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Research Article

PRESENT STATUS OF STURGEON IN THE LOWER SAKARYA RIVER IN TURKEY

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ABSTRACT

The Hydro development started in the 1960s with building 3 major dams in the upstream section of the Sakarya River. During the 1980s the development of the floodplain sections of the river had its onset. Under these altered conditions *Huso huso, Acipenser nudiventris*, and *Acipenser sturio* disappeared from the river until the 1980s but *Acipenser gueldenstaedtii, as well as Acipenser stellatus,* were shown to still reproduce in the remaining section of the river by 2013. The construction of three additional HEPPs begun in the river section below Pamukova, blocking migration and cutting off major spawning sites. While fish passage facilities were included in the construction of the HEPPs since the 1980s, their design and location, as well as the maintenance rendered them completely dysfunctional. A survey was carried out in the remaining free flowing section of the lower river in 2014 to determine fish community composition and water quality at 4 stations below Adasu HEPP. While a few *A. gueldenstaedtii* juveniles were observed in Sakarya River mouth close to the Black Sea, only one young-of-the- (YOY) (*A. stellatus*; W:25g; TL:28cm) was reported which was captured from the Lower Sakarya River.

Keywords: Lower Sakarya River, Sturgeon, HEPP, Fish Passage

Introduction

Sakarya River is the third largest river in Turkey, its springs are located in the Anatolian mountains approx. 400 km west of Ankara and enters the Black Sea approx. 100 km east of Istanbul. It is 810 km long and up to-150 m wide. Sakarya River is defined hydrologically in three parts: upper, middle and lower. Sakarya River Basin is characterized by flood plain areas separated through mountain ridges. Sturgeon fishery was important in the Sakarya River mouth area (Karasu- Yenimahalle region) until the 1970ies (Anon, 1992). Arısoy (1968) reported that sturgeons spawned in the Sakarya River between February and June, while one month later, in August, sturgeon fingerlings were observed in the lower reaches to enter the Black Sea.

Over the past 50 years, hydropower was considered a priority development in Turkey, facilitating the supply of an industrializing society while minimizing the running cost and interdependence from oil and gas supplies. As a result, the first hydropower dams were constructed in the 1950s on the large rivers in Turkey, mainly those entering the Black Sea.

Dam constructions started in the middle part of Sakarya River basin after the 1950s, for hydropower generation, flood control and the management of the flow regime in the lower Sakarya River. After construction of the three dams Sarıyar Dam (1956), Gökçekaya Dam (1972) and the most upstream Yenice Dam (1985-2000), flow and sediment transport characteristics of the river changed drastically. It was observed that sediment transport was decreased by 40-65% after the construction of Gökçekaya Dam (Saltabaş et al., 2003; Doğan et al., 2016). By comparison of cross section measurements in 1965 and 2003, an enlargement in the width and scouring in the depth of the river up to 7 m were reported (Işık et al., 2006; Doğan et al., 2016).

Şengörür and İsa (2001) recorded that the Sakarya River basin is polluted by industrial wastes and sewer system, especially heavy metals such as Iron (Fe), Copper (Cu), Lead (Pb), Mercury (Hg) from the Çarksuyu area to the Black Sea. Gümrükçüoğlu and Baştürk (2007) reported that water quality levels in the lower section of Sakarya River below the Gökçekaya Dam to River Mouth were evaluated as 3rd class (polluted) based upon the NO2-N and BOD5 levels according to the Ministry of Environment and Urbanization (Official Gazette, 2004). Lower Sakarya River is classified as 3 and 4 (polluted to highly polluted) water quality due to the Nitrate and Total Phosphorus pollution (Anon. 2013).

Habitat degradation resulting from river gravel extraction, diking, as well as chemical load due to sewage, agricultural and communal nutrient input and industrial pollution decreased fish populations of Sakarya River. Besides human-made obstructions, toxins and heavy metals, pesticides and other polychlorinated hydrocarbons impose a major impact upon the fish communities (Anon. 2013).

Human activities on river including hydropower stations, water diversion, and over-fishing have resulted in the interruption of migration routes and effectuated a significant decline in the range and population sizes of sturgeon species in Turkey (Anon. 2013; Edwards and Dorosov, 1989; Rosenthal et al., 2015).

The development of hydroelectric power plants (HEPP) in the remaining floodplain sections started in the 1980s when low-head dams such as the Pamukova HEPP were constructed 150 km upstream from the sea to increase the energy yield. After the construction of migratory obstructions, A. gueldenstaedtii and A. stellatus were shown to still reproduce in the remaining section of the river by 2011. In 2012 the construction of three additional HEPPs (Doğançay I-II and Adasu) started in the river section below Pamukova, further reducing the remaining section of the free-flowing river to approx. 90 km. In the light of this development, this study focused the effects of the impoundments upon the fish community in the lower river section, the effect upon the water quality and the state of the nursery grounds to assess the potential of the remaining river section as sturgeon habitat.

Material and Methods

The sampling took place from April 2014 to September 2014 in a first attempt to evaluate the effects of the anthropogenic impacts upon the remaining sturgeon populations and their available habitat.

Study Area

This study was conducted in the lower Sakarya River in the Karasu Region at four stations (Figure 1). The first station was on the right bank of the river at 2.6 km from the Black Sea in Yenimahalle District (41°06'15.883"N; 30°38'45.023"E); The second station was 6 km on the left bank in Tuzla District (41°04'37.350"N; 30°38'14.234"E); The third station was at 17 km on the left bank in Akkum District (41°04'00.450"N; 30°36'14.593"E); And the fourth station was located at around 18 km on the left bank in Ferizli-Adatepe District (41°03'52.745"N; 30°36'28.250"E). The stations were chosen based on the experience of local fishermen about river fish catching areas.

Figure 1. Sampling stations in the lower Sakarya River Basin (Google Earth Map)

Fish Presence

Fyke nets were used at all four stations. The fyke nets were fixed on the bottom (180 cm depth) by stakes and had wings which guide the fish towards the entrance of the bags (FAO, 2001; Buysse et al., 2008). The nets had a mesh size of 70 mm and were made of polyfil nylon. The nets were produced by a local fisherman according to meet the size requirements for migrating mature sturgeon. The fyke net entrance was 140 cm in diameter; the nets were cone-shaped and had a length of 5 m and were equipped with 6 chambers. In order to catch sturgeons moving from the Black Sea to the Sakarya River between April and September (6 months), the net-openings were positioned to face the sea. Nets were checked once every week. Fish were identified as species level.

Additional sturgeon catch data were collected from regional fishermen after carrying out an information campaign. Fishermen were contacted individually and a reward for the catch information was established.

Water Quality

Dissolved oxygen (DO), temperature (°C) and pH were measured in situ by a portable WTW Multi-Parameter Instrument (Multi 3430 MultiLine IDS) in the late morning. A secchi disc (30 cm diameter) was used to determine water transparency. River depth of the sampling area was measured by a meter.

Benthos

The sampling stations were sampled for benthic fauna by using an Ekman-Birge grab (15x15 cm), sieved on a 0.5 mm mesh size and kept individually in plastic bottles preserved in 70% ethanol. Sediment samples were taken at triplicate at each station in every survey. Samples were washed with 0.5 microns 30 cm radius filters. Individual organisms were counted in 100g subsamples. Organisms were determined according to Brinkhurst (1963).

Statistical Analysis

The results were statistically analysed using SPSS v21.0 for Windows software. The statistical differences were determined using a one-way analysis of variance (ANOVA) followed by a Tukey's comparison test at $p<0.05$.

Results and Discussion

Physico-chemical parameters, transparency, depth of water and sediment sampling

The water quality (temperature, dissolved oxygen, and pH), transparency and depth at the sampling points in the Lower Sakarya River revealed that water temperature, dissolved oxygen and pH levels were similar between the four stations. There were no significant differences between water quality parameters of the sampling stations ($p>0.05$). Water temperature showed an average of 22.6 ±0.99°C between May and August and showed a marked decrease after August. The pH values reveal a stable level at around 7.7 ±0.1 but their development shows marked differences with larger fluctuations in the first 3 months of the sampling period in the upper three stations while the lower river values are rather stable. The oxygen contents at all 4 stations are low with an average of 4 ±1.16 mg/l (Figure 2). At mean water temperatures of 22.6°C, this reflects saturation levels of 50-55% indicating massive oxygen consumption through sewage and nutrient discharge.

On a monthly base, a gradual decrease in water transparency was observed for 4 stations with the highest values in April (53.7 ±13.7 cm) to the lowest in September (24.5 ±4.27 cm). Monthly changes in discharge were related to HEPP operation and did result in fluctuations of up to 80 cm between April and September.

Sampled sediment consisted of mud was dark coloured with organic decay odour. Bottom and turbidity surveys showed that from the Black Sea up to Akkum region (3rd station) there are high amounts of debris and decaying organic materials (plants, leaves, seeds, litter etc.) (Table 1).

During sampling, sediment samples from the sampling stations were analysed to evaluate the presence and composition of the macrozoobenthos serving as important feed organisms for sturgeon (Table 2). The samples taken were only comprised of oligochaete larvae (Brinkhurst 1963).

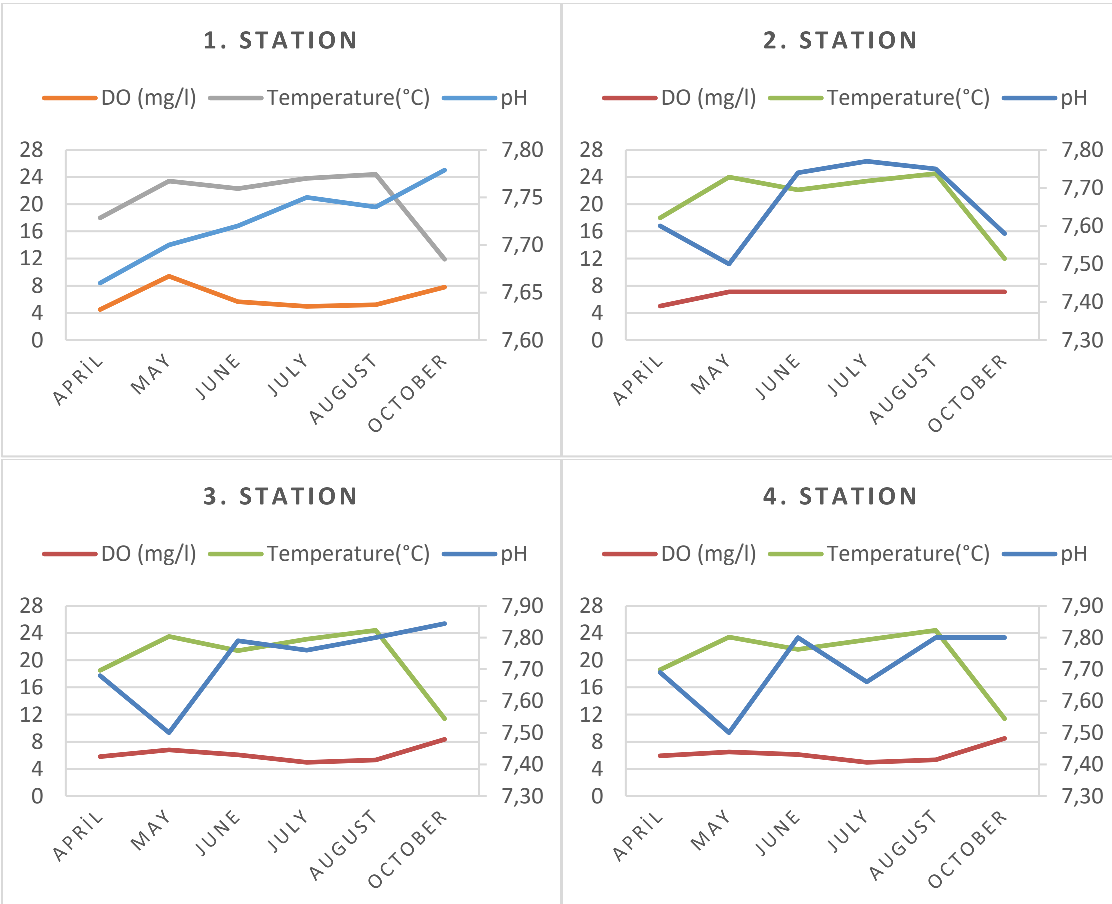

Figure 2. Water quality parameters (temperature (°C), dissolved oxygen (mg/L), pH) during the stations throughout the study.

Table 1. Description of the sediment sampling in stations in Sakarya River.

Stations	Sediment	Macrophytes
1	Mud	+
2	Mud	+
3	Organic mud	+
4	Mud	+

Table 2. Zoobenthic fauna (oligochaete larvae) and monthly changes of the Lower Sakarya River (mean number of individuals/100g/m^2).

Months	1.Station	2.Station	3.Station	4.Station
April	-	-	-	-
May	-	-	-	-
June	2	-	-	17
July	-	-	-	-
August	1	9	-	24
September	-	-	-	-

High population density in Sakarya River basin results in industrial and agricultural pollution in Sakarya River. Chemical parameters of the river are adversely affected by the pollutants as well as high heavy metal contents. Treatment facilities for industrial establishments and urban wastes should be mandatory and minimum discharge should be allowed to decrease pollution in this river. Erosion, silt, and sand coming from the river bed results in elevated turbidity and high suspended solid load in the water. Many sand quarries operating on Sakarya River, removing gravel from the river bed or from adjacent pits adversely affect the natural river bed through the removal of gravel and the input of fines (Anon, 2013). In the current study, we determined structural and physical activities on the Sakarya River and their adverse effects on fish populations and most importantly sturgeon fish populations.

Fish Composition

Fyke nets located at the four stations during the study determined nine fish species including; pike (*Esox lucius*), wels catfish (*Silurus glanis),* tench (*Tinca tinca),* common carp (*Cyprinus carpio*), Prussian carp *(Carassius gibelio),* mullet (*Mugil sp.*), common bream (*Abramis brama*), white bream *(Blicca bjoerkna)* and rudd (*Scardinius erythrophthalmus)*. The catches of the nine fish species mostly comprise a few or single individuals during the sampling periods (Table 3). There was no captured fish in fyke nets in April because of overflow. One fyke net was lost in the 2nd station. It was drifted by flood and a substitute fyke net was put at the same point. Sturgeons were the most famous and valuable fish in Sakarya River in the past 50 years. Recently, 11 fish species were reported from the lower part of the Sakarya River between 2011 and 2013 using fyke nets and gill nets (Akmirza and Yardımcı, 2014). *Rutilus rutilus* and *Barbus barbus* species were not found in all stations in this study.

Buysse et al. (2008) captured diadromous fishes with fyke nets in the Scheldt River (Belgium). They reported that exotic Siberian sturgeon (*Acipenser baerii*) were captured during downstream migration using mesh sizes of 8 mm. Fyke nets located on the migration route proved to be ineffective to capture sturgeons during the sampling period in the Sakarya River. The catch of other fish species by local fishermen varies largely between sites and months. Since a lot of sturgeons captured in the coastal waters were close to the Sakarya River mouth, it seems probable that both *A. gueldenstadtii* and *H. huso* originate from stocking or natural reproduction in the Danube and Ukrainian waters. The only exception is YOY *A. stellatus* caught on 31.09.2014 in the freshwater section of Sakarya River close to the river mouth (Table 4). Since the fish are caught in freshwater and are too small (25 g) to have migrated through full strength seawater over such a considerable distance (Khodorevskaya et al., 2009) it is most probable that this individual originated from reproduction in the river of the same year. Fishermen told that the catch of sturgeon with fishing rods and gill nets between the second and the third stations during the sampling period. Most fish were caught in brackish water along the coast at left and right side of Sakarya River Mouth.

This is verified for the tagged sturgeons with a CTW tag (Present or absent) in Table 4 which released from Danube River in Romania. During the study, a larger number of small stellate sturgeons were caught by local fishermen in the catching area out of which only one *A. stellatus* of 25g was made available (Table 4).

Table 3. Fish species captured with fyke nets between April and September 2016 at four sampling stations through the down Sakarya River

Months	1st Station	2nd Station	3rd Station	4th Station
April	-	-	-	-
May	Pike	-	-	Wels, Prussian carp, Tench
June	-	Wels, Common carp	Wels, Common carp	White bream
July	-	Chub	wels	
August	-	-	Chub	Common bream
September	-	-	Common bream, Mullet	-

Table 4. Reported by-catch sturgeon species inside and around Sakarya River mouth.

Date	Species	Live Weight (g)	Total Lenght (cm)	CTW tag Present (P) or Absent (A)
24 August 2013	*A.stellatus**	1000	30	A
15 May 2014	*H.huso*	1520	65	P
July/September 2014	*A.stellatus***	-	-	A
31 September 2014	*A.stellatus****	25	28	A
7 November 2014	*A.stellatus*****	-	-	A
28 November 2014	*A.stellatus*	258	48	A
25 November 2015	*A. gueldenstaedtii*	300	46	P
25 November 2015	*A. gueldenstaedtii*	245	43	P
25 November 2015	*A. gueldenstaedtii*	285	47	P
25 November 2015	*A. gueldenstaedtii*	265	45	P
24 February 2016	*A. gueldenstaedtii*	812	61	P
24 February 2016	*A. gueldenstaedtii*	504	51	P
24 February 2016	*A. gueldenstaedtii*	411	47	P
24 February 2016	*A. gueldenstaedtii*	538	49	A
02 March 2016	*A. gueldenstaedtii*	-	-	A

*Stellat sturgeon captured by amateur fishermen by fishing rod inside the river.
**All *A.stellatus* samples informed by fishermen inside the Lower Sakarya River and they released them (around 40 individuals) during these periods.
***Only one small live stellat sturgeon which captured from the Sakarya River with a gill net.
**** This fish reported by Adasu HEPP's worker which they saw dead stellat sturgeon below the Adasu HEPP.

Investigated HEPPs and Man-Made Structures on Sakarya River

The investigation of HEPPs was conducted between the Sakarya River mouths to Pamukova Regulator. This covered 154 km river length. Pamukova Regulator and HEPP, Doğançay Regulator and HEPP I, Doğançay Regulator and HEPP II, Adasu Regulator and HEPP were investigated onsite for suitability of sturgeon migration and fish passage availability. Details of the design of fish passages were not shared by the companies during the investigations. All passages were either vertical slot designs or baffle designs and comprised two passes, one with 20 m length to overcome the spillway and the second pass of 50 m lengths that was intended to overcome the dam section. Passage facilities covered a height of 10m over 50m length, were equipped with very small chambers of 0.6m length and 20X20cm baffles which were not suitable for sturgeon. In all passage facilities, the migration pathways were either not connected to the downstream aggregation areas, were blocked by building material, did not receive sufficient water flow or were disconnected from the water level upstream of the HEPPs. The legislation states that "water discharge from a HEPP construction should at least be 10% of the last 240 decade's average natural water flow". In addition, upstream fish passages/ladders are mandatory to ensure uninterrupted fish migration for HEPPs and regulators (Anon, 2013). Yet, their functionality is not monitored and the enforcement of retrofitting is missing. As such the biggest problem on Turkish inland water resources in the last decade had resulted from the energy production with HEPP installations. Emerging need for energy resulted in a disregard for the environment and lack of planning about ecosystem interactions of these HEPPs.

In addition, water quality is low, largely impacted by wastewater loads from rural, industrial and agricultural sources, reducing the oxygen contents to levels at which embryonic development becomes inhibited (Delage, 2015). Also, the bottom characteristics pose a risk for sturgeon reproduction with a high percentage of the fish prefers to lay their eggs on gravel. Additionally, the surveyed area had sand most probably generated by the sand quarries operating on the river. As revealed by the reported catch of a 25 g YOY stellate sturgeon in 2014 mature fish still reproduce in Lower Sakarya River and young fish are returning to the sea.

Both EU Water Directive (EU Directive 60/2000/EG), CITES agreement and Turkish legislation (Fisheries Law No. 1380) dictates that any activity which adversely affects the life cycle of sturgeon fish should be under control and migration of this fish should not be obstructed. Also, the location of the HEPP should provide sufficient habitat for the fish to reproduce and grow up rather than reflecting only the maximum utilization of the hydropower potential available. In the past, these precautionary approaches have not been taken into consideration.

Conclusion

Sakarya River has lost the majority of the functional spawning and nursery habitats between Adasu HEPP and Pamukova HEPP (Rosenthal et al., 2015). After the construction of 3 HEPPs 90 km of free river flow remains. But, with anymore HEPP projects, access to this last breeding ground will be impossible and the population will finally be lost. The last free 90 km river must be left alone and further monitoring of this species must continue in the river. In addition, proper criteria for the construction of functional sturgeon migration facilities both upstream (DWA, 2014; Tiril and Memiş, 2018) and downstream are not available on present structures. These must be implemented in a timely fashion to reopen the important habitats upstream of Adasu HEPP's. HEPPs which has dysfunctional fish passages should be revised for sturgeon species at least for *A. stellatus*. And, according to Anon (2018) there is an urgent need for coordinated efforts and centralized facilities in order to save this species which one may be the last living sturgeon species in Lower Sakarya River habitat.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Ethics committee approval: All procedures were performed involving fish were in accordance Law on Veterinary and Medical Activities and National Animal Welfare Act, thus ethical approval was not required.

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