STURGEON BROODSTOCK REARING IN FLOATING CAGES FOR ADAPTABILITY TO CLIMATE CHANGE CONDITIONS

F.M. Dima[1,2], V. Nistor[1], M. Tenciu[1], E. Sîrbu[1*], M.C. Chioveanu[1,3], V. Savin[1], L.B. Athanasopoulos[1], M. Roman[1,3]

[1]Institute for Research and Development in Aquatic Ecology, Fishing and Aquaculture, 54 Portului Street, 800211 Galati, Romania
[2]Faculty of Engineering and Agronomy in Braila, "Dunarea de Jos" University of Galati, Calea Călărașilor no. 29, 810017, Brăila, Romania
[3]Faculty of Food Science and Engineering, "Dunarea de Jos" University of Galați, 800008 Galați, Romania

Abstract
In the context of global climate change, which influences the availability of water resources for use in aquaculture and agriculture, impacting food production and ensuring food security. Recent studies have reported promising results in fish farms and hatcheries despite the challenges of adopting cost-effective approaches to mitigation and adaptation to climate change in practice. The study aimed to evaluate the adaptation of sturgeon broodstock to climate change conditions, reared in a floating cage. A number of 165 specimens of the species Acipenser gueldenstaedtii (Brandt & Ratzenburg, 1833), with an average mass of 1000 g/fish, were reared in a 5x5x3 m cage made of galvanized panels and located in the CM Lunca irrigation canal. At the end of the experimental period, after 45 days, the results showed an individual growth of 800 g and an adequate health status due to the adaptability of this species to the conditions of sturgeon broodstock rearing under climate changes.

Key words: *Sturgeon, cage, climate change*

INTRODUCTION

Aquaculture contributes to conserving sturgeon species and reducing fishing pressure on wild populations. However, aquaculture and restocking of juvenile sturgeon are not the solutions to the problem; they are only temporary actions [1].

The cages can be installed on non-navigable rivers, lakes, waterways, reservoirs, etc. The advantages of the cage method over recirculation aquaculture systems are that it is convenient and less economical, initial capital investment is 2-3 times lower, and minimal electricity consumption [2].

The cages are often made of polyethylene or metal netting, assembled in rectangular or circular cages with supporting frames, fixed blocks, and floats. In some provinces, such as Hubei, the surface water temperature often exceeds 28°C in summer, which exceeds the tolerance range for some sturgeon species and might lead to high mortality. The cages are modified to allow movement down the water column to lower temperature depths to compensate for high summer temperatures. Because the cages enable efficient water exchange, higher stocking densities can be maintained at high yields.

*Corresponding author: sirbu.elena@asas-icdeapa.ro
The manuscript was received: 19.09.2024
Accepted for publication: 24.10.2024

Sturgeon cage farming products can range from 35-40 kg/m^3 [3-6].

The main advantages of cage rearing include low capital costs and easy harvesting. However, the open farming environment results in a relatively low feeding rate and a higher feed conversion ratio (about 1.8-2.0). Besides increasing rearing costs, this also increases effluent N and P levels. Water quality degradation and the resulting eutrophication problems in some reservoirs where cage culture is widely practiced have an impact on the morbidity of farmed sturgeon. Cage culture problems have attracted the attention of the national government, which has introduced strict management measures and improved cage technology [7].

The major reasons are that the ponds cannot meet the sturgeon's needs for higher dissolved oxygen (DO) concentrations, and water temperatures often exceed 30°C in the main sturgeon farming areas. Many new problems have arisen as sturgeon farming has intensified, as expected, and needs attention [8].

Most dataset case studies (52%) focus on identifying climate change as a significant factor influencing various aspects of aquaculture systems, such as economic impacts, risk, uncertainty, and management challenges. The primary areas where climate change impacts are documented include extreme events like floods, droughts, and cyclones, which account for 25% of cases and cause damage to aquaculture systems [9-11]. Other key impacts include general climate effects (18%) [12-14] and changes in aquaculture-related systems, such as mangroves, livelihoods, landscapes, and supply chains (16%) [15-17].

The study aimed to evaluate the adaptation of sturgeon broodstock from a recirculating aquaculture system to climate change conditions reared in a floating cage.

MATERIAL AND METHOD

The experimental module for rearing the three summer-old Russian sturgeon (*Acipenser gueldenstaedtii*) was a 5×5×2 m cage made of galvanized panels. The useful volume of the cage is 38 m^3, and the safety guard is 0.45 m. The cage was equipped with floats to ensure its buoyancy.

The CM Lunca irrigation canal placement was performed using a motorboat and steering lines.

The biological material of the Russian sturgeon was transferred to the Pilot Station of the Institute for Research and Development in Aquatic Ecology, Fishing, and Aquaculture, Galati, from the company SC Marfishing SRL, and then populated in the floating cage on the CM Lunca irrigation canal.

The biological material consisted of extruded feed, recommended for intensive rearing, with high digestibility, a crude protein content of 49%, a lipid content of 20%, and a pellet size of 4.5 mm.

Several 165 specimens of the species *Acipenser gueldenstaedtii* (Brandt & Ratzenburg, 1833), with an average mass of 1000 g/fish, were reared in a 5×5×3 m cage made of galvanized panels and located in the CM Lunca irrigation canal.

Photo 1. Floating cage

Biotechnological indicators and hematological parameters were analyzed by description according to Sîrbu et al. 2022 [18].

Water quality. The physicochemical parameters of water (temperature, dissolved oxygen, and pH) were recorded daily, with the sensors from the system, and once a week, the nitrogen compounds (N-NO_2^-, N-NO_3^-, N-NH_4^+,) were determined using Spectroquant Nova400 type spectrophotometer, compatible with Merk kits. The water sample for analysis was collected early in the morning before the feeding.

Statistical analyses were performed using SPSS software 21 for Windows (SPSS Inc.). Results regarding fish growth performance and hematological parameters were expressed by means and standard deviations.

RESULTS

In the context of global climate change, which influences the availability of water resources for use in aquaculture and agriculture, impacting food production and ensuring food security. Recent studies have reported promising results in fish farms and hatcheries despite the challenges of adopting cost-effective approaches to mitigation and adaptation to climate change in practice.

Developing aquaculture in arid climate conditions forces the adoption of production strategies focused on good water management, which includes water savings and recycling practices. Floating cages are also commonly found in dams or disused mines, allowing fish growth in low or non-exploited artificial water bodies.

During the experimental period, the physicochemical parameters of the water were determined, especially in the morning before sunrise (6°a.m.). Temperature and dissolved oxygen were recorded during the experiment, and the measured values are shown in Figure 1 and Figure 2.

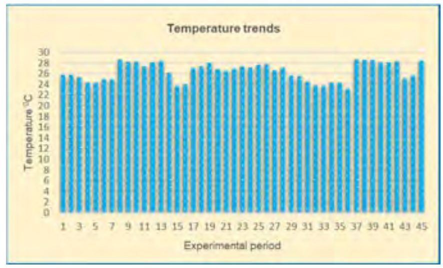

Fig. 1. Temperature trends during the experimental period

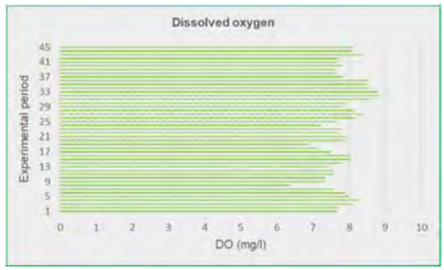

Fig. 2. Dissolved oxygen during the experimental period

Water temperature averaged 26.42±1.67 throughout the experiment, and dissolved oxygen averaged 7.86±0.48 being ensured by using aerators in the optimum sturgeon rearing. Organic matter, pH, and nitrogen compounds were monitored and presented in Dima et al. 2023 [19].

The biotechnological indicators of Russian sturgeon are shown in Table 1.

Table 1. The table regarding the biotechnological indicators of farmed Russian sturgeon in a floating cage

Experimental variant Indicators	Floating cage
The initial number of fish	165
The final number of fish	163
Survival rate [%]	98
Initial biomass [g]	165
Initial biomass [kg/m^3]	4.4
Final biomass [g]	293.4
Final biomass [kg/m^3]	7.82
Biomass gain [g]	128.4
Biomass gain [kg/m^3]	3.42
Mean initial weight [g/ex]	1000
Mean final weight [g/ex]	1800
Individual weight gain [g]	800
Experimental period (days)	45

At the end of the experimental period, after 45 days, the results obtained showed an individual growth of 800 g and an adequate health status due to the adaptability of this species to the conditions of sturgeon rearing in cages located in irrigation canals, which indicated a positive impact to climate change.

By investigating certain qualitative and quantitative characteristics of blood we can obtain valuable information on the physiological state of the cultured biomass. Changes in certain blood characteristics represent the ecophysiological response of blood that ensures the organism's survival under different environmental conditions.

According to the study by Duman Selçuk, 2020 [20] reference ranges of hematological parameters of *Acipenser gueldenstaedtii* species are reported as follows: Erythrocyte 0.77 - 1.23 ($\times 10^6/mm^3$); Hematocrit 22.14 - 28.63 (%) and hemoglobin 7-9 g/mL. Both hematological indicators and erythrocyte constants showed values within the normal range of the species *Acipenser gueldenstaedtii,* (Brandt & Ratzeburg, 1833), and did not show significant changes resulting from the action of the gentle increase in water temperature.

Photo 2. Sturgeon broodstock

The results obtained at the end of the experiment on hematological parameters are presented in Table 2.

Table 2. Values of hematological parameters at the end of the experiment

Hematological parameter (mean values ±SD)					
PVC (%)	**Hb (g/dL)**	**RBCc×10^6/µl**	**MCV (µm^3)**	**MCH (pg)**	**MCHC (g/dl)**
23.34±1.73	7.38±0.98	0.98±0.03	231.34±21.44	71.06±6.29	32.75±2.89

DISCUSSIONS

Although most studies focus on small-scale aquaculture farmers [21-23], they often overlook differences among these farmers. Future research could benefit from examining whether certain groups of aquaculture farmers are more vulnerable to climate change, more inclined to adapt or face greater barriers to adaptation compared to others.

Significant attention and resources will likely be required to help the aquaculture sector develop strategies and tools for adapting to both current and future climate change. This study underscores how climate change impacts aquaculture systems and the adaptation responses that can influence global aquaculture production. A decline in production affects farmers and has broader implications for a growing global population, as it is closely tied to food security [24-25].

Ongoing research into climate change adaptation in aquaculture is essential for improving adaptation strategies. By shifting focus toward developing national and regional adaptation policies, while also scaling up community-level adaptations, research could enhance production, alleviate poverty, and improve food security for many populations. To build resilience and maintain production in the face of climate change, aquaculture producers must adapt in the short term using available options, while also making long-term adjustments to their production practices to mitigate the effects. This addresses key aspects of climate change and aquaculture production but identifies several limitations that present important areas for future research. For instance, it focuses on the production and input supply stages of the aquaculture value chain, without addressing other critical stages such as trade, processing, and consumption. Furthermore, within the production stage, there is a lack of clarity on how economically important species at different life stages will respond to climate change information that would be crucial for adaptation strategies that might require shifting to more climate-resilient species.

The studies also highlight the scarcity of practical examples illustrating the implications of climate change on aquaculture sustainability. Many studies are biased toward environmental sustainability, often neglecting the social and economic dimensions. As the aquaculture sector grows and the effects of climate change become more apparent, a holistic approach is needed to project climate change impacts and address these challenges. This will enable more effective mitigation and adaptation strategies. However, achieving this requires further research, particularly in regions that are more vulnerable due to their lower adaptive capacity. International cooperation could play a crucial role in helping poorer economies, which stand to benefit the most from such collaboration.

A hemoglobin assay is considered an accurate and rapid test to verify hematological homeostasis to evaluate the physiological status of fish. If the numerical evolution of erythrocytes shows the quantitative aspect of the integrity of respiratory function, the qualitative aspect is indicated by erythrocyte constants that provide information on the functional nature of hematological indices.

Hematological parameter differences in fish may be due to different environmental factors such as changes in physico-chemical water parameters, season, water temperature, stocking density, and photoperiod. Besides, many other factors affect fish hematological parameters such as age, sex, stress, food content, maturity, hypoxia, and disease [26-30]. Our preliminary study showed a favorable adaptability to growth in a floating cage located in the CM Lunca irrigation canal.

The negative effects of heat stress on sturgeon health are an economic challenge for farms, endangering the development and sustainability of sturgeon aquaculture [31]. Considerations about the impact of global warming on sturgeon aquaculture are increasing, and recent studies have examined the effects of high and extremely high temperatures (near 30^0C) on several organs and physiological functions of different *Acipenser* species [32, 33].

CONCLUSIONS

Sturgeon farming, which thrives in diverse aquatic environments, has evolved significantly since the beginning of the 20th century, adapting to modern production requirements and EU regulations. Today, intensive farming systems, which allow efficient management of water resources and optimization of environmental conditions, are essential for intensive sturgeon aquaculture in Romania. They offer promising opportunities due to the high added value of sturgeon species on the market, promising production conditions, and suitable climatic regimes.

This article has emphasized the potential effects of climate change on aquaculture production and its implications for the sector's sustainability. While aquaculture is considered the primary solution for meeting the growing global demand for aquatic products, it faces increasing threats from human-induced climate change, which presents both current and future challenges. Moreover, while climate change poses a global risk to food production, the risks to aquaculture will likely vary based on factors such as geographical location, national economy, water environments, production systems, scale of production, and the species being farmed.

In conclusion, the broodstocks of the Russian sturgeon showed a favorable adaptability to rearing in a floating cage, located in the CM Lunca irrigation canal, therefore future research on a longer period is needed to investigate the impact of climate change on this sturgeon species.

ACKNOWLEDGMENTS

This research work was carried out with the support of the Research and Development Sectorial Plan of the Agriculture and Rural Development Romanian Ministry - ADER contract no 12.1.2., "Research on assessing the selective breeding potential and epigenetic programming to improve adaptation to changing environmental conditions (temperature, oxygen, water quality, feed, etc.)".

REFERENCES

1. Lydia M. Vasilyeva, Ashraf. I. Gh. Elhetawy, Natalia V. Sudakova, Svetlana S. Astafyeva, History, current status and prospects of sturgeon aquaculture in Russia, Aquaculture Research. **2019**; 50:979–993, DOI: 10.1111/are.13997.
2. Alharthi, 1. Vlasenko, S. A., Guteneva, G. I., &Fomin, S. S., Estimation of the effectiveness of natural reproduction of sturgeon in the Lower Volga. Fisheries Bulletin, **2012**, 13, 736–753. (In Russian).
3. Ji H., Sun H., Shan S., Evaluation of nutrient components and nutritive quality of muscle between pondand cage reared paddlefish (*Polyodon spathula*). *Journal of Fisheries of China*, **2011**, 35 (2), 261–267. (in Chinese).
4. Zhu Y., Yang D., Chen D., He Y. Intercropping mode of sturgeon culture in double layer cage. *Hubei Agricultural Science*, **2011**, 50 (3), 998–1000. (in Chinese).
5. Jiang Z., Technology of ecological sturgeon farming in reservoir cages. Technology in Oceans and Fisheries, **2014**, 4, 64–65. (in Chinese).
6. Chen D., Su S., Li H., Experiments on running water hybrid sturgeon farming in hills in Chongqing. *Scientific Fish Farming*, **2015**, 5, 40–41. (in Chinese).
7. FAO Fisheries and Aquaculture Report - Special Session On Advancing Integrated Agriculture-Aquaculture Through Agroecology, Montpellier, France, 25 August **2018**, ISSN 2070-6987.
8. Deguo Yang, Guojun Ma, and Dajiang Sun, Sturgeon Culture: Status and Practices, Aquaculture in China: Success Stories and Modern Trends, First Edition, **2018**, John Wiley & Sons Ltd. Published 2018, DOI: 10.1002/9781119120759.ch3_5
9. Hossain MAR, Ahmed M, Ojea E, Fernandes JA, Impacts and responses to environmental change in coastal livelihoods of south-west Bangladesh. Science of the Total Environment, **2018**, 1: 954–970.
10. Limuwa MM, Singini W, Storebakken T, Is fish farming an illusion for Lake Malawi riparian communities under environmental changes? Sustainability **2018**, 10: 1–23.
11. Lebel L, Lebel P, Lebel B, Uppanunchai A, Duangsuwan C, The effects of tactical message inserts on risk communication with fish farmers in Northern Thailand. Regional Environmental Change, **2018b**, 18: 2471–2481.
12. Van Putten I, Metcalf S, Frusher S, Marshall N, Tull M, Fishing for the impacts of climate change in the marine sector: a case study. International Journal of Climate Change Strategies and Management, **2014**, 6: 421–441.
13. Rodrıguez-Rodrıguez G, Ramudo RB, Market-driven management of climate change impacts in the Spanish mussel sector. Marine Policy, **2017**, 83: 230–235.
14. Tran N, Rodriguez U-P, Chan CY, Phillips MJ, Mohan CV, Henriksson PJG et, al. Indonesian aquaculture futures: an analysis of fish supply and demand in Indonesia to 2030 and role of aquaculture using the Asia Fish model. Marine Policy, **2017**, 79: 25–32.
15. Paprocki K, Cons J, Life in a shrimp zone: aqua-and other cultures of Bangladesh's coastal landscape. Journal of Peasant Studies, **2014**, 41: 1109–1130.
16. Orchard SE, Stringer LC, Quinn CH, Impacts of aquaculture on social networks in the mangrove systems of northern Vietnam. Ocean & Coastal Management, **2015**, 114: 1–10.
17. Orchard SE, Stringer LC, Quinn CH, Mangrove system dynamics in Southeast Asia:

linking livelihoods and ecosystem services in Vietnam. Regional Environmental Change, **2016**, 16: 865–879.
18. Elena Sîrbu, Maricel Floricel Dima, Magdalena Tenciu, Mirela Cretu, Marian Tiberiu Coadă, Aurelia Țoțoiu, Victor Cristea and Neculai Patriche, Effects of Dietary Supplementation with Probiotics and Prebiotics on Growth, Physiological Condition, and Resistance to Pathogens Challenge in Nile Tilapia *(Oreochromis niloticus),* Fishes **2022**, 7(5), 273; https://doi.org/10.3390/fishes7050273.
19. Dima F.M., Sîrbu E., Chioveanu M.-C., Nistor V., Athanasopoulos L.B., Jalbă A., Patriche N., The Plasticity of Juveniles to *Acipenser gueldenstaedtii* under Conditions of Rearing in a Floating Cage Located on a Pond, Animal & Food Sciences Journal Iasi, **2023**, 80(4), 46-50, ISSN 2821 – 6644.
20. Selçuk Duman, Determination of Reference Values of Some Hematological and Immunological Parameters in Healthy Russian Sturgeon (*Acipenser gueldenstaedtii*), Journal of Anatolian Environmental and Animal Sciences, **2020**, No: 2, 2020 (212-217), https://doi.org/10.35229/jaes.714366
21. Galaz V, Crona B, Osterblom H, Olsson P, Folke C., Polycentric systems and interacting planetary boundaries-emerging governance of climate change–ocean acidification–marine biodiversity. Ecological Economics, **2012**, 81: 21–32.
22. Fleming A, Wise RM, Hansen H, Sams L, The sustainable development goals: a case study. Marine Policy, **2017**, 86: 94–103.
23. Bene C, Arthur R, Norbury H, Allison EH, Beveridge M, Bush S, et al. Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. World Development, **2016**, 79: 177–196.
24. Bene C, Barange M, Subasinghe R, Pinstrup-Andersen P, Merino G, Hemre G-I et al. Feeding 9 billion by 2050–Putting fish back on the menu. Food Security, **2015**, 7: 261–274.
25. FAO The State of World Fisheries and Aquaculture **2016**, Contributing to Food Security and Nutrition for All. Food and Agriculture Organization of the United Nations, Rome.
26. Affonso, E.G., Polez, V.L.P., Correa, C.F., Mazon, A.F., Araujo, M.R.R., Moraes, G., & Rantin, F.T., Blood parameters and metabolites in the teleost fish *Colossoma macropomum* exposed to sulfide or hypoxia. Comp Biochem Physiol C Toxicol Pharmacol, **2002**, 133, 375-382. Doi: 10.1016/S1532-0456(02)00127-8.
27. Ruchin, A.B. Effect of photoperiod on growth, physiological and hematological indices of juvenile Siberian sturgeon *Acipenser baerii*. Biology Bulletin, **2007**, 34, 583-589. Doi:10.1134/S1062359007060088.
28. Bucur, C., Radu, D., Marica, N., Oprea, D., & Stancioiu, S. Preliminary hematologic studies on *Polyodon spathula* (Walbaum, 1792) reared in a controlled system. Annals of the University Dunarea de Jos of Galati Fascicle VI--Food Technology, **2009**, 3(33), 62-69.
29. Sadati, M.A.Y., Pourkazemi, M., Shakurian, M., Hasani, M.H.S., Pourali, H.R., Pourasaadi, M., & Yousefi, A. Effects of daily temperature fluctuations on growth and hematology of juvenile *Acipenser baerii*. Journal of Applied Ichthyology, **2011**, 27(2), 591-594. Doi:10.1111/j.1439-0426.2011.01667.x.
30. Duman, S. The effect of anesthetic (2-phenoxyethanol) application on some biochemical and hematological parameters in Russian sturgeon (*Acipenser gueldenstaedtii*) and Siberian sturgeon (*Acipenser baerii*) during transport. Turkish Journal of Veterinary and Animal Sciences, **2019b**, 43(6), 825-833. Doi: 10.3906/vet-1812-96.
31. Maulu S., Hasimuna O.J., HaambiyaL.H., Monde C., Musuka C.G., Makorwa T.H., Munganga B.P., Phiri K.J., Nsekanabo J.D., Climate change effects on aquaculture production: sustainability implications, mitigation, and adaptations, Front. Sustain. Food Syst. 5, **2021**, https://www.frontiersin.org/articles/10.3389/fsufs.2021.609097.
32. Yebra-Pimentel E.S., Gebert M., Jansen H.J., Jong-Raadsen S.A., Dirks R.P.H.,Deep transcriptome analysis of the heat shock response in an Atlantic sturgeon (*Acipenser oxyrinchus*) cell line, Fish Shellfish Immunol. **2019**, 88, 508–517, https://doi.org/10.1016/j.fsi.2019.03.014.
33. Bugg W.S., Yoon G.R., Schoen A.N., Weinrauch A.M., Jeffries K.M., Anderson W.G., Elevated temperatures dampen the innate immune capacity of developing lake sturgeon (*Acipenser fulvescens*), J. Exp. Biol. **2023**, 226, jeb245335, https://doi.org/10.1242/jeb.245335.