, which would require sufficiently large fish for individual tagging. Released, tracking of fish for habitat analysis and identification of potential threats are envisaged. These measures will be an important element of the project as there are many issues concerning the ecology and the biology of this species which can only be determined with the help of the fish themselves.

#### 3.8.3.7 Public awareness campaigns

Continuation of increasing the public awareness on restoration of *A. sturio* in Germany will be an important element of the project aiming at the general public but especially at fishermen and other users of the resources.

#### 3.8.3.8 International cooperation

The restoration of *Acipenser sturio* in Germany is a long-term project that will only be successful in the frame of close and continuous international cooperation (see for instance Gessner, 2000; Kirschbaum, 2002; Kirschbaum & Gessner 2000, 2002). For the Baltic Sea, a project group of the HELCOM Habitat was established in 1997. The project group aimed at the preparation of the restoration in the Baltic Sea.

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