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Short Communication

The Death of the Beluga Sturgeon (*Huso huso*) Rediscovered in the Küçükçekmece Lagoon: Let's Focus on Causes

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ABSTRACT

Sturgeon, a key species in fisheries and aquaculture due to their high economic and ecological value, face numerous challenges in their natural habitats. The spawning grounds in rivers, essential for sturgeon reproduction, are often compromised by the blockage of migration routes caused by various obstacles. Lagoons, providing favorable conditions for fish growth, are also hunting grounds for predatory fish species. The Küçükçekmece Lagoon, located within İstanbul's borders in Türkiye, stands as one of the most significant lagoons in the region, especially noted for its position on the bird migration route. However, it has been suffering from unplanned urbanization, leading to a notable decline in water quality due to improper urban planning and industrial activities over the years. This decline is aggravated by waste drainage into the lagoon's wetland area. Notably, the last sturgeon sighting in the Küçükçekmece Lagoon was in 1986. After approximately 35 years, the discovery of two deceased beluga sturgeon (*Huso huso*) in the lagoon, which connects to the Marmara Sea in Türkiye, marked a significant event. This study aims to investigate the causes behind the death of these beluga sturgeons and also proposes potential solutions for enhancing the ecosystem's vitality of the lagoon. These solutions include addressing waste drainage, ensuring shoreline compliance, improving the sediment structure laden with organic matter, and artificially introducing fresh water. Such measures are crucial for the restoration and maintenance of the ecological balance in the Küçükçekmece Lagoon, which is vital for the survival of significant species like the sturgeon.

Keywords: Acipenseridae, brackish water, eutrophication fish migration, water pollution

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INTRODUCTION

Over recent decades, there has been a continuous and significant decrease in natural sturgeon populations (Pikitch, et al., 2005; Zhang, et al., 2019). This trend, combined with the ongoing high demand for caviar on the market, has paved the way for the growth of sturgeon farming, with a primary focus on caviar production, as reported by Bronzi & Rosenthal (2014). These fish are typically recognized for their distinctive appearance, massive size, and their renowned product, caviar. They are an ancient species that inhabit only the northern hemisphere (Ustaoğlu & Okumuş, 2004). Currently, all Eurasian sturgeon species are facing a significant threat, while the situation is somewhat better in America (Williot et al., 2011).

Memis (2014) reported that the status of all sturgeon species in Türkiye has undergone a complete transformation in the past 40 years, and many are now on the brink of extinction. This change is believed to be due to various factors, including human-made modifications to rivers, such as the construction of embankments, dams, regulators, and hydroelectric power plants, which have prevented upstream migration to spawning sites (Ustaoğlu Tırıl & Memiş, 2018). Pollution from industries, agriculture, and sewage, as well as overfishing, have also been identified as significant contributors to

the drastic decline in sturgeon populations, both along the Black Sea coast and in Türkiye's three largest rivers (Kızılırmak, Yeşilırmak, Sakarya) (Ustaoğlu Tırıl & Memiş, 2018; Memiş et al., 2019).

Due to the significant decline in sturgeon populations, this species has been under protection since the 1980s. Türkiye signed the CITES agreement on 22 December 1996 and the catching and sale of sturgeon was banned by the Turkish authorities on April 1, 1998 (Memiş et al., 2020). In an effort to preserve natural sturgeon populations, sturgeon are being bred through aquaculture methods and released into the wild, contributing to the conservation of these endangered species (Akbulut et al., 2011).

Wetlands are the most productive areas on earth in terms of biological production and are also very rich in biodiversity (Tırıl, 2004). Lagoons have a special place among wetlands due to their connection to the sea. They are formed by the complete or partial closure of river mouths that flow into the sea with a coastal spit and sometimes by the accumulation of sea sand transported by currents in front of bays or gulfs (Joyeux & Ward, 1998; Karataş, 2005). They cover 13% of the continental coastal zone and are of great importance for biochemical processes and high productivity. Also, because of differences in salinity values, they have special ecological conditions that contribute to the richness of lagoon areas in terms of biodiversity (Gilabert, 2001; Çevik et al., 2008; Acarlı et al., 2009). They provide suitable conditions for fish to spawn and grow, as well as being preferred places for predatory fish species to feed. With these features, lagoons are also attractive centers for waterbirds and important feeding and offspring care areas.

Küçükçekmece Lagoon is one of the most important lagoons in Türkiye. Because of urbanization and industrialization, deterioration in water quality affects the ecosystem significantly (Albay et al., 2005; Köker et al., 2021). In the 1980s, various species of commercial fish were detected in the lagoon, but the fish population decreased in the early 2000s (Topcuoğlu et al., 1999). In the study conducted by Meriç (1986) on Küçükçekmece Lagoon, it was reported that 31 fish species inhabit the lagoon. These were *Acipenser gueldenstaedtii*, *Alburnus istanbulensis*, *Alosa tanaica*, *Anguilla anguilla*, *Aphanius fasciatus*, *Atherina boyeri*, *Belone belone*, *Clupeonella cultriventris*, *Chelon ramada*, *C. aurata*, *C. saliens*, *Engraulis encrasicolus*, *Esox lucius*, *Gasterosteus aculeatus*, *Huso huso*, *Knipowitschia caucasica*, *Mugil cephalus*, *Mullus surmuletus*, *Neogobius melanostomus*, *Nerophis ophidion*, *Petroleuciscus borysthenicus*, *Platichthys flessus*, *Proterorhinus semilunaris*, *Sander lucioperca*, *Sardina pilchardus*, *Scardinius erythrophthalmus*, *Pomatomus saltatrix*, *Sprattus sprattus*, *Syngnathus abaster*, *Trachurus mediterraneus* and *Vimba vimba* (Meriç, 1986; Deveciyan, 2006). Because of water pollution, many fish species have moved away from this lagoon and its fish population and diversity have decreased in recent decades (Özuluğ & Saç, 2019).

Beluga sturgeon (*Huso huso* Linnaeus, 1758) has not been recorded in Küçükçekmece Lagoon since 1986 (Meriç, 1986). Recently, two beluga sturgeon were found in the lagoon after 35 years. While the original goal of this study was to investigate their existence and causes of death, it has become evident that a broader approach is required. Given the deteriorated condition of the fish, which precludes detailed biochemical or histopathological analysis, the study now emphasizes understanding the lagoon's ecosystem structure and identifying ways to improve it. This approach is crucial, considering the fragile state of species like the beluga sturgeon and the need for a comprehensive strategy to enhance the resilience and health of the entire ecosystem.

MATERIALS AND METHODS

Study area and environmental variables

Küçükçekmece Lagoon, located in the west of Istanbul and connected to the Marmara Sea by a narrow channel, is 18 m deep and has a surface area of 15.22 km^2 (Figure 1). Eşkinoz, Nakkaşdere and Sazlıdere creeks flow into the lagoon and these creeks show seasonal flow (Albay et al., 2005, Topcuoğlu et al., 1999). Sazlıdere Dam, which is a drinking water supply, is located on Sazlıdere, the most important freshwater source of the lagoon. Due to this dam, the freshwater inflow into the lagoon has decreased.

During our field studies, the discovery of two nearly decomposed *H. huso* individuals on July 1, 2020, in the Küçükçekmece Lagoon was initially reported by local residents who frequently visit the lagoon's shores for recreational and fishing activities. This encounter was later confirmed by public officials who monitor the lagoon. The discovery was facilitated by wave movements bringing the fish to the shore (Figure 2). One of the individuals was found to be completely deteriorated with body integrity lost.

The length of the other fish stranded on the shore was measured on the field with a 1 mm calibrated meter, and a sample was taken from the pectoral fin rays to determine its age. The fin ray was prepared for reading by being placed in bleach for 2 min, and all excess tissue and skin were removed using a scalpel and forceps (Parr et al., 2018). The fin ray was sectioned using a Metkon low-speed saw (Metkon Microcut, Bursa) equipped with two diamond-tipped blades (Metkon Microcut 150) and a 0.15 mm spacer between the blades (Deval et al., 2018). Three sections were cut serially, beginning at approximately 25% of the total length of the fin ray, starting at the condyle base (Parr et al., 2018). The method for determining the age of the beluga sturgeons involved analyzing the sectioned fin rays, specifically focusing on the number of translucent bands present. Following the approach outlined by Bakhshalizadeh et al. (2017), we identified both opaque and translucent bands as annual growth rings, or annuli, on the fin ray. This identification is based on the principle that these bands represent distinct periods of growth and development in the beluga sturgeon's life cycle. Fin ray sections were examined and photographed under the reflected light using an Olympus SZX16 stereo microscope (with 2 × 10 magnification) (Deval et al., 2018). The fish species identification was made according to Akşıray (1987) and Kottelat & Freyhof (2007). The current scientific names of the species were verified according to Fricke et al. (2022).

For water quality analysis, water samples were taken from the surface waters where the beluga sturgeon were found. The YSI multiparameter (YSI 650 MDS) was used to measure dissolved oxygen, salinity, pH, and temperature *in situ*. Chlorophyll-*a* (chl-*a*)

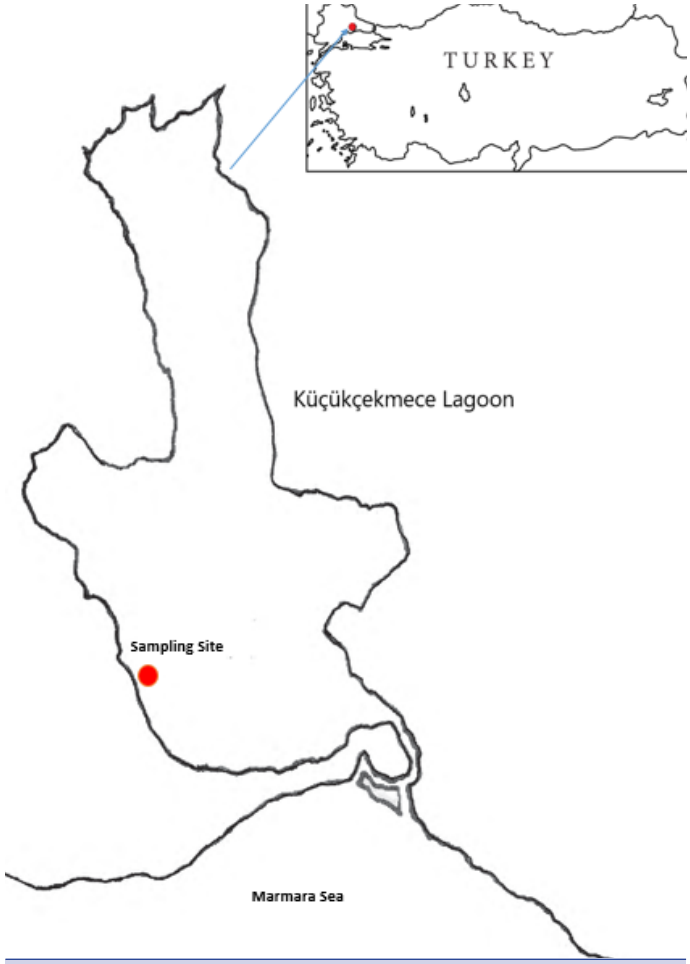

Figure 1. Location of Küçükçekmece Lagoon. (Modified from Köker et al., 2021).

was determined using the method of ISO 10260 (1992). Nutrient concentrations: total inorganic nitrogen (TIN: NO_2-N+NO_3-N+NH_4-N) and total phosphorus (TP) were measured according to APHA-AWWA WPCF (2005). The Secchi depth (SD) was measured *in situ*. The trophic state of the Küçükçekmece Lagoon, Carlson Index was used and total phosphorus (TP), chlorophyll-a (Chl-*a*), and Secchi depth (SD) measurements were used to calculate the index (Carlson, 1977).

RESULTS AND DISCUSSION

The subject of this present study is the beluga sturgeon-*Huso huso*, an anadromous fish species that migrates kilometers upstream to the source of rivers from the seas in order to spawn on deep and gravelly-stony river bottoms (Chebanov & Galich, 2013). It is known that beluga sturgeon entered the Küçükçekmece Lagoon in the past (Meriç, 1986). This species would enter the lagoon not for reproduction but for feeding purposes. The fish species known to inhabit the Küçükçekmece Lagoon are among the preferred food sources in the diet of beluga sturgeon.

The beluga sturgeon (*Huso huso*) can reach approximately 6 m in length and up to 1000 kg in weight, with records indicating lengths of 8 m and weights of 3200 kg. Individuals are typically found to measure between 120-260 cm and weigh up to 363 kg (Berg, 1948). In the Küçükçekmece Lagoon, the age of the beluga sturgeon found in July 2020 was determined from the pectoral fin ray and it was around 20 years old. The specimen measured 250 cm in total length, indicating that the beluga sturgeon had reached the reproductive stage.

There are numerous reports that various hydraulic obstacles such as hydroelectric power stations, bridge abutments, and culverts built on rivers affect fish migration (DWA, 2005; Shortnose Sturgeon Status Review Team, 2010; Nyqvist et al., 2017; Nielsen and Szabo-Meszaros, 2022). Küçükçekmece Lagoon is a special wetland due to its location in the middle of Istanbul and it is an important habitat for living organisms from bacteria to fish. Since the 2000s, the lagoon has continued to be polluted, and with the construction of the Sazlıdere dam, the ecosystem has faced change and collapse due to the decrease in freshwater input (Köker et al, 2023). It has been reported that algal blooms have occurred in the Küçükçekmece Lagoon since the 1990s, resulting in the death of some fish (Albay et al. 2005; Köker et al. 2021).

Due to the increase in the salinity of the water, cyanobacterial blooms ceased to occur. The calculated $TSI_{(Chl\text{-}a)}$ and $TSI_{(TP)}$ mean values ($TSI_{(mean)}$=58.21) suggest that the Küçükçekmece Lagoon is in a nutrient-rich, eutrophic condition.

The physicochemical parameters measured during the investigation of the death of the beluga sturgeon individuals are shown in Table 1. The measured water temperature value was within the normal range for the summer season. Although it is known that the salinity level varies between 6-9 ppt in the area of Sazlıdere Dam where the freshwater inflow enters (Köker et al., 2021), the salinity level was determined as 13.5 ppt in the sampling area with currents coming from the channel where the lagoon connects to the Marmara Sea. The most important parameter was dissolved oxygen which measured 0.78 mg L^{-1}.

The trophic state of Küçükçekmece Lagoon was determined by following formulas based on total phosphorus (TP) and chlorophyll-*a* (Chl-*a*) (Carlson, 1977): $TSI_{(Chl\text{-}a)}$=9.81ln(Chl-*a*)+30.6, and $TSI_{(TP)}$=14.42ln(TP)+4.15. According to Table 1, it was determined that Küçükçekmece Lagoon is eutrophic.

Table 1. Some physical and chemical variables of the Küçükçekmece Lagoon during the sampling.

Environmental Parameters	June 2020
Temperature (°C)	26.35
Dissolved oxygen (mg L^{-1})	0.78
Salinity (ppt)	13.49
pH	8.20
Chl-*a* (µg L^{-1})	1.11
TIN (µg L^{-1})	5559.2
TP (µg L^{-1})	270.1
$TSI_{(TP)}$	84.88
$TSI_{(Chl\text{-}a)}$	31.53
$TSI_{(mean)}$	58.21

In July 2020, two individuals of *H. huso* who had died and whose bodies had washed ashore were found. One individual's tissues had completely decayed and its total length could not be measured. The total length of the other individual, which was in the process of decay, was 250 cm (Figure 2). Based on the overall condition of the fish bodies, it was clear that they had died a few days before our sampling.

The exact age of the *H. huso* individual shown in Figure 2-3, could not be determined due to the deterioration of the fin rays (Figure 4). The first ray of the pectoral fin taken from the 250 cm long fish and used for age determination was sectioned at the base. It was estimated to be approximately 20 years old (Figure 4).

Figure 2. Measurement of the length of the *Huso huso* individual.

Figure 3. Investigation of the species from the mouth and barbels.

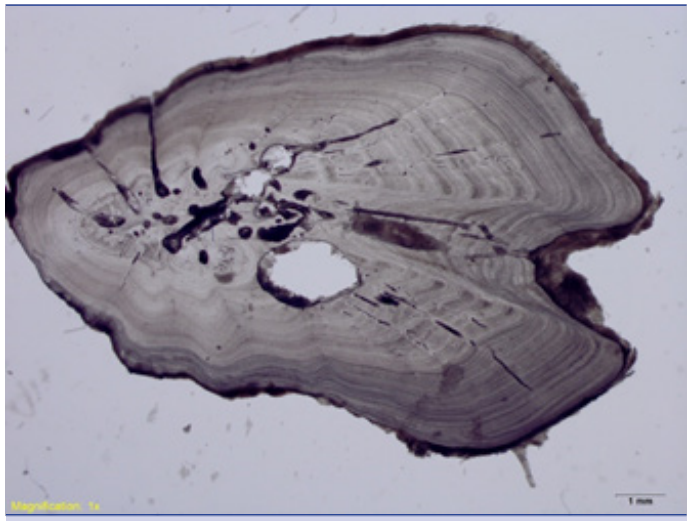

Figure 4. Pectoral fin barb beam section for age determination of beluga sturgeon.

Although the gonad examination of the fish suggested that it was female based on the consistency of the mass of the gonad and its large volume, there are signs similar to a male (M. Chebanov, personal communication, 7 July 2020).

Particularly during the summer season, factors such as increased water temperature and biological decomposition of waste within the lagoon lead to significant decreases in dissolved oxygen levels, even dropping to 0.78 mg O_2 L^{-1} (Table 1). The formation of oxygen-depleted zones throughout the water column, from the surface to the bottom of the lagoon, results in mass mortality events, especially among benthic invertebrates (e.g., crabs) and bottom-dwelling fish species (e.g., Gobiidae, Syngnathidae), as well as pelagic species like *A. boyeri* and *Chelon* spp., which have been observed during field observations. Atlantic sturgeon populations have been found to be declining in the Chesapeake Bay due to increased hypoxia (Secor & Gunderson, 1998; Secor & Niklitschek (2001). Even if the sturgeon has adapted physiologically to the environment, hypoxic conditions impair its respiratory metabolism, foraging activity, and growth (Wilson & Mckinley, 2004). These fish are typically sensitive to dissolved oxygen decreases. Cech & Doroshov (2004) reported that at moderate hypoxia (3 mg O_2 L^{-1}) at 15 °C, the activity of Atlantic sturgeon did not change but gill ventilatory frequency increased by 50%. Also, Jenkins et al. (1993) report that regardless of the life stage, shortnose sturgeon died at oxygen concentrations of 2 mg O_2 L^{-1}. For beluga hybrid sturgeon the critical concentration of dissolved oxygen was determined as 4 mg O_2 L^{-1} at 25 °C and the threshold concentration was 1.5 mg O_2 L^{-1} mg at 25 °C (Secor & Niklitschek, 2002). The natural stocks of this species are classified as Critically Endangered (CR) according to IUCN criteria (Gessner et al., 2022). The conservation of Küçükçekmece Lagoon, which serves

as a feeding ground for endangered species such as the beluga sturgeon, is crucial for their continued existence. To this end, improving water quality through appropriate measures is essential. In the short term, immediate action should focus on reducing pollution sources, such as enforcing stricter controls on industrial effluents and urban wastewater discharges into the lagoon. This would quickly alleviate some of the direct pressures on the water quality.

In the medium term, efforts should concentrate on restoring the natural flow and water levels of the lagoon by reevaluating the impact of the Sazlıdere Dam and exploring ways to increase freshwater input. This step will help in balancing the lagoon's ecosystem and reducing the salinity levels, which have been identified as a contributing factor to the deterioration of the habitat. Moreover, the employment of sturgeon culture facilities for conservation purposes, including the restocking of sturgeon into the lagoon or connected river systems, should be considered. This approach would not only aid in the direct replenishment of the sturgeon population but also serve as a vital tool for their conservation and genetic diversity.

For long-term sustainability, a comprehensive management plan should be developed, focusing on habitat restoration, including the revitalization of native vegetation along the shores and the creation of buffer zones to reduce nutrient runoff (Gessner et al., 2014). Additionally, establishing a continuous monitoring system to track water quality and biodiversity changes in the lagoon will provide valuable data for ongoing conservation efforts and help in adapting strategies as needed.

Implementing these measures in a phased approach will not only aid in the recovery and preservation of the Küçükçekmece Lagoon's ecosystem but also ensure the protection of species such as the beluga sturgeon, which rely on this habitat for survival.

CONCLUSIONS

In summary, the deaths of beluga sturgeon individuals and other fish species in the Küçükçekmece Lagoon, primarily attributed to pollution, algal blooms, and oxygen depletion, highlight the urgent need for conservation and rehabilitation efforts, especially during the summer season. Factors such as high temperature and salinity likely contributed to the stress on the beluga sturgeon, exacerbating their vulnerability. The broader challenges facing sturgeon species in Türkiye, including habitat degradation and migration barriers like hydroelectric power plants and bridges, further complicate their survival and reproduction.

While the sturgeon's current situation in Turkish waters is alarming, with their migration routes and spawning grounds severely impacted, there remains a significant opportunity to revitalize the Küçükçekmece Lagoon. This lagoon, situated within one of the world's major metropolises, Istanbul, still holds potential as a living wetland. To enhance the vitality of this critical habitat, specific measures are recommended:

1. Improving waste management and drainage systems to prevent pollution of the lagoon,
2. Ensuring compliance with and respect for the shoreline, thereby reducing habitat destruction and erosion,
3. Enhancing the organic-laden sediment structure, which is vital for the growth and sustenance of various aquatic species,
4. Replenishing Küçükçekmece lagoon with fresh water to balance the salinity levels and improve overall water quality.

Implementing these measures will not only contribute to the vitality of the Küçükçekmece Lagoon but also set a precedent for the conservation of other sturgeon habitats in Türkiye. It is imperative that a 'National Action Plan for the Conservation and Restoration of the Sturgeons of Turkey' be developed and executed by relevant authorities (Anon., 2015). This plan should focus on identifying and protecting the most suitable rivers for sturgeon survival and restoring their natural spawning grounds. Such efforts are crucial for the recovery of these ancient fish species and for preserving the biodiversity and ecological balance of Türkiye's aquatic ecosystems.

The findings of this study underscore the urgent need for a comprehensive and coordinated approach to conservation, highlighting the potential for recovery and revitalization of lagoon life, including the Küçükçekmece Lagoon. It is hoped that these insights will inform and inspire local, national, and international institutions to take decisive actions towards the sustainable management and preservation of these vital ecosystems.

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