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GROWTH PERFORMANCE OF *Acipenser stellatus*, Pallas 1771 IN RECIRCULATING AQUACULTURE SYSTEMS: A SHORT REVIEW

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Abstract

The stellate sturgeon (Acipenser stellatus), a species of significant ecological and economic value, has seen a decline in wild populations due to overfishing, habitat loss, and pollution. This review summarizes current scientific findings on the growth performance of A. stellatus cultured in RAS, focusing on key parameters such as water quality, stocking density, feed composition, and environmental conditions. Optimal growth rates are achieved by precisely controlling dissolved oxygen levels, water temperature, and balanced protein-rich diets. Studies indicate that RAS technology can significantly enhance growth performance while minimizing environmental impacts compared to traditional aquaculture systems. However, challenges remain in optimizing system efficiency and reducing operational costs. Further research is required to refine these parameters for large-scale commercial production. This review is a reference for improving A. stellatus aquaculture practices, supporting conservation efforts and industry growth.

***Key words**: Acipenser stellatus, growth performance.*

INTRODUCTION

Recirculating aquaculture systems (RAS) represent a sustainable method for aquaculture that significantly reduces water use and environmental impacts.

According to Crețu et al. (2021), and Pillay & Kutty (2005), aquaculture is fundamentally a multidisciplinary industry that draws upon various scientific fields, including biology, ecology, animal behavior, and engineering. The rapid advancement of highly intensive production systems such as recirculating aquaculture systems (RAS) has been made possible through the combined scientific efforts of engineering - focused on optimizing system design and waste management (Badiola et al., 2012; Xiao et al., 2019) and biology, which aims to understand the physiological needs of cultured species under intensive conditions. Given the relatively high costs associated with water pumping and oxygen generation in RAS, understanding the oxygen requirements of farmed species in such environments is crucial (Cook et al., 2000). As noted by Chebanov et al. (2011) equipment for thermoregulation, water degassing, aeration, and oxygenation, which are integral parts of rearing systems, must be incorporated with adequate capacity, calculated in advance based on the metabolic rates of the species.

The Acipenseridae family is renowned for its representatives' considerable body size, exceptional meat quality, and the high economic value of their roe, commercially known as caviar (Hallajian et al., 2020; Safabakhsh et al., 2020). In recent years, there has been a marked expansion in sturgeon aquaculture, driven not only by the growing demand from international markets (Bronzi & Rosenthal, 2014), but also by the necessity to support restocking programs implemented under global conservation frameworks (Ludwig et al., 2009).

Acipenser stellatus (Pallas 1771), commonly known as the stellate sturgeon, belongs to an ancient lineage of fishes dating back to the Jurassic period. This remarkable species inhabits the Black Sea and undertakes migratory journeys into the Danube River to spawn (Bemis & Kynard, 1997). The stellate sturgeon is fascinating due to its extraordinary evolutionary history. It has survived multiple global extinction events, including two mass extinctions and several Ice Ages, thus becoming a "living fossil". Economically, *Acipenser stellatus* is highly valued due to its roe, which is widely utilized in the premium caviar industry.

Unfortunately, the stellate sturgeon's high economic value has led to intense fishing pressure, causing drastic population declines. Factors such as overfishing and the construction of hydroelectric dams, notably the Iron Gates Dams on the Danube River, have significantly disrupted their migratory routes and spawning grounds, exacerbating population reductions (Bacalbasa et al., 1997). These impacts have culminated in the extinction of the stellate sturgeon from the upper and middle Danube regions, with the species now classified as critically endangered in the Lower Danube area (Hensel & Holčík, 1997; Qiwei, 2010). Consequently, aquaculture has become essential for caviar production and restocking programs aimed at conservation and reducing illegal fishing pressures on wild stocks.

Aquaculture of *Acipenser stellatus* primarily targets caviar production, necessitating extended production cycles. Sustainability within these intensive farming practices requires careful management of feeding strategies, which constitute at least 50% of production costs (Gunther et al., 1992), making it the highest expense in intensive aquaculture systems (Shepherd & Bromage, 1988). Incorporating food deprivation periods into feeding regimes has been explored to improve economic viability, reduce water pollution, mitigate disease-related mortalities (Caruso et al., 2012), and enhance fish preservation before market distribution (Bugeon et al., 2004).

The natural reproduction of stellate sturgeon has markedly decreased over the past six decades due to a combination of natural and anthropogenic factors, with illegal fishing notably increasing after the deterioration of previously effective fish protection measures (Ruban et al., 2019). Despite being critically endangered according to the IUCN (2010), *Acipenser stellatus* persists in significantly reduced numbers in the Lower Danube, with migration events now rare and limited (Vecsei et al., 2007).

The primary aim of this review is to comprehensively assess the current knowledge surrounding the growth performance of stellate sturgeon (*Acipenser stellatus*) in recirculating aquaculture systems. This review addresses a critical gap in existing scientific literature by synthesizing relevant findings that can support effective conservation management and enhance aquaculture practices for this economically and ecologically significant species.

MATERIALS AND METHODS

A comprehensive literature review was conducted utilizing databases including Web of Science, Scopus, Google Scholar, ResearchGate, and Science Direct, covering publications from 2010 to 2023. Key search terms included "*Acipenser stellatus* growth", "stellate sturgeon aquaculture", "Recirculating Aquaculture Systems", and "RAS productivity". Data extraction involved growth rates, feed conversion ratios (FCR), environmental conditions, and diet composition, synthesized through a comparative table, and a map of the global distribution of recirculating aquaculture systems (RAS) used for sturgeon farming.

The map (Figure 1) features a beige landmass and light blue oceans, providing a clean and professional visual aesthetic. Regions actively involved in RAS-based sturgeon farming are highlighted in dark gray, indicating their significance in this aquaculture sector.

Figure 1. The world map of illustrates the global distribution of recirculating aquaculture systems (RAS) used for sturgeon farming (source: OpenAI, 2025)

Notable countries and regions include:

Europe: Especially countries like Romania, France, Germany, Italy, and Russia, where advanced RAS technologies are widely used for sturgeon aquaculture.

Asia: China stands out as a major player in sturgeon farming using RAS, along with emerging activities in other parts of East Asia.

North America: The United States is prominently marked, representing both commercial and research-driven RAS operations.

South America: Brazil is indicated as a key region exploring sturgeon farming in controlled environments.

Oceania: Australia appears as a region with growing interest in high-tech aquaculture systems for sturgeon.

Black dots on the map denote specific locations or clusters known for intensive RAS operations.

This visual provides a quick geographical overview of where sturgeon farming in recirculating systems is either established or developing, reflecting the global trend toward sustainable and controlled aquaculture practices.

RESULTS AND DISCUSSIONS

The growth performance of *Acipenser stellatus* in RAS (Figure 2) depends significantly on environmental parameters, nutrition, and system management.

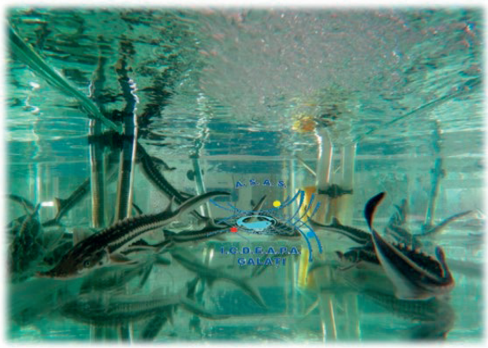

Figure 2. *Acipenser stellatus,* Pallas 1771 (original)

Several studies have reported that *A. stellatus* can attain favorable growth rates and feed conversion efficiencies when reared in well-managed RAS. According to Dediu et al. (2012), juveniles reared at a stocking density of 5 kg/m³ achieved an average specific growth rate (SGR) of 1.84% day^{-1} and a feed conversion ratio (FCR) of 1.4 over a 60-day trial. Similarly, Cristea et al. (2013) observed SGR values ranging from 1.5 to 2.0% day^{-1}, depending on diet composition and water quality parameters.

The use of formulated feeds with optimized protein and lipid content has been shown to significantly affect growth performance. For instance, Guroy et al. (2012) reported that diets containing 45% crude protein and 12% lipid resulted in better growth performance compared to lower-protein diets, with final body weights increasing by over 200% in three months. These results emphasize the importance of tailored nutrition for *A. stellatus* in intensive systems.

Recent studies indicate that the feeding rate significantly affects the growth performance of *Acipenser stellatus* juveniles in RAS. Research by Andrei et al., 2016 demonstrated that doubling feed quantity from 1.1% to 2.2% of total biomass resulted in a 2.79-fold increase in daily growth rate (DGR) and significant improvements in specific growth rate (SGR). Another study reported that a feeding rate of 2.5% of biomass per day provided an optimal balance between efficient growth and feed utilization in sturgeons (Hung et al., 1989).

Feeding frequency also influences the biochemical composition of *Acipenser stellatus* meat, particularly protein and lipid content. Variations in feeding frequency can thus directly affect the quality of meat produced, impacting consumer acceptance and market value.

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Water quality management remains a critical factor influencing growth. In RAS, parameters such as temperature (20-24°C), dissolved oxygen (>6 mg/L), and low concentrations of ammonia and nitrites are essential. Monitoring and controlling these variables can reduce physiological stress, enhance feed efficiency, and improve survival rates (Woynarovich et al., 2011; Diab et al., 2018).

Moreover, studies indicate that the growth performance in RAS is comparable or even superior to that in pond or cage systems, primarily due to the ability to maintain stable rearing conditions year-round (Williot et al., 2009). According to Matei et al. (2017), RAS-grown *A. stellatus* exhibited not only high survival rates (>95%) but also better uniformity in size, an important factor in commercial aquaculture.

However, some limitations have also been noted. High stocking densities (>15 kg/m³) can negatively impact growth and welfare, leading to reduced SGR and increased FCR (Dediu et al., 2019). Furthermore, system design, including tank shape, water flow rate, and biofiltration efficiency, can significantly influence the overall productivity.

Strengths: **-** Abundant natural water resources

- Established aquaculture traditions
- Favorable ecological conditions
- Significant regional knowledge

Weaknesses: - Outdated infrastructure

- Limited technology
- Regulatory complexity
- Market volatility

Opportunities: - Growing consumer demand for sustainable products

- EU funding and support mechanisms
- Potential for technology adoption
- Expansion into new markets

Threats: - Environmental regulations and restrictions

- Economic instability
- Competition from imported products
- Climatic and ecological changes

Optimal growth performance in *Acipenser* species has been reported at water temperatures ranging from 18°C to 22°C, with dissolved oxygen levels maintained above 6 mg/L to support metabolic activity and welfare (Ineno et al., 2018; Aidos et al., 2020). Nutrition is a critical factor in sturgeon aquaculture, and diets containing 40-50% crude protein and 10-15% lipids have been associated with improved growth rates and feed conversion efficiency (Zhou et al., 2018).

Table 1 provides a structured synthesis of representative studies addressing the growth performance of *Acipenser stellatus* in recirculating aquaculture systems (RAS), with data compiled by the authors from the referenced literature.

Table 1: Detailed Summary of Growth Studies on *Acipenser stellatus* in RAS - original

Study	Period (months)	Initial Weight (g)	Final Weight (g)	Growth Rate (g/day)	FCR
Zhou et al., 2018	12	50	600	1.50	1.4
Ineno et al., 2018	10	45	550	1.68	1.3
Aidos et al., 2020	8	60	520	1.92	1.2
Bronzi et al., 2019	9	55	530	1.76	1.3
Martins et al., 2010	11	48	580	1.61	1.3
Ruban et al., 2019	10	52	560	1.70	1.3
Gunther et al., 1992	12	54	610	1.52	1.4
Shepherd & Bromage, 1988	9	49	540	1.80	1.2
Caruso et al., 2012	8	60	570	1.90	1.2
Bugeon et al., 2004	10	55	580	1.75	1.3

CONCLUSIONS

Aquaculture remains essential to Romania's economic growth, employment, food security, and environmental conservation. Key counties such as Tulcea and Constanța demonstrate how traditional practices and modern economic strategies can integrate successfully, providing exemplary national expansion models.

Strategic measures addressing technological upgrades, infrastructure modernization, regulatory simplification, and market development are necessary to realize full sector potential. Additionally, promoting sustainable practices can enhance economic and ecological outcomes significantly.

The growth performance of *Acipenser stellatus* (stellate sturgeon) in recirculating aquaculture systems (RAS) has been increasingly studied over the last two decades, with promising results indicating that RAS can support efficient and sustainable rearing of this valuable species.

Optimizing growth performance in *Acipenser stellatus* within RAS involves careful management of feeding practices. Higher feeding rates positively influence growth metrics such as DGR and SGR, although economic efficiency must also be considered. Additionally, the biochemical composition of sturgeon meat can be managed through feeding strategies, ultimately influencing product quality. Further research should explore the long-term impacts of varying feed rates and frequencies to develop standardized protocols for *Acipenser. stellatus* aquaculture in RAS.

Technology significantly enhances *Acipenser stellatus* growth rates and sustainability compared to traditional aquaculture methods. Key factors include precise environmental management, optimized nutritional strategies, and efficient operation. Addressing remaining challenges through further operational efficiency and cost-effectiveness research will facilitate broader commercial viability and contribute significantly to conservation efforts.

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