Food and Agriculture Organization of the United Nations

EUROPEAN INLAND FISHERIES AND AQUACULTURE ADVISORY COMMISSION

EIFAAC/OP55 (En)

EIFAAC OCCASIONAL PAPER

ISSN 2221-6650

EUROPEAN INLAND FISHERIES AND AQUACULTURE ADVISORY COMMISSION

Proceedings of the

EIFAAC SYMPOSIUM ON BUILDING A SUSTAINABLE FUTURE FOR INLAND FISHERIES AND AQUACULTURE IN A TIME OF MULTIPLE STRESSORS

Pula, Croatia, 7–9 October 2024

REPUBLIC OF CROATIA
Ministry of Agriculture, Forestry and Fisheries

EUROPEAN INLAND FISHERIES AND AQUACULTURE ADVISORY COMMISSION

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Rome, 2025

Required citation:
FAO. 2025. *Proceedings of the EIFAAC Symposium on Building a sustainable future for inland fisheries and aquaculture in a time of multiple stressors – Pula, Croatia, 7–9 October 2024*. EIFAAC Occasional Paper, No. 55. Rome. https://doi.org/10.4060/cd4788en

ISSN 2221-6650 [Print]
ISSN 2958-8480 [Online]

ISBN 978-92-5-139692-6

PREPARATION OF THE DOCUMENT

An international Symposium on “Building a sustainable future for inland fisheries and aquaculture in a time of multiple stressors” was organized in conjunction with the Thirty-second Session of the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) in Pula, Croatia from 7 to 9 October 2024.

This occasional paper contains the conclusions and recommendations of the symposium to the subsequent EIFAAC session and selected abstracts from presentations and posters presented at the symposium.

The Thirty-second Session of the EIFAAC, held in Pula, Croatia, on 9–11 October 2024, endorsed the conclusions and recommendations of the symposium (FAO, 2024a).

The international Symposium was organized by EIFAAC and hosted by the University of Zagreb Faculty of Agriculture and the Ministry of Agriculture, Forestry and Fisheries of the Government of Croatia. This document was prepared by Marina Piria and Ana Gavrilović (University of Zagreb) and Raymon van Anrooy (FAO). The document was formatted by Maria Eugenia Escobar (FAO).

The document has attempted to capture the issues raised by each presenter faithfully. The summaries of the presentations and posters included in Appendices C and D of this paper have been reproduced as submitted with some light editing. The editors apologize for any misrepresentation that may have arisen in their summation. All photographs and figures in Appendices C and D were kindly provided by the authors.

The preparation, coordination, and planning for this Symposium was in the capable hands of Marina Piria and Ana Gavrilović, who also chaired the Organizational and Scientific Committees of the symposium. Their work and the support of their team is greatly acknowledged in making the symposium a success. The list of members of the Organizational and Scientific Committees can be found in Appendix F.

The symposium would not have been possible without the support from a range of public institutions and private sector companies.

EIFAAC also recognizes the assistance provided by Duygu Maktav, Roberth Arthur and James Geehan of FAO’s Fisheries and Aquaculture Division (NFI), Eniko Koti of the FAO Regional Office for Europe and Central Asia (REU), Haydar Fersoy (CACFish Secretary) and the chairpersons to the symposium sessions is also appreciated.

Finally, the EIFAAC secretariat to the symposium would like to acknowledge the important contributions of scientists and other experts from the EIFAAC Member states to the symposium and the work of EIFAAC.

ABSTRACT

The international Symposium on Building a sustainable future for inland fisheries and aquaculture in a time of multiple stressors was organized on 7–9 October 2024 in conjunction with the Thirty-second Session of EIFAAC in Pula, Croatia. The Symposium was by the Government of Croatia and the University of Zagreb Faculty of Agriculture. The symposium was attended by 120 participants from 24 countries. The main documentation comprised 5 invited papers, 50 experience papers and 23 posters.

The symposium had eight major themes, which were: 1) Stock assessment and freshwater fish management; 2) Developments and challenges in freshwater aquaculture; 3) Migratory fishes – problems and conservation; 4) Freshwater invasives networking for strategy (FINS III); 5) Exploring the use of artificial intelligence in inland fisheries and aquaculture; 6) Climate change and impacts on inland waters, fisheries and aquaculture; 7) Innovative management for conservation of freshwater areas and aquatic biodiversity and advances in recreational fisheries research and management; and 8) Citizen science and socioeconomic aspects of freshwater fishery and aquaculture.

Within the symposium various technical workshops were held: 1) on Solving bottlenecks in eel reproduction to support sustainable aquaculture (EELSUPPORT); 2) on Freshwater Invasives Networking for Strategy (FINS III), and 3) on Management advice for reducing the impact of cormorant predation on fish and fisheries. A panel discussion on the future of European freshwater aquaculture was also organized at the symposium.

The symposium provided valuable networking opportunities for the participating scientists. Many research study findings and innovative research methodologies were presented. This Occasional Paper presents the proceedings of the symposium.

The Thirty-second Session of EIFAAC, held in Pula, Croatia, on 9–11 October 2024, endorsed the conclusions and recommendations of the symposium.

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ACKNOWLEDGEMENTS

The symposium organizers gratefully acknowledge the main sponsor, PP Orahovica d.o.o., for its generous support. We also thank our other sponsors: Aquatika – Karlovac Freshwater Aquarium Public Institute, City of Pula, Aquarium Pula, Croatian National Tourist Board, and Select Fishing.

This symposium was further supported by the Croatian Agency for Agriculture and Food (HAPIH), Croatian Chamber of Economy (HGK) and Josip Juraj Strossmayer Institute for Water.

The workshop organized by COST ACTION 22163 "Solving bottlenecks in eel reproduction to support sustainable aquaculture" (EELSUPPORT) was supported by COST (European Cooperation in Science and Technology).

The workshop on management advice for reducing the impact of cormorant predation on fish and fisheries received financial support from the European Maritime, Fisheries and Aquaculture Fund (EMFAF) within its work programme for 2024–2025, under the FAO-European Commission Trust Fund project on ‘Developing Europe-wide management advice to protect vulnerable and endangered fish species from unsustainable predation by cormorants” (GCP/RER/069/EC).

INTRODUCTION

1. The Symposium on Building a sustainable future for inland fisheries and aquaculture in a time of multiple stressors was organized on 7–9 October 2024 in conjunction with the Thirty-second Session of EIFAAC in Pula, Croatia. The symposium was by the Government of Croatia and University of Zagreb Faculty of Agriculture. The symposium was attended by 120 participants from 24 countries. The main documentation comprised 5 invited papers, 50 experience papers and 23 posters.

I. OPENING OF THE MEETING

2. The participants were welcomed by representatives of Croatia and EIFAAC. The dean of the University of Zagreb Faculty of Agriculture, Aleksandar Mešić, commended the scientists for their important work on increasing aquatic ecosystems sustainability and their contributions to aquatic foods production. Ksenija Vukman of the Croatian Chamber of Economy noted that "bird damage is increasing year by year and is questioning the survival of the freshwater aquaculture sector, due to multiple increases in unmanaged predator populations", and that research and predator management are urgently needed. She also mentioned that inland aquaculture in Croatia is suffering from droughts and that investment in the construction of water reservoirs is required to adapt to the changing climate. Drazen Knežević of the Croatian Agency for Agriculture and Food informed the participants of the One-health approach, and that inland fisheries and aquaculture are important contributors to food security and food safety in Croatia. Magdalena Andreea Strachinescu Olteanu, Head of Unit Maritime Innovation, Knowledge and Investment of the European Union's DG Mare spoke about the Mission Oceans and the importance of knowledge, innovation and investment, in which fisheries and aquaculture scientists play a key role.

3. Petri Heinimaa, chairperson of EIFAAC, officially opened the international Symposium and said that "EIFAAC offers scientists the possibility to bring their research to the attention of policy and decision makers throughout Europe and to make an impact. If research projects produced findings that should be disseminated or scientific recommendations should be applied in the whole region, then make use of what EIFAAC can offer".

4. The symposium had eight major topics, which were:

(i) Stock assessment and freshwater fish management (stocking, habitat improvements).
(ii) Migratory fishes – problems and conservation – including a Workshop organized by the European Cooperation in Science and Technology (COST) ACTION 22163 "Solving bottlenecks in eel reproduction to support sustainable aquaculture" (EELSUPPORT).
(iii) Developments and challenges in freshwater aquaculture (technology, environment, economic and circular economy aspects).
(iv) Freshwater invasives networking for strategy (FINS III).
(v) Climate change and impacts on inland waters, fisheries and aquaculture.
(vi) Innovative management for conservation of freshwater areas and aquatic biodiversity and advances in recreational fisheries research and management.
(vii) Citizen science and socioeconomic aspects of freshwater fishery and aquaculture.
(viii) Exploring the use of artificial intelligence in inland fisheries and aquaculture – covered within topic vi.

5. The symposium programme can be found in Appendix A and the list of participants in Appendix B.

6. The abstracts of presentations made at the symposium are provided in Appendix C and a summary of presented posters can be found in Appendix D.

II. SUMMARY OF THE SYMPOSIUM

Session 1: Stock assessment and freshwater fish management (stocking, habitat improvements)

7. This session aimed to address issues associated with stock assessment and freshwater fish management, including enhancement measures such as stocking and habitat improvements. The ses6+sion was composed of six presentations and was chaired by Fiona Kelly (Inland Fisheries Ireland, Ireland) and Kurt Pinter (Boku University, Austria).

Summary overview:

8. The session reiterated the need for objectives and indicators and precautionary measures for successful stocking programmes as well as the need to consider alternative management measures. Additional considerations for stocking programmes included addressing technical requirements, risk assessments, establishing decision frameworks and implementation and monitoring and evaluation arrangements. The session also contributed to the growing body of empirical research by demonstrating national level experiences with stocking programmes and stock assessment approaches and methods in EIFAAC Member countries, Albania, Austria, Croatia, North Macedonia, Serbia and Sweden.

9. The session discussed how systematic approaches to stock assessments could be developed based on data availability and used to assess the effects of changing fishing pressure on life history parameters. The session also discussed the challenge of addressing wider aspects of environmental management. Predation on fish stocks by increasing cormorant populations and issues of pollution and habitat degradation were identified as important conservation issues. The session also considered how habitat assessments could be used to identify critical overwintering habitats such as deep pools. The session identified a need for mechanisms to bring water and fisheries stakeholders together.

Session 2: Migratory fishes – problems and conservation

10. The first part of this topic was covered by a workshop organized by European Cooperation in Science and Technology (COST) ACTION 22163 "Solving bottlenecks in eel reproduction to support sustainable aquaculture" (EELSUPPORT).The plenary lecture by Sylvie Dufour (National Center of Scientific Research/ National Museum of Natural History, France) that preceded this session, highlighted the key knowledge and gaps on the eel life cycle, the multiple anthropogenic threats that make eels critically endangered species, the current bottlenecks and research perspectives for closing the European eel life cycle in captivity, and introduced the COST ACTION EELSUPPORT.

11. The goal of this session was to address gaps in the understanding of specific habitat requirements, breeding behaviours, and life cycle stages of migratory species, and the extent to which these conditions can be replicated in captivity. Secondly, to present the latest knowledge on effective management practices and technologies that support the unique needs of migratory fish.

12. The session was divided into two parts, focusing first on solving bottlenecks in eel conservation, broodstock management and reproduction to support sustainable aquaculture as part of the COST ACTION EELSUPPORT, which was launched in 2023. This part of the session was composed of seven presentations and was chaired by Marina Morini (Polytechnic University of Valencia, Spain) and Sylvie Dufour (National Museum of Natural History, France).

13. The second part of the session continued with an exploration of factors affecting migratory fish with a view to sharing knowledge and expertise on physical factors affecting fish migration and methods to assess and mitigate them. The session was composed of four presentations and was chaired by Cathal Gallager (Inland Fisheries Ireland).

Summary overview:

14. Migratory fishes face numerous challenges, including habitat destruction and fragmentation from dams, weirs and other barriers that obstruct their natural migratory routes and hinder access to spawning and feeding grounds. Additionally, pollution, pathogens, overfishing, and climate change exacerbate these problems, further threatening migratory species.

15. The first part of the session discussed the importance of habitat quality, broodstock health, and closing the eel life cycle to ensure sustainable aquaculture as a crucial solution to both conserving European eel stock and as a viable food source, in the context of global changes. The session included an example of impact assessment of eel stocking in the river Gudenaa, Denmark, in the frame of the eel management plan. The importance of assessing broodstock health was highlighted by the development in Croatia of molecular screening for microbiome in eel skin and gill, and by the survey of eel pathogens in the UNESCO heritage site of Ohrid lake in North Macedonia. Türkiye was highlighted as an example of successful experience and best practices in terms of marine aquaculture, and environmentally friendly recirculating aquaculture systems (RAS); an expertise that should be beneficial to current objectives of eel reproduction and sustainable aquaculture. It was also emphasized that to ensure the protection of eels, action needs to be taken in their different stages in life (i.e., glass eel, yellow eel, and silver eel), and habitats. Current research advances were illustrated by a project, coordinated by France, on the identification of thermoreceptors potentially involved in the impact of temperature variations, including climate change, on eel life cycle.
The second part of the session discussed the approaches for assessing barriers and their impacts on fisheries, including through their effects on water quality and sediments, at different scales using examples from Europe and Southeast Asia. Interesting discussions took place around presentations on river fragmentation, vertical and lateral connectivity and temperature and sediment transport effects of barriers, effects of barrier removal. These discussions highlighted the importance of considering the impacts of barriers and barrier removal in the context of climate change and the often important socioeconomic, cultural and biological values of migratory species.

16. Participants agreed that tools and methods to assess the potential and priorities for barrier removal and river habitat restoration will be important for identifying adaptive management strategies.

Session 3: Developments and challenges in freshwater aquaculture (technology, environment, economic and circular economy aspects)

17. Although freshwater aquaculture benefits from technological advancements and opportunities for economic growth and circular economy practices, it faces significant environmental and economic challenges that must be addressed within the framework of sustainable development. In order to realize its full potential, secure affordable and healthy aquatic foods for the future, and respect the socioeconomic and environmental conditions, the sector must innovate and overcome current challenges.

18. This session consisted of ten presentations and was chaired by David Bassett - European Aquaculture Technology and Innovation Platform (EATIP) and Béla Urbányi (Hungarian University of Agricultural Sciences, Institute of Aquaculture and Environmental Safety, Hungary).

Summary overview:

19. The session presentations discussed research outcomes and innovations in freshwater aquaculture, challenges to aquaculture development and how to overcome these, in terms of technological, environmental, economic and circular economy aspects. Topics covered included the importance of capacity building, strengthening competencies, communication between different players in the

aquaculture sector as well as innovation in pond fish production, application of cryopreservation techniques, the potential of low-fish meal to improve production sustainability, and shortening the breeding cycle of common carp using combined farming in RAS and earthen ponds.

20. It was emphasized that the aquaculture industry cannot expand to the levels necessary to meet demand and that legal scrutiny reduces investment in more efficient technologies and management methods.

Session 4: Freshwater invasives networking for strategy (FINS III)

21. This session highlighted research and shared experiences related to approaches to assess threats from non-native species with a focus on fish, other aquatic animals and plant species and potential mitigation measures.

22. This session was composed of four presentations and was chaired by Ivana Vitasović Kosić (University of Zagreb Faculty of Agriculture, Croatia).

23. The session was followed by a workshop (FINS III), which was moderated by Lorenzo Vilizzi (University of Lodz, Poland), Marina Piria and Ivana Vitasović Kosić (University of Zagreb Faculty of Agriculture, Croatia).

Summary overview:

24. The session presentations discussed the presence of non-native species in different aquatic habitats including streams, small artificial ponds and canals. These water bodies represent important biodiversity hotspots, and the presence of non-native species may result from illegal and *ad hoc* introductions. The session presentations described studies to monitor non-native species and highlighted their widespread presence in different aquatic environments within Croatia and examples of potential risks.

25. The session discussed the challenges to eradicate non-native species and the need for awareness raising regarding translocations of plants and animals. The discussions also highlighted the importance of planned stocking programmes and risks of *ad hoc* introductions as well as the potential benefits of guidelines for construction and maintenance of waterways from an environmental perspective.

26. The participants of FINS III workshop highlighted minor improvements in the last 10 years regarding control and management of non-native species (NNS), noting that standardized assessments of NNS are ensured with climate change accounted for. However, many of the threats identified previously (at the FINS I workshop in 2013 and FINS II workshop in 2016) remain unresolved, including insufficient education on NNS, lack of funding for monitoring and eradication, unchanged or overly complex transboundary legislation on NNS, and burdensome administrative protocols for research, eradication and management of NNS. Moreover, new threats have emerged: inadequate training for certified NNS assessors, which may lead to species wrongly identified as high risk; a lack of risk assessments based on biogeographical regions; and local governments' avoidance of managing invasive NNS that are not included on the European Union list.

Session 5: Climate change and impacts on inland waters, fisheries and aquaculture

27. The session presented research, and shared experiences related to the impacts of climate change on fisheries. The session was composed of two presentations and was chaired by Jan Kubečа (Institute of Hydrobiology, Czechia).

Summary overview:

28. The presentations and subsequent discussions considered investigations in response to changes in fish populations and the effects of interactions between environmental change and variability and the

effects of regulation. Presentations described examples from the Oder River in Poland and Lipno reservoir in Czechia. This included the use of parametric and non-parametric modelling approaches respectively to explore the effect of multiple drivers of observed changes in fish growth and mortality.

Session 6: Innovative management for conservation of freshwater areas and aquatic biodiversity and advances in recreational fisheries research and management

29. This session shared knowledge and experiences on the use of different sampling and survey methods and the combining of approaches and methods to support assessment and management of inland fisheries for conservation and fisheries management.

30. The session was composed of eight presentations that covered examples from marine, brackish and freshwater environments and freshwater aquaculture. The session was chaired by Ivan Špelić (University of Zagreb Faculty of Agriculture, Croatia) and Matej Vucić (University of Zagreb Faculty of Science, Croatia).

Summary overview:

31. This informative session considered presentations on methods for monitoring aquatic environments, fish population dynamics and aquaculture performance in the context of environmental and anthropogenic pressures. Approaches and case studies drawing on combinations of river mapping, long-term fisher logbook data, fish and fry catch surveys were presented. Methods from marine environments also included the use of cameras and acoustic sensors, eDNA and plankton classifiers mounted on fixed and mobile platforms to provide temporal and spatial data.

32. Analytical methods discussed included otolith, scale shape and stomach content as well as non-invasive length frequency and eDNA analysis, the latter highlighted as useful for cryptic species. The utility of stakeholder engagement to prioritize and increase the acceptability of management measures was described in connection with large scale river restoration. For aquaculture, an example from Germany highlighted the need for economic assessments of aquaculture performance and for stakeholder engagement related to products.

33. Interesting discussions took place around presentations on pike-perch fry feeding strategies, predation and recruitment, including possible responses to climate change, as well as on the development of models and use of artificial intelligence (AI) for fish identification linked to camera sampling. The discussions also considered the potential for development of models and communications materials to increase understanding of conservation and habitat management options and awareness raising. Further discussions related to extensive carp aquaculture highlighted the potential cultural and environmental benefits related to landscape conservation of traditional extensive aquaculture practices.

34. The session participants agreed on the importance of considering economic and environmental drivers, including connectivity and water quality, that influence fish populations and aquatic environmental dynamics and the importance of including these aspects when assessing management options.

Session 7: Citizen science and socioeconomic aspects of freshwater fishery and aquaculture

35. This session aimed to share experiences related to citizen science approaches used to monitor fisheries and identify potential fisheries and ecosystem-based management options with a focus on stakeholder engagement, methods to support data collection, collaborative analysis, co-design of management interventions and information sharing.

36. The session was composed of three presentations and was chaired by Dr Björn Rogel (Swedish University of Agricultural Sciences, Drottningholm, Sweden).

Summary overview:

37. The session emphasized the knowledge and experience that fisheries stakeholders have and the commitment that they often have in contributing to environmental care and stewardship. This commitment can provide a basis for engagement in citizen science initiatives that can contribute to increased understanding of the status and dynamics of inland fisheries and aquatic environments. This can be particularly important when communities are dependent upon the ecosystem services that these environments provide, including subsistence, cultural and social protection roles. The presentations contributed different experiences with citizen science, including the use of voluntary schemes to collect data on angling catches and fish distributions. Examples from the global south highlighted the opportunities to explicitly consider linkages between environmental and human health and the impact that multiple stressors can have on health and livelihoods. Extending citizen participation to include analysis and reflection on fisheries and environmental trends was illustrated. An improved collective understanding of social and environmental processes and how these are affected by changing conditions can contribute to identifying appropriate management strategies.

38. The session discussed challenges and opportunities related to wider participation and increasing adaptive capacity, including data quality, bias and cultural aspects that might affect participation. The participants also considered opportunities to link participatory science with management interventions to deliver social and environmental benefits.

III. POSTER SESSION

39. In addition to the oral presentations, the poster session at the symposium provided details of studies on assessment and management of inland fisheries and aquaculture, including: (i) data collection and monitoring methods for inland fisheries, (ii) assessment of the risks and impacts of fishing, and biodiversity and aquatic habitat change on freshwater fish stocks, endangered species and food-webs, (iii) the role of management measures, including stocking, in adaptation strategies, and (iv) the potential of dietary supplements in aquaculture.

40. The session comprised 23 posters demonstrating experiences from EIFAAC Member countries Croatia, Finland, Latvia, and Lithuania.

IV. SYMPOSIUM RECOMMENDATIONS

41. The symposium recommended that EIFAAC considers the following:

- The necessity of evaluating economic performance to address the challenges facing freshwater aquaculture and inland fisheries for improved management and policymaking.
- The need for responsible management of stocking in inland water bodies, including stocking programmes and ad-hoc stocking.
- The importance of increasing collaboration between EIFAAC Members in monitoring the impacts of climate change on inland fisheries and aquaculture, and in joint development of solutions for climate change adaptation and mitigation in inland fisheries and aquaculture.
- Habitat assessments can support environmental management and restoration for productive capture fisheries and conservation. Engagement with wider water sector stakeholders is needed to develop more integrated habitat and landscape management plans.

- Further research is needed on the impacts of change in aquatic environments, including barriers and barrier removal and other forms of environmental restoration in aquatic landscapes given the often important socioeconomic, cultural and biological values of these landscapes.
- To establish training for certified assessors of non-native species.
- To consider approaches to Non-Native Species (NNS) risk assessments based on biogeographical regions.

42. The thirty-second session of EIFAAC, held in Pula, Croatia, on 9–11 October 2024, endorsed these recommendations.

V. PANEL DISCUSSION ON THE FUTURE OF EUROPEAN FRESHWATER AQUACULTURE

43. A set of three panel discussions was dedicated to the future of freshwater aquaculture in Europe and identified problems and constraints which freshwater aquaculture has been facing in the last decade, including: lack of water supply, strict environmental regulations and increasing bureaucracy, damage from predators (especially piscivorous birds), climate change, low diversity of products, health and welfare of cultivated aquatic animals, food safety, lack of investment and innovation, and underestimation of the sector.

44. The panel discussions were moderated by Jurica Jug-Dujaković (M.J.D. Consulting, Croatia) and Béla Urbányi (Hungarian University of Agricultural Sciences, Hungary).

45. Panelists in the first part of panel were: Haydar Fersoy (Senior Fishery and Aquaculture Officer and CACFish Secretary, FAO Regional Office for Europe and Central Asia), Magdalena Andreea Strachinescu-Oltenau (Head of Unit Maritime Innovation, Knowledge and Investment DG MARE-European Commission), Ana Gavrilović (Mission Restore Our Ocean and Waters, Board Member), Tatjana Boroša Pecigoš, (Ministry of Agriculture, Forestry and Fisheries, Croatia) and Daržen Knežević (Head of the Centre for Food Safety of the Croatian Agency for Food).

46. Panelists in the second part of panel were: Daniel Żarski (Board member of the European Aquaculture Society), Andrea Fabris (Chairman of the Fish Health & Welfare Commission in the Federation of European Aquaculture Producers), David Basset (General Secretary of the European Aquaculture Technology and Innovation Platform (EATIP), and Christian Philip Unmack (Senior Project Manager, Eurofish International Organization).

47. Panelists in the third part of panel were: Tamás Bardócz (Aquaculture and inland fishery consultant and R&D and innovation expert, director of Ecovision kft.), Niels Thorvald Jepsen (DTU-Aqua, Denmark), Ferenc Lévai Jr. (Hungarian representative in FEAP, Deputy Director of Aranyponty Halászati ZRt), Tomislav Slačanac (representative of PP Orahovica) and Robert Reinhardt (founder, and CEO of Algen).

48. The panel produced a "Declaration on the future of European freshwater aquaculture", which is provided in Appendix E, and was endorsed by the Thirty-second session of EIFAAC, held in Pula, Croatia, on 9–11 October 2024 (FAO, 2024a).

VI. WORKSHOP ON MANAGEMENT ADVICE FOR REDUCING THE IMPACT OF CORMORANT PREDATION ON FISH AND FISHERIES

49. Within the symposium EIFAAC organized a "Workshop on management advice for reducing the impact of cormorant predation on fish and fisheries" in hybrid mode on 8 October 2024. The workshop was attended by 78 participants from 24 countries. The workshop reported on the use of European

Union Birds Directive Article 9 derogations, regulations and management measures to reduce the impact of cormorants on fish populations, fisheries and aquaculture in the EIFAAC member countries. A compilation of management advice for reducing the impact of cormorant predation on fish, fisheries and aquaculture was discussed, as well as the outcomes of recent EIFAAC surveys and some potential regional cormorant management measures.

50. The EIFAAC survey findings showed an increase in cormorant conflicts with recreational fishing and conservation interests, and that many different management measures are applied throughout Europe. Seventy percent of the EIFAAC Members consider that a pan-European management plan for cormorants would be beneficial for inland fisheries and aquaculture. The workshop participants provided valuable contributions to the management planning process, with a focus on research needs and monitoring the impact of regional management measures.

51. Participants also discussed their challenges to reduce cormorant predation on aquaculture ponds, how cormorants negatively impact European Union Water Framework Directive outcomes, and whether cormorants could be placed on Annex II (huntable species) of the European Union Birds Directive. It was agreed that the management plan should be Europe-wide and not limited to the European Union, and that all key stakeholders should be invited to join in the planning and review process of the plan.

52. The report of the workshop was published as EIFAAC Occasional Paper No 56. (FAO, 2024b).

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APPENDIX A

SYMPOSIUM PROGRAMME

Monday 7 October

Plenary lectures Hall 1 (Ulika)

9.30–10.00 **Sylvie Dufour**: The quest for eel reproduction: a millennial history and current challenges.

10.00–10.30 **Jurica Jug Dujaković:** Recirculating aquaculture systems development and perspectives**.**

10.30–11.00 Coffee break.

Time	Hall 1 (Ulika) **Stock assessment and freshwater fish management (stocking, habitat improvements).** **Chairpersons**: Fiona Kelly & Kurt Pinter.
10.30– 11.00	**Coffee break**
11.00	Ian Cowx, Raymon van Anrooy: *Fish Stocking in Inland Waters in Europe and Central Asia: Issues and Solutions*.
11.20	Alfred Sandström, Björn Rogell, Göran Sundblad, Thomas Axenrot, Patrik Bohman, Natalia Kulatska, Martin Ogonowski, Helena Strömberg & Sofia Brockmark: *Challenges and Trends in the Management of Swedish Inland Fisheries*.
11.40	Björn Rogell, Alfred Sandström, Göran Sundblad, Magnus Karlsson, Daniel Bergdahl: *Life-History and Management of Common Bream – An Underutilized Species.*
12.00	Kurt Pinter, Michael Grohmann: *Cormorant Predation in a Grayling Stream in the Austrian Foothills: Insights from Pit-Tagging.*
12.20	Dusica Ilik-Boeva, Violeta Mihajloska: *the Process of the Endemic Lake Ohrid Trout (Salmo Letnica) Artificial Spawning and Breeding for Restocking Purposes – Retrospective.*
12.40	Sara Polojac, Zrinka Mesić, Matija Kresonja, Ivona Žiža, Dominik Mihaljević, Milorad Mrakovčić, Ana Đanić: *Fish Wintering Habitats in the Danube River from Batina to Ilok.*
	Discussion.
13.00– 14.00	**Lunch break**

Plenary lecture Hall 1 (Ulika)

14.00–14.30 **Lorenzo Vilizzi**: the Future of non-Native Species Risk Analysis.

Time	Hall 1 (Ulika) **Developments and challenges in freshwater aquaculture** **Chairpersons**: David Bassett & Béla Urbányi
14.35	David Bassett, László Váradi, Béla Halasi-Kovács: *Research and Innovation Considerations for Freshwater European Aquaculture.*
14.55	Urbányi, Bela and Horváth, Ákos: how *Does R&D serve the Development and Innovation of Pond Fish Production?*
15.15	Ákos Horváth, Zoran Marinović, Ana Gavrilović, Béla Urbányi: *Application of Cryopreservation Techniques to Aquaculture Practice.*
15.35	Urbányi, Bela, Horváth, Á., Halasi-Kovács, B., Tóth, P., Lovászi, P.; Görögh, Z.; Karcza, Zs.; Nagy, K.; Csörgits, G. and Faragó, S.: *the Situation and Status of Great Cormorants (*Phalacrocorax carbo*) in Hungary.*
	Discussion.
16.00–16.20	**Coffee break**
16.20	Balázs Kovács, Réka Enikő Balogh, Julianna Kobolák, Dániel Péter, Zoltán Bokor, Gábor Szilágyi, Béla Urbányi: a*n African Catfish Line Selected for Low-Fish-Meal Feed Could Improve Production Sustainability.*
16.35	Tomislav Slačanac, Jasna Ipša, Ana Gavrilović: *Shortening the Breeding Cycle of Common Carp (*Cyprinus carpio*) using Combined Farming in Ras and Earthen Ponds.*
16.50	Mirna Habuda-Stanić, Ana Gavrilović: A*pplications of Fish and Seafood Processing by-Products in Watertreatment Processes.*
17.05	Ana Gavrilovic, Mirna Habuda Stanić, Jurica Jug-Dujaković: *Restoring our Ocean and Waters using Different Models of Inclusion Aquaculture into Circular Bioeconomy.*
17.20	Paul Mosnier, Robert Wakeford, Adam Mytlewski, Marcin Rakowski, Barbara Urban Malinga, Aleksander Drgas, Katarzyna Nadolna–Ałtyn, Tomasz Kulikowski, Sander van den Burg, Marnix Poelman, Josien Hendricksen, Tamas Bardocz, George Triantaphyllidis, John (Ioannis) A. Theodorou, Dimitrios Moutopoulos, Leire Arantzamendi, Jesús Belzunce, Neil Ruane, Ayesha Power: *Environmental Benefits of Aquaculture and Challenges and Opportunities in Promoting those Benefits.*
	Discussion
18.00–18.30	Poster session

Monday 7 October parallel session (Hall 2 - Bianca Istriana)

Time	Hall 2 (Bianca Istriana) **Migratory fishes** **Workshop organized by COST ACTION 22163 "Solving bottlenecks in eel reproduction to support sustainable aquaculture" (EELSUPPORT), supported by COST (European Cooperation in Science and Technology). Presentations open to all.** **Chairpersons:** Marina Morini & Sylvie Dufour.
10.30– 11.00	**Coffee break**
11.15	Marina Morini, Christina A. Bergqvist, Juan F. Asturiano, Dan Larhammar, Sylvie Dufour: *Looking for Transient Receptor Potential Receptors in the European eel: An Evolutionary Approach.*
11.30	Ana, Gavrilović, Oliver Barić, Tena Radočaj, Ákos Horváth, Tamás Müller, Kinga Katalin Lefler, Réka Enikő Balogh, Irena Vardić, Nevena Kitanović, Damir Kapetanović, Jurica Jug-Dujaković: *Screening of eel Population for Broodstock Selection.*
11.45	Michael I. Pedersen, Gorm Rasmussen, Niels Jepsen: *Impact Assessment of eel Stocking Upstream Vestbirk Hydropower Station, Gudenaa, Denmark.*
12.00	Milán Farkas, Balázs Kovács, Irena Vardić Smrzlić, Damir Kapetanović, Tena Radočaj, Oliver Barić, Jurica Jug Dujaković, Ana Gavrilović: *Preliminary Analyses of eel Skin and Gill Microbiome from the Neretva Delta, Croatia.*
12.15	Dijana Blazhekovikj - Dimovska, Stojmir Stojanovski: *Status of eel Population in Ohrid Lake.*
12.30	Devrim Memiş, Gökhan Tunçelli, Süleyman Öztürk: *Aquaculture Opportunities for the Conservation of European eels in Turkey: Challenges and Potential Solutions.*
12.45	Jurica Jug-Dujaković, Ana Gavrilović: *the Importance of System Design on the Early Larval Rearing of eel.*
	Discussion
13.00–14.00	**Lunch break**

Monday 7 October parallel session (Hall 2 - Bianca Istriana)

Time	Hall 2 (Bianca Istriana) **Continued: Migratory fishes – problems and conservation.** **Chairperson**: Cathal Gallager
14.35	Eevi Kokkonen, Alisa Koski, Jukka Syrjänen, Anssi Vainikka: *Management Model for Freshwater Stock of Brown Trout* (*Salmo trutta*).
14.55	Ian Cowx, An Vu, Zeb Hogan, Quan Lai, Catherine Sayer: *Understanding the Threats to Fish Migration: Applying the Global Swim Ways Concept to the Lower Mekong.*
15.15	Róisín Donovan, Brian Coghlan, Sarah Keane, Ciara O'Leary: *Invisible Actors: Thermal Responses to Low Head Impounding Structures.*
15.35	Wouter van der Bund, Piotr Parasiewicz, K. Belka: Free flowing river methodology.
	Discussion
16.00–16.20	**Coffee break**
Time	**Freshwater Invasives Networking for Strategy (FINS III).** **Chairperson**: Ivana Vitasović Kosić.
16.20	Vojislav Sokolović, Ana Marić, Tamara Kanjuh, Vera Nikolić, Dubravka Škraba Jurlina, Predrag Simonović: *First Records of Genetic Variability of Rainbow Trout* Oncorhynchus mykiss (*Walbaum* 1792) i*n Serbia Obtained using Mitochondrial DNA.*
16.40	Marina Piria, Ivan Špelić, Ana Štih Koren, Ana Gavrilović, Tena Radočaj, Dragica Šalamon: *Potential Threats to Native Turtle Communities from Non-Native Fish Species in Isolated Ponds And Canals.*
17.00	Kristina Ašenbrener, Marija Kovačević, Ivica Samarđić, Ivana Vitasović Kosić: *Invasive Freshwater Macrophyte* Ludwigia peploides *Impact on Ecosystems - Case Study of the River Ilova (Croatia).*
17.20	Ivan Špelić, Marina Piria *Mimicking Nature in Artificial Canals: A Key to Restoring Lowland Native Fish Communities and at-Risk Native Species.*
17.40–18.00	FINS III Workshop discussion Moderators: Lorenzo Vilizzi, Marina Piria and Ivana Vitasović Kosić -Development models of prioritizing species (inland waters, aquaculture) -Early warning systems -Prevention, management and eradication -Public awareness, literacy and engagement -Pressure on species on the Red List threatened by IAS

19.00–21.00 Pula walking tour – optional (meeting in the main hall of Hotel Histria)

Tuesday 8 October

8.00 a.m.-onwards Registration

Plenary lectures Hall 1 (ULIKA)

9.00–9.30 **Daniel Žarski**: Building resilience in percid fish aquaculture: failures and successes

9.30–10.00 **Catarina Silva:** Innovations and challenges in advancing AI for fish size estimation from images.

Time	**Hall 1 (Ulika)** **Climate change and impacts on inland waters, fisheries and aquaculture.** **Chairperson**: Jan Kubečka.
10.05	Piotr Parasiewicz, K. Suska, Subham Wagh, Jacek Szlakowski, Agnieszka Napiórkowska-Krzebietke, Andrzej Kapusta: *Hydromorphological Catalyst of Climate Change Impact - the Role of Oder River Regulation in the Ecological Disaster Of* 2022.
10.25	Brabec, M.; Bydžovský, J.; Soukalova, K.; Tesfaye, M. G.; Kubecka, J.: *Pikeperch* (Sander lucioperca) *Annual Increment Reconstruction and Modeling Systematic Environmental Effects.*
	Discussion
10.40–11.00	**Coffee break**
	Innovative management for conservation of freshwater areas and aquatic biodiversity &Advances in recreational fisheries research and management. **Chairpersons:** Ivan Špelić & Matej Vucić
11.00	Jan Kubečka, Million Tesfayea, David Boukala, Tomáš Jůzaa, Lukáš Vejříka, *et. al.*, Allan T. Souza: *Reservoir Fisheries in the Changing World: Will the Anglers Paradise Come Back?*
11.20	Amanda Vasule, Kaspars Abersons, Jolanta Jēkabsone, Jānis Šīre, Linda Fībiga: f*rom Survey to Action* - Lessons Learnt from *Large-Scale Planning and Implementation of Fish Habitat Improvements in Rivers.*
11.40	Matej Vucić, Thomas Baudry, Maks Deranja, Karmela Adžić, *et al.*, Frédéric Grandjean: *Implementing a double Approach for Enhanced Conservation Efforts: Example of Single-Target and Metabarcoding Environmental DNA for Fish Assessment in Southern Croatia and Bosnia & Herzegovina.*
12.00	Matko Dražić, Jakov Radečić, Ivan Špelić, Marina Piria *Impact of a Dam on Reproductive Traits of Chub* (Squalius cephalus).
12.20	Jakov Radečić, Matko Dražić, Ivan Špelić, Marina Piria t*wo Populations of Chub (*Squalius cephalus*) separated by A Dam Exhibit Differences in Otolith and Scale Shape.*

12.40	Marco Francescangeli, Damianos Chatzievangelou, Gerard Llorach-Tó, Antonio Castellicchio, *et al*., Nathan J. Robinson, Jacopo Aguzzi: t*he Obsea Demo-Site Within the Digi4eco Project.*
	Discussion
13.00– 14.30	**Lunch break**
	Continued: Innovative management &Advances in recreational fisheries **Chairpersons**: Ivan Špelić & Matej Vucić
14.30	Reinhold Hanel: *Challenges and Innovations in German Freshwater Aquaculture.*
14.50	Radka Symonová, Million Tesfaye, David Boukal, Tomáš Jůza, *et al*., Jan Kubečka: t*he Onset of a Predator: Ecological and Molecular Mechanisms for the Formation of Successful Pikeperch Year Class.*
Time	**Tuesday 8 October (Hall 1 - Ulika)** **Citizen science and socioeconomic aspects of freshwater fishery and aquaculture.** **CHAIRPERSON**: Göran Sundblad.
15.15	Göran Sundblad: *Development and Status of a Citizen Science Angler App – the Swedish Case.*
15.35	Kiran Thomas, Lukáš Kalous, Marek Brabec, Petr Velenský, Milan Gottwald, Daniel Bartoň, Sandip Tapkir, Yevdokiia Stepanyshyna, Zuzana Šmejkalová, Marek Šmejkal: *A Citizen Science Endeavour: Changing the Plight of a Critically Endangered Native Freshwater Fish, the Crucian Carp in Czechia.*
15.55	Robert Arthur: *Insights from Participatory and Collaborative Research in Africa and Asia: Opportunities for Strengthening the Assessment and Management of Inland Capture Fisheries.*
	Discussion
16.10–16.30	**Coffee break**
16.30–18.00	Poster session
18.00	Closure of the symposium

Tuesday 8 October parallel session (Hall 2 - Bianca Istriana)

Hall 2 (Bianca Istriana) **Workshop on management advice for reducing the impact of cormorant predation on fish and fisheries.** **Chairpersons:** Raymon van Anrooy, Ian Cowx & Niels Jepsen.
9.00–9.15 Opening of the Workshop – Welcome words on behalf of EIFAAC. Introduction of participants. Adoption of the agenda.
9.15–9.20 Background and objectives of the workshop (Dr Raymon van Anrooy, FAO).
9.20–10.00 Draft summary report on the use of Article 9 derogations (Birds Directive), regulations and management measures to reduce the impact of cormorants on fish population, fisheries and aquaculture that are in place in the EIFAAC member countries (Dr Niels Jepsen, Danish Technical University) – including also the outcomes of the 2024 EIFAAC Cormorants survey.
10.00–10.30 Discussion on the report findings.
10.30–10.45 Coffee break + group picture
11.45–11.30 Draft compilation of management advice for reducing the impact of cormorant predation on fish, fisheries and aquaculture (Dr Ian Cowx, Angling Trust/ University of Hull) – including an initial assessment of potential regional management measures.
11.30–12.15 Discussion on the draft assessment of potential regional management measures.
12.15–12.45 Discussion on the process to remove the Great cormorant (*Phalacrocorax carbo*) from protected species lists.
12.45–13.00 Next steps discussion.
13.00 Workshop closure.
13.00–14.30 Lunch break

Tuesday 8 October parallel session (Hall 2 - Bianca Istriana)

PANEL DISCUSSION: Future of European Freshwater Aquaculture. **Moderators**: Jurica Jug-Dujaković & Béla Urbányi.
14:30–15:15 PANEL DISCUSSION (Part 1) **Haydar Fersoy**, Senior Fishery and Aquaculture Officer and CACFish Secretary, /FAO Regional Office for Europe and Central Asia. **Magdalena Andreea Strachinescu-Olteanu**, Head of Unit Maritime Innovation, Knowledge and Investment DG MARE- European Commission. **Ana Gavrilović**, Mission Restore Our Ocean and Waters Board Member. **Tatjana Boroša Pecigoš**, Ministry of Agriculture, Forestry and Fisheries, Croatia. **Dražen Knežević**, Head of the Centre for Food Safety of the Croatian for Agriculture and Food.
15:15–16:00 PANEL DISCUSSION (Part 2). **Daniel Żarski**, Board member of EAS (European Aquaculture Society). **Andrea Fabris**, Chairman of the Fish Health & Welfare Commission in FEAP. **David Basset**, general Secretary of EATIP (European Aquaculture Technology and Innovation Platform). **Christian Philip Unmack**, Senior Project Manager, Eurofish International Organization.
16.00–16.30 Coffee break
16.30–18.00 PANEL DISCUSSION (Part 3). **Tamás Bardócz**, Aquaculture and inland fishery consultant and R&D and innovation expert, director of Ecovision kft. **Niels Thorvald Jepsen**, DTU-Aqua, Section for Freshwater Fisheries Ecology. **Ferenc Lévai Jr**., Hungarian representative in FEAP, Deputy Director of Aranyponty Halászati ZRt. **Tomislav Slačanac**, representative of PP Orahovica. **Robert Reinhardt**, founder, and CEO of Algen.

Tuesday 8 October parallel session (Hall 3 - Belica)

Hall 3 (Belica). **Workshop organized by COST ACTION 22163.** **Moderators**: Marina Morini & Sylvie Dufour.
11.30–14.30 Workshop organized by COST ACTION 22163 "Solving bottlenecks in eel reproduction to support sustainable aquaculture" (EELSUPPORT), supported by COST (European Cooperation in Science and Technology). Open to All. Work in groups: defining bottlenecks and possible solutions.
Lunch break
Freshwater Invasives Networking for Strategy (FINS III). **Moderators**: Lorenzo Vilizzi, Marina Piria and Ivana Vitasović Kosić.
14.30–16.00 FINS III Workshop discussion – continued.
16.00–16.30 Coffee break
16.30–18.00 FINS III Synthesis session. 18.00 Workshop closure.

LIST OF POSTERS

Nico Alioravainen, Cornelya Klütsch, Tuomas Leinonen, Hallvard Jensen, Snorre Hagen: DEVELOPING A GENETIC MONITORING PROGRAM FOR TRANSBOUNDARY FISHERIES MANAGEMENT OF MIGRATORY FISH

Christian Bauer, Günther Gratzl, Martin Fichtenbauer, Elisabeth Peham: IMPACTS OF CLIMATE CHANGE AND CARP POND FARMING IN AUSTRIA

Maja Berden Zrimec, Borut Lazar, Robert Reinhardt: UNLOCKING THE POTENTIAL OF ALGAE: SUSTAINABLE PRODUCTION, CHALLENGES, AND INNOVATIONS FOR FOOD, FEED, AND BIOECONOMY IN THE EU

Žanna Bertaite, Mārcis Ziņģis, Santa Purviņa: IMPROVEMENTS OF PIKEPERCH ARTIFICIAL REPRODUCTION AND REARING METHODS IN LATVIA FOR MORE SUSTAINABLE RESTOCKING AND AQUACULTURE

Dijana Blazhekovikj - Dimovska, Stojmir Stojanovski: THE POTENTIAL OF USING MEDICINAL PLANTS FOR TREATING THE PARASITES IN FISH

Milán Farkas, Balázs kovács*, Irena Vardić Smrzlić, Damir Kapetanović, Tena Radočaj, Oliver Barić, Jurica Jug Dujaković, Ana Gavrilović: PRELIMINARY ANALYSES OF EEL SKIN AND GILL MICROBIOME FROM THE NERETVANERETVA DELTA, CROATIA

Petri Heinimaa, Nico Alioravainen: EXPERIENCES OF MANAGING STOCKING OBLIGATION IN AN ARCTIC LAKE INARI IN FINLAND

Goran Jakšić, Marina Piria, Krešimir Kuri, Margarita Maruškić Kulaš, Nikolina Boić: AN APPLICATION OF THE LINEAR OBSTACLE DENSITY CALCULATION METHOD USING GOOGLE EARTH

Kseniia Kortunova, Eevi Kokkonen, Timo Huttula, Teija Kirkkala, Mikko Kolehmainen: SIMULATION-BASED VENDACE (*Coregonus albula*) BIOMASS ASSESSMENT IN A BOREAL LAKE WITH THE AQUATOX MODEL

Tomislav Kralj, Damir Valić: MONITORING FISH SPECIES IN THE DOBRA RIVER AFTER CONSTRUCTION OF THE LEŠĆE HYDROELECTRIC PLANT

Danilo Mrdak, Dragana Milošević, Vukoica Despotović, Stefan Ralević: POOR MANAGEMENT OF PROTECTED AREA AND ITS FISH POPULATIONS LEADS TO DRAMATIC CHANGES IN THE STRUCTURE OF FISH COMMUNITIES – CIJEVNA RIVER CASE STUDY (MONTENEGRO)

Mikko Olin, Sami Vesala, Kimmo Murto: OMAKALA (MY FISH) - APPLICATION TO RECREATIONAL FISHERY DATA COLLECTION

Matija Pofuk: DISTRIBUTION OF DANUBE SALMON (*Hucho hucho*) IN CROATIA BASED ON ANGLERS' CATCH DATA

Santa Purviņa, Ruta Medne, Olga Revina, Žanna Bertaite: LONG-TERM SALMONID RESTOCKING PRACTICE AND CONTEMPORARY CHALLENGES IN LATVIA

Tena Radočaj, Oliver Barić, Irena Vardić Smrzlić, Damir Kapetanivić, Jurica Jug-Dujaković, Ana Gavrilović: INFESTATION OF EUROPEAN EEL (*Anguilla anguilla*) WITH *Acanthocephalus* sp. IN THE NERETVA DELTA

Olga Revina, Vjačeslavs Revins, Dina Cīrule, Anda Valdovska: EFFECTS OF PROLONGED DIETARY β-GLUCAN AND BGN-2 SUPPLEMENTATION ON TNF-α, IL-6, HSP-70, GROWTH HORMONE, AND GROWTH PERFORMANCE IN SEA TROUT

Vjačeslavs Revins, Olga Revina, Žanna Bertaite, Santa Purviņa, Justīne Padrevica, Kristofers Millers, Rainers Džeriņš: IMPACT OF PROBIOTIC SUPPLEMENTATION ON THE SKIN-MUCUS MICROBIOTA, HEALTH, AND GROWTH PERFORMANCE OF REARED ATLANTIC SALMON

Roberts Strazdins, Edmunds Berzins, Janis Dumpis, Ruta Medne, Armands Erglis, Kaspars Holms: USING FISHERMAN FOR COLLECTING DATA ABOUT NORTHERN PIKE AND ZANDER

Tea Tomljanović, Maria Špoljar, Daniel Matulić: FISH AND INVERTEBRATES INTERACTIONS IN THE SAVA RIVER FOLLOWING EXCESSIVE CHANGE IN HYDROLOGICAL REGIME

Svjetlana Višnić Novaković, Matija Pofuk, Ivana Vukov, Mirta Novak, Tatjana Boroša Pecigoš, Irena Jahutka: PRODUCTION AND TRADE BALANCE TRENDS OF FRESHWATER AQUACULTURE PRODUCTS IN CROATIA 2013–2023

APPENDIX B

LIST OF PARTICIPANTS

ALBANIA

Enton Spaho
Officer
Ministry of Agriculture

AUSTRIA

Christian Bauer
Researcher
Federal Agency for Water Management, Institute for Aquatic Ecology and Fisheries management

Andi Melcher
Researcher
The University of Natural Resources and Life Sciences, BOKU

Kurt Pinter
Researcher
The University of Natural Resources and Life Sciences, BOKU

BELGIUM

David Bassett
Secretary General
European Aquaculture Technology & Innovation Platform, EATIP

Magdalena Andreea Strachinescu-Olteanu
Officer
Head of Unit Maritime Innovation, Knowledge and Investment DG MARE
European Commission

BOSNIA AND HERZEGOVINA

Vildana Tahirovic
Officer
Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina
Veterinary Office

CROATIA

Nikolina Boić
Officer
AQUATIKA – Karlovac Freshwater Aquarium

Tatjana Boroša
Officer
Ministry of Agriculture, Forestry and Fisheries

Marko Ćaleta
Professor
Faculty of Teacher Education

Matko Dražić
Student
Faculty of Agriculture
University of Zagreb

Ana Gavrilovic
Professor
Faculty of Agriculture
University of Zagreb

Mirna Habuda-Stanić
Professor
Faculty of Food Technology Osijek

Goran Jakšić
Researcher
AQUATIKA – Karlovac Freshwater Aquarium

Jurica Jug Dujaković
Consultant
M.J.D. Consulting d.o.o.

Dražen Knežević
Officer
HAPIH,Croatian Agency for Agriculture and Food

Tomislav Kralj
Researcher
Ruder Boskovic Institute

Matija Kresonja
Researcher
Oikon Ltd

Krešimir Kuri
Researcher
AQUATIKA – Karlovac Freshwater Aquarium

Aleksandar Mešić
Dean
Faculty of Agriculture
University of Zagreb

Silvija Cukon
Student
Faculty of Agriculture
University of Zagreb

Katica Petko
Advisor
PP Orahovica

Marina Piria
Professor
Faculty of Agriculture
University of Zagreb

Matija Pofuk
Expert Advisor
Forestry and fisheries
Ministry of Agriculture

Sara Polojac
Student
Karlovac university of Applied Science

Jakov Radečić
Student
Faculty of Agriculture
University of Zagreb

Tena Radočaj
PhD Student
Faculty of Agriculture
University of Zagreb

Tomislav Slačinac
Producer
PP Orahovica

Mario Šiljeg
Officer
Director of Josip Juraj Strossmayer Water Institute

Ivan Špelić
Researcher
Faculty of Agriculture
University of Zagreb

Tea Tomljanović
Professor
Faculty of Agriculture
University of Zagreb

Svejetlana Višnić Novaković
Officer
Forestry and Fisheries
Ministry of Agriculture

Ivana Vitasović Kosić
Associate Professor
Faculty of Agriculture
University of Zagreb

Matej Vucić
Researcher
Faculty of Science
University of Zagreb

Ksenija Vukman
Director
PP Orahovica

Davor Zanella
Professor
Faculty pf Science, Department of Biology
University of Zagreb

Boris Župan
Officer
Ministry of Agriculture, Forestry and Fisheries

CZECHIA

Marek Brabec
Researcher
Department of Statistical Modeling,
Institute of Computer Science,
The Czech Academy of Sciences

Jan Kubečka
Researcher
Department of Statistical Modeling,
Institute of Computer Science,
The Czech Academy of Sciences

Jakub Mořický
Officer
Ministry of Agriculture of the Czech Republic

Tomas Parys
Officer
Ministry of Agriculture of the Czech Republic

Radka Symonová
Researcher
Biology Centre CAS

Kiran Thomas
Researcher
Institute of Hydrobiology, Biology Centre CAS

DENMARK

Niels Jepsen
Senior Researcher
DTU-Aqua

Michael Pedersen
Biologist
Danish Technical University

Christian Philip Unmack
Officer
Eurofish International Organization

FINLAND

Nico Alioravainen
Researcher
Natural Resources Institute Finland (Luke)
Oulu

Petri Heinimaa
Researcher
Natural Resources Institute Finland (Luke)
Jyväskylä

Eevi Kokkonen
Researcher
University of Eastern Finland

Kseniia Kortunova
Researcher
University of Eastern Finland

Sami Vesala
Researcher
Natural Resources Institute Finland, Turku

FRANCE

Erik Bernard
Officer
WWF Adria

Sylvie Dufour
Researcher
National Museum of natural History (MNHN)
National Center for Scientific Research

Anne Oswald
Policy Officer
Directorate General for Maritime Affairs
Fisheries and Aquaculture, DGAMPA

GERMANY

Lars Dettmann
Managing Director
Brandenburg/Berlin State Fishing Association

Reinhold Hanel
senior Researcher
Thünen Institute of Fisheries Ecology

GREECE

Georgia Papaioannou
Policy Officer
Directorate General of Fisheries
Directorate of Aquaculture
Department of Extensive Aquaculture,
Ministry of rural Development & Food

HUNGARY

Tamas Bardocz
Consultant
Self-employed

Andrea Fabris
Research Officer
Federation of European Aquaculture
Producers, FEAP

Bela Halasi-Kovacs
Consultant
Federation of European Aquaculture
Producers, FEAP

Ákos Horváth
Professor
Hungarian University of Agriculture and Life
Sciences

Balázs Kovács
Professor
Hungarian University of Agriculture and Life
Sciences

Ferenc Lévai
Researcher
Hungarian Aquaculture and Fisheries Inter-
Branch Organization MA-HAL

Priya Sharma
Researcher
Hungarian University of Agriculture and Life
Sciences (MATE)

Béla Urbányi
Professor
Hungarian University of Agriculture and Life
Sciences
Institute of Aquaculture and Environmental
Safety

ICELAND

Guðni Magnús Eiríksson
Officer
Ministry of Food, Agriculture and Fisheries

Kristjan Helgason
Officer
Ministry of Food, Agriculture and Fisheries

IRELAND

Róisín Donovan
Research Officer
Inland Fisheries Ireland, IFI

Cathal Gallagher
Research Officer
Inland Fisheries Ireland, IFI

Fiona Kelly
Research Officer
Inland Fisheries Ireland, IFI

LATVIA

Žanna Bertaite
Researcher
Institute of Food Safety, animal Health and
Environment, BIOR

Ruta Medne
Senior Researcher
Institute of Food Safety, Animal Health and
Environment, BIOR

Santa Purvina
Researcher
Institute of Food Safety, Animal Health and Environment, BIOR

Olga Revina
Researcher
Institute of Food Safety, Animal Health and Environment, BIOR

Vjačeslavs Revins
Researcher
Institute of Safety, Animal Health and Environment, BIOR

Roberts Strazdins
Researcher
Institute of Safety, Animal Health and Environment, BIOR

Didzis Ustups
Researcher
Institute of Safety, Animal Health and Environment, BIOR

Amanda Vasule
Researcher
Institute of Safety, Animal Health and Environment, BIOR

LITHUANIA

Loreta Brazinskaite
Researcher
Ministry of Agriculture of the Republic of Lithuania

MONTENEGRO

Danilo Mrdak
Professor
University of Montenegro

NETHERLANDS (KINGDOM OF THE)

Julien Cotte
Officer
Ministry of Agriculture, Fisheries, Food Security and Nature

NORTH MACEDONIA

Dijana Blazhekovikj – Dimovska
Researcher
University St. Kliment Ohridski
Faculty of Biotechnical Sciences

Dushica Ilikj-Boeva
Head of Department of Salmonid Fauna
Applied fishery and Aquaculture, Forestry and Water Economy

Violeta Mihajloska
Officer
ministry of Agriculture, Forestry and Water Economy

POLAND

Kate Kaminska
Chief Expert
Ministry of Agriculture and Rural Development

Piotr Parasiewicz
Head of Department
inland Fisheries Institute

Lorenzo Vilizzi
Researcher
University of Lodz

Igor Wawrzyniak
Chief Specialist
Ministry of Agriculture and Rural Development

Daniel Żarski
Researcher
Institute of Animal Reproduction and Food Research, Polish Academy of Sciences

PORTUGAL

Catarina Silva
Researcher
Centre for Functional Ecology
Science for People & the Planet, CFE
Associate Laboratory TERRA
Department of Life Science, University of Coimbra

REPUBLIC OF MOLDOVA

Serghei Balacci
Policy Officer
Ministry of Environment

ROMANIA

Elena Coman
Researcher
Institute for Research and Development in Aquatic Ecology, Fishing and Aquaculture

SERBIA

Gavrilo Božić
Officer
Multidisciplinary Digital Publishing Institute, MDPI

Mirko Novaković
Officer
Ministry of Agriculture, Forestry and Water Management

Vojislav Sokolović
PhD Student
Faculty of Biology
University of Belgrade

SLOVENIA

Igor Miličić
Secretary General
Fishing Association of Slovenia

Robert Reinhard
Expert Advisor
Algen, Algal Technology Centre

Maja Berden Zimec
Experto Advisor
Algen, Algal Technology Centre

SPAIN

Marco Francescangeli
Researcher
Institut de Ciències del Mar, ICM-CSIC

Marina morini
Researcher
Universitat Politécnica di Valencia

SWEDEN

Dan Blomkvist
Officer
The County Administrative Board of Norrbotten

Sofia Brockmark
Officer
Swedish Agency for Marine and Water Management

Jessica Dolk
Officer
The Swedish Angler Association

Tobias Lind
Officer
Country Administrative Board of Norrbotten

Lars Ljunggren
Officer
The Swedish Anglers Association

Björn Rogell
Researcher
Swedish University of Agricultural Sciences
Department of Aquatic Resources
Institute of Freshwater Research

Alfred Sandström
Researcher
Swedish University of Agricultural Sciences

Göran Sundblad
PhD
Swedish Federal Food Safety and Veterinary Office

SWITZERLAND

Gary Dealay
Research Officer
Swiss Federal Food Safety and Veterinary Office

Oliver Selz
Scientific Advisor
Federal Office of Environment

TURKIYE

Hasan Alper Elekon
Officer
General Directorate of Fisheries and Aquaculture
Ministry of Agriculture and Forestry

Devrim Memis
Researcher
Istanbul University
Faculty of Aquatic Sciences Aquaculture Department

Süleyman Öztürk
Researcher
Mediterranean Fisheries Research Production and Training Institute

UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAN

Ian Cowx
Professor Emeritus
University of Hull

FAO

James Geehan
Fisheries Statistician NFISS
Food and Agriculture Organization FAO

Duygu Maktav
Programme Support/Consultant NFIFO
Food and Agriculture Organization FAO

Raymon van Anrooy
Senior Fishery Officer / Team Leader NFIFO
Food and Agriculture Organization FAO

Haydar Fersoy
Officer
Central Asian and Caucasus Regional Fisheries
and Aquaculture Commission
Food and Agriculture Organization, FAO

Nabil Gangi
deputy Regional Representative, Europe and
central Asia
Food and Agriculture Organization, FAO

APPENDIX C

ABSTRACTS OF PRESENTATIONS

PLENARY LECTURES

THE QUEST FOR EEL REPRODUCTION: A MILLENNIAL HISTORY AND CURRENT CHALLENGES

Sylvie Dufour
National Center for Scientific Research, Paris, France
Arjan Palstra
Wageningen University & Research, the Kingdom of the Netherlands

The question of the mystery of the eel reproduction was raised more than two thousand years ago by the Greek philosopher Aristotle, in the books « History of Animals » and « Generation of Animals ». The European eel, *Anguilla anguilla*, has indeed a complex migratory life cycle with the reproduction in a still undiscovered spawning area in the Sargasso Sea and the juvenile growth in continental waters. Furthermore, the European eel is still sexually immature when it leaves the continent at the silver stage and remains blocked at this prepubertal stage as long as the reproductive migration is prevented, such as in captivity.

First attempts to induce the eel sexual maturation by hormonal treatments were successfully performed by Maurice Fontaine and co-workers at the National Museum of Natural History (MNHN), Paris, in the male (1936), and then in the female (1964). Based on these pioneer advances in the European eel, huge research efforts in Japan were dedicated to the Japanese eel, *A. japonica*, leading to the completion of its life cycle in captivity (2010).

As for other eel species, the population of the European eel has dramatically declined in the last decades, and it is classified as a critically endangered species in the red list of the International Union for Conservation of Nature (IUCN). The collapse of the eel population is emblematic of the multiple impacts of anthropogenic global change, such as overfishing, habitat reduction and degradation, migration impairment, pollutants, and climate change.

Eel aquaculture is largely developed in Asia, and at a much lesser extend in Europe. However, in both cases, aquaculture still depends on catches of wild juvenile glass eels, thus being unsustainable and contributing to the pressure on wild eel populations. This is because on the one hand the control of the Japanese eel life cycle has not reached yet a commercial scale, and on the other hand the life cycle of the European eel has not yet been completed in captivity.

Concerning the control of eel sexual maturation, progress has been made in the characterization of the neuroendocrine systems involved in the blockade and stimulation of the gametogenesis, providing the knowledge base for current or new hormonal treatments. However, large research avenues are still open to decipher the role and interactions of the environmental factors of the oceanic reproductive migration and spawning ground, and how they would be involved in the natural activation of eel sexual maturation and reproduction. These factors, potentially as diverse as swimming activity, salinity, temperature, light, hydrostatic pressure, geomagnetism, and social cues, may lead to innovative ecophysiological methods to induce eel sexual maturation, or at least to facilitate and improve the effects of hormonal treatments.

A European Union COST Action «Solving bottlenecks in eel reproduction to support sustainable aquaculture » (EELSUPPORT) has been launched in 2023. This international consortium aims at sharing the state-of-the-art, identifying and filling knowledge gaps, in order to collaboratively design optimal protocols for broodstock conditioning, for induction of sexual maturation, egg and larvae production, and for rearing larvae to the glass eel stage. EELSUPPORT's ambition is to contribute to closing the European eel lifecycle, in order to support sustainable aquaculture.

Beside aquaculture for consumption, completing the eel life cycle would also provide compulsory knowledge and expertise for potential *ex situ* conservation of the European eel, in the context of the dramatic decline of its population, as currently attempted for other critically endangered migratory European fishes such as the Allis shad or the European sturgeon. Investigating the impact of environmental factors, such as temperature increase or anthropogenic contaminants, on eel broodstock quality and reproduction, will also provide a relevant knowledge base for European eel conservation and management in the context of the impact of global change on watersheds.

Acknowledgement

This research has been supported by the European Cooperation in Science and Technology (COST) Action EELSUPPORT, CA22163.

INNOVATIONS AND CHALLENGES IN ADVANCING AI FOR FISH SIZE ESTIMATION FROM IMAGES

Catarina NS Silva
University of Coimbra, Portugal
Ricardo Cardoso Pereira
Miguel Torga Institute of Higher Education and University of Coimbra, Portugal
Sean Simmons
MyCatch and Angler's Atlas, Prince George, Canada
Asta Audzijonyte
Nature Research Centre, Vilnius, Lithuania and University of Tasmania, Hobart, Australia

Most fish populations lack essential data for stock assessments, leaving their status largely unknown. In particular, fish size data is often missing, which is critical for assessing population health and managing sustainable fisheries. While fisheries and aquaculture have been slower to adopt artificial intelligence (AI) compared to other sectors, innovations are emerging that can help close these data gaps. One such advancement is the use of machine learning (ML) for fish species identification and size estimation from images captured by fishers through smartphone applications, citizen science programmes, and social media. These platforms provide a wealth of data that can be analyzed using ML-based methods to estimate fish sizes from photos of anglers holding fish, even without common reference objects for measurement.

Figure 1: Example of an image from the Angler´s Atlas fishing app

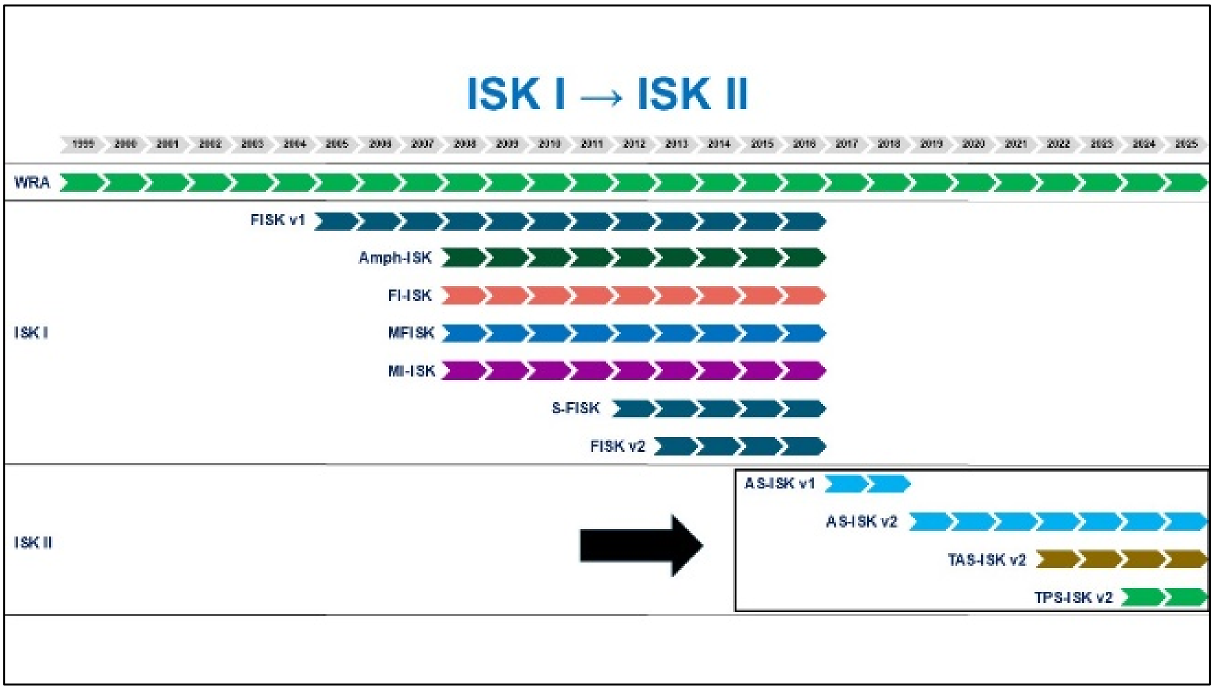
The authors explored how AI is helping to address data gaps in fisheries and demonstrate the potential of citizen science and ML to enhance stock assessments in data-poor fisheries. The authors also presented a case study showcasing the development of a model that estimates fish size from such images, grouping them into size classes similar to those used in underwater visual fish surveys. This approach has demonstrated that photo-based fish size classification is feasible and can contribute to understanding size diversity in data-poor fisheries, including many recreational and artisanal fisheries.

THE FUTURE OF NON-NATIVE SPECIES RISK ANALYSIS

Lorenzo Vilizzi
University of Lodz, Poland and University of Santo Tomas, Manila, Philippines

Biological invasions, driven by the increasing spread of invasive species, constitute a critical international issue due to their profound economic and ecological impacts globally. Quantifying the risks of invasiveness posed by non-native species is fundamental for the successful implementation of control, containment, mitigation, and eradication measures. Within the emerging field of invasion science, non-native species risk analysis has also become a relatively new discipline.

The risk analysis of non-native species involves a three-step sequential process: risk identification (or risk screening), risk assessment, and risk management. Risk identification determines which non-native species are likely to become invasive in a given area. Identifying these species is crucial for developing policies and management actions aimed at preventing or mitigating the impacts of biological invasions. Risk assessment requires a thorough investigation into the likelihood and magnitude of risks associated with the introduction, establishment, dispersal, and impacts of a non-native species. Risk management evaluates the risks of non-native species and informs the implementation of appropriate management strategies.



Source: authors' own elaboration.

To facilitate the risk analysis process, electronic decision support tools have proven especially useful for both scientists and environmental managers. Over the past 20 years, significant progress has been made in the development of the Invasiveness Screening Kit 'ISK' tools for risk identification. This progress has culminated in the creation of the taxon-generic, multilingual Aquatic Species Invasiveness Screening Kit (AS-ISK), Terrestrial Animal Species Invasiveness Screening Kit (TAS-ISK), and Terrestrial Plant Species Invasiveness Screening Kit (TPS-ISK). These toolkits, which have been used globally on more than 1 800 taxa, enable the screening of all non-native organisms, including aquatic and terrestrial animals and plants. Conversely, the current schemes for risk assessment and risk management, such as the European Non-native Species in Aquaculture Risk Scheme (ENSARS) and the Modular Management Tool (MMT), remain underutilized.

Looking to the future of non-native species risk analysis, making ENSARS and MMT available as easily deployable, user-friendly electronic tools, similar to the ISKs, will significantly aid in completing the full risk analysis process for species at high risk of invasion. Furthermore, adding species-specific risk information to databases such as the European Alien Species Information Network (EASIN) will provide invasion scientists, stakeholders, and the general public with a powerful reference repository.

BUILDING RESILIENCE IN PERCID FISH AQUACULTURE: FAILURES AND SUCCESSES

Daniel Żarski
Polish Academy of Sciences, Olsztyn, Poland

Percid fish species, notably European perch (*Perca fluviatilis*) and pikeperch (*Sander lucioperca*), have become important aquaculture candidates in Europe due to their high market value and consumer demand. As wild stocks decline and fishing pressures increase, aquaculture offers a sustainable alternative to meet the growing demand for these species. To meet this challenge, the development of percid aquaculture has been significantly propelled by dedicated research efforts, advancing our understanding of their biology and farming requirements and enabling the year-round supply of high-quality juveniles—an essential milestone in the aquaculture of these species.

Recirculating Aquaculture Systems (RAS), or combinations of RAS with semi-intensive production systems (e.g. split-ponds or pond-in-pond installations), have emerged as the most economically and biologically feasible methods for farming percids. These systems provide precise control over environmental parameters essential for their sensitive developmental stages. However, despite technological advancements, there are still very few economically viable farms operating at scale. While the technology is nearly sufficient, further innovation is needed to improve domestication success and selective breeding programmes. Ongoing research plays a critical role in these areas, aiming to develop strains that are resilient to stress and better suited for intensive aquaculture conditions.

Over the years, several farming attempts have failed due to excessive production costs, with the major contributing factor being relatively low production efficiency. Key issues include high mortality rates, disease outbreaks, and suboptimal growth, often resulting from inadequate management of complex RAS technology and insufficient domestication of the species. Conversely, partial successes have been achieved where operations have invested in specialized staff proficient in fish biology, water chemistry, and biosecurity measures, and where research has directly addressed specific farming practices.

A significant barrier to breaking the current stagnation of this emerging sector is the lack of specific funding for targeted operations that bring together experts from various European countries to collaborate on advancing percid aquaculture. Such collaborative efforts are essential to develop RAS-dedicated fish strains and share innovations in technology and husbandry practices. By fostering international cooperation and investing in research and development, the industry can overcome current challenges and build resilience in percid fish aquaculture. This should also be coupled with targeted education and training of future aquaculture innovators, who can learn from past failures and further develop resilient percid aquaculture.

In conclusion, building resilience in percid fish aquaculture in Europe still requires addressing the shortage of specialized professionals, increasing investment in research and innovation, and fostering collaborative efforts across countries. By learning from past failures, capitalizing on successes, and supporting targeted funding initiatives, the European aquaculture sector can sustainably expand perch and pikeperch production to meet market demands.

RECIRCULATING AQUACULTURE SYSTEMS DEVELOPMENT AND PERSPECTIVES

Jurica Dujaković
M.J.D. Consulting d.o.o., Stari Grad, Croatia
Ana Gavrilović
University of Zagreb Faculty of Agriculture, Croatia

The growing need for food and the preservation of the environment dictates an increasing need for changing designs of fish cultivation systems. Although they may sound nice and environmentally friendly, limited amounts of water, land prices, negative impact on the environment and water quality, coupled with an increased number of diseases, make traditional aquaculture technologies less and less acceptable and less sustainable. Long and unpredictable, semi-intensive and intensive farming cycle under uncontrolled conditions is financially unpractical, unreliable and unprofitable. Farms located outdoors in ponds and net pens are exposed to numerous risks (weather, predators, pollution, diseases and ever-tighter legal regulations).

The recirculating aquaculture system (RAS) minimizes water use and land requirements and reduces food consumption. With full control of the breeding environment, it shortens the production cycle and gives full control over the fish inventory. A limited amount of wastewater can be economically treated to remove both solid and dissolved waste.

RAS has been under development and refinement for the past 50 years. After the initial research phase, the primary focus has been to create, develop, and refine recirculating technologies that can produce food fish on an economically competitive basis. Optimal water temperature and water quality should be maintained through the entire fish rearing period, providing a nurturing and stress-free environment, which enhances the health and growth of the cultured fish. The water that is being recycled should also be constantly filtered and sterilized. These processes include mechanical, electrical and biological components, which combine to provide for the continuous recirculation and reuse of the culture water during intensive fish growing regimes.

Basic Closed Recirculating System design includes several necessary components: culture tank (where fish are grown), pumping component (for the movement of water between the tank and the water purification unit), mechanical filtration system (for the removal of solid wastes), biofiltration system (for the aerobic removal of ammonia and anaerobic removal of nitrates), pH controlling system, degassing component (for the removal of excess carbon dioxide), an injection component (for the reintroduction of oxygen), and sterilization and polishing system (UV, ozone).

The success of business involving recirculating aquaculture depends as much on the careful integration of the individual components of the system, as with the implementation of a viable management and marketing strategy.

In addition to the basic requirements for the design of a successful RAS, the presentation gives several examples of incompetent and unsuccessful RAS projects, as well as several successful examples. Undefined trends in the development of RAS were noted and examples of unnecessary and unforgivable mistakes that ruined the image of recirculation technology are given. Today's significant investments show the interest of large financial institutions in the future of closed recirculation systems, but the successful identification of competent designs and management is still questionable due to too few successful projects.

SESSION 1. STOCK ASSESSMENT AND FRESHWATER FISH MANAGEMENT (STOCKING, HABITAT IMPROVEMENTS)

FISH STOCKING IN INLAND WATERS IN EUROPE AND CENTRAL ASIA: ISSUES AND SOLUTIONS

Ian Cowx
University of Hull, and Angling Trust, United Kingdom of Great Britain and Northern Ireland
Raymon van Anrooy
Food and Agriculture Organization of the United Nations, Rome, Italy

Stock enhancement through formal stocking programmes was long recognized as an important tool to compensate the loss of productivity and diversity and is widely implemented across Europe and the Central Asian regions to increase or maintain fish productivity. However, there are ongoing concerns about the benefits and successes associated with stocking fishes in the region, as well as the potential risks, particularly with respect to ecosystem functioning, changes in community structure, disease transmission and losses of genetic integrity. Consequently, there is a need to review the factors that drive the successes and failures of stocking programmes and the risks from stocking fishes so enhancement programmes to mitigate negative environmental effects are carried out in the most effective way.

This presentation summarized the main conclusions of various reviews about the benefits and impacts of stocking, and developed a framework to mitigate the negative impacts and maximize the benefits of such activities. The main solution for successful, environmental and socially acceptable fish stocking in freshwaters were discussed. EIFAAC Occasional Paper No. 54 on Fish stocking in inland waters in Europe and central Asia: issues and solutions, presents an overview.

CHALLENGES AND TRENDS IN THE MANAGEMENT OF SWEDISH INLAND FISHERIES

Alfred Sandström, Björn Rogell, Göran Sundblad, Thomas Axenrot, Patrik Bohman, Natalia Kulatska, Martin Ogonowski & Helena Strömberg
Swedish University of Agricultural Sciences, Drottningholm, Sweden
Sofia Brockmark
Swedish Agency for Marine and Water Management, Gothenburg, Sweden

Inland fisheries provide livelihood, recreation and food security for local communities worldwide. However, the services given by local fisheries and the ecosystems that support them are facing numerous challenges. The authors presented an evaluation of recent trends and challenges in the stock assessment and management of Swedish inland fisheries concentrating on the four largest Swedish lakes, which are governed by national and regional authorities. These lakes, some of Europe’s largest, have diverse and important fisheries. All four lakes are of national importance, not only via fisheries but also since they provide drinking water for millions of people, transport, tourism, recreation and many other important societal services.

The authors synthesized lake-specific attempts to identify major challenges to the ecosystem and fisheries and highlight recent advances within three important areas:

1. data collection, stock assessment and scientific evaluation and advice;
2. food security; and
3. ecosystem-based approaches, the importance of stakeholder involvement and regional consultation structures.

LIFE-HISTORY AND MANAGEMENT OF COMMON BREAM – AN UNDERUTILIZED SPECIES

Björn Rogell, Alfred Sandström & Göran Sundblad
Swedish University of Agricultural Sciences, Drottningholm, Sweden
Magnus Karlsson
IVL Svenska Miljöinstitutet AB, Stockholm, Sweden
Daniel Bergdahl
Länsstyrelsen i Örebro län. Sweden

Common bream, *Abramis brama*, is an ecologically important species that mainly inhabits eutrophic rivers and lakes, as well as the coastal areas of the Baltic Sea. While bream was historically important for local fisheries, during the last century its popularity has decreased significantly in Scandinavian countries. This has led to very low harvest. In recent years fisheries for bream are increasing, partly due to an initiative to increase fisheries on underutilized species and partly due to that bream is used as bait in trap-fisheries for crayfish. Bream's habit as a sediment feeder causing bioturbation, in combination with its often-large proportion of the total biomass, also makes it a focal species for biomanipulation efforts. Motivated by the increased interest in landing bream, the authors conducted a series of studies regarding life history characteristics, biomass and environmental contaminant levels in a range of Swedish lakes, and along the Swedish Baltic Sea coast. The authors found that bream is often a dominating species in eutrophic lakes, and that it has low levels of environmental contaminants, compared to other more frequently harvested species. However, the bream populations in Sweden exhibit characteristics typically associated with slower life-histories, e.g. long lifespan, low mortality, slow growth and a relatively high age at maturity. The low amounts of environmental contaminants indicate that bream would be a strong candidate for human consumption. The slow life-history was discussed in the context of increasing harvest rates in the future. The age of bream was very high, up to 45 years in some systems, as was the age of sexual maturity raising the question of how bream may cope with increased fishing.

CORMORANT PREDATION IN A GRAYLING STREAM IN THE AUSTRIAN FOOTHILLS: INSIGHTS FROM PIT-TAGGING

Kurt Pinter, Michael Grohmann
BOKU University, Vienna, Austria

The authors investigated the effects of cormorant predation on fish communities in the Lower Traun River and its tributaries, the Ager and Alm Rivers, between Gmunden and the confluence with the Alm River in Upper Austria. Fish were tagged with passive integrated transponders (PIT-tags) in 2019 and 2020 and later searched for at four cormorant roosting sites. Three main questions were addressed: (1) the extent of predation based on tagged and consumed fish, (2) spatial variation in predation pressure across roost sites, and (3) cormorant preferences for specific fish species or sizes. More than 12 800 fish, both stocked and wild, were tagged in the rivers Alm, Traun and Ager. Tagging took place in summer and autumn 2019, with searches in the following winters. The recovery rate of PIT tags was about 10%. Consumed fish ranged from 12 to 44 cm, with stocked brown trout and rainbow trout being the most commonly consumed species. Relative predation was highest on grayling, especially those between 25 and 35 cm. Predation rates adjusted for detection limits suggested a removal rate of around 40% for grayling, compared to 20–30% for perch and pike. Wild fish experienced slightly higher predation pressure than stocked fish. Lower cormorant numbers in the second season were associated with a reduced impact on fish populations. Spatial analysis showed that predation pressure decreased with distance from roosting sites. The results confirm that cormorants exert significant pressure on fish populations, especially grayling, in the Lower Traun region. This persistent predation threatens the recovery of already weakened fish stocks, indicating a likely further ecological decline without management intervention.

THE PROCESS OF THE ENDEMIC LAKE OHRID TROUT (*Salmo letnica*) ARTIFICIAL SPAWNING AND BREEDING FOR RESTOCKING PURPOSES – RETROSPECTIVE

Dusica Ilik-Boeva
PSI Hydrobiological Institute, Ohrid, North Macedonia
Violeta Mihajloska
Ministry of Agriculture, Forestry and Water Economy, Skopje, North Macedonia

Although the earliest archaeological artifacts and historical records of fishing activities in ancient Lake Ohrid date back to the Neolithic period and the initial settlements along its shores, commercial fishing operations officially started in the late 1920s, marking a significant shift in the utilization of the lake's resources.

The Lake Ohrid trout has been the most market-demanded and highly-priced fishing object over the past nine decades. To ensure the long-term viability of its population, artificial spawning and breeding practices have been systematically implemented. The first hatchery was established in 1935, under the Hydrobiological Station – Ohrid, which later evolved into the Hydrobiological Institute. Subsequently, an additional hatchery was established in 1960 in the village of Shum, near Struga, and one hatchery five years later in Albania. Hence, this process became transboundary, with joint efforts of the two countries, SFR Yugoslavia (later R.N. Macedonia) and R. Albania.

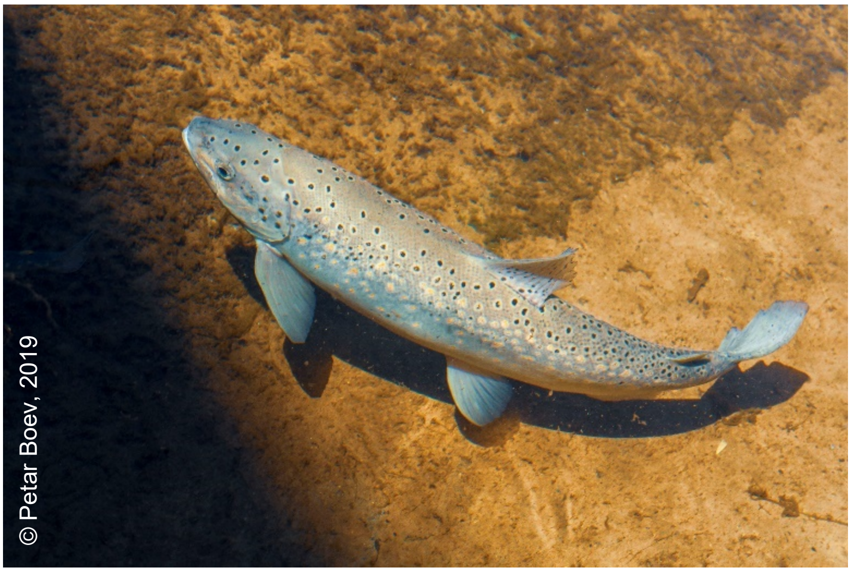


Figure 1. Lake Ohrid trout

Historically, various development stages, including fertilized eggs, fry, alevins, fingerlings, and juveniles, have been used for restocking purposes of Lake Ohrid.

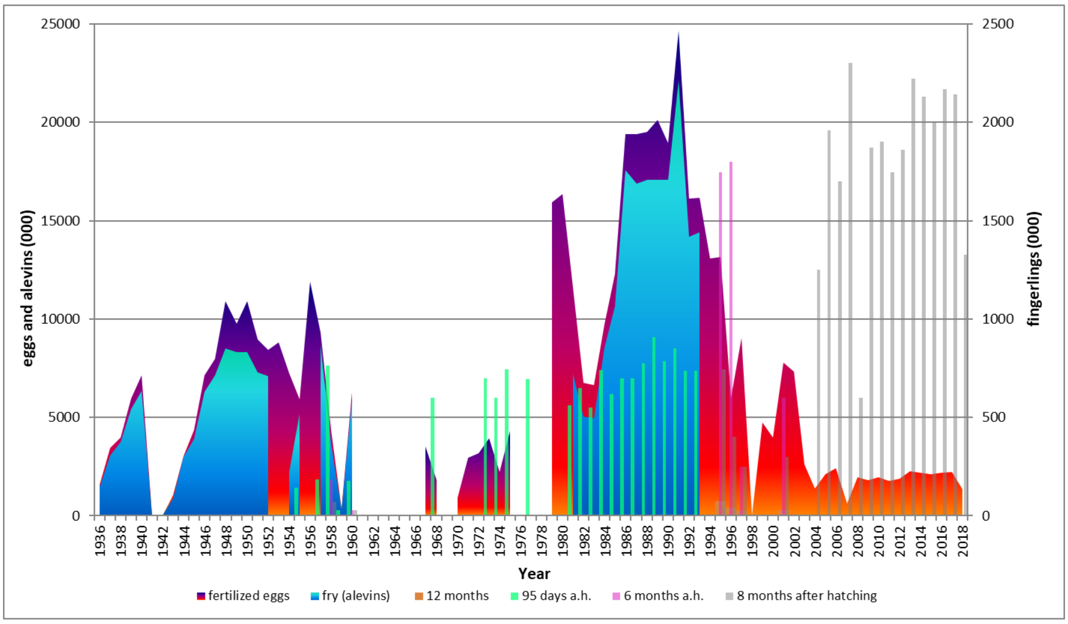


Figure 2. Lake Ohrid trout restocking on the Macedonian side of the lake *Source*: Modified (added 2016–2018) from **Spirkovski, Z., Paluuuqi, A., Flloko, A., Miraku, T., Kapedani, E., Ilik-Boeva, D., Talevski, T., Trajcevski, B., Ritterbusch, D., Brämick, U., Pietrock, M., & Peveling, R**. 2017. *Fish and Fisheries Lake Ohrid – Implementing the European Union Water Framework Directive in South- Eastern Europe*. Technical Report. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Bonn, Eschborn, Pegi Sh.P.K. Book Publishers, Tirana, Albania, pp. 99.

Over the course of this extensive period of implementation, the process of artificial spawning of Lake Ohrid trout underwent significant development and modernization. Since 2000, the collection and fertilization of eggs and milt from the spawners post-fishing at the natural spawning grounds, have been conducted aboard the research vessel of the Hydrobiological Institute, enhancing the efficiency and precision of the artificial spawning process. Furthermore, a comprehensive upgrade and modernization of all the equipment in the hatchery and the breeding hall were completed to align with the technological advancements. In 2003, a state-of-the-art hatchery was constructed in the village of Lin, Albania, replacing the one from 1965. Presently, the hatchery with the longest tradition has a production capacity of 5 million eggs, complemented by 1–2 million in the newest and 0.5–0.7 in the third hatchery unit.

Since 2004 a catch-and-release approach has been implemented for fishing spawners on the Macedonian side of the lake, aiming to maintain the reproductive potential of the population by allowing the same spawners to contribute to future generations in the following years to avoid the bottleneck of the species gene pool. Simultaneously, a comprehensive fishing moratorium was enforced, remaining in effect until 2012. However, despite these conservation efforts, detrimental shifts in the natural population have been observed, including reduced abundance in specific length classes, a transition in diet from zooplankton to benthic fauna due to the food niche competition with *Alburnus scoranza* (the bleak), and compromised spawning grounds by heightened anthropogenic impacts and illegal fishing practices.

Over the past two decades, restocking efforts have focused on the release of nine-months from fertilization and six months fed fingerlings, strategically timed to coincide with the autumn peak of zooplankton abundance in Lake Ohrid. This targeted approach ensures that the fingerlings' mouth size aligns with that of their primary natural diet, zooplankton, optimizing their feeding efficiency and facilitating successful adaptation to their natural ecosystem.

The Lake Ohrid trout restocking efforts faced a five-year disruption on the Macedonian side of the lake, from 2019 to 2023, being a consequence of legislative changes, not considering species biology. As a result of this interruption, during these five years, a higher number of fingerlings were released on the Albanian side, with 1.7 million fingerlings reported in 2023. Following the resumption of restocking activities in North Macedonia, a collaborative effort facilitated the release of 2.2 million fingerlings in 2024, demonstrating a concerted bilateral commitment to the conservation and sustainability of Lake Ohrid's endemic and endangered trout.

Artificial spawning, breeding, and restocking protocols established for Lake Ohrid trout are essential for preserving the ecological balance within this distinctive ecosystem. Given the exclusive predatory nature of trout species within Lake Ohrid, comprehending and managing their population dynamics is critical for maintaining harmony in the lake’s ecosystem. Collaborative conservation efforts aimed at the Lake Ohrid trout management not only serve to protect the biodiversity but also enhance the resilience of this ancient lake environment. Future efforts should prioritize continuous monitoring and adaptation of conservation strategies to ensure the long-term sustainability of this unique ecosystem.

FISH WINTERING HABITATS IN THE DANUBE RIVER FROM BATINA TO ILOK

Sara Polojac & Zrinka Mesić
Karlovac University of Applied Sciences, Croatia
Matija Kresonja, Ivona Žiža, Dominik Mihaljević, Milorad Mrakovčić & Ana Đanić
Oikon Ltd. – Institute of Applied Ecology, Zagreb, Croatia

Freshwater fish species overcome the cold part of the year using wintering habitats, which are typically the deepest, low flow velocity sites in the river. The research of wintering habitats along the Danube riverbed was conducted as part of the project “Monitoring of the hydrological, hydraulic and morphological characteristics of the Danube River and inventory of biodiversity components on the joint Croatian-Serbian sector of the Danube River”, which was implemented within CEF 2014 – 2020 transport project "Preparation of FAIRway2 works on the Rhine-Danube corridor". The goal was to enhance our understanding of fish ecology, specifically their habits and movements within the Danube, and to contribute to protection of these crucial river habitats. Fish wintering habitats are typically depressions in the riverbed, characterized by various biotic and abiotic factors, with the most critical being the slow water flow, allowing fish to conserve energy during the winter months.

The GIS analysis of the Danube riverbed bathymetry indicated 31 potential locations for wintering habitats from Batina to Ilok along the Croatian and Serbian parts of the river, respectively. The potential habitats were surveyed visually in the field an assessed by ichthyologists. According to the assessment, 19 locations were researched in February 2024 with the sonar HUMMINBIRD Helix 9 Chirp. The potential locations were scanned by sonar in more details to collect more information about the morphology of the locations and to record fish presence. For that purpose, 3D models of the locations were built in the specialised software. The analysis of the sonar records confirmed that 7 locations are active winter refuges for fish. Nine (9) locations have morphological characteristics that could provide conditions for the wintering habitats but during the survey the fish were recorded on the edge of the pithole in the riverbed. Therefore, those locations were not recognized as active wintering habitats. For such locations more detailed sonar recording should be conducted, as well as repeated recording during (several) winters.

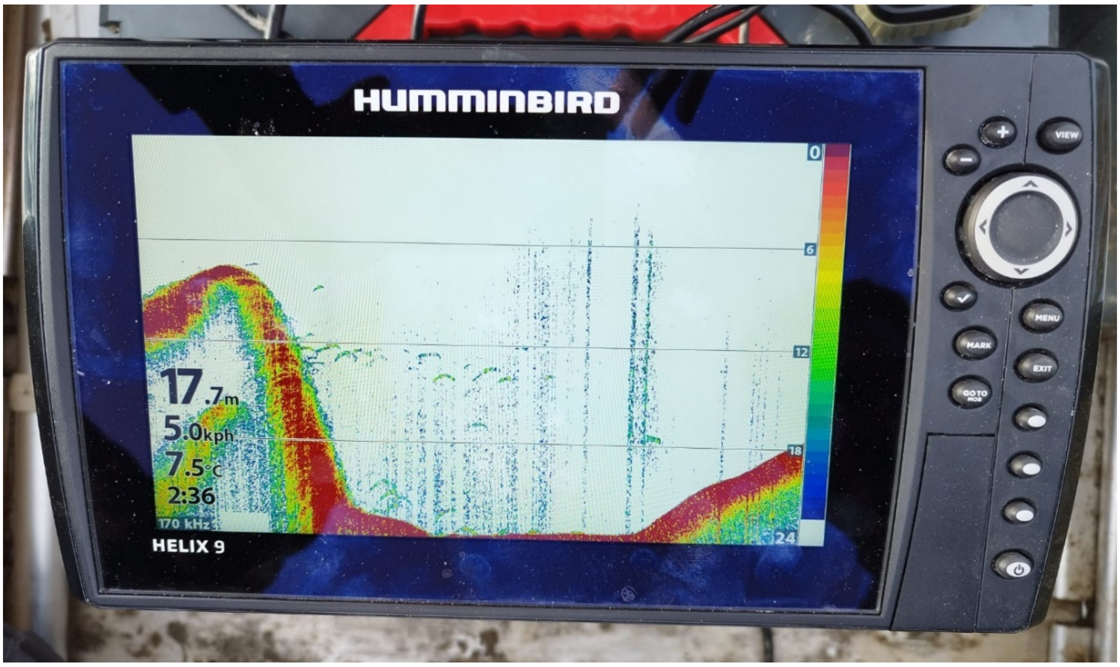


Figure 1. Active wintering habitat scanned with sonar
Source: **Polojac S.** 2024. *Mapping of the fish wintering habitats in the Danube River from Batina to Ilok*. Undergraduate thesis. Karlovac University of Applied Sciences**.**

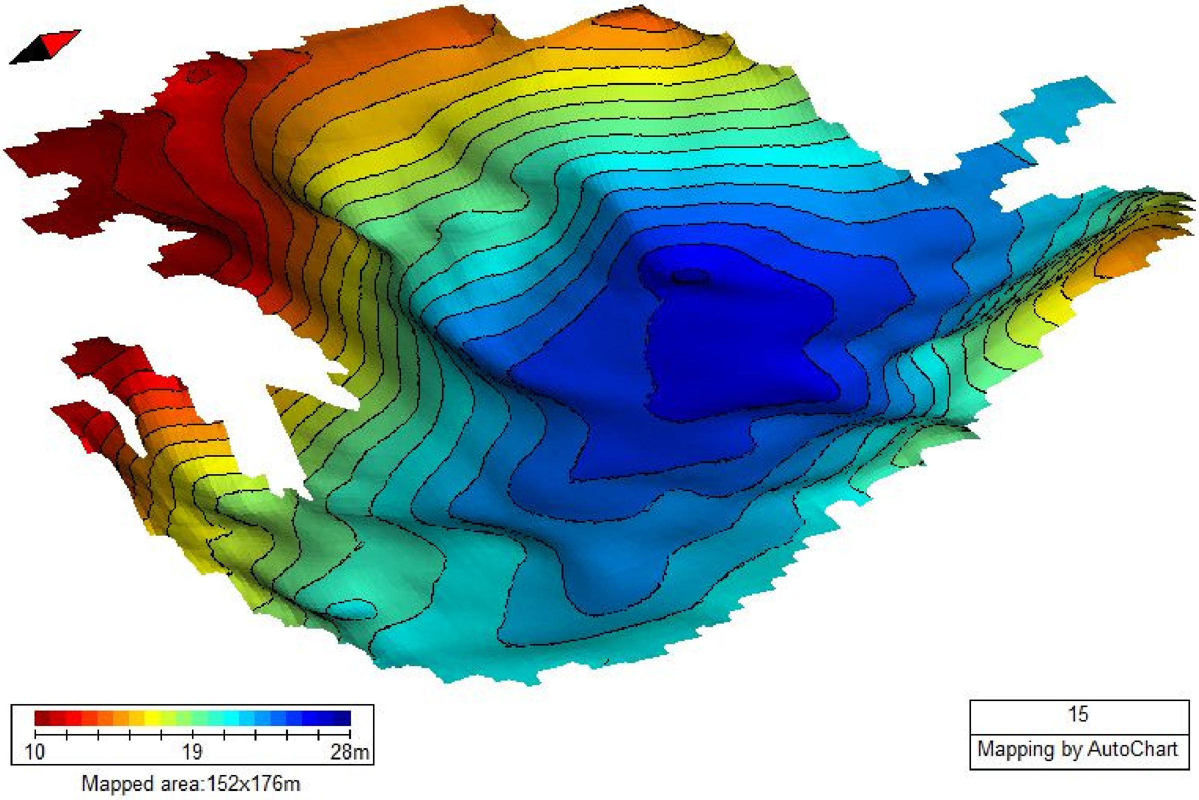


Figure 2. 3D model of the active wintering habitat scanned with sonar
Source: **Polojac S.** 2024. *Mapping of the fish wintering habitats in the Danube River from Batina to Ilok*. Undergraduate thesis. Karlovac University of Applied Sciences**.**

SESSION 2. MIGRATORY FISHES – PROBLEMS AND CONSERVATION

The first part of this session was organized in workshop style by the European Cooperation in Science and Technology (COST) ACTION 22163 "Solving bottlenecks in eel reproduction to support sustainable aquaculture" (EELSUPPORT).

LOOKING FOR TRANSIENT RECEPTOR POTENTIAL RECEPTORS IN THE EUROPEAN EEL: AN EVOLUTIONARY APPROACH

Marina Morini
Sorbonne University, Paris, France and Universitat Politècnica de València, Spain
Sylvie Dufour
Sorbonne University, Paris, France
Juan F. Asturiano
Universitat Politècnica de València, Spain
Christina A. Bergqvist & Dan Larhammar
Uppsala University, Sweden

The Transient Receptor Potential (TRP) channels constitute a superfamily of multifunctional membrane proteins, involved in many sensory and physiological functions. Currently, the TRP superfamily members have been classified into nine TRP families in metazoans, including TRPV and TRPM families. In 2021 the Nobel prize was attributed to the discovery in mammals of TRPV1 and TRPM8 sensitive to hot and cold temperatures, respectively. Few data are yet available in other vertebrates and metazoans. This study aimed to investigate the number, origin, and evolution of TRPV and TRPM families among metazoans, with a special focus on the impact of whole genome duplications (WGD), gene-specific duplications, and gene losses, in teleosts and in particular in the European eel (*Anguilla anguilla*).

Fish, as ectothermic organisms, are sensitive to temperature changes related to seasons or environmental transitions. They are particularly vulnerable to the increase in watershed or ocean temperature due to global warming. Temperature may affect all aspects of fish life cycle and physiological functions, such as development, metabolism, growth, reproduction, migration, etc.

The European eel species is in the red list of the International Union for Conservation of Nature (IUCN) as critically endangered. Eel overfishing, together with other anthropogenic factors such as pollution, river dams, diseases, and global climate change, have indeed caused a drastic reduction of the eel populations during the last decades. Eels have a complex lifecycle and encounter high variations in temperature and salinity during their continental and transoceanic migrations. For instance, decreasing temperature is reported as one of the environmental factors triggering the silver eel downstream migration. It has been also suggested that final sexual maturation in the spawning ground would be related to an increase in water temperature. The eel's perception mechanisms of temperature variations at these key stages and the physiological responses are still unknown, as well as the potential impact of global warming on these regulations. The eel, as a representative of elopomorphs, an early diverging group of teleosts, the largest group of vertebrates, presents also the interest of a key phylogenetical position for the evolutionary studies.

The authors performed gene searches, phylogenetic and syntenic analyses across metazoans, and revealed larger number and lineage specific diversity of TRPV and TRPM genes than previously assumed. Four TRPV types (A, B, C and D) and four TRPM types (alpha, beta, beta-like and gamma) were identified in non-vertebrate metazoans. In vertebrates, local gene duplications and vertebrate WGD (1R/2R) led to the expansion of the TRPM and TRPV families with up to nine TRPV types

(TRPV1 to 9) resulting from TRPVC and D, and up to eight TRPM types (TRPM1 to 8) resulting from TRPM alpha and beta.

The additional teleost WGD (3R), as well as species-specific local gene duplications and gene losses, led to diverse repertoires of TRPM and TRPV across teleost species. The European eel possesses ten TRPM resulting from the conservation of two 3R-paralogs (a and b) of TRPM1, TRPM4 and TRPM7 while of only a single 3R-paralog of TRPM2, TRPM3, TRPM5 and TRPM6. This species possesses three TRPV corresponding to the conservation of a single 3R-paralog of TRPV1, TRPV4 and TRPV5.

This study proposes a phylogenetically based classification of TRPM and TRPV types across metazoans, and provides necessary tools for predicting and naming TRPM and TRPV types and paralogs according to lineages and species, as well as for relevant inter-specific comparative investigations. These data open new research avenues for the comprehensive studies of the multiple TRPM and TRPV and their potential involvement in sensing and responses to environmental changes.

Acknowledgement

This publication is based upon work from COST Action EELSUPPORT, CA22163, supported by COST (European Cooperation in Science and Technology), Seal of Excellence MSCA Post-doctoral Fellowship from Sorbonne University, MCIN with funding from European Union NextGenerationEU (PRTR-C17.I1) and by Generalitat Valenciana (THINKINAZUL/2021/012) to SEASPERM, Swedish Research Council, Swedish Brain Foundation.

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SCREENING OF EEL POPULATION FOR BROODSTOCK SELECTION

Ana, Gavrilović, Oliver Barić & Tena Radočaj
University of Zagreb Faculty of Agriculture, Croatia
Ákos Horváth, Tamás Müller, Kinga Katalin Lefler & Réka Enikő Balogh
Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary
Irena Vardić, Nevena Kitanović & Damir Kapetanović
Institute Ruđer Bošković, Division for Marine and Environmental Research, Zagreb, Croatia
Jurica Jug-Dujaković
M.J.D. CONSULTING d.o.o., Stari Grad, Croatia

The basis for collecting and selecting the broodstock of eel, as well as other types of fish, is the good condition and health of the individuals. In addition, the presence of numerous toxic chemicals, including pesticides and heavy metals, in the body of fish are known to cause reproductive disorders (Delbes *et al*., 2022). For the success of the broodstock conditioning, it is also necessary to know the stage of gonadal development (gametogenesis) in the natural environment so that the conditioning can be carried out as efficiently as possible. Since the commercial fishing of European eel in the Neretva delta in Croatia represents a long-standing tradition that has been maintained to this day, despite the decline in catches, this area represents a potential place for the selection of eel broodstock for artificial spawning. Given that the eel population of the Neretva delta is a potential location for collecting the broodstock, the aim of this work was to examine the health status, the concentration of pesticides in the meat, as well as to determine the stage of gonadal development.

Asymptomatic eels were sampled from the catches of commercial fishermen from January to November 2021. Of the 94 eels collected during this period, 32 specimens from January and May were subjected to virological analyzes. Three different organs (liver, spleen and kidney) were isolated and stored in 70% ethanol. Detection of the most frequently reported eel viruses, AngHV-1 and EVEX, was performed by PCR. All 94 collected eels were processed for routine histology of the gonads to determine maturation stage, endo parasitological analysis, analysis of pesticide concentration and mercury (Hg) in the meat.

A total of 14 out of 32 fish were positive on AngHV-1, while all samples were negative on EVEX. The prevalence of most widespread genus of intestinal fish parasites, the thorny headed worms *Acanthocephalus* sp., was 56.5%, while the prevalence of swim bladder parasite *Anguillicoloides crassus* was 32%. The concentration of Hg varied from 0.9 to 0.17 mg/kg. Out of 14 examined pesticides, endosulphane alfa and p, p – DDE were above the detection limit. Several different oocyte maturation stages described by Lokman and Young (1998) were identified.

In addition to the importance of using broodstock from virus-free areas and virological examinations of eel from the areas of unknown health status, these results highlight the importance of broodstock health assessment and biosecurity measures, including quarantine and preventive bathing, to ensure higher survival and better larval quality. Detoxification protocols should be considered in case of accumulation of endocrine disruptors.

Acknowledgement

This study is based upon work from COST Action CA22163 “Solving bottlenecks in eel reproduction to support sustainable aquaculture” (EELSUPPORT), supported by COST (European Cooperation in Science and Technology). Part of the activities was financed within the Project "Fisherman- Scientific Network of the City of Ploče" performed under Measure I.3., "Partnership between scientists and fishermen for the period 2020–2022".

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IMPACT ASSESSMENT OF EEL STOCKING UPSTREAM VESTBIRK HYDROPOWER STATION, GUDENÅEN, DENMARK

Michael I. Pedersen, Gorm Rasmussen & Niels Jepsen
Danish Technical University, Silkeborg, Denmark

To meet the European Union's recovery plan for eels, about 1.5 million on-grown eels (2–5 g) are stocked into freshwater areas in Denmark annually. Knowledge about the effect of stocking is insufficient. The purpose of this study has therefore been to shed light on the effect of stocking eel in the upper part of river Gudenå. In the experimental area, the natural immigration of elvers is limited and a fish trap at Vestbirk Hydropower can retain fish that migrate downstream from the upstream rearing area.

In 2001 and 2002, a total of 78 633 eels were stocked with an invisible CW (Coded Wire) tag. The fish were released in two size groups of 2.8 grams and 9.5 grams respectively. The 2001 release was in the main stem of the river and in 2002 it was in tributaries. After 6 years, the first eel with a CW-tag was recaptured in the fish trap. In the years from 2007 until 2020, 712 tagged eels were recaptured. The gender distribution of the recaptured eels was 27% males at length 33–42 cm (62–155 g) and 73% were females at length 45 to 90 cm (174–940 g).

The catch efficiency of the trap was estimated to be 37% of all eels migrating from the release area and the total migration was thus estimated to be 1 924 silver eels. This corresponds to a total survival of 2.45% of the 78 633 eels that were released. The survival of the "large" eels averaged 2.51% and the small eels 2.38%. The small 2.8 gr eels have roughly the same survival in 2001 (2.33%) as in 2002 (2.43%), but the survival of the large eels is almost double as high in 2001 (3.11%) compared to 2002 (1.87 %), which indicates higher survival when large eels are released into the Gudenå's main stem contrary to release into the tributaries ($P< 0.001$).

The average annual growth in length in the two size groups were similar between 2.9 and 3.4 cm/year for small versus large eel respectively and were not significantly different ($P= 0.1542$). The average annual growth in length were significantly faster for females compared to males ($P= 0.007$).

The gross yield per released eel is positive for both size groups, but if the yield is calculated as net yield, i.e. minus the released biomass, the net yield is positive for the small, released eels (3.3 and 3.4 g per stocked eel) but negative for the large, released eels (-1.6 and -4.5 g per released eel).

The total survival and thus the yield were less than what was documented in similar studies e.g. marine Fjord areas, which possibly can be attributed to slower growth and higher age and the presence of predators, cormorants, and otters, in the river Gudenå.

PRELIMINARY ANALYSES OF EEL SKIN AND GILL MICROBIOME FROM THE NERETVANERETVA DELTA, CROATIA.

Milán Farkas & Balázs Kovács
University of Zagreb Faculty of Agriculture, Croatia
Oliver Barić, Tena Radočaj & Ana Gavrilović
Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary
Irena Vardić Smrzlić & Damir Kapetanović
Institute Ruđer Bošković, Zagreb, Croatia
Jurica Jug Dujaković
M.J.D. CONSULTING d.o.o., Stari Grad, Croatia

Next to the parasites and viral infections, the bacterial community has been suggested to play an important role in the decline of the panmictic population of the European eel (*Anguilla anguilla*). Despite the recognized importance of microbiome research, relatively little is known about the microbial communities in wild populations of this species. Such knowledge is critical for the selection of healthy broodstock from natural populations. The Neretva Delta, Croatia, represents an optimal site for potential broodstock selection, where commercial eel fishing continues despite a noted decline in catch volumes. The objective of this study was to characterize the microbiomes associated with the wild European eel.

The samples were collected in winter (January) and spring (May) 2021 by professional fishermen. The microbial samples were taken from the gills and skin of the fish using sterile swabs and immediately stored in liquid nitrogen and transported to the laboratory. They were stored in the laboratory at -70 °C to preserve sample integrity before analysis. DNA was extracted from the collected swab samples using the PowerSoil DNA Isolation Kit (Qiagen) according to the manufacturer`s instructions. The concentration and quality of extracted DNA were quantified using Qubit 4, followed by commercial next generation sequencing (NGS) analysis by Novogene Co, Ltd (Beijing, China). A total of 14 samples underwent metagenomic amplicon sequencing (Illumina), targeting the V3-V4 region of the 16S rDNA gene to accurately determine the composition of the bacterial communities in the selected samples.

The analysis revealed significant individual variation in bacterial communities. The phylum *Actinobacteriota* and *Bacteroidota* were present in all samples with a relative abundance exceeding 1%, although this ranged up to 35.8 %. While the *Firmicutes* phylum was significantly abundant in the skin samples (41–79.9%) compared to the gill (2.5–20%) samples. The phylum *Proteobacteria* showed the opposite trend, lower abundance was found in the skin (4.6–41.3%), and the dominance of the phylum was observable in the gill samples (19.1–74.9%). Pathogenic taxonomic groups, including the families *Vibrionaceae*, *Pseudomonadaceae*, *Aeromonadaceae* and *Flavobacteriaceae* were detected in nearly all samples, albeit in the gills we generally found a higher ratio (up to 4.2%, 3.5%, 14% and 31% respectively). Additionally, the genera Salmonella and Listeria were identified in three samples each, at low abundances (<0.00098%).

The presented results contribute to filling knowledge gaps in microbiome research of eel and point out that individual microbiome differences are significant in natural populations. Moreover, the detection of pathogenic bacteria underscores the necessity of health assessments and stringent biosecurity measures, including quarantine and molecular/microbial testing, for eel producers to enhance survival rate and quality.

Acknowledgement

This study was based on work from COST Action CA22163 “Solving bottlenecks in eel reproduction to support sustainable aquaculture” (EELSUPPORT), supported by COST (European Cooperation in Science and Technology). Part of the activities was financed within the Project "Fisherman- Scientific Network of the City of Ploče" performed under Measure I.3. "Partnership between scientists and fishermen for the period 2020–2022. Another part of the study was supported by the Ministry of Innovation and Technology within the framework of the Thematic Excellence Programme 2021, (TKP2021-NVA-22), the Flagship Research Groups Programme of the Hungarian University of Agriculture and Life Sciences.

STATUS OF EEL POPULATION IN OHRID LAKE

Dijana Blazhekovikj & Dimovska
University “St. Kliment Ohridski”, Ohrid, North Macedonia
Stojmir Stojanovski
Hidrobiological Institute, Ohrid, North Macedonia

Lake Ohrid, known as one of the oldest lakes globally, has the distinction of being the deepest lake in the Balkans region, with a maximum depth of 288 m and a mean depth of 155 m. Even with its exceptionally high level of endemism (approximately 1 200 native species, at least 212 endemics; almost half of the 21 native fish species are endemic), the presence of non-endemic species is still considerable in Lake Ohrid. The lake likely stands out as the only one in the world that primarily receives water from many surface and sub-lacustrine springs. The River Crn Drim, part of the Adriatic drainage basin, is the only outlet for the lake. The non-endemic category consists of species that are mobile or migratory, like the European eel. Over the past 60 years, the natural migration routes for eels in Macedonia have been blocked due to the construction of dams for hydroelectric power stations on the River Crn Drim. The eels are obstructed by the dams as they try to leave Lake Ohrid and reach the sea, where they naturally spawn. The issue is somewhat addressed by importing and introducing young eels into Lake Ohrid.

In the past 7–8 years, juvenile eel has not been introduced into Lake Ohrid. The visible decrease in the population of this fish species is noticeable every year. The State Statistics Office has reported the following results in the catch of eel (in kg) in recent years: 2020–200 kg; 2021–280 kg; 2022–293 kg and 2023–282 kg.

In the past few decades, the focus on eel diseases has been dominated by the nematode *Anguillicola crassus*. The Japanese eel (*Anguilla japonica*) is the native host, and the parasite is prevalent in both open waters and fish farms in Japan, but it causes minimal damage since it is almost non-pathogenic for the Japanese eel. The introduction of the parasite in Europe occurred in the early 1980s through the import of infested eels from East and Southeast Asia. The spread of *Anguillicola crassus* quickly reached many European countries, affecting open waters and fish farms and resulting in significant losses.

Anguillicola crassus in Lake Ohrid was determined by Cakić *et al*. (2002) to be present in nearly half (39.71%) of the eel population in the lake, likely introduced through the import of young eels for stocking. Stojanovski *et al.* (2010) discovered that *Pseudodactylogyrus anguillae* and *Pseudodactylogyrus bini*, monogenean trematodes, were present in 51.31% of the eel examined in Lake Ohrid. The presence of gyrodactylid species in Lake Ohrid was last investigated in 2018 (within the Bilateral Macedonian - Austrian Scientific - Research Project 2018–2020) by Blazhekovikj - Dimovska and Stojanovski during their eel sampling, but no parasites in eel were found.

Acknowledgment

This publication is based on work carried out under COST Action EELSUPPORT, CA22163, supported by COST (European Cooperation in Science and Technology).

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AQUACULTURE OPPORTUNITIES FOR THE CONSERVATION OF EUROPEAN EELS IN TURKEY: CHALLENGES AND POTENTIAL SOLUTIONS

Devrim Memiş & Gökhan Tunçelli
Istanbul University, Türkiye
Süleyman Öztürk
Ministry of Agriculture and Forestry, Antalya, Türkiye

European eels are distributed from the northern coasts of the Atlantic Ocean to the Baltic and Mediterranean Seas. They can migrate as far as Asia and South America, but they do not breed in those regions. The European eel (*Anguilla anguilla*) is the only species of the Anguillidae family that inhabits the Mediterranean, Aegean Sea, and Black Sea. These migratory species spend most of their lives in rivers (from 6 to 20 years) and generally move to the sea from April to November to spawn at ages of 6 to 9 years or older. During this transition, the color of the eels turns silver in about 3–4 months. When they reach 60–80 cm in length, they achieve sexual maturity in their silver form. The stages of an eel's life are as follows: Leptocephalus (pelagic larval eel), glass eel (transparent small eel), elver (small juvenile eel), yellow eel (juvenile eel residing in continental waters), and silver eel (sexually maturing eel) (EIFAC/ICES, 2001).

Eels can grow to a length of 50–150 cm, rarely up to 200 cm, and can weigh 4–6 kg, living up to 85 years. Male eels typically do not exceed 51 cm in length. eels spawn in their natural environment in the western Atlantic Ocean, at a depth of 1000 m, in waters with a minimum temperature of 7 °C and salinity not less than 35.5‰. Spawning occurs from early spring to late summer. Larvae, which are 7–15 mm long, live at depths of 200–300 m. By the end of the third month, at water temperatures of 20 °C, they reach a length of 25 mm and reside at 25–50 m depths. When the larvae reach 50–55 mm in length by June of their second summer, they migrate to the central parts of the Atlantic Ocean. By the third summer, they grow to 60–88 mm and reach the European coast. At this point, they finally take the shape of a small eel. Eels that arrive in rivers feed on worms, crustaceans, insect larvae, mollusks, fish, frogs, fish eggs, and other creatures (Slanstenenko, 1955).

Glass eels migrate upriver, crossing all kinds of obstacles. In river environments, eels face challenges in reaching maturity and preparing for spawning migration to the Atlantic Ocean. Many studies on eel stomach contents show that eels are carnivorous, feeding on fish as well as benthic invertebrates (Yalçın Özdilek & Solak, 2007). Eels may remain in the yellow eel stage, characterized by golden pigmentation, for up to 14 years and reach a length of 60 to 80 cm. After this stage, they move back to the sea, often crossing wet grasslands in search of an appropriate river or lake, particularly at night (Akşıray, 1987).

Eel fisheries and capture-based eel aquaculture are unique among fisheries due to the extremely migratory nature of the eel's life cycle (Ottolenghi *et al*., 2004). *Anguilla anguilla* are found in marine, brackish, and freshwater environments worldwide, where they are consistently caught due to their accessibility and market demand. In 1998, the International Council for the Exploration of the Sea (ICES) declared that the eel spawning stock was beyond safe biological limits (EIFAC/ICES, 2002).

Today, according to the official website of the General Directorate of Fisheries and Aquaculture of the Ministry of Agriculture and Forestry, European eels (*Anguilla anguilla*), whose exports are subject to a quota under the "Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)," have an export quota for 2024 set at 100 tonnes per year.

At present, the dramatic decline in eel stocks indicates that eels are under pressure, either from fishing activities or environmental degradation. It is necessary to update the reasons for the decrease in European eel stocks under current conditions and prepare an action plan to assess and protect the existing stocks in Turkey. More research projects are needed to monitor these fish, re-determine their existing habitats, and explore opportunities for breeding them under controlled conditions. In this study, important eel habitats in the Mediterranean region will be investigated, and potential opportunities for aquaculture will be explored.

Acknowledgment

This publication is based on work carried out under COST Action EELSUPPORT, CA22163, supported by COST (European Cooperation in Science and Technology).

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THE IMPORTANCE OF SYSTEM DESIGN ON THE EARLY LARVAL REARING OF EEL

Jurica Jug-Dujaković
M.J.D. CONSULTING d.o.o., Stari Grad, Croatia
Ana Gavrilović
University of Zagreb Faculty of Agriculture, Croatia

The focus within the project on eel larvae breeding was concentrated on food and feeding. Despite its importance, the design of larval rearing systems was completely outside the project's focus. This article highlights the correlation between larval feeding and behaviour, as well as relevant environmental factors and the design of larval rearing systems.

Given the similar situation in fish species whose early-stage breeding has been established and is successfully taking place, the development of the breeding system took place in parallel with the development of larval nutrition and feeding strategy. Feeding with live food requires a completely different approach to the design of the drain and supply of fresh water to the tanks, unlike feeding with inert food. System and tank designs for the laboratory research have their specificities and were never fully applied in commercial production.

Even discussions on some relevant environmental factors of the rearing of eel larvae (as temperature) were insufficient. During the early development of the larvae, a temperature of 18 ºC is recommended for optimal utilization of the yolk, but at this temperature it has been recorded that the larvae become immunologically weakened and very sensitive to pathogens. Slow decrease in temperature during yolk-sac larval stage was not suggested, but according to latest meeting with Japanese experts, temperature of 24 ºC was mentioned as optimal for larval stage during initial feeding. Negative phototaxis was used in the feeding strategy to scare the larvae and impel them to move to the bottom where slurry-type feed was spread. Light at the surface and feeding at the bottom of the tank determine the specific design of the tank with a drain at the bottom but considering the speed of decomposition of small food particles, an additional drain can be applied. The method of water intake and the speed and manner of water movement, especially due to the applied feeding method and the desired movement of the larvae during feeding, are of key importance. The shape of the larval tank as well as its volume will also determine the movement of the water. Even though in European eel the expression of digestive enzymes was detected just after hatching, the introduction of probiotics into larval tanks is being considered. The bacterial load would strongly influence the water quality, and the design of the tank would have to be adjusted if another way of introducing probiotics was not applied. The colour and transparency of the wall and bottom of the larval tank was changed several times in most protocols for different species. In research laboratory conditions, transparent tank walls are suitable, but in commercial systems they are usually inefficient and are not used.

Successful research results in early larval rearing of various fish species include effective rearing system design that correlates with other relevant rearing factors, and eel larval rearing is certainly no exception. This is why this type of bioengineering must be included in the research.

Acknowledgement

This publication is based on work carried out under COST Action EELSUPPORT, CA22163, supported by COST (European Cooperation in Science and Technology).

MANAGEMENT MODEL FOR FRESHWATER STOCK OF BROWN TROUT (*Salmo trutta*)

Eevi Kokkonen
University of Eastern Finland, Kuopio, Finland
Alisa Koski, Jukka Syrjänen
University of Jyväskylä, Finland
Anssi Vainikka
University of Eastern Finland, Joensuu, Finland

Main life history strategies of brown trout *Salmo trutta* classify as river resident and migratory types; potamodromous in a river system, lacustrine adfluvial or allacustrine potamodromous, and anadromous. Some stocks also show partial migration with unclear population structure. Adfluvial brown trout is the most threatened because of damming, intensive land use and high fishing pressure in lakes and rivers. The wild southern migratory brown trout populations are completely protected from targeted fisheries in Finland.

The authors reviewed published life-history parameter data on brown trout to create and calibrate a size-, maturity-, age- and habitat structured population model. Here, the authors presented preliminary results for an example population of adfluvial brown trout that were used to exemplify the effects of fisheries management and habitat restoration measures.

Figure 1. Brown trout (*Salmo trutta*)

The results show that fishing mortality and egg survival constrain the brown trout population size. Fisheries adjusted to ensure efficient 60 cm minimum size limit saves more individuals from by-catch mortality than 50 cm minimum size limit, but in all cases very low bycatch mortality is required to maintain natural populations. Habitat restoration by dam removal in Heinävesi watercourse would increase the breeding area and population size. Population models are crucial in developing knowledge-based conservation and management of brown trout beyond the optimistic hopes set in public discussion.

UNDERSTANDING THE THREATS TO FISH MIGRATION: APPLYING THE GLOBAL SWIMWAYS CONCEPT TO THE LOWER MEKONG

Ian Cowx
University of Hull, United Kingdom of Great Britain and Northern Ireland
An Vu
Charles Sturt University, Albury, Australia
Zeb Hogan
University of Nevada, Reno, United States of America
Quan Lai
Mekong River Commission Secretariat, Vientiane, Lao PDR
Catherine Sayer
Centre for Science and Data, Cambridge, United Kingdom of Great Britain and Northern Ireland

The Mekong River basin is a biodiversity hotspot and supports the largest inland capture fishery globally. The fish and fisheries, especially migratory species that underpin the capture fisheries, are, however, under threat from multiple pressures, not least hydropower development, expansion of irrigated agriculture and aggregate mining. In this paper the Global Swimways concept was used to understand migratory patterns in different Mekong fish species and provide insights for management and conservation of migratory species in the basin.

Information was collated from existing databases, FishBase (Froese and Pauly, 2024), and literature searches to determine the significance of migration routes of the river system. A total of 1 395 fish species was recorded. About 33% of these are migratory species, mostly potamodromous and amphidromous species, and contribute ≈70 % of catch. Distribution of fish in the Mekong River exhibits a well-defined zonation pattern, with species diversity highest in the lower floodplains and delta reaches. Three main migration zones occur in the Lower Mekong Basin (LMB) but with considerable migration of some species between zones. Some species adopt multiple migration strategies as opposed to simple longitudinal or lateral migrations, with sub-populations occurring in different reaches of the LMB exhibiting different migratory strategies. Approximately 11% of native fish are threatened; among migratory species 35% are threatened.

There are multiple challenges to maintaining swimways in the Mekong, including improved understanding of migratory pathways, managing intensification of environmental pressures and managing heavy fishing pressure. Measures to conserve and protect the migratory fish species in the Mekong are suggested.

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INVISIBLE ACTORS: THERMAL RESPONSES TO LOW HEAD IMPOUNDING STRUCTURES

Róisín Donovan, Brian Coghlan, Sarah Keane, Ciara O'Leary
Inland Fisheries Ireland, Dublin, Ireland

Low head impounding structures alter the natural processes of rivers through a modification of key parameters. The modified parameters have the potential to extend the influence of the obstacle beyond its immediate environment. Temperature is one such critical parameter that determines both the biotic and abiotic elements of aquatic habitats. In the context of climate change, the impacts of artificially altered thermal regimes are set to be exacerbated rather than ameliorated.

Temperatures were recorded upstream and downstream of multiple structures during five summer periods in two large rivers systems on the east coast of Ireland, as part of an ongoing study. Significant differences in upstream and downstream temperature trends were observed. Probes immediately downstream of structures recorded extended periods of temperatures above the upper thermal limit for brown trout growth (19.5 ºC), in contrast to upstream control sites. Raised temperatures were found to persist for a distance of up to 800 metres downstream. The water temperature within impoundments was also found to spend significantly more time above the upper thermal limit for brown trout growth compared to free-flowing control locations. Explanatory factors such as impoundment residence time, exposed surface area, height of structure, riparian canopy cover, and the degree of groundwater influence were also investigated. The higher water temperatures extending behind and downstream of structures may function as a secondary, invisible, barrier to diadromous fish migration.

There are approximately 2 900 weirs in the Irish river network. Mitigation strategies must see beyond fish passage to include the broader hydromorphological health of the reaches adjacent to impounding structures. The documented dual impact of impeded passage along with thermal regime degradation imposed by instream infrastructure must be seen as a priority for mitigation to protect our cold-water migratory fish species in a warming climate.

FREE FLOWING RIVERS METHODOLOGY

Wouter van der Bund
Joint Research Centre European Commission, Ispra, Italy
Piotr Parasiewicz, K. Belka
National Inland Fisheries Research Institute, Olsztyn, Poland

The European Union Biodiversity Strategy includes the target that at least 25 000 km of rivers should be restored into free-flowing rivers by 2030 through the removal of primarily obsolete barriers and the restoration of floodplains and wetlands. This document proposes criteria for identifying free-flowing rivers, taking into account longitudinal, lateral, and vertical connectivity at local and catchment scale. The aim is to provide a tool that can be used by authorities to calculate the increase of the length of free-flowing rivers resulting from restoration projects and that can be counted against the European Union target of 25 000 km of free-flowing rivers.

Key elements of the method are (1) segmentation of the river into homogeneous reaches; (2) criteria for longitudinal, lateral and vertical connectivity within a homogeneous reach; (3) a large scale assessment taking into account sediment connectivity and migration barriers for target fish species; and (4) minimum length criteria to ensure hydromorphological processes and ecological functioning.

SESSION 3. DEVELOPMENTS AND CHALLENGES IN FRESHWATER AQUACULTURE.

RESEARCH AND INNOVATION CONSIDERATIONS FOR FRESHWATER EUROPEAN AQUACULTURE

David Bassett
EATiP, Liège, Belgium
László Váradi
NACEE and HUNATiP, Szarvas, Hungary
Béla Halasi-Kovács
NACEE and HUNATiP, Szarvas, Hungary and SCIAP Consulting, Debrecen, Hungary

Aquaculture plays a special role in global food supply, which is growing in importance thanks to the comparative advantages of the sector compared to other food sectors. It is well known that aquaculture is one of the fastest growing food sectors in terms of production volume on a global level, in which the freshwater aquaculture contribution is dominant with a share of 64% (FAO, 2024). However, European Union Aquaculture accounts for only 2.7% of global production (FAO, 2024), whilst the European Union aquatic food market is sustained through imports equating to roughly 70% of total consumption (EUMOFA, 2023). At the same time, global aquaculture output has been growing at 6.5 percent per year whilst European Union aquaculture production is growing at just under 2 percent. In contrast to the volume of production, the European Union is a leading region in aquaculture innovation, where aquaculture has been developed into a modern food system in the past few decades. However, food systems, including fisheries and aquaculture are facing great challenges recently to meet the growing population's need for healthy food. There is a need for changes not only driven by the triple planetary crisis of climate change, biodiversity loss, and pollution; but also, the increasing demand of domestic production both from economic and food safety point of view.

From a global perspective, raising finfish and other species in constructed earth ponds currently remains by far the most widespread culture method. Fish production in freshwater ponds is one of the oldest types of aquaculture production and one that has more than a two-thousand-year history across both Asia and Europe. Pond fish farming is a diverse sector within global aquaculture, not only concerning the wide range of species produced, but also the wide spectrum of production methods from intensive through to traditional extensive production. At a European Union level pond fish farming is a special segment of the diverse aquaculture sector. Although traditional pond aquaculture may produce less in terms of volume/tonnage that other production systems, pond aquaculture brings with it diverse and complex environmental benefits. Through maintaining 250 000 ha of man-made wetlands in the European Union, pond farms significantly contribute to preserving wetland related biodiversity (FDFS & HAKI, 2020). Ponds also contribute to increased climate resilience with carbon sequestration and better water management. Pond aquaculture provides one of the most complex webs of different ecosystem services connected the human food production systems (Willot *et al*., 2019, Palásti *et al*., 2020, Färber *et al*., 2020). The cultural value of traditional pond fish farming has also been recognised by various international schemes (FAO, 2024). The multifunctional characteristics of pond fish farms is also increasing (Békefi & Váradi, 2007; Popp *et al*., 2018, 2019).

In addition to the preservation of this European cultural heritage, space must be open to increase viability of pond farming through research and innovation along the whole value chain. Sustainability levels of traditional pond fish production can be further increased by applying new systems and technologies. Fishponds can be important components of Combined Intensive Extensive systems for sustainable intensification as well as enhancing the circular approach integrated with other food production systems, either animal husbandry or plant production. The application of early integrated systems (e.g. fish-cumduck or fish-cum-rice) can also be reconsidered, using new methods, equipment and facilities that are now available as a result of research and technology development.

The different freshwater fishes produced have the potential in Freshwater Integrated Multi Trophic Aquaculture (FIMTA) Systems which are based on the systemic linking of fed aquaculture units, organic extractive aquaculture units and inorganic extractive units in which aquatic plants are cultured. Plants produced in FIMTA can be used for a variety of purposes or as substrate in insect farming. These innovations could make pond aquaculture a key player in the freshwater blue bioeconomy.

Future opportunities in freshwater fish genetics and breeding include genomic selection and molecular techniques, disease resistance and health management, climate adaptation and environmental sustainability, including in adaption to FIMTA principles and using data driven decision making with AI. There is a need to find novel methods and solutions in the marketing of freshwater products, including the penetration of new export markets, angling markets, product development and use of labelling and geographical indication. Integration of "Industry 4.0" technologies is essential in creating competitiveness in the future. Application of sensors in water quality management and data-driven nutrient management have the potential in reducing environmental effects and increasing cost-effectiveness.

Land based recirculating technologies permit the farming of a wide range of species and are being increasingly used in freshwater aquaculture both in the farming of traditional but also now novel species. The sophistication of RAS systems continues to evolve, as does the potential for RAS systems to be used in the bio secure production of novel or alien and locally absent species. In addition to allowing for compliance with strict environmental parameters, recirculation may allow for a higher and more stable aquaculture production with less disease challenge and better ways to control the specific hatchery parameters that may influence growth and mortality.

At a European Union level, regional innovation transfer policies designed to support Regional Development and Cohesion policies have recently been extended to the Blue Economy sector, to support and promote inter-regional innovation transfer. The European Commission, through the Strategic guidelines for a more sustainable and competitive European Union aquaculture for the period 2021 to 2030 and the European Union Aquaculture Assistance Mechanism, supports and promotes the development of freshwater and low trophic aquaculture within part of the vision for the expansion and development of the European aquaculture sector.

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HOW DOES R&D SERVE THE DEVELOPMENT AND INNOVATION OF POND FISH PRODUCTION?

Béla Urbányi, Ákos Horváth
Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary

The economic, social and environmental changes of recent times have posed serious challenges for businesses in the agricultural sector. One of the most affected sectors within the sector is aquaculture, including pond fish production, which is highly vulnerable to changing ecological conditions resulting from climate change.

This exposure and the negative effects on production have in recent years increased the importance of research and development (R&D) as a solution to these problems. R&D has been a constant presence in pond fish production over the past decades, but the development and implementation of practical solutions has not been intensive: the pond sector has not demanded this potential and has not needed the methodologies and technologies developed by researchers.

This situation has changed radically in recent years, as those in academia and the business sector have realised that a key criterion for the survival of the sector is for the actors concerned to deepen their cooperation and carry out R&D that produces real, practical results. Cooperation between the academic and business sectors in the field of R&D offers significant benefits for both parties. This cooperation helps to accelerate innovation, to put scientific results into practice and to develop sustainable and competitive knowledge-based production.

By cooperation, companies will have access to the latest scientific findings and research methods, allowing them to respond more quickly to market changes and increase their competitiveness. For academic partners, this gives them the opportunity to test and apply their research in a real industrial environment. Academic research focuses on long-term results, while companies often pursue short-term, market-driven goals. To address this, it is important to define common goals and to communicate continuously. It is important to stress that R&D is an expensive process and funding is often limited. Joint funding models and the involvement of public grants and tenders can address this problem.

The most critical areas identified are fish reproduction and reproductive biology, fish genetics, fish nutrition and fish health, water quality research areas and fishpond management problems of general relevance. Joint development and innovation actions have been launched that will greatly improve the safety of production, reduce the environmental exposure of production systems and increase the profitability of the sector.

Acknowledgement

This work was supported by the Flagship Research Groups Programme of the Hungarian University of Agriculture and Life Sciences.

APPLICATION OF CRYOPRESERVATION TECHNIQUES TO AQUACULTURE PRACTICE

Ákos Horváth, Zoran Marinović & Béla Urbányi
Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary
Ana Gavrilović
University of Zagreb Faculty of Agriculture, Croatia

Cryopreservation of gametes is a widely used technique in certain areas of animal husbandry, allowing the indefinite storage of frozen cells. In dairy cattle breeding, it has become an indispensable assisted reproductive technique, accompanied by a highly successful business sector. In the case of fish, cryopreservation of gametes (mainly sperm) has been a field of research since the 1950s, but its commercial application became a reality only in the last decade. There were several reasons for this (male reproductive material is rarely a limiting factor in fish farming, the simultaneous production and use of large quantities of reproductive material, etc.), but ultimately a change in perspective among researchers and industry players was necessary for the breakthrough. Today, it is not the researcher who tries to convince the producer that sperm frozen by his method is no less fertile than freshly collected sperm. On the contrary, it is a businessman who convinces the producer that not using frozen sperm risks a production shortfall. Thanks to this change of perspective, sperm freezing has become a widely used method, especially in the breeding of salmonids in Western and Northern European countries such as France, Norway and Iceland. In Hungary, the authors have established a frozen gene bank of common carp varieties in 2003 which exists to this day and has been used for the restoration of individual varieties in 2013. In addition, a frozen gene bank of pikeperch and wels catfish has been created in 2017 and is maintained to this day. The freezing of fish eggs and embryos remains unsolved: the structure of the embryos, the different water content release of the separated yolk and embryonic tissues do not allow a successful freezing. The successful methods that have been published are either difficult to replicate or extremely expensive. In contrast, the gametes and even larvae of shellfish species bred under aquaculture conditions can be successfully frozen. Practical applications of this can be seen, for example, in France and New Zealand. Finally, freezing primordial germ cells of different fish species and transplanting them within or between species is a unique opportunity.

THE SITUATION AND STATUS OF GREAT CORMORANTS (*Phalacrocorax carbo*) IN HUNGARY.

Urbányi, B. & Horváth, Á.
Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary
Halasi-Kovács, B.
Sciap Ltd. Debrecen, Hungary
Tóth, P.; Lovászi, P.; Görögh, Z.; Karcza, Zs. & Nagy, K.
BirdLife Budapest, Hungary
Csörgits, G.
Ministry of Agriculture, Budapest, Hungary
Faragó, S.
University of Sopron, Hungary

The great cormorant (*Phalacrocorax carbo*) is one of the key species for fisheries and fishing (angling) in Europe today, mainly because its populations have increased over the last three decades. The great cormorant was a protected species in Hungary between 1954 and 1987, with an estimated conservation value of 1 000 HUF. Afterwards, as its population increased, this protection was lifted, and Regulation 8/1993 FM (FM = Ministry of Agriculture) established a year-round hunting season. In Regulation 30/1997 FM, however, it was no longer included in the list of huntable species, i.e. it was no longer considered game, but at the same time it was not subject to protection either or was transferred to the

category of species of uncertain status. In the European Community, it has been granted the status of a species of conservation importance by the directive on the conservation of wild birds (2009/147/EC) and in line with this, Hungarian legislation introduced the possibility of authorized regulation in 2008 (Regulation 13/2001 of the Ministry of Environment, so great cormorant populations can be regulated by a permit for reasons of agricultural interests (i.e., fish farming). The current conservation value of this species is 25 000 HUF.

In the case of some protected bird species in Hungary, some conflicts have arisen or may arise among fish farmers, anglers, and conservationists due to their feeding habits. In terms of body size and numbers, one of the potentials 'conflict species' is the great cormorant. The problem is that the damage caused to fish farmers by great cormorants, which cause significant financial losses, is difficult to assess using precise methods, and there is currently no aid available to compensate for the loss of income.

In recent years, the previous autumn peak in population size has declined significantly, from around 6 000 individuals in October-November (total data from synchronous areas) to 4 000. The load in August fell from 3 to 1 thousand and from 4.5 thousand to 1.5 thousand in September. December-April (between 2–3 thousand) is broadly unchanged. All this suggests a peak in autumn, but not as marked as before. During the summer there was a sharp decline in the size of the population. It is important to point out that the most recently published bird atlas of Hungary still mentions a breeding population of 2 400–2 700 pairs (2013–2017), but the unpublished data from the Ministry of Agriculture and national park authorities show a decline even compared to this, with a breeding population of less than 2 000 pairs.

Based on the trends shown, the migration and wintering behaviour of great cormorants has been changing in recent years, probably due to climate change, with a significant decrease in the typical population size during the previous peak periods. Great cormorants are the 'public interest' segment in terms of their impact on fish stocks, but the causes of change in fish stocks need to be considered in a complex way: lack of spawning areas, changes in flooding (lack of floodplain flooding), invasive species, water clarity and quantity, impact of weirs, stocking aspects.

Fish farmers and anglers are expected to reduce the size of great cormorant populations. However, the serious drawback of controlling the population at nesting sites is that it increases the tendency for old birds to stray and choose new nesting sites. This, in turn, serves to keep the population in a continuous growth phase rather than adjusting the population through intraspecific barriers, contrary to the objectives of population reduction.

Acknowledgement

The work was supported by the Ministry of Agriculture under grant project HAGF/10/2022.

AN AFRICAN CATFISH LINE SELECTED FOR LOW-FISHMEAL FEED COULD IMPROVE PRODUCTION SUSTAINABILITY

Balázs Kovács, Réka Enikő Balogh, Julianna Kobolák, Dániel Bokor & Béla Urbányi
Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary
Péter, Zoltán
National Centre for Biodiversity and Gene Conservation, Gödöllő, Hungary
Gábor Szilágyi
Bajcshal Ltd., Kisbajcs, Hungary

The sustainability of intensive aquaculture production is highly influenced by feed cost, mainly due to the provision of sufficient protein content. Nowadays, protein supply is covered by fish meal among others, although fish meal production is gradually decreasing while its price is increasing. Several studies have been performed to investigate different alternative protein sources; however, most of them revealed inadequate growth performance in fish with alternative protein feeds. Nevertheless, better economic indexes could be achieved in some fish species with selection for feed utilization. African catfish is an important species in freshwater aquaculture production in numerous countries. The research objective was to select African catfish for better utilization of low fish-meal feeds.

In the first generation, the reduced growth performance was detected but in later generations (F3 and F4), significant gains were achieved.

The selected lines demonstrated higher growth rate compared with the control genotype. In flow-through-system the direct selection gain in body mass was 11% in the F3 and 21% in the F4 generations when fed the experimental diet (ED), and 14% and 26% when fed the control diet (CD), respectively. While in RAS the average selection gain was 32% and 33% in F3 and F4 fed with the experimental diet (ED), and 12% in both generations with the control diet. Although feed-specific differences were not detected in the flow-through system, RAS showed a significant feed-specific selection gain of 21% in both the F3 and F4 generations between the control and experimental diets.

The authors concluded that the selected lines outperformed the control genotype in all tests conducted on the F3 and F4 generations, highlighting the potential of selective breeding to enhance sustainability in intensive aquaculture. However, a significant effect of selection for low-fish-meal feed was only observed in the RAS system in both the F3 and F4 generations, suggesting that highly standardized production conditions provide a better opportunity to realize genetic potential, enabling more sustainable practical production.

Acknowledgement

This work was supported by the iFishIENCi project (EU's Horizon 2020 research and innovation programme grant agreement No 818036). The project was co-financed by the European Union and the European Social Fund, the Ministry of Innovation and Technology within the framework of the Thematic Excellence Programme 2021, (TKP2021-NVA-22), and the Flagship Research Groups Programme of the Hungarian University of Agriculture and Life Sciences.

SHORTENING THE BREEDING CYCLE OF COMMON CARP (*Cyprinus carpio*) USING COMBINED FARMING IN RAS AND EARTHEN PONDS

Tomislav Slačanac & Jasna Ipša
PP Orahovica d.o.o., Croatia
Ana Gavrilović
University of Zagreb Faculty of Agriculture, Croatia

Common Carp (*Cyprinus carpio*) is the most important warm-water species in freshwater European aquaculture and is mainly cultivated extensively or semi-intensively (Bostock *et al*., 2010). The largest producers of this species in Europe are the, Poland, Czech Republic, Hungary, Germany and Romania (EUMOFA, 2022). Traditional production in ponds takes place in a three-year breeding cycle, which reduces the profitability of production and increases the risk of losses caused by fish-eating birds and diseases. In addition, in recent years, as a result of climate change, the lack of water in the summer period has become increasingly pronounced. All of the above imposes the need to develop new breeding technologies that would significantly reduce the risk of losses. One of the promising possibilities is the combination of traditional cultivation with the recirculation aquaculture system (RAS), that will shorten the production cycle, improve growth and survival by extending the first growing phase in an indoor nursery. This implies advanced technology of early offseason spawning and inclusion of indoor recirculating nursery technologies, that will allow the indoor breeding of common carp in intensive production systems and transfer of few weeks old fish to ponds when the water temperatures rise to those suitable for feeding and growth (Mihaly-Karnai *et al*., 2024).

The aim of this experiment conducted at the carp farm PP Orahovica was to achieve off-season spawning in March and to breed the fry in the RAS for four weeks, until the outside temperature is at the level of those for the start of feeding.

Broodstock conditioning started on 12 March 2023 and the spawning took place on 29 March 2023. The fry was kept in the RAS nursery (Figure 1) for four weeks (until 26 April 2024), until they reached a weight of 0.1 ± 0.008 g when they were transferred the nursery pond, and later to four pond breeding sites (Figure 2). Control samplings and measurements were performed every seven days and compared with carp spawned in May, in the conventional way and settled in the control pond.

Figure 1. Larvae in RAS

Figure 2. Fingerlings

At the end of October 2023, the fry produced by the combination of rearing in RAS reached a weight of 1110 ± 94.16 g, while the fry produced by conventional technology, under exactly the same conditions of rearing in the pond, weighed only 334 ± 50.67 g. Juveniles breed by a combination of off-season spawning and one-month rearing in RAS reached the target weight of 1 800 to 2 000 g the following summer. In this way, the growing cycle is shortened to 15 to 16 months, which is extremely important for the profitability of the production, and supplying the market in the summer months.

In addition to the combined technology, broodstock with great genetic growth potential, continuous aeration and high-quality extruded feed also influenced the success of the experimental results. However, even this kind of production needs to be optimized by testing each production step in order to ensure maximum survival and thereby achieve maximum profit.

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APPLICATIONS OF FISH AND SEAFOOD PROCESSING BY-PRODUCTS IN WATER TREATMENT PROCESSES

Mirna Habuda-Stanić
Josip Juraj Strossmayer University of Osijek, Croatia
Ana Gavrilović
University of Zagreb Faculty of Agriculture, Faculty of Agriculture, Croatia

According to the latest report of the Food and Agriculture Organization of the United Nations (FAO), aquaculture production increased to 223.2 million tonnes (185.4 million tonnes of aquatic animals and 37.8 million tonnes of algae) during 2022, the world production of fisheries and aquaculture reached a new maximum (FAO, 2024). In addition to the report above, FAO emphasizes that further transformation and application of the circular economy is necessary to make seafood production more sustainable and resistant to all the challenges brought by climate, security, and economic crises, as well as the increasing demand for food worldwide.

During the fish and seafood production, large amounts of by-products are generated, and many scientists and industries have invested considerable effort and resources to transform those by-products into new products through various conversion processes since most of those materials contain a high ratio of fatty acids, biopolymers, proteins and enzymes which make fish and seafood industry by-products valuable resources for pharmaceutical, biotechnological, biomedical and nutritional industries. One of those valuable compounds is chitin.

Chitin is a polysaccharide found in large quantities in the shells of crabs and shellfish. Deacetylation of chitin produces chitosan, a nontoxic cationic polymer with biodegradable and biocompatible properties. Chitosan exhibits a wide range of biological effects, including antibacterial, antifungal, anti-inflammatory, and anti-carcinogenic effect, as well as the ability to bind fat, film formation, antioxidants, and chelation, for application in several industrial sectors (Skendrović *et al*., 2023).

The possibility of using chitin and chitosan in water treatment was already examined at the end of the last century when scientists announced that the dosage of polycationic chitin and/or chitosan during water treatment using the coagulation and flocculation method contributes to the formation and binding of flakes and increases the effectiveness of removing turbidity and various organic pollutants. This led to the appearance of commercial products based on chitosan and their application in water treatment processes, which are still often used in practice today (Habuda-Stanić and Stjepanović, 2019).

New sustainability strategies and green policies have encouraged scientists to further investigate the characteristics and possibilities of using chitin and chitosan in water treatment processes. The authors of the studies reported that chitosan and its composites can be used as promising low-cost adsorbents due to their low price and easily available large quantities and high efficiency for the removal of various toxins (pesticides, heavy metals, microplastic, pharmaceuticals etc.) from wastewater, while current studies are focused on increasing the selectivity, and mechanical strength and reducing the solubility of chitosan-based adsorbents (Bhatt *et al*., 2023).

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RESTORING OUR OCEAN AND WATERS USING DIFFERENT MODELS OF INCLUSION AQUACULTURE INTO CIRCULAR BIOECONOMY

Ana Gavrilović
University of Zagreb Faculty of Agriculture, Croatia
Mirna Habuda-Stanić
Josip Juraj Strossmayer University of Osijek, Croatia
Jurica Jug-Dujaković
M.J.D. Consulting d.o.o., Stari Grad, Croatia.

Fish and other aquatic foods are increasingly recognized for their key role in food safety and nutrition, not only as a source of protein, but also as a unique and extremely diverse supplier of essential omega-3 fatty acids and bioavailable micronutrients. Overfishing, degraded ecosystems, increased loss of biodiversity and intensification of climate change as well as increased food needs have led to the accelerated development of aquaculture as a substitute for fish caught from natural populations (FAO, 2022). Increased production, accompanied by an increase in processing and preparation of products for the market, inevitably leads to an increase in the amount of waste, which in some cases can reach 70% of the basic mass of raw materials. The aquaculture production process continuously generates both solid and liquid organic wastes, as well as CO_2. Approximately 25% of the feed given to fish is excreted as solid waste. Discharged liquid wastes include ammonia, nitrites, nitrates, phosphates, and other dissolved wastes within the culture water (Gavrilović *et al*., 2017). Wastewater treatment methods depend on the production system (flow-through, cage, fish farms/ground basins, RAS), volume and concentration of wastewater. Flow-through systems discharge large quantities of water that contains a low concentrations of dissolved waste and mechanical particles, and have a low value of biological (BOC) and chemical (COD) oxygen consumption. Unlike them, recirculation systems release small amounts of wastewater containing high concentrations of dissolved waste substances and mechanical particles. The technologies developed for the treatment and purification of waste waters offer several possible options: sedimentation lagoons, application to agricultural land, artificial wetlands, mechanical and biological filtration, hydroponics and SBR ("sequencing batch reactor") technologies (Jug-Dujaković *et al*., 2012). By combining fish production with hydroponic cultivation, or more sophisticatedly with aerobic stabilization and hydroponic cultivation of plants an aquaponic system is created where the synergy of aquaculture and waste disposal represent a profitable business model (Gavrilović *et al*., 2017; Jug-Dujaković *et al*., 2018). On addition to the conventional hydroponic systems, microalgae could be also grown on aquaculture waste waters, where CO_2 also could be efficiently used (Gavrilović *et al*., 2017).

Processing waste and dead fish, as another group of solid waste, are also one of the basic problems on farms and fish processing facilities. Available and proven methods used for its disposal or removal are silage, packaging in special containers and submitting to animal feed producers, bacterial digestion in biological reactors to polypeptide chains and composting (López-Mosquera *et al*., 2011).

The remaining proteins in fish processing residues are easily digestible and can be used to produce hydrolysates containing various peptides and amino acids. Furthermore, collagen, gelatin, as well as hydrolyzed collagen can be produced from collagen materials such as bone, shell, or skin, etc. In addition to fish proteins and oils, other valuable components, including enzymes, nucleic acids, minerals and other bioactive compounds such as is chondroitin sulfate (CS), etc. can be recovered. Recovered fish oil is rich in n-3 fatty acids such as eicosatetraenoic acid (EPA) and docosahexaenoic acid (DHA), phospholipids, squalene, fat-soluble vitamins, etc. (Habuda-Stanić *et al*., 2022).

With the help of innovative technologies and proper management, aquaculture waste and by-products of fish processing can be used for the production of biogas and biodiesel and thus increase the sustainability and profitability of the business. The produced biogas is then used to heat the cultivation facilities and produce electricity. Unlike biodiesel, digestate, which is a by-product of biogas production, is further processed and used as fertilizer (Gavrilović *et al*., 2012).

Traditional aquaculture technologies are increasingly considered "polluting" and "unsustainable". Inclusion in the circular economy will improve the existing production practice and ensure its sustainability, efficiency and profitability. Such a trend allows the integration of aquaculture with other branches of agriculture, and the use of by-products that have so far been proclaimed as waste, in the creation of commercially interesting products and the production of energy from renewable sources.

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ENVIRONMENTAL BENEFITS OF AQUACULTURE AND CHALLENGES AND OPPORTUNITIES IN PROMOTING THOSE BENEFITS

Paul Mosnier, Robert Wakeford, Adam Mytlewski, Marcin Rakowski, Barbara Urban Malinga, Aleksander Drgas, Katarzyna Nadolna–Ałtyn, Tomasz Kulikowski, Sander van den Burg, Marnix Poelman, Josien Hendricksen, Tamas Bardocz, George Triantaphyllidis, John A. Theodorou, Dimitrios Moutopoulos, Leire Arantzamendi, Jesús Belzunce, Neil Ruane & Ayesha Power

MRAG Europe Ltd., Dublin, Ireland

The Strategic guidelines for a more sustainable and competitive European Union aquaculture outline the steps required to drive the development of aquaculture in a manner that aligns with goals of the European Green Deal (EC, 2021). Low trophic aquaculture, in particular the farming of marine bivalves and low-trophic finfish (in ponds, lagoons, estuaries, reservoirs and wetlands) presents a viable option for a resilient, competitive and enviro-compatible aquaculture sector in the European Union due to the favourable ecosystem conditions, markets for and historical experience in farming such species. Despite indications that these types of aquaculture can have minimal impact on the environment (and in some cases be beneficial to the environment), there are no defined measures for, and standardized techniques to assess the sustainability and eco-compatibility of these types of aquaculture. Negative consumer perceptions and a lack of awareness of the potential benefits, coupled with environmental, regulatory and economic challenges, present significant barriers for the growth of this sector.

The present study aims to assess the environmental benefits of these types of aquaculture through a semi-quantitative analysis of the available scientific evidence and through engagement with key stakeholders. The study seeks to highlight if and how these types of aquaculture can and are being promoted across the Member States, as well as providing recommendations to overcome barriers. The study looks to provide an overview of how these types of aquaculture, and their positive environmental impacts, can be successfully promoted, with the aim that aquaculture in the European Union can become a global reference for sustainability.

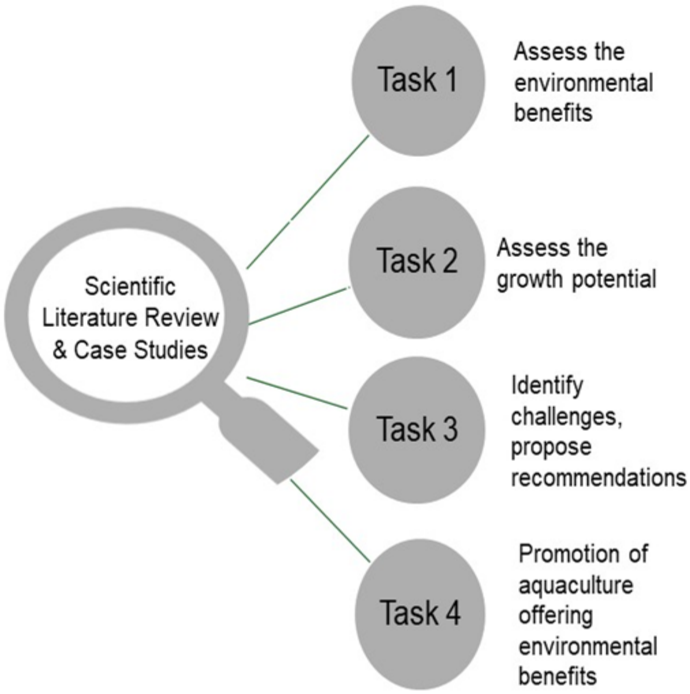

Figure 1. The project structure and activities
Source: author's own elaboration.

This study falls under the European Union Commission project *Assessing the environmental benefits of aquaculture and* challenges *and opportunities in promoting those benefits.* The presentation focused on the contextual background and project methodological approach, setting the context for elaboration on future project results.

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CHALLENGES AND INNOVATIONS IN GERMAN FRESHWATER AQUACULTURE

Reinhold Hanel
Thünen-Institute of Fisheries Ecology, Bremerhaven, Germany

German aquaculture is largely restricted to cold-water systems (mainly for trout farming) and warm-water ponds (mainly for carp production) with a total production of 15 800 tonnes. Both production forms are currently facing significant challenges in order to meet environmental, social and economic pressures. In addition to climate change related shifts in water supply and temperature, a shortage of approved fish therapeutants and vaccines as well as the increase in predator populations are among the most influential factors. The rearing of fish in technical systems operated with heated water amounted to 2 500 tonnes. While technical innovations offer some conceivable alternatives, rising energy costs currently result in a reversal of the trend. A critical ecological and economic evaluation of the prospects for European aquaculture in international competition and the adjustment of contradictory political framework conditions may be needed for the preservation of a viable freshwater aquaculture in Europe.

SESSION 4. FRESHWATER INVASIVES NETWORKING FOR STRATEGY (FINS III)

FIRST RECORDS OF GENETIC VARIABILITY OF RAINBOW TROUT *Oncorhynchus mykiss* (Walbaum 1792) IN SERBIA OBTAINED USING MITOCHONDRIAL DNA

Sokolović Vojislav, Marić Ana, Kanjuh Tamara, Nikolić Vera, Škraba Jurlina Dubravka & Simonović Predrag

University of Belgrade, Faculty of Biology, Serbia

Rainbow trout *Oncorhynchus mykiss* is one of the most widespread freshwater alien fish species (AFS), and it has been introduced to at least 99 countries outside its native area (Gherardi 2010). Despite the large introduction range, confirmed self-sustaining populations outside native range are rare, especially in Europe (Stanković *et al.,* 2015). In Serbia, stocking with rainbow trout is prohibited. However, there are reports about unauthorized stocking for fishing purposes. Two vectors common for introduction of AFS in the Balkans aquaculture and angling (Piria *et al*., 2017), acted also in a case of rainbow trout. That increased the risk of their introduction and dispersal there. Data on rainbow trout in streams at Serbia are very scarce and are mainly based on information available from fisheries management plans. This species is considered only as a feral species. Self-sustaining (i.e., the naturalized) rainbow trout have not yet been recorded in Serbia.

The aim of this research was to examine the genetic variability in two potentially self-sustaining populations of rainbow trout in the Grza and the Dičina rivers, including two hatchery stocks (Grza River fish farm and Radovanjska River hatchery) from which they likely originated. In total, 47 specimens were analyzed using mitochondrial DNA (mtDNA) Control Region (CR) marker (Table 1) Total DNA was isolated from the tissue samples of the anal fin clips. CR has been amplified using forward (Brunelli *et al.* 2010) and reverse (Snoj *et al*., 2000) primers (5’-CCA CTC TTT ACG CCG GTA G-3’ and 5’-CAC CCT TAA CTCCCA AAG CTA AG-3’, respectively). Generated PCR products were purified and sequenced in both directions by Macrogen Europe (Amsterdam, Netherlands). Sequences were aligned and analyzed using MEGA 11 software and compared with those deposited in the NCBI GenBank using BLAST.

Six different haplotypes were recorded (Table 1). Three haplotypes found in the Grza River suggested that rainbow trout stock originated from various sources, not being only an escapee from a local fish farm. The haplotypes recorded in the Dičina River almost certainly indicated an unauthorized stocking. There is no trout hatchery in the Dičina River and therefore there is no chance that sampled rainbow trout were the fish farm escapees. These first results for rainbow trout in Serbia implicated the remarkable genetic diversity, in both rivers and fish farms. This and further research would enable determination and characterization of the rainbow trout stocks origin and reveal the extent of unauthorized introduction of rainbow trout in Serbia, including the risk for their naturalization in recipient ecosystems there.

Table 1. Sampling locations in Serbia with coordinates. Details of samples: sample size and haplotype abundance

Code	Location	Coordinates	Sample size	MYS01 G-1-EU	MYS10-RTDL17-EU	MYS01H -RTDL36-EU	MYS03B -RTDL20-EU	MYS03 B-2-EU	MYS03 B-1-EU
1	Grza River	43°53'48.65"N 21°38'43.14"E	9	3	5	1	/	/	/
2	Dičina River	44° 0'6.46"N 20°21'30.03"E	23	/	/	/	13	/	10
3	Grza River fish farm	43°53'48.44"N 21°38'48.97"E	5	/	/	4	1	/	/
4	Radovanska hatchery	43°53'47" N 21°47'11" E	10	5	/	/	/	5	/

Source: author's own elaboration.

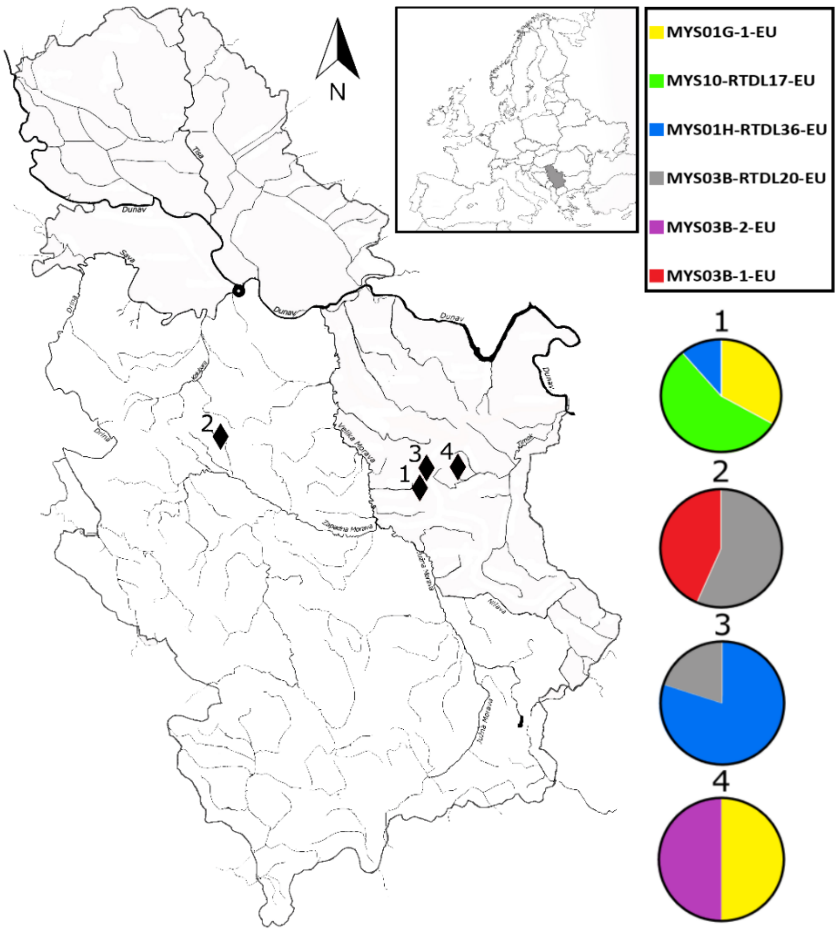

Figure 1. Map of sampling locations (source: Directorate for Water of Serbia. (https://www.srbijavode.rs/mapa-vodenih-podrucja.html). Tile symbols represent sampling locations. Location code, name of the location and coordinates are listed in Table 1. Pie charts represent frequencies of mitochondrial control region haplotypes per site.

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POTENTIAL THREATS TO NATIVE TURTLE COMMUNITIES FROM NON-NATIVE FISH SPECIES IN ISOLATED PONDS AND CANALS

Marina Piria

University of Zagreb Faculty of Agriculture, Croatia and University of Łódź, Poland

Ivan Špelić, Ana Gavrilović & Tena Radočaj

University of Zagreb Faculty of Agriculture, Croatia

Ana Štih Koren

Association Hyla, Zagreb, Croatia

Dragica Šalamon

University of Zagreb Faculty of Agriculture, Croatia.

Freshwater ponds and canals along the karstic eastern Adriatic Sea (EAS) coastline in Croatia were originally constructed for drinking water and agricultural purposes and agro amelioration, dating back to antiquity. Today, these water bodies are largely left to natural succession and anti-flood maintenance, often without regard to water supply and retention needs (Figure A). These small anthropogenic water bodies within the EAS serve as important biodiversity hotspots and primary habitats for native freshwater turtle species.

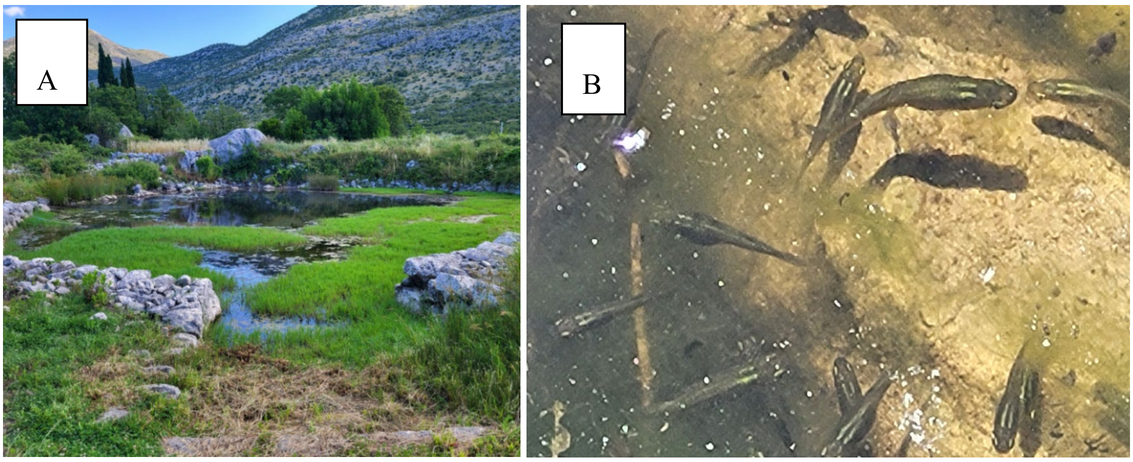

Figure 1. (A) Pond in the Dubrovnik-Neretva County; (B) dense population of *Gambusia holbrooki*
Source: Authors' own photo archive.

Balkan terrapin *Mauremys rivulata*, which is protected under the Habitats Directive, is limited to four isolated populations in the southern EAS, while European pond turtle *Emys orbicularis* has a distribution extending across the entire EAS and the Pannonian region. Both species are threatened by habitat loss and degradation, as well as the introduction of invasive species such as pond slider *Trachemys scripta*. Data on fish species in EAS's small anthropogenic water bodies are sparse, with limited information mainly noting the presence of invasive Eastern mosquitofish *Gambusia holbrooki*. However, the impact of introduced fish species on native turtle populations is less well known. It has been documented that species such as *G. holbrooki* and common carp *Cyprinus carpio* reduce the diversity of macroinvertebrates, a key food source for turtles. Additionally, *G. holbrooki* may carry ranaviruses and pentastomid parasites (Woodyard *et al*., 2019), while bullheads *Ameiurus* sp. has sharp spines that can cause injury if ingested by predators.

This study aimed to identify fish species and assess their abundance in the Dubrovnik-Neretva County. In 2023, samples were collected from nine ponds and two canals. Two ponds were found to be fishless. In total, four non-native fish species were identified: *G. holbrooki*, *C. carpio*, black bullhead *Ameiurus melas*, and rainbow trout *Oncorhynchus mykiss*. A single specimen of European eel *Anguilla anguilla*, a native species, was also observed. *Gambusia holbrooki* was the most abundant species (Figure 1B). Interestingly, masculinization of *G. holbrooki* was observed in an agricultural canal, suggesting the presence of endocrine-disrupting compounds in the water (Hou *et al*., 2018) that may also affect the reproduction of native turtle species.

Most of the fish introductions were likely conducted illegally, with unknown dates and pathways, that can be sources of disease threats for native biodiversity (Conn, 2013; Purse *et al*., 2020). *Gambusia holbrooki* was probably introduced for mosquito control, while no specific purpose is known for the introduction of other fish species. It is crucial to prevent further uncontrolled introductions, propose freshwater non-native species control programmes and assess microbial and parasite impact to native freshwater turtle populations.

Acknowledgment

The data for this work were obtained as activities of the European Union project LIFE21-NAT-HR-LIFE for Mauremys funded by CINEA LIFE Programme (GA: 101071737) and co-financed nationally by the Environmental Protection and Energy Efficiency Fund and Office for Cooperation with NGOs.

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INVASIVE FRESHWATER MACROPHYTE *Ludwigia peploides* IMPACT ON ECOSYSTEMS - CASE STUDY OF THE RIVER ILONA (CROATIA)

Kristina Ašenbrener, Marija Kovačević & Ivica Samarđić
Public institution for the management of the protected areas of Požega-Slavonia County, Croatia
Ivana Vitasović Kosić
University of Zagreb Faculty of Agriculture, Croatia

As part of the project "Control, monitoring and conservation of biodiversity in Požega-Slavonia County-control of populations of priority invasive alien species", the monitoring and eradication of the invasive macrophytic plant species *Ludwigia peploides* (Kunth) P. H. Raven will be carried out from 2023 onwards. *L. peploides* forms extensive monospecific populations and can thrive in slow-flowing waters as well as along the banks of lakes, rivers and canals.

In the first year of the study, field data was collected to assess the impact of this invasive alien species (IAS) on the environmental parameters and plant diversity of the affected habitats. A protocol for the removal and eradication of the IAS was established. Chemical control is not permitted in this Natura 2000 site; only mechanical eradication is allowed.

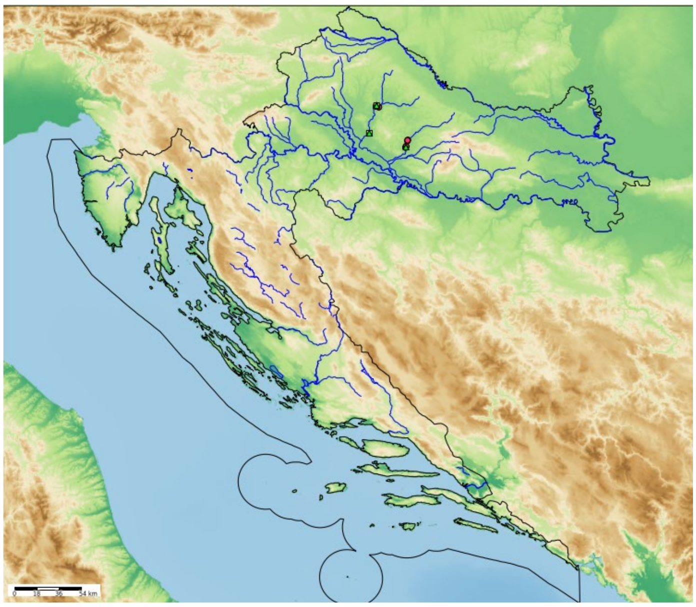

Figure 1. Distribution of *Ludwigia peploides* (Kunth.) P. H. Raven in Croatia *(source*: https://hirc.botanic.hr/fcd/)

Figure 2. Adult, upright specimen

During the initial year of fieldwork, it was observed that the Ilova River is flooded due to hydromorphological changes, and there are only a few locations where safe mechanical access is possible along the stretch where the plant occurs (approximately 12 km). Observations of the species phenology revealed that biomass increases almost exponentially during the summer months, particularly when compared to the beginning of the growing season. Dense communities developing in larger areas (> 20 m^2) occur from July in parts with calmer and warmer water. The plant spreads extremely rapidly due to the ecosystem disturbance and the opening of a free ecological niche, potentially leading to greater damage after mechanical removal. Further observation of the species phenology shows that the species propagates easily through fragments and develops a robust root system that allows it to endure in coastal drifts, while climatic conditions in our area have not yet permitted the seeds to ripen. Due to its well-developed root system, large quantities of sludge are produced during removal, which significantly increases the total biomass that has to be disposed of accordingly. Consequently, intensive removal of the plant at the beginning of the vegetation period and the implementation of further measures proposed in the protocol are planned for subsequent years.

Figure 3. Larger areas densely covered with *Ludwigia peploides* a) the river Ilova b) in the canals

The research findings have shown that aquatic *L. peploides* populations, characterized by leaves floating on the water surface, modify the habitats they colonize by reducing the available light and thus limiting the growth of other aquatic plants. These populations negatively affect aquatic plants, as a higher degree of invasion correlates a decline in plant diversity. Additionally, there is a need to enhance public awareness and inform the scientific community to prevent the further spread of the species.

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MIMICKING NATURE IN ARTIFICIAL CANALS: A KEY TO RESTORING LOWLAND NATIVE FISH COMMUNITIES AND AT-RISK NATIVE SPECIES

Ivan Špelić & Marina Piria

University of Zagreb Faculty of Agriculture, Croatia

Man-made canals can have varied impacts on native biodiversity in different regions. They can serve as refuges for native species and even act as biodiversity hotspots. However, they can also become pathways for the invasion of non-native species. In continental Croatia, artificial waterways primarily consist of irrigation and drainage canals, with a limited number of flood-protection canals and fish farm water management canals (Hrvatske vode, 2022). The aim of this research was to investigate the ichthyofauna of these man-made watercourses and assess the diversity of these communities, with special focus on determining the type of canals that best support native biodiversity.

Electrofishing sampling was conducted on 36 artificial waterways in the Sava River Basin in continental Croatia over two years. Each canal was sampled by wading along a 300 meter transect. Sampled individuals were counted and released, except for non-native species, which were retained according to national legislation. Diversity indices were calculated for all sampled waterways. Canals were ranked and evaluated according to their fish diversity and presence of non-native and protected species.

During the sampling, 33 fish species were recorded, of which three were protected species and six non-natives. The average number of species per canal was below six. Non-native species accounted for more than 60% of the total collected specimens and they were dominant (more than 50% in number of individuals) in more than half of the sampled canals. The data showed that many of these canals generally hosted poor fish communities, were dominated by non-native fish species and had low diversity, especially those located in the areas with intensive farming. Only several canals exhibited satisfactory diversity and some of them even provided good habitats for at-risk native species (protected species). The habitats that sustained the most diverse communities and at-risk species were one flood protection canal and two drainage canals (Narodne novine, 2024). All three were relatively large and deep, not severely fragmented and were in a proximity to the natural rivers that enabled them to be replenished by native species. The flood protection canal was diverse, with gravel and rock substrate and providing both lentic and lotic habitat zones. Drainage canals were located in a wooded area, under a high rate of succession and with preserved riparian zone.

Figure 1. Example of a canal with diverse native community on the left, and with poor community on the right

It seems that canals can provide a quality habitat for native fish communities if they are built and maintained to be similar to natural waterways, either by being diverse in terms of habitats they provide, or by having preserved natural riparian zones and being large enough to have stable hydraulic characteristics. On the other hand, small, polluted urban canals with heavily impacted riparian zones are often hosting a poor fish community dominated by non-native species (Fig. 1). Although most of the current canals in continental Croatia do not provide high-quality habitats for supporting native fish diversity, the results of this research can serve as valuable guidelines for future construction or maintenance of existing waterways.

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SESSION 5. CLIMATE CHANGE AND IMPACTS ON INLAND WATERS, FISHERIES AND AQUACULTURE

HYDROMORPHOLOGICAL CATALYST OF CLIMATE CHANGE IMPACT – THE ROLE OF ODER RIVER REGULATION IN THE ECOLOGICAL DISASTER OF 2022

Piotr Parasiewicz, K. Suska, Subham Wagh, Jacek Szlakowski, Agnieszka Napiórkowska-Krzebietke & Andrzej Kapusta
National Inland Fisheries Research Institute, Olsztyn, Poland

During the ecological disaster in the Oder River which took place during the summer 2022, above 249 tonnes of dead fish belonging to different species were found. An intensive study of the Oder River by the National Inland Fisheries Institute followed to investigate the magnitude of environmental loss, reasons and mechanisms of the disaster. Historical data was analyzed in conjunction with new data collected in post-disaster survey of fish, invertebrates, water quality and habitat parameters. Hyperspectral aerial imagery calibrated for recognizing chemical water composition and statistical predictive models were also applied to investigate the phenomenon.

In 2022 favorable environmental conditions (high salinity from the mining industry, extended drought, high water temperature) caused an intense bloom of toxic nanoflagellate *Prymnesium parvum.* Most likely, in response to rapid change in environmental conditions (i.e. water salinity) the algae released encapsulated toxins triggering the mass fish kills. Approximately 50% of the fish population was lost at the length of almost 700 km. This included endangered Amur bitterling (*Rhodeus sericeus)* and Spined loach (*Cobitis taenia)*, which occupied the groin fields of the rivers mid-section in large numbers. Rapid decomposition of accumulated cadavers of fish and mollusks in these areas caused oxygen deficiency, which was the reason for secondary mass mortality of aquatic organisms further downstream.

Therefore, the authors concluded that the altered hydromorphology played an essential role in the intensity of the disaster. Since, due to climate change, the likelihood of similar accidents in the future is growing, it is necessary to improve the resilience of the Oder River ecosystem by introducing appropriate channel restoration measures.

PIKEPERCH (*Sander lucioperca*) ANNUAL INCREMENT RECONSTRUCTION AND MODELING SYSTEMATIC ENVIRONMENTAL EFFECTS

Brabec M.
The Czech Academy of Sciences. Praha, Czechia
Bydžovský J., Soukalova K., Tesfaye M. G. & Kubecka J.
The Czech Academy of Sciences, Ceske Budejovice, Czechia

Using long-term data from a large systematic study of pikeperch (*Sander lucioperca*) biology in Lipno reservoir (Czech Republic), the authors first reconstructed pikeperch length increment from locally calibrated allometric relationship between otolith characteristic size and body length. Using the reconstructed lengths, the authors modeled resulting annual length increments and their relationship to several important environmental variables. The modeling was based on GAMM (Generalized Additive Mixed Effects Model) and aims at: i) correctly accounting for consequences of intraclass correlation induced by the longitudinal nature of the data and hence preventing pseudo-replication effects, ii) allowing for (biologically plausible) nonlinear effects of important covariates and hence preventing systematic biases in the fitted growth model. Effectively, the approach amounted to a nonparametric hierarchical growth model free of a priori functional assumptions. Clearly, the strongest predictor of length increments was the age (more than order of magnitude stronger when viewed through the F-ratio). Absolute and relative increments decreased dramatically during the lifetime. Starting with an age-cohort model showing very systematic inter-cohort differences, it demonstrated that a substantial part of the differences related to temperature in the increment year. The temperature effect is clearly nonlinear even on the log scale. In addition to age, temperature (and individual-specific growth effects), the modeling demonstrated systematic biologically interpretable effects of food amount available (taken either as percid fry or young-of-the-year pikeperch quantifications). Much smaller (about an order of magnitude smaller than effects of temperature and food), but still highly significant was the effect of the initial length on increment growth. Namely of the ratio of the individual length at the beginning of increment interval to the median length of the individuals of the same age. The model can be used for predicting pikeperch growth increments in future seasons.

SESSION 6. INNOVATIVE MANAGEMENT FOR CONSERVATION OF FRESHWATER AREAS AND AQUATIC BIODIVERSITY AND ADVANCES IN RECREATIONAL FISHERIES RESEARCH AND MANAGEMENT

RESERVOIR FISHERIES IN THE CHANGING WORLD: WILL THE ANGLERS PARADISE COME BACK?

Tomáš Jůza, Lukáš Vejřík, Marek Šmejkal, Katerina Soukalová, Daniel Bartoň, Martin Čech, Josef Hejzlar, Marie Prchalová, Milan Muška, Michal Tušer, Luboš Kočvara, Zuzana Sajdlová, Vladislav Draštík, Karlos Ribeiro de Moraes, Milan Říha & Mojmír Vašek
Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia
Million Tesfaye
Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia and University of South Bohemia in České Budějovice, Vodňany, Czechia
Jan Kubečka, David Boukal, Petr Blabolil & Radka Symonová
Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia and University of South Bohemia, Faculty of Science, České Budějovice, Czechia
Carlos Martinez
Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia and School of Biochemical Engineering, Pontificia Universidad Católica de Valparaíso, Chile
Marek Brabec
Institute of Computer Science, Czech Academy of Sciences, Prague, Czechia
Allan T. Souza
Institute for Atmospheric and Earth System Research INAR, Forest Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Finland

The Lipno Reservoir was once the most productive pikeperch (*Sander lucioperca*) angling fishery in the Czech Republic. However, around 2005, catches of this species abruptly dropped to 10% of their previous levels. Growth analyses using otoliths and scales showed slow growth (legal size attained after 7–8 years) probably due to insufficient food resources. In response, stricter pikeperch protection measures were implemented in 2009. Over the following years, the food base for pikeperch improved, leading to increased recruitment and growth rates. As the population started to recover, some protection measures were alleviated in 2016, resulting in a partial recovery of catches. Despite the expectations, population growth stagnated in 2018, and both numbers and biomass started to decline. A detailed cohort analysis revealed a 20–30% increase in annual natural mortality during 2017-2020. An even higher increase of mortality was observed in the carp population (*Cyprinus carpio*) in the same period. This rise in mortality coincided with a dramatic increase in the biomass of wels catfish (*Silurus glanis*). Population estimates indicated a surprisingly high biomass of catfish (35 kg/ha in deeper parts of the reservoir). Carp and pikeperch comprised 46% and 11% of weight of the catfish's ingested prey, respectively. This suggests that the fishery management strategies in the reservoir must adapt to the presence of this new top predator.

The study underlines the need for thorough assessment of all important players in the food web to develop robust predictive models that explain changes in fish populations. Reliable models are invaluable for making the right decisions in stock management under changing conditions.

FROM SURVEY TO ACTION – LESSONS LEARNT FROM LARGE-SCALE PLANNING AND IMPLEMENTATION OF FISH HABITAT IMPROVEMENTS IN RIVERS

Amanda Vasule & Kaspars Abersons
Institute of Food safety, Animal Health and Environment "BIOR", Riga, Latvia
Jolanta Jēkabsone, Jānis Šīre & Linda Fībiga
Latvian Environment, Geology and Meteorology Centre, Riga, Latvia.

Fish are a very important group of aquatic organisms. They are an integral part of the ecosystem and important bioindicators, but they also have a high socioeconomic importance (Roni and Beechie, 2012). Fish populations have declined in recent centuries, mainly due to hydromorphological changes in rivers (EEA. 2012). To reverse these changes, river restoration measures have been implemented. However, the environmental objectives of these measures are often not achieved, mainly due to insufficient initial research. LIFE GoodWater IP is a large-scale project that aims to improve the status of water bodies at risk. Among other things, the project pays particular attention to reducing or mitigating the effects of hydrological and morphological alterations of water bodies at risk and to improving the quality of habitats for ecologically vulnerable fish species. In order to increase the effectiveness of the restoration measures, the planning of these measures has been based on extensive river mapping.

The rivers of interest were mapped using two methods: the Standard River Habitat Survey or RHS (Raven *et al*., 1998), which shows the overall condition of river habitats, and the Trout Habitat Survey or THS (ICES, 2011), which shows the suitability for trout reproduction. The methodology of the THS was modified to allow mapping of larger river reaches than the original (Tutiņš, 2019). A total of 152.3 km was mapped in four rivers (Aģe, Mergupe, Auce and Zaņa) and some of their tributaries. The status of the fish fauna was assessed by electrofishing. A total of 50 sampling sites were surveyed.

The mapping exercise identified a total of 96 measures to improve the quality and accessibility of fish habitats. These measures range from large-scale solutions, such as minimizing the impact of river bed straightening and hydropower development, to local measures such as stone pile weirs, poorly constructed culverts and others. The measures identified were later discussed with the local community and other stakeholders, and a final list of measures was developed. The list contains four groups of measures: 1-Priority measures to be implemented within the LIFE GoodWater IP project; 2-measures to be implemented if there is a surplus of resources after implementation of the priority measures; 3-other measures that can reduce the impact of hydromorphological changes; and 4-important measures beyond the scope of the LIFE GoodWater IP project. The first two groups mainly include reducing the impact of straightening of riverbeds and other measures to increase hydromorphological diversity and habitat quality. Groups 3 and 4 mainly include waste removal and large-scale solutions for fish migration.

Since 2021, the practical implementation of the identified measures has begun. One of the most effective measures so far is the artificial spawning ground created as part of environmentally friendly channel maintenance in the river Mazupīte. The spawning ground was created in the summer of 2023, and in 2024 the spawning of river lamprey *Lampetra fluviatilis* was observed in this area, and the density of sea trout *Salmo trutta* parr reached 22.4 ind./100 m^2. Implementation of other measures is scheduled for the next few days and ongoing monitoring takes place to evaluate the achieved results. Unfortunately, not all of listed measures can be implemented. There are various reasons for non-implementation, but the most common are opposition from landowners or other stakeholders, insufficient budget, inadequate legal support, or opposition from the public/landowners.

Figure 1. Lamprey spawning in the newly created spawning site in Mazupīte river

In summary, river mapping facilitated the identification of several previously unknown yet significant objects and factors, there by confirming the utility of the approach (large-scale mapping prior to planning restoration measures). A positive aspect was the early involvement of stakeholders. However, it must be acknowledged that several measures may still not be implemented. Clearly, future projects need to place much greater emphasis on engaging the local community, landowners, and other stakeholders. Legislation also plays a crucial role.

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IMPLEMENTING A DOUBLE APPROACH FOR ENHANCED CONSERVATION EFFORTS: EXAMPLE OF SINGLE-TARGET AND METABARCODING ENVIRONMENTAL DNA FOR FISH ASSESSMENT IN SOUTHERN CROATIA AND BOSNIA & HERZEGOVINA

Matej Vucić & Ana Galov
University of Zagreb Faculty of Agriculture, Croatia and eDNAture, Grubišno Polje, Croatia
Göran Klobučar
University of Zagreb Faculty of Agriculture, Croatia
Thomas Baudry & Frédéric Grandjean
Université de Poitiers, France
Maks Deranja & Karmela Adžić
Croatian Biology Research Society, Zagreb, Croatia
Dušan Jelić
BIOTA, Grubišno Polje, Croatia
Željko Pavlinec
University of Zagreb Faculty of Agriculture, Croatia and Aquarium Pula, Croatia

Environmental DNA (eDNA) is an innovative and efficient method, which has revolutionized the fish biomonitoring, giving access to taxonomic lists in a non-disruptive way, unlike traditional sampling techniques, reputed non-selective and sometimes harmful for the environment. Consequently, the use of eDNA enables research on aquatic ecosystems without the need to collect biological specimens, thus minimizing the risk of depleting wild fish populations and biomass through sampling, particularly for species that are rare, elusive and/or endangered. Environmental DNA, derived from fish releasing DNA into the water through feces, tissues, or secretions, can be utilized to track crucial elements of fish ecology, such as the composition and distribution of taxa, species abundance, and population dynamics (Thomsen and Willerslev, 2015; Xing *et al*., 2022). It is particularly effective for detecting rare, endangered, or elusive species, providing unprecedented sensitivity and the ability to monitor ecosystem-level processes. eDNA is extensively used in fish ecology for species diversity studies, conservation efforts, and monitoring of threatened and invasive species (Bohmann *et al*., 2014; Xing *et al*., 2022).

Dinaric Karst is the hotspot of freshwater fish biodiversity, harboring numerous endemic and stenoendemic species, which are distributed in streams, rivers or even in underground cave systems, often difficult to access and sample. One of the largest and most diverse freshwater systems in the Bosnian Dinarids and Croatian Adriatic is the Neretva River system, a key river ecosystem, hosting over 30 species, with 17 of them being classified as endemic. Konavosko polje is the most southernly located karst field in Croatia, inhabited by stenoendemic cyprinid species, *Telestes miloradi*, as well as by *Anguilla anguilla*, both threatened by multiple non-native and invasive freshwater fish species.

The authors conducted eDNA sampling on 8 localities in the Konavosko Polje and 25 localities in Neretva River system by filtering 3-6 liters of water per filter. The authors applied a combination of single target detection, for *A. anguilla* (Weldon *et al*., 2020) and *T. miloradi* (designed in the present study) by RT-PCR with fluorescent TaqMan probes, and a metabarcoding approach *via* Illumina NextSeq 2000 sequencing (2 x 150 bp kit) using the universal 12S rRNA (MiFish) primers (Miya *et al*., 2015). Both single-target detection and metabarcoding approaches indicated the continued presence of *T. miloradi* in the Konavosko polje, while its detection using electrofishing was not possible. *Anguilla anguilla* is known to be distributed extensively in the Neretva River, particularly in the Neretva River delta, including subterranean habitats (Vucić *et al*. 2023). Interestingly, eDNA metabarcoding also revealed the presence of *A. anguilla* in Konavosko polje. Moreover, this latter also alerted to the presence of non-native and invasive freshwater fish species in the studied areas (such as *Cyprinus carpio*, *Lepomis gibbosus*, etc.), together with rare and endangered species, such as *Acipenser* sp. The research showed the high reliability of the eDNA tools (both single-target and metabarcoding) when it comes to investigate fish communities, with the detection of some rare or highly invasive species, non-detected by traditional methods. As described in many other studies, eDNA metabarcoding represents a good tool for stakeholders in future biomonitoring and early detection of invasive species studies. Nevertheless, despite the groundbreaking capabilities of eDNA metabarcoding in providing essential information for species identification and conservation activities, the authors warn the future users about some limitations. First, the databases required for the taxonomic assignment during the metabarcoding workflow can be insufficient, leading to taxonomically biased results, and it can be necessary to complete them. In line with that, a good knowledge of the studied ecosystem is essential for an accurate taxonomical classification of caught individuals (for database completion) and interpretation of the results. This can provide a more significant challenge for regions with high numbers of endemic and rare species that are inadequately covered by databases.

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IMPACT OF A DAM ON REPRODUCTIVE TRAITS OF CHUB (*Squalius cephalus*)

Matko Dražić, Jakov Radečić & Ivan Špelić
University of Zagreb Faculty of Agriculture, Croatia
Marina Piria
University of Zagreb Faculty of Agriculture, Croatia and University of Lodz, Poland

Dam construction directly impacts water flow, sediment transport, water temperature, and habitat. These changes negatively affect fish communities, disrupt natural fish migrations and may reduce the reproductive success (Vörösmarty *et al*., 2010). The habitat above the barrier becomes more similar to stagnant water, while the habitat below the barrier retains river-like conditions. This is especially evident in smaller watercourses where small hydropower plants (HPP) without fish passages have been constructed. The Sunja River is a small river located in the Black Sea Basin in continental Croatia, which is fragmented by a number of weirs and dams on its course. The chub (*Squalius cephalus*) is one of the main angling species in the area, because it reaches a considerable size and has a large population in the Sunja River. The aim of this research was to investigate differences in the reproductive behaviour of chub populations isolated eight years in the reservoir above the dam compared to those inhabiting the river situated in Black Sea Basin below the dam.

Sampling was conducted on the Sunja River at three locations: Klipić (KL), Mlin (ML), and Staza (ST), using an electrofishing device and recreational fishing methods. The KL location is situated downstream of the hydroelectric power plant (HPP) on the Sunja River, where fish are only connected to the main course of the Sava River due to the absence of a fish pass. ML is located near the HPP barrier, within the HPP reservoir, while ST is situated further upstream. Between ML and ST are the remnants of an old mil which represents another barrier. During flood periods fish can migrate between ML and ST and this stretch is used for sport fishing purposes. Water temperature was measured at each sampling location.

A total of 42 adult chub specimens were analysed (12 from KL, 15 from ML, and 15 from ST). The total length (TL, cm) and weight (W, g) of each specimen were measured. The gonads were then removed, weighed (GW, g), and preserved in alcohol. The gonadosomatic index (GSI) was calculated using the formula: GSI = 100 (Wg/W) and the dataset was transformed using Log10 due to non-normal data distribution. Variations in GSI between sex, sampling locations, dates, and water temperature were analysed and tested using a two-way ANOVA.

The water temperature at the ST location was the highest compared to the other sampling locations. No significant differences in GSI were found between sexes or between the ML and ST locations ($p>0.05$). Therefore, the dataset from the areas above the dam was considered as representing a single population, with sexes grouped together. A box-and-whisker plot shows lower GSI values on 19 April at the locations above the dam (ST), when the water temperature was 11.2 °C. The outliers represent specimens that had not yet spawned (Figure 1).

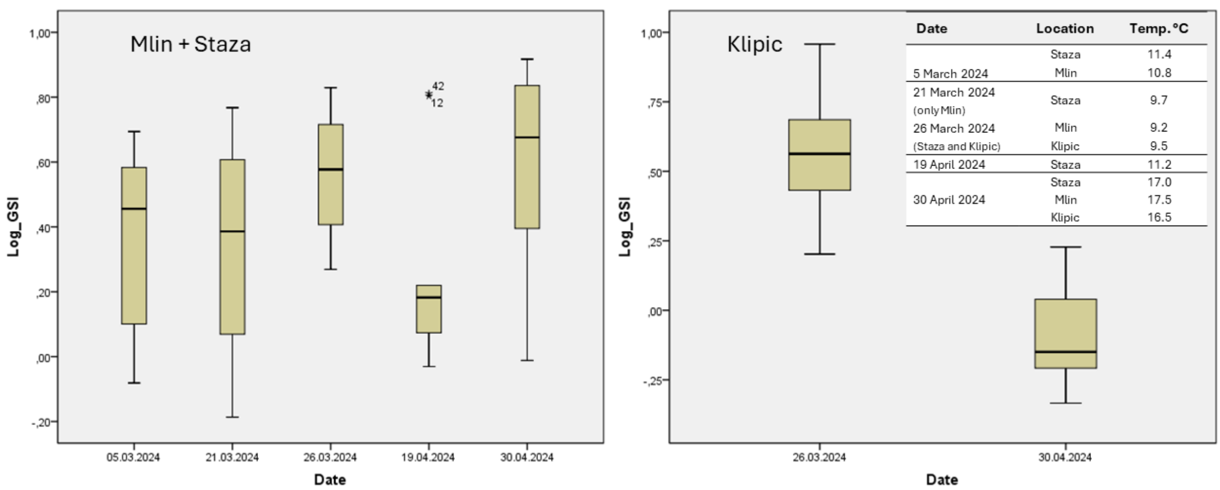

Figure 1. Water temperatures and GSI values distribution in chub (*Squalius cephalus*) during spring at locations above the dam (Mlin + Staza) and below the dam (Klipić) on the Sunja River. *Source*: author's own elaboration.

A statistically significant difference in GSI was found between the KL and ST locations. Testing GSI between sites above and below the dam on specific dates and temperatures revealed that GSI was significantly lower at ST on April 19 (11.2 °C) and at KL on April 30 (16.5 °C) ($p < 0.05$). On April 30, fish above the dam had a significantly higher GSI.

Although data on 19 April missing on KL, results suggest that individuals above the dam spawned earlier than those below the dam. Populations above the dam are likely already preparing for the next spawning cycle, as chub are known to be portion spawners (Raikova-Petrova *et al*., 2012).

Based on the findings of this research, it can be concluded that chub spawning in the Sunja River occurs in April, at water temperatures between 11.2 °C and 16.5 °C. The results also suggest that in still water habitats, such as the HPP reservoir, chub begin their first spring spawning at lower temperatures and potentially earlier than in natural river conditions. These differences are likely caused by the HPP barrier and the absence of fish passes. However, further investigation into chub reproductive behaviour is needed due to limitations in the sampling design of this study.

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TWO POPULATIONS OF CHUB (*Squalius cephalus*) SEPARATED BY A DAM EXHIBIT DIFFERENCES IN OTOLITH AND SCALE SHAPE ORAL PRESENTATION

Jakov Radečić, Matko Dražić & Ivan Špelić
University of Zagreb Faculty of Agriculture, Croatia
Marina Piria
University of Zagreb Faculty of Agriculture, Croatia and University of Lodz, Poland.

The construction of dams and barriers disrupts river continuity, directly hindering fish migrations. In addition to the obvious physical obstruction, dams cause complex changes such as increased fluctuations in water levels and temperature downstream, and the transformation of upstream rivers into more stagnant conditions (Mrakovčić *et al*., 2006). These altered environmental conditions affect fish populations by influencing their feeding habits, spawning times, and even impacting body asymmetry, otolith growth, and scale development (Planchet *et al*., 2023). The primary aim of this study was to use geometric morphometrics method to differentiate fish populations from different habitats by analyzing the shapes of otoliths and scales in chub (*Squalius cephalus*), as chub is one of the most numerous and most desirable angling species in the area.

The study was conducted on the Sunja River in central Croatia, with three locations selected: one downstream of the hydropower plant (Klipić, KL) and two upstream of the dam (Mlin, ML, and Staza, ST) (Figure 1A).

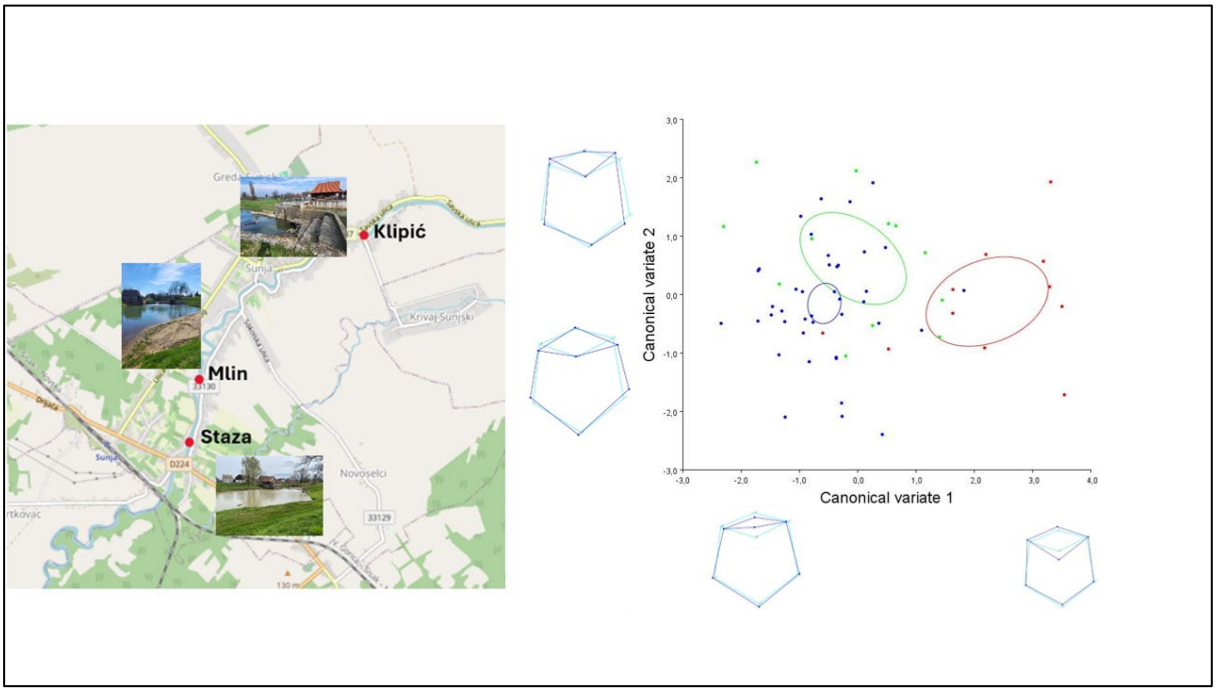

Figure 1. (A) Sampling sites; (B) Visualization of CVA analysis results and differences in the shape of chub scales (red colour: Klipić; green colour Mlin, blue colour Staza location) using deformation grids (CV1 and CV2, extremes 3 and -3);
Sources: Author's own elaboration. Map: OpenStreetMap (2024).

A total of 64 individual chub were collected using electrofishing methods. Scales and otoliths were extracted for further analysis. Photographs of the scales and otoliths were taken using a stereomicroscope equipped with a camera, and landmarks were marked using TpsDig2 software. The images were then analyzed with MorphoJ software to determine whether significant shape differences existed between the groups from the different locations.

Results from Canonical Variate Analysis (CVA) indicated that the most significant shape differences were observed in the portion of the scales that penetrates the fish's skin and in the overall scale width (Figure 1B). Both CVA and Discriminant Function Analysis (DFA) revealed significant differences in the shape of scales between the ST and KL locations ($p<0.01$). Similar findings were observed for otoliths.

These results suggest that chub populations at the ML and ST locations, compared to those at the KL location, have developed distinct features in the shapes of their scales and otoliths after eight years of isolation. This differentiation may be attributed to varying biological and hydrological conditions, particularly since fish from KL live in running water and can freely migrate downstream, in contrast to the ML and ST populations, which are confined to still water environments. Such conditions could, over time, impact chub populations and affect the area's ecosystem services, particularly angling. This study demonstrates that geometric morphometrics applied to fish scales and otoliths is a powerful tool for distinguishing between fish populations exposed to different environmental conditions.

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THE OBSEA DEMO-SITE WITHIN THE DIGI4ECO PROJECT

Marco Francescangeli, Damianos Chatzievangelou, Giacomo Picardi, Ivan Masmitja, Nixon Bahamon, Juliana Quevedo, Jordi Grinyó, Nathan J. Robinson & Jacopo Aguzzi
Institut de Ciències del Mar (ICM-CSIC), Barcelona, Spain
Gerard Llorach-Tó, Jordi Ribera-Altimir & Joan B. Company
Institut de Ciències del Mar (ICM-CSIC) and Institut Català de Recerca per la Governança del Mar (ICATMAR), Barcelona, Spain
Antonio Castellicchio & Rahul Barbagi
University of Pula, Croatia
Joaquin Del Río & Daniel Mihai Toma
Universitat Politècnica de Catalunya, Barcelona, Spain
Morane Clavel-Henry
GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany
Marta Pujol Baucells
Institut Català de Recerca per la Governança del Mar (ICATMAR), Barcelona, Spain
Ana Gravilovic & Oliver Baric
University of Zagreb Faculty of Agriculture, Croatia
Neven Cukrov
Ruđer Bošković Institute, Šibenik, Croatia
Alan Berry
Marine Institute, Galway, Ireland
Elias Chatzidouros
EGINTECH Systems International, Limassol, Cyprus

Climate change and human activities are having an increasingly detrimental impact on marine ecosystems and resources at a global scale (Halpern *et al*., 2019). To cope with this alarming situation, the European Commission (EC) adopted the Marine Action Plan to protect and restore marine ecosystems in the European Union (EU). In this context, Digital Twins of the Ocean (DTOs) are virtual representations of the physical ocean, or Physical Twin (PT), that allow for predictive simulations of marine ecosystems, including protected areas and their conservation status (Nativi *et al*., 2021).

The DIGI4ECO European project aims to obtain new knowledge for marine ecosystems' management and restoration collecting advanced biodiversity and ecology information, as this is a today's DTOs gap (Aguzzi, 2024). Within this project, the OBSEA multiparametric platform (www.obsea.es) was designated as a demo-site to host a network of robotic fixed and mobile platforms (a satellite video-lander, a surface meteo-buoy and a benthic video-crawler) as a PT. The seafloor cabled video-observatory OBSEA is operating since 2009 in the NW Mediterranean Sea at 4 km off Vilanova i la Geltrú (Barcelona, Spain) harbour and 20 m depth inside the "*Colls i Miralpeix*" Natura2000 marine reserve (Del Río *et al*., 2020). The fixed cameras in the OBSEA platform (i.e., one of the cabled observatory itself and one installed on a lander) capture images synchronously and in continuous time-lapse (30 min. frequency). The mobile crawler is matching this frequency with 10 m-long, back and forth visual census transects. (Falahzadeh *et al*., 2023). Image and video data records are accompanied by a concomitant environmental data collection, either in-situ with the OBSEA or at the surface with a meteorological buoy station.

All imaging products are being processed with Artificial Intelligence (AI) algorithms for automated fish detection and classification, which generates real-time time-series of species counts. Derived biological information is analysed with environmental conditions, via multivariate statistic approaches, to establish relationships to be used for ecological modelling. Local results are being spatially scaled with nearby commercial and recreational fisheries data on coastal fishes from ICATMAR (Ribera-Altimir et al., 2023), to extrapolate local count results to population densities over larger areas. Crawler imaging is being used for seascape ecology approaches based on photo-mosaicking supporting interactive web applications to visualise a monitoring scenario of environmental and biological fluctuations and trends. This will be the core of the OBSEA DTO with real-time data (Figure 1) (Llorach-Tó *et al.*, 2023). Finally, experience and knowledge from data collection, storage and treatment from OBSEA will be used to implement the video monitoring practices of a coastal Natura2000 area at the Krka delta (Sibenik, Croatia) (Aguzzi *et al.*, 2020). A tandem and synchronous multiparametric collection at both NW and E Mediterranean sites will improve our knowledge of the ecological niches of common fishes under different latitudinal and oceanographic scenarios in the Mediterranean Sea, as well as the presence of new invasive species.

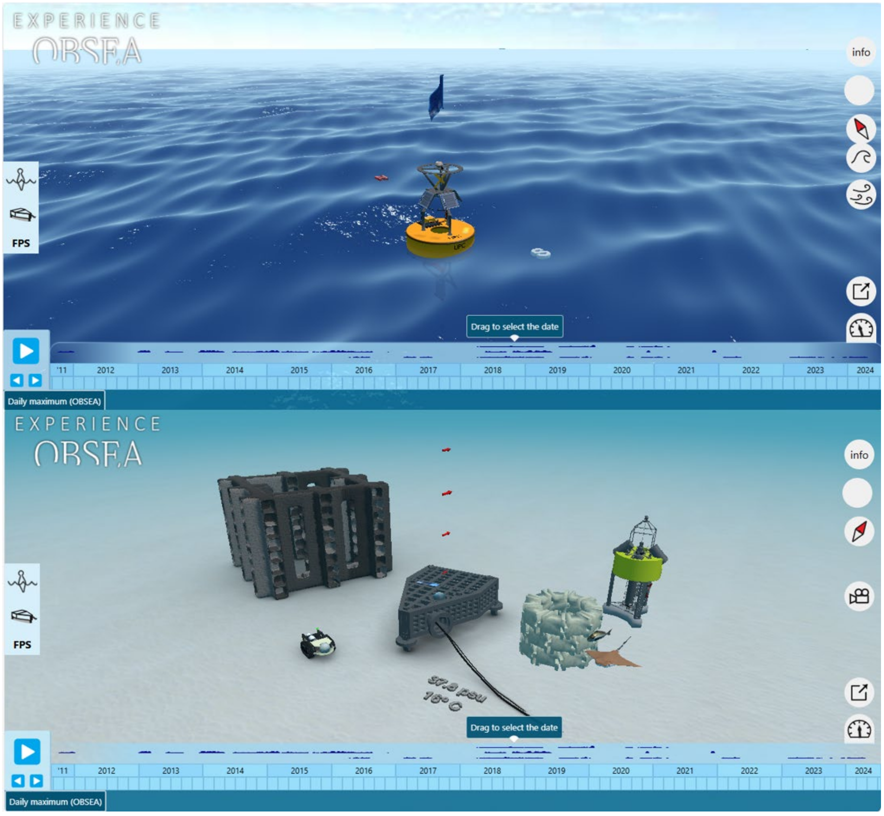

Figure 1. Virtualization of the OBSEA monitoring environment as an interactive web application displaying the ecological monitoring platforms and historical data collected by the platforms. Top panel: meteorological buoy; bottom panel: permanent seabed cabled observatory, video-crawler, biotope structures (concrete and metallurgic industrial slag), and satellite lander.

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THE ONSET OF A PREDATOR: ECOLOGICAL AND MOLECULAR MECHANISMS FOR THE FORMATION OF SUCCESSFUL PIKEPERCH YEAR CLASS

Tomáš Jůza, Lukáš Vejřík, Marek Šmejkal, Kateřina Soukalová, Daniel Bartoň, Martin Čech, Josef Hejzlar, Marie Prchalová, Milan Muška, Michal Tušer, Luboš Kočvara, Zuzana Sajdlová, Vladislav Draštík, Karlos Ribeiro de Moraes, Milan Říha & Mojmír Vašek
Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia
Million Tesfaye
Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia and University of South Bohemia in České Budějovice, Czechia.
Radka Symonová, David Boukal, Petr Blabolil & Jan Kubečka
Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia and University of South Bohemia, Faculty of Science, Department of Ecosystem Biology, České Budějovice, Czechia
Carlos Martinez
School of Biochemical Engineering, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile
Marek Brabec
Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia and Institute of Computer Science, Czech Academy of Sciences, Prague, Czechia
Allan T. Souza
University of Helsinki, Finland

In the late summer, young-of-the-year (YOY) pikeperch (*Sander lucioperca*) can be grouped into three subcohorts: extremely small (ES) dwarfs, normal fingerlings, and piscivores. Dwarfs and normal fingerlings are planktonic and planktivorous. Piscivorous YOY are demersal and to large extent cannibalistic preying on their planktonic conspecifics and perch. The authors analysed 12 years of biotic and abiotic data collected between 2003 and 2022 at Lipno Reservoir (Czechia) to identify drivers of variability in the abundance of individual pikeperch subcohorts and their impact on the new year class (Table 1).

Table 1. Significant predictors (drivers) of the abundance of the subcohorts in the most significant months of the first year of pikeperch life.

YOY's subcohort	**Months**					
	March	April	May	June	July	August
Dwarfs		T			Cladocera>1 700 µm, Copepoda 1–3 mm and 0.5–1 mm	Copepoda 1–3 mm
Normal fingerlings	T		T	T, P	Cladocera>1 700 µm	
Piscivorous					Cladocera>1 700 µm	YOY perch, dwarfs, Cladocera>1 700 µm, P

Notes: P, precipitation; T, Temperature; YOY, young-of-the-year.
Source: author's own elaboration.

The importance of dwarf pikeperch achieving the standard length 10-40 mm at the end of August (Jůza *et al*., 2013) appears to be mainly in providing initial food for the larger cohorts. The authors found no correlation between the abundance of this subcohort and the year class strength at the age 1+.

The switch to piscivory is desirable in the (semi)natural conditions like water reservoirs to assure the species recruitment. In aquaculture, piscivory and cannibalism represent a serious problem. Hence, the authors explored molecular and cellular mechanisms accompanying the switch from planktivory to piscivory in YOY pikeperch. The authors analysed brain transcriptomes of individuals of the planktivorous and piscivorous subcohorts from the Lipno 2022 ichthyological survey. The data indicate a less dynamic brain development activity in planktivores with the focus on transcription of non-muscle myosins and related genes. In piscivores, the authors recorded a far more dynamic development dominated by brain collagen metabolism genes and extracellular matrix (ECM)-related genes. A highly dynamic transcription occurred in piscivores with significantly upregulated genes belonging to all Gene ontology (GO) categories (i.e. cellular components, molecular function and biological process) and numerous GO terms. In planktivores, while less GO categories and terms were significantly upregulated, indications of transcription of appetite regulators, (an)oregixenic factors, suggest so far ununderstood molecular drivers of voracity (Symonová *et al*., submitted). These may be very important for the planktivorous fingerlings as they have virtually several weeks to switch towards demersal piscivory to catch up with their piscivorous conspecifics.

In August, planktivorous fingerlings are more than 20 times more abundant than piscivorous individuals but their survival expectancy is lower. However, larger abundance plays also an important role. The comparison of subcohorts abundances with the abundance of age 1+ pikeperch shows that both subcohorts contribute nearly equally to the recruitment of the new pikeperch year classes. During autumn, some planktivorous fingerlings still have a good chance to switch to piscivory.

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Acknowledgement

This study was supported by the ELIXIR Staff Exchange Project CZ-USB-2023-SEP-46 to R. Symonová.

SESSION 7. CITIZEN SCIENCE AND SOCIOECONOMIC ASPECTS OF FRESHWATER FISHERY AND AQUACULTURE

DEVELOPMENT AND STATUS OF A CITIZEN SCIENCE ANGLER APP – THE SWEDISH CASE

Göran Sundblad
Swedish University of Agricultural Sciences, Drottningholm, Sweden

Angler apps have become useful tools to collect data supporting assessments of fish stocks and providing advice for fisheries management. Along the entire coastline of Sweden and in the five largest lakes, angling with rod-and-line is open access for all, both for national and international anglers, entailing a significant challenge for recreational fisheries surveys. The top three targeted species in Swedish recreational fisheries are Eurasian perch, northern pike and brown trout. Coincidentally, current monitoring for northern pike and brown trout is inadequate and there is a need to develop monitoring or other data collection methods. In 2021, the researchers were commissioned to initiate an angler app to obtain better data for status assessments and at the same time increase stakeholder involvement in (recreational) fisheries management. The researchers developed the app together with professional fishing guides to make it as simple and user-friendly as possible while meeting scientific standards and needs. The app was strategically launched as a citizen science project in spring 2024, by expanding from fishing guides to the rest of the angler community. An obligatory survey directed to interested opt-in users highlight the current user group as a high-avidity expert set of anglers.

Data collected by the app include individual trip information (time, effort and target species), catch data (species, length, weight, and when relevant stocked or wild origin) as well as positions, either collected through the GPS during live-reporting, or by clicking on a map for post-trip reporting. The app also includes the possibility to report interactions with cormorants and seals, to collect data to inform management on predator-fisheries conflicts. Key data include fish length, which is used for length-based stock assessments. To motivate reporting, users receive personalized fishing diaries, including maps, generated through a library developed in the statistical software R.

A CITIZEN SCIENCE ENDEAVOUR: CHANGING THE PLIGHT OF A CRITICALLY ENDANGERED NATIVE FRESHWATER FISH, THE CRUCIAN CARP, IN CZECHIA

Daniel Bartoň, Sandip Tapkir, Yevdokiia Stepanyshyna, Zuzana Šmejkalová & Marek Šmejkal
Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia
Kiran Thomas
Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia.and Faculty of Science, University of South Bohemia, České Budějovice, Czechia.
Lukáš Kalous & Milan Gottwald
Czech University of Life Sciences, Prague, Czechia.
Marek Brabec
Institute of Computer Science, Czech Academy of Sciences, Prague, Czechia
Petr Velenský
Zoo Praha, Prague, Czechia

The citizen science approach helps to gather relevant ecological data with high coverage and reduces time and cost to solve intriguing conservation issues. Native crucian carp (*Carassius carassius*) has encountered a sharp population decline in central Europe and is currently critically endangered in the Czech Republic, prompting conservation measures. The citizen science project “Save the Crucian Carp” has been started to map current distribution, conserve, and restore it. The project aimed to analyse the effectiveness of this project which recorded the current and historical distribution of the crucian carp and the invasive gibel carp (*Carassius gibelio*), which is largely behind this decline.

A total of 953 citizens provided information on the species distribution and details of occurrence. The authors summarized this dataset for the success of tips, citizens' emotional attitudes towards conservation, and how outreach activities increase citizen participation. A comparison with the National Conservation Agency dataset was also carried out. The success rate of respondents' tips after verification was 35% for crucian carp. A positive correlation was observed between respondents’ species identification quiz scores and the number of tips they provided. Respondents between the ages of 30 and 50 responded more positively to conservation efforts than other age groups. The increase in citizen participation associated with the dissemination of information through public media underscores the importance of conservation awareness for the success of citizen science endeavours. This project is currently making a significant contribution towards conservation and can promote this approach for the conservation of other freshwater species worldwide.

INSIGHTS FROM PARTICIPATORY AND COLLABORATIVE RESEARCH IN AFRICA AND ASIA: OPPORTUNITIES FOR STRENGTHENING THE ASSESSMENT AND MANAGEMENT OF INLAND CAPTURE FISHERIES

Robert Arthur
Food and Agriculture Organization of the United Nations, Rome, Italy.

Inland capture fisheries create numerous challenges for assessment and management. In changing environments and with diverse and evolving needs and opportunities, there is increasing need for evidence to inform decision-making. In often dispersed and dynamic management contexts, collaborative approaches between researchers, government agencies, users can facilitate shared understandings and create opportunities for adaptive management. Experiences in different inland fisheries settings with approaches that provided opportunities for engaging fishers in research, monitoring and assessment are described, based on examples from Africa and

South and Southeast Asia. These approaches included the documentation of local knowledge, development of monitoring programmes, collective identification of critical uncertainties and development and implementation of adaptive management strategies to address critical uncertainties and improve fisheries management outcomes to better meet local needs. The potential for these approaches, based on strengthening local capabilities, for citizen science and collaborative management of inland fisheries are explored.

APPENDIX D

ABSTRACTS OF POSTER PRESENTATIONS

AN APPLICATION OF THE LINEAR OBSTACLE DENSITY CALCULATION METHOD USING GOOGLE EARTH.

Goran Jakšić, Krešimir Kuri, Margarita Maruškić Kulaš & Nikolina Boić
AQUATIKA – KARLOVAC FRESHWATER AQUARIUM Public Institute, Croatia
Marina Piria
University of Zagreb Faculty of Agriculture, Croatia and University of Lodz, Poland.

For migratory species, particularly Acipenseridae and Salmonidae, dams and obstacles (e.g. remnants of old watermills) represent a major threat to their survival (Jakšić et al., 2023). Obstacles can be very dense in some areas and may pose significant problems for migratory species, especially during low water levels. These structures in the river are clearly visible in Google Earth (earth.google.com), making it possible to count them (Figure 1). The aims of this paper are to: (a) determine an equation that calculates linear obstacle density in aquatic environments, and (b) apply this method to a section of the Kupa River to assess number obstacles per unit length which may represent barriers for migration of Danube salmon (*Hucho hucho*).

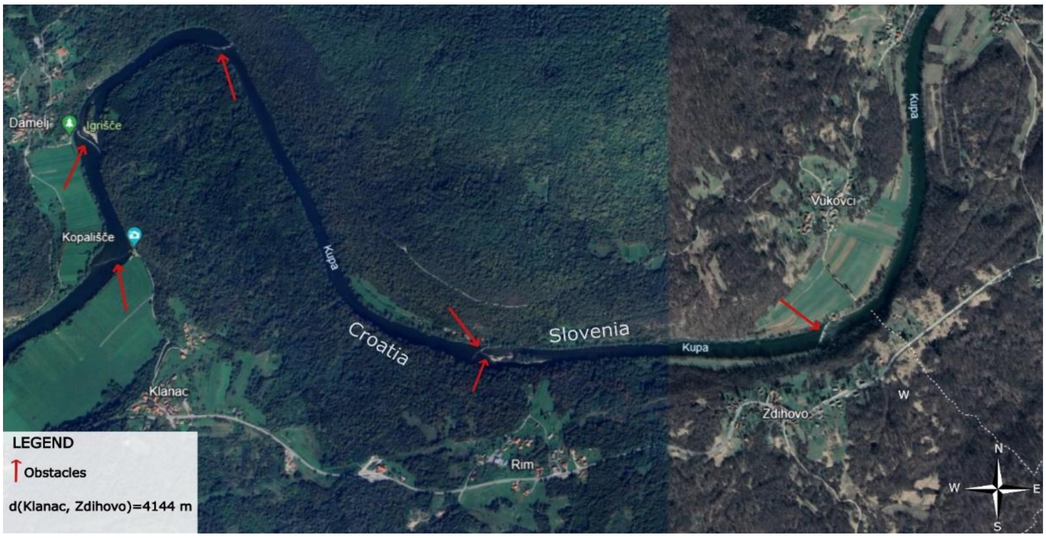

Figure 1. A Google Earth clip showing the obstacles to migratory fish during low water levels on the Kupa River
Source: authors' own elaboration.

Linear density (λ) is a measure of the amount of any characteristic value per unit length. A mathematical equation for calculating the *Linear Obstacle Density* (acronym *LOD*) was introduced for the purpose of estimating the number of obstacles $\sum N_i$ (i denotes any one obstacle in a series) per transect unit $d(A,B)$ (river transect from site *A* to site *B*):

$$LOD = \lambda \stackrel{\text{def}}{=} \frac{\sum N_i}{d(A,B)}.$$

The testing the *LOD* method the five observers (authors of this research) independently counted obstacles visible in Google Earth on the transect of the Kupa River [$d(A, B) = d$ (Kupa source, town of Ozalj) = 133 km]. This transect was taken because this is territory which Danube salmon can use for their migration.

Results indicated that the selected transect has an average of 52 obstacles. The calculation of *LOD* approximately shows that there are two obstacles for every five kilometres in the Kupa River (*LOD* = 0.39 ± 0.04 1/km) (Table 1).

Table 1. Results of the *Linear Obstacle Density* method for the obstacles in the Kupa River from its source to Ozalj town (133 km) counted by five observers (OBS) using Google Earth (SD = standard deviation)

Observer	d (A, B) [km]	$\sum Ni$	LOD [1/km]
OBS1	133	52	0.39
OBS2	133	44	0.33
OBS3	133	51	0.38
OBS4	133	56	0.42
OBS5	133	57	0.43
Average±SD	133	52±5.14	0.39±0.04

*Observer = Author (1–5).
Source: authors' own elaboration.

Considering the density of obstacles identified in this work, the Danube salmon likely has difficulty migrating upstream to spawn in the Kupa River, especially if the water level is low during the spawning season. The disadvantage of this method is the potential for errors in identifying barriers whose origin (e.g. artificial or natural) is not clearly visible on Google Earth. However, evaluation by several observers may reduce these mistakes.

For the preservation of the species, the authors strongly recommend the removal of non-functional obstacles. It is also necessary to consider reducing future planned construction of dams and obstacles on the Kupa River and its tributaries to prevent the extinction of the Danube salmon.

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MONITORING FISH SPECIES IN THE DOBRA RIVER AFTER CONSTRUCTION OF THE LEŠĆE HYDROELECTRIC PLANT

Tomislav Kralj, Damir Valić
Ruđer Bošković Institute, Zagreb, Croatia

The distribution of fish species was studied from 2012 to 2023 in the karst river Dobra. After the construction of the Lešće Hydroelectric Power Plant (HPP), which altered the river's ecosystem, fish monitoring (May and October) was established biannually to observe changes in fish distribution. There were five monitoring sites in total. Four sites were located along the river: two in the flow reservoir (Trošmarija and 100 m above HPP Lešće), one at the start of the reservoir (downstream of the Gojak HPP) and one downstream of the Lešće dam (Skukani). There was also one site in the tributary of the Dobra, in the Bistrica stream. A total of 31 fish species were detected at the five sites, including three invasive species. Most species (26), were found at the Gojak site, while the fewest species (12), were found in the Bistrica stream. Invasive species were found at all five sites. All three invasive species (*Carassius gibelio*, *Lepomis gibbosus* and *Oncorhynchus mykiss*) were detected in Trošmarija site. Two invasive species (*L. gibbosus* and *O. mykiss*) were found at the 100 m above HPP Lešće and downstream of the Gojak HPP sites. In contrast, only one invasive species (*L. gibbosus*) was detected at the Skukani and Bistrica sites. Although the presence of invasive species at all monitoring sites is of particular concern because they can disrupt local ecosystems and outcompete native fish populations, the current data indicate that they do not currently pose a major threat to native species. This is particularly true for the Skukani site, where the last invasive species was detected in 2012, and for the Gojak and Bistrica sites, where invasive species were only detected in very small numbers (less than 5 individuals). The last occurrence of *L. gibbosus* was detected in Gojak in 2020 and in Bistrica in 2019. Continuous monitoring and management measures are essential to contain the impact of these invasive species and preserve the river's biodiversity. The data collected over the eleven-year period provides valuable insights into the ecological dynamics of the river and its tributaries. Understanding how the fish populations have responded to the environmental changes caused by the hydroelectric power plant, it will be possible to develop future conservation strategies and help maintain the ecological balance. The study shows the importance of regular and systematic monitoring to detect changes in biodiversity and implement effective environmental management. It also highlights the need for proactive measures to prevent the establishment and spread of invasive species to ensure the long-term sustainability of the Dobra River ecosystem.

LONG-TERM SALMONID RESTOCKING PRACTICE AND CONTEMPORARY CHALLENGES IN LATVIA

Santa Purviņa, Ruta Medne, Olga Revina & Žanna Bertaite
Institute of Food Safety, Animal Health and Environment "BIOR", Riga, Latvia.

The artificial stocking of salmonid resources in Latvia already takes place for 140 years, periodically interrupted by regional conflicts but resiliently continuing thereafter. The construction of hydroelectric power stations on the Daugava River, Latvia's primary salmon river, in the mid-20th century, necessitated the establishment of a scientifically based salmon stock reproduction programme. This initiative focused on maintenance of salmonid resources through the rearing of juveniles at the "Tome" fish hatchery. Despite the cessation of natural spawning grounds below the Rīgas hydropower plant, the artificially maintained salmon population has demonstrated long-term preservation of homing instincts, underscoring the programme's success. Additionally, salmon populations exist in the Gauja, Venta, Salaca, and in other Latvian rivers. However, the challenges of the 21st century, including climate

change and anthropogenic impacts, complicate the maintenance of healthy salmonid populations. To counteract declining population trends in the whole Baltic Sea area, concerted efforts are necessary to optimize hatchery operations, restore river ecosystems, and implement effective management strategies in future. Latvia's current strategy emphasizes balancing of wild stock enhancement, effective hatchery-based restocking, and habitat restoration.

IMPACT OF PROBIOTIC SUPPLEMENTATION ON THE SKIN-MUCUS MICROBIOTA, HEALTH, AND GROWTH PERFORMANCE OF REARED ATLANTIC SALMON

Vjačeslavs Revins, Olga Revina, Žanna Bertaite, Santa Purviņa, Justīne Padrevica, Kristofers Millers & Rainers Džeriņš
Institute of Food Safety, Animal Health and Environment "BIOR", Riga, Latvia

The skin of teleost fish, including reared Atlantic salmon (*Salmo salar*), serves as a flexible, scaled barrier that protects against external environmental threats. The outermost layer of this skin is coated with mucus, which not only acts as the first line of defense against infectious pathogens but also hosts a diverse bacterial community, comprising both commensal and opportunistic species. Despite its critical role, there is limited knowledge about the skin-mucus microbiome in reared Atlantic salmon, particularly in relation to overall health.

To enhance the health of reared salmon in an environmentally sustainable manner, fish farms should consider incorporating probiotics into aquaculture practices. These beneficial microorganisms can naturally and effectively improve fish health. This study investigates the composition of the salmon skin mucus microbiota and evaluates the impact of probiotic supplementation on the microbial community within the fish skin mucus.

Additionally, the research assesses the broader effects of probiotic supplementation on the health and growth performance of Atlantic salmon reared in a flow-through aquaculture system. The study focuses on key parameters such as growth rate, feed conversion efficiency, and disease resistance in salmon populations. The methodology includes administering selected probiotics through feed and bathing, also systematically monitoring fish health indicators and water quality.

Preliminary findings suggest that probiotic supplementation may enhance feed conversion ratios and improve resistance to common pathogens, though these results are still under investigation. The anticipated final results are expected to provide valuable insights into the benefits of probiotics in sustainable aquaculture practices, contributing to improved fish welfare and increased fish farm productivity. The outcomes of this study could have significant implications for the development of more efficient and eco-friendly salmon farming techniques, advancing the field of sustainable aquaculture.

SIMULATION-BASED VENDACE (*Coregonus albula*) BIOMASS ASSESSMENT IN A BOREAL LAKE WITH THE AQUATOX MODEL

Kseniia Kortunova, Eevi Kokkonen & Mikko Kolehmainen
University of Eastern Finland, Kuopio, Finland
Timo Huttula
TH Environmental Consulting, Finland
Teija Kirkkala
Pyhäjärvi Institute, Eura, Finland.

The challenge to protect biological resources and biodiversity is currently becoming one of the most socially significant problems, due to severe changes in natural ecosystems as a result of anthropogenic impact. This includes fish resources which play an important role in world economics. Vendace (*Coregonus Albula*) is one of the valuable fish species which faces intense commercial fishing pressure. It is found in a wide range of habitats - in the water bodies of England, Sweden, Finland, Norway, Denmark and other countries of the Baltic Sea basin and requires a modern assessment of its population dynamic in various environments. However, there is a lack of mechanistic modelling studies of boreal lakes ecohydrology. Based on the process-based model for ecological risk assessment AQUATOX the authors evaluated impact of fishing on vendace (*Coregonus albula*), nutrients and oxygen dynamics. The research was carried out in the mesotrophic boreal lake Pyhäjärvi in southwestern Finland (60°54′–61°06′N, 22°09′–22°25′E) (area 155 km^2, mean depth 5.4 m, max depth 26 m). The lake is covered by ice from November to April.

Figure 1. Vendace (*Coregonus albula*) as an example of commercial fishing, Finland
Source: Author's own personal archive.

The model describes an aquatic food web including detritus, planktonic algae, several types of invertebrates and several types of fish e.g. vendace (*Coregonus albula*) and ensures the mass balance for biomass and nutrients. The lake was allowed to stratify into epilimnion and hypolimnion. When the temperature was below 3 °C The ice cover condition was applied. It affects model atmosphere-lake exchange and significantly decreases light. Fishing of vendace older than 1 year was simulated as a boundary condition. Modeled time series of food web compartment biomass were obtained and analyzed for the modeling period 01.01.1992 – 31.12.2001. The effects of fishing on dynamics of vendace population and nutrient regime were evaluated with particular emphasis on lake restoration and risk assessment as related to overfishing.

IMPROVEMENTS OF PIKEPERCH ARTIFICIAL REPRODUCTION AND REARING METHODS IN LATVIA FOR MORE SUSTAINABLE RESTOCKING AND AQUACULTURE

Žanna Bertaite, Mārcis Ziņģis & Santa Purviņa

Institute of Food safety, Animal Health and Environment "BIOR", Riga, Latvia.

Pikeperch is considered one of the most promising freshwater fish species for domestic aquaculture in Europe. As a predator it has an important role in freshwater ecosystems, however, it is crucial to improve and adapt its existing reproduction and farming methods to ensure the future successful resource restocking and overall development of freshwater aquaculture on a European scale. In order to ensure the successful, economical production of this fish species in modern systems – recirculation aquaculture systems (RAS) – and maximise the number of healthy pikeperch larvae and fingerlings, artificial intensive breeding methods must be learned and, if necessary, adapted to local conditions.

The methods of the pikeperch artificial reproduction have been successfully tested using broodfish from Latvian waterbodies, annually adding and adjusting the applied biosecurity and hormonal stimulation methods, as well as egg incubation and fingerling feeding protocols. This year, in the newly built Aquaculture research and innovation infrastructure centre of the Institute "BIOR", the full cycle of pikeperch artificial reproduction and larvae rearing was carried out in fully controlled conditions, using three different recirculation systems with specialised tanks.

Figure 1. Good cortical reaction of the pikeperch eggs
Source: Author's own personal archive.

Figure 2. Pikeperch egg incubation in a recirculation aquaculture system
Source: Author's own personal archive

New facilities in Lithuania ensured the application of previously tested methods in a new, higher quality, which led to a significant improvement in the results obtained both in terms of the quality of the eggs and the number of obtained larvae to the total volume of eggs. The developments and gained experience will allow high-quality training for fish farmers and other experts in aquaculture, increase the number of released fingerlings for restocking of natural resources in conditions of a shortage of high-quality breeders, and will also allow for the constant maintenance of broodstock and off-season spawning in the future.

POOR MANAGEMENT OF PROTECTED AREA AND ITS FISH POPULATIONS LEADS TO DRAMATIC CHANGES IN THE STRUCTURE OF FISH COMMUNITIES – CIJEVNA RIVER CASE STUDY (MONTENEGRO)

Danilo Mrdak, Dragana Milošević & Vukoica Despotović
University of Montenegro, Faculty of Sciences and Mathematics, Podgorica, Montenegro
Stefan Ralević
Natural History Museum of Montenegro, Podgorica, Montenegro.

The Cijevna River was declared a Natural Monument on 21 December 2017. Prior to the designation of the river and its canyon as a protected area, fish populations were managed by the Podgorica Sport Fishing Association. Two consecutive studies, one conducted in June 2015 and another in June 2020, show drastic differences in the composition of fish fauna. In the most recent study, marble trout (*Salmo marmoratus*) was completely absent from the samples taken from the Cijevna River. Furthermore, the structure of the fish community had completely changed, with a dramatic decline in both abundance and biomass of brown trout (*Salmo farioides*) observed in Cijevna River. In 2020, NPUE (Number of Fish Per Unit Effort) decreased by 35%, while CPUE (Catch Per Unit Effort) values were lower by as much as 65% compared to those detected with the same tools, in the same season, and at the same locations in 2014. In 2020, cyprinid species were dominant both in terms of relative abundance and relative biomass in this river, which was not the case in 2014. Despite being protected as a natural monument, this river has experienced significant degradation in terms of fish populations. This indicates that legal protection alone, without active management and proper organization of a service to enforce this protection, brings no benefit to fish populations. Simply banning fishing or implementing stricter fishing rules has the opposite effect if there is no ranger service to enforce them on the ground. In this way, only legal sport fishers have been removed from the river, creating an open space for unregulated and uncontrolled fishing by poachers, which has led to the current state.

EXPERIENCES OF MANAGING STOCKING OBLIGATION IN AN ARCTIC LAKE INARI IN FINLAND

Petri Heinimaa & Nico Alioravainen
Natural Resources Institute Finland (Luke), Jyväskylä and Oulu, Finland.

In the arctic Lake Inari, the regulation of the water level was initiated in 1941 for hydropower plants in the outflow river Paatsjoki. To compensate for the losses to fisheries a stocking obligation was ordered by the water court and stocking activities initiated in 1976 to the Lake Inari and in 1985 also to tributaries which had been affected by the water level regulation.

The target species include native brown trout (*Salmo trutta lacustris*), arctic charr (*Salvelinus alpinus*) and large sparsely-rakered whitefish (*Coregonus lavaretus fera*). Also, non-native species have been used in the stocking, namely land-locked salmon (*Salmo salar sebago*) in 1976–1985, lake trout (*Salvelinus namaycush*) in 1976–2012 and large densely-rakered whitefish (*Coregonus lavaretus pallasi*) in 1977–1989.

To improve the management of fish stockings an adaptive stocking process was introduced in 1996. Thereafter the stockings have been guided by information obtained from stocked fishes by markings, from fish stocks and fishing in the lake by samples and inquiries from the fishery. Since then, also the stockings have been planned in five years cycles.

Since 2001 based on the court decision the previously separate compensation areas of Lake Inari and tributaries have been handled as a uniform area, thus giving better possibilities to alternate the stockings in changing fish stock and environmental situations.

There are annual research activities to gather the information needed for the decision making in developing the profitability of the stockings. All stocked fishes have been marked with Alitzarin Red S as eyed eggs or newly hatched fry since 2004. This enables to distinguish the stocked fish from naturally reproduced individuals in the fish catches to the follow-up of the success of the stocked fishes. After omitting the stockings of non-native fish species, the amount of whitefish stocking has been the biggest disagreement between different stakeholders and research.

INFESTATION OF EUROPEAN EEL (*Anguilla anguilla*) WITH *ACANTHOCEPHALUS* SP. IN THE NERETVA DELTA

Tena Radočaj, Oliver Barić & Ana Gavrilović
University of Zagreb Faculty of Agriculture, Croatia
Irena Vardić & Damir Kapetanivić
Institute Ruđer Bošković, Zagreb, Croatia
Jurica Jug-Dujaković
M.J.D. CONSULTING d.o.o., Stari Grad, Croatia

One of the most widespread genus of intestinal fish parasites in Europe is Acanthocephalus. These are obligate pathogenic worms that cause considerable damage to the intestinal wall. Most of them infest different fish, but some species prefer the European eel (*Anguilla anguilla*) as final host. *A. anguilla* is a catadromous species assessed as critically endangered. Some of the causes of endangerment are habitat loss, pollutants and diseases. The aim of the study was to determine the prevalence of acanthocephalans in digestive system of *A. anguilla* in the Neretva Delta. Eel sampling was carried out from January to

November 2021, at the main confluence of the Neretva River and 94 eels were collected. Clinical examination revealed the presence of parasites in the digestive system. The parasites found were counted for each individual fish, morphologically examined and stored in 96% ethanol for molecular analysis. Molecular analysis of the parasites in the digestive system confirmed the morphological determination, i.e. that they are thorny headed worms *Acanthocephalus* sp. The prevalence in the total sample was 56.5%. In further research, more detailed analysis of the relationship between the fish size and the degree of infestation and water quality parameters should be performed.

Acknowledgement

This study is based on work from COST Action CA22163 “Solving bottlenecks in eel reproduction to support sustainable aquaculture” (EELSUPPORT), supported by COST (European Cooperation in Science and Technology). Part of the activities was financed within the Project "Fisherman- Scientific Network of the City of Ploče" performed under Measure I.3., "Partnership between scientists and fishermen for the period 2020–2022."

THE POTENTIAL OF USING MEDICINAL PLANTS FOR TREATING THE PARASITES IN FISH

Dijana Blazhekovikj – Dimovska
University “St. Kliment Ohridski”, Ohrid, North Macedonia
Stojmir Stojanovski
Hidrobiological Institute, Ohrid, North Macedonia

The growth of aquaculture in recent years has made it a viable source of food supply, as long as it is conducted in a way that is environmentally friendly, socially responsible, and takes into account food safety and animal welfare.

The number of infectious disease outbreaks, specifically parasitic diseases, has increased in aquaculture, affecting the fish population and causing significant economic losses. Conventional treatments like antibiotics, anti-parasitics, and chemical compounds have been used by fish farmers to prevent and control fish diseases. Numerous studies have demonstrated the accumulation of these chemical residues in fish tissues, enhanced resistance to pathogens, and a negative effect on aquatic organisms' environment. Chemical compounds are difficult to control in open waters where aquaculture is conducted.

Nowadays, alternative methods are being developed by scientists and fish technologists, with many plant-derived compounds from selected plant species becoming increasingly promising supplements, because of their effectiveness, safety, environmental protection, and lower drug resistance. A significant number of compounds derived from plant extracts can be used to prevent and control fish parasites in aquaculture, particularly against protozoans, myxozoans, and monogeneans.

Essential oils are secondary metabolites of medicinal plants that possess biological compounds such as terpenes, terpenoids, alkaloids, flavonoids, saponins, coumarins, and phenolics. Preventing and controlling diseases in aquaculture systems can be achieved by using them as an effective treatment. Using essential oils in fish diets can also have an effect on their growth, immunity, and resistance to infectious diseases.

In recent years, the use of plant-derived compounds and the potential to discover new formulas containing essential oils, plant extracts, and their bioactive compounds have been continuously increasing, in relation to phytotherapy. Serious research and further examinations are required to determine the appropriate concentration for the administration and to demonstrate the effectiveness of these plant-derived compounds and their pharmacological activities in controlling fish parasitic diseases.

Acknowledgement

This publication is based on work carried out under COST Action EELSUPPORT, CA22163, supported by COST (European Cooperation in Science and Technology).

DEVELOPING A GENETIC MONITORING PROGRAMME FOR TRANSBOUNDARY FISHERIES MANAGEMENT OF MIGRATORY FISH

Nico Alioravainen
Natural Resources Institute Finland, Oulu, Finland
Cornelya Klütsch, Hallvard Jensen & Snorre Hagen
NIBIO Svanhovd, Svanvik, Norway
Tuomas Leinonen
Natural Resources Institute Finland, Helsinki, Finland

The brown trout, which is of great local and regional socioeconomical value for both Norway and Finland, is facing multiple challenges such as damming of rivers, climate change, overexploitation, and stocking. This has led to a concerning nationwide decline in wild, migratory brown trout populations. Reconciling the conservation and fisheries management of transboundary watercourse requires up-to-date stock assessment and common objectives within the watercourse.

The Lake Inari-Pasvik River watercourse represents a unique model system for studying the impacts of human activities on brown trout populations. Lake Inari hosts genetically diverse brown trout populations, while genetic diversity in the Pasvik River and its tributaries has declined due to hydroelectric power dams. Genetic diversity plays a crucial role in buffering species against environmental changes, but anthropogenic activities such as habitat destruction and stocking threaten these populations.

The project aims to investigate anthropogenic effects at the genetic level to inform future management strategies for preserving the unique, migratory brown trout populations of the Inari-Pasvik River catchment. By leveraging existing stocking and monitoring programmes in Finland and Norway, this study will establish best practices for systematic genetic monitoring in conservation management. Specifically, it will provide baseline data on genetic diversity, identify unique genetic traits of migratory brown trout at risk of extinction, and recommend adaptive management practices for cross-border conservation efforts.

By modernizing genetic methodologies, including the development of a SNP panel, the project aims to identify genes under natural and human-induced selection pressures across different river sections and environmental conditions.

Key outcomes will include a standardized genetic assessment framework for brown trout conservation in the Pasvik-Inari watershed, insights into genetic adaptations under various environmental pressures, and guidelines for cooperative management of stocking programmes to preserve genetic diversity and functional traits of migratory fish. Ultimately, this research will serve as a model for transboundary biodiversity conservation in watercourse-level management practices.

DISTRIBUTION OF DANUBE SALMON (*Hucho hucho*) IN CROATIA BASED ON ANGLERS' CATCH DATA

Matija Pofuk
Ministry of Agriculture, Forestry and Fisheries, Zagreb, Croatia.

Danube salmon (*Hucho hucho*) is the largest salmonid species in inland waters of Europe. However, the distribution and abundance of the species has been significantly reduced, and according to its conservations status on the IUCN Red List of Threatened Species it is still considered endangered (EN). In Croatia, the historical record (linguistic references, catch data) from the late 19th century until the first half of the 20th century indicates that Danube salmon was highly migratory, with a wide area of distribution that spanned across permanent habitats in the Drava, Sava, Una, Kupa, and Dobra rivers as well as in transitory habitats in their larger and smaller tributaries, and in Korana, Mrežnica and Danube rivers. Presently, however, the lack of available data limits a reliable determination of the species distribution, thus hindering the establishment of appropriate protection and preservation measures. To determine the current distribution of Danube salmon in Croatia, official catch data from anglers, which are reported to the Ministry of Agriculture, Forestry and Fisheries, were gathered and analysed. The time series includes the period from 2004 to 2023 and incorporates the data of anglers' retained catch of Danube salmon. For the analysed time series, anglers caught Danube salmon in four rivers, retaining in total 80 individuals weighting 507.1 kg. The majority of retained individuals as well as the largest volume were caught in Kupa (47 ind., 58.75%; 319.5 kg, 63.01%) and Una (20 ind., 25%; 137 kg, 27.02%) rivers, which concurs with scientific estimates that these watercourses are the only ones in Croatia left with a self-sustaining populations of Danube salmon. Catches in Drava and Sava River need to be considered sporadic as only 8 individuals (10%) weighing 25.6 kg (5.05%) and 5 individuals (6.25%) weighing 25 kg (4.93%), respectively, were retained. The majority of retained individuals from Sava River were caught in or close to the confluence with Una River during winter period, when Danube salmon undertakes downstream feeding migrations. The origin of the individuals caught in Drava River is unknown but could possibly be a population from the upper reaches of Drava in Slovenia. The data indicate that the distribution of Danube salmon in Croatia has been significantly reduced compared to historical records. However, more extensive research is required to determine the exact distribution of Danube salmon populations as well as their population dynamics, and accordingly, to establish appropriate management measures of protection and preservation with the aim of recovery and restoration of Danube salmon populations in Croatia.

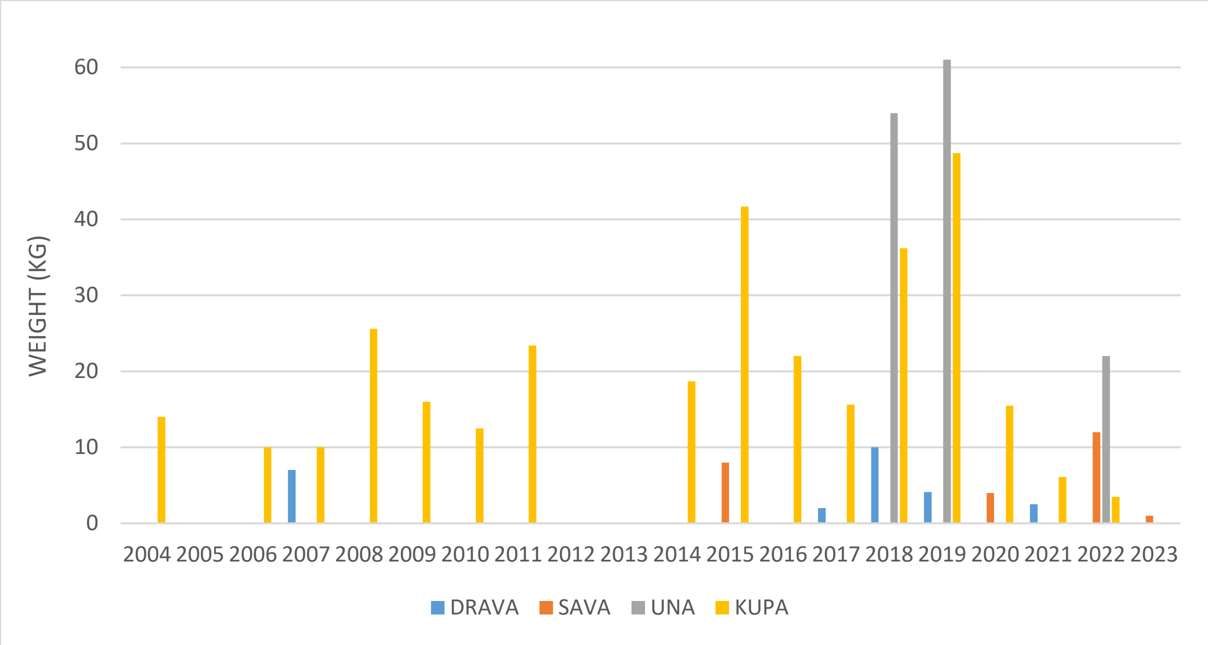

Figure 1. Anglers' retained catch (kg) of Danube salmon in Croatia, 2004–2023
Source: Ministry of Agriculture, Forestry and Fisheries, Croatia.

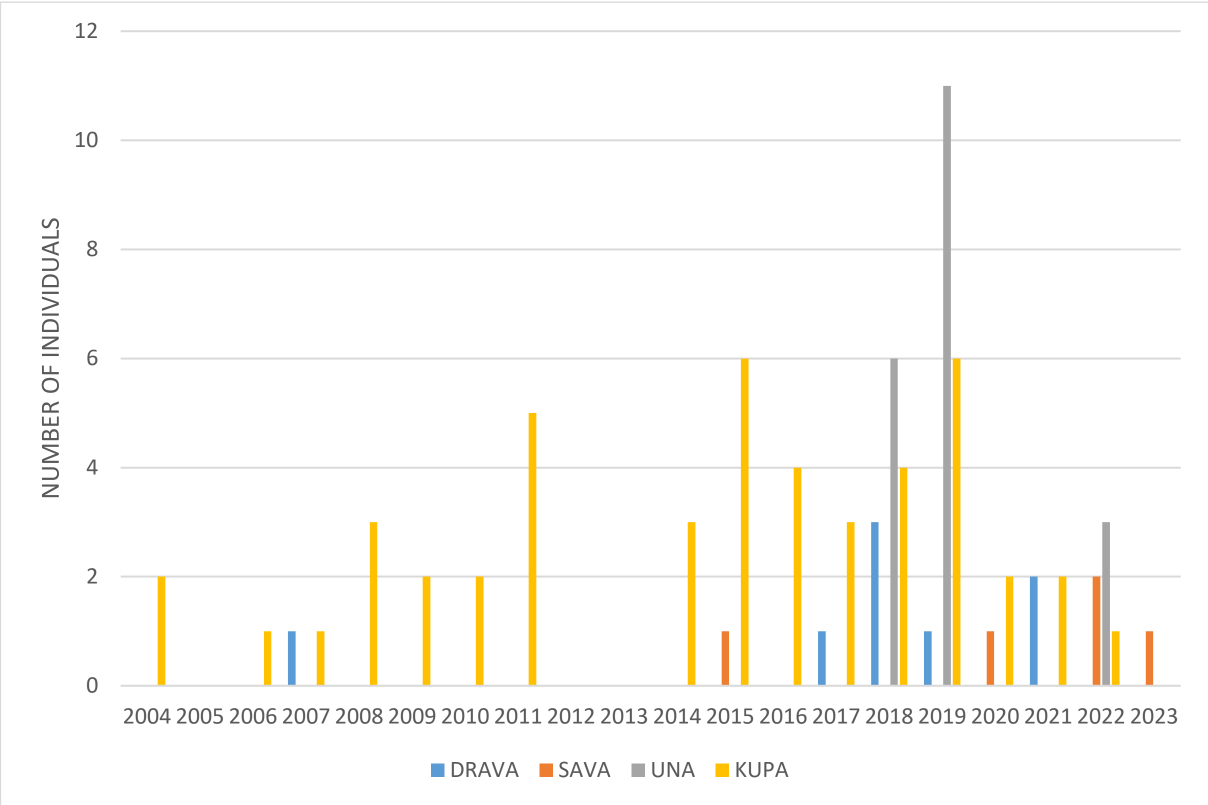

Figure 2. Anglers' retained catch (individuals) of Danube salmon in Croatia, 2004–2023
Source: Ministry of Agriculture, Forestry and Fisheries, Croatia.

EFFECTS OF PROLONGED DIETARY β-GLUCAN AND BGN-2 SUPPLEMENTATION ON TNF-α, IL-6, HSP-70, GROWTH HORMONE, AND GROWTH PERFORMANCE IN SEA TROUT

Olga Revina
Institute of Food Safety, Animal Health and Environment "BIOR", Riga, Latvia and University of Life Sciences and Technologies, Jelgava, Latvia
Vjačeslavs Revins & Dina Cīrule
Institute of Food Safety, Animal Health and Environment "BIOR", Riga, Latvia
Anda Valdovska
Latvia University of Life Sciences and Technologies, Jelgava, Latvia

This study examined the impact of long-term dietary administration of β-glucan and a β-glucan-containing product (BGN-2) on the immune response and growth performance of sea trout (Salmo trutta). The research focuses on the expression of tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), fish heat shock protein 70 (HSP-70), and fish growth hormone (GH), along with growth performance metrics like weight gain and specific growth rate. The study involved 15 000 sea trout juveniles divided into five groups: one control group (D1) and four experimental groups receiving varying doses of β-glucan and BGN-2. The experimental diets included a basal diet alone (D1), basal diet with 1 g kg^{-1} β-glucan (D2), 3 g kg^{-1} β-glucan (D3), 6 g kg^{-1} BGN-2 (D4), and 14 g kg^{-1} BGN-2 (D5). The immune parameters (TNF-α, IL-6, HSP-70, and GH) were measured using enzyme-linked immunosorbent assays (ELISA) across different months. Growth performance indicators such as weight gain, specific growth rate, and Fulton's condition factor were monitored over the trial period.

The fish in groups D4 and D5, which received higher doses of BGN-2, exhibited significantly higher levels of IL-6, HSP-70, and GH compared to the control group. TNF-α levels varied significantly only in certain months for specific groups, with no consistent pattern across the entire study period. The growth performance of sea trout was notably improved in the D4 and D5 groups, with the highest final weights and specific growth rates observed in these groups. The D5 group, which received the highest BGN-2 dosage, showed the most significant overall growth, suggesting a strong correlation between BGN-2 supplementation and enhanced growth.

The study concluded that dietary supplementation with BGN-2, particularly at higher doses, significantly boosts the immune response and growth performance in juvenile sea trout. These findings support the use of BGN-2 as an effective immunostimulant and growth enhancer in aquaculture, potentially leading to more robust and faster-growing sea trout smolts.

PRODUCTION AND TRADE BALANCE TRENDS OF FRESHWATER AQUACULTURE PRODUCTS IN CROATIA 2013–2023

Svjetlana Višnić Novaković, Matija Pofuk, Ivana Vukov, Mirta Novak, Tatjana Boroša Pecigoš & Irena Jahutka
Ministry of Agriculture, Forestry and Fisheries, Zagreb, Croatia.

Croatian freshwater aquaculture has a long tradition in salmonid and cyprinid production, but contrary to global aquaculture trends, in the last decade, in Croatia there has been stagnation in both segments, with some signs of recovery in recent years. This paper analyses production (Ministry of Agriculture, Forestry and Fisheries) and trade balance data (Croatian Bureau of Statistics) over eleven years (from the accession to the European Union in 2013 to the most recent available data from 2023) and lays out the overall production and trade balance trends as well as the unique

socioeconomic characteristics of salmonid and cyprinid freshwater aquaculture, which further influence the growth of the sector.

Salmonid production is focused on two species (Rainbow and Brown trout), with 20 active license holders and around 90 employees, reached 438 tonnes in 2023, which is an increase of 25% compared to 2013 and a 5% increase compared to the average in the period 2013–2022. Import in increased by 8% compared to the average in the period 2013–2022, amounting 835 tonnes of estimated live weight. Exports considerably vary throughout the time series, from 40 tonnes in 2014 to 627 tonnes live weight in 2016. Finally, in 2023 around 304 tonnes live weight of farmed salmonids were exported, which is a 42% increase compared to the average in the referent period.

Cyprinid and catfish production is more varied, with five main species (Common carp, European catfish, Grass carp, Silver carp and Bighead carp), 11 active license holders, around 350 employees and 3 237 tonnes of production in 2023. The exports in these segments significantly increased from 2018 onwards and in 2023 reached 1019 tonnes live weight, while imports, although significantly increasing in the last three years, remained relatively low compared to production and export with 178 tonnes live weight in 2023.

The evolution of average prices suggests a differentiation between export and import prices. Salmonids reported considerably higher export prices (14.1 €/kg in 2023) than import prices (7,65 €/kg) targeting mostly neighbouring and central European countries (36% Slovenia). Conversely, the price of imported cyprinids in 2023 (8.78 €/kg), was considerably higher than export price (5.04 €/kg). The most important export countries in 2023 were Serbia, Romania and Bulgaria. The results of this analysis indicate that the domestic production of salmonid species falls short of consumer demand. Nevertheless, due to the lower average prices, the market fulfils the demand from the import, while production in the cyprinid segment mostly covers domestic market demands and gradually turns to export. Salmonid production has until recently been characterized by small companies with limited production capacity. The production has undergone changes recently, by expanding production capacities, although it is uncertain whether this will have a long-term effect on the total aquaculture production, which might significantly depend on external factors, such as climate change in particular. Cyprinid production is conducted by larger companies, recently introducing new species, developing marketing strategies and processing activities, which should improve the value of the final product.

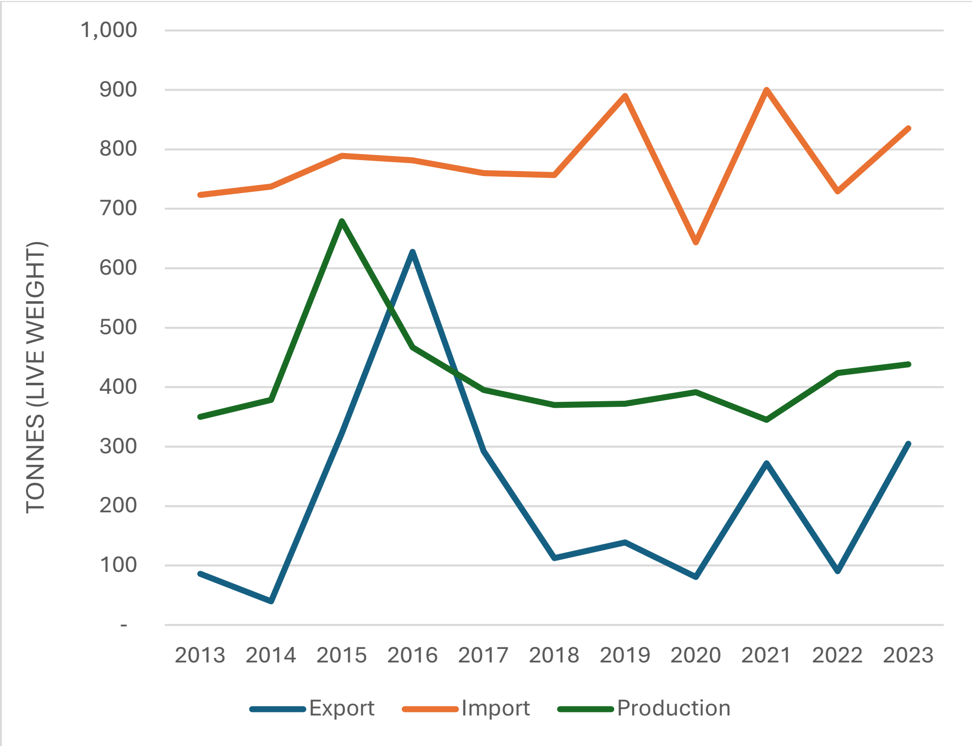

Figure 1. Production and trade balance of salmonid aquaculture in Croatia, 2013–2023
Source: Ministry of Agriculture, Forestry and Fisheries, Croatia and Croatian Bureau of Statistics.

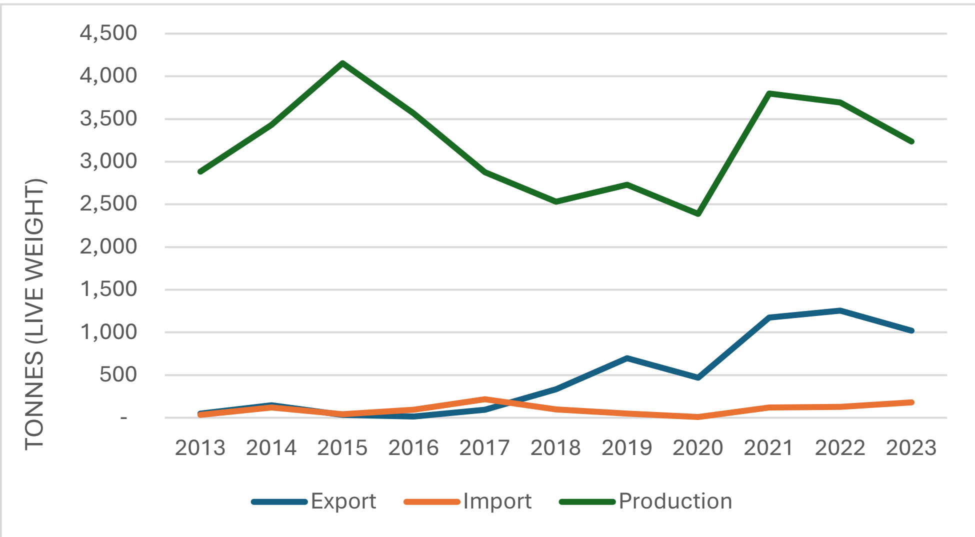

Figure 2. Production and trade balance of cyprinid aquaculture in Croatia, 2013–2023
Source: Ministry of Agriculture, Forestry and Fisheries, Croatia and Croatian Bureau of Statistics.

UNLOCKING THE POTENTIAL OF ALGAE: SUSTAINABLE PRODUCTION, CHALLENGES, AND INNOVATIONS FOR FOOD, FEED, AND BIOECONOMY IN THE EUROPEAN UNION

Maja Berden Zrimec, Borut Lazar & Robert Reinhardt
Algen, Algal technology centre, Ljubljana, Slovenia

Global interest in algae is growing due to their role as an alternative resource for sustainable food and feed systems, functional ingredients, renewable energy, and various other industries, while also offering environmental benefits such as climate change mitigation and bioremediation. Most microalgae production is land based cultivation in the raceway ponds and photobioreactors. Production is focused on dried biomass as functional foods or dietary supplements (*Chlorella* and *Spirulina*), and the extraction of various bioactive or biochemical compounds, such as (i) pigments as nutritional supplements; (ii) live feed enrichment for early (hatchery) stages of aquaculture production, and omega-3 rich oils; (iii) polysaccharides as an additive to cosmetic products; and (iv) natural food colourants (EC, 2016, Cai *et al*., 2021). Europe currently possesses extremely low share of World's micro- and macroalgae production. In the global microalgae production, European Union share is estimated to be only 5% (EABA, 2021). New algae produced for food must follow Novel food regulation 2283/2015 (EC, 2017). Currently, only 29 algal species are considered not novel food (5 microalgae, 24 macroalgae) (EABA, 2021).

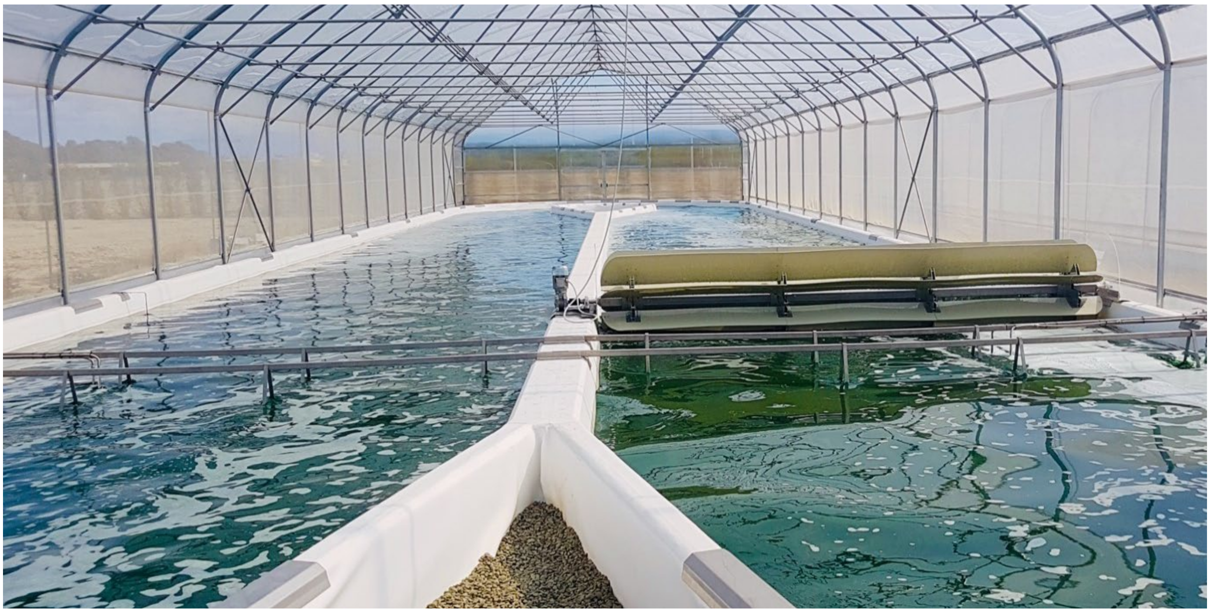

Figure 1. Typical raceway pond in a greenhouse for the large-scale algal production (Algen high-grade food Spirulina production pond, Grosseto, Italy)
Source: Author's own archive.

While microalgae can grow very fast under suitable conditions, the productivity of large-scale microalgae cultivation in open systems (e.g. ponds or raceways) tends to be hampered by various chemical, physical and biological factors, including (i) contaminants (i.e. non-target microalgae); (ii) viruses, pathogens, parasites and predators; (iii) insufficient nutrients or carbon dioxide; (iv) insufficient sunlight due to self-shading from high cell density; (v) photooxidation and death due to excess accumulation of oxygen during the day; and (vi) significant shifts in culture pH with photosynthesis (absorbing carbon dioxide) during the day and respiration (releasing carbon dioxide) at night. Several technology challenges still prevent commercially competitive prices: Closed cultivating systems (e.g. photobioreactors) provide better controlled cultivation environments, but they are expensive to build and operate. The high cost of harvesting (i.e. dewatering) and refining cultivated microalgae biomass is another factor contributing to the high production cost of microalgae, which is a main constraint over viable commercialization of microalgae biofuel production. Algae cultivation in waste streams (wastewaters – municipal and various industries, liquid anaerobic digestate from biogas plants) is one way of lowering the costs of cultivation, but the produced biomass can't be used for food and feed products, except potentially with the side-streams from food and drink processing.

To unlock the potential of the algae sector, various European Union initiatives, such as the Farm to Fork, the Bioeconomy Strategies, and the Blue Bioeconomy Forum, called for action to better exploit algae. In this way, a recent European Union Algae initiative set out how the European Union can increase the sustainable production, safe consumption and innovative use of algae and algae-based products (EC, 2022). Additionally, several algal species have been added to a list of novel foods which compiles all the authorised novel foods in the European Union which are considered "important as a diverse and nutritious food component in Europe" (EC, 2017).

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IMPACTS OF CLIMATE CHANGE AND CARP POND FARMING IN AUSTRIA

Christian Bauer, Günther Gratzl, Martin Fichtenbauer & Elisabeth Peham
Federal Agency for Water Management (BAW), Institute for Aquatic Ecology and Fisheries Management, Mondsee, Austria

The Waldviertel in Lower Austria is the most important carp breeding area in Austria. A large proportion of the approximately 650 tonnes of table carp produced annually in Austria comes from there. The Waldviertel is a highland area with a low mountain range character, which was originally characterized by long, snowy winters. As a result, the production of table carp took four years. However, in recent decades there has been a significant change in climatic conditions, with corresponding effects on fish farming.

- The significant increase in temperatures has extended the production period (Figure 1). This means that carp reach their slaughter weight faster. Often three years are sufficient instead of four.
- The higher water temperatures in the fall cause problems when it comes to harvesting, as cooler water temperatures are advantageous at this time. However, harvesting cannot be postponed indefinitely into the fall/winter, as the ponds have to be refilled with water in time for spring. This is becoming increasingly difficult due to the reduced precipitation (snow) in winter.
- Higher water temperatures go hand in hand with lower oxygen levels in the water, especially in the summer months. This is increasingly causing problems, not only for the carp but also for sensitive fish species such as whitefishes (Coregonus), which also have a hard time coping with the high temperature peaks in summer.
- Blue-green algae blooms occur more frequently into the fall and in deep ponds, stratification occurs with an oxygen-free deep zone.

Pond management is therefore faced with a series of challenges that need to be overcome in order to lead a centuries-old form of aquaculture, which has shaped a whole cultural landscape, into the future.

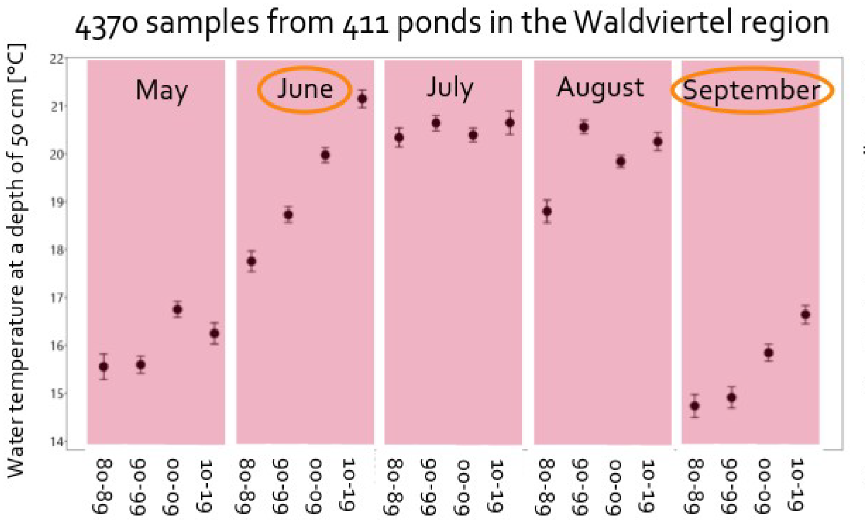

Figure 1: Average monthly temperatures of the ponds in the decades from 1980 onwards. In particular, the increases in June and September are striking.
Source: Pond database, BAW-Őkostation.

FISH AND INVERTEBRATES INTERACTIONS IN THE SAVA RIVER FOLLOWING EXCESSIVE CHANGE IN HYDROLOGICAL REGIME

Tea Tomljnović & Daniel Matulić
University of Zagreb Faculty of Agriculture, Croatia
Maria Špoljar
University of Zagreb Faculty of Science, Croatia

Riverine ecosystems combine a complex of diverse and varied hydrological, geological and limnological conditions along with the longitudinal and transverse profiles. As expected, numerous studies in lotic habitats refer to fish, benthic macroinvertebrates, i.e. insect larvae, bivalves and gastropods, while riverine phytoplankton and zooplankton, i.e. potamoplankton, have been less studied. A similarly under-studied component is zooseston, it represents faunistic components in streamflow consisting of benthic (bed or periphyton) and planktonic organisms (from upstream lentic sections, lakes, accumulation). This lack of research may be due to the fact that running waters are not a suitable environment for plankton development due to the residence time required for their life cycle and growth, except in lentic sections of rivers, e.g. riverine lakes, low-land slow-flowing parts and inflows. However, these small organisms in zooseston are important food resources for benthic invertebrates and fish.

Global climate change is affecting precipitation patterns, resulting in heavy rainfall with intense flooding and transport of matter from terrestrial into aquatic systems, simultaneously leaching fertilizer and soil from the field into the river. High flow velocities destroy and prevent the rooting of macrophytes. In the littoral zone, macrophytes suppress water turbulence by slowing the current, trapping sediments and particulate organic matter, and acting as a sink for nutrients.

The purpose of the present investigation was to assess the influence of hydrological extremes on fluctuations in environmental drivers and biocoenoses, and trophic relationships between fish, macroinvertebrates and zooseston, in an attempt to reveal the trophic interactions in the riverine littoral zone.

Sampling sites were selected considering the sample accessibility and representativeness in terms of different anthropogenic sources of pollution (e.g. industry, traffic, agricultural and urban activities). Sampling was conducted in the spring (May/June) of 2014 and 2015, along with the longitudinal profile across Croatia.

Study of interactions between fish, macrozoobenthos and environmental conditions in the spring season of two extreme hydrological years indicates that the composition of fish and benthic communities in the littoral zone of the Sava River significantly correlated. The results obtained also indicate the possible eco-logical consequences of the changes in the hydrological system triggered by climate change. Thus, the insight into the patterns of structural and functional characteristics of littoral communities in large rivers, as obtained in the present study, provides a promising basis for better understanding, prediction and management of risks to freshwater communities due to possible water level fluctuations and changes in precipitation intensity.

OMAKALA (MY FISH) – APPLICATION TO RECREATIONAL FISHERY DATA COLLECTION

Mikko Olin, Sami Vesala & Kimmo Murto
Natural Resources Institute Finland, Turku, Finland.

Recreational fishing produces a large and growing fraction of the total fish catch worldwide. The catch of the recreational fishery, however, is hard to estimate and traditional methods e.g. postal enquiries suffer from nonresponse bias. Mobile applications are promising tools to collect detailed and on-line recreational fishery data. The Omakala ("Myfish") implementation project is focused on developing, deploying, and maintaining the Omakala e-service including mobile applications for Android and iOS as well as web platform. This sophisticated digital platform is engineered to enhance the management and dissemination of fisheries data across Finland, with a primary target of serving the recreational fishing community. The mobile application was published in June 2022 and nowadays it has more than 13 000 users. Omakala forms an extensive, detailed, and up-to-date sample of recreational fishing in Finland. It produces diverse material for research related to recreational fishing and fish stocks. The problem is that the material is focused on anglers and the most active fishing enthusiasts. The goal is to make Omakala more available to other groups as well.

USING FISHERMAN FOR COLLECTING DATA ABOUT NORTHERN PIKE AND ZANDER

Roberts Strazdins, Edmunds Berzins, Janis Dumpis & Ruta Medne
Institute of Food Safety, Animal Health and Environment "BIOR", Riga, Latvia
Armands Erglis & Kaspars Holms
Association "Sporta makšķerēšanai", EBOAT FISHING TEAM, Riga, Latvia

There are often limited data available to support sustainable management of recreational fisheries. In times were so called "Catch and release" (C&R) fishing is getting more popular, the information about survival of specimen fish is crucial. "Citizen science" is getting much more popular across the world for gathering crucial information about animal species (also fish) populations. In recent years there has been significant development in recreational fishing tehnology, for example "live-sight" echolotes, therefore increasing the chance for catching a trophy fish multiple times. Today in Latvia, the number of fishermen equipped with such echolotes is getting bigger and the pressure to trophy predator fish like pike and zander is getting also much higher, raising the question how does it influence the population of these fishes and if there is a need to change fishing legislations in order to limit fisherman pressure on these fish. Albeit there are plenty of scientific studies about the populations of pike and zander, and also C&R fishing for northern pike (much less about zander), there has been practically none done in Latvia.

That is why in cooperation with fisherman for predatory fish, the authors gathered information about trophy size (starting from +/- 70 cm in total length) pike and zander populations in the inland waters of the city of Riga from the year of 2020. Before release, fish caught were tagged with T-bar anchor tags. Also notes about fish size, fishing depth, visual health *etcetera* were collected. Results about the research were published on social media platforms (e.g. Facebook).

Figure 1. Trophy zander with T-bar anchor tag caught once again

From 2020 to the end of 2023, a total of 703 fish (comprising 317 northern pike and 386 zander) were caught, marked, and released. Research data indicates that the catch-and-release method is suitable for Latvian predatory fish species such as zander and northern pike. The current findings demonstrate that these fish can survive after being caught and released, as evidenced by the recapture of more than 22% of northern pike and 9% of zander. Overall, the study offers valuable insights into the sustainability of trophy zander and northern pike populations, the impact of live sonar technologies on these species, and their ability to survive post-release.

APPENDIX E

DECLARATION ON THE FUTURE OF EUROPEAN FRESHWATER AQUACULTURE

In 2022 for the first time in history, aquaculture surpassed capture fisheries as the main producer of aquatic animals. Global aquaculture production reached 130.9 million tonnes, of which 94.4 million tonnes were aquatic animals, representing 51 percent of the total aquatic animal production. Global consumption of aquatic animals reached 167.5 million tonnes in 2022, with global per capita annual consumption rising from 9.1 kg in 1961 to 20.7 kg in 2022. Algae production, often overlooked, reached 38 million tonnes (wet weight), of which 97 percent comes from aquaculture.

Within the EIFAAC area, the freshwater aquaculture sector produced more than 460 000 tonnes of freshwater fish with a value of more than USD 1 815 million. The largest producers include France, Türkiye, Poland, Germany, and Czechia. Production was dominated by rainbow trout and common carp, accounting respectively for 67 percent and 16 percent of freshwater aquaculture fish production by volume and 80 percent of its value (respectively 65 percent and 14 percent). Other important cultured species are North-African catfish, herbivorous carp species (bighead carp, silver carp, grass carp), European eel, and sturgeons.

Rainbow trout is more suitable for temperate environments, while carp is adapted to the more extreme continental conditions of Central Europe (hot summers, cold winters). These two species require different aquaculture production technologies. The European Union (EU) market for carp in 2018 was estimated at 82 500 tonnes. The supply chain analysis shows that carp is produced primarily for domestic markets, except for Czechia (the only Member State with significant exports). Germany is the largest market for trout in the European Union with an apparent consumption estimated at 66 243 tonnes. Germany is also the largest importer of trout, with over 60 000 tonnes imported in 2018. The main suppliers are Poland (providing 39 percent of German imports), Denmark (24 percent), Türkiye (10 percent), Austria (9 percent) and France (7 percent). France is the second largest market, with a significant share of what is consumed being produced in France.

The eel market in the European Union is characterized by a continued decline in trade. This decrease is often explained by the irregular trend of supply of young glass eels caught in the estuaries and the endangered status of the species.

While trout is mostly reared in intensive flow-through systems, carps are mostly produced in ponds, through more extensive and traditional techniques mainly in Central Europe, where Czechia, Poland and Hungary are the main producers. According to EUMOFA estimations, ponds used for fish production in the European Union cover an area of almost 360 000 hectares. By transforming nutrients into high quality protein, carp production is one of the most resource efficient types of aquaculture in terms of fish meat output per feed input. The carbon footprint of freshwater aquaculture and especially pond aquaculture is one of the lowest in animal husbandry.

In spite of these impressive facts and the significant size of freshwater aquaculture production in Europe has decreased since the beginning of the 21st century. The only country in Europe where freshwater aquaculture production continued to increase in the last decades was Türkiye. The amount of salmonids and cyprinids produced in inland water aquaculture facilities in Türkiye reached 156 647 tonnes in 2023.

European freshwater aquaculture development has been facing several problems and constraints, including:

- limitations in water supply;
- strict environmental regulations and increasing bureaucracy;

- damage from predators, especially piscivorous birds;
- low investments and innovation;
- low diversity of freshwater aquaculture products in the market;
- climate change, causing higher water temperatures and floods;
- health and welfare issues with some fish stocks; and
- underestimation of the sector by the governments.

However, there are significant growth opportunities due to the increasing gap between supply and demand for fish products resulting from the stagnation or decline of marine catches, increased demand, and growing population. Following those opportunities the goal of the thirty-second session of EIFAAC was not only to identify problems but to provide recommendations to address them.

The freshwater aquaculture sector in Europe presents a wide range of production methods and technologies including extensive production methods to highly technological intensive methods. While the extensive methods provide socioeconomic services to local communities, maintain areas of environmental importance and conserve traditions and cultural heritage of producing and consuming fish, innovative intensive methods and technologies bring higher production yields while being capable of managing environmental impacts. Extensive fishponds are usually surrounded by reed belts and natural vegetation, thus providing important habitats for flora and fauna. They play a growing role in rural tourism. Besides fish production, ponds provide various other services for recreation, maintenance of biodiversity and improvement of water management.

Both methods have their advantages and disadvantages. Intensive production systems, like recirculating aquaculture systems (RAS) have higher capital investments and production costs, but a significantly shorter production cycle and year-round market supply. On the other hand, some semi-extensive and extensive farms and methods have diversified their activities, offering some types of hospitality such as excursions, fishing and educational tours. The lack of comparable financial feasibility studies of the two production methods did not allow for a proper comparison between these two business models.

The future growth of the sector largely depends on the ability to manage sustainable production. In this respect, it is important to consider the contributions of the sector to the United Nations Sustainable Development Goals (SDGs), where SDG 2 highlights the importance of a food systems perspective and the contributions to food production, provisioning (trade and processing) and consumption and of responsible production and consumption and the circular economy. Key opportunities exist not only in sustainable aquatic foods production but also in customized and innovative solutions and technologies addressing post-harvest and consumers, and inclusion into the circular economy. Research and development have been a constant feature in freshwater aquaculture during the past decades. Yet the development and implementation of solutions has faced obstacles, including that the production sector did not think that it needed methodologies and technologies developed by researchers. This situation has been changing in recent years, because those in the academic community and the business sector have realized that a key criterion for the survival of the sector is for the relevant actors to deepen their cooperation and conduct research and development that produces real, practical results. This collaboration helps accelerate innovation, puts scientific results into practice and develops sustainable and competitive knowledge-based production processes. The adoption of innovative solutions should be encouraged by appropriate regulations, simplified procedures and improved access to funding. This should concern the development of sustainable fish production, such as integrated-multitrophic aquaculture (IMTA), culture of new species, and energy-efficient recirculating aquaculture systems.

Due to the overemphasis on its negative impact on the environment, extensive water consumption and the occupation of too much land, the potential of the freshwater aquaculture sector in Europe has been overlooked and the sector faces regulatory barriers. The advantages and opportunities that this branch of agriculture brings have consequently not been realized. New approaches and new technologies provide for the inclusion of freshwater aquaculture in a circular economy, first by sustainable fish production, then by the realistic possibilities of full water recirculation including nutritionally potent wastewater usable in hydroponics production (a technology successfully used for more than a hundred years which is treated as a new and unproven technology within aquaponic aquaculture) and the use of released CO_2 in hydroponic production, which makes the CO_2 footprint of freshwater aquaculture negligible. Probably due to the lack of understanding and incompetent valuation, such sustainable industrial aquaculture projects have been declared unproven and undeveloped and are ignored. The importance of the freshwater aquaculture sector is underestimated also due to the low coverage of data collection systems and the low understanding of the role played by the freshwater aquaculture in providing food and employment opportunities while maintaining European landscapes and Europe's cultural heritage.

Special attention is required for the prevention and treatment of fish diseases. Harmful residues in the breeding environment should be reduced to the smallest possible extent by the application of various types of prevention, including vaccination and supply of probiotics in certain periods of the year. This reduces the use of antibiotics and other antimicrobials harmful to the environment and human health.

Several new and promising molecular genetic methods have been developed in the last decades that use large genetic/genomic databases. These data can be used for aquatic biodiversity monitoring, invasive species detection, and product authentication as well as to detect fish, parasites, viruses or bacteria species present in aquatic environments, on/in aquatic organisms and aquatic products. These methods represent future opportunities in freshwater fish genetics including genomic selection of fast-growing lines, disease-resistant lines and lines that are better adapted to new climate conditions.

Climate change is already a part of everyday farming and the accumulated experience, no matter how short-lived, needs to be comprehensively analyzed and used in planning and further adaptation strategies. In addition to known challenges, climate change also brings some unsolved issues that require a serious and above all responsible scientific approach. Higher water temperatures go hand in hand with lower oxygen levels in the water, especially in the summer months. This is increasingly causing problems, not only for the carp, but also for sensitive fish species such as whitefish (*Coregonus*), which also have difficulty coping with the high temperature peaks in summer, in particular between June and September. Blue-green algae blooms occur more frequently into fall and in deep ponds stratification occurs with an oxygen-free deep zone. Pond management is therefore faced with a series of challenges that need to be overcome to maintain a centuries-old form of aquaculture.

There is a need for the improvement of data supply and processing in European freshwater aquaculture for better monitoring of sector performance and to improve communication. In the European Union, the scope of the Data Collection Framework (DCF) should be extended to ensure accurate monitoring of freshwater aquaculture production. Information from the DCF can facilitate strategic planning and can also contribute to the better recognition and acknowledgement of the specificities and benefits of freshwater aquaculture. The use of new techniques and methods for environmental and breeding data collection and analysis should be expanded, along with the use of artificial intelligence in making aquaculture management and development decisions.

The opportunity for future growth lies also in the improvement of processing and marketing strategies to provide diversified products, which could promote sales in new market segments and for carp outside the typical marketing season. This could also increase the demand of freshwater fish and promote the consumption of new species. Beyond the overall national production and consumption figures, the importance of freshwater fish consumption must be considered at regional or local level, where it is often a key element in the way of life and traditions of communities living in large wetlands areas in Europe (Hungary, Poland, Romania, Finland, Lithuania, etc.).

Through its structural funding (e.g. the European Maritime and Fisheries Fund), the European Union provides compensation to pond owners for practices contributing to biodiversity conservation, but there is a need for further evaluation of the points that affect the economic profitability and ecological sustainability of pond production with special reference to the damage caused by piscivorous birds and their compensations.

Panel recommendations

- An adequate assessment of the economic efficiency of freshwater aquaculture is needed for different technologies and business models, considering the application of new technologies or their inclusion in traditional production or traditional business models.
- The adoption of innovative solutions should be encouraged by appropriate regulations, simplified procedures and improved access to funding. This should concern the development of sustainable fish production such as integrated-multitrophic aquaculture, production of new species, and properly designed energy-efficient recirculating aquaculture systems.
- New approaches and new technologies that enable the inclusion of freshwater aquaculture in the circular economy should be evaluated. There is a need for competent experts.
- It is necessary to consider the sustainable production of fish in RAS, because of its possibilities of full water recirculation, including nutrient rich wastewater from the recirculation system usage in hydroponics (creating an aquaponic system) and the use of released CO_2 in hydroponic production, due to which the CO_2 footprint will be negligible.
- Climate change is already a part of everyday farming and the accumulated experience, no matter how short-lived, needs to be comprehensively analyzed and used in planning further strategies. In addition to known challenges, climate changes also bring some unsolved issues that require a serious and above all responsible scientific approach.
- Special attention is required for the prevention and treatment of fish diseases. Harmful residues in the breeding environment should be reduced to the smallest possible extent by the application of various types of prevention, including vaccination and supply of probiotics in certain periods of the year, instead of the use of antibiotics and other antimicrobials harmful to the environment and human health.
- The application of biosecurity measures according to new European legislation is a first important barrier to combat diseases, but should be tailored to the specific characteristics of the different types of fish farms.
- Freshwater aquaculture also has deep connections to cultural traditions that sometimes conflict with the needs in terms of food safety and animal welfare. This is a new challenging area in which we will have to work also on the development and revision of appropriate regulatory frameworks.
- There is a need for the improvement of data supply and processing in European freshwater aquaculture for better monitoring of sector performance. In the European Union, the scope of the Data Collection Framework (DCF) should be extended to ensure accurate monitoring of freshwater aquaculture production.
- Improving communication about freshwater aquaculture at all levels of society, from citizens to policy makers, to overcome the present underestimation of the sector is important.

- There is a need for the improvement of processing and marketing strategies to provide diversified products which could promote sales in new market segments as well as outside the typical marketing season for carp. This would also increase the demand for freshwater fish and promote the consumption of new species.

There is a need for further evaluation of the points that affect the economic profitability and ecological sustainability of pond production, with special reference to the damage caused by piscivorous birds and compensation for this damage.

APPENDIX F

COMPOSITION OF THE SYMPOSIUM ORGANIZATIONAL AND SCIENTIFIC COMMITTEES.

Organizational committee.

President:

Marina Piria, University of Zagreb Faculty of Agriculture, Croatia (EIFAAC – Management Committee – MC)

Vice president:

Ana Gavrilović, University of Zagreb Faculty of Agriculture, Croatia (EIFAAC – Technical and Scientific Committee – TSC)

Members:

Ivica Kisić, University of Zagreb Faculty of Agriculture, Croatia

Aleksandar Mešić, University of Zagreb Faculty of Agriculture, Croatia

Tea Tomljanović, University of Zagreb Faculty of Agriculture, Croatia

Daniel Matulić, University of Zagreb Faculty of Agriculture, Croatia

Ivan Špelić, University of Zagreb Faculty of Agriculture, Croatia

Tena Radočaj, University of Zagreb Faculty of Agriculture, Croatia

Ante Mišura, Ministry of Agriculture, Directorate of Fisheries, Zagreb, Croatia

Ivana Petrina, Ministry of Agriculture, Directorate of Fisheries, Zagreb, Croatia

Josip Suić, Ministry of Agriculture, Directorate of Fisheries, Zagreb, Croatia

Raymon van Anrooy, EIFAAC Secretary, Fisheries and Aquaculture Division (NFI), Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Eniko Koti, Programme and meeting assistant, FAO Regional Office for Europe and Central Asia, Budapest, Hungary

Duygu Maktav, Fishing Technology and Operations Team (NFIFO), Fisheries and Aquaculture Division (NFI), Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

Scientific committee

President:

Ana Gavrilović, University of Zagreb Faculty of Agriculture, Croatia (EIFAAC – TSC)

Vice president:

Marina Piria, University of Zagreb Faculty of Agriculture, Croatia (EIFAAC – MC)

Members:

Tea Tomljanović, University of Zagreb Faculty of Agriculture, Croatia

Daniel Matulić, University of Zagreb Faculty of Agriculture, Croatia

Ivan Špelić, University of Zagreb Faculty of Agriculture, Croatia

Tena Radočaj, University of Zagreb Faculty of Agriculture, Croatia

Ivana Vitasović Kosić, University of Zagreb Faculty of Agriculture, Croatia

Petri Heinimaa, Natural Resources Institute Finland (LUKE) (Chairperson of EIFAAC – MC)

Fiona Kelly, Inland fishery Ireland Dublin, Ireland (Chairperson of EIFAAC – TSC)

Jan Kubecka, Institute of Hydrobiology, Biology Centre of the Czech Academy of Sciences, České Budějovice, Czechia (EIFAAC – TSC)

Robert Arlinghaus, Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Germany (EIFAAC – TSC)

Klaus Wysujack, Thünen Institute of Fisheries Ecology, Germany (EIFAAC – TSC)

Ali Serhan Tarkan, Department of Basic Sciences, Faculty of Fisheries, Muğla Sıtkı Koçman University, Muğla, Türkiye (EIFAAC – TSC)

Dijana Blazhekovikj – Dimovska, Faculty of Biotechnical Sciences – Bitola, Department of biotechnology, University "St. Kliment Ohridski" – Bitola, North Macedonia

Jurica Jug-Dujaković, Sustainable Aquaculture Systems/MJD Consulting, Croatia

Ákos Horváth, Hungarian University of Agriculture and Life Sciences, Institute of Aquaculture and Environmental, Hungary

Martin Kocour, University of South Bohemia Research Institute of Fish Culture and Hydrobiology Joint Laboratory of Genetics, Physiology and Reproduction of Fish, Institute of Animal Physiology and Genetics, Academy of Sciences Czechia

Kurt Pinter, Institute of Hydrobiology and Aquatic Ecosystem Management, Department of Water, Atmosphere and Environment, BOKU – University of Natural Resources and Life Sciences, Vienna, Austria

Predrag Simonović, University of Belgrade, Faculty of Biology, Belgrade, Serbia

Béla Urbányi, Hungarian University of Agriculture and Life Sciences, Institute of Aquaculture and Environmental; Hungary

Daniel Żarski, Institute of Animal Reproduction and Food Research, Polish Academy of Sciences in Olsztyn, Poland

The international Symposium on Building a sustainable future for inland fisheries and aquaculture in a time of multiple stressors was organized on 7–9 October 2024 in conjunction with the Thirty-second Session of EIFAAC in Pula, Croatia. The symposium was by the Government of Croatia and the University of Zagreb Faculty of Agriculture. The symposium was attended by 120 participants from 24 countries. The main documentation comprised 5 invited papers, 50 experience papers and 23 posters.

The symposium had eight major themes, which were: 1) Stock assessment and freshwater fish management; 2) Developments and challenges in freshwater aquaculture; 3) Migratory fishes – problems and conservation; 4) Freshwater invasives networking for strategy (FINS III); 5) Exploring the use of artificial intelligence in inland fisheries and aquaculture; 6) Climate change and impacts on inland waters, fisheries and aquaculture; 7) Innovative management for conservation of freshwater areas and aquatic biodiversity and advances in recreational fisheries research and management; and 8) Citizen science and socioeconomic aspects of freshwater fishery and aquaculture.

This EIFAAC Occasional Paper presents the proceedings of the symposium.

The Thirty-second Session of EIFAAC, held in Pula, Croatia, on 9–11 October 2024, endorsed the conclusions and recommendations of the symposium.

ISBN 978-92-5-139692-6 ISSN 2221-6650

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CD4788EN/1/04.25