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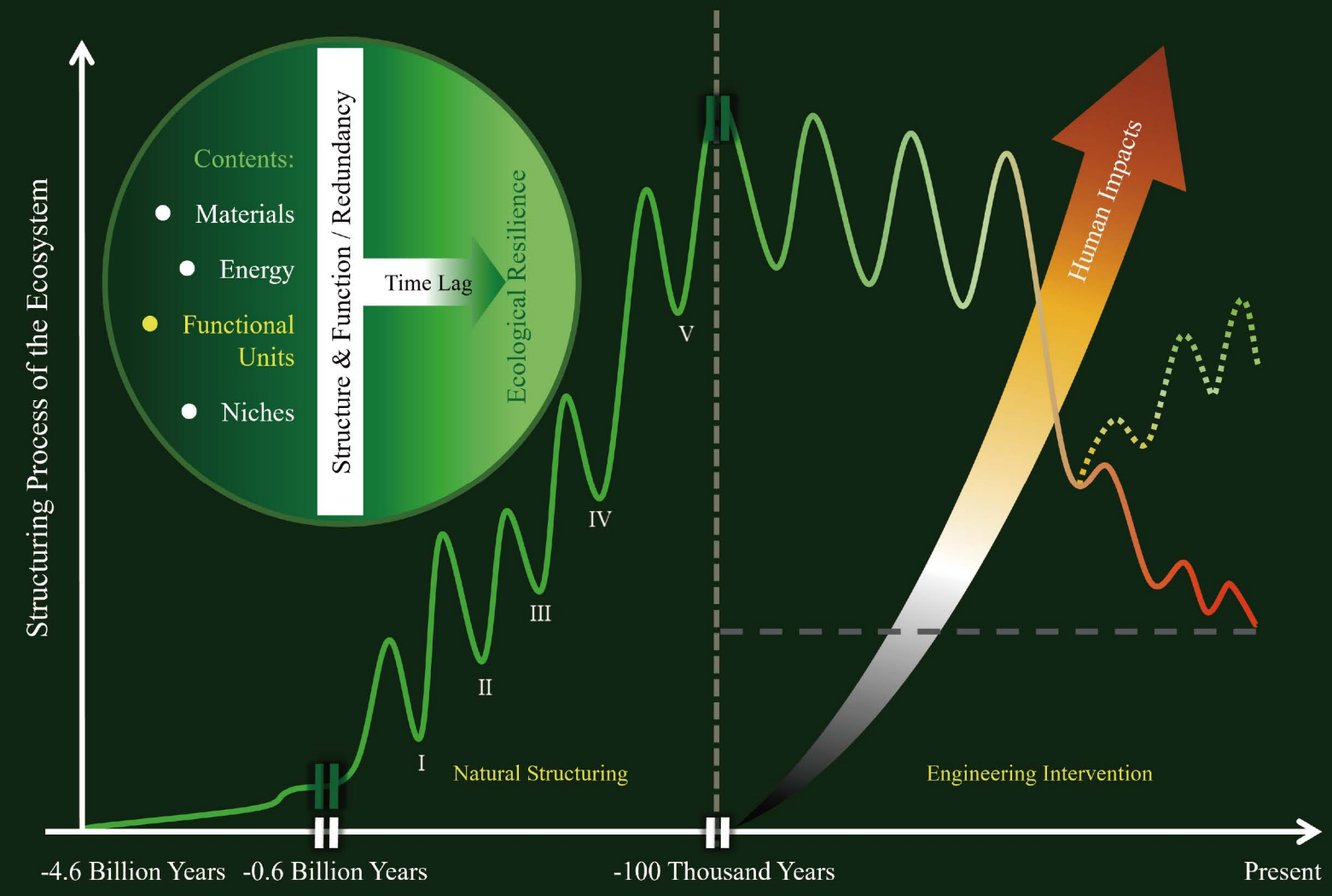

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CONTENTS

Restoration of Wild Sturgeon Populations of the Lena and Amur Rivers

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Summary: Over a quarter of a billion years of their existence, the Acipenseriformes have survived many climatic cataclysms and have come to this day, practically unchanged. But human intervention in their habitat and unbridled fishing pressure has led their populations to the brink of extinction over a century and a half. Artificial reproduction of sturgeon, which has become widespread since the 1950s with the start of large-scale construction of dams, and the ban on commercial fishing partially compensate for the numerical damage inflicted on the populations. But at the same time, the diversity of genes and the ability to self-reproduce are reduced in artificially maintained populations. The sturgeon populations of the once richest basins of the Caspian and Azov Seas are currently maintained mainly by artificially bred individuals, and therefore it is not entirely correct to regard them as wild and predict their independent reproduction. However in Russia there are huge waterways, where sturgeon populations have, to some extent, retained their original state. From the Ural Mountains to the Anadyr Lowland and from 48° to 74° N, the Siberian sturgeon, *Acipenser baerii* Brandt, 1869, inhabits all large rivers and their tributaries. The relatively small Amur River basin is the habitat of the Amur sturgeon, *Acipenser schrenckii* Brandt, 1869, and the Kaluga, *Huso dauricus* Georgi, 1775. The Kaluga can be found in the sea area from the northern shores of the Sea of Okhotsk to Southern Primorye and Hokkaido Island. These species have historically been the objects of commercial fishing, which on the Amur reached its peak in the late 1800s, and on the main Siberian rivers in the early to mid-1900s. Excessive catch volumes on the background sparse distribution of the resource, as well as neglect of the permitted catch size and fishing periods, led to a sharp decline in the sturgeon stock. Strict regulation of fishing partially contributed to their recovery. However, the construction of hydroelectric power stations on the Ob', Yenisei, Zeya and Bureya rivers led to the final stoppage of fishing and the inclusion of sturgeon populations of these and other Siberian rivers in the Red Book of the Russian Federation. The sturgeon populations of the Lena and Amur rivers are luckier. There are no dams on these rivers, natural spawning grounds and floods have been preserved here. The Lena River is currently the only body of water where commercial sturgeon fishing is permitted. Artificial reproduction of sturgeon in the Amur and Lena rivers began in the 2000s. The volumes of releases of artificially bred juveniles are insignificant and far from the volumes of theoretically possible natural spawning. Therefore, the sturgeon populations of these two rivers are maintained due to natural spawning and retain natural genetic polymorphism, which is of the greatest interest in terms of their ability to self-recovery in modern conditions of existence. Our study provides a retrospective review of fishery dynamics, assessment of the current state and self-restoration of Siberian sturgeon of the Lena River and Amur sturgeon and Kaluga of the Amur River.

Keywords: Siberian sturgeon *Acipenser baerii* Brandt, 1869; Amur sturgeon *Acipenser schrenckii* Brandt, 1869; Kaluga *Huso dauricus* Georgi, 1775; The Lena River; The Amur River; Fisheries; Current state; Restoration

Exploring Welfare Implications of Caviar Production: Stakeholder Perspectives from the European Sturgeon Farming Sector

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ABSTRACT: While sturgeon aquaculture plays a central role in caviar production globally, the welfare of these long-lived, late-maturing fish remains poorly understood. Amid increasing public and regulatory attention on animal welfare, the industry faces growing scrutiny—particularly regarding traditional versus "no-kill" harvesting methods. This study aims to provide the first qualitative snapshot of welfare-related perceptions, practices, and concerns within the European sturgeon farming sector. Through in-depth interviews with 20 stakeholders—including producers, veterinarians, researchers, and hatchery managers—we explored current husbandry methods, attitudes towards fish welfare, and views on the feasibility of ethical improvement. Our findings highlight wide variability in both practices and awareness, as well as strong interest in identifying measurable indicators of good welfare. While many respondents associated no-kill methods with higher welfare potential, concerns were raised about technical challenges, reliability, and market acceptance. Participants expressed openness to external guidance but emphasised the need for species-specific protocols and the importance of producer-led solutions. Several reported perceived links between improved welfare and product quality, though empirical evidence was limited. A tension emerged between economic drivers and moral obligations, underscoring the complexity of improving welfare in this high-value, low-volume sector. These insights will inform the next phase of our work: the co-development of a practical, credible framework for assessing sturgeon welfare. We propose that transparent, stakeholder-informed approaches can help safeguard fish welfare while supporting responsible aquaculture development in this sensitive sector.

Keywords: Sturgeon; Welfare; Aquaculture; Caviar; Stakeholder consultation; No-kill; Animal ethics; Europe

Review of Bycatch Prevention and Mitigation Measures for Sturgeons in Europe

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ABSTRACT: The eight native sturgeons found in Europe are under massive threat of extinction. Anthropogenic pressures such as historic overexploitation and in some regions continued illegal fishing are the primary reasons for steep population declines. Damming, navigation, dewatering, pollution and climate change continuously affect the suitability of their habitats. Historically, the presence of sturgeon has been documented in at least 78 river systems throughout the European continent but today their presence is limited to approximately 15 river drainages with almost all populations depending on active recovery measures. Bycatch of sturgeon in a variety of fisheries poses a significant and often neglected threat to the recovery of critically endangered populations in Europe, as it removes rare individuals from already very small remaining populations. This impact is especially pronounced in late maturing and long lived species such as sturgeons while the exact dimension of the impact is unknown due to the uncertainty surrounding the magnitude of sturgeon accidentally caught in the diverse fisheries and their fate remains unknown. Despite existing obligations under the Habitats Directive to establish a system to monitor the levels and extent of injuries resulting from incidental capture of the animal species listed in Annex IV, there are no official records available. Our reliance on voluntary declarations by fishers at best provides patchy data and are known to massively underestimate the extent of the impact. In the frame of a contract with the European Commission, we summarized the available information on sturgeon bycatch in Europe supplemented by experience from North America. The outcome contributes to the implementation of the PANEUAP aiming to “reduce accidental removal to levels allowing population recovery” by raising awareness as well as outlining available approaches at hand for the prevention, the mitigation or the improved knowledge base on the impact of commercial and recreational fisheries. Among the options discussed are the reduction of fishing pressure through temporal or spatial closures, gear alterations, technical surveillance systems or awareness raising and involvement of fishers.

Keywords: Bycatch; Fisheries; Mortality; Capturability; Europe; Ocean; Estuaries

Caviar Preference among Sustainability-Minded Youth

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ABSTRACT: While caviar markets and marketing are perhaps well-developed fields of inquiry, little is known about the preferences of consumers in their twenties. This study provides insights into preferences for sturgeon caviar, salmon caviar, and faux caviar among potential new consumers in the United States. Results from a questionnaire of 40 respondents are presented, which includes information compiled about caviar preferences among youth participants who are familiar with the environmental and sustainability concerns of caviar production and who are interested in addressing their "foodprint", the carbon footprint related to food production, transport, consumption, and waste. Conclusions and recommendations for future marketing are provided.

Keywords: Caviar; Sustainability; Affordability; Perception; Youth

How Can Acoustic Telemetry on Sturgeons Increase the Potential for River Restauration?—The Swedish Case with Re Introduction of Atlantic Sturgeon

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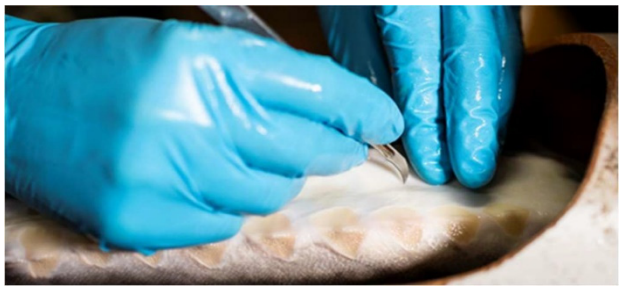
The Atlantic sturgeon declined drastically from Europe in the early years of 1900 and the last known specimen was caught in the wild 1996. Re introduction started in the German-Polish border river of Odra in the early 2000 and the German case has been a vital inspiration for the rest of the Baltic countries. In Sweden, Atlantic sturgeon was present in a number of large rivers including the Göta River on the west coast. Göta is the only river with confirmed spawning, a fact verified through preserved specimens at the Gothenburg Museum for Natural History (Picture 2). The Swedish re introduction started late but has since then worked hard to catch up. The first juveniles were brought in spring 2024 and released via a specially designed soft release cage (Picture 1). A facility for rearing was built and the second batch was released in spring 2025.

Two hundred sturgeons have been equipped with acoustic telemetry, serving as a vital part of the monitoring of the re introduction program. By triangulating the habitat usage of the sturgeon in the river, the foraging pattern can be detected (Figure 1). This information is closely related to occurrence of benthic fauna and can be used to plan for future restoration of the heavily modified river. (Figure 2) The preliminary results show a high level of survival and an extensive migration pattern. Samples of other river fishes show a gap in the food web suitable for sturgeon juveniles.

Picture 1. Atlantic sturgeon leaving the soft release cage in Lilla Edet, Sweden.

Picture 2. Preserved juveniles is proof of historical spawning.



Picture 3. Acoustic transmitter is surgically inserted into the body cavity.

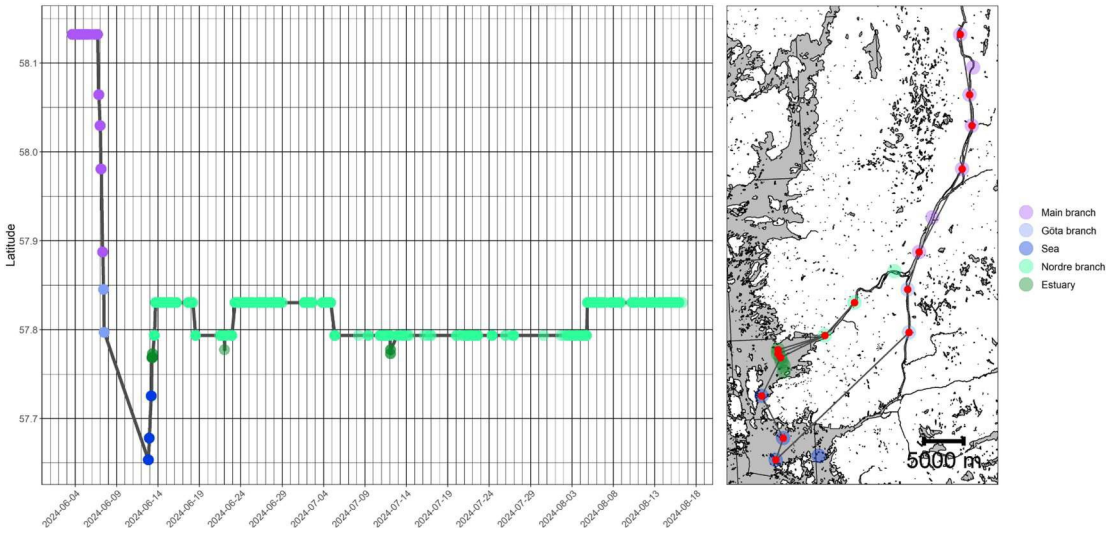


Figure 1. The juvenile sturgeon show an extensive migration pattern.

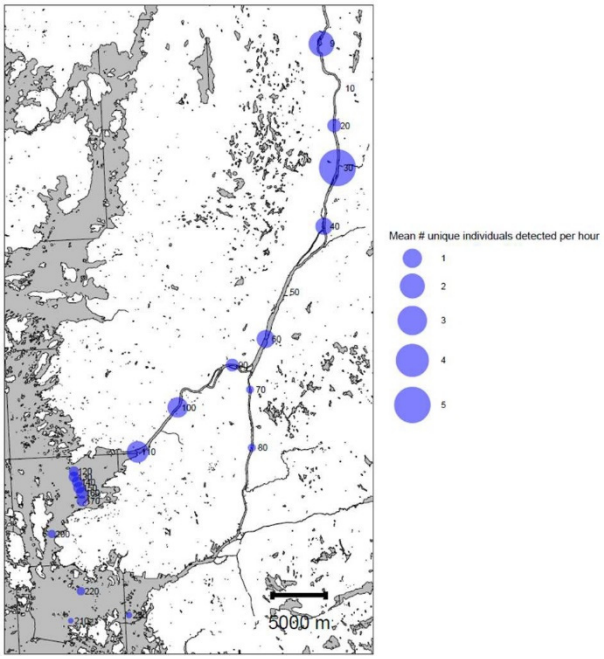


Figure 2. Acoustic telemetry can help planning future river restoration.

The plans for the future is to study the foraging pattern and the migration of the sturgeons into more detail using a combination of telemetry, by-catch reports, benthic samples and a close collaboration with other organizations.

What Are the Effects of Imidacloprid, A Neonicotinoid Insecticide, on the Embryo-Larval Stages of the Sterlet Sturgeon, *Acipenser ruthenus*?

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ABSTRACT: Imidacloprid is an insecticide of the neonicotinoid family used to protect different types of crops such as wheat, beet or fruit trees. This substance is regularly detected in European surface waters. Nevertheless, the toxic effects on highly sensitive early life stages of fish at realistic environmental concentrations are not really known. The sturgeon taxa include several endangered species whose decline is multifactorial but for a part is linked to water pollution. The aim of this work was to assess the potential toxic effects of imidacloprid on Sterlet sturgeon (*Acipenser ruthenus*) when exposed during embryo-larval stages. To achieve this, exposure to environmental concentrations of imidacloprid (0.04 µg/L to 4 µg/L) was carried out from egg fertilization to resorption of the yolk sac under controlled laboratory conditions. In addition to survival, hatching success and growth (in size and weight) several toxicological endpoints were measured including, malformations, cardiac activity, swimming behavior, biomarkers (SOD, AchE, GST, TBARs, carbonylated proteins) and transcriptomics (gene expression). The results show that there was no mortality and no disruption of hatching success at any concentration. Growth criteria showed a significant difference in weight at the highest concentration, and a significant difference in head and eye size at the lowest concentration. No difference was observed for swimming behavior, but cardiac activity showed bradycardia at all concentrations compared with the control. Concerning gene expression, IMI-induced effects were found to be more pronounced at the lowest concentrations tested and were mainly associated with genes involved in energy metabolism (mitochondria) and nervous system development.

Keywords: Ecotoxicology; Embryos; Imidacloprid; Experimentation

Effect of Two Fungicides Boscalid and Imazalil on the Development of *A. ruthenus* Embryos Based on An Experimental Approach

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ABSTRACT: Among the factors included in the global changes that have led to the scarcity of the sturgeon, water contamination occupies a special place. A few studies have been carried out in contexts of very high with lethal effects, but apart from that, we have very little information on the possible effects of chronic contamination on the functioning of sturgeon populations. In order to assess the tolerance of sturgeon embryos to substances widely used in agriculture, we carried out experiments with two fungicides used to treat certain crops and to preserve fruit and vegetables: Boscalid and Imazalil. Two series of experiments were carried out with *A. ruthenus* embryos obtained by assisted reproduction at an INRAE station, in 2021 and 2022. We exposed freshly fertilized embryos, embryos at the end of yolk sac resorption, and larvae to environmental concentrations of Boscalid (1–10 µg/L) and Imazalil (1–10 µg/L). The results showed that at these concentrations, there was no lethal effect and no impact on embryo hatching success. Among the sublethal effects, we observed earlier hatchings at the highest concentrations tested of the two fungicides and at concentrations of 1 µg/L, boscalid caused a reduction in the heart rate of the larvae. In addition, at the lowest concentrations, both fungicides induced abnormal growth and a change in larval swimming behaviour. Genetic analyses carried out on larvae exposed to the highest concentrations of boscalid and imazalil revealed a disturbance in the metabolism of xenobiotics, lipids, steroids and mitochondria. Genes involved in development, neurotransmission and defence against oxidative stress were also altered. This study showed that at environmental concentrations, boscalid and imazalil affected various physiological functions in *A. ruthenus* larvae. These two compounds could therefore pose a major risk to populations of sterlet and other sturgeon species.

Keywords: Ecotoxicology; Embryo development; Fungicides; Effects

Predation Risk in Stocking Programs: Case Study on A Diadromous Critically Endangered Species, *The European Sturgeon*

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ABSTRACT: Stocking programs are conducted in sturgeon species for conservation purposes to avoid their extinction. Juveniles produced in hatchery can present depleted behavioral capacity compared to wild conspecifics, especially unappropriated anti-predator responses. In this study, predation risk was assessed for two juvenile stages of *Acipenser sturio*, the last native sturgeon species of Western Europe, thanks to two complementary techniques: diet analysis of a top predator and telemetry tools. Experiments were conducted in two large rivers (Dordogne, Garonne) in the South West of France. After the stocking of 3 months old juveniles, *Silurus glanis* diet was assessed using direct stomach content examination and molecular analysis of their feces via digital PCR targeting 6 potential preys. Molecular analysis of *S. glanis* feces indicated a moderate predation on sturgeon, detected in 30% of the fecal samples, a level similar to that observed for *Cyprinus carpio* and *Faxonius limosus*. *Eriocheir sinensis* was detected in 52% of the samples, while *Anguilla anguilla* was highly consumed (82% of the fecal samples). *Alosa* sp. juveniles were also search but not detected in the feces analysis. No diadromous fish were detected in the direct stomach analysis, which highlighted the usefulness of the molecular approach. Eleven-month-old juveniles were equipped with acoustic predation tags and released in the wild to assess their predation rate during their downstream migration. A high predation rate in the Dordogne River with more than 80% of the individuals predated before they reached the saline estuary was revealed. In contrast, a moderate predation rate was observed in the Garonne River but linked to a peak of water flow the day following the release, transporting rapidly the individuals towards the saline estuary. Results are interpreted in the light of the literature review of predation risk along the continuum from freshwater to the sea for *A. sturio*.

Keywords: Predation; Telemetry; Digital PCR; Acipenser sturio

Diagnosis and Prevention Strategies of Sturgeon Diseases

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ABSTRACT: Since 2003, the production of sturgeon aquaculture in China has been continuously increasing, from 10,900 tons in 2003 to nearly 150,000 tons in 2024. With the continuous increase in the production of artificially farmed sturgeon, frequent occurrence of diseases has become the main limiting factor in sturgeon farming. Our team has been committed to the research and development of sturgeon disease diagnosis and detection kits, as well as the screening of antibacterial drugs for the past decade, and has achieved a series of research results. Firstly, various pathogenic bacteria were isolated and identified in sturgeons such as Chinese sturgeon (*Acipenser sinensis*), Yangtze sturgeon (*A. dabryanus*), hybrid sturgeon, including *Staphylococcus sciuri, Aeromonas veronii*, *A. hydrophila*, *Citrobacter freundii*, *Yersinia ruckeri*, *Mycobacterium marinum*, and *Plesiomonas shigelloides*; Secondly, the focus was on exploring the pathogenic mechanisms of *Y. ruckeri*, *M. marinum* and *S. sciuri* on sturgeons; At the same time, a diagnostic method for detecting whether sturgeons are infected with *M. marinum* has been successfully established, which can effectively prevent the occurrence of non-tuberculous mycobacteria in sturgeons; In addition, a large number of experiments have been conducted to demonstrate the excellent antibacterial effect of type I interferon IFNf and its a4 domain protein (IFNf a4) in sturgeon; Finally, a strain of *Fictibacillus nanhaiensis* was screened from the intestinal tract of Chinese sturgeon, which can effectively inhibit the growth of *M. marinum*, *Y. ruckeri*, *A. veronii*, demonstrating good practical application value. In addition to studying bacterial diseases in sturgeon, the team also discovered type I herpesvirus in juvenile Chinese sturgeon. After infection with this virus, the mortality rate of juvenile Chinese sturgeon reached 80%. The study of the infection process and pathogenic mechanism of pathogenic pathogens in sturgeon can effectively prevent the occurrence of diseases, reduce the mortality rate of sturgeon, and improve the economic benefits of aquaculture.

Keywords: Sturgeon; *Mycobacterium marinum*; *Yersinia ruckeri*; IFNf; *Fictibacillus nanhaiensis*

Historical and Contemporary Overview of Sturgeon and Caviar Production Worldwide

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ABSTRACT: Sturgeon and caviar production have undergone profound changes over the past decades, driven by both conservation needs and market dynamics. Once reliant on wild fisheries, global production has shifted almost entirely to aquaculture following the decline of natural populations and the enforcement of strict protective measures. Today, caviar is produced almost exclusively from captive broodstock, maintained and reproduced under controlled conditions, with increasing use of hybrid strains developed to optimize yields and adapt to intensive aquaculture systems. This overview examines historical production patterns and provides an updated analysis of worldwide sturgeon and caviar production up to 2024. Data indicate that while more than 50 countries are now involved, production remains highly concentrated among a smaller group of major producers in Europe and Asia. Global and country-level contributions are presented, alongside trends in farmed species, the evolution of caviar production under CITES regulation, and the growing role of caviar substitutes. Despite challenges in collecting reliable statistics, the analysis highlights the rapid expansion of aquaculture, with China now accounting for the majority of global production. By contrasting past and present, this contribution underscores aquaculture's dual role: as a key economic sector and as a critical reservoir of broodstock essential for restocking and recovery programs for endangered sturgeon species.

Keywords: Caviar

Chronic Heat Stress Caused Lipid Metabolism Disorder and Tissue Injury in the Liver of *Huso dauricus* via Oxidative Stress-Mediated Ferroptosis

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† Whom has the equal contribution to this study.

ABSTRACT: High temperature stress has become an important factor that restricted the aquaculture industry. *Huso dauricus* is a high economic value fish that faced the thermal stress threat. In this study, we set one control group (19 ℃) and four high-temperature treatment groups (22 ℃, 25 ℃, 28 ℃, 31 ℃) with 40 fish in each group for continuous 53-day heat exposure. Histological analysis, biochemical detection and transcriptome technology were used to explore the effects of heat stress on the liver structure and functions of juvenile *Huso dauricus*. It suggeated that heat stress induced hepatic vacuolization, nuclear atrophy, cytoplasmic disintegration in juvenile *Huso dauricus* with time/temperature-dependent manner. Serum total protein, transaminase, and alkaline phosphatase activities showed significant changes under heat stress. Hepatic reactive oxygen species level and lipid accumulation in heat groups were also observed. In addition, 6433 differentially expressed genes (DEGs) were identified based on the RNA-seq project. Gene Ontology enrichment analysis showed that the DEGs were mainly related to energy metabolism, lipid metabolism and amino acid metabolism. KEGG enrichment and immunohistochemistry analysis showed that ferroptosis and FoxO signaling pathways were significantly enriched. These results demonstrated that thermal stress induced oxidative stress damage in the liver of juvenile *Huso dauricus*, which triggered lipid metabolism disorder and hepatocyte ferroptosis to disrupt the normal liver functions. In conclusion, our investigation contributed to understand the molecular mechanism on the chronic heat stress-induced injury in *Huso dauricus.* It is of certain significance for the healthy breeding of *Huso dauricus* and the protection strategy development of wild population.

Keywords: *Huso dauricus*; Oxidative stress; Heat stress; Liver; Transcriptome

Market Control Study on Sturgeon Products in the European Union and Switzerland

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ABSTRACT: A market study on sturgeon products collected in Bulgaria, Romania, France, Italy, Germany and Switzerland resulted in a total of 128 caviar samples and 25 samples of meat (in total 163 samples). Multilocus genetic analyses based on microsatellite analysis for detecting the ploidy level and for species/hybrid identification, SNP genotyping for species/hybrid identification and sequencing of mitochondrial DNA used for the identification of the maternal species were done for verification of species declaration. At the same time, isotope analyses were involved for the discrimination of wild and aquaculture origin. The outcome comprised caviar sold in violation of CITES and EU regulations, and cases of consumer deception (e.g., artificial products sold as sturgeon caviar or meat from other species declared as sturgeon origin). Of particular concern are those samples where products were assessed as originating from wild-caught sturgeons, despite their strict legal protection. Any import of products from wild-caught sturgeons is prohibited in the EU and also no commercial fishing is allowed for the last remaining wild sturgeon populations in the EU. Although poaching and illegal wildlife trade are often considered a problem in countries outside the EU, our findings bear evidence that CITES regulations are not being adequately enforced to protect wild sturgeons and that poached sturgeon products are sold in EU Member States too. We conclude, that caviar and sturgeon trade urgently needs improvement to ensure that sturgeon populations will have a future and do not only survive in aquaculture.

Keywords: Caviar; Market control; DNA; Isotope analysis

Genetic Profiling of Ukrainian Stellate Sturgeon Based on Microsatellite Analysis

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ABSTRACT: The Stellate sturgeon (*Acipenser stellatus*, Pallas) is one of the valuable representatives of the Ukrainian waters. Despite its commercial and ecological importance, there is insufficient information about the genetic status of the Stellate sturgeon population in the north-western part of the Black Sea basin. The aim of the study was to bring light in the genetic diversity of the Stellate Sturgeon. Therefore, microsatellites has been used. Thirty-two individuals of Stellate sturgeon obtained from wild spawning grounds in the Dnieper River basin, Black Sea were studied. The following six microsatellite DNA markers were used for the molecular genetic studies: LS-19, LS-39, LS-68, LS-54, Aox-27 and Aox-45. The study identified 40 alleles. The most polymorphic locus was Aox-45 with 12 alleles. The LS-39 locus was monomorphic, which is a marker for species identification in this species. The results obtained in this study should be taken into account in the future monitoring of the genetic status. They microsatellite profiles can also be taken for assignment of river origin.

Keywords: Stellatus; Sevruga

Dynamic Impacts of Stock Enhancement on Kaluga Sturgeon (*Huso dauricus*): Novel Conservation Strategy Insight from Gut Microbe Composition and Gene Expression Mode

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ABSTRACT: Sturgeon population underwent strict threats due to inordinate human activities in the past decade and had been classified into the Red List of Threatened Species in recent years. Stock enhancement is one effective practice for the conservation practice of wild sturgeon. However, the survival condition of sturgeon was not satisfactory after direct re-stocking to natural habitat. *Huso dauricus* is one important protected sturgeon species and appropriate conservation strategy for wild population is urgent. To clarity the dynamic adaptability of *Huso dauricus* to wild environment, one thousand individuals were released to natural river. On the 0th d, 7th d, 14th d and 30th d, five re-captured individuals were used to evaluate the dynamic trends of biochemical biomarkers, intestinal histomorphology, gut microbe taxa composition and transcription profile during 30 d stock enhancement. Our results indicated that *Huso dauricus* individuals were still in physiological stress status in 7th d and then gradually adapted to wild habitat after 14 d reintroduction based on the serum cortisol level. Meanwhile, feeding habitat, organ functions indicators and growth performance also showed similar dynamic changes within 30 d. Interestingly, gut bacteria diversity and taxa structure also fluctuated during 30 d re-stocking, which accompanied with the dynamic changes in intestinal pathological injury and tight junction protein expression in this period. Transcriptome revealed that dynamic adaptability of *Huso dauricus* to wild habitat associated with the expression mode of FoxO family, immune, cytochrome family and ATP metabolism-related genes. Taken together, the present research demonstrated that artificial reintroduction possessed dynamic impacts on the health condition of *Huso dauricus* and 14 d wilderness training might be essential for sturgeon re-stocking practice. Our study reveal the adaption mechanism of *Huso dauricus* during re-stocking period from molecular level and shed light on the theoretical guideline for wild sturgeon conservation.

Keywords: Stock enhancement; Sturgeon; Environment adaption; *Huso dauricus*; Conservation biology

Effects of α-Lipoic Acid Supplementation in High Plant-Protein Diets on Growth Performance and Health of Hybrid Sturgeon

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ABSTRACT: This study evaluated the efficacy of α-lipoic acid (LA) in mitigating the adverse effects induced by high plant protein-based replacement of fishmeal in hybrid sturgeon (*Acipenser baerii*♀ × *A. schrenckii*♂). Four diets were formulated: a positive control (PC; 50% fishmeal) and three experimental diets with 70% fishmeal replaced by plant protein: NC (0 mg LA/kg), L200 (200 mg LA/kg), and L400 (400 mg LA/kg). Juvenile sturgeon (initial weight 29.38 ± 0.10 g) were fed these diets for eight weeks. The NC group exhibited significantly lower growth performance and feed utilization than the PC group ($p < 0.05$). Although dietary LA supplementation did not significantly improve weight gain or feed conversion ratio ($p > 0.05$), the hepatosomatic index in the L400 group was significantly lower than that in the NC group ($p < 0.05$). The apparent digestibility coefficients (ADC) of nutrients in the NC group were significantly lower than those in the PC group, whereas LA supplementation significantly increased ADC of dry matter and energy ($p < 0.05$), thereby optimizing energy and nitrogen balance. No significant differences were observed in whole-body or hepatic proximate composition among treatments ($p > 0.05$). Serum analysis revealed that the L200 group had significantly lower alanine aminotransferase (ALT) and malondialdehyde (MDA) levels ($p < 0.05$), but higher total glutathione (T-GSH), oxidized glutathione (GSSG), superoxide dismutase (SOD), and catalase (CAT) activities ($p < 0.05$). In the liver, the L200 group showed significantly reduced MDA content ($p < 0.05$) and restored SOD, CAT activities, and glutathione (GSH) concentration to PC-comparable levels. Histological examination indicated more severe hepatocellular vacuolation and nuclear displacement in the NC and L400 groups, and impaired intestinal villus structure in NC; these pathological changes were attenuated by LA supplementation. In summary, dietary LA under high plant-protein feeding did not enhance growth but improved feed utilization, modulated energy/nitrogen retention, enhanced antioxidant capacity, and ameliorated hepatic and intestinal health in hybrid sturgeon.

Keywords: Aquaculture; Diet; Additive; Growth; Health

The Effects of Dietary Arachidonic Acid (ARA) on Growth, Fatty Acid Deposition, Blood Hormone Levels, and Ovarian Development in Stage III Female Yangtze Sturgeon

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ABSTRACT: To assess the impacts of dietary ARA supplementation at varying levels on growth, fatty acid deposition, blood hormone profiles, and ovarian development in stage III female Yangtze sturgeon, three experimental diets were formulated by supplementing a basal diet with 0%, 1%, or 2% ARA. These diets were administered to stage III female Yangtze sturgeon (initial body weight: 15.23 ± 2.54 kg) over a 12-month feeding trial. The experiment included three treatment groups, each consisting of 9 fish. Dietary ARA levels did not significantly affect the growth of stage III female Yangtze sturgeon broodstock ($p > 0.05$). Tissue fatty acid profiles correlated with dietary fatty acid composition, with dietary ARA supplementation significantly increasing the proportion of n-6 polyunsaturated fatty acids (PUFAs) in tissues ($p < 0.05$). Serum estradiol (E_2) levels increased progressively with rising dietary ARA levels. In contrast, testosterone (T), luteinizing hormone (LH), and follicle-stimulating hormone (FSH) concentrations peaked in the 1% ARA group. No significant differences in oocyte diameter were observed among treatment groups ($p > 0.05$). However, the 1% ARA group exhibited the highest proportion of lipid droplet area in oocytes. The proportion of broodstock advancing to stage IV was higher in the 1% ARA group compared to the 0% ARA group. These findings indicate that dietary supplementation with a certain amount of ARA enhances ARA deposition in Yangtze sturgeon broodstock and influences hormone synthesis and developmental status.

Keywords: Arachidonic acid; Sturgeon; Growth; Ovarian development

Research on Intelligent Measurement Methods and Equipment Development for Sturgeon Phenotypes

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ABSTRACT: To enhance the efficiency and accuracy of phenotypic data acquisition in sturgeon aquaculture, this study systematically investigates intelligent measurement methods and equipment for sturgeon phenotypes. By integrating 3D vision imaging, depth-brightness mapping models, and machine vision-based segmentation algorithms, a series of models for estimating individual and grouped sturgeon weights were developed, including models based on body length and area, 3D surface area, and volume. Based on these methods, which were validated through both controlled laboratory experiments and on-site field trials to ensure accuracy, a series of devices and platforms were developed. These include a portable in-situ measuring device, a high-throughput intelligent weighing platform, and an AR-based wearable measurement system, all featuring high throughput, portability, and high precision, achieving ~90% segmentation accuracy under occlusion and weight prediction correlations above 0.86. Laboratory and field tests demonstrated the systems' ability to perform accurate and efficient sturgeon weight and swimming behavior monitoring. These validated outcomes, demonstrating robust segmentation and reliable weight prediction performance, provide effective tools for sturgeon species evaluation, farming management, and digital twin modeling, promoting the development of intelligent aquaculture technologies.

Keywords: Sturgeon; Phenotype measurement; Intelligent equipment; Digital twin

Slow-Warming Heat Stress Reveals Organ-Specific Responses and Breeding Indices in Sturgeon and Reciprocal Hybrids

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ABSTRACT: To identify practical, physiology-based indicators of thermal tolerance under ecologically realistic slow warming, and to compare reciprocal hybrids for breeding and management use. Juveniles of Acipenser baerii and reciprocal hybrids (*A. baerii*♀ × *A. schrenckii*♂, BS; *A. schrenckii*♀ × *A. baerii*♂, SB) were ramped at 1 °C per 8 h to loss of equilibrium (LOE). A subset underwent 24 h rapid cooling for recovery. We measured serum cortisol, lactate, and glucose; antioxidant status (SOD, CAT, T-AOC, MDA); tissue LDH activity; and hsp70/hsc70/hsp90 expression in liver, gill, and kidney, with parallel histopathology. LOE occurred near 33 °C in *A. baerii* and 34–35 °C in hybrids. BS outperformed SB in survival and functional recovery. Heat stress increased cortisol and lactate, while glucose tended to decline. Antioxidant metrics changed little overall, whereas LDH rose, especially in kidney. HSP induction was tissue- and cross-direction-specific (predominantly liver in BS, gill in SB), aligning with pathology (hepatic vacuolar degeneration *vs.* gill epithelial lesions). Many variables normalized within 24 h of cooling, revealing substantial physiological reversibility. Slow-warming plus recovery tests expose resilience that acute shocks miss and can be deployed on farm. We recommend a composite selection index for thermotolerance—LOE temperature + serum lactate/LDH + tissue-specific HSP expression—and targeted husbandry during heatwaves: staged cooling and organ-specific support (hepatoprotectants for BS, gill-protective measures for SB). Breeding programs should incorporate slow-warming screens to identify thermotolerant broodstock and to validate genomic predictors.

Keywords: Slow-warming heat stress; Sturgeon; Reciprocal hybrids; Organ-specific responses; Heat shock proteins (HSPs); Lactate dehydrogenase (LDH); Loss of equilibrium (LOE)

Utilizing SNPs and InDels from Whole-Genome Sequencing to Improve Genomic Prediction in Sturgeons

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ABSTRACT: Whole-genome sequencing captures a wide spectrum of genomic variations beyond single nucleotide polymorphisms (SNPs). Harnessing these diverse variations could be beneficial for genomic prediction. This study investigates the influence of SNPs and insertion-deletions (InDels) on genomic prediction within the Russian sturgeon (*Acipenser gueldenstaedtii*) population, focusing on key traits such as caviar yield, caviar color, and body weight. We generated whole-genome sequencing data comprising 10,409,793 high-quality SNPs and 4,938,138 InDels from 673 sequenced individuals (~13.68×). Using linkage disequilibrium pruning, we reduced whole-genome sequencing data to approximately 50K markers, facilitating an evaluation of various prediction methods. Our results reveal that prediction accuracy improves with increased marker density, peaking around 50K markers, and that the inclusion of InDels from whole-genome sequencing further enhances prediction accuracy for specific traits. The multi-source BLUP (MSBLUP) method, which integrates both SNPs and InDels, achieves an average prediction accuracy 1.5% higher than GBLUP. Additionally, Bayesian methods demonstrated comparable prediction accuracy to GBLUP. Kernel ridge regression achieved the highest prediction accuracy, with an average improvement of 2.2% over GBLUP across all traits assessed. Overall, these results highlight the benefits of utilizing a diverse set of genetic markers and advanced prediction methods to enhance genomic prediction accuracy in aquaculture breeding programs.

Keywords: Genomic prediction; Linkage disequilibrium pruning; Bayesian methods; Machine learning methods; Sturgeon

Not Only Sexing and Stagging: Possibilities of Un-Alternative Noninvasive Ultrasound Express Screening for Optimization Farmed and Wild Broodstock Management

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ABSTRACT: To evaluate the possibilities of ultrasound screening of the reproductive system and internal organs of sturgeon fish to optimize broodstock management. At present, these are especially urgent in conditions of intensive aquaculture, decreasing genetic diversity of sturgeon broodstock, climate change, pollution, and alteration of the water regime of rivers. In the present paper we present the results of long-term all season ultrasound monitoring of 160 large broodstocks of 13 sturgeon species in intensive aquaculture and wild specimen, based on the analysis of circa 5 mln. echograms. Affordable (less than 5000 US$) ultrasound scanners Mindray 6600–6900 (frequency 1.5–10 MHz) have been used. This has allowed to conduct an analysis of species-specific peculiarities of sturgeon reproductive status at all-year round alive obtaining of ovulated eggs and controlling seasonality of females maturation. It has been established, that timely non-invasive express ultrasound detection of females with gonads at II fatty stage for further separate feeding allows to considerably shift the ratio of somatic growth and generative metabolism in favor of the latter. This allows to prevent obesity of the gonads, liver, heart; as well as cyst formation and more dangerous negative consequences of metabolic disorders. Echograms serve as indicators for optimizing the feeding regime and subsequent (from III–IV maturity stage) temperature changes for the accelerated onset and following completion of vitellogenesis, prevention of oocyte atresia and increase the rate and quality of fertilized eggs and caviar. Considering an immediate result for tagging and simultaneous distribution of sturgeon specimens already in the course of the broodstock assessment or field monitoring of wild individuals—ultrasound screening has no alternative, especially for large sturgeon hatcheries and caviar-oriented farms.

Keywords: Sturgeons; Ultrasound screening; Reproductive system; Heterochrony of maturation; Vitellogenesis; Optimization of the structure of farmed broodstock; Wild specimens

Transcriptomic Analysis Reveals the Protection Effects of Organic Selenium on Heat Stress-Induced Liver Injury in Kaluga Sturgeon (*Huso dauricus*)

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ABSTRACT: To investigate the molecular mechanisms on the alleviating effects of organic selenium on heat stress-induced liver injury in *Kaluga sturgeon*. Four experimental groups were established as followed: control group (C, commercial feed at 19 °C), organic selenium supplement group (S, commercial feed supplemented with 5 mg/kg Se at 19 °C), heat stress group (R, commercial feed at 28 °C), and heat stress + organic selenium group (RS, 5 mg/kg Se feed at 28 °C). Liver tissues were sampled after 30 d heat stress treatment for subsequent transcriptome sequencing. Differentially expressed genes (DEGs) were identified and mapped to corresponding GO terms/KEGG pathways while PI3K-Akt pathway-related genes were validated by qRT-PCR. 8715 DEGs were identified (3642 up-regulated, 5073 down-regulated) between R group and C group. GO enrichment analysis revealed DEGs could be enriched into cell cycle regulation, cell division, DNA repair, and transcription factor binding. KEGG analysis showed PI3K-Akt signaling pathway, cell cycle checkpoints, DNA replication, p53 pathway and glutathione metabolism could be significant enriched. qRT-PCR validation showed that heat stress significantly down-regulated CCND1 and mTOR by 2.3-fold and up-regulated HSP90 by 2.9-fold. Interestingly, organic selenium supplement effectively reversed these expression patterns changes induced by thermal exposure. Organic selenium effectively alleviated heat stress-induced liver injury in *Kaluga sturgeon* by regulating PI3K-Akt signaling pathway. Our study would provide molecular evidence for understanding the detailed mechanism on the negative effects of heat stress on aquatic animals and pave path for the development of bio-active feed supplement agent to attenuate the harmful impacts of thermal stress.

Keywords: *Kaluga sturgeon*; Organic selenium; Heat stress; Transcriptomics

Induction of Out-of-Season Spermiation in Sterlet *Acipenser ruthenus* through Hormonal Injection under Controlled Conditions

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ABSTRACT: Inducing out-of-season spermiation in fish can be achieved through both hormonal treatments and environmental manipulations. This method separates reproduction from seasonal limitations, facilitating effective broodstock management and supporting year-round aquaculture production. This study aims to evaluate the effectiveness of LHRHa2 administration in the induction of out-of-season spermiation in sterlet *Acipenser ruthenus*. Fifteen male sterlets, with an average weight of 1106.0 ± 125.5 g, were divided into two groups and injected with LHRHa2 at a dose of zero (control, $n = 5$) and 2.0 (LHRHa2, $n = 10$) µg kg^{-1} of body weight. Sperm was collected 24 hours post-injections using a catheter. The study was conducted in November at a water temperature of 14.1 ± 0.36 °C. Blood samples were also taken from the fish to measure total protein (TP), hematocrit value (HCT), and plasma testosterone (T). The results indicated that spermiation success in the LHRHa2 treatment was 60%, which was significantly different ($p < 0.05$) from the control group, where no fish (0%) achieved spermiation. The mean sperm volume, spermatocrit, spermatozoa motility, and motility duration in LHRHa2 treatment were 3.9 ± 1.9 mL, 2.0 ± 0.3%, 9.0 ± 3.8%, and 64.0 ± 3.2 s, respectively. The highest T level was recorded in the LHRHa2 treatment, which was 7.07 ± 0.14 ng mL^{-1} ($p < 0.05$). No significant differences were found in HCT and TP content between groups ($p > 0.05$). The study results showed that hormonal treatment can induce spermiation in the sterlet outside of the spawning season, although the collected sperm does not have acceptable quality. Considering the observed effects on plasma T level and sperm quality parameters, altering the hormonal treatment strategy may lead to better outcomes for out-of-season induction of male sterlet broodstock. Consequently, increasing the dose and frequency of hormonal injections can be considered in future studies.

Keywords: Artificial reproduction; Broodstock management; Hormonal treatment; Motility; Semen; Stimulation

Growth, Hematological and Biochemical Responses to Feed Restriction and Re-Feeding in Siberian Sturgeon (*Acipenser baerii*): A Size-Based Approach

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ABSTRACT: Efficient feeding management is a key component in aquaculture, particularly under suboptimal environmental conditions, where maximizing growth performance and maintaining physiological homeostasis are essential for sustainable production. This study investigated the impact of different feeding regimes followed by a re-feeding phase on compensatory growth, hematological indices, and biochemical responses in different size of juvenile Siberian sturgeon (*Acipenser baerii*). For this purpose, fish experienced an initial 45-day feeding period under six groups: large-sized fish fed to satiation (LA), large-sized fish receiving 50% of satiation (LR), large-sized starved fish (LS), small-sized fish fed to satiation (SA), small-sized fish with 50% satiation (SR), and small-sized starved fish (SS) followed by 45 days of re-feeding to satiation for all groups. Initial mean weights were 465.75 ± 11.18 g and 250.40 ± 12.00 g for large and small size fish, respectively. Growth performance was assessed at the end of the experiment, and blood samples were collected for hematological and biochemical analyses. Results revealed that small fish subjected to starvation exhibited the lowest growth parameters after re-feeding, indicating persistent detrimental effects of early feed deprivation. No significant differences in growth were observed between restricted and satiated groups within the size classes. Most hematological parameters remained stable across treatments after re-feeding, except for white blood cell counts, which significantly varied; the highest values were recorded in LS and SA groups. Additionally, fish in the SS group showed markedly elevated glucose and cholesterol concentrations compared to other treatments. Albumin levels were significantly higher in the SS group compared with LS. These findings indicate that fish in restricted feeding in both size achieved compensatory growth while maintaining physiological homeostasis. Conversely, prolonged starvation impairs growth and alters biochemical profiles particularly in small size class. This feeding strategy may offer a cost-effective approach to optimize growth performance under challenging environmental conditions.

Keywords: Aquaculture management; Acipenserid; Compensatory growth; Size; Starvation

Thyroxine Administration in Sterlet *Acipenser ruthenus* Brooders: Reproductive Performance and Physiological Features

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ABSTRACT: To find the effects of thyroxine (T4) on the physiological and reproductive performances of sterlet broodstock, three groups of fish were considered and administrated 0, 1, and 10 mg of T4 per kg of body weight (BW) via peritoneal injection during post-vitellogenesis until before the final maturation. The fish were tagged, injected three times with 45-day intervals and held in circular concrete tanks, each containing five fish with two replicates for each treatment. At the water temperature of 15–16 °C the germinal vesicle migration was checked and the fish were injected with 4 μg of LHRHa2/kg BW. Additionally, blood samples were taken to assay physiological parameters. The ovulated eggs were fertilized with sperm and incubated in a Yushchenko incubator. The results showed that the highest triiodothyronine and T4 concentrations in plasma and eggs were found in fish that received the highest T4 level. Furthermore, the highest levels of sex steroids were found in this group. The best reproductive performance in terms of egg diameter and survival at 3 days post-hatch was achieved in 10 mg/kg group. This study highlights the role of T4 in fish physiology and reproduction and suggests its potential application for enhancing performance in sturgeon breeding programs.

Keywords: Blood biochemistry; Reproduction; Sturgeon; Triiodothyronine; Thyroxine

Multidimensional Crisis: Geographic Range Contraction, Phenotypic Degradation, Genomic Erosion, and Cultural Exploitation of the Critically Endangered Amu Darya Shovelnose Sturgeons

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ABSTRACT: Freshwater ecosystems, despite occupying less than 1% of Earth's surface, harbor a disproportionately high share of aquatic biodiversity yet they are experiencing catastrophic declines under accelerating human pressures. Conservation assessments for critically endangered species often rely on outdated data that fail to reflect ongoing anthropogenic impacts. Here, we provide a comprehensive reassessment of two endemic and critically endangered Amu Darya Shovelnose Sturgeons (*Pseudoscaphirhynchus kaufmanni* and *P. hermanni*) by integrating field surveys, morphometric measurements, mitogenomic analyses, and sociocultural data. Five consecutive years of fieldwork (2019–2024) reveals drastic range contractions and population collapse, with the long-snouted form of *P. hermanni* likely extinct and the short-snouted form persisting only in fragmented habitats. Morphological data show ecotype-specific degradation: wide-snouted *P. kaufmanni* exhibit declining body mass despite increased length, suggesting stress-induced metabolic trade-offs, while narrow-snouted forms display growth release amid demographic collapse. Mitochondrial diversity has declined sharply since the 1990s, likely driven by habitat fragmentation and poaching-induced bottlenecks. Social surveys and trade records expose culturally entrenched beliefs in the sturgeons' medicinal properties, fueling targeted poaching and illegal trade. Undercover market investigations documented the illegal hunting and sale of at least 170 individuals of *P. kaufmanni* for fertility-related treatments between 2021 and 2023. Our findings reveal a multidimensional extinction trajectory, encompassing range loss, phenotypic miniaturization, genomic erosion, and cultural overexploitation. These results highlight the urgent need for coordinated regional and international conservation strategies to halt the collapse of these evolutionary relicts and safeguard the ecological integrity of the Amu Darya River Basin.

Keywords: Pseudoscaphirhynchus; Anthropocene freshwater crisis; Population collapse; Illegal poaching; Conservation strategy

Tubifex Feeding During Pre-Release Acclimation Enhances Intestinal Health and Improves Survival Rates in Stocked Sturgeons

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ABSTRACT: When artificially farmed sturgeons were directly released into the natural habitats, they would exhibit stress response, which would display negative impacts on the survival rate of wild population. It indicated that wilderness training was necessary before formal artificial stock enhancement. In this study, three breeding modes were set: Group A (non-feeding group), Group B (commercial feed group), and Group C (*Tubifex*-feeding group). All sturgeons in these three groups were reared in the wild environment. On the 14th day, 15 individuals were randomly selected from each group, and the intestinal tissues and contents were collected for subsequent analysis. Hematoxylin-eosin staining showed that the intestinal villus height in the Group C was significantly higher than that in Group A and Group B. In addition, 16S rDNA sequencing technology was used to detect the diversity and community composition of intestinal microorganisms in sturgeon. α-diversity and β-diversity analysis showed that there was no significant difference between Group A and B while Group C showed obvious differences compared with Group A and B. Specifically, in the phylum level, the phyla Bacteroidota, Actinobacteriota, and Fusobacteriota in Group C showed higher relative abundance than another two groups. Meanwhile, in the genus level, *Bacteroides*, *Yersinia*, and *Hafnia−Obesumbacterium* in Group C also exhibit greater abundance than these in another two groups. This study confirmed that feeding with *Tubifex* during wilderness training could effectively improve the intestinal health of sturgeons, which had important practice significance for enhancing the beneficial effects of artificial re-stocking and promoting the recovery of wild sturgeon population. Our investigation not only provided the scientific basis for sturgeon species protection but also established solid foundation for the development of stock enhancement strategy, which would benefit for the sustainable recovery of wild sturgeon populations.

Keywords: Sturgeon; Stock enhancement; *Tubifex*; Intestinal microbiota; Population

Peculiarities of Life Strategies of Ship Sturgeon *A. nudiventris*: Analysis of Data from Natural Habitats and Experiments on the Assessment of Swimming Ability and Types of Rheoreactions of Juveniles, Obtained from the Farmed Broodstock

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ABSTRACT: A critically endangered anadromous *Acipenser nudiventris* (*A.n.*)—inhabited many Eurasian rivers. During the program for *A.n.* re-acclimatization in the Kuban River, where it was extinct, the heterogeneous *A.n.* broodstock was formed. The different age-graded offspring from farmed broodstock are released annually: hundreds thousands larvae and dozens mature tagged females and males to natural spawning grounds 200 km above the upper dam in protected natural zones; and thousands juveniles, 2–4 years old—into the Krasnodar reservoir. From 2018, there has been a passage of mature *A.n.* breeders from the river by fish lift through a dam into the reservoir headwater. Analysis of previous publications showed that in natural propagation conditions in the Kura and Ural rivers different age-graded *A.n.* (residents), grown from juveniles, not run off to the Caspian Sea, were represented mainly by males (till mature), but gonads of few encountered elder females did not developed above maturity stage I. Conversely, mature females dominated in the spawning ship sturgeon contingent, which run to the rivers from the sea (migrants). These species-specific distinctive features of the behavior and formation of phenotypic groups of *A.n.* should be considered at recovery of *A.n.* population. Therefore, the presentation considers the experiments results on determination the ratio of rheoreaction types of same-aged (60–61 days) *A.n.* juveniles using a straight-through 10-chambers hydrodynamic "fish pass" with video recording. Threshold V_t and critical V_k (carrying) water flow velocity for hungry (1–3 days) and fed *A.n.* juveniles were determined at different lighting. It was established, that unlike Russian and stellate sturgeons within the velocity range 0.3–0.7 V_k, 5–10 grams *A.n.* juveniles reliably differed in the ratio of rheoreaction types (against/along the current and finding sections without current). This may serve as one of the reasons of life history peculiarities for the division of *A.n.* juveniles into groups (residents and migrants) with different behavioral and settlement strategies.

Keywords: *A. nudiventris*; Juveniles; Behavior experiments; Fish passage; Rheoreactions; Restocking; Residents and migrants

Exploring the Adaptation Process of *Huso dauricus* to High Temperature Based on Changes in Intestinal Microbiota

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ABSTRACT: Global warming has led to rising water temperatures, posing a significant threat to fish survival. Understanding the mechanisms through which fish respond to and adapt to temperature variations is thus of considerable importance. This study employed high-throughput 16S rRNA gene sequencing and bioinformatics to investigate changes in the intestinal microbiota of the kaluga sturgeon (*Huso dauricus*) under four temperature conditions (19 ℃, 25 ℃, 28 ℃, and 31 ℃) and its relationship with adaptation to high-temperature stress. The results indicated that temperature variations caused significant changes in the intestinal microbiota. Over time, differences in microbiota structure became more pronounced under different temperature conditions, and within-group variability gradually decreased. At higher temperatures, the relative abundance of *Sphingomonas* significantly decreased, while *Clostridium sensu stricto 1*, *Cetobacterium*, and *Plesiomonas* exhibited a significant increase in relative abundance. Upon cessation of rapid mortality under various high-temperature conditions, the intestinal microbiota structure and composition became highly similar, with *Clostridium sensu stricto 1* dominating both in terms of composition and relative abundance, suggesting a central role in adaptation to high-temperature stress. This study preliminarily confirms that the high-temperature adaptability of *Huso dauricus* is closely related to the structure and composition of its intestinal microbiota, with bacteria such as *Clostridium sensu stricto 1* playing an important role. These findings provide new scientific insights into enhancing fish adaptability to high-temperature stress.

Keywords: High-temperature stress; *Huso dauricus*; Intestinal microbiota; High-temperature adaptability

The Use of Non-Invasive Ultrasound Diagnostic Method to Detect Pathologies of the Internal Organs of Sturgeon Fish Species

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ABSTRACT: To restore the stocks of sturgeon fish species in depressed state, it is necessary to form repair and uterine stocks in hatchery farms. The technology of forming uterine stocks with use of recirculation water systems is far from perfect due to the low fish breeding performance of spawners. The purpose of this work was to use non-invasive express method of ultrasound diagnostics for the early detection of pathologies and diseases of sturgeon internal organs. In addition to two-dimensional black-and-white image, the following Doppler techniques were used: pulse-wave and constant-wave Doppler imaging, tissue harmonic imaging, energy Doppler, elastography. If 2D sonography data did not provide sufficient information about the anatomical object, panoramic scan was performed. Regular sonographic studies of sturgeon abdominal organs, carried out in 2018–2024 at 20 fish breeding enterprises in Siberia revealed a number of common pathologies and diseases: cystosis and polycystic disease of reproductive system and liver, hydrocele, fatty degradation of gonads and liver, atrophy and torsion of testes, neoplasm in generative tissue, hermaphroditism, thickening of cover and sludge in the gallbladder, some others. The number of individuals with disorders in the development of internal organs at some enterprises reached 67.9%, an average 24.8%. Three stages of cystic degeneration of female ovaries were characterized by ultrasonic scanning. A significant increase in the number of females over the age 9 years with replacement of generative tissue with connective tissue (13.6% of individuals) should be noted. With the help of ultrasonic monitoring and histological studies to study the nature of "ink spots" on the skin epithelium of Siberian sturgeon spawners of natural Lena population, malignant skin neoplasms were detected and treatment routes were outlined. So, the annual ultrasonic monitoring of sturgeon fish internal organs for the early detection of pathological changes will allow timely measures to prevent and treat fish.

Keywords: Ultrasonic monitoring; Neoplasm; Polycystic; Sturgeon fish; Diseases; Ovaries; Testes; Liver; Gall bladder; Neoplasm; Polycystic; Ink spots

Multi-Omics Analysis Reveals the Capacity for Bile Acids Synthesis and Secretion in Ovarian Cells of Sterlet *Acipenser ruthenus*

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ABSTRACT: As the terminal metabolites in cholesterol catabolism, bile acids function as biological surfactants for lipid and nutrient solubilization while simultaneously serving as regulatory molecules in metabolic pathways. And have long been believed to be synthesized exclusively in the liver. Although recent studies have detected the existence of bile acids in mammalian ovarian follicular fluid, their precise origins and the mechanisms underlying their synthesis and secretion remain unclear. In this study, the pathways of bile acid synthesis and secretion were identified in sterlet (*Acipenser ruthenus*) ovarian cells cultured *in vitro*. Transcriptome analysis revealed significant changes in the expression of genes responsible for bile acid synthesis and secretion during cell proliferation. Furthermore, primary bile acids were found to be markedly increased in the culture medium of ovarian cells, while initial cholesterol metabolites were significantly reduced. Targeted metabolomics further identified significant variations in six bile acid species within cell culture supernatants. Therefore, based on the experimental results, we proposed a novel finding that *in vitro* cultured sterlet ovarian cells possessed the capacity for bile acids synthesis and secretion.

Keywords: Bile acids; Ovarian cells; Sterlet

Succession Patterns and Assembly Mechanisms of Bacterial Communities in *Huso dauricus* Larvae

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ABSTRACT: Intestinal microbiota of fish plays critical roles in growth and development, nutrient absorption, immune regulation, and other aspects. Therefore, revealing the dynamic succession patterns and colonization mechanisms of the intestinal microbial composition in *Huso dauricus* provides the theoretical foundation for regulating sturgeon growth and development. This study aimed to investigate the characteristics of the microbial communities in the intestine of *Huso dauricus* larvae, food, and water to identify the factors influencing intestinal microbiota colonization of sturgeon. Samples were collected from 36 *Huso dauricus* larvae. DNA samples were extracted from intestinal contents, food sources, and water, followed by 16S rRNA gene sequencing at the key developmental stages: 7 days (benthic stage), 14 days (fed with chironomid larvae), 23 days (fed with a mixture of chironomid larvae and formulated feed), and 41 days (fed with formulated feed). Results revealed that at the genus level, the predominant bacterial taxa in the intestinal microbiota, chironomid larvae, and feed was *Pseudomonas*, while the dominant bactreia flora in water was *Clostridium*. After feeding with chironomid larvae, the intestinal microbiota was gradually similar with chironomid larvae, indicating that food primarily influences the structure and composition of the intestinal microbiota in sturgeon. Furthermore, KEGG pathway enrichment analysis showed that the relative abundances of the "Biosynthesis of amino acids" and "Microbial metabolism in diverse environments" pathways decreased from days 14–23 compared to day 7, and reached to the peak at day 41, and showed no significant difference between day 41 and day 7. Our study demonstrated that *Huso dauricus* larvae could adapt to the external environment during the growth and development stage through the dynamic changes in the metabolism functions of gut microbe community.

Keywords: *Huso dauricus*; Microbial community succession; Gut microbe; Aquaculture

Mining of NAIP/NLRC4 in Sturgeon and Its Role in the Inflammatory Response of Siberian Sturgeon

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ABSTRACT: As a pivotal node species between ray-finned fish and teleost, Acipenseriformes retain partial ancestral genetic signatures while exhibiting enhanced disease resistance among extant farmed fish. The molecular mechanisms underlying their unique specific genes remain poorly characterized. Through OrthoFinder-based comparative genomics sturgeon and teleost, our study establishing a species-specific gene library comprising 1246 orthologous clusters. Integrated analysis of four NCBI-released infection transcriptomes identified 579 immune-related specific genes, with notable enrichment in NF-κB, RIG-I-like receptor, and NOD-like receptor signaling pathways. Among these, 81 genes including NAIP, CASP1, and ASC formed a core regulatory network. T-cloning, qRT-PCR, and overexpression experiments were employed to demonstrated Siberian sturgeon NAIP/NLRC4 role in mediating inflammatory. They responses through complex formation that triggers IL-1β release and pyroptosis. These findings establish NAIP/NLRC4 as a phylogenetically ancient immunoregulator that triggers inflammatory cascades, offering novel targets for disease-resistant breeding.

Keywords: Acipenseriformes; Anti-infection immunity; NAIP; NLRC4; Orthologous; Inflammatory cascades

Approach to Overcome the Extinction of Caspian Sturgeon Stocks (Global Experience, National and Regional Action)

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ABSTRACT: The Caspian Sea is currently facing a serious ecological crisis (climate change, reduced inflow, periodic recession, sea level drop, *etc.*), and a serious crisis in sturgeon stocks has arisen due to the failure of joint cooperation between five countries after 14 years of banning commercial fishing and caviar exports. The objective of this article attempts to present the current challenges and problems of the Caspian Sea, while also proposing solutions for implementation that can be considered as a model for various countries. The following measures, appropriate to the current realities, can slow down the rate of extinction and saving the valuable genetic resources and taking a step towards joint cooperation. The proposed measures include: National partnership to combat and reduce illegal fishing. Encourage and support the private sector to participate and invest in restocking juvenile to restore habitats and migration sites. Allocate all sturgeons rood stocks to hatcheries and establish a gene bank without killing breeders, along with the use of genetic and physical tags, cryopreservation with live gene bank based on genetic criteria. Increasing the weight of fingerlings from 3 gr. to at least 25 gr. with the participation of local communities and stakeholders. Introducing immature and propagated brood stock in sea cages. Cooperation and implementation of bilateral or multilateral joint programs with the countries of the Caspian region. Sharing and getting the Benefits from the experiences of international participation of WSCS, IUCN, FAO, CITES. National and regional policy-making and planning for the development of an action plan for implementation. In conclusion this approaches may not fully implemented or not supported by all Caspian countries however may lead to save local population/species for gene banking as well as sustainable aquaculture development.

Keywords: Sturgeon; Caspian Sea; Genetic resources; Action plan

Our Forgotten Giants: Re-Establishing Sturgeon Populations to United Kingdom

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ABSTRACT: Despite still being considered a 'royal fish', the existence of sturgeon populations in Great Britain had largely been forgotten. Few realise that these giant fish were once common in our rivers and coastal waters. There are two species of sturgeon native to the United Kingdom, the European sturgeon *Acipenser sturio* and the Atlantic sturgeon *Acipenser oxyrinchus*, although they were long thought to be the same species. The IUCN Red List classifies *A. sturio* as 'Critically Endangered' and *A. oxyrinchus* as 'Vulnerable'. Various factors have likely driven the decline of the two species in the UK, including fishing pressure, migration barriers, and habitat degradation. Their extirpation from UK river systems means that they are now listed as 'vagrant' or 'visitors' when being considered for assessment under the IUCN Red List. With extensive recovery efforts underway in Continental Europe, and given their migratory life cycle, the UK must become 'sturgeon ready'. The UK Sturgeon Alliance, a coalition of eNGOs working with government, is contributing to this pan-European effort. In 2023, we published the first UK Sturgeon Conservation Strategy and Action Plan 2023–2033 which has the goal to achieve Favourable Conservation Status. For England, this means populations thriving sustainably into the future, with both juvenile and adult sturgeon present in suitable habitats across coastal waters and estuaries, and with viable populations in all major rivers. Beyond population recovery, the aim is to renew the cultural, historical, and ecological relationship between people and sturgeon.

Keywords: Sturgeon; Conservation strategy; Reintroduction; Favourable conservation status; *Acipenser sturio*; *Acipenser oxyrinchus*

Using Historical Bycatch Records to Direct Restoration Efforts in United Kingdom

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ABSTRACT: There are two species of sturgeon native to the waters of the United Kingdom: the Atlantic sturgeon (*Acipenser oxyrinchus*) and the European sturgeon (*Acipenser sturio*), although they were long thought to be the same species. Both species have faced enormous declines across their European ranges due to a combination of overfishing, pollution, habitat modification and degradation. The Atlantic sturgeon is now listed as 'Vulnerable' and the European sturgeon as 'Critically Endangered' on the International Union for Conservation of Nature (IUCN) red list of threatened species. Due to their extirpation from the UK river systems and a lack of robust historical data, modern records classify sturgeons only as 'vagrant' or 'visitors' to the British waters. With the aim to document existing records of sturgeons in British waters and analyse their distribution. Historical data on sturgeon captures and sightings were collected from digitised newspaper archives, museum records, and reports from anglers and commercial fishermen. These were further complemented by recent UK captures or sightings and modern records from European restoration programmes. Over 5000 records dating from 1198 to the present have been compiled, covering coastal and river environments. More than half of these include location information, which enabled analysis of their historical spatial distribution in the UK. Insights from this analysis contribute to the UK and pan-EU conservation efforts, as well as informing policy decisions, and providing a foundation for future restoration programmes. The dataset has also been made publicly accessible as an interactive online map, displaying all known UK sturgeon records over time.

Keywords: Sturgeon; Historical record; Newspaper archive; Museum record; Distribution analysis; *Acipenser sturio*; *Acipenser oxyrinchus*

Current Status and Advances in Sturgeon Breeding Research in China

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ABSTRACT: Commercial sturgeon farming in China, initiated around 1995, has evolved into a global industry leader, accounting for 80% of global production by 2009 and 85% by 2020 according to FAO statistics. China's sturgeon industry has shifted its focus from "quantity" to "quality", with the selection of superior breeds becoming a key strategy. Hybrid breeding plays a critical role in sturgeon development. Notable achievements include the cultivation of "Jinglong No. 1," a fast-growing hybrid sturgeon for meat production, and "Xunlong No. 1", which is optimized for caviar production. Sex control is another essential aspect of sturgeon breeding, with the ultimate goal being all-female breeding. Sturgeon follows the ZW sex-determination system. Through sex-reversal techniques, female sterlet sturgeons (*Acipenser ruthenus*) have been induced to develop as males, creating "neomales". Artificial breeding of these neomales has produced over 100,000 offspring, with the aim of identifying "WW" superfemales. Gene-editing tools (CRISPR/Cas9 and TALEN) demonstrate >90% knockout efficiency through microinjection, enabling precise trait modification. While most farmed sturgeon reach sexual maturity in 6–8 years (extending to >10 years in kaluga, *Huso dauricus*), genomic selection accelerates breeding cycle. This method has been successfully applied to optimize traits such as growth rate, fecundity, and egg color in sturgeon. To ensure CITES compliance and genetic integrity, genome-resequencing-derived diagnostic markers now authenticate China's five principal farmed species—*A. gueldenstaedtii*, *A. baerii*) *A. ruthenus*, *A. schrenckii*, *H. dauricus*—alongside their hybrids.

Keywords: Sturgeon aquaculture; Hybrid breeding; Sex-reversal; Gene-editing; Genomic selection

Research on the Mechanism of Ammonia Nitrogen Stress Inhibiting Feeding in Siberian Sturgeon

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ABSTRACT: Ammonia-N is a common toxic factor in aquatic environments, which inhibits fish feeding, but its mechanism remains unclear. To investigate the mechanism in inhibiting fish feeding, this study conducted experiments exposing juvenile Siberian sturgeon (*Acipenser baerii*) to ammonia-N at concentrations of 0, 5, 10, and 15 mg/L for 14 days. The results revealed a significant reduction in both daily and cumulative food intake. Obviously decreased hepatosomatic index (HSI), and viscerosomatic index (VSI) at 15 mg/L. On the 14th day, the serum ammonia concentration significantly increased, while the neurotoxic marker acetylcholinesterase (AchE) significantly increased. Brain tissue demonstrated damage; the activity of superoxide dismutase (SOD) was significantly increased. RNA-seq analysis and qPCR indicated that appetite-promoting factors agouti-related protein (*agrp*) and neuropeptide Y (*npy*) were significantly down-regulated, appetite-suppressing factors pro-opiomelanocortin (*pomc*), cocaine- and amphetamine-regulated transcript peptide (*cart*), and corticotropin releasing factor (*crf*) were significantly up-regulated. This study lays the groundwork for deeper understanding of the toxicological mechanism of ammonia-N on aquatic animals, particularly its detrimental effects on fish brain function and feeding behavior.

Keywords: *Acipenser baerii*; Ammonia-N; Food intake; Feeding regulation

Development and Application of Methods for Sturgeon Species Identification

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ABSTRACT: With the continuous expansion of sturgeon aquaculture worldwide, the widespread circulation of various breeds and hybrid individuals has led to germplasm mixing, affecting product quality and traceability. There is an urgent need for rapid, accurate, and cost-effective identification technologies. Based on whole-genome resequencing data from several sturgeon species, this study screened species-specific locus and developed corresponding molecular markers. Through the design and validation of PCR primers, the specificity and universality of these markers were verified in several major cultured sturgeon species in China. The dominant and co-dominant molecular markers developed by this method have been validated in a large number of purebred and hybrid sturgeon, yielding accurate and reliable results. Compared with traditional microsatellite marker methods, the detection period was reduced from 10 days to 4 hours. The speices identification method based on sturgeon SNP/InDel molecular markers mined from resequencing data offers high sensitivity, high throughput, and low cost. It meets the needs of aqua-farms for rapid identification, superior breed promotion, and product traceability, and holds significant value for the sustainable development of the sturgeon industry and the conservation of genetic resources.

Keywords: Sturgeon; Species identification; Whole genome resequencing; Molecular marker

Inadequate Broodstock Handling Prior to Artificial Reproduction Triggers Spontaneous Autotriploidy in Sterlet (*Acipenser ruthenus*)

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ABSTRACT: Artificial reproduction stands as an essential source of sturgeon progeny for restocking, commercial production, or research. However, a fraction of offspring with altered ploidy levels often arises unintentionally in sturgeon hatcheries, usually for no obvious reason. Ploidy-abnormal individuals exhibit impaired physiology and reproduction, making their occurrence undesirable for both sturgeon farmers and conservationists. We conducted three experiments to test whether the temperature for holding females before reproduction (THF) contributes to the incidence of ploidy abnormalities in sterlet. The eggs were obtained at different THFs within 2 h post-ovulation and fertilized within 30 min; ploidy was analysed in prelarvae. In Experiment 1, we worked with pooled batches of eggs that were collected at a wide range of THFs: 10, 12, 14, 15, 16, 18 and 20 °C. Based on the results, Experiment 2 was designed to confirm the potential of some THFs for increased production of ploidy-abnormal progeny using an individual fertilization scheme. In Experiment 3, THF that previously yielded many abnormal individuals was combined with *in vitro* egg ageing for 0, 3 and 8 h and two fertilization environments: 10^5 and 10^6 spermatozoa/egg to compare ploidy structure under various fertilization conditions. In Experiment 1, we observed that THFs 10–16 °C resulted in low incidence of ploidy abnormalities, while THFs 18 and 20 °C were associated with significantly higher occurrences of spontaneous triploids. In Experiment 2, certain females held at 18 and 20 °C showed a strong tendency to produce triploid progeny, with the highest proportion exceeding 50%. In Experiment 3, varying fertilization conditions did not elevate the incidences of triploidy; however, triploidy remained extremely high (over 70%) in three out of four females held at 18 °C. We conclude that holding sterlet female broodstock at a temperature of 18 °C or higher should be avoided due to its unpredictable effect on the incidence of spontaneous triploidy.

Keywords: Reproduction; Triploidy

Study on Antioxidant Capacity in Farmed Beluga (*Huso huso*) Fry Fed with *Echinacea purpurea* and *Allium sativum* Powder Extracts

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ABSTRACT: This study was performed to evaluate the effects of two types of powdered extract echinacea (*Echinacea purpurea*) and garlic (*Allium sativum*) on antioxidant capacity of farmed beluga *Huso huso* fry during a two-month period. For this purpose, 210 fry with an average weight of 27.74 ± 0.26 g were randomly placed in 21 500-Litre fiberglass tank in seven different treatments with three replications, including a control group and three experimental groups of different amounts of Echinacea powder extract (250, 500 and 1000 mg/kg) and three experimental groups of different amounts of garlic powder extract (250, 500 and 1000 mg/kg) were studied for 8 weeks. At the end of experiment, the amount of catalase, GPX, SOD and MDA enzymes was meseared in six fish per treatment. The amount of catalase, SOD and MDA in the blood serum in the treatments increased compared to the control. The amount of catalase in treatment 5 was significantly higher than other treatments and the lowest amount of catalase was observed in control and treatment 1. The amount of SOD in treatments 2, 3, 5 and 6 was significantly higher than other treatments and the lowest amount of SOD was observed in the control. The amount of MDA in treatments 3, 5 and 6 was significantly higher than other treatments and the lowest amount of MDA was observed in the control. The amount of GPX in fish blood serum in treatments 6, 5 and 4 was significantly higher than other treatments and the lowest amount of GPX was observed in treatments 1, 2 and 3. Based on the observed results, it can be concluded that the oral administration of the powdered extract of echinacea and garlic has a positive effect on the antioxidant capacity of farmed beluga fry.

Keywords: Sturgeon; Antioxidant enzymes; Medicinal plants; Nutrition; Food additive

Effects of Specific Probiotics on Growth Performance, Liver Enzymes and Immune Indices in the Reared of Siberian Sturgeon (*Acipenser baerii*)

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ABSTRACT: With the development of sturgeon farming in the country, we can expect the occurrence and increase of various infectious diseases in farms, and in this regard, the use of specific probiotics (*Weissella confusa* and *Lactococcus lactis*) are important in promoting the health of these fish. In this research, which was conducted at the Iranian sturgeon research institute (Guilan-Rasht), a total of 500 pieces of Siberian sturgeon were randomly introduced in 12 fiberglass tubs with a total volume of 500 L and a dewatering volume of 300 L. The fish had an average weight of 84.08 ± 3.12 g. This study with 3 experimental treatments (each treatment with three replications) including 150 mg (treatment 1), 300 mg (treatment 2) and 450 mg (treatment 3) specific probiotics per kg of food and a group. The control (basal diet without probiotic bacteria) was performed for 10 weeks. The effect of adding two probiotic strains (*Weissella confusa* and *Lactococcus lactis*) isolated from the intestine of Siberian sturgeon on growth indices, Liver enzymes, Immune markers were determined. The results of this study showed that by adding native and specific probiotics in different concentrations to the diet, a significant difference was observed in the feed conversion ratio ($p < 0.05$). There was no significant difference between daily growth, specific growth rate, body weight gain and obesity coefficient between treatments and the control group ($p > 0.05$). The highest and lowest values of immunoglobulin M and lysozyme were observed with significant differences in treatments 1 and 3, respectively ($p < 0.05$). Based on the results of this study, it can be stated that the optimal concentration of specific probiotics used in the diet of Siberian sturgeon to improve growth and safety indices is equivalent to 300 mg/kg of feed.

Keywords: Siberian sturgeon; Specific probiotics; Growth indices; Immune

In Vitro Egg Ageing and Sperm Quantity: The Less, the Better When It Comes to Spontaneous Autotriploidy and Mosaicism in Sterlet?

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ABSTRACT: The sterlet (*Acipenser ruthenus*) is an object of restocking, valuable aquaculture species and experimental model. However, its artificial reproduction often results in the unintentional production of individuals with species-atypical ploidy and impaired physiological/reproductive performance: autotriploids and haplo-diploid mosaics. We evaluated the effects of *in vitro* egg ageing and the fertilization environment on the incidence of ploidy abnormalities in sterlet to propose protocol that can ensure a good balance between ploidy structure and progeny yields. We conducted two experiments involving eggs from nine females fertilized by two males. The eggs were collected within 2.5 h post-ovulation and stored in ovarian fluid at 15 °C (150-g portions); ploidy was analysed 2–3 days post-hatching. In Experiment 1, eggs were fertilized within 20 min post-collection (0 h) and after 8 h using spermatozoa:egg ratios of 10^5 and 10^6 and an egg:water ratio of 1:4 (=4 variants). In experiment 2, two fertilization environments, 10^5/1:4 and 10^4/1:15, were applied to eggs stored for 0 h, 3 h, 6 h and 12 h (=10 variants). *In vitro* egg ageing for 8/12 h affected the incidence of ploidy abnormalities (autotriploids and haplo-diploid mosaics) in 33% of females (6/18) and in some cases reduced progeny yields. Egg ageing up to 6 h had a negligible effect on ploidy abnormalities, hatching and malformations in all but two females that had considerably prolonged latency. Increasing spermatozoa:egg ratio from 10^5 to 10^6 did not impact fertilization rate but it reduced hatching and elevated occurrence of haplo-diploid mosaicism in 44% of females (4/9). A spermatozoa:egg ratio of 10^4 was insufficient for adequate fertilization and never produced significantly fewer abnormal individuals than 10^5. We conclude that storing regularly collected sterlet eggs up to 6 h at 15 °C and fertilization using 10^5 spermatozoa:egg and 1:4 egg:water ratio will ensure low incidence of ploidy abnormalities and high progeny yields, and that late-ovulating females should be used with caution.

Keywords: Artificial reproduction; Ploidy abnormalities; Second polar body retention; Polyspermy; Spermatoza:egg ratio

Temperature-Driven Metabolic and Hormonal Shifts in Fasting Stellate Sturgeon: Relevance for Aquaculture and Conservation

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ABSTRACT: This study examined the physiological, biochemical, immune, endocrine, and metabolic responses of juvenile stellate sturgeon *Acipenser stellatus* to prolonged fasting under different thermal conditions. One hundred and fifty juveniles (43.4 ± 0.8 g) were acclimated and then distributed into nine tanks (three replicates per treatment) at low temperature (LT, 8 °C), moderate temperature (MT, 18 °C), and high temperature (HT, 28 °C). Following a gradual thermal acclimation, fish were maintained under each regime for 21 days without feeding. At the end of the trial, hematological and biochemical parameters, innate immunity, thyroid hormones, cortisol, oxygen consumption, and gill ventilation rates were assessed. Albumin and glucose levels were not significantly affected by temperature ($p > 0.05$), whereas cholesterol, lactate, total protein, and triglycerides exhibited significant temperature-dependent variation ($p < 0.05$). Cholesterol, lactate, and triglycerides were highest at HT, while total protein peaked at MT. Immune parameters displayed distinct patterns: IgM concentrations were significantly greater at LT, whereas complement components of C3 and C4 increased with temperature, reaching maximum values at HT. Cortisol concentrations were significantly higher in HT group, indicating a pronounced stress response, while thyroid hormones (T3, T4) were also significantly elevated at HT compared with LT and MT ($p < 0.05$). Metabolic measurements revealed a marked temperature effect, with oxygen consumption and gill ventilation rates increasing progressively from LT to HT. Fish at HT exhibited the highest oxygen consumption (193.6 mg O_2 kg^{-1} h^{-1}) and ventilation rate (39.9 min^{-1}), followed by MT (125.3 mg O_2 kg^{-1} h^{-1}; 30.2 min^{-1}) and LT (76.0 mg O_2 kg^{-1} h^{-1}; 13.8 min^{-1}). Overall, elevated temperatures intensified metabolic demand, altered biochemical and hormonal profiles, and modified immune responses during fasting, suggesting potential thermal stress. These results provide insights into the thermal physiology of *Acipenser stellatus* and have implications for aquaculture management and conservation strategies under changing climate conditions.

Keywords: *Acipenser stellatus*; Temperature; Starvation physiology; Immune response; Oxygen consumption

Thyroxine As a Multifunctional Regulator in Sterlet Sturgeon Aquaculture: From Broodstock to Larvae

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ABSTRACT: Thyroid hormones (THs) serve as fundamental regulators of growth, metabolism, and reproduction in teleost fish, yet their targeted applications in sturgeon aquaculture remain largely unexplored. This comprehensive research program, comprising six integrated studies, systematically investigates the dose- and stage-specific effects of thyroxine (T4) administration in Sterlet sturgeon (*Acipenser ruthenus*). In broodstock, chronic T4 administration (10 mg/kg BW via intraperitoneal injection) elicited profound physiological responses, including an increase in weight gain, significant improvements in hematological parameters (RBC count, hemoglobin, and hematocrit), and enhanced immune competence (IgM and complement activity). These benefits were accompanied by elevated cortisol levels, indicating a stress response. Notably, maternal T4 treatment substantially improved reproductive outcomes, increasing ovarian fluid protein content, lipid levels, and critical mineral concentrations (Ca and Mg), while boosting larval survival to 92.2% at 3 dph compared to 67.2% in controls. For early life stages, T4 immersion protocols (1 mg/L for 120 min post-fertilization) demonstrated remarkable efficacy, increasing embryonic survival rates and hatching success. These improvements correlated with optimized TH profiles, particularly sustained T3:T4 ratio during critical developmental windows. Metabolic studies revealed that even acute T4 exposure induced prolonged effects, with plasma triglyceride levels remaining elevated for 60 days post-treatment and glucose metabolism showing significant enhancement. Dose-response analyses established clear thresholds for therapeutic benefit, with 10 mg/kg BW optimal for broodstock conditioning and 1 mg/L for egg immersion. Lower doses (0.01–0.1 mg/L) showed intermediate effects, suggesting potential for tailored applications. These findings collectively position T4 as a powerful, multi-functional tool for sturgeon aquaculture, capable of simultaneously improving growth performance, immune function, and reproductive success.

Keywords: Growth enhancement; Hormonal regulation; Egg hormone treatment; Spawning improvement; Immunity performance

Fishing Practice and Sturgeon Conservation in the Szczecin Lagoon Area of Poland and Germany

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ABSTRACT: A survey was conducted among 53 professional fishers from Poland (44%) and 5 German (26% of registered fishers, respectively) to assess fishing practices, catch composition, and perception of conservation measures, with emphasis on sturgeon (*Acipenser* spp.) recovery management. Both groups predominantly employed set gillnets and trammel nets, while other gear types comprise various fyke net types. Fisheries were characterized by small operational scale (1–3 permanent employees; 1–2 vessels), and long-term experience (median: 21–30 years). Primary target species include eel (*Anguilla anguilla*), perch (*Perca fluviatilis*), pikeperch (*Sander lucioperca*) in both groups, with herring (*Clupea harengus*), roach (*Rutilus rutilus*) and bream (*Abramis brama*) constituting important bycatch. Key differences are: In Poland 83% of the fisherman reported protected species in their catch. A substantial proportion (91%) had previously caught sturgeon, but only 25% reported these captures. Supportive stocking, particularly for eel and sturgeon, were perceived as highly important for recruitment, restoration and species conservation. Of the German respondents 80% reported having caught sturgeon and 60% reported those captures. 85% of Polish participants supported sturgeon reintroduction, while their general concerns mainly focused on gear damage, declining fish abundance, habitat alterations (e.g., channel deepening), and inadequate communication from management bodies. German respondents showed greater ambivalence toward the reintroduction of sturgeon. Only 1 respondent explicitly “welcomed” it, while the remainder expressed neutrality or scepticism, and emphasized caution regarding the efficacy of stocking and a distrustful stance toward research. None of the German respondents declared their interest in sturgeon being a target species in the future, while over half (~51%) of the Polish fisherman would welcome this. In conclusion, the findings underscore the necessity for integrated co-management that aligns conservation objectives with socio-economic sustainability, incorporating financial incentives, improved reporting mechanisms, and trust building. This interpretation is constrained by the low number of German fishermen participating which is indicative of the attitude encountered.

Keywords: Fishing practice; Sturgeon conservation; Szcecin lagoon; Fisher perceptions; Socio-economic sustainability; Co-management

Addressing Recruitment Failure of Endangered White Sturgeon: A Case Study Using Structured Decision Making to Guide Spawning Habitat Restoration in the Upper Columbia River, Canada

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ABSTRACT: Recovery of critically imperiled taxon like sturgeons (order *Acipenseriformes*) requires effective conservation actions that address multiple concurrent stressors on population persistence. Geomorphological change to substrate conditions at spawning sites was identified as the most plausible cause where restoration could have a positive effect on recruitment for endangered white sturgeon (*Acipenser transmontanus*) in the Upper Columbia River. Here we describe outcomes from a formal process to prioritize sites for spawning habitat restoration that met biological and physical criteria to ensure effectiveness following implementation. Existing substrate conditions were described at multiple spawning locations and the biological (e.g., interstitial space) and physical (e.g., substrate mobility) functionality was assessed using expert opinion and existing literature. Structured decision-making was used to develop restoration alternatives and prioritize one for construction in-river. The leading alternative was built in-river between October 2022 and April 2023 over an area of 5800 square meters. Substrate material was placed to a depth of two times the largest particles size (*i.e.*, 0.60 m), and the composition of the rock provided a mix of larger material (maximum size = 0.30 m diameter) to provide substrate retention and smaller material (minimum size = 0.10 m) to provide suitable interstitial habitat for sturgeon early life stages. Multiple spawning events were detected in each of the first three years following construction and physical monitoring indicates limited infilling of substrates. While simple in concept, implementation of substrate restoration within large river habitats is a challenging undertaking but represents a positive shift toward habitat-based recovery efforts.

Keywords: *Acipenser transmontanus*; White sturgeon; Spawning; Habitat restoration; Endangered species recovery; Structured decision making

Reproductive Structure of Hatchery-Origin Pallid Sturgeon above Fort Peck Dam in the Missouri River

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ABSTRACT: Hatchery-origin pallid sturgeon (*Scaphirhynchus albus)* have been stocked into the upper Missouri River above Fort Peck Dam since the late 1990s in response to a lack of natural recruitment. Understanding when the hatchery-origin fish within the population reaches sexual maturity is critical to understanding the effectiveness of the program in recovering this federally endangered species. Using combined historical and contemporary data (n = 752; 2011–2024), we described sex-specific relationships between age and size at first maturity and spawning periodicity and evaluated false maturation rates in female pallid sturgeon. Males are reaching sexual maturity at a smaller size and younger age than females. Males are physiologically capable of annual spawning, but not all males spawned every year. Females are physiologically capable of spawning every two years, but the spawning periodicity ranged from two to five years once sexual maturity was attained. False maturation occurred during the first reproductive cycle as females initiated but failed to complete vitellogenesis, and mass follicular atresia was found to occur in some subsequent cycles. The rate of false maturation was compared to the rate of mass follicular atresia occurring in females that had spawned previously. Understanding fish reproductive biology is essential for successful management and conservation of this species.

Keywords: Reproduction; Spawning periodicity; Pallid sturgeon; Age at first maturity; Size at first maturity

Developing an Integrated Monitoring Framework for the Baltic Sturgeon (*Acipenser oxyrinchus*) in the Odra Estuar

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ABSTRACT: The Baltic sturgeon (*Acipenser oxyrinchus*) recovery program has been conducted for almost 20 years and has resulted in increasing numbers observed in the environment. However, the current status of the population remains insufficiently understood. As a result a methodology to monitor the sturgeon population in the Odra estuary was developed and tested, based upon the monitoring guideline provided by the Bern Convention. Three complementary components integrate scientific surveys with fisheries cooperation: (1) scientific fishing campaigns conducted in spring and autumn in Odra River using gillnets (GNS) and drift nets (GND) as well as in the Pomeranian Bay using bottom trawls (OTB) and GNS; (2) participatory monitoring carried out by five selected fishers: one operating in the Odra River with Fyke Nets (FYK) and GNS, three operating in the Szczecin Lagoon and Lake Dąbie with FYK and GNS, and one team in the Pomeranian Bay with two vessels using both OTB and GNS, providing detailed data on sturgeon bycatch, fishing effort, and locations; (3) a network of 63 fishers reporting incidental sturgeon bycatch with basic information on fishing sites and gear used.. The integration of these three data sources provides detailed information on this extremely rare species, while ensuring cross-validation comprehensive picture of sturgeon abundance and age structure in the Odra estuary. Preliminary results confirm the presence of sturgeons across the full range of habitats. Effectiveness was highest in GNS both in scientific and fisher-reported catches, with FYK coming in closely. OTB combined low efficiency with high costs, whereas drift nets (GND) demonstrated strong potential for monitoring in the river. The proposed methodology combining standardized scientific fishing, targeted fisher collaboration, and a broad reporting system can become a practical tool for assessing the status of *A. oxyrinchus* populations valuable for long-term management of the species, with high potential for its application in other regions of the Baltic Sea basin.

Keywords: Reintroduction; Bycatch; Population monitoring; CPUE; Selectivity

Whole-Genome Sequencing of Persian Sturgeon (*Acipenser persicus* Borodin, 1897) Broodstock Revealed Shallow Population Structure in the South of the Caspian Sea

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Summary: Restocking has been considered the primary practical tool in gene pool conservation of sturgeons in the Caspian Sea since five decades ago. In spite of the long term restocking activities in southern Caspian Sea, no genetic monitoring using novel genomic-based approaches has been done to investigate the genomic population structure of these valuable species in the south of the Caspian Sea. *Acipenser persicus* is the main species under restocking program in the south of the Caspian Sea, hence, during the present study we used low-pass whole-genome sequencing method to investigate the genetic consequences of restocking on this species across the southern Caspian basin. For this, we sampled fin tissue of 20 wild *A. percisus* being caught for restocking in two main restocking centers across the south of the Caspian Sea (located in Guilan and Mazandaran provinces). After genomic DNA extraction, whole-genome libraries were sequenced on a lane of Illumina Novaseq 6000 at the facilities of Novogene as 150 bp paired-end reads. The observed heterozygosity based on 57 million SNPs obtained 0.34 and 0.36 and the inbreeding coefficient (*Fis*) was 0.09 and 0.06 at Guilan and Mazandaran, respectively. The *Fst* as an index of populations' segregation was 0.024, indicating a low rate of populations' separation. Supportively, the admixture analysis showed a considerable admixture structure implying a shallow population structure between the two investigated geography regions. However, Co-ancestry based analysis illustrated that still two genetic populations of *A. persicus* can be taken into consideration for genomic conservation purposes in the south of the Caspian Sea. The output of this study reviled that while restocking has aided the genetic conservation of *A. persicus*, actions other than that of seldom restocking such as river rehabilitation are required to prolong the resilience of *A. persicus* in the south of the Caspian Sea.

Keywords: Genomic conservation; Molecular ecology; Persian sturgeon; Population assignment; Restocking

Effects of Lipotropic Additives on Gonadal Fat Reduction and Caviar Yield in Siberian Sturgeon Broodstock

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ABSTRACT: The global depletion of natural sturgeon populations and the rising demand for caviar have made sturgeon aquaculture an essential and economically significant industry. The Siberian sturgeon (*Acipenser baerii*) is widely cultured due to its adaptability and high-quality, moderately priced caviar. However, excessive fat accumulation in broodstock gonads negatively impacts caviar yield and quality, posing a challenge to commercial production. This study aimed to evaluate the effectiveness of dietary lipotropic compounds in reducing gonadal fat and improving caviar output. Four premix formulations containing L-carnitine, bile acids, inositol, methionine, choline, betaine, emulsifiers, and vitamin B6 were tested at inclusion levels of 7.0%, 8.0%, 9.0% and 1.0% in broodstock diets. The experiment was conducted over one year in a commercial sturgeon farm located in Fars province, Iran, using five dietary treatments (including a control) fed to *A. baerii* broodstock (average weight 5000 ± 300 g) under standardized conditions. Key performance indicators—including visceral fat index, gonadosomatic index (GSI), caviar yield, and ratios of caviar to gonad and body weight—were measured. Statistical analysis (one-way ANOVA, SPSS v21) revealed that lipotropic premixes significantly decreased visceral and gonadal fat ($p < 0.05$), with the 8.0% premix producing the highest caviar yield and best fat mobilization. These findings suggest that targeted nutritional strategies using lipotropic additives offer a practical and cost-effective approach for improving reproductive efficiency, caviar yield, and product quality in Siberian sturgeon aquaculture.

Keywords: Siberian sturgeon; Caviar yield; Lipotropic compounds; Broodstock nutrition

The Roughness of the Body Surface Is a Method to Detect the Sex of Young Cultured Beluga Sturgeon (*Huso huso*)

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ABSTRACT: Cultivation of sturgeon for the purpose of producing caviar requires the keeping and breeding of female fish. But because there are no sexual differences and no external signs to determine sex in sturgeon even at the time of final sexual maturity, Accordingly, early identification of the sex of sturgeon in aquaculture farms is essential in order to reduce breeding costs and optimize farm management. Normally, one of the possible methods of biopsy or laparoscopy or ultrasound is used to determine the gender of sturgeon. These methods are quite stressful and costly for the fish. Since it is impossible to recognize their gender through external signs, Therefore, the gender of 80% of farmed beluga sturgeon under one year can be recognized by hand, the roughness of the ventral surface and the lateral surface of the female fish. In this regard, the breeder can separate the female fish from the male based on the appearance obtained from the research results without paying the cost and with minimal stress on the fish (due to manipulation).

Keywords: Beluga sturgeon; Sex identification; Roughness; Ventral surface; Lateral surface; Female sex

Selection of a Reliable Method for Sex Detection in Sturgeon Fish

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ABSTRACT: Fish are among the most diverse and numerous groups of vertebrates and have amazing reproductive strategies and processes to maintain their populations. The duration of sexual maturity varies among fish genera and species, and reaching the first fertilization takes from several months to several years depending on the genus and species. Among fish, the sturgeon family, unlike bony fish, reaches sexual maturity late, and it is impossible to determine their sex at an early age through morphometry. Therefore, depending on the age of the sturgeon, using one of the methods such as surgery, laparoscopy, ultrasonography and souk to determine the gender of the sturgeon is necessary and mandatory. This prevents financial losses for the breeder due to the cost of raising male fish for several years due to the lack of gender determination. Although each of these methods is stressful for the fishes in turn, the results of the research showed that the Surgery is the most appropriate method for fishes that are in stage 1 to 2 of sexual maturation, Laparoscopy is the most appropriate and reliable method for fishes that are in stage 2 to 3 and 3 to 4 of sexual maturation, Ultrasonography is the most suitable method for fishes that are in stage 3 to 4 and 4 of sexual maturation and Souc or Trocar is the most suitable method for fishes that are in stage 4 of sexual maturity for the purpose of hormone therapy, are considered.

Keywords: Sturgeon; Reliable method; Stages of sex maturation

The Effects of Dietary β-1,3/1,6-Glucan on the Growth Performance, Innate Immunity, and Resistance to Bacteria in Juvenile Beluga

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ABSTRACT: Bacterial diseases particularly those caused by *Aeromonas hydrophila* are a major constraint in aquaculture, causing significant economic losses and threatening the sustainability of high-value species such as *Beluga sturgeon* (*Huso huso*). Enhancing innate immunity through dietary immunostimulants is a promising strategy to improve fish health and disease resistance. This study investigates the effects of dietary β-glucan supplementation on growth performance, immune response, and resistance to *Aeromonas hydrophila* in juvenile *Beluga sturgeon* (*Huso huso*; average weight 22 ± 1.7 g). Fish were randomly assigned to three treatment groups and fed diets containing 0% (control), 0.1%, or 0.2% yeast-derived β-1,3/1,6-glucan for eight weeks. Growth performance parameters—including final weight, weight gain (WG), and specific growth rate (SGR)—were significantly improved in β-glucan-supplemented groups compared to the control ($p < 0.05$). Immunological assays showed enhanced lysozyme activity, alternative complement pathway activity (ACH50), total immunoglobulin (Ig), and IgM levels, particularly in the 0.2% β-glucan group ($p < 0.05$). Following a bacterial challenge with *A. hydrophila*, cumulative mortality was highest in the control group and progressively lower in the 0.1% and 0.2% β-glucan groups, with the 0.2% level conferring the strongest protection. Relative percent survival (RPS) was significantly higher in β-glucan-fed fish. These findings highlight the potential of dietary β-glucan, especially at 0.2%, to enhance innate immunity, reduce mortality and provide effective protection against *Aeromonas hydrophila* infections in juvenile *Beluga sturgeon*.

Keywords: Beluga; β-glucan; Growth; Immune response; *Aeromonas hydrophila*

U.S. Endangered Species Act Sturgeon Status Update

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ABSTRACT: The U.S. Endangered Species Act (ESA), enacted as a law in 1973, provides a means to conserve threatened and endangered species as well as these species' habitat. This U.S. law extends beyond the borders of the U.S. and will consider species anywhere on earth. As of 2024, the ESA has 2300 U.S. and foreign animals and plants listed as either threatened or endangered. Although the purpose of the ESA is to conserve species found in the wild, there is no legal distinctions of these targeted populations of wild species from captive-bred or aquacultured populations. This means when a sturgeon species is listed under the ESA, captive-bred sturgeon populations must comply with the same restrictions and prohibitions as the wild populations. These prohibitions may include closure of the U.S. borders to imports, or in the case of captive-bred sturgeon operations within the U.S. or its territories, forced depopulation. An explanation of the ESA listing process is presented, as is an update on the current status of 10 sturgeon species going through this listing process. The status of potential legislative solutions to this problem are also discussed.

Keywords: Endangered species act; Sturgeon

Reproductive Structure of Hatchery-Origin White Sturgeon in the Upper Columbia River

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ABSTRACT: White sturgeon (*Acipenser transmontanus*) in the transboundary reach of the Upper Columbia River have low rates of natural recruitment, and the wild population has been supplemented with hatchery-origin fish annually since 2002. While releases of hatchery-origin sturgeon have prevented extirpation of the population, determining when the hatchery-origin segment reaches sexual maturity is critical to describing changes to numbers of mature spawners after decades of recruitment bottlenecks. To assign sex and stage of maturity of hatchery-origin sturgeon, gonad biopsies and blood plasma were collected from fish throughout habitats in Canada and the US from 2015–2024. Sex and stage of maturity was assigned using histological analysis of the gonad tissue, and steroid concentrations for estradiol and testosterone were paired with histology to develop less invasive indicators of sex-specific reproductive status. We compared size at maturation for hatchery-origin and wild sturgeon and incorporated information from adjacent white sturgeon populations. Females have not progressed past the pre-vitellogenic stage, with the oldest females assessed being 23 years of age. Females are just reaching a size (>160.0 cm) where they may reach puberty based on other populations. A portion of males have reached maturity (mean age of 12.3 years (range 8.3–16.4), mean fork length of 138.4 cm (range 89.5–161.0), and mean weight of 21.5 kg (range 4.9–36.1)). Fifty percent of males were mature at a size of 149.3 cm fork length (144.7–156.2, 95% CI). Reproductive males are distributed across multiple year classes and families in both countries, with more reproductive males in the US. Testosterone was a significant predictor of reproductive status for males, with 40 ng/L (34.7–47.8 95% CI) representing a threshold where 50% of males were reproductive. Describing rates of maturation of hatchery-origin fish is critical to understanding the effectiveness of conservation aquaculture in achieving population recovery.

Keywords: Reproduction; Conservation aquaculture; Sexual maturity; Endangered species

Effects of *Aloe vera* Extract on the Activity of Antioxidant Enzymes, Survival Rate and Non-Specific Immunity of Siberian Sturgeon (*Acipenser baerii*)

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ABSTRACT: This research was conducted with the aim of investigating the effects of *Aloe vera* extract on antioxidant enzymes, survival rate and non-specific immune indices of Siberian sturgeon (*Acipenser baerii*). A total of 180 Siberian sturgeon with an average weight of 10.95 ± 0.04 g were randomly distributed into four groups including a control group and three experimental groups (each group with three replications). *Aloe vera* powder extract was added to the special diet of the experimental groups in proportions of 0.5, 1 and 1.5%. Fish were fed manually with their special diet in fiberglass tanks for eight weeks. At the end of the breeding period, catalase, GPX and SOD enzymes were measured. The results showed that the amount of catalase, SOD and GPX in the blood serum of the fish in the treatments increased compared to the control ($p < 0.05$). The amounts of lysozyme and ACH50, as non-specific immune components, were measured. The results showed that there is a significant difference in the amount of lysozyme and ACH50 in the treatments compared to the control group ($p < 0.05$). In addition, during the breeding period, no losses were observed in the reservoirs, and the survival rate in the treatments and the control was 100%. Based on this, it was determined that *Aloe vera* extract has non-specific immune enhancing effects and its use at the rate of 1.5% in the diet can improve the activity of antioxidant enzymes and also as an immune stimulant in order to prevent disease be effective in the Siberian sturgeon.

Keywords: Siberian sturgeon; *Aloe vera* extract; Antioxidant enzymes; Survival; Immune

Conservation Achievements and Challenges for the Yangtze Sturgeon *Acipenser dabryanus* at Mid-Stage of Ten-Year Fishing Ban: A Review

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ABSTRACT: The Yangtze River Ten-year Fishing Ban, now at its mid-stage, has significantly aided the recovery of the critically endangered Yangtze sturgeon (Acipenser dabryanus). Key achievements include: (1) Artificial Breeding and Population Growth: Captive breeding programs expanded the population from under 80 individuals in the 1990s to over 4000 multi-generation individuals, with annual breeding capacity exceeding 4 million; (2) Stock Enhancement and Rewilding: Since 2007, cumulative releases include 1400 parent sturgeons, 10,000 sub-adults, and 2 million juveniles. Rewilding techniques increased catch per unit effort (CPUE) by over 100-fold, enabling the species to reappear in historical distribution areas; (3) Progress in Spawning Habitat Restoration: by analyzing the functional maintenance mechanism of the natural spawning grounds of the Yangtze sturgeon, technologies for creating and restoring spawning habitats have been broken through. From 2023 to 2025, released parent sturgeons successfully achieved reproduction in wild, with exceeding 1.2 million eggs layed and hatched out consequently, identifying an effective pathway to restore the natural reproduction of the Yangtze sturgeon. Persistent Challenges: Habitat fragmentation from dam construction and waterway dredging remains a major obstacle, disrupting ecological connectivity and natural population self-sustainability. Recommendations: Establish natural reproduction demonstration zones, conduct in-situ spawning ground restoration, and improve ecological scheduling of cascade hydropower stations. The IUCN's "extinct in the wild" assessment may soon be revised, reflecting progress toward restoring natural reproduction and offering a model for global riverine conservation.

Keywords: Yangtze sturgeon; Habitat restoration; Stock enhancement; Population rewilding; Rehabilitation

Insights from Field Breeding Trials of the Yangtze Sturgeon: Focusing on Spawning Ground Restoration as the Core

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ABSTRACT: The Yangtze sturgeon (*Acipenser dabryanus*) is a critically endangered species endemic to the upper reaches of the Yangtze River. Since the late 20th century, its natural reproduction has ceased, making population recovery a central task in ecological conservation of the upper Yangtze River. To address the challenges of field reproduction, the Yangtze River Fisheries Research Institute conducted a series of systematic breeding trials during 2023–2025. In 2023 and 2024, spawning grounds at Jiang'an were strictly reconstructed based on indoor experimental parameters, with each trial yielding approximately 500,000 eggs. In 2025, a trial in the Chishui River involved only 20 broodstock, yet produced about 200,000 eggs under rigorous habitat modification. However, a parallel trial in the historical spawning grounds of the Jinsha River, despite using 102 broodstock, did not achieve the expected outcome, suggesting that spawning ground functionality in this area has been severely degraded. These findings indicate that, unlike species such as the Adriatic sturgeon, which can restore natural reproduction through stocking and improved river connectivity, the Yangtze sturgeon cannot establish self-sustaining populations without functional spawning habitats. Therefore, systematic and scientifically designed implementation schemes should prioritize spawning ground restoration as the core measure to enhance natural reproduction and promote the long-term recovery of the Yangtze sturgeon population.

Keywords: Yangtze sturgeon; Spawning ground restoration; Breeding trials

Effects of Alkalinity Stress on Amino Acid Metabolism Profiles and Oxidative Stress-Mediated Apoptosis/Ferroptosis in Hybrid Sturgeon (*Huso dauricus*♀ × *Acipenser schrenckii*♂) Liver

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ABSTRACT: Alkaline water has toxicity to cultured aquatic animals that frequently lived in pH-neutral freshwater. Overfishing and habitat destruction contributed to decline the wild sturgeon population size, therefore, domestic hybrid sturgeon became an increasingly important commercial species in China. Hybrid sturgeon are widely cultured in alkaline water, but little has been known about the effects of alkalinity stress on hybrid sturgeon liver tissues. We exposed hybrid sturgeon to four alkaline concentrations (3.13–3.20 mmol/L, 7.47–7.73 mmol/L, 11.6–12.6 mmol/L and 14.4–16.67 mmol/L). Histopathology, biochemical indexes assessment, gene expression level detection and metabonomics analysis were used to investigate the negative effects on liver functions following exposure to $NaHCO_3$. Severe tissue injury and obvious apoptosis characteristics were shown in livers under the alkaline stress. With increased exposure concentrations, the hepatic superoxide dismutase, catalase, glutathione peroxidase and alkaline phosphatase activities significantly decreased in a dose-dependent manner. $NaHCO_3$ exposure up-regulated the transcriptional levels of apoptosis/ferroptosis-related genes in livers. Similarly, the expressions trends of interleukin-1β and heat shock protein genes also increased in high-alkalinity. However, the expression levels of Complement protein 3 significantly decreased ($p < 0.05$). Hepatic untargeted metabolomics revealed the alteration conditions of various metabolites associated with the antioxidant response, ferroptosis process and amino acid metabolism (such as beta-alanine metabolism, alanine, aspartate and glutamate metabolism, glycine, serine and threonine metabolism). These data provided evidence that $NaHCO_3$ impaired immune functions and the integrity of hybrid sturgeon liver tissues by mediating oxidative stress-mediated apoptosis and ferroptosis. Our results would shed light on the breeding welfare of domestic hybrid sturgeon and promote the economic development of fishery in China.

Keywords: *Huso dauricus*; *Acipenser schrenckii*; Liver; Oxidative stress-mediated

Diet Transition and Training to Improve the Post-Release Fitness of Captive-Bred Yangtze Sturgeon

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ABSTRACT: Yangtze sturgeon (*Acipenser dabryanus*) is a critically endangered endemic species in the Yangtze River. No natural reproduction has been observed since 2000, and its wild population is considered extinct. Establishing large-scale conservation breeding populations and releasing captive-bred individuals into appropriate reaches is the only way to restore the natural Yangtze sturgeon populations. In reintroduction projects, pre-release diet training could effectively increase post-release fitness and survival by improving animals' adaptation to transformation from artificial to natural environments. However, the effects of early-life dietary transition and training on the post-release adaptation of Yangtze sturgeon remain unclear. To explore these issues, we investigated the transcriptional/metabolic levels and intestinal microbiota changes of juvenile Yangtze sturgeon during the transition from natural to formula diets. Meanwhile, the growth characteristics and gut microbes of Yangtze sturgeon trained with natural and formula diets at both the pre-release and post-release stages. The results showed that (1) diet transition involved microbiota simplification, reduced lipid mobilization, and weakened antioxidant defense, (2) the gut microbial communities of the individuals trained with a natural diet and formula diet evolved to the optimal status for their corresponding diet provisions, (3) the individuals trained with the natural diet paid a lower cost (*i.e.*, changed their gut microbial communities less) during diet transformation and release into the natural environment than did the individuals trained with the formula diet, and (4) the gut microbes in the natural diet group better supported post-release fitness and survival than did the gut microbes in the formula diet group. The results indicated that better pre-release diet training could improve the reintroduction of Yangtze sturgeon by adjusting the pre-release gut microbial community.

Keywords: *Acipenser dabryanus*; Reintroduction; Diet transition; Diet training; Gut microbes

Expression Profiles of Housekeeping Genes and Tissue-Specific Genes in Different Tissues of Chinese Sturgeon (*Acipenser sinensis*)

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ABSTRACT: The Chinese sturgeon (*Acipenser sinensis*), an ancient fish with important ecological and evolutionary significance, has been listed as a critically endangered species. To comprehensively characterize the expression profiles of genes and their associated biological functions across different tissues, we performed a transcriptome-scale gene expression analysis, focusing on housekeeping genes (HKGs), tissue-specific genes (TSGs), and co-expressed gene modules in various tissues. We collected eleven tissues to establish a transcriptomic repository, including data from Pacific Biosciences isoform sequencing (PacBio Iso-seq) and RNA sequencing (RNA-seq), and then obtained 25,434 full-length transcripts, with lengths from 307 to 9515 bp and an N50 of 3195 bp. Additionally, 20,887 transcripts were effectively identified and classified as known homologous genes. We also identified 787 HKGs, and the number of TSGs varied from 25 in the liver to 2073 in the brain. TSG functions were mainly enriched in certain signaling pathways involved in specific physiological processes, such as voltage-gated potassium channel activity, nervous system development, glial cell differentiation in the brain, and leukocyte transendothelial migration in the spleen and pronephros. Meanwhile, HKGs were highly enriched in some pathways involved in ribosome biogenesis, proteasome core complex, spliceosome activation, elongation factor activity, and translation initiation factor activity, which have been strongly implicated in fundamental biological tissue functions. We also predicted five modules, with eight hub genes in the brown module, most of which (such as *rps3a, rps7, rps23, rpl11, rpl17, rpl27*, and *rpl28*) were linked to ribosome biogenesis. Our results offer insights into ribosomal proteins that are indispensable in ribosome biogenesis and protein synthesis, which are crucial in various cell developmental processes and neural development of Chinese sturgeon.

Keywords: Chinese sturgeon; Transcriptome sequencing (RNA-seq); Housekeeping gene; Tissue specific gene; Co-expression; Ribosomal protein gene

A Review of the Combined Effects of Antistressors on Improving Productivity and Health of Sturgeon under Environmental Stress Conditions

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ABSTRACT: Considering the importance of sturgeon and the fact that these fish with high economic value are in danger of extinction, it has led to a shortage of healthy and quality sturgeon fry. One of main bottlenecks in the production of sturgeon fry is their high mortality. Mortality is due to various stress factors such as increasingly density movement and sudden changes in temperature, water and oxygen, water quality and feed appropriate to the needs of aquatic animals at different weights or even pathogens. Stress management in aquaculture through the use of additives or medicinal feeds (functional foods) is considered an ideal strategy. The aim of this review research is to emphasize the combined use of dietary anti-stress agents to prevent various stresses in sturgeon fry. Depending on the species, using effective combined anti-stressors with relevant stresses in different culture systems can be used to determine the optimization and efficiency of production management of sensitive sturgeon fry. This review article examines the effects of compounds such as astaxanthin, vitamin E, and selenium on improving the physiological performance of Beluga (*Huso huso*) under environmental stress conditions. The combination of these antistressors can produce synergistic effects in dealing with environmental stresses and improve productivity in aquaculture. This article also provides suggestions for future research in the field of combined use of antistressors in aquaculture under different stressful conditions.

Keywords: Anti-stressors; Heat shok protein; Environmental stresses; *Huso huso*

Stock Enhancement Effect of Acipenser Dabryanus in the Middle Yangtze River Downstream of the Gezhouba Dam

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ABSTRACT: Yangtze Sturgeon (*Acipenser dabryanus*) is an endemic species to China. Influenced by human activities such as pollution, dam constructions and overfishing, its natural population in the wild has disappeared. It was listed as the first order category of the protected animals in China, and was proclaimed to extinct in the wild in 2022 by IUCN. To protect this species, 60,055 propagated juveniles and adults were released in the middle Yangtze River between Yichang and Wuhan section since 2012. According to the data of fishery surveys from 2012 to 2023 in the middle Yangtze River and accidental capture data, 50 individuals with total length of 20–100 cm were recaptured in the trunk section from Yichang to Huanggang, and one was recaptured in the south Dongting Lake. The body length of recaptured individuals ranged from 47 to 103 cm, and the body tights ranged from 520 to 6500 g. Based on the survey results, increasing of number of released *Acipenser dabryanus* and carrying out of effective tracking and survey in the middle Yangtze River was suggesting.

Keywords: *Acipenser dabryanus*; Artificial releasing and enhancement; Conservation

Effects of Sexual Dimorphism Traits and a Marine-Blended Dietary Strategy on Ovarian Development and Serum Metabolites in the Chinese Sturgeon (*Acipenser sinensis*)

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ABSTRACT: The Chinese sturgeon (*Acipenser sinensis*) is a critically endangered species whose conservation depends on hatchery releases, yet most captive females fail to mature past ovarian stage II. To reveal the metabolic basis of this sexual dimorphism and improve breeding protocols, we compared serum physiology, steroid hormones and lipid metabolites between 11-year-old male and female sturgeons at stage II, then tested whether a two-year diet supplemented with the marine fish Setipinna taty accelerates ovarian development. Males displayed significantly higher testosterone, dihydrotestosterone, 7α, 25-dihydroxycholesterol, polar lipids, cholesterol esters, PGE2, C18:1n9c, MUFA, SOD and glucose, but lower LDL, C18:3n3 and n-6 PUFA than females ($p < 0.05$). Of 1469 lipid species, 65 differed between sexes and mapped to bile secretion, steroid and ovarian steroidogenesis pathways. PCA linked female yolk-forming indicators with cholesterol, HDL and LDL. In the feeding trial, fish receiving 50% marine fish for 24 months outgrew controls in length, weight and girth ($p < 0.05$); ovarian mass and thickness reached stage III criteria while controls remained stage II. Serum SOD, CAT, TP, HDL, LDL, cholesterol and 17β-estradiol rose ($p < 0.05$), n-3 PUFA (EPA, DHA) and n-3/n-6 ratio doubled, and glycerophospholipid metabolites (lyso-PC, lyso-PE) were up-regulated, indicating enhanced antioxidant capacity and lipid-driven steroid synthesis. These results demonstrate pronounced metabolic sexual dimorphism in Chinese sturgeon and show that marine-fish supplementation can overcome the female maturation bottleneck by supplying n-3 PUFA that fuel E2 production and ovarian growth. The findings furnish biochemical markers for sex identification and a practical dietary intervention to optimize artificial propagation and recovery of this flagship species.

Keywords: Chinese sturgeon; Feeding strategy; Biochemical indices; Fatty acids; Metabolomics; Ovarian development

Serum and Mucus Biomarkers in Chinese Sturgeon: Implications for Health Monitoring and Conservation Management

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ABSTRACT: The Chinese sturgeon (*Acipenser sinensis*) is a critically endangered aquatic species endemic to the Yangtze River. With the expansion of artificial conservation programs, health monitoring has become critical for effective management. However, research data remain limited due to the species' rarity. Blood collection is a commonly used method for health monitoring, offering small wounds and low infection risks, but mucus sampling presents a more effective, non-invasive, and non-lethal alternative, as fish skin mucus provides key health information. This study aimed to identify health biomarkers in Chinese sturgeon and evaluate the effects of different environments on their health by combining biochemical analysis with molecular ecological methods. Eleven biochemical parameters in serum and mucus were measured, and their correlations systematically analyzed. Investigating the effects of environmental differences on mucus indicators and microbial communities of Chinese sturgeon under indoor and outdoor environmental conditions. The results indicated that alanine aminotransferase, aspartate aminotransferase, cortisol, and lysozyme levels were significantly higher in mucus than in serum, whereas alkaline phosphatase, acid phosphatase, lactic acid, lactate dehydrogenase, creatine kinase, and total protein were higher in serum. Acid phosphatase, cortisol, and lysozyme showed strong positive correlations between serum and mucus. Mucus samples from indoor-raised sturgeon exhibited higher levels of total protein, cortisol, alanine aminotransferase, aspartate aminotransferase, and lactate dehydrogenase, but lower levels of lysozyme compared to outdoor-raised sturgeon. Mucus microbiota composition significantly differed between environments: outdoor microbiota was associated with nutrient catabolism, while indoor microbiota was linked to pathogenesis and microbial antagonism. This study provides baseline data on the biochemical parameters and microbiota of Chinese sturgeon, highlights environmental impacts on their health, and offers a foundation for conservation and non-invasive monitoring of this endangered species.

Keywords: Chinese sturgeon; Serum; Mucus; Biochemical parameters; Microbiota; Environmental factors

Advances in Health Assessment Technologies for Chinese Sturgeon: Developing Non-Invasive Monitoring to Intelligent Early-Warning Systems

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ABSTRACT: The Chinese sturgeon (*Acipenser sinensis*), designated as a Class I Protected Species in China and classified as Critically Endangered (CR) on the IUCN Red List, remains at risk despite expanding artificial breeding efforts. While stock enhancement programs have successfully increased captive populations, persistent health challenges in both broodstock and juveniles continue to compromise reproductive efficiency and post-release survival, underscoring the urgent need for a non-invasive health assessment system capable of early anomaly detection, timely warnings, and effective intervention. To address these critical needs, our research team has conducted systematic investigations across three key aspects: (1) Characterization of physiological responses to multi-dimensional stressors, (2) Identification of health biomarkers for early warning, (3) Quantification of health-associated behavioral characteristics. Our future research will focus on integrating big data analytics with multi-modal sensing technologies to establish an intelligent healthy monitoring system. This AI-driven platform will combine wearable biosensors (equipped with microsensors, BIA, and eDNA sampling capabilities) with comprehensive biomarker and behavioral databases. We aim to develop a predictive health management system that transforms current reactive approaches into proactive, data-driven conservation strategies for this endangered species. The resulting Digital Sturgeon Management System is expected to provide unprecedented precision in monitoring physiological-behavioral responses while creating scalable methodologies applicable to other threatened aquatic species.

Keywords: Chinese sturgeon (*Acipenser sinensis*); Health assessment; Non-invasive monitoring; Healthy biomarkers; Intelligent early-warning system

Lactococcus petauri Alleviate *Aeromonas hydrophila*-Induced Damage Risk in Hybrid Sturgeon (*Acipenser baerii* ♀ × *Acipenser schrencki* ♂)

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ABSTRACT: *Aeromonas hydrophila* is a common opportunistic pathogen in aquaculture, which readily infects sturgeon under stress conditions. This study investigated the prophylactic efficacy of *Lactococcus petauri* strain JLlg08PX against *A. hydrophila* in hybrid sturgeon (*Acipenser baerii* × *Acipenser schrencki*). In vitro experiments revealed that the cell-free supernatant of *L. petauri* significantly inhibited *A. hydrophila* growth by disrupting bacterial cell integrity, leading to DNA and lactate dehydrogenase (LDH) leakage. In a 21-day feeding trial, hybrid sturgeon fed *L. petauri* exhibited significantly reduced mortality after *A. hydrophila* challenge, alongside decreased pathogen loads in the liver and head kidney. Concurrently, serum levels of nitric oxide (NO) and lysozyme were elevated. Histopathological analysis demonstrated that the *L. petauri* supplemented group alleviated hepatic damage, maintained intestinal epithelial integrity, reduced inflammatory responses and tissue lesions. These findings indicated that *L. petauri* JLlg08PX reduced *A. hydrophila* infection risk in hybrid sturgeon through dual mechanisms, direct antagonism of the pathogen and enhancement of innate immunity. This study provides a novel strategy for eco-friendly disease control in aquaculture.

Keywords: Lactococcus petaurid; Aeromonas hydrophila; Antagonistic effect; Anti-infection; Sturgeon

Study on Apoptosis of Various Tissues at Different Intervals after Death of Yangtze Sturgeon (*Acipenser dabryanus*)

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ABSTRACT: The collection and preservation of post-mortem genetic material from recently deceased animals of rare and endangered species represent a critical yet underexplored avenue in conservation biology. While extensive research has been conducted on the human post-mortem interval (PMI), there is a notable gap in understanding the post-mortem preservation of germplasm in endangered species. This study aimed to investigate the dynamics of apoptosis in various tissues of the Yangtze sturgeon at different post-mortem time points, and to provide a reference for identifying the optimal time window for germplasm preservation in rare and endangered fish in the wild. TUNEL (terminal deoxynucleotidyl transferase-mediated dUTP nick-end labeling) assay and tissue morphology analyses were used to investigate apoptosis in the brain, heart, fin, liver, gonad, muscle, spleen, and skin of the Yangtze sturgeon at five different time points: 0, 4, 8, 12 and 16 h post-mortem. The results revealed a dynamic pattern of apoptosis: all tissues exhibited a time-dependent increase in apoptotic rate, indicating a clear correlation between PMI and apoptosis progression. This temporal pattern underscores the importance of timely genetic resource preservation, as the integrity of genetic material deteriorates progressively after death. Histomorphological analysis further demonstrated progressive degradation of tissue structure, especially in metabolically active tissues such as the gonad and fin. Based on the findings, we recommend that the genetic resources of the Yangtze sturgeon be preserved as soon as possible after death, particularly within the first 12 h when tissue integrity remains sufficient for viable cell isolation or cryopreservation. This window is critical for metabolically active tissues, which show marked changes over time and may be important for post-mortem identification. Further research should explore cryopreservation and antioxidant treatments to extend the preservation window for germplasm resources, ensuring the long-term viability of these valuable genetic materials.

Keywords: Yangtze sturgeon; Post-mortem interval; TUNEL; Cell apoptosis; Germplasm preservation

Effects of Vitamin D3 on Glucose and Lipid Metabolism in Chinese Sturgeon (*Acipenser sinensis*)

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ABSTRACT: Beyond its established role in mineral homeostasis, 1,25-Dihydroxyvitamin D3 (1,25$(OH)_2D_3$), the active hormonal form of vitamin D3, is integral to a variety of physiological processes. However, its regulatory effects on glucose and lipid metabolism in the Chinese sturgeon (*Acipenser sinensis*) remains inadequately characterized. This study employed intraperitoneal injection and *in vitro* hepatic cell culture to investigate these effects. The intraperitoneal administration of 1,25$(OH)_2D_3$ resulted in a significant reduction in blood glucose (GLU) and triglyceride (TG) levels. *In vitro* experiments demonstrated that treatment of hepatocytes with 1,25$(OH)_2D_3$ led to a decrease in cellular TG content, accompanied by an upregulation in mRNA expression and activity of ATGL and HSL. Furthermore, 1,25$(OH)_2D_3$ enhanced the activity of pyruvate kinase (PK), a key glycolytic rate-limiting enzyme. Investigation of mitochondrial function revealed that 1,25$(OH)_2D_3$ elevated cellular ATP levels and acetyl-CoA content. Collectively, these results demonstrate that 1,25$(OH)_2D_3$ modulates glucose and lipid metabolism in the liver of Chinese sturgeon, promoting mitochondrial ATP production to fuel physiological energy demands. This study provides foundational insights for future investigations into the regulatory role of vitamin D_3 on gonadal development via its effects on glycolipid metabolism in this species.

Keywords: 1,25$(OH)_2D_3$; Chinese sturgeon; Glycolipid metabolism; Mitochondrial function; Hepatic cell

LC-PUFA Biosynthesis Pathway in Chinese Sturgeon (*Acipenser sinensis*): Functional Analysis and Expression Patterns of Elovls

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ABSTRACT: The Chinese sturgeon (*Acipenser sinensis*), a representative ancient species of Acipenseriformes, is a basal branch that diverged early from modern teleostei fishes. It shows morphological traits of both cartilaginous and bony fish, highlighting its important role in fish evolution. This study focused on the catalytic functions and expression patterns of key LC-PUFA biosynthesis enzymes, namely fatty acyl desaturases (Fads) and elongation of very long-chain fatty acids (Elovls) proteins. Previous research showed that Chinese sturgeon Fads1 and Fads2 have more similarities with those in cartilaginous and ancient bony fish. Here, we identified three crucial LC-PUFA biosynthesis elongases (Elovl2, Elovl5a, and Elovl5b) and found they are more evolutionarily related to bony fish elongases. Using the Saccharomyces cerevisiae expression system, we discovered that Elovl5a and Elovl5b can elongate C18 and C20 PUFA substrates, with a stronger preference for C18 PUFAs, while Elovl2 mainly elongates C20 and C22 PUFA substrates. The spatio-temporal distribution of the three elovls genes was similar to that of *fads1* and *fads2*. All six genes had distinct tissue-specific expression patterns, but the liver had the highest expression. Temporally, their expression increased from 0 to 103 hours post-fertilization and from 0 to 20 days post-hatching. Molecular evolution, functional, and spatio-temporal expression analyses indicated that Chinese sturgeon's key enzymes have unique features compared to those in cartilaginous and modern bony fish. This study offers vital information on the LC-PUFA biosynthesis pathway in Chinese sturgeon and new insights into the Acipenseriforme lineage.

Keywords: Chinese sturgeon (*Acipenser sinensis*); LC-PUFA biosynthesis; Elovls; Functional characterization

Habitat Utilization and Movement Patterns of Reintroduced Baltic Sturgeon and Overlap with Anthropogenic Activities in the Oder River

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ABSTRACT: As part of the ongoing conservation and reintroduction program of the Baltic sturgeon (*Acipenser oxyrinchus*), a species regionally extinct, the preferential habitats and potential aggregation spots are identified, intra-specific variability in movement behavior is assessed, and interactions with anthropogenic impacts (dredge sites, fishing gear) are to be evaluated. A total of 74 individuals were monitored over several weeks using a combination of active and passive telemetry: 25 individuals (average FL = 305 mm) released in winter 2024 and 49 individuals (average FL = 829 mm) released in summer 2025. Monitoring extended. The data acquired were complemented by catch-reports from local fishermen. Habitat characteristics were assessed through river mapping using a side-scan sonar (Hummingbird Solix 12). Three main behavioral patterns were identified: (i) *fast movers*, migrating downstream within a few days; (ii) *residents*, remaining in localized habitats for extended periods; and (iii) *explorers*, repeatedly moving upstream and downstream in a 40 km range. Aggregation behavior was inconsistent, with no stable group movements detected. In total, 4% and 25% of tagged individuals were captured in fishing gear, primarily gillnets, in winter and spring respectively. The preliminary results highlight pronounced intra-specific variability in movement strategies, emphasizing the need to account for different behavioral profiles in conservation planning. Maintaining and protecting suitable habitats along the Oder River is crucial to accommodate both mobile and resident individuals. Habitat-focused management, combined with measures to reduce risks from fishing fatalities, will be key to supporting the long-term success of Baltic sturgeon restoration.

Keywords: Telemetry; Intra-specific variability; Habitat use; *Acipenser oxyrinchus*; Migration behaviors

Genome-Wide Identification of Vitellogenin Genes in the Chinese Sturgeon: Genomic Characterization, Phylogenetic Analysis, and Expression Profiles

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ABSTRACT: The Chinese sturgeon (*Acipenser sinensis*), a critically endangered Chondrostean fish, serves as a key model for understanding vertebrate genome evolution due to its unique lineage-specific whole-genome duplication (As3R), distinct from the teleost-specific Ts3R event. Despite the critical role of vitellogenin (Vtg) in ovarian maturation, the *vtg* gene family remains poorly characterized in sturgeons. Here, we performed a genome-wide identification and comprehensive analysis of *vtg* genes in *A. sinensis*. Three *vtg* genes (*vtgAB1*, *vtgAB2a*, and *vtgAB2b*) were identified and characterized in terms of genomic organization, conserved protein domains, and phylogenetic relationships. All three Vtgs exhibited complete domain architectures and conserved estrogen-responsive elements in their promoter regions. Phylogenetic reconstruction revealed clear orthology groups within Acipenseriformes and highlighted the basal position of sturgeon Vtgs relative to teleosts. Spatial and temporal expression profiling confirmed the exclusive hepatic origin of all Vtgs with specific transcription in hepatocytes. The study provides the first systematic molecular characterization of the *vtgs* in *A. sinensis*, offering valuable insights into the evolutionary diversification of Vtgs following sturgeon-specific genome duplication and establishing a foundation for improving artificial reproduction protocols for this endangered species.

Keywords: Chinese sturgeon; Vitellogenin; Gene family; Genome-wide identification; Phylogeny

Habitat Evolution Characteristics of Historical Spawning Grounds for Yangtze Sturgeon (*Acipenser dabryanus*) in the Jinsha River Reach from Xiangjiaba to Yibin

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ABSTRACT: Based on the significant impact of the operation of the Xiangjiaba Hydropower Station in the upper Yangtze River on the downstream hydrological regime and river geomorphology, this study takes the historical spawning grounds (Anbian, Sankaishi, Xuetan) of the Yangtze sturgeon (*Acipenser dabryanus*) as the research object. By comparing hydrological data, topographic surveys, and hydraulic parameters before and after dam construction (1965–1975 *vs.* 2020–2022), we systematically analyze the process and mechanistic effects of habitat parameter changes on the decline of its spawning capacity. The results show that dam operation led to an increase in the variability of monthly average flow (standard deviation increased from 532 to 998), higher flow reversal frequency, and significantly elevated rates of flow rise and fall. The hydrological rhythm shifted from natural and steady to pulsed regulation, disrupting the hydrological stability essential for Yangtze sturgeon spawning. Meanwhile, changes in water depth, flow velocity, substrate conditions, and vorticity in the spawning grounds further reduced their suitability. This study reveals how dam regulation alters hydrology and topography, leading to systematic degradation of the spawning habitat of the Yangtze sturgeon, thereby providing a scientific basis for its conservation and ecological scheduling.

Keywords: Historical spawning grounds; Hydrological data; Bathymetric survey; Hydraulic parameters

Silent Survivors: How Monitoring and Genetics Reveal the Recovery of the Adriatic Sturgeon

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ABSTRACT: The Adriatic sturgeon (*Acipenser naccarii*) is a *Critically Endangered* species endemic to northern Italy. Once considered possibly extinct in the wild, recent monitoring and genetic evidence suggest encouraging signs of persistence and potential recovery. Between 2019 and 2024, monitoring activities were conducted in the Veneto Region, primarily in the Livenza River, in collaboration with local fishermen. Captured individuals were scanned for microchips, measured, and tissue samples were collected when possible. Genetic analyses combined mitochondrial sequencing, species-specific nuclear markers, and microsatellite genotyping to assess species identity, detect hybrids, and evaluate genetic diversity. A total of 104 sightings were recorded, including five juveniles smaller than 25 cm—below the size threshold of stocked fish—suggesting natural reproduction. Of 27 tissue samples analyzed, 24 individuals were genetically identified as pure *A. naccarii*, consistent with the founding broodstock, while three were confirmed as interspecific hybrids (*A. gueldenstaedtii* × *A. naccarii*, and *A. transmontanus* × *A. naccarii*). Microsatellite analyses revealed low diversity within pure *A. naccarii*, reflecting their common origin, while hybrids formed distinct clusters. These findings confirm that restocking programs have maintained *A. naccarii* in the wild and suggest that spontaneous reproduction is occurring. However, the detection of hybrids highlights risks posed by alien sturgeons and underscores the need for strict genetic screening of broodstocks, biosecurity in aquaculture, and legislative measures to prevent introductions of non-native species. Coordinated monitoring, centralized data collection, and alignment with international conservation frameworks are essential to safeguard the genetic integrity and long-term survival of the Adriatic sturgeon.

Keywords: Adriatic sturgeon; Hybridization; Restocking

A New Effort for the Conservation of the Adriatic Sturgeon in Italy

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ABSTRACT: The conservation of the Adriatic sturgeon (*Acipenser naccarii*) in Italy has involved at least four LIFE projects and numerous local initiatives, mainly focused on restocking captive-bred fish. Over 600,000 individuals have been released in the past 30 years, preventing extinction but failing to restore a self-sustaining wild population. The species remains *Critically Endangered* (IUCN) and assessed as *Unfavourable-Bad* (U2) under the Habitats Directive. Limited success is linked to the release of small fish, predation by invasive alien species (IAS) such as *Silurus glanis*, poaching, and lack of coordinated range-wide strategies. LIFE RESTORE addresses these gaps following the Pan-European Action Plan for Sturgeon Conservation (Bern Convention, 2019), combining restocking, IAS control, and large-scale stakeholder engagement. Over six years, more than 75,000 fish will be released with the support of two hatcheries. Most will be ≥3 years old to improve survival, while smaller fish will be stocked only in rivers with low predator density. IAS control will focus on catfish removal along 105 km of the Po River and parts of the Sesia and Scrivia rivers. Monitoring will cover 13 rivers and 45 Natura 2000 sites, using telemetry and citizen science. Anglers' associations will be trained to collect and share data. Awareness campaigns will involve >200,000 people, including thousands of students. The project expects a wild population increase of about 14,000 sturgeons, nearly 20 times higher than the 700 individuals reported in the last Habitats Directive assessment. It aims to foster natural reproduction, observed sporadically in recent years, and to establish a coordinated, long-term conservation framework endorsed by five regional administrations. Finally, the project also aims to raise public awareness of sturgeons and spread understanding of their ecological importance.

Keywords: *Acipenser naccarii*; LIFE RESTORE; Restocking

Anesthesia Using Clove Oil for Various Ages and Sizes of Juvenile *Acipenser nudiventris*

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ABSTRACT: Ship sturgeon (*Acipenser nudiventris* Lovetsky, 1828) is one of the most endangered species. To restore the wild ship sturgeon population, the assessment of the quality of the offspring from farmed broodstock is necessary. The objective of this study is to evaluate the anesthetic effects of clove oil on the different-sized ship sturgeon juveniles by measuring the times to anesthesia and recovery. The experiment was conducted in 2018 and 2020 for juveniles aged 50, 70, 90, 120 and 150 days at a water temperature of 20–22 °C, oxygen—6.8–7.5 mg/L with the addition of an aqueous emulsion of clove oil of 0.07 ml/L. Each anesthetic effect of clove oil was tested in three groups of fish with different body sizes. The first stage (10–30 s), anesthetized juveniles showed excitement, with subsequent complete loss of equilibrium and tail fin movement stop, which was considered complete anesthesia. It is known that resistance to neurotropic drugs correlates with the overall viability of fish, which is determined by the best physiological state of low-sensitivity individuals. In 2018, juvenile ship sturgeons were used, which were interpopulation hybrids of F3-F4 and entered anesthesia more quickly, but reanimated more slowly. In 2020, the experiments were conducted on juveniles of the Caspian populations generation F2, which proved to be more resilient and recovered faster. It was also found that the average juveniles in both experiments, at the age of 70 days and weighing 5 g, were the most resilient. This method can be used to immobilize juveniles and young sturgeon fish for various manipulations and studies where waste is not allowed. It can also be used as an assessment of physiological status for the development of therapeutic and preventive measures and the release of high-quality juveniles.

Keywords: Ship sturgeon; Health and welfare; Anestezia; Clove oil; Eugenol; *Acipenser nudiventris*

Exploring the Genuine Habitat Preferences of Fish by Monitoring Their Behavior within Near-Natural Experimental Environments

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ABSTRACT: The establishment of hydropower projects has altered the flow regime and structure of fish habitats. Various habitat restoration measures based on natural river morphology have been implemented, but the effects of habitat restoration and the hydrodynamic mechanisms of fish preferred topography remain unclear. We constructed diverse near- natural microtopographic habitats and monitored test fish behavior in real time using a Radio Frequency Identification (RFID) system with Passive Integrated Transponder (PIT) tags. Studies have demonstrated that fish trajectory tracking based on PIT radio frequency identification system is feasible in small natural rivers. Experimental fish exhibited more active upstream movements under low-flow conditions and adjusted their trajectories in response to changes in discharge. Complex flow fields generated by different channel morphologies exerted varying degrees of attraction on fish habitats under different flow regimes. Both the habitat selection model based on hydrodynamic indicators and the model incorporating channel morphology and discharge showed good predictive performance for fish habitat use. The findings provide theoretical support for optimizing river restoration projects and contribute to the recovery of fish resources and population abundance.

Keywords: Fish behavior; Habitat restoration; Hydrodynamic method

Genetic Load and Fitness in a Polyploid Sturgeon

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ABSTRACT: Genetic load, the accumulation of deleterious mutations, may threaten population viability by reducing individual fitness. In polyploids, allelic redundancy may mask deleterious alleles, but it can also promote their accumulation. We experimentally tested this relationship in the tetraploid Adriatic sturgeon (*Acipenser naccarii*). Twelve captive breeders were sequenced, and ~1000 SNPs of predicted impact were selected. About 400 offspring from controlled crosses were genotyped and monitored for survival and growth over one year. Load indices were computed and correlated with fitness traits. Larvae that died before yolk sac absorption carried significantly higher loads at high-impact sites compared to surviving juveniles. Among juveniles, genetic load at high-impact loci showed a strong negative correlation with body size, with individuals carrying higher loads displaying up to 30% reductions in length and weight. Our study provides the first experimental validation in a polyploid vertebrate linking predicted genetic load to observed fitness. Results demonstrate that tetraploidy does not completely buffer deleterious mutations and that load accumulation can affect both survival and growth. These findings highlight the importance of managing genetic diversity and minimizing inbreeding in ex-situ breeding programs for endangered sturgeons.

Keywords: Adriatic sturgeon; SNPs; Endemixit

Re-Breeding of Wild Persian Sturgeon (*Acipenser persicus*) in Farmed Conditions

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ABSTRACT: Every year, a large number of natural breeders of sturgeon fish killed during artificial reproduction due to reason of their inability to adapt to nutrition in breeding conditions. A total of 4 (2 females + 2 males) wild Persian sturgeon (*Acipenser persicus*) caught from the southern coasts of the Caspian Sea and transferred to artificial reproduction center (Iran) in 2017. The micro incision of oviduct was used for artificial reproduction. After propagation, fish were transferred to a 20-ton fiberglass tank equipped with hole and river water supply and aeration systems and fed with different diets such as a diet inspired by nature, a wet food composition containing 49% protein, 14% fat, 20% carbohydrates, vitamins, minerals, nutrient absorbents, and commercial concentrate. Based on results, a wild female and male *A. persicus* showed a significant increase in somatic growth and gonadic development. The trend of somatic growth (weight) of fish decreased until adaptation to feeding in reared conditions (6 months–1 years), and then it increased gradually. So that the body weight of one of female fish from 20 kg at the beginning reached to 34 kg at the end. In gonadal growth, 1 female + 1 male breeder matured again during 3.5 years for second time and matured sexually again after 2 years (for third time). The diameters of the eggs were 2.9 mm and 3.2 mm in the second and the third times, respectively. The female breeder was injected using $LHRH_{A2}$ hormone again, and due to the sudden increase in temperature, the eggs did not ovulate. From a male *A. persicus*, 200 mL of high quality sperm with a motility rate of 85% were obtained after 2 years. In general, according to the results, the biotechnique of maintaining natural sturgeon has been obtained and recommended for avoid killing them.

Keywords: Wild sturgeon; Brood stocking; Adaptation; Rearing conditions; *Acipenser persicus*

Application of Synthetic Hormonal Induction in Sterlet Sturgeon Based on Indigenous Technical Knowledge

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ABSTRACT: Artificial rearing conditions that limit exposure to natural spawning environments can disrupt gonadotropin secretion, impairing both spawning and spermiation. To address reproductive limitations in captivity, artificial induction methods are commonly implemented. Currently, sturgeon hatcheries predominantly use synthetic gonadotropin-releasing hormone analogues, most being imported. To address the demands of the national aquaculture sector, three analogues of gonadotropin-releasing hormone were synthesized. After obtaining high purity of peptides by analytical HPLC and confirming their identity by mass spectrometry, the *in vivo* biological evaluation of the peptides was performed to compare its performance with commonly available commercial hormone. The study results on Sterlet sturgeon (*Acipenser ruthenus*) broodstocks indicated that the two synthetic analogues effectively enhanced the reproductive response to hormone therapy in both male and female Siberian sturgeon. Hence, they can be recommended as effective agents for the artificial reproduction of Sterlet sturgeon in Iran.

Keywords: Siberian sturgeon; Spawning; Hormone therapy; Reproductive performance

Whole Genome Sequencing Reveals Autooctoploidy in the Chinese Sturgeon and Its Evolutionary Trajectories

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ABSTRACT: The order Acipenseriformes, which includes sturgeons and paddlefishes, represents “living fossils” with complex genomes that are good models for understanding whole genome duplication (WGD) and ploidy evolution in fishes. Here we sequenced and assembled the first high-quality chromosome-level genome for the complex octoploid *Acipenser sinensis* (Chinese sturgeon), a critically endangered species that also represents a poorly understood ploidy group in Acipenseriformes. Our results show that *A. sinensis* is a complex autooctoploid species containing four kinds of octovalents (8*n*), a hexavalent (6*n*), two tetravalents (4*n*), and a divalent (2*n*). We propose based on an analysis taking into account delayed rediploidization that its octoploid genome composition results from two rounds of homologous whole genome duplications (WGDs), and further provide insights into the timing of its ploidy evolution. This study provides the first octoploid genome resource of Acipenseriformes for understanding ploidy compositions and evolutionary trajectories of polyploidy fishes.

Keywords: Chinese sturgeon; Whole-genome sequencing; Autooctoploid; Polyploidization and diploidization; Whole genome duplication

Dam-Induced Mechanisms Driving Endangered Fish Species toward Extinction: A Landscape-Scale Habitat Suitability Framework for Conservation

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ABSTRACT: The degradation of the last remaining spawning grounds of the critically endangered Chinese sturgeon (*Acipenser sinensis*) exemplifies the global crisis of dam-induced riverine ecosystem degradation. By integrating geo-detector-weighted hydrodynamic parameters with landscape connectivity metrics, we develop a novel habitat suitability framework that quantifies previously overlooked mechanisms: First, hydrodynamic thresholds (e.g., turbulent intensity, depth, shear velocity) emerge as primary drivers of habitat selection, with parameter interactions amplifying explanation by 56.25% compared to single-factor assessments. Second, dam impoundment and channelization led to an 81.82% reduction in highly suitable habitat (2012 *vs.* 1999), driven by hydrological alteration, riverbed erosion and habitat fragmentation (patch density increased 91.50%, connectivity decreased 65.06%). These changes directly contributed to a 99.96% decline in egg density, forcing the species to shift to suboptimal upstream zones where reproduction ceased since 2013. To reverse these declines, we propose flow optimization (10,000–15,000 m^3/s spawning season discharge) to manage turbulence thresholds and cobble rehabilitation to restore bathymetry conditions, strategies expected to restore 56.13–72.80% of Landscape-Integrated Geo-Detector Weighted Usable Area (WUA_{GL}). This study fills critical gaps in traditional habitat models and provides a replicable framework for conserving dam-affected freshwater ecosystems through actionable, threshold-based management.

Keywords: Chinese sturgeon; Spawning ground; Eco-hydraulic modeling; Geo-detector approach; Landscape indices; Analytic hierarchy process; Habitat suitability model; Yangtze River

Biochemical Composition and Transcriptome Analysis Revealed Nutrients Consumption and Physiological Characteristics of Chinese Sturgeon Larvae during Yolk-Sac Stage

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ABSTRACT: During the yolk stage, the nutrients of larvae consumed are from the yolk sac, which greatly affect the survival and quality of fish. The aim of this study was to investigate the metabolic changes, physiological characteristics and the related molecular mechanism of Chinese sturgeon larvae during yolk stage (vertical, flat and benthic). The results showed that both total amino acid and protein contents showed a trend of first decreasing and then increasing. The lipid content was stable in the early stages, but decreased significantly in the benthic stage. In terms of amino acid profile, the contents of leucine, isoleucine and lysine were relatively high in EAAs, and the contents of glutamate, aspartate and serine were relatively high in NEAA. As for fatty acid content, the most abundant fatty acids are palmitic acid, oleic acid, linoleic acid and DHA. According to KEGG enrichment analysis on the DEGs, the up-regulated DEGs *mGlu3, mGlu5, NMDAR, PepT1, TAT1, EAAT3, CYP51A1* and *CYP7A1* were significantly enriched in pathways related to the nervous system, protein digestion and absorption, steroid synthesis, cholesterol metabolism and bile acid biosynthesis in early development of larvae. Down-regulated DEGs *Drg1, NHP2, KRE33* and *MPP10* were enriched in the ribosome biogenetic pathway. In late development, up-regulated DEGs, *cGAS, IRF3, TRAF2, MHC-I, MHC-II* and *TAR2*, were enriched in pathways associated with innate and adaptive immunity. Down-regulated *DKK2* and *FGFRs, ITGAs* were enriched in Wnt signaling pathway and PI3K-AKT pathway, respectively. In summary, this study revealed that the larval fish consumed protein as the main nutrient from the vertical stage to the flat stage, while mainly consumed lipid from the flat stage to the benthic stage, and highlighted the pathways of DEGs involved in the nervous system and immune system.

Keywords: Chinese sturgeon; Yolk stage; Biochemical analysis; KEGG path analysis

Caviar Extracted Peptides Uses in Baby Food and Supplements

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ABSTRACT: This research focuses on the essential need for complementary foods tailored to different age groups to support healthy growth and development during early childhood. After six months, breast milk alone no longer satisfies infants' increased requirements for protein and essential fatty acids. Therefore, we explored the potential of hydrolyzed sturgeon caviar, known for its rich nutritional content—including high-quality proteins, bioactive peptides, and key micronutrients like DHA, EPA, vitamins, and minerals. To prepare the supplement, fresh caviar was first freeze-dried and powdered. Using a supercritical extraction method, approximately 80% of the oil was removed from the powder. The remaining protein fraction was then enzymatically hydrolyzed, ultrafiltered, and freeze-dried again to obtain a protein powder suitable for use in children's diets. This powder was packaged into convenient 25-gram sachets. Three formulations were created to meet the nutritional needs of different pediatric groups: infants aged 6 months to 1 year, toddlers from 1 to 3 years, and children older than 3 years. Each formulation was tested over a three-month period in groups of 25 children, alongside a control group of 18 children receiving no caviar-enriched supplements. Results showed that children consuming the caviar-enriched foods experienced significantly greater improvements in weight gain, bone development, attention span, and cognitive testing compared to those in the control group. Notably, combining the caviar protein with beef protein produced the most pronounced benefits. Furthermore, administering these supplements via gavage in hospital settings led to measurable positive impacts on patients' health. In summary, this study demonstrates the promising role of marine-derived hydrolyzed sturgeon caviar protein as a functional ingredient to improve complementary feeding strategies and ultimately enhance child health outcomes.

Keywords: Complementary feeding; Hydrolyzed sturgeon caviar protein; Bioactive peptides; DHA and EPA; Protein hydrolysis; Nutrient supplementation

Three Advanced Formulations Based on Enzymatically Hydrolyzed Caviar for Use in Cosmetic Products

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ABSTRACT: This study investigates the skincare benefits of Iranian Beluga sturgeon caviar, rich in bioactive compounds such as essential fatty acids, peptides, vitamins, and minerals. The caviar protein was enzymatically hydrolyzed on an industrial scale, and peptides were separated by ultrafiltration. Antioxidant activity was measured using DPPH and ABTS assays, showing significant free radical scavenging. At 1 mg/mL, the total hydrolysate inhibited 45.59% of DPPH and 71.24% of ABTS radicals, while the <3 kDa peptide fraction inhibited 23.35% and 82.19%, respectively. Human foreskin fibroblasts treated with these hydrolysates demonstrated increased cell viability and enhanced type I collagen production, confirmed via immunocytochemistry. Under oxidative stress, fibroblast viability rose to 165.9% with total hydrolysate and 86.16% with the low-molecular-weight fraction at 25 µg/mL. Both treatments significantly stimulated collagen synthesis, indicating potential for anti-aging skincare. Based on these findings, three cream formulations were developed: a hydrating eye contour cream targeting wrinkles, an anti-blemish product to reduce inflammation and even skin tone, and a brightening cream to enhance radiance through antioxidant and collagen-boosting effects. These products were tested on 48 volunteers aged 38 to 45, showing clear improvements in wrinkle reduction, skin smoothness, and brightness. This work demonstrates the promising role of hydrolyzed sturgeon caviar peptides as natural, effective ingredients for advanced skincare products, combining traditional luxury with scientific validation to support skin rejuvenation and anti-aging care.

Keywords: Sturgeon caviar; Iranian Beluga; Hydrolyzed protein; Antioxidant activity; Collagen synthesis; Anti-aging skincare

Chinese Sturgeon Germplasm Conservation: Strategies and Practices

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ABSTRACT: The planet is currently experiencing a sixth mass extinction event, primarily driven by anthropogenic activities, which poses severe threats to global fish biodiversity. Despite extensive conservation initiatives—including stock enhancement, population surveys, and habitat restoration—the decline of sturgeon populations worldwide remains largely unabated. Within China, which harbors eight native sturgeon species, the Chinese paddlefish (*Psephurus gladius*) has been declared extinct since the onset of the 21st century, and the Yangtze sturgeon (*Acipenser dabryanus*) has experienced a complete cessation of natural reproduction in the wild. Similarly, the Chinese sturgeon (*Acipenser sinensis*), an endemic anadromous species, has exhibited no evidence of successful natural reproduction for eight consecutive years. This species is now classified as critically endangered and faces imminent risk of extinction in its natural habitat. This escalating crisis necessitates a critical reevaluation of existing conservation paradigms and underscores the urgent need for innovative strategies focused on germplasm resource protection. The effective preservation of the Chinese sturgeon's germplasm has thus emerged as a pivotal challenge. This report systematically examines the historical and current status of germplasm conservation efforts for the Chinese sturgeon, proposes an integrated preservation strategy encompassing *in situ*, *ex situ*, and off-site methods, and delineates priority actions and future research directions to enhance conservation outcomes.

Keywords: Chinese sturgeon; Germplasm conservation

Evaluation of the Antifungal Efficacy of Dietary Nanocurcumin in Sturgeon

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ABSTRACT: The alarming rise in microbial drug resistance necessitates an urgent search for effective alternative antimicrobial agents that exhibit minimal cytotoxicity in humans. Curcumin, the active compound derived from turmeric, has demonstrated broad-spectrum biological activities, including antibacterial, antifungal, antiviral, and antiprotozoal effects. This study investigated the antifungal efficacy of nanocurcumin as a dietary supplement in sturgeon. The experimental design included four treatments: a control diet (T1), and diets supplemented with 25 (T2), 50 (T3), and 75 (T4) mg/kg nanocurcumin. Sampling was conducted on days 0, 7, 14, 28 and 56 of the feeding trial. The results indicated that dietary nanocurcumin reduced the fungal load in the feed compared to the control group. In conclusion, nanocurcumin is a potent natural antifungal agent that can effectively improve feed safety and quality in sturgeon aquaculture.

Keywords: Nanocurcumin; Antifungal agent; Sturgeon; Feed safety; Sustainable aquaculture

Feeding *Hediste diversicolor* with Beluga Sturgeon (*Huso huso*) Waste at Different Densities in IMTA Systems

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ABSTRACT: This study confirms the potential of *Hediste diversicolor* as a sustainable tool for bioremediation in beluga sturgeon aquaculture, promoting circular practices within integrated multi-trophic aquaculture (IMTA) systems. The polychaete efficiently converts fish waste into nutritionally valuable biomass due to its trophic plasticity and resilience. Waste-fed worms produce viable biomass, though with lower nutritional quality (e.g., PUFA content) compared to those fed commercial feed. Key findings include the importance of density optimization: low densities (1000–2500 ind./m²) is ideal for producing large, high-quality worms for premium markets like bait, while high density (5000–7500 ind./m²) is better suited for waste treatment and bulk biomass production. Nutritional quality, particularly PUFA content, can be enhanced by supplementing diets with lipids from microalgae or oils, maintaining. Based on the successful validation of *H. diversicolor* as a sustainable bioremediation tool for aquaculture, this study provides a concrete pathway toward more circular practices. The worm is an exceptional candidate for IMTA due to its ability to directly convert fish waste into nutritionally valuable biomass through its trophic plasticity and resilience. The research offers a scalable model centered on density optimization and dietary enhancement. For the primary goals of waste treatment and producing bulk biomass, a higher density of 5000–7500 ind./m² is optimal. This model provides a scalable solution to reduce aquaculture's environmental impact and create economic value from waste.

Keywords: Bioremediation; Polychaete culture; Waste valorization; IMTA

Distribution Behavioral Characteristics of the Reproductive Populations of Chinese Sturgeon and Habitat Assessment in the Yichang Spawning Ground Reach after the Interruption of Natural Reproduction

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ABSTRACT: The Chinese sturgeon (*Acipenser sinensis* Gray, 1835), a large anadromous migratory fish, has experienced a drastic decline in its wild population in recent years, presenting a grave threat to its survival. Notably, the construction of large scale water conservancy projects such as the Gezhouba Dam and the Three Gorges Dam has significantly modified the natural hydrological rhythms of the downstream river. Key environmental variables, including river flow dynamics, water level fluctuations, and water temperature variations, have been altered, thereby disrupting both the physical and biological conditions essential for the natural reproduction of the Chinese sturgeon. In addition, human induced factors like environmental pollution have severely impacted its reproductive activities. Alarmingly, since 2013, 2015, and continuously from 2017 to the present, no natural spawning events of the Chinese sturgeon have been detected in the spawning grounds downstream of the Gezhouba Dam, raising serious concerns about the species' population status. Current research on the Chinese sturgeon predominantly focuses on population resource surveys, mostly relying on hydroacoustic detection methods. There is a conspicuous lack of novel technological approaches for its monitoring. Moreover, integrated analyses of the physical habitat suitability and biological integrity in the Chinese sturgeon spawning ground reaches are scarce. To elucidate the population size dynamics and spatial distribution patterns of the Chinese sturgeon's reproductive groups in the spawning ground reaches following the cessation of natural spawning, this study adopted a combined approach of fishery hydroacoustic surveys and environmental DNA (eDNA) monitoring techniques. Continuous multi year synchronous monitoring was conducted in the Yangtze River sections within the Hubei Yichang Chinese Sturgeon Provincial Nature Reserve (hereinafter referred to as the "Reserve"). Additionally, a habitat suitability model for the Chinese sturgeon spawning grounds was developed. This model was based on a two-dimensional hydrodynamic model, constrained by fuzzy-logic rules and a temperature suitability index. Simultaneously, a multi- trophic level index of biological integrity for the spawning ground reaches was constructed using eDNA metabarcoding technology. These methods were employed to objectively evaluate the physical habitat suitability and biological integrity of the Chinese sturgeon spawning-ground reaches. By considering both abiotic and biotic factors of the sturgeon's habitat, the critical roles of physical habitat suitability and biological integrity in maintaining the Chinese sturgeon population were analyzed, and scientific recommendations and countermeasures for the conservation of this species were proposed. The main findings of this study are as follows: (1) A five-year continuous survey of the Chinese sturgeon's reproductive group abundance and spatial distribution in the Reserve was carried out using fishery hydroacoustic methods. In terms of population size, from 2019–2023, the number of reproductive group individuals in the Reserve fluctuated between 9 and 14, indicating a consistently low population with relatively stable changes. Regarding spatial distribution, during the annual spawning season, the majority of the reproductive groups were concentrated near the Gezhouba Dam and Miaozui. A small number were observed near Yanzhi Dam, and only a few were found near Qingjiang River estuary and its tributaries, with almost no presence in the mainstream reaches below Qingjiang River estuary. In the non-spawning season, Chinese sturgeons were still present in the Reserve, mainly distributed in the mainstream reaches below Qingjiang River estuary and the Qingjiang River tributary. In terms of fish size, the Chinese sturgeons in the Reserve were predominantly small to medium sized, with large and medium sized individuals being scarce. The echo intensity of other common fish species ranged from −65 to −45 dB, accounting for approximately 92% of the total, suggesting that the fish resources in the Reserve were mainly composed of small fish and juvenile individuals. (2) The complete mitochondrial genome of the Chinese sturgeon was sequenced from fin or tissue samples. After comparing with mitochondrial sequences of other closely related species in the NCBI database, a set of highly specific biological probes based on Locked Nucleic Acid (LNA) modification technology was designed. These probes could amplify the target mitochondrial gene fragments of the Chinese sturgeon but not those of other related species. A digital droplet PCR based quantitative detection standard for Chinese sturgeon eDNA was established, with a minimum detection limit of 0.12 copies/μL. Application of these probes in the Reserve revealed distinct patterns in eDNA concentration distribution. Before the spawning season, high eDNA concentration areas were located in the mainstream reaches above Qingjiang River estuary. During spawning, high concentration areas shifted to the downstream of the dam. After spawning, high concentration areas were observed in the mainstream reaches below Qingjiangkou. Temporally, in both the Yangtze River mainstream and Qingjiang River tributary, eDNA concentrations increased before spawning and decreased thereafter. A strong correlation was found between eDNA detection results and hydroacoustic survey data, validating the feasibility of eDNA technology for detecting rare and endangered species. Based on the combined positive results of eDNA

and hydroacoustic methods, the Qingjiang River tributary was hypothesized to be a potential Chinese sturgeon habitat. (3) Using historical data on the Chinese sturgeon's distribution depth and velocity, *in situ* fish finder data, and the average daily water temperature during 52 spawning events since 1981, fuzzy logic rules for hydraulic suitability and a Water Temperature Suitability Index (WTSI) were developed. A habitat suitability model for the Chinese sturgeon spawning grounds was then constructed by coupling a two dimensional hydrodynamic model with these rules and the WTSI. Validation using actual Chinese sturgeon location data yielded a correlation coefficient of 0.86, demonstrating the model's effectiveness. Model simulations of spawning conditions from 1981 (after Gezhouba construction) to the present showed a significant reduction in the weighted usable area (WUA) and habitat hydraulic suitability (HHS) after the impoundment of the Three Gorges Dam. The spawning areas exhibited a fragmented and discontinuous Habitat Suitability Index (HSI) distribution, leading to a decline in habitat quality, reduction in spawning ground space, limitation of the reproductive group size, and decreased reproductive efficiency. The Gezhouba river regime adjustment and waterway regulation projects had only local impacts on the spawning ground reaches. Hydraulic model construction and habitat suitability simulations for the downstream reaches of the Reserve and the Qingjiang River showed that the downstream reaches had high hydraulic suitability, with HSI values ranging from 0.7 to 0.9. Three well connected areas (Yanzhi Dam, Honghuatao, and Meizixi reaches) with minimal flow induced changes were identified. The Yanzhi Dam reach, in particular, had a large and continuous HSI high value area, making it a promising candidate for an artificial spawning ground restoration project. In contrast, the Qingjiang River had low hydraulic suitability (mostly below 0.4), although its temperature suitability during the sturgeon's spawning season was relatively high (usually above 0.9). Thus, while the Qingjiang River may not be suitable as a spawning ground in terms of hydraulics, it could potentially serve as a pre-spawning habitat.

Keywords: Chinese sturgeon; Hydroacoustics; Environmental DNA; Habitat suitability

From the Analysis of the Silent Disappearance of the Three Sturgeons of the Po River to the Life Restore Project for the Recovery of the Adriatic Sturgeon

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ABSTRACT: Three sturgeon species—the common European (*Acipenser sturio*), beluga (*Huso huso*), and Adriatic sturgeon (*Acipenser naccarii*)—coexisted in the Po River Basin until the mid-1970s, embodying centuries of bio-cultural heritage for northern Italy's riverine communities. Despite their cultural and economic importance, the dynamics of their decline have remained largely undocumented. This study reconstructs the final phase of natural sturgeon populations in the Po through a systematic analysis of quantitative sources from 1970–1990, including scientific monitoring records, fish market auction data, grey literature, and interviews with veteran fishermen. Results reveal distinct extinction trajectories: beluga disappeared by 1974, the last common sturgeon was captured in 1984, while the Adriatic sturgeon persisted longer, surviving in the Po with low but stable numbers. Overfishing emerges as the principal driver of decline. Historical fisheries targeted spawning migrations along the river, but mechanization from the 1960s—motorized boats and nylon nets—greatly intensified pressure. Coastal trawling in the northwestern Adriatic further impacted anadromous sturgeons across their life cycle, compounding losses. Although a ministerial decree in 1987 introduced a 100 cm minimum landing size, this regulation arrived too late to prevent collapse. By integrating ecological, economic, and oral histories, this research provides the first comprehensive baseline of pristine sturgeon populations in the Po River ecosystem. It illustrates how technological intensification and unsustainable exploitation dismantled centuries-old ecological and cultural relationships. The decline of sturgeons in the Po reflects the broader interdependence between functional river ecosystems and human societies, and the urgent responsibility to safeguard this intertwined natural and cultural heritage, in a common aim between conservation and community engagement. These findings provide essential context for ongoing restoration efforts, such as the Life Restore Project, aimed at strengthening past restocking efforts, which have been carried out for the Adriatic sturgeon over the last 35 years.

Keywords: *Acipenser naccarii*; *Acipenser sturio*; *Huso huso*; Fish conservation; Bio-cultural heritage; Po River restoration

Common Diseases in Sturgeon Farming: Pathogenicity and Prevention Strategies

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ABSTRACT: Diseases occur frequently during sturgeon farming, primarily including viral, bacterial, and parasitic diseases. As early as the 1990s, over ten viruses, such as sturgeon nucleocytoplasmic large DNA virus, herpesvirus, and *Acipenser transmontanus* adenovirus 1, were successively reported in white sturgeon and paddlefish. However, viral diseases have rarely been reported in sturgeons within China. Diseases affecting sturgeon species in China are mainly bacterial, including sepsis caused by motile Aeromonas, enteritis caused by Streptococcus, granulomas caused by Mycobacterium, red mouth disease and enteritis caused by Yersinia, as well as diseases caused by other pathogens. Common prevention and treatment methods typically involve incorporating probiotics (e.g., *Bacillus subtilis*, *Pseudobacillus nanhaiensis*) into feed, using antimicrobial peptides, inactivated vaccines, and antibiotics. It is recommended to strengthen research and development of probiotics and inactivated vaccines to support green and healthy aquaculture practices for the sturgeon industry.

Keywords: Sturgeon; *Mycobacterium marinum*; Pathogenicity

Eastern & Western Cultures and Sturgeon Caviar

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ABSTRACT: (1) Chinese caviar producers collectively create over 50% of the international market supply. Pioneering companies prioritized quality; newcomers must adhere to this quality-first mindset to continue providing high-quality products to the international market. (2) Prospects and consumption potential of the Chinese market: domestic market growing from scratch, with annual consumption increases; analysis of market capacity and trends. (3) Introduction of caviar culture and product innovation: “Introducing in and going global”, adhering to “caviar + X” category innovation, developing products like caviar ice cream, caviar chocolate, caviar mooncakes, caviar cakes, *etc.*, to lower barriers, bring consumers closer, and gradually open new domestic consumption scenarios including business banquets, afternoon tea, weddings, and gifts. (4) Development and brand promotion in emerging markets like Southeast Asia. (5) In Europe, “caviar + champagne” symbolizes the good life; China has created “caviar + Moutai” as a new symbol of the good life. [For the Chinese people, caviar represents not luxury, but an elegant, comfortable, and relaxed lifestyle.]. (6) ESG practices carried out by leading caviar enterprises like Kaluga Queen: stock enhancement of Amur sturgeon in Heilongjiang, processing farmed fish waste into organic fertilizer for pomelo orchards, promoting employment for rural revitalization, *etc.*

Keywords: Caviar; Eastern practices

Effects of the Mismatch between Water Temperature of the Yangtze River and Specific Requirements of Chinese Sturgeon

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ABSTRACT: Natural reproduction events of Chinese sturgeon, Acipenser sinensis failed in 2013 and 2015, and no successful natural spawning has been recorded since 2017. Key factors contributing to reproduction impairment of Chinese sturgeon include declined population size, limited spawning ground and mismatched spawning conditions, among which suitable water temperature is critical for specific requirement during gonad development and spawning. However, the immense regulatory capacity of large-scale water conservancy projects has drastically altered the thermal rhythm of the Yangtze River. To investigate the thermal drivers behind reproduction failure, this study analyzed water temperature trends and antecedent characteristics before spawning from 1981 to 2023, testing the hypothesis that long-term water temperature changes have exceeded the adaptive capacity of Chinese sturgeon. This study innovatively developed the Binseg-RBF method and identified the years with the most significant changes in spawning water temperature includes 2006 and 1998. Building on this, this study compiled historical data on spawning dates and overwintering gonad development water temperatures to estimate the suitable temperature range. Since 1998, temperatures in mid-October, the original spawning period, have risen above the previous maximum average. Furthermore, after 2006, suitable low temperatures have failed to occur even by early November. Corresponding to these temperature shifts, spawning date shifted around 2006 from mid October to late November. In 2017, for the first time, water temperature fluctuations during the maturation phase revealed significant reduction in dynamics. Years with significant spawning delays were consistently associated with fluctuations in gonadal development and water temperatures at spawning time. This synchronicity strongly indicates a close correlation between spawning delays and changes in river temperature. To examine the consistency of spawning temperature preferences and significant differences in spawning dates across periods (before 1997, 1998–2005 and after 2006), spawning date-water temperature samples were divided into three groups and compared via a two-sided Mann-Whitney U test. The results showed no significant difference in spawning temperatures among the spawning groups, suggesting a stable preference for spawning at around 18.5 °C. Additionally, the median spawning date for each group closely aligned with the date when water temperatures cooled to the temperature preferred for reproduction. This coupling indicates that reaching this threshold temperature is likely a necessary condition for spawning initiation. To further investigate, we analyzed pre-spawning water temperatures and established a non-spawning sample set for comparison. This analysis found no statistical differences in the range or standard deviation of pre-spawning temperatures among the spawning groups across different periods. However, these parameters differed significantly from the non-spawning group, suggesting spawning may require certain fluctuations and declines in pre-spawning temperatures. Following, an RBF neural network model was applied to analyze water temperature fluctuation. Results indicated a marked reduction in temperature fluctuations around 2016. Key variability metrics—including standard deviation, amplitude, frequency, and daily fluctuation rate—decreased by 40.5%, 19.7%, 59.7%, and 56.7%, respectively. This decline in hydrological dynamics may have exacerbated the mismatch between background conditions and specific requirements for reproduction of Chinese Sturgeon.

Keywords: Chinese sturgeon; Water temperature; Natural reproduction; Spawning delay; Hydrological rhythm; Human impact

Precision Nutrition in Sturgeon Aquaculture: Unlocking Growth, Health, and Caviar Quality

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ABSTRACT: Precision nutrition in sturgeon farming tailors feed to optimize metabolic pathways and gut microbiota, enhancing growth and caviar quality. By activating pathways like PPAR (master gene of fat metabolism), it improves energy efficiency, sparing protein for immune function and growth. Simultaneously, the mTOR pathway (master gene of protein metabolism) is targeted to maximize protein synthesis. The gut microbiome acts as a vital organ, producing bioactive metabolites that boost health. This strategy dynamically adjusts for environmental factors like temperature, aiming to maximize the fish's genetic potential for efficient, high-yield production. The physical and durability parameters of pellets are critical for feeding behavior and nutrient intake, as fish preferences are not defined by human perceptions of taste or smell. Precision nutrition optimizes fish feed by aligning nutrient delivery with the fish's genetics, fish acceptance, and environment, maximizing growth efficiency (FCR) while minimizing waste output. This approach tailors diets to unlock genetic potential under specific farming conditions.

Keywords: Precision nutrition; Sturgeon; Lipid metabolism; Protein metabolism; Microbiota; Pellet quality

Evaluation of the Migratory Characteristics and Effects of the Released Chinese Sturgeons Based on Ultrasonic Remote Sensing and Capture Monitoring

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ABSTRACT: Chinese sturgeon (*Acipenser sinensis*) has been listed among the first-class protected animals in China, and a flagship species in the aquatic ecosystem of the Yangtze River. Due to hydraulic engineering construction, shipping, overfishing and environmental pollution, the population in wild is exhausted. Artificial propagation and releasing are the main strategies for the restoration of Chinese sturgeon resources. However, it was until 2024 that the large-scale release had been initiated, and the cumulative released number exceeded one million for the first time throughout the year. To comprehensively evaluate the effect of releasing, such as the adaptability of the released individuals and calculate the population of arrival in the estuary, net recapture and ultrasonic tagging monitoring have been adopted to track the Chinese sturgeon released in 2025. As a result, more than 80% of the recaptured juvenile Chinese sturgeon showed good adaptive capacity to the wild environment based on the biological information. Among the population marked with ultrasonic tags, 80.6% of the individuals have been monitored along Yangtze River main stream, in which 57.9% reached the estuary, indicating the maintaining of migratory instincts of the artificially-bred Chinese sturgeons.

Keywords: Chinese sturgeon; Ultrasonic detection; Restocking; Net recapture

Development and Application of Genetic Markers of Chinese Sturgeon (*Acipenser sinensis*)

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ABSTRACT: The Chinese sturgeon is classified as a first-class protected wild species in China. Since the 1980s, concerted efforts have been undertaken to conserve its genetic resources through artificial breeding programs. The current population includes the first filial generation, the second filial generation, and the wild population. However, due to suboptimal initial breeding conditions and incomplete breeding records, the genetic background of the existing Chinese sturgeon population remains ambiguous, and its genetic structure is not well understood. Consequently, breeding pairings might involve individuals with closely related genetic backgrounds, leading to progeny with suboptimal developmental performance. This situation has adversely affected the sustainable population management and conservation of the Chinese sturgeon. This study employs whole-genome SNP markers to conduct the inaugural population genetic analysis of a large-scale Chinese sturgeon population, comparing the genetic structures and diversity across different populations, thereby elucidating the current status of the genetic resources within the extant population. The findings indicated that, based on the Chinese sturgeon population samples analyzed, the genetic diversity of both the wild and first-generation populations was relatively high. In contrast, the second-generation population exhibited the lowest genetic diversity and effective population size. These results underscore the necessity of prioritizing the maintenance of genetic diversity during the artificial breeding of Chinese sturgeon. Furthermore, multiple genetic markers, including whole-genome SNPs, mitochondrial DNA, and microsatellites, were employed to conduct family analyses of populations with ambiguous genetic backgrounds. This approach corrected and supplemented existing population family information, thereby providing crucial data to inform breeding pair strategies in future artificial breeding endeavors for the Chinese sturgeon.

Keywords: Chinese sturgeon; SNPs; Population management

Mid-Term Evaluation of the Implementation of the Pan European Action Plan for Sturgeons

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ABSTRACT: Sturgeon populations in European rivers and coastal waters have undergone a dramatic decline over the last 150 years. In addition to overharvest, the intensive development of hydropower and river channelization have led to massive habitat loss and fragmentation affecting all stages of their life-cycle. As a consequence, all eight sturgeon species found in European waters are threatened with extinction (International Union for Conservation of Nature—IUCN 2022) and are reported as being in "unfavourable" conservation status under the European Union (EU) Habitats Directive. To improve this situation, the Pan-European Action Plan for sturgeons (PANEUAP) was adopted under the Bern Convention in 2018 and endorsed for implementation under the Habitats Directive, thus providing a guiding framework of actions to be implemented in sturgeon range countries by regional stakeholders including regional sea and river commissions. The Action Plan requests all signatory countries to "restore all existing sturgeon populations to "least concern" (IUCN) or "favourable" (Habitats Directive) status and re-establish self-sustaining sturgeon populations as well as their life-cycle habitat in their historic range to an extent that ensures species survival and representation of the subpopulations where possible". To assess the progress made in the range countries, a survey was conducted in the frame of an EC contract comprising 85 questions. Potential respondents from authorities responsible for biodiversity and water management, as well as one national sturgeon expert were included in 18 countries throughout the range. In some countries fisheries agencies were also contacted. Overall, a minimum of three responses per country were received. These responses were reviewed and rated with a traffic light system for each country and present the deliverable "information sheets". The results were analysed in reports for five river and sea basins in Europe (North-East Atlantic, Baltic, Mediterranean, Upper-Middle Danube and Lower Danube/Black Sea) including single country information as well as a comparison of all countries of one region. The reports also include maps of each river basin depicting potential and confirmed sturgeon habitats.

Keywords: Bern convention; Action plan; Evaluation; Implementation

Migratory Movement Patterns of Chinese Sturgeon in the Lower and Middle Reaches of the Yangtze River

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ABSTRACT: Given the alarming decline in the wild population of Chinese sturgeon (*Acipenser sinensis*), as evidenced by the absence of natural reproduction in recent years, artificial propagation and stock enhancement have become critical strategies for the conservation of this species. The release of second filial generation Chinese sturgeons has emerged as a primary method for maintaining their numbers. Ultrasonic telemetry tracking was conducted from Yichang to Jiangyin between 2015 and 2021, involving a total of 318 Chinese sturgeons. The results indicated that the monitoring station passing percentage (MSPP) gradually declined as the migration distance increased. The average MSPP in Jiangyin was 52.54%, reaching a peak of 73.3% in 2019. The released sturgeons could quickly adapted to the natural environment of the Yangtze River, commencing their migration within 0.9–2.1 hours after release and arriving at the Jiangyin section as early as 11.3 days. The average migration speed was 77.47 (±5.84) km/day. These results provide crucial scientific evidence for evaluating release effectiveness and enhancing life cycle data documentation of Chinese sturgeons in the Yangtze River.

Keywords: Chinese sturgeon; Ultrasonic telemetry tracking; Migration; Artificial release

Habitat Selection Strategies and Spawning Habitat Suitability of Chinese Sturgeon in a Semi-Natural Controlled River Environment

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ABSTRACT: The Chinese sturgeon (*Acipenser sinensis*), a critically endangered flagship species of the Yangtze River, faces severe reproductive failure due to habitat fragmentation and dam-induced flow regulation. This study investigates the spawning habitat selection strategies and suitability of Chinese sturgeon under semi-natural controlled conditions. In a side channel at Yanziba (Yichang, China), captive-bred broodstock were released into a flow-regulated reach designed to mimic natural hydrodynamic and substrate features. A multi-sensor acoustic monitoring system—including DIDSON imaging sonar, M1200d acoustic camera, Simrad EY60 echosounder, and a Vemco Positioning System (VPS)—was deployed to record three-dimensional movement trajectories and spawning behavior. Simultaneously, hydrodynamic simulations and field measurements characterized flow velocity, depth, temperature, and substrate distribution. Preliminary results indicate that the sturgeon exhibit a clear preference for 3–5 m deep gravel-bed areas with moderate flow (0.6–1.0 m/s) during the spawning period. Behavioral data and habitat models suggest that flow regulation can significantly influence microhabitat suitability and spawning success. The study provides an experimental framework linking fish behavior, hydraulic environment, and reproductive outcomes. Findings will support ecological flow design and habitat restoration strategies for Chinese sturgeon recovery in the Yangtze River.

Keywords: Chinese sturgeon; Spawning behavior; Hydrodynamic modeling; Habitat suitability; Yangtze River conservation

Determination of the Maximum Allowable Concentration of Selenium and Iron Nanoparticles in the Diet of the Nereis Worm, a Live Feed for Sturgeon

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ABSTRACT: This study aimed to determine the toxicity and maximum allowable levels of selenium (Se-NPs) and iron (Fe-NPs) nanoparticles for the Nereis worm (*Hediste diversicolor*). This worm is a critical live feed source in sturgeon aquaculture, directly influencing the health and growth of larvae and juveniles. Determining safe dietary levels of nanoparticles in this organism is therefore essential for ensuring the safety of the entire sturgeon feed chain. Worms were exposed to six concentrations (0, 100 µg/kg, 1, 10, 100 mg/kg, and 1 g/kg diet) of each nanoparticle for 96 h. Throughout the experiment, aeration was provided, and worm behavior was monitored. Cumulative mortality was recorded at 24, 48, 72, and 96-hour intervals. Data were recorded in Microsoft Office Excel 2019, and statistical analysis was performed using SPSS software (Version 20). Data were analyzed by Probit analysis with a 95% confidence level. The LC_{10}, LC_{50}, and LC_{90} values of Se-NPs were calculated as 291.2 mg/kg, 989.8 mg/kg, and 1.69 g/kg, respectively. For Fe-NPs, these values were 924.3 mg/kg, 3.3 g/kg, and 5.7 g/kg, respectively. This study establishes critical toxicity thresholds for Se-NPs and Fe-NPs in Nereis worms. The findings provide essential data for developing safe feeding protocols in sturgeon aquaculture, helping to prevent potential nanoparticle toxicity transfer through contaminated live feed and ensuring sustainable sturgeon production.

Keywords: Sturgeon; Live feed; *Hediste diversicolor*; Nanoparticles; Selenium; Iron

Effect of Different Flow Rates on Serum and Muscle Quality of Sturgeon Larvae

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ABSTRACT: To evaluate the effects of water flow velocity on growth performance, muscle composition and blood biochemical parameters of juvenile hybrid sturgeon, thereby providing a reference for sturgeon seed production in Guizhou. Juvenile hybrid sturgeon (*Acipenser baerii* ♀ × *A. schrenckii* ♂; initial weight 10.82 ± 0.56 g, *n*= 360) were randomly allocated to four flow treatments (1 BL/s, 2 BL/s, 3 BL/s, and 4 BL/s) and reared for 40 days. Growth indices, muscle nutritional composition and serum biochemical parameters were determined at the end of the trial. Weight gain rate followed a parabolic trend with increasing flow velocity, peaking at 3 BL/s ($p < 0.05$). quadratic regression indicated an optimal velocity of 2.61 BL/s. Muscle crude fat(CF), total amino acids(TAA), essential amino acids(EAA), flavor amino acids(FAA), and total fatty acids(TFA) were maximized in the 2 BL/s and 3 BL/s groups, with significant enrichment of unsaturated fatty acids including DHA and ARA ($p < 0.05$). Serum γ-glutamyl transferase (GGT), creatine kinase (CK), and blood urea nitrogen (BUN) showed significant changes, with GGT and CK reaching their highest levels at 3 BL/s. Moderate flow velocities (2–3 BL/s) significantly enhanced growth, improved muscle nutritional quality, and promoted physiological health of juvenile hybrid sturgeon.

Keywords: Flow rates; Juvenile sturgeon; Growth properties; Muscle nutritional composition; Blood biochemical indices

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