

Reasons for the decline of *Acipenser sturio* L., 1758 in central Europe, and attempts at its restoration

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ABSTRACT

Sturgeons are becoming increasingly threatened world-wide by commercial exploitation and environmental stress. A species that anticipated the development of the remaining sturgeon species is *Acipenser sturio* L., 1758. Since the end of the last century, diminishing stocks have caused severe concern with regard to the survival of the species. Several attempts at management measures have been suggested, but due to economic and political pressure, as well as to very limited knowledge on the biology of the species, rarely have any effective protection measures been taken. Conservationists and fisheries biologists in many countries had given up hope of saving the species from extinction after early attempts at artificial reproduction and restocking had failed. Additionally, protection and conservation of the species, until the 1990s, was at the national level only. Under these conditions, French researchers have set an example with a long-term recovery programme that also tries to close the gaps of knowledge in many fields of biology. Until the mid-1990s this was the only active approach to protect and save the species from extinction. Recently, the restoration and conservation of *A. sturio* have received increased attention in several countries. The impacting factors upon the decline, based on the data from Central European rivers, as well as their relevance for restoration, are discussed. The national and international attempts to protect the species are summarised. The evaluation of their efficiency and an outline of potential alternatives are also presented.

Key words: Atlantic sturgeon, management, protection, recovery.

RESUMEN

Razones del declive de Acipenser sturio L., 1758 en Europa central e intentos para su recuperación

Los esturiones están siendo crecientemente amenazados en todo el mundo por la explotación comercial y la presión ambiental. Una especie que anticipó lo ocurrido con las restantes especies de esturiones es *Acipenser sturio* L., 1758. Desde finales del siglo XIX, los mermados stocks han causado grave preocupación respecto a la supervivencia de la especie. Se han intentado diversas medidas de gestión, pero debido a las presiones económicas y políticas, así como al muy limitado conocimiento de la biología de la especie, raramente las medidas tomadas han sido de protección efectiva. En muchos países, los conservacionistas y biólogos pesqueros han perdido la esperanza de salvar a la especie de la extinción después de haber fracasado los primeros intentos de reproducción artificial y repoblación. Adicionalmente, la protección y la conservación de la especie, hasta la década de los noventa, se acometían sólo a escala nacional. Bajo estas condiciones, los investigadores franceses han constituido un ejemplo, con un programa de recuperación a largo plazo que también trata de llenar los vacíos de conocimiento en muchos campos de la biología. Hasta la mitad de los noventa, ésta fue la única perspectiva para la protección de la especie y salvarla de la extinción. Recientemente, la restauración y la conservación de *A. sturio* han recibido creciente atención en varios países. Se discuten los factores de impacto para su declive, a partir de los datos de los ríos centroeuropeos, así como su relevancia para la restauración. Se resumen los intentos nacionales e internacionales para proteger a la especie y se presentan la evaluación de su eficacia y un bosquejo de las potenciales alternativas.

Palabras clave: Esturión atlántico, gestión, protección, recuperación.

INTRODUCTION

Sturgeon conservation has been the object of growing interest during recent years worldwide (Rochard, Castelnaud and Lepage, 1990). Management of the sturgeon species is demanding, due to their long life-cycles and diversity of habitats. In addition, such programmes might prove their efficiency after 15-25 years only – a time-frame that is almost inapplicable for administrative policies. For the European Atlantic sturgeon *Acipenser sturio* L., 1758, management and conservation are even more difficult, because the major decline had already begun in the 19th century. For most sturgeon species, overfishing was considered to be one of the main threats to the stocks (Debus, 1997). Previously, the decline in *A. sturio* was also attributed solely to fishing pressure on the species. A closer look at the impact of environmental alterations caused during the Industrial Revolution has shown that this cause-effect relationship seems rather preliminary. Important reasons for the decline of the sturgeon should be identified more precisely in order to outline persistent critical factors, adversely affecting successful restoration.

WHAT IS RESTORATION?

Restoration is defined as the “Return to a healthy and vigorous state or to an unimpaired and vigorous position” (Fowler and Fowler, 1971), thus emphasising the quality of the alterations as the main criterion to separate restoration from other remediation options. According to the National Research Council (Anon., 1992): “The aim should be the restoration of the whole ecosystem, even if sometimes some particular components or attributes are emphasised”. In contrast, Bradshaw (1996) points out that “The endpoint of full restoration, although it might seem ethically the most justifiable and therefore the most obvious to adopt, may in fact not always be the most sensible in practical or biological terms”.

For *A. sturio*, any attempt to restore either stocks or habitat has to be preceded by an analysis of the reasons for the decline of the species, thus directly imposing demands upon planned restoration attempts.

CASE STUDY

An analysis of the reasons for the decline of sturgeon populations and the restoration requirements deriving therefrom is exemplified for the Elbe River, outlining mechanisms observed in Central Europe in general (Kirschbaum and Gessner, 2000).

Figure 1 gives the catch data of the lower Elbe River in northern Germany from 1858 until 1920. Since 1840 until the end of the 1880s catches from the Elbe River averaged 7 000 mature sturgeons annually.

Initially, the fishery targeted migrating adults in the river from April to July with a knot to knot mesh size of 20 cm, allowing fish of less than 1.5 m to escape. Since the 1870s, the number of fishing-vessels increased drastically (Koos, 1924), thereby decreasing the CPUE. Beginning in 1888, the catch declined drastically to approx. 50 % of the average return of the previous decades (Mohr, 1952). The fishermen therefore were moving to the lower estuary and the Wadden Sea (Blankenburg, 1910), not waiting for the fish to enter the river. A decrease in mesh size to 15 cm in the river and 12.5 cm in the coastal waters resulted in the increased catch of juvenile fish (Anon., 1914). In the 1890s, the proportion of marine and coastal catches therefore increased to 66 % of the total catch (Blankenburg, 1910). Despite the increased effort, the landings were decreasing continuously. After the First World War, the sturgeon fishery in the Elbe River was insignificant, being eliminated within 25 years.

In addition to the described fisheries-related impact, other human activities altered the environment for the species significantly (figure 2). Since the 11th century deforestation along the rivers has led to increased sediment transport, re-forming the deltas of large rivers such as the Vistula (Hoffmann, 1996). The anthropogenic impact was intensified throughout mediaeval times (mill-weirs and deposition of wastes), and peaked during the Industrial Revolution of the 18th-20th centuries (Schirmer, 1994).

Taking into account a generation period for *A. sturio* of 20-25 years (Elvira, Almodóvar and Lobón-Cerviá, 1991; Fernández-Pasquier, 2000), the critical period for the development of the stocks must have occurred before 1870.

Two major factors unrelated to the fishery could have contributed to this development. Firstly, the

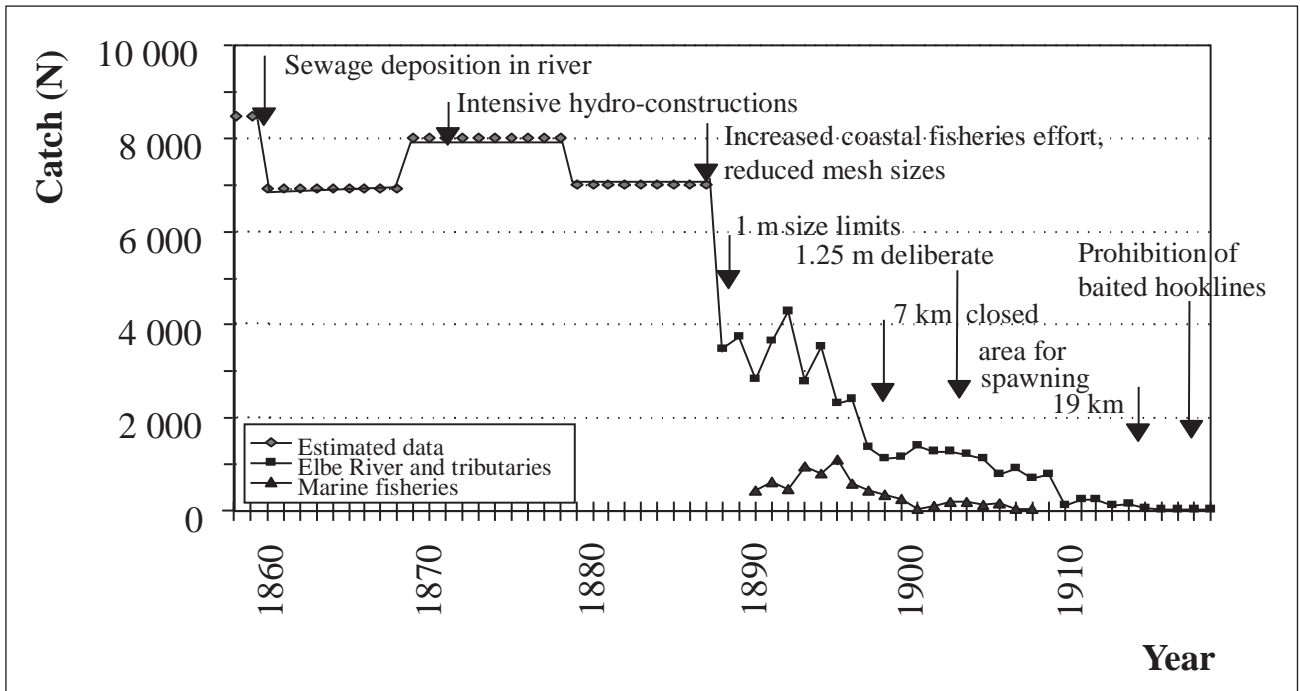


Figure 1. Sturgeon *A. sturio* catches in the lower Elbe River, its confluences and adjacent coastal and marine areas of northern Germany from 1858 to 1918; arrows indicate selected impact (after various authors)

cities of Hamburg and Altona began to dump their sewage into the Elbe River above the main spawning grounds at Koehlbrandt, in 1862 and 1868, re-

spectively (Bonne, 1905). Additionally, intensively developing industrial settlements along the Elbe (Kisker, 1926; Bonne, 1905) also utilised the river

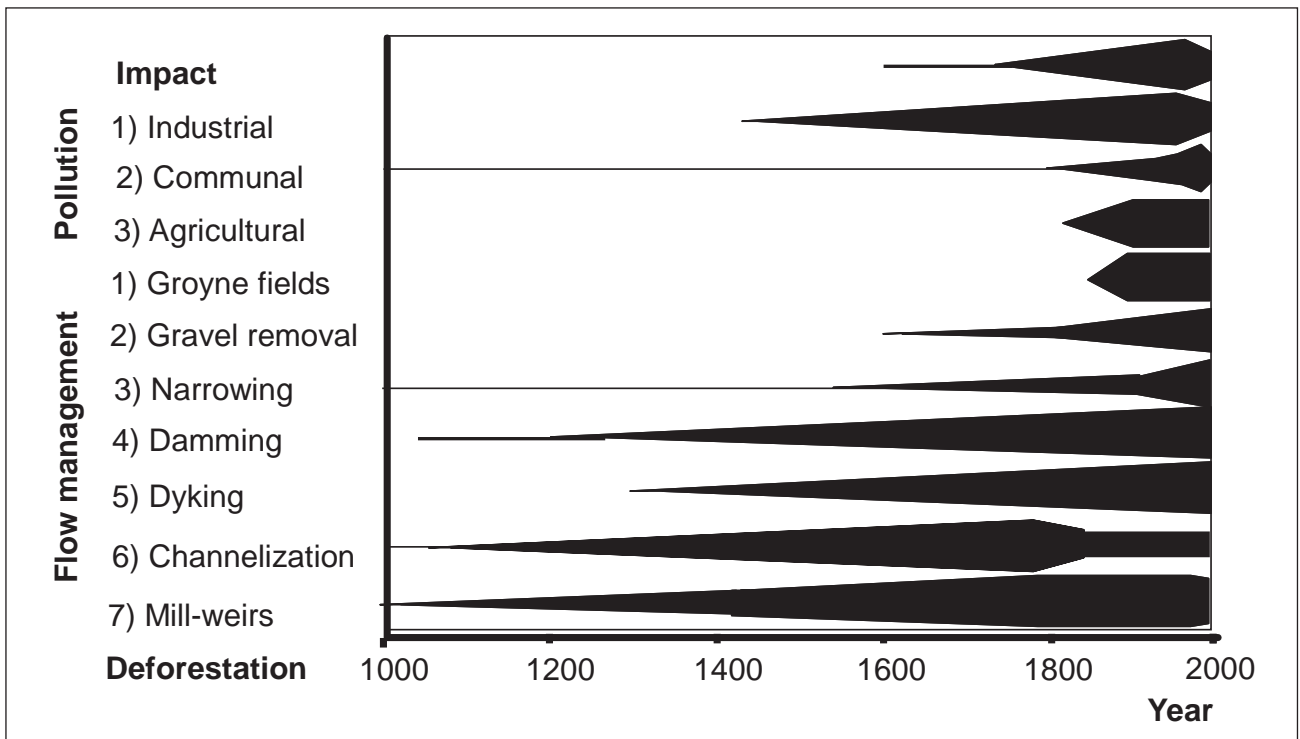


Figure 2. Development and relative intensity of alterations in river habitat in Central Europe over the previous 1000 years (after various authors)

Table I. Impact assessment for major anthropogenic influences on different life stages of sturgeons; factors were assessed for direct impact on life-cycle stage; effects classified as T = leading to total loss; (-): adverse; (o): neutral; (+): beneficial

Life-cycle stage	Pollution			River management							Fisheries
	Industry	Comm.	Agric.	Mill Weirs	Meliorations	Dyking	Narrow	Groyne	Subst. removal	Dam	
Maximum cumulative effect	T	T	T	T	-	T	T	-	T	T	T
Adult mating	-	-	o	o	-	o	o	-	-	o	-
Adult migration	-	-	o	-	-	o	-	-	o	-	-
Pre-adult	-	-	o	o	o	o	o	o	o	o	-
Juvenile	-	-	-	-	o	-	-	+	o	-	-
Fingerling	-	-	-	-	-	-	-	+	o	-	o
First feeding	-	-	-	-	-	-	o	+	o	-	+
Yolk-sac larvae	T	T	T	T	-	T	T	o	-	-	+
Embryo	T	T	T	T	-	T	T	o	-	-	+

to remove their production wastes. Since the 1860s this led to oxygen depletion, as was described in detail by Bonne (1905).

Secondly, increasing demand for mass transportation of goods and raw materials resulted in increased hydro-constructions (Keweloh, 1985), thus increasing the uniformity of the riverbed and leading to losses of important habitats (Kausch, 1996a, b). The potential impact of different habitat alterations upon the subsequent life-stages of sturgeons are given in table I, mainly reflecting a worst-case scenario.

These factors, interacting with fisheries pressure upon larger juveniles and adult fish, can be considered the main reasons for the decline of *A. sturio*, although certain fishing activities might have a positive effect upon early life stages by decreasing predatory pressure, as well as decreasing the concurrence for habitat and food. Anadromous fish stocks, as well as rheophilic species, were largely affected by the habitat alterations (Bauch, 1958). As a consequence of the changing environment, ubiquists became the dominant species and the typical fauna extirpated (Lozan *et al.*, 1996; Wolter and Vilcinskis, 1997). Here again, *A. sturio* seems to have anticipated the development for other species.

EARLY MANAGEMENT EFFORTS AND EFFECTS

Various catch regulations were applied throughout Europe. From 1273, regulations excluding *A. sturio* from common fishery rights are documented from the Baltic fresh lagoon (Benecke, 1881).

Management was mainly a question of the utilization of the resource, with the aim of increasing income from the fishery rights.

Management as a means to protect the resource was a reaction to the apparent decrease of the catches in the 19th century. The measures taken were comparable throughout the range of the species. Comparable restraints were anticipated when their application was attempted. Basically, three different management tools were used: catch regulations by size limits or mesh size limitations, closed areas, and the protection of the species by temporal or total inhibition of catches.

Figure 1 indicates the main measures taken in the Elbe River tributaries (after Blankenburg, 1910; Ehrenbaum, 1913, 1936):

- 1886 increase in size limit to 1.5-2.0 m neglected (too few juveniles in the fishery)
- 1890 size limit of 1.0 m
- 1904 deliberate size limit of 1.25 m by the fisheries co-operatives
- 1915 baited hook-lines prohibited in the Eider River (to avoid mass mortality of juveniles)
- 1918 baited hook-lines forbidden in the Oste River (see above)
- 1923 a size limit of 1.5 m after 9 years of ongoing debate was adopted
- 1924 size limit abolished

In other European regions, the struggle for the protection of the sturgeon was comparable. In the Gironde River basin (Trouvery, Williot and Castelnaud, 1984), for example:

- 1890 size limit imposed was 0.14 m
- 1923 increased size limit to 1.5 m

1924 reduction of size limit to 1.0 m (following protest from fishermen)

1939 size limit increased to 1.5 m

1950 size limit reduced to 1.3 m

1952 size limit of 1.45 m was agreed upon

Closed areas and closed seasons for sturgeon fisheries were applied in a variety of combinations for the Elbe River (after Quantz, 1903; Ehrenbaum, 1923):

1890 closed seasons from 26 July until 26 August

1898 Elbe River annually varying fishing leases to allow limitation of the fishing effort

1898 closed seasons from 15 July until 26 August

1898 Oste River, 7 km spawning sanctuaries where fertilised eggs were found

1904 fisheries ban after 1 August until the end of the year

1914 Oste River, 19 km of spawning sanctuaries

In the Gironde basin, the main measures, according to Trouvery, Williot and Castelnaud (1984) were:

1939 closed season during June/July (the fishery was still vital)

1950 closed season from July-December

1952 Gironde estuary transformed into a closed area

Summarising the fisheries regulations –especially the size limits applied– to protect *A. sturio*, they must be classified as ineffective. This was already known at the time when the size limits were discussed (Ehrenbaum, 1916). Sufficient size limits, which would have protected the spawners for at least one reproduction, were not applicable from a political point of view (*ibid*; Trouvery, Williot and Castelnaud, 1984). Closed areas, such as spawning sanctuaries, did not increase significantly the number of juveniles (Quantz, 1903; Koos, 1924).

CONSERVATION

A total ban of fisheries for sturgeons was first initiated by the Polish government in 1932 (Witkowski, 1992). In the former USSR, the necessity for increased protection of the species in the Newa River was recognised timely, as well (Berg, 1935). Since 1967, the species was protected at sea in the Georgian SSR (Ninua and Tsepkin, 1984). Attempts to artificially reproduce occasional catches of the species have been unsuccessful since the 1970s due to the unavailability of ripe fish of both sexes (Zarkua, pers. comm.).

In France, a total ban on fishing and marketing of the species was applied in 1982. Spain followed in 1983, with a total protection status for the species.

German attempts to conserve *A. sturio* had their onset in 1886 and 1891, when artificial reproduction and subsequent release of yolk sac larvae were carried out. Further trials failed due to the lack of simultaneous availability of ripe males and females. Comparable attempts were made in the Vistula area after 1906 (Seligo, 1907), and more recently in the Eider River, since 1953 (Spratte, 1994), without success.

Although various environmental alterations have been discussed as reasons for the decline of the anadromous fish species (Benecke, 1881; Volk, 1910; Schiemenz, 1913; Seligo, 1931), practical consequences for protection have not resulted.

CURRENT STATE OF STOCKS

Today, only one population with proven reproduction persists, in the Gironde and its tributaries in France. The situation of the population is described in great detail in the present volume (Elvira (ed.), 2000). One population, in extremely uncertain conditions, thrives in the Rioni River, Georgia. Furthermore, only single catches throughout the former range (Holčík *et al.*, 1989) have been confirmed for Lake Ladoga (Podushka, 1985), in Cadiz Bay (Elvira and Almodóvar, 1993), in the North Sea (Spratte and Rosenthal, 1996), and in the Baltic Sea (Paaver, 1997).

RECENT PROTECTION EFFORTS FOR *A. sturio*

General protection was considered only after the main phase of decline was witnessed and the stocks were reduced to an economically insignificant factor. The ban on catches throughout the range, their background and intentions, were not communicated to the fisheries effectively. Therefore, despite the protection status, sturgeons were caught and sold. Overall population sizes continued to decrease. Recent attempts in France, including public awareness campaigns, seem to have improved the interaction with fishermen significantly.

Active measures for the restoration of the population were begun in only one case while a stock was still present (Elie, 1997; Williot *et al.*, 1997). In other countries, fisheries biologists have long considered the extirpation of the species as an inevitable consequence of the alterations that followed the economic development of Central Europe and have only served as its witnesses (Nellen, 1992).

The disappearance of *A. sturio* was finally accompanied by its listing in the Red Books of the European Union. With the Washington Convention on Trade with Endangered Species, it was listed in Appendix I of the CITES Regulations in 1973. This attempt was aimed at prohibiting or strictly regulating international trade in the species.

Furthermore, the EU made an attempt to protect not only the species, but to provide measures to protect its habitat, when listing *A. sturio* as a species of special concern in Appendix II of regulation 92/43/EEC, thereby requiring measures for the restoration of habitat in order to protect the species.

Finally, the listing of the species in Appendix 2 of the Bern Convention in 1998 is aimed at the prohibition taking into possession of catches of sturgeon in international waters. This measure is extremely important, as outlined by Lepage and Rochard (1997), because the main losses from the population are attributed to the accidental captures in fisheries today. According to recent esti-

mates, these catches alone would be sufficient to extirpate the population in a course of approximately 15 years.

OUTLINE OF CURRENT REMEDIATION ATTEMPTS

The attempts or considerations for the protection and re-establishment of *A. sturio* in Europe are summarised in table II. In general, *ex-situ* measures, including the catch of fish in the wild and subsequent rearing under controlled conditions as a means of protection, are the general objectives. Most of the measures are aimed at restocking natural water bodies with the FI of these catches. The subsequent development of breeding plans based on sound genetical analysis and broodstock management is the next step necessary in this approach. Habitat assessments and recovery measures seem inevitable, given the reasons for the decline discussed above.

France

Since 1980, intensive activities to restore the Gironde stock of *A. sturio* have been carried out, including: stock assessment, habitat identification, artificial reproduction and stocking from artificially reproduced spawners, as well as social mediation

Table II. Current status of remediation efforts for *A. sturio* in Europe. (BSD): Broodstock Development (rearing of specimens to contribute to a broodstock in captivity, origin not defined); (ESM): *Ex-Situ* Measures (catch of animals from the wild and rearing under controlled conditions); (ER): Experimental Restocking (release of artificially propagated fish under current scientific control and assessment); (HI): Habitat Identification; (HR): Habitat Remediation; (RS): Restocking (release of juveniles after artificial reproduction); (SA): Stock Assessment; (SE): Stock Enhancement (support of native stock by restocking)

Country	Onset	Status	Main aims
Albania	1995	Suspended	ESM, BSD, SE
France	1980	Ongoing	ESM, BSD, HI, HR, ER, SA, SE
Georgia		In preparation	ESM, HI, HR, SA, SE
Germany	1996	Ongoing	ESM, BSD, ER, HI, HR
Hungary		In preparation	BSD, HI, RS
Poland		In preparation	BSD, HI, RS
Russia	1997	Ongoing	ESM, BSD, RS
Romania		Planned	BSD, RS
Spain		Suspended	?
Sweden		Planned	BSD, RS
Baltic Sea (HELCOM)	1997	Ongoing	ESM, BSD, HI, co-ordination of national programmes, enhancement of collaboration

of the recovery plan. The techniques and results are described in a series of publications, also in the present volume (Elvira (ed.), 2000).

Germany

Since 1994, the Society to Save the Sturgeon (*A. sturio*) has tried to develop and co-ordinate projects for the restoration of *A. sturio* in Germany and to increase scientific collaboration. The programme is presented in some detail in the present volume (Elvira (ed.), 2000). The measures comprise *ex-situ* measures, genetical analysis, broodstock development, optimization of rearing techniques, habitat assessments, and planned experimental release of fish after tagging with transmitters to assess habitat utilization.

Georgia

The documentation on the Rioni stock dates back to Marti (1939) and Ninua (1976). Until 1990, annual monitoring activities were carried out on the shelf, estimating the stock size to comprise 200-400 individuals of the age classes 2+ (Zarkua, pers. comm.). Since 1990, no further surveys or research on *A. sturio* have been conducted. Recent activities in conservation and stock assessment are limited to a critical extent by the country's devastating economic situation. During 1997 and 1998, fishing trials for migrating adults and juveniles have been carried out in an attempt to check the status of reproduction of this stock. Neither adults nor migrating juveniles of *A. sturio* were caught during these trials.

Remediation activities in other European countries

In other European countries, the interest in restoration or remediation of *A. sturio* has increased recently. Here, the main target is to re-establish the species in its previous range, with the increasing tendency to use the available material rather than hypothetical remains of historical populations. Anyhow, analysis of the *A. sturio* complex seems required to precisely define the species that was historically dominant in the area in question (Holčík, 2000). In most cases, the absence of *A. sturio* from the waters can be documented for a num-

ber of years, if not decades. All remediation attempts or plans mainly suffer from the unavailability of the species in question. This is an obstacle that in future years is very unlikely to be overcome on more than a very limited scale. This obstacle also prevents administrators and researchers for expending more efforts on the subject.

The CITES listing banned transfer over international borders, but commercialization persisted (Germany 1992, Estonia 1996, UK 1998). Listing in EU directive 493/92 provided the legal status for future implementation which should lead towards the urgently-needed effective, active protection in European waters.

CONCLUSIONS

Information requirements

The anthropogenic impact on *A. sturio* was not assessed in quantitative or qualitative terms (Riedel-Lorje and Gaumert, 1982). Cause-effect relationships or rankings of effects on population dynamics are available neither for the impact of pollution nor the effects of hydro-construction. Today, the available resources are restricted to only one confirmed population with irregular natural reproduction –thus limiting the potential for experimental work on the species. Additionally, general transfer of information between different sturgeon species is of limited applicability, due to differences in behaviour (Jatteau, 1998). In any case, the potential for transfer of results from *Acipenser oxyrinchus* Mitchill, 1815 to *A. sturio* should be the subject of further research.

Broodstock development is essential in order to obtain stocking material, but requires the development of management plans (US Fish and Wildlife Service) (Anon., 1995; Elie, 1997). Furthermore, problems related to rearing *A. sturio* in captivity have been described recently (Williot *et al.*, 1997; Kirschbaum and Gessner, 2000), and are as yet unresolved.

Research targets

The main factors to be dealt with in the near future are the genetic characterization of remaining as well as missing/extinct populations (Holčík,

2000; Ludwig *et al.*, 2000). This is urgently required to outline the status of the species and to support the development of breeding programmes to increase genetic heterogeneity.

The physiological requirements of the species have to be determined for successful rearing. In order to improve the security of *ex-situ* measures, biotechnologies such as cryopreservation, androgenesis and gynogenesis should be focused upon in order to evaluate their potential for the conservation of genetic heterogeneity.

Furthermore, a variety of topics concerning the environmental interaction and ecology of the species requires in-depth research, e.g. an assessment of the reasons for the decreasing fertility of male sturgeons in the Gironde described by Williot *et al.* (1997).

Targeted management strategies

Ex-situ measures seem to be the only remaining tool to allow the species to survive, and to conserve remaining genetic heterogeneity. These measures should provide a sensible division of risk to protect available resources. Therefore, such research should be carried out under the joint responsibility of at least two countries working on restoration to allow effective management.

Improvement of rearing techniques aimed at achieving high survival rates and effective growth under *ex-situ* conditions should be stimulated to increase chances for success.

To improve future research and effective utilization of funds, increased international collaboration is considered highly necessary.

In order to improve public awareness, effective utilization of available communication channels to mediate the work to the public should be developed further.

Political targets

To date, international harmonization of activities and adoption of international agreements among the various countries involved are still lacking to protect the species effectively during its marine phase (Rochard, Lepage and Meauze, 1997).

To increase effective protection for the survival of migrants, to allow the long-term aims to be

reached and effective re-establishment to be successfully carried out, the initiative of the German government to list the diadromous sturgeon species under the Bonn Convention should be supported.

It is strongly recommended that the managing authorities adopt viable *A. sturio* populations as one of the main criteria for successful habitat restoration in European rivers.

In general, the inclusion of all anadromous fish species into the protection management of river basins should lead to a significant increase in effectiveness when approaching the restoration of habitat or ecosystems.

The development of an international pressure group to affect and influence political decisions is considered vital for the fate of this species in the future (Pustelnik and Guerri, 2000).

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