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Assessment of extinction risk and reasons for decline in sturgeon

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Abstract. Sturgeon populations in the Danube River have been affected by a combination of hydropower development, over-harvesting, habitat degradation from agricultural and industrial practices and from urbanization. The effects of these changes have been monitored on six sturgeon species inhabiting the Danube River. Two of them are resident species, while the other four migrate to the river for spawning. Atlantic sturgeon (*Acipenser sturio*) has completely disappeared from this region. Ship sturgeon (*Acipenser nudiventris*) is very rare in professional fishing catches. Beluga (*Huso huso*), Russian sturgeon (*Acipenser gueldenstaedtii*), stellate sturgeon (*Acipenser stellatus*) and sterlet (*Acipenser ruthenus*) are endangered with different levels of extinction risk. Here, we model the time dependence of the beluga and Russian sturgeon catch in the Serbian part of the Danube River. Predicted extinction of Russian sturgeon was estimated to fall around the middle of the century, and for beluga approximately at middle of the millennium. Suggestions for sturgeon conservation measures on a national level and coordination of all relevant institutions in Serbia are also presented.

Introduction

Sturgeons (Teleostei: Acipenseridae) are amongst the most threatened of fish species because of water pollution, habitat destruction and over-fishing for its much-prized caviar (Reinartz et al. 2003). All living species are listed in Appendix I or II of Convention on International Trade of the Endangered Species (CITES). Atlantic sturgeon (*Acipenser sturio*) and ship sturgeon (*Acipenser nudiventris*) have almost disappeared in the Danube River Basin. Better regulation of the existing fishery on some sturgeon species (beluga – *Huso huso*, Russian sturgeon – *Acipenser gueldenstaedtii*, stellate sturgeon – *Acipenser stellatus*, sterlet – *Acipenser ruthenus*) in the Lower Danube Region and developing aquaculture in some European countries since 1990 (Arndt et al. 2002), could offer a chance for concentrating efforts of scientists and managers through Europe to support the preservation of this valuable resource and to maintain overall biodiversity.

River regulation in the Djerdap region in the period 1890–1896 prevented sturgeon from reaching the upper part of the Danube River (Petrovic 1998).

More recently, dam building has affected sturgeon, with 50% of all dams in Eurasia constructed during the period 1960–1980 (Williot et al. 2002). Dams block free access to many sturgeon-spawning grounds and, therefore, are considered to be one of the main reasons for the decline of their stocks (Lenhardt et al. 2004a). The construction of a hydro-energetic system in the region of Djerdap gorge resulted in formation of two reservoirs with a total area of about 25,000 ha (Jankovic 1994). Djerdap I was constructed in 1970 and Djerdap II in 1984, at the 943 km and 863 km locations, respectively. A complex of technical and ecological factors have caused a series of great changes in the aquatic ecosystem. Partitioning of the Danube River caused changes in distribution of fishes as well as changes in commercial fishing practice (Jankovic 1993). Construction of Djerdap II shortened the migratory route of the Black Sea migratory species to 863 km (Navodaru et al. 1999).

The discharge of industrial, agricultural and domestic wastewater into the environment results in the pollution of aquatic ecosystems. Fish are often exposed to highly contaminated water that leads to different changes ranging from biochemical alterations in single cells up to changes in the whole population (Bernet et al. 1999). In a study performed by Lenhardt et al. (2004b), connections between unacceptable concentrations of heavy metal and anthracene in sediment and sublethal histopathological changes on gill, skin and liver in sterlet populations were found. Studies on sterlet in the Danube showed an increase in activity of superoxide dismutase and glutathione peroxidase, as a result of the presence of certain contaminants in the ecosystem, originated from the Danube-Oil refinery (Stanic et al. 2004).

According to Williot et al. (2002), the main reason for the constant decline of sturgeons in the Volga River, from the 1970s onwards, is the detrimental effect of poor water quality on survival of juveniles. The deleterious effects of pollutants in the Volga, the Ural River and the Caspian Sea as well, were extensively highlighted in eggs, larvae and adult fish, and are now recognized as major threat (Khodorevskaya et al. 1997). Pollution of the Northern Caspian Sea and adjacent land and rivers (Volga and Ural) is most likely responsible for that situation: the petrol and gas industry being an important source of disturbances as well as biocides from agriculture and many other xenobiontes (Williot et al. 2002). The Black Sea is considered to be one of today's most endangered seas, particularly affected by river nutrient discharges, with 70% of them coming from the Danube River. Increased nitrogen and phosphorus inputs led to frequent hypoxic and anoxic events and decrease of zoobenthos and macroalgae stocks in the Black Sea shelf (Humborg and Kölle 1999), which can seriously affect both juvenile and adult sturgeons.

The last decade of the 20th century was a very stormy period, both politically and economically, for countries in the Lower Danube Region. Since 1990, fishing effort has been increasing in the Lower Danube Region because there is no regulation, except in Serbia (Navodaru et al. 1999). The major factor driving unsustainable legal and illegal sturgeon fisheries in this region is the fact that beluga caviar is one of the most prized fish products worldwide (Nikcevic et al. 2003).

In this work the beluga and Russian sturgeon catch data in the Serbian part of the Danube River was modeled to obtain a prediction of extinction risk for these species. We also discuss the threats to other sturgeon species. Suggestions for possible cooperation among scientific institutions, ministries and other stakeholders to achieve sturgeon conservation in Serbia are then presented.

Materials and methods

Catch data in Serbia, for the period 1960–1997, were obtained from the Serbian Institute of Statistics. All data are related to the catch in the Serbian part of the Danube River from 991 to 845 river km.

The time dependence of beluga and Russian sturgeon catch was modeled as a process consisting basically of three components:

1. steady-state;
2. sinusoidal spontaneous oscillation; and
3. exponential extinction process.

The actual 5-parameter analytical expression with which the data were fitted was

$$I(t) = [A\sin(2\pi f_r t + \varphi) + c]e^{-k_e t}$$

where $I(t)$ denotes annual sturgeon catch expressed in total weight (kg); A, f_r and ϕ – amplitude, frequency and initial phase of the one-frequency spontaneous oscillation, respectively; c – steady-state level; and k_e – extinction coefficient.

In this work we suggest this particular model as a mathematical description of the fish catch time-dependence by observing the data profile itself. Namely, it was noticed that, without the extinction component, population of both species would exhibit a relatively simple oscillatory pattern (with one dominant frequency), superimposed on a steady-state level. When introducing the extinction process into the model, population decrease should affect both the amplitude of the oscillatory component and the steady-state. Therefore, it was logical to model the whole process by multiplying both of these components by an exponentially decreasing function.

During this period, an impulse-like increase of fish catch was observed in six of the years (1966, 1967, 1968, 1975, 1982 and 1983). All these impulses, (except 1975), were consequences of the Djerdap dam construction. Raw data for these years were replaced with values obtained by linear interpolation between adjacent raw values. Non-linear fitting of the impulse-free data was performed using the Nead–Melder simplex algorithm, in Matlab 6.5.

Results

Beluga, Russian and stellate sturgeon

The change in catch in the Serbian part of the Danube River (Figure 1), during the period 1960–1997, was mainly induced by building of two dams (Djerdap I and Djerdap II). The start of construction of the Djerdap I dam prevented migrations of Acipenseridae and, at first (during 1966–1968), there was a pronounced increase in catch of all three species. By the time Djerdap I dam was finished, however, stellate sturgeon was rarely caught and a similar thing happened with Russian sturgeon after completion of the Djerdap II dam (Lenhardt et al. 2004a).

Unfortunately, there was only enough data available for beluga and Russian sturgeon to allow modeling. Results of the fitting process are presented in Figures 2 and 3. In this model the oscillation periods for beluga and Russian sturgeon are similar (21.89 and 27.12, respectively). However, extinction coefficients, k_c, are remarkably different (0.0074586 for beluga and 0.063308 for the Russian sturgeon). These numerical results, as well as the graphic form, indicate that for Russian sturgeon the danger of extinction could be estimated to fall around the middle of the century. For beluga, on the other hand, analogous analysis points towards the middle of millennium (small plot inserted on Figure 2).

Sterlet, Atlantic and ship sturgeon

In the Serbian part of the Danube River, the last specimens of Atlantic sturgeon were registered in period 1948–1954, two in 1948, one in 1950, one in 1952 and two in 1954 (Ristic 1963). Nowadays, it occurs on the Eastern coast of the Black Sea, and it is still found in the area adjacent to the Inguri and Rioni Rivers (Bacalbasa-Dobrovici and Holcik 2000).

The last findings of the ship sturgeon (*Acipenser nudiventris* L. 1828) in the Serbian section of the Danube River were in period 1948–1954, when only five specimens were registered (Ristic 1963), with one recent finding in 2003, in the Danube at 1401 river km (Simonovic et al. 2005).

Sterlet catch experienced significant decrease in Serbia during the 20th century. Comparison of sterlet catch in the period 1948–1967 and 2002–2003 showed a shift towards lower length classes in recent years, as well as changes in the shape of the frequency distribution curve (Lenhardt et al. 2004c).

Sturgeon conservation

Sturgeon conservation in Lower Danube Region should include both national and regional conservation programs. On a transboundary level in Lower Danube Region, sturgeon trade is regulated by CITES, while the International Commission for the Protection of the Danube River (ICPDR) and International Association for Danube Research (IAD) could serve as moderator organizations; ICPDR on an intergovernmental and scientific level and IAD on a scientific level.

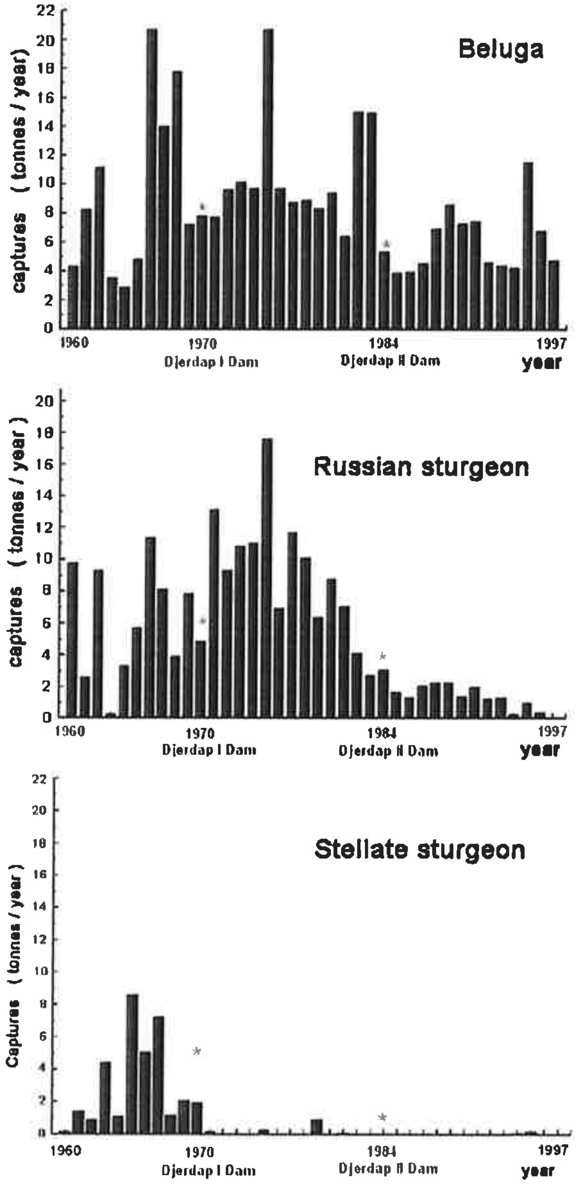

Figure 1. Sturgeon captures in Serbia from 1960 to 1997 [data from the Serbian Institute of Statistics]; asterisks on figures represent time of Djerdap I and II dams building.

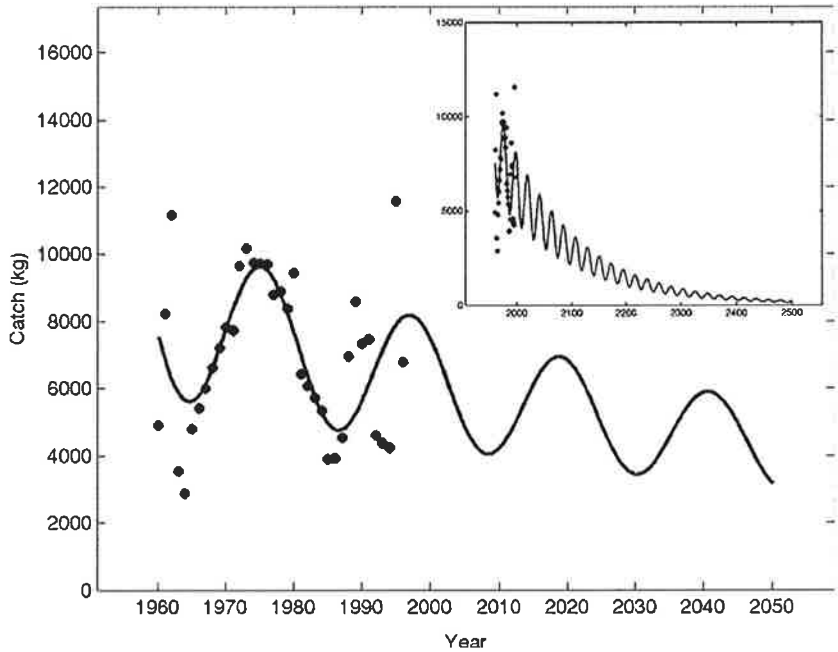

Figure 2. Experimental data (circle) for beluga catch (1960–1996); sinusoidal oscillation model with exponential extinction (solid line), after nonlinear fitting of its five parameters 1960–2050, main plot; 1960–2500 small plot inserted in the upper right corner. Parameter values obtained: $A = 2489.95$; $f_r = 0.045678$; $\varphi = 3.444$; $c = 8284.0298$; $k_e = 0.0074586$.

On the national level in Serbia, the Ministry of science and environmental protection of Republic Serbia has a key role in protection of sturgeon. Nowadays it coordinates activity relating to sturgeon conservation. Scientific institutions are working on an Action Plan for sturgeon in Serbia, on the basis of existing data on catch statistics and scientific investigations. This Action Plan will include all relevant scientific institutions, holders of fishing rights, sturgeon hatcheries and aquaculture, as well as nongovernmental organizations, which are responsible for public awareness, especially in local communities (Figure 4).

Discussion

The Danube is still important for sturgeon populations, because it still provides access to spawning habitats and enables their successful reproduction. Recent surveys of juvenile abundance confirm that beluga is still reproducing in several reaches of the Lower Danube (Vecsei et al. 2002). Continued spawning success of this population almost certainly results from the relatively lengthy expanse

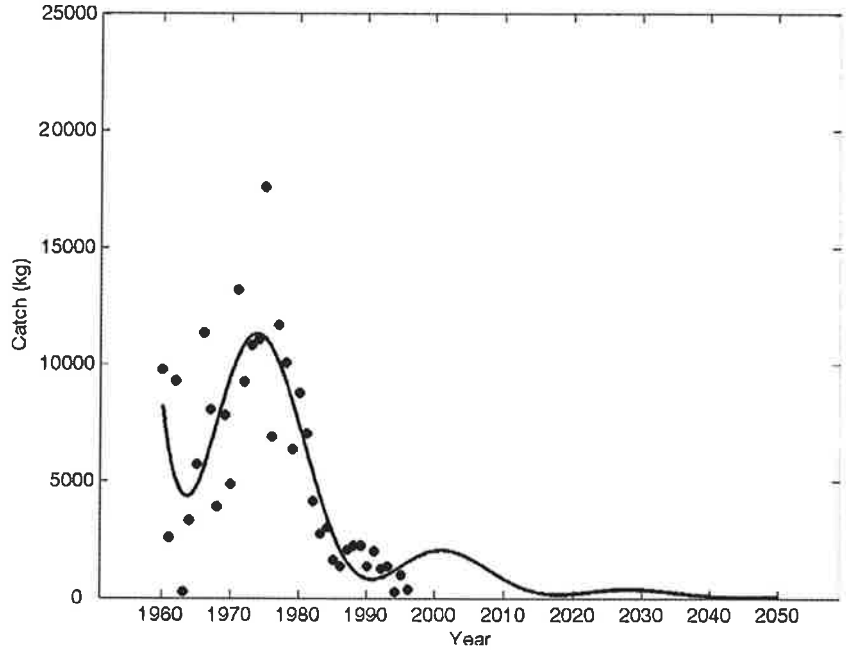

Figure 3. Experimental data (circle) for Russian sturgeon catch (1960–1996); sinusoidal oscillation model with exponential extinction (solid line), after nonlinear fitting of its five parameters 1960–2050. Parameter values obtained: $A = 12100.2576$; $f_r = 0.036879$; $\varphi = 4.0052$; $c = 17449.6982$; $k_e = 0.063308$.

(850 km) of uninterrupted spawning habitat available to beluga in this system. According to Kynard et al. (2002), there are at least five potential spawning sites of beluga in the middle part of the Lower Danube River, between 150 and 600 river km. Beluga spawning sites, situated in the sector downstream close to the Djerdap II dam, were established in 2002 (Vassilev 2003).

Extinction risks for beluga and Russian sturgeon predicted in this paper were based only on catch statistics. Knowledge of life histories and ecology, time-series analyses that examine changes in abundance and demographic analyses are three general approaches to assessing extinction risk (Dulvy et al. 2004). In this work we used catch time-series of 38 years to monitor changes in abundance of the mature part of sturgeon population. Life history and ecology, as well as demographic approach, could provide better estimation of extinction risk for these species. Paragamian and Beamesderfer (2004), based on demographic analysis with data collected from 1978 through 2002, predicted that the wild white sturgeon population in the Kootenai River would be nearly extinct within 30 years. As opposed to existing highly developed statistical population models like MULTIFAN-CL (Fournier et al. 1998) or SEPODYM (Bertignac et al. 1998), our model is relatively simple

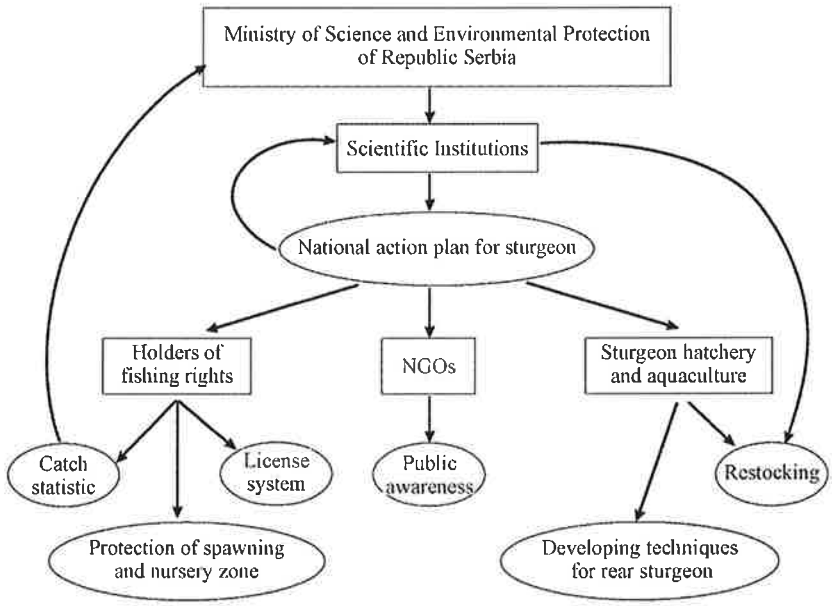

Figure 4. Flow chart presenting institutions and tasks needed to achieve sturgeon conservation in Republic of Serbia.

and empirically based. It allows, however, future sophistication such as including climatic, physical and chemical environmental influences.

Differences in sturgeon population declines in this work could be partly explained by different lifespan – 118, 46 and 27 years for beluga, Russian and stellate sturgeon, respectively, as well as in the age at maturity. Gross et al. (2002) pointed out that differences among sturgeon species in the elasticity of life stage survival are largely due to differences in the number of years spent in the juvenile stage relative to the adult. Results in this work are related to extinction risks on a local level (the Serbian part of the Danube River) and additional analysis could be done to achieve results for extinction risks at a regional level.

Nowadays in Serbia relatively good conditions exist for a start of common action among state representatives, scientists, holders of fishing rights, fishermen and private sturgeon hatcheries to solve the problem of sturgeon extinction risk. The role of all interested parties will be defined by National Action Plan for Sturgeon. The main problem is that sturgeon recovery, as well as their extinction, is a multi-decadal affair. So, resources user groups must be patient enough to support recovery plans for species which will permit only small fisheries or for species that currently can only be captured by our imagination (Secor et al. 2002).

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