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Long-term changes of sterlet (*Acipenser ruthenus*) population in the Hungarian section of the Danube

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Abstract. Sturgeons had played an important role in the history of Hungarian fisheries, but due to over-fishing, followed by extensive river regulations and deterioration of habitats, there has been a considerable decrease in populations which are now on the verge of extinction. Sterlet (*Acipenser ruthenus*) is only a common species caught for commercial and recreational purposes. The main factors of sterlet population dynamics were evaluated according to the new international efforts for sturgeon conservation. A moderate correlation was confirmed between the annual sterlet catches and the fluctuation of the hydrological regime of the Danube. Assessment of restocking activity and population recruitment demonstrated low efficiency of remedial measures for the Danubian sterlet.

INTRODUCTION

A number of historical records prove the importance of sturgeon fisheries along the Middle Danube from the Palaeolithic Age. Remains of large sturgeons were recovered from archaeological sites in the Iron Gate Gorge and in the Little Hungarian Plane (Bartosiewitz, 1997). These records indicate the role of the sturgeons in prehistoric nutrition 7000–9000 years ago and in the Roman Ages (1st to 4th century). In the Middle Ages, between the 11th and 16th centuries sturgeon fishery flourished along the Middle Danube, however, the regulation of sturgeon fishery became powerless during the 16th century, and most of the fish migrating to spawn for the first time were caught. The fishing mortality surpassed the recruitment of populations and this over-exploitation caused a decreasing trend in catches in the following centuries and the large sturgeon species became an occasional capture along the Middle Danube in the 19th century (Kriesch, 1876; Károli, 1877; Herman, 1887; Khin, 1957; Hensel & Holčik, 1997; Guti, 1998, 2006, 2008). Remnants of anadromous sturgeon populations have collapsed due to the blocking of their spawning migratory way since the construction of 'Iron Gate I' (1970) and 'Iron Gate II' (1984) hydroelectric dams. Nowadays great sturgeon (*Huso huso*) and stellate sturgeon (*Acipenser stellatus*) are practically eliminated from the Middle Danube and small stocks of ship sturgeon (*A. nudiventris*) as well as the resident form of Russian sturgeon (*A. gueldenstaedti*) occur sporadically. Sterlet (*A. ruthenus*) is the only common species caught for commercial and recreational purposes (Bacalbasa-Dobrovici, 1989, 1997; Hensel & Holčik, 1997; Reinartz, 2002; Guti, 2008).

The sterlet was formerly very abundant and regularly occurred from Regensburg to the Danube Delta. It inhabited most of the major tributaries of the Middle Danube: the Rivers Morava, Váh, Hron, Ipel, Rába, Dráva, Sava, Tisza, Szamos, Bodrog, Zagyva, Körös, Maros (Heckel & Kner, 1858; Herman, 1887; Sokolov & Vasil'ev, 1989; Hensel & Holčik, 1997; Reinartz, 2002). Nowadays, sterlet is the most widely distributed sturgeon in the Danube; however, it has been almost extirpated in the German and Austrian section of the river, where its occurrence depends on stocking (Zauner, 1997; Reinartz, 2002), and it has a limited distribution in the basin of the Middle and the Lower Danube (Hensel & Holčik, 1997; Reinartz, 2002). It is an endangered species according to the IUCN Red List (Kottelat & Freyhof, 2007), but it plays a remarkable role in the fisheries in the Hungarian section of the Danube. The catches were unbalanced in the last half century and the main factors determining changes in sterlet population were analyzed in relation to the international efforts for the conservation of the Danubian sturgeons (Bloesch *et al.,* 2005, 2006).

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METHODS

Changes of sterlet population was described by published catch statistics and personal interviews with fishermen. Data relating to long-term sterlet catch of the Hungarian fishermen were published (Jaczó, 1974; Tóth, 1979; Jancsó & Tóth, 1987) and Serbian catch statistics were obtained from the Serbian Statistic Institute. The Hungarian Angler Association provided further information on recreational catches. Cross-correlations were used to analyse retarded effects of water level fluctuations on annual yields of sterlet. Series of monthly water level data were gathered from the internet (www.datanet.hu/hydroinfo). The statistical analyses were performed using the PAST software package (Hammer *et al*., 2001).

Change in biomass of a year-class in the population can be estimated by data of growth and survival (Ricker, 1975). Growth data of sterlet were obtained from the Hungarian-Slovak section of the Danube (Kovrižnych, 1988). The mean of annual survival rate was calculated by age distribution data surveyed in the Serbian section of the Danube (Janković, 1958).

RESULTS

In the second half of the 20th century, annual catches of commercial fishery varied from 0.5 ton in 1956 to 12.7 tons in 1995 and averaged 3.2 tons in the Hungarian section of the Danube. The catches indicated a decline in the 1950s and 1960s and started to increase in the 1970s and were relatively high till the end of the 1990s. Since the beginning of the 21st century, the annual catch is below the average.

Data of commercial fishery indicated a notable inconstancy in longitudinal distribution of sterlet (Fig. 1). Well-known sterlet fishing sites are at Győr and Paks in the Danube, where catch is related to spawning habitats and traditions of commercial fishery (Pintér, 2002). In the 1950s and 1960s 78% of catch was originated from the lower part of the Hungarian section of the Danube (downstream of Paks, r.km 1560–1433) and 11–11% was caught in the upper (upstream of Esztergom, r.km 1850–1709) and middle (between Esztergom and Paks, r.km 1709–1560) parts, while in the 1970s when catches improved, 62% of sterlet was fished in the middle stretch and 33% and 5% in the lower and upper stretches, respectively (Tóth, 1979).

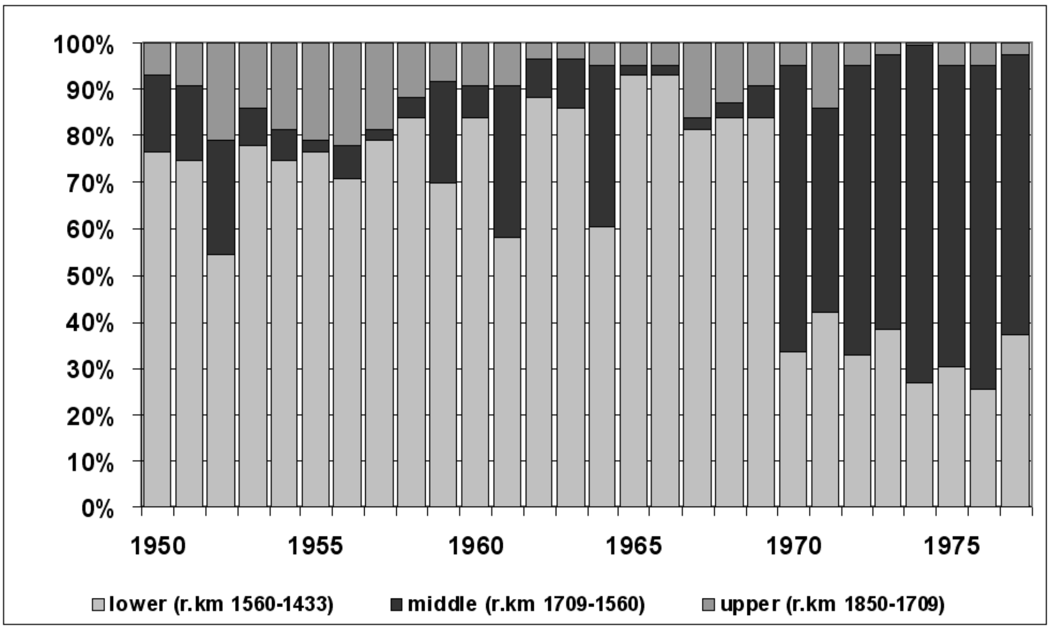

Figure 1. Relative catches of sterlet in three parts of the Danube in Hungary between 1950 and 1977

According to several fishery managers, artificial recruitments contributed to the improvement of sterlet catches from the 1970s. Regular restocking of sterlet started in the second half of the 1970s, when its artificial propagation was developed in Hungary. Individuals of young sterlet fry of 3–10cm were released in the Danube and Tisza in the 1980s; however, this restocking activity was not systematic and its documentation is incomplete. Estimated quantity of restocked juveniles varied between 10,000 and 100,000 specimens annually. Sterlet fry stocking has become occasional recently: 80,000 individuals in 1988; 3,000 in 1991; 5,000 in 1992, 20,000–20,000 in 1996, 1999 and 2000, and 60,000 in 2002 were released in the Hungarian section of the Danube.

The mean of annual survival rates (S = 0.54) was estimated by age distribution of 1246 specimens (age: from 3+ to 13+) collected in the Serbian section of the Danube (Janković 1958). In the event of the stocking of 0+ juvenile by 10,000 individuals (length 10cm, weight 8.7g), the expected biomass of the age group could weigh about 150kg when they reach the spawning maturity (5+) (Fig. 2). At the 5+ age the mean length of the individuals is close to the minimum size at which sterlet could be legally caught.

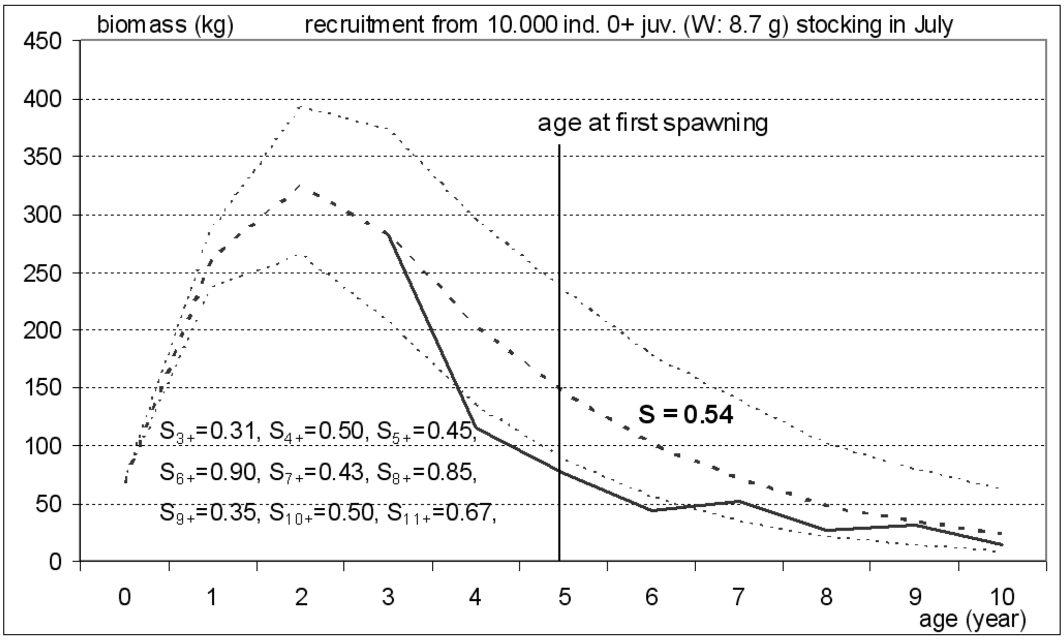

Figure 2. Course of change in biomass of a hypothetical year-class in sterlet population from 10,000 individuals of recruits at 0+ age in the Middle Danube (thick broken curve) according to an estimated mean survival rate (S). Thin broken curves mark standard error. Solid curve indicates the variation in biomass according to the calculated annual survival rates (S_{3+} - S_{11+}) (computation from data of Janković, 1958 and Kovrižnych, 1988)

Changes of sterlet population dynamics are presumably conditioned by the long-term fluctuation of the hydrological regime of the Danube (Fig. 3). Cross-correlation functions detected retarded effects of water level fluctuations on annual catch of sterlet between 1950 and 1977 in the Hungarian section of the Danube. Moderate significant negative correlation was recognized between the annual catch and water levels recorded 1–4 or 5 years earlier from March to June and September. In contrast, positive correlation was established between the annual catch and average monthly water levels recorded 10–12 years earlier in May (Fig. 4).

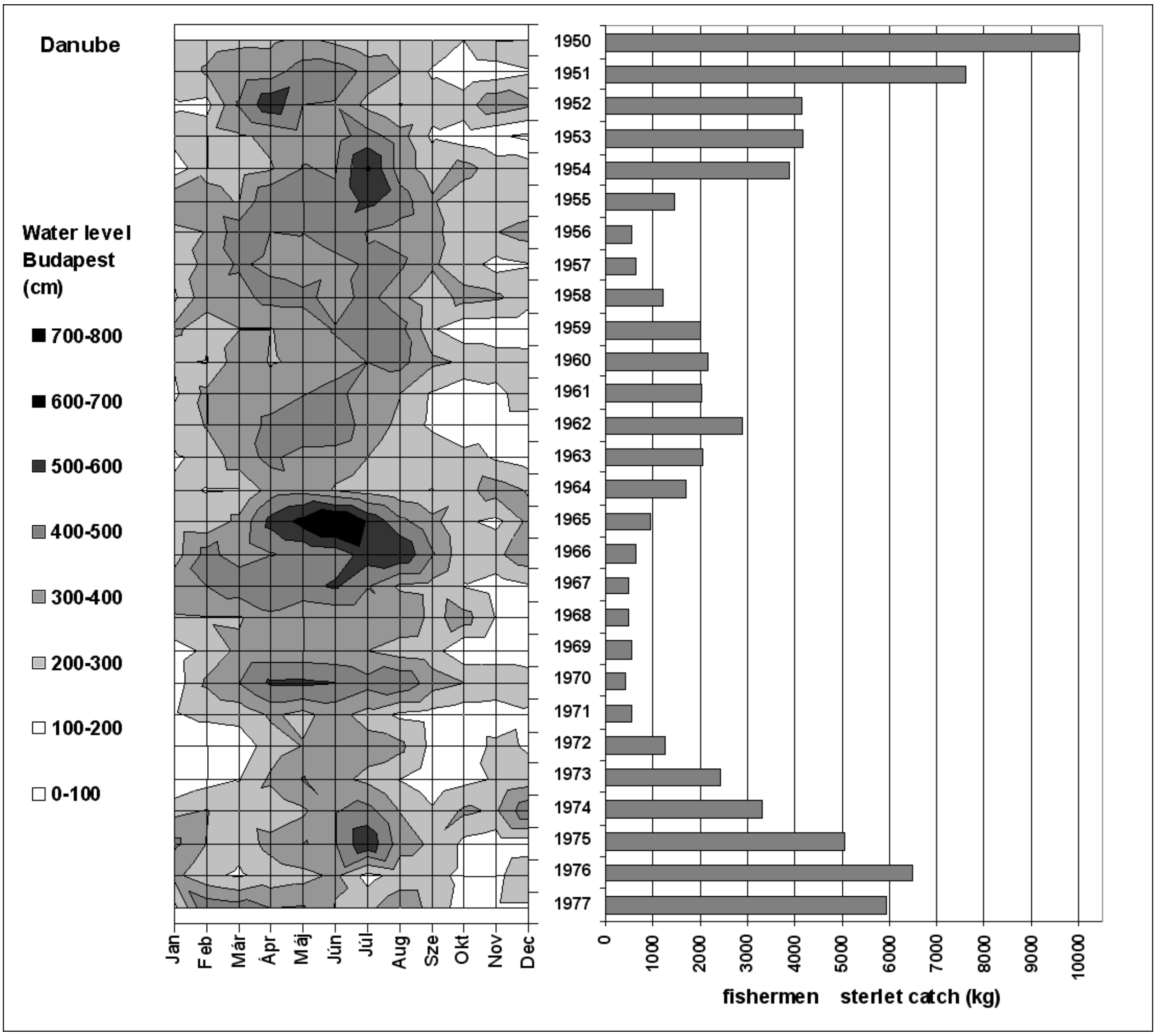

Figure 3. Changes of the average monthly water levels at Budapest and sterlet catches of commercial fishermen in the Hungarian section of the Danube between 1950 and 1977

The influence of hydrological regime on sterlet population is demonstrable by the correlation betwen water levels and catches. Considerable negative correlation ($R^2 = 0.90$) was established between the 5 year average of monthly low water levels and 5 year average of sterlet catches in the upper part of the Hungarian section of the Danube (r.km 1850–1768) in a forty-year period, between 1950 and 1990 (Fig. 5).

Temporal changes of sterlet catches can be related to habitat alterations. In the Danube stretch between r.km 1850–1768 sterlet catches began to improve in the 1980s (Fig. 6), when the mean annual catch increased from 0.15 tons to 2.0 tons (Jancsó & Tóth, 1987). However, catches declined sharply due to alteration of local spawning sites of sterlet after construction of the Gabčikovo hydropower station and annual catches of fishermen have been fewer than 10 specimens since 1992 (Guti, 2008).

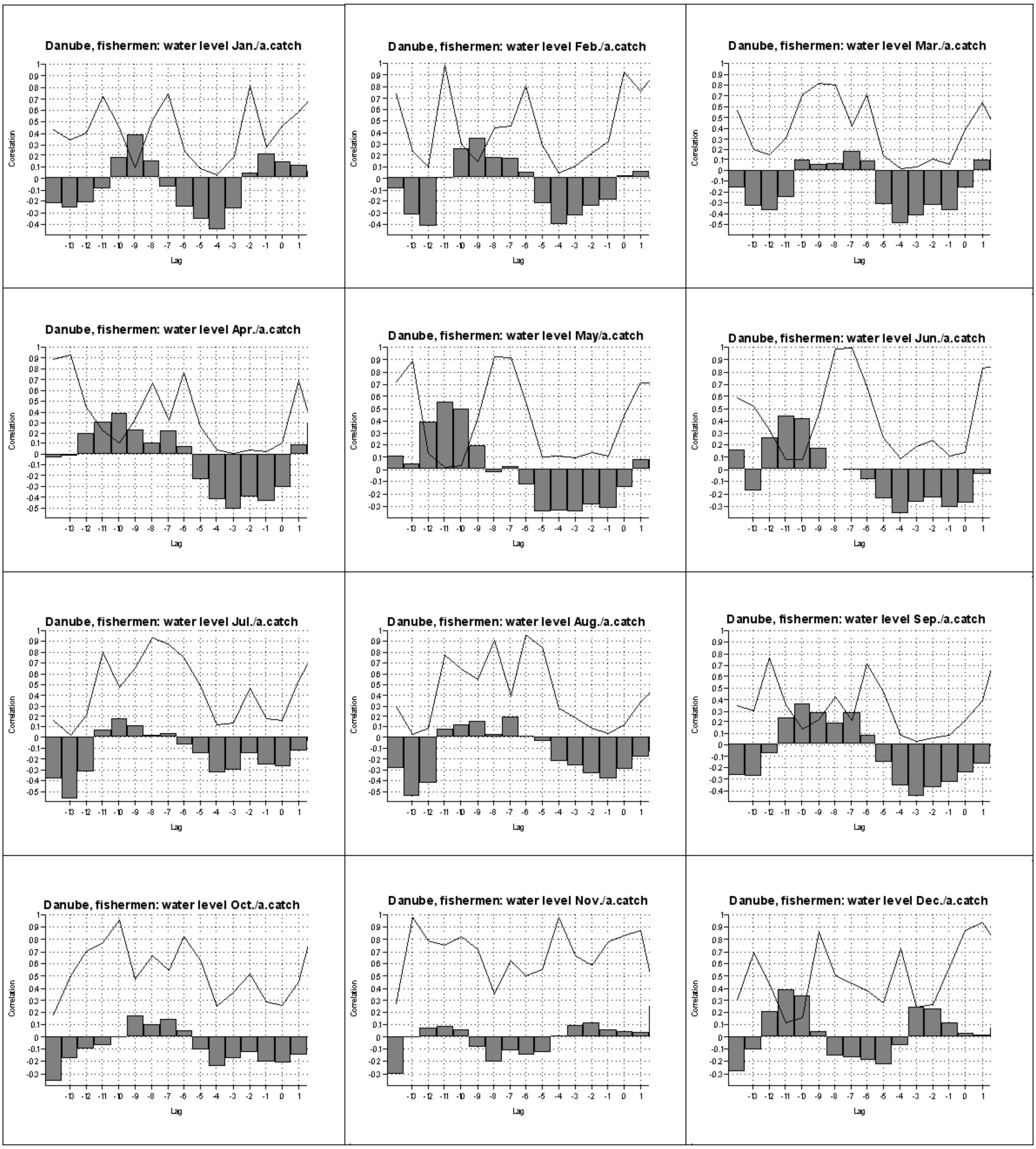

Figure 4. Cross-correlation between the average monthly water levels at Budapest and the annual sterlet catches of commercial fishermen in the Hungarian section of the Danube. The line marks the positive range of the confidence limit. The negative range is its mirror image. Lag number correspond to years

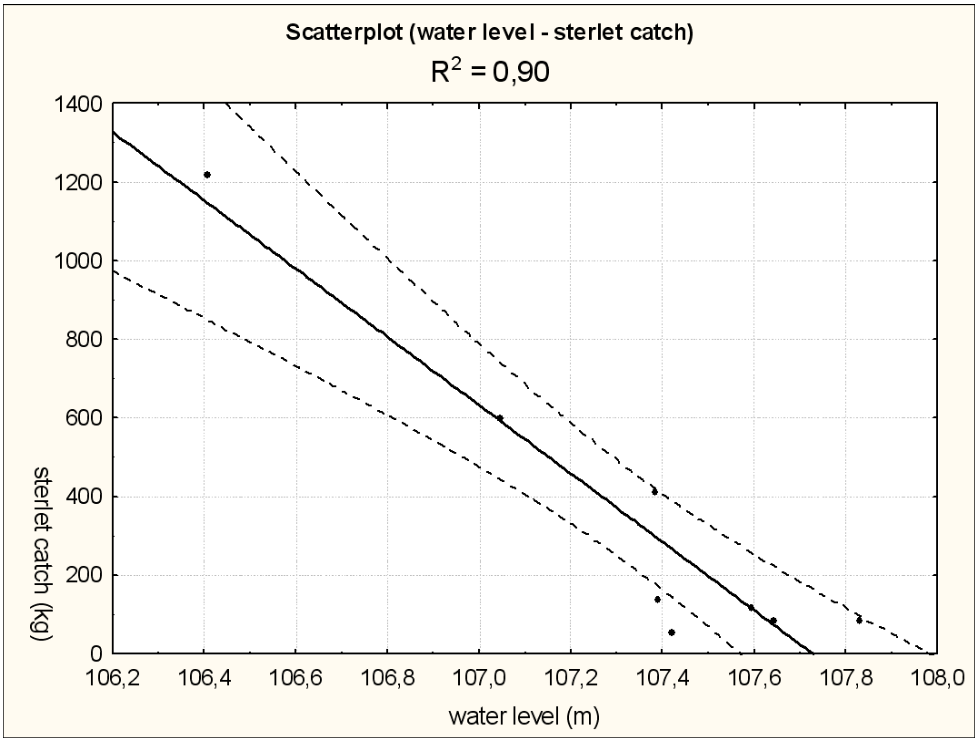

Figure 5. Correlation between the 5 year average of monthly low water levels at Gönyü and 5 year average of sterlet catches in the upper part of the Hungarian section of the Danube (r.km 1850–1768) between 1950 and 1990

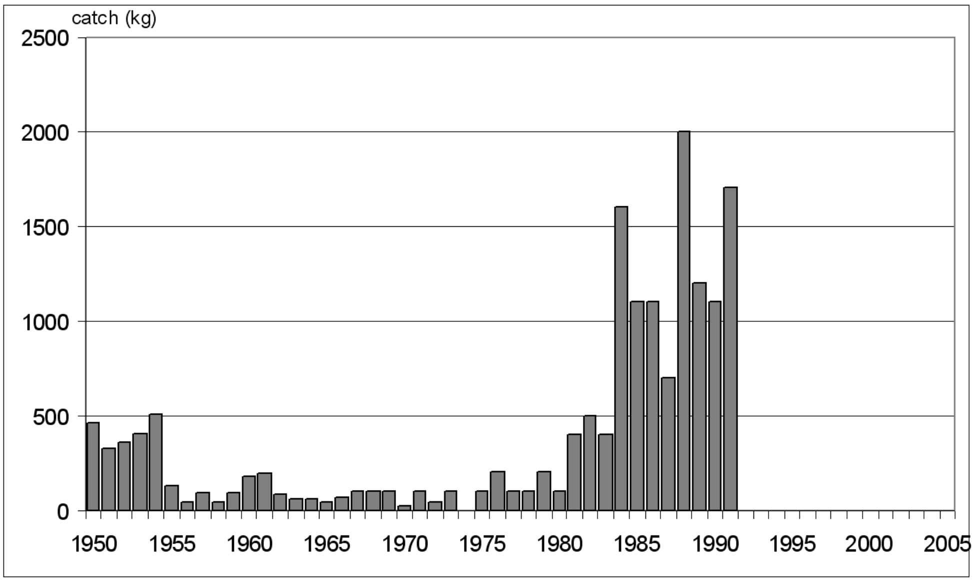

Figure 6. Sterlet catches of commercial fishery (data of the fishery cooperative of Győr) in the upper part of the Hungarian section of the Danube (r.km 1850–1768) between 1950 and 2005

DISCUSSION

The catch statistics indicate an unbalanced sterlet population in the Hungarian section of the Danube in the second half of the 20th century. The stock was partially recovered from the 1970s to the 1990s (Fig. 3, Fig. 6). According to several authors (Tóth, 1979; Pintér, 1991; Hensel & Holčik, 1997) the population increases in the 1970s were presumably due to emigration of individuals from the impoundment of the Iron Gate I dam, as well as the improving water quality and stocking of juveniles. In the fishing area of Smederevo in the former Yugoslavia (upstream of the Iron Gate I dam and downstream of the Sava tributary) a rapid and considerable increase (more than 6-fold) was observed in sterlet catches in 1973–1974 after the construction of the Iron Gate I dam; however, in the fishing area of Vojvodina (upstream of the Sava tributary) catch increased less (43%) in the same period but raised gradually in the second half of the 1970s. Sterlet catch had a similar trend in Hungary and there is a good correlation ($r = 0.82$) between the catches of the Hungarian and the Vojvodina sections of the Danube from 1969 to 1977. Therefore, catch statistics verify only a restricted upstream movement of sterlet from the Iron Gate dam to the upper part of its impoundment and do not confirm the presumption of sterlet migration to the Hungarian section of the Danube.

According to the general view of Hungarian fishermen, restocking program contributed to the improvement of sterlet catches. The quantity of restocked juveniles varied between 10,000 and 100,000 individuals from the second half of the 1970s to the end of the 1980s. The posterior output of this activity was about 150–1,500kg annual additions to the total biomass of the adult sterlet population (Fig. 2) in the 1980s and 1990s, but then again catches started to rise in the first half of the 1970s, before the beginning of the regular restocking program and the increase was more than 5,000kg between 1971 and 1976, that is significantly higher than the calculated artificial recruitment.

Remarkable fluctuation in sterlet catches (Fig. 3) may be related to temporal changes of essential habitats. Cross-correlation analysis indicates the retarded effects of the water levels on sterlet catches (Fig. 4). In river ecosystems, floods and droughts are primary sources of disturbance and restricted availability of spawning and nursery habitats may significantly impact on population recruitment and juvenile fish (Répássy, 1914; Kushlan, 1976; Poff & Allan, 1995; Wolter & Menzel, 2005). The significant correlation between the annual catch and the water levels recorded 1–5 years earlier during the spawning period leads to the conclusion that sterlet reproduction is more successful during low water level periods than floods. This supposition is confirmed by the high negative correlation ($R^2 = 0.90$) between the 5 year average of monthly low water levels and 5 year average of sterlet catches.

There are two kinds of sterlet spawning sites: the river bed and the fast flowing sites in the floodplain flooded by rising water. Spawning on the river bed occurs at a depth from 6 to 10m between April and May. The eggs are laid on mud-free pebbles 1 to 7cm in diameter, and rarely on gravel and sand bottoms. The current velocity at the spawning site ranges from 1.5 to 2.5m s^{-1} (Janković, 1958; Sokolov & Vasil'ev, 1989; Pintér, 2002). During a flood the increasing shear stress may destroy the eggs or juvenile specimens at the spawning and nursery sites.

Catches in the Szigetköz section of the Danube (Fig. 6) demonstrate the detrimental effect of sedimentation on sterlet reproduction. Nearly 80% of the discharge of the Danube has been diverted to the bypass canal of the Gabčikovo hydroelectric dam (r.km 1821) since 1992 (Guti, 1993, 2002). The extensive regulation altered the water flow and severely modified the sediment transport in the tributary of the Bagoméri sidearm (r.km 1810), which is the single spawning site of sterlet in the Szigetköz. The composition of the bed material has been heavily changed, 346,000m^3 silt accumulated in a 4km long section of the side arm from 1992 to 2005. The average sediment thickness on the spawning substrate is 60cm, the upper third of which consists of fine mud fractions (Rákóczi & Sass 2005). Changes of the spawning substratum can prevent the successful reproduction of sturgeons (Rochard at al. 1990, Auer 1996, Reinartz 2002), therefore the spawning site deterioration may be the main reason of the disappearance of the sterlet in the Szigetköz section of the Danube.

For conservation of the Danubian sterlet population, special and effective rehabilitation measures are needed. The existing legal measures, as temporal fishing ban or size limit cannot guarantee recovery of the threatened species. Restoration of the key habitats is an essential requirement. Considering the endangered Red List status of the sterlet and other sturgeon species, joint efforts of the Danubian countries are indispensable for the effective conservation of the sturgeons.

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