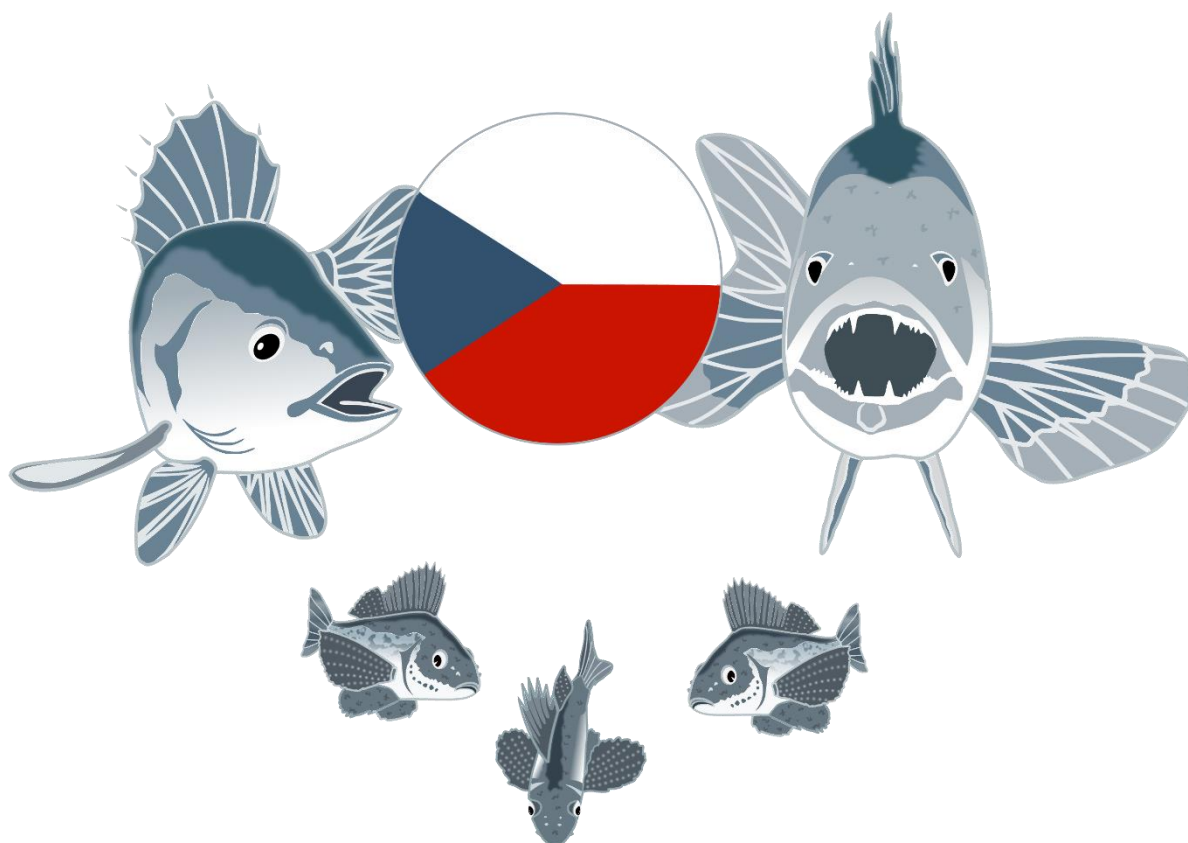


# 5th International Percid Fish Symposium

## Percis V

2022



### Book of abstracts

September 18-23, 2022

České Budějovice, Czech Republic

Editor: Michaela Holubová

Biology centre CAS, v.v.i., Institute of Hydrobiology in České Budějovice



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This symposium is dedicated to our colleague and friend, Assoc. prof. Josef Matěna, former director of IHB (1998 - 2012) and Percis III participant, who passed away on September 22, 2021 after a long illness in a hospital in České Budějovice. Josef was an outstanding mentor and lecturer, a scientist with a vast encyclopedic knowledge and a true specialist in percid fishes. We would like to dedicate the Percis V Symposium to this great personality.

Rest in peace



## The Statutory town of České Budějovice

*Dear visitors, welcome to the royal town of České Budějovice!*

*We are glad that you have chosen our beautiful and ancient town as a destination and wish you a pleasant stay. Take a leisurely walk through our streets, soak up the atmosphere, admire the square and architecture, look at the town from the Black Tower, enjoy our excellent Budvar beer and have a traditional South Bohemian meal. Enjoy your visit in peace and serenity. We believe that you will fall in love with České Budějovice and will return again and again.*

*We wish you a pleasant stay.*

757 years ago, the Czech king Přemysl Otakar II founded the town of České Budějovice at the confluence of the Malše and Vltava rivers. The layout of the newly founded town was ingeniously measured out by the burgrave Hirzo of Zvíkov, connecting a network of streets with the central square with an area of 133 x 137 meters. Two churches and a number of burgher houses were built around the square, including the town hall. The whole town was surrounded by a fortification with





watchtowers and three town gates.

Soon after its foundation, České Budějovice became the power and economic metropolis in South Bohemia and the pillar of royal power. In the 14th century, King Charles IV increased its privileges and the town became the centre of trade and crafts. České Budějovice also flourished through the mining of silver and the minting of coins in the nearby town of Rudolfov.



The fortified town withstood the pressure of the Hussite movement, and its economic boom was only limited by the Thirty Years' War and a major fire in the second half of the 17th century. The renewal of the town continued for decades in the Baroque style, changing its architectural character. A number of religious buildings and institutions were built, such as the bishop's residence, but also numerous secular buildings.

The industrial development of the 19th century led to numerous changes in transportation and production. In 1832, the first waggon of the horse-drawn railroad ran from České Budějovice to Linz. It was the first railroad on the European continent. A pencil factory, an enamel factory, a tobacco factory and breweries were also established here. Fortunately, industrial development did not destroy the historical centre of the city.

The city is the seat of the University of South Bohemia, many technical schools, scientific institutes, the South Bohemian Theatre with three ensembles, the South Bohemian Museum and numerous private museums and galleries.

Among the important companies, the breweries Budějovický Budvar and Budějovický měšťanský pivovar (formerly Samson), the dairy Madeta, the pencil factories Koh-i-Noor Hardmuth and Gama, and the engineering companies Robert Bosch and Motor Jikov should be mentioned.

After the opening of the borders, tourism experienced a boom. The town has much to offer visitors, Not only cultural experiences but also sporting events and shopping. Nature lovers will also find plenty to enjoy. České Budějovice is surrounded by picturesque countryside with ponds, rivers, forests and the hills of Blanský Forest and Novohradské Mountains, the sites of architectural gems such as Hluboká Castle or the town of Holašovice with its rural baroque buildings and Český Krumlov with the castle and historical centre, both UNESCO heritage sites. České Budějovice is a friendly and hospitable town. Come and see for yourself.



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## **Abstracts of plenary sessions**

(alphabetic in order of presenters)

## **Exploitation of perch (*Perca fluviatilis*): Patterns and mechanisms**

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In addition to being a keystone predator in many temperate ecosystems, the perch (*Perca fluviatilis*) is also a much sought-after target for commercial and recreational fisheries. Recreational exploitation of perch has seen a dynamic development in recent years, characterized by an increasing number of artificial lure types and tournaments happening throughout Europe. Angler surveys also indicated that perch consistently features among the top five recreational targets. In this talk, I will provide an overview about published and unpublished studies with implications for the sustainability of perch recreational fishing. In terms of the individual phenotype as target of recreational fishing, several laboratory and field studies have documented that perch exhibit personality, i.e., consistent individual differences in behavior, but exactly identifying which behavioural phenotype angling selection acts has been a challenge. While laboratory studies revealed the potential for exploration behavior to be selected upon by hook-and-line, field harvesting experiments failed to relate swimming activity and home range extension to angling vulnerability, instead revealing that more vulnerable perch were selecting for certain habitats. Vulnerability to fishing was also heavily influenced by the skill of the angler, with less consistent impacts of the lure type. In contrast to expectations by angling industry and some anglers, lure fluorescence did not increase catch rates or the size of perch that was captured. At the population level, perch are among the most resilient species to overharvest, but the size structure is sensitive to exploitation. The trophy potential of perch strongly depends on the lake environment, hence the abundance of large perch is jointly affected by both fishing pressure and ecological processes within lake ecosystems.



## **An historical review of the biology of perch, *Perca fluviatilis***

Craig, J.F.<sup>1,\*</sup>

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Over the years, percid species have received considerable attention from research scientists, fishers (commercial and anglers), aquaculturists and conservationists. The volume of information amassed has been considerable and indicates that *Perca* spp. make perfect models to study teleost biology. I will take an historical approach to the study of one species, *Perca fluviatilis*, and outline features to substantiate this claim. These features will include among others: anatomy, physiology, behaviour, genetics, population dynamics, adaptation to its environment and responses to its exploitation. I will try and illustrate where important discoveries have been made, as well as provide an update on present knowledge.

## **Individual variation in multiple traits of perch shape community interactions in lakes**

Eklöv, P.<sup>1,\*</sup>, Andersson, M.<sup>1,3</sup>, Bartels, P.<sup>2</sup>, Chaguaceda, F.<sup>3</sup>, Marklund, M.<sup>5</sup>, Olsson, J.<sup>3</sup>, Quevedo, M.<sup>4</sup>, Scharnweber, K.<sup>6</sup>, Svanbäck, R.<sup>1</sup>

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Perch is a key species in forming community structure and regulating food web processes in freshwater systems. From zooplanktivorous juveniles to adult piscivores perch are subjected to strong trade-offs between finding resources and avoiding predation where lakes provide strong differences in food availability and predation risk that occurs across habitats. Our studies have shown a trophic polymorphic pattern of perch with a general deeper body form in the littoral and a shallower fusiform body form in the pelagic. We have also shown that a differentiation into littoral and pelagic perch ecotypes has consequences for how littoral and pelagic food webs are coupled. For example, individual specializations of perch to habitat can lead to a strong development of habitat specific foraging modules with relatively small overlap of resource use across habitats. We also show that the overlap in resource use between littoral and pelagic perch ecotypes depends on environmental gradients regulating light conditions in lakes where perch in lakes with high organic carbon concentrations became more pelagic compared to perch in more clear water conditions. We also found that the coupling between habitats of perch was more asymmetric than expected based on habitat structure and resources due to that one part of the littoral perch used a higher proportion of pelagic resources than expected. This was likely related to the fish taking the advantage of longer chain polyunsaturated fatty acids in pelagic resources. In our research we have found that the phenotypic differentiation of perch that occurs across habitats in lakes likely involve multiple traits of resource use, morphology, fatty acid content and metabolic rate.

## **Lessons learned over recovery of Saginaw Bay's walleye (*Sander vitreus*) population; a multigenerational journey**

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Saginaw Bay is a 2,770 km<sup>2</sup>, cool water embayment of Lake Huron in the Laurentian Great Lakes of North America. Saginaw Bay is a percid-dominated fish community with Walleye as the apex predator, and historically generated commercial annual yields in excess of 1 million Kilograms until it's collapse in the mid-1940s. The collapse was a result of habitat degradation, declines in water quality, and the effects of invasive species. The commercial fishery probably hastened the collapse after environmental degradation, but was likely not the sole cause. The foundation for recovery came in the early 1970s as key water quality legislation led to a lessening of pollution. A Walleye fingerling stocking program was implemented in the early 1980s and a recreational fishery developed. The commercial fishery remained closed. The Walleye population remained dependent on stocking and the principal obstacle to natural reproduction was predation and competition from invasive Alewives. A series of cascading food-web changes took place in Lake Huron in 2003, resulting in the sudden collapse of Alewives. Walleye natural reproduction surged in response. Walleye fingerling stocking was discontinued in 2006 and recovery targets were formally met in 2009. Management shifted from an emphasis on recovery to one of managing for sustainability. Yellow Perch reproduction also surged but are heavily consumed by Walleye and their numbers have not recovered. Key lessons learned include 1. Recovery depends initially on the restoration of water quality. 2. Maintenance of a depressed population by stocking can be a valuable tool. 3. Ecosystems are resilient and will respond quickly if provided relief from stressors (like Alewives in this case). 4. Long term research and monitoring are essential to charting and informing the recovery process. 5. Resolve and commitment by fishery professionals and stakeholders is critical for achieving restoration.

## **Perch population responses to different changes in lake environments and perch as a tool in environmental monitoring**

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Perch (*Perca fluviatilis* L.) is living across Europe along environmental gradients including coastal waters of the Baltic Sea. Biological productivity of the lakes together with biotic interactions and environmental conditions affect the characteristics of perch populations. The density dependent growth of perch was clearly documented in acidifying lakes of northern Europe in late 1980s. In such conditions with low intra- or interspecific resource competition, perch growth in sparse populations could be very fast but decreased after chemical and biological recovery of the lakes due to increased population density. In eutrophicated lakes, perch often suffer from resource competition with cyprinid fishes resulting in low biomass proportion of perch in fish community and slow growth. In winterkill lakes, a temporal shift of dominance from roach (*Rutilus rutilus* L.) to perch with increased growth of has been recorded. Introduction of adult or juvenile (0+) perch to formerly fishless lakes has resulted in clearly increased growth. This high plasticity of perch growth responses to various environmental conditions is one of the key factors of its success. During the 2000s, the effects of climatic change on aquatic ecosystems have increasingly been studied including the perch population responses. Increasing temperature, associated with hydrological changes, lake browning and productivity have been observed to affect perch biomass and production. In temperate and boreal lakes, the responses are variable but in subarctic lakes positive. In the latter, the climate change and intensified land use appear to turn the salmonid dominated subarctic lakes towards the direction of percid and cyprinid dominated boreal lakes. Perch is a useful environmental indicator species through bioaccumulation of pollutants, for example in mercury monitoring of perch muscle according to European Water Framework Directive. Perch as one of the most common freshwater fish species in Europe provide valuable resource to study responses to environmental changes.

**Oral presentations**  
(alphabetic in order of presenters)

## **Population genetic structure and variation of pikeperch (*Sander lucioperca* L.) in Lake Balaton**

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The Hungarian stock of pikeperch has unique genetic background as it segregates from both the Baltic and the Central European populations. Lake Balaton is one of the largest natural habitats of this species in Hungary. The large extent of the lake (594 km<sup>2</sup>) and its unique elongated shape, - in which each basin has a different character- may have led to the local adaptation of the pikeperch stock. The aim of our research was to investigate the genetic diversity, and structure, the extent of inter-area migration, or isolation in the lake. We were able to define two genetic clusters within the Balaton stock. However, these clusters could not be assigned to separated subpopulations only their ratio changes in the different basins. The genetic variance between the subpopulations was only 2.20% (P = 0.001), but Keszthely basin showed higher separation with Siófok and Tihany subpopulations (pairwise 0.042 and 0.047). The partial east-west segregation of the stock was also supported by the significant regression between the genetic and geographic distances (mantel test:  $r^2=0.82$ ,  $P=0.001$ ).

## **Changes in perch and roach diet in a eutrophic shallow Danish lake after a major roach removal**

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The diet of perch and roach was investigated before and after a large-scale fish removal (approximately 70-80% biomass) of roach in a shallow temperate Danish lake using stomach content analysis. We expected both perch and roach to show significant changes in diet after the restoration to reflect reduced intra- and interspecific competition. Further, we expected larger perch to help control the population of roach, as they are known to overcompensate in abundance after fish removal. Before and after the fish removal (May-Sep, 2020 and 2021, respectively) perch and roach were collected and their stomach content analysed on a monthly basis. The stomach content analysis used a volumetric points system where fish stomach fullness was assigned a value from 0 (empty) to 5 (completely full), followed by an allocation of individual diet items numbered from 0 (0%) to 10 (100%) depending on contribution to the diet of each individual fish. In total we analysed 1324 fish stomach across 16 months. For both species, there was a significant difference in stomach content before and after the fish removal. For large perch (> 15 cm), there was a surprising decrease in piscivory and an increase in zoobenthivory following the removal. For both large roach and small (< 15 cm) perch and roach, there was a decrease in zooplanktivory and an increase in zoobenthivory following fish removal. Our results indicate that zoobenthivory is more prevalent after fish removal and that large perch do not perform piscivory to the same extent as before the fish removal.

**Influence of locality and depth on abundance, size and growth rate of pikeperch (*Sander lucioperca*) early juveniles in a deep elongated reservoir**

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Fish recruitment is affected by many factors that can be locally specific and its precise estimation is valuable for proper fisheries management. This is especially true for predatory fish with a positive effect on water quality. In this study, abundance, size and growth rate of pikeperch (*Sander lucioperca*) early juveniles were monitored in three parts and two depth layers of a canyon-shaped reservoir at night and day periods during four sampling terms. The highest pikeperch fry abundance was observed in the middle part and the fish size increased from the dam towards the tributary. Moreover, larger and older pikeperch individuals migrated to deeper layers during the daytime. The temperature and productivity gradients were suggested as the main drivers affecting the pikeperch early juveniles distribution. This study highlights the relevance of detailed fish monitoring and environmental variables modelling for the efficient control of natural resources in the conditions of heterogeneous waterbodies with distinct longitudinal and depth gradients.



## **The German common name Sander is not a valid Latin name or scientific name for walleye, sauger, and European pikeperches**

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Sander, the German common name for *Stizostedion lucioperca* (Percidae), is an alternate spelling of Zander. Sander (Oken 1817) is not a valid Latinized scientific name and nor is it available as a generic name. Stark (1828) was the first to correctly form the Latin nominative singular noun *Sandrus* using the prefix “Sandr-” and the suffix “-us,” eight years after Rafinesque (1820) coined the senior synonym *Stizostedion*. A hox cascade of poor scholarship and lack of classically trained biologists has led to the mistaken belief the vernacular name Sander can be used as a Latinized generic name for Walleye, Sauger, and European pikeperch. Collette (1963), the first reviser of Percidae, came to the conclusion *Stizostedion* Rafinesque 1820 is the correct name. The International Commission on Zoological Nomenclature in Opinion 417 (Hemming 1956) rejected Oken’s (1815-1816) encyclopedia for nomenclatorial purposes because of his use of common names as scientific names. Gill (1903) discovered Oken’s publications and wrote incorrectly Sander is a Latin name. Eschmeyer and Bailey (1990), citing Gill (1903), wrote Sander was the senior synonym of *Stizostedion*, but did not investigate its Latinization. If they had, they would have found Bloch (1783) and Fischer (1791) both wrote Sander is a vernacular name. Kottelat (1997) citing Gill (1903) and Eschmeyer and Bailey (1990), but ignoring publications of the former Soviet Union and North American publications, emphasized Sander was the correct generic name. Nelson et al (2003) publication in AFS *Fisheries* supported Sander but was never sent out for peer review because it was considered a committee report. The AFS/ASIH *Common and Scientific Names of Fishes* (Nelson et al 2004, Page et al 2013) in recognizing Sander, have forced fishery biologists wishing to publish in their journals to use the wrong generic name for a Walleye fishery worth billions of dollars.

## **The pikeperch (*Sander lucioperca*) population in Tunisian reservoirs: Status investigation for Good Management Practices**

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This work seeks to assess the pike-perch “*Sander lucioperca*” population structure and status in Tunisian reservoirs aiming to monitor and optimize fishing and stock and to ensure good management practices. Three Tunisian reservoirs were prospected: Lahjar, Kasseb and Siliana. Multi-mesh gillnets were deployed as a sampling technique in accordance with the European standard CEN pr EN 14757, which was implemented by the Technical Center of Aquaculture in cooperation with the Higher Institute of Fisheries and Aquaculture of Bizerte. This method allowed us to catch 328 specimens of pikeperch throughout the five seasonal surveys (spring 2020 until summer 2021). The highest CPUE and BPUE were observed in Lahjar Reservoir followed by Siliana and Kasseb respectively as follows: 90.91 ind/1000m<sup>2</sup>-19912.9g/1000m<sup>2</sup>, 15.28 ind/1000m<sup>2</sup>-3885.39 g/1000m<sup>2</sup> and 0.92 ind/1000m<sup>2</sup>-234.19 g/1000m<sup>2</sup>. Catch and biomass per Unit Effort varied significantly between reservoirs and between seasons ( $P < 0.05$ ). Most of the pikeperch caught in the three reservoirs were found in the upper layer (0-3m and 3-6m) of the column water during the study period, except for autumn where 56% of the captured pikeperch in Siliana Reservoir resided in the deep layer (6-12m). Length averages of the fished pikeperch in this study are 32.34 cm, 31.64 cm and 30.70cm, respectively in Kasseb, Lahjar and Siliana. Pikeperch size exceeded the length of maturity and it was significantly impacted by seasons and reservoirs alike ( $F=14.033$ ,  $P=0.000$ ). These findings pinpointed an alarming condition for pikeperch in Siliana Reservoir and a state of overexploitation in Kasseb Reservoir. Eventually, a rapid intervention of seeding these reservoirs with fry and broodstocks is strongly recommended to preserve the pikeperch population.

## Rise and fall of the bathypelagic percid early juveniles scattering layer in Czech canyon-shaped reservoirs

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In many Czech canyon-shaped reservoirs, the pelagic stage of percid (European perch *Perca fluviatilis*, zander *Sander lucioperca*, ruffe *Gymnocephalus cernua*) early juveniles has been observed to occur in two different communities originally reported as epipelagic perch/percid fry (EPF) and bathypelagic perch/percid fry (BPF; Čech *et al.* – 2005 – *J. Fish Biol.*). Bathypelagic percid fry perform diel vertical migrations (DVM) being in the epilimnion during the night and migrating to the cold hypolimnion during the day. In deeper parts of the reservoir these fish create a distinct, several meters thick, scattering layer usually occurring between 8 and 14 m depth (depending on the water transparency). In shallower areas closer to the shore or in shallower tributary parts of the reservoir these fish change to bottom dwelling fish (deep benthic percid fry; Čech *et al.* – 2017 – *Hydrobiologia*). The community of EPF is present in warm and zooplankton rich epipelagic water 24 hours a day. The presence of both pelagic percid early-juvenile communities has been reported from reservoirs belonging to both North Sea and Black Sea drainage areas. Sub-recently, communities of EPF and BPF have been studied quite extensively including their distribution, abundance, age, growth performance, behavior, genetics or parasites. The Římov Reservoir, Vltava River basin, became the flagship locality for this research. In recent years, however, the BPF completely vanished from this reservoir, which fact has been ascribed to increase in water dystrophy.

## **Recreational fishing impacts can be high and targeted on prized predatory species**

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In Lithuania, and in many other European countries, recreational fishing effort is poorly regulated. In densely populated areas recreational fishing can potentially have large impacts on fish stocks, but this impact is hard to assess. Kaunas Water Reservoir in Lithuania is a large (65 km<sup>2</sup>) and productive water body and one of the most popular angling destinations. For decades it supported a commercial fishery, but during 2000s the stocks were severely overfished, and in 2013 all commercial fishing was banned. The reservoir is regularly monitored with scientific surveys, which presented a unique opportunity to assess recovery rates in main monitored fish species– roach, bream, perch, silver bream and pikeperch. Standardised catch per unit effort (CPUE) from scientific surveys showed very rapid post-2013 recovery in roach and silver bream, but no recovery in perch or pikeperch stocks. This raised a question of whether recreational fishing might be preventing the rebuilding of predatory fish species. We conducted over 900 surveys of recreational anglers during 2016 - 2021 and assessed recreational effort using drone-based surveys and anonymous user data from a fishfinder sonar device. Our data shows that recreational fishing pressure on perch and pikeperch is very high and greatly exceeds that of former commercial fishing. Estimated recreational fishing mortality across these species was highly correlated with their trends in scientific CPUE, suggesting that anglers are having a major impact on predatory and highly prized fish species, can alter relative species composition and possibly change ecosystem state and dynamics.

## **Patterns in angler-caught walleye diets from Saginaw Bay, Michigan, USA**

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Walleye (*Stizostedion vitreum*) are a top predator in Saginaw Bay, Lake Huron, Michigan, USA. Walleye abundance has increased almost 4-fold over the past 20 years and met recovery targets in 2009. The Lake Huron and Saginaw Bay foodweb experienced concurrent prey fish changes, perhaps the most significant being the collapse of the alewife (*Alosa pseudoharengus*) population and the establishment of round goby (*Neogobius melanostomus*), both invasive species. To assess potential effects of these foodweb changes on predator consumption, angler-caught walleye diets were examined from 2009-2011 to assess immediate diets shifts and from 2017-2018 to determine if diets remained similar. Angler-caught samples were collected during local tournaments and bi-weekly from freezers at fish cleaning stations. Walleye were measured for total length and stomachs were brought back to the lab where diet items were identified to the lowest practical taxon. Ration sizes were similar between the two study periods, but the major species consumed were different. Smaller yellow perch (*Perca flavescens*) were consumed during 2017-2018, which is consistent with fishery-independent assessments of yellow perch size information. Despite round goby comprising large proportions of other predators' diets in Lake Huron during the 2017-2018 seasons and yellow perch abundance being at very low levels, walleye decreased their consumption of round goby and increased their consumption of yellow perch and invertebrates between the two periods in Saginaw Bay. Invertebrates consumed included *Bythotrephes*, Ephemeroptera, and Diptera. However, changes in walleye consumption identified in the 2009-2011 study, mainly the lack of alewife and lower consumption of rainbow smelt (*Osmerus mordax*), suggest that some diet changes identified in the 2009-2011 study were still present during 2017-2018. Updated consumption information can provide information for managers to assess predation pressure and understand the roles of invasive species in Saginaw Bay and Lake Huron.

## **Exploration of Diplobiome inside the fisheye: intra- and interspecific diversity of Diplostomidae communities revealed by metabarcoding**

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Fisheye flukes (Platyhelminthes: Trematoda: Diplostomidae) are a very common globally distributed parasites with a complex life cycle involving fishes as one of their intermediate hosts. The lack of taxonomically informative features renders Diplostomidae diversity estimation very difficult especially during its metacercariae stage. Modern molecular methods, specifically metabarcoding, offer opportunity to circumvent such a challenge and reveal not only inter but also intra-specific diversity of such a cryptic parasite group. In this study, the intra- and interspecific diversity of fisheye fluke communities and environmental factors affecting the diversity were studied in seven Estonian lakes using novel high throughput metabarcoding method. In total, 234 Eurasian perch (*Perca fluviatilis*) and 250 common roach (*Rutilus rutilus*) samples were collected during summer of 2020. Whole eye DNA was used to prepare quadruple-indexed libraries using a dual PCR method (Adapterama I) and sequenced using an Illumina MiSeq instrument (2 x 300 bp). We determined the environmental factors affecting the diversity of parasite communities and identified how host characteristics affect fisheye flukes' diversity. Our results indicate that high throughput metabarcoding is a fast and cost-effective method to shed light on both intra- and interspecific diversity of fisheye fluke communities.

## **Percids in commercial fishery in inland waters of Ukraine**

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Among ten species of Percidae inhabiting inland waters of Ukraine, two ones such as pikeperch and European perch are harvested by commercial fishery. Other freshwater percids are listed as endangered in the Red Book of Ukraine or are trash fish. Commercial fish harvest is practiced in the Dnieper River and its reservoirs, lower Danube and Dniester. Pikeperch is the most important piscivorous fish in freshwater commercial ichthyofauna of Ukraine, the share of which in commercial catches in 2017-2021 varied from 2.8 % to 3.7%, where 96.8 % to 98.0 % of this species were caught in Dnieper Reservoirs. The share of perch varied from 1.7 % to 2.4 %, where the majority (81.2-94.5%) were also caught in Dnieper Reservoirs. The maximum catches of pikeperch in Dnieper Reservoirs were recorded in 1985-89, when they amounted to 831.7 tons. They declined to 193.8 tons in 2000-2005 and then increased to 255.0 tons in 2010-2015 and to 492.4 tons in 2016-2021. Thus, commercial catches of pikeperch in Dnieper Reservoirs did not show particularly negative trends compared to another piscivorous fish such as pike. Catches of perch, on the other hand, increased from 89.2 tons in 1985-89 to 264.8 tons in 2017-2021 that may be due to an increase in the minimum mesh size of gill nets resulting in the shift of fishing pressure toward older age groups. An increase in pikeperch catches in 2016-2021 was probably due to intensive harvest of age-4 and age-5 fish resulting in a shift in the mode of the length frequency distribution to the left and in a reduction of the maximum age. Accordingly, the major way for more effective management of this species is a reduction of fishing effort on middle age groups by increasing the legal size limit (up to 50 cm SL compared to current 42 cm SL).

## Seasonal variation of percids and wider fish community composition – year-round study from deep and humic boreal lake

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Organisms living in the boreal zone have to adapt to seasonal changes, such as variable temperature, oxygen and light conditions. Three percid fish in Finland in decreasing temperature preferences are pikeperch (*Sander lucioperca*), perch (*Perca fluviatilis*), and ruffe (*Gymnocephalus cernua*), but we know little about their activity level in different seasons. Perch is a generalist fish and one of the most common fish species in Finland, while piscivorous pikeperch and benthivorous ruffe are missing from the northernmost parts of the country. High proportion of lakes in northern hemisphere are under lake ice for part of the year, but we know very little about year-round activity of different fish.

We asked how the proportion of different fish species change in catches throughout the year, how the catch per unit effort (CPUE), size and condition factor change and what are the underlying variables behind putative changes. Fish were sampled with experimental gill net series from three main habitats (littoral, pelagic and profundal) in open-water months April-December and under lake ice in January-March, and physical-chemical measurements were taken.

Perch was the second most abundant fish in the lake by number and pikeperch by biomass. Highest numbers of perch and pikeperch were caught in August, most ruffe were caught in February. Both numerical and biomass proportions of pikeperch in fish community were higher in winter than in summer. Generally, CPUE was the lowest during winter and the highest in summer. Percids were the second most abundant order after cyprinids. Perch and pikeperch were smaller in late summer than in winter, whereas ruffe were larger in summer. Average condition factor was highest in summer. Variables explaining CPUE changes were condition factor, temperature, nitrogen and pH. Further research is needed from different years and lake productivities to evaluate what are the year-round variations spatially and temporally.



## **Controlled reproduction of pikeperch (*Sander lucioperca*); First step to domestication process**

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One of the most important stages of domestication in each species is to maintain the animal in a rearing condition up to reaching to maturity and reproduction. Therefore, this study was performed with the aim of reproducing the pikeperch (*Sander lucioperca*) grown in a captivity condition. For this purpose, two groups of fish including control group (without hormone injection) and hormone induction group (HCG injection at 200 IU/kg) were considered and each group consisted of two replicates and 5 fish in each tank. The results showed that the fish spawned after 74 to 90 hours, but the difference between the two groups in this regard was not significant. The latency time was determined in case of degree-hour in non-injected brooders to  $1396.9 \pm 157.2$  and in injected brooders to  $1261.5 \pm 34.2$  degree-hours ( $P = 0.356$ ). The response rate of fish in non-injected brooders was  $87.5 \pm 17.7\%$  and in injected brooders was  $75.0 \pm 0.0\%$  ( $P = 0.423$ ). The quality of nests did not show any significant difference between the two groups. Fertilization rate was  $87.3 \pm 3.5\%$  in non-injected fish and  $82.7 \pm 5.4\%$  in injected fish ( $P = 0.412$ ). According to the obtained results, it can be concluded that due to the complete adaptation of farmed fish to the captive rearing condition, it can be possible to propagate pikeperch without hormonal induction while the desired temperature and suitable spawning ground are available.

## **Could reproduction limit lifetime growth? Evidence from a population of mixed-ploidy walleye**

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One of the most characteristic features of the growth of fishes is that the annual growth rate of fish slows as they age. However, there is on-going debate on what causes this decline in growth rate, which has been called one of the most critical unresolved issues in ichthyology by several authors. That is, how do the energetic demands of reproduction affect lifetime growth? The classic, uniphaseic von Bertalanffy growth function (VBGF) assumes that the size-dependency of anabolism decreases as the size-dependency of catabolism increases as fishes age, and that when these two relationships converge, growth ceases. In contrast, the biphasic growth hypothesis suggests that the slowing of growth as fishes age is the consequence of the energetic costs of reproduction. We compared the lifetime growth of sterile triploid and fertile diploid Walleye in Narraguinnep Reservoir, Colorado, USA to assess the validity of the biphasic growth hypothesis. The biphasic growth hypothesis predicts that growth in triploid Walleyes should not slow as they age, and they should ultimately reach larger sizes than their diploid conspecifics because triploid Walleye are sterile and do not invest any energy towards reproduction. We used a Bayesian approach to test these two hypotheses. We fit the VBGF and Lester biphasic growth model (LBGM) to length-at-age data for each sex-ploidy group. Surprisingly, we found that triploid Walleye, despite their lack of reproductive development, grow similarly to their diploid counterparts. The LBGM (model weight = 0.559) explained growth slightly better than the VBGF (model weight = 0.441) for diploid Walleyes, while the VBGF (model weight = 0.997) was far superior to the LBGM (model weight = 0.003) for explaining the growth of triploids. This evidence suggests that reproductive development does not limit lifetime growth in Walleye, and that lifetime growth is more likely limited by metabolic processes.

## **Is biculture with tench (*Tinca tinca*) a way to improve growth and physiological status of pikeperch (*Sander lucioperca*) reared in RAS?**

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Pikeperch (*Sander lucioperca*) is a very promising species for the development of the European inland aquaculture, however its high sensitivity to stress remains a major bottleneck. In the ancient literature, tench (*Tinca tinca*) is often considered a “doctor fish”. Thus, a biculture tench-pikeperch in recirculated aquaculture systems (RAS) could be an opportunity for improving its breeding compared to monoculture. Indeed, associations between complementary species can lead to an improvement in feed allocation, welfare or immunity status. This study aims to assess the effect of tench on pikeperch when reared together in RAS. In order to describe the response of pikeperch, several indicators were measured at the beginning of the experiment and 84 days later. Stress (cortisol and glucose rates in plasma and percentage of hematocrits), immunity (lysozyme and complement activity) and zootechnical indicators (growth parameters, feed conversion ratio, between others) were investigated. For now, our results show that the biculture with tench has a significant and positive impact on growth parameters such as final weight gain, specific growth rate and daily weight gain. Also, there is a positive and significant impact on feed conversion ratio compared to control and the tank cleanliness. On the other hand, other important parameters such as pikeperch survival rate or condition index are not impacted by the biculture with tench. In order to better understand the response of pikeperch and the factors influencing these first promising results, ongoing analysis are exploring the physiological response in that target species. The final objective of this data collection is to have a comprehensive dataset to assess if the biculture with tench is a possible way for improving pikeperch welfare in RAS.

## Population-specific immune response of *Perca fluviatilis* towards *Aeromonas hydrophila*

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European perch is frequently cited as a suitable candidate species for freshwater intensive aquaculture diversification. While percids have been introduced in intensive aquaculture about 40 years ago, only a handful of commercial percid farms are in operation nowadays. The lack of wide commercial-scale production is mainly caused by the absence of full-scale comprehensive selective breeding programs, although selective breeding for several traits is recommended for percids. Disease resistance is one of the evaluated traits considered for selection. It was reported that the efficiency of innate immune responses to pathogens is inheritable, whereas the specific activities of adaptive response are not inheritable but generated somatically, primarily during ontogeny. In 2018, we tested the extent of the immune response in six different European perch populations following in vivo stimulation with Gram-negative *Aeromonas hydrophila*. The *A. hydrophila* injection-induced two types of reactions. The fish originated from Finland (FV) and Slovakia (SL and SV) showed a dramatic influx of leukocytes during the first 24 hours (around 6-7 million cells; 4 million myeloid cells) in the peritoneal cavity, while the fish from the Czech Republic (CN), Italy (IS), and Poland (PS) reached only 1-2 million myeloid cells. Oppositely, while the fish from FV, SL, and SV group reduced myeloid cell amount to just 500,000 on the third day, the fish from PS, IS and CN were up to three times higher (1-1.5 million). We suggest that the obtained results indicate that the innate resistance against *A. hydrophila* may be genetically manifested in perch. However, we know too little about this genetic association between perch resistance to different diseases in perch. The challenge now is to identify the involved immune-related genes and determine the mechanisms underlying immune responses among different European perch populations.

## Shifting perch reproduction phenology in response to climate change

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Climate change modifies the phenology of organisms. Fish, as ectotherms, are very sensitive to global warming. Increase in water temperatures can change the reproduction, embryonic and larval development dates. These changes can lead to a situation of "mismatch" between predators and preys and, as a result, have an influence on recruitment and on the food webs functioning. Perch (*Perca fluviatilis*) spawning occurs in spring in Lake Geneva and requires a water temperature above 10°C. With climate change, this threshold value should be reached earlier, modifying the reproduction dates for this species. In order to follow the reproductive phenology and to study the perch spawners, artificial spawning grounds have been set up every year in Lake Geneva since 1986. Previous studies have shown that the number of egg ribbons deposited on artificial spawning grounds is a reliable indicator of the number of spawners present in the area. This method has the advantage of attracting females and allows the observation of a large number of egg ribbons. This study proposes to analyse the perch reproduction phenology data collected during 35 years to investigate the effect of global warming on this population. The results highlight the impact of climate change with a timing shift for perch reproduction period and the adaptation of the species using deeper layer to reproduce in response to environmental changes.

## **Are perch (*Perca fluviatilis* L.) getting larger or smaller in Swedish lakes?**

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Recreational fishermen report on more large perch in recent years in northern Sweden. This seems counterintuitive to the temperature-size rule, where individuals are expected to mature at a smaller size in a warmer climate, and sacrifice growth to larger adult body sizes to ensure reproductive success. It also contrasts previous observations of smaller average size of perch and other species in warmer lakes, when using the space-for-time approach. This study relied on fish sampling using standard multi-mesh gillnets in Swedish lakes during 1994-2021. Perch were caught on 3,668 occasions, including 544 lakes in northern Sweden and 1620 lakes in southern Sweden. From 1996 onwards, at least 19 lakes per year were sampled within each region, and eight northern and 32 southern lakes were sampled at least ten times. Within sampling years the average size of perch was larger and the proportion of perch above 200 mm was higher in northern than in southern lakes. Both size metrics were higher in northern lakes sampled in recent years compared to lakes sampled 1996-2005. The proportion of lakes with at least one very large perch ( $\geq 350$  mm) was also higher in recent years, but with no difference between regions. Within time-series lakes the mean size more often decreased than increased in southern lakes, but no trends were observed within northern lakes. However, the proportional catch of large perch were more often increasing than decreasing in lakes of both regions. To conclude, perch are getting both larger and smaller in Swedish lakes, depending on region, analysis approach and size metrics used.

## **Behavioural rarities of European perch (*Perca fluviatilis*) in the pelagic habitat of a freshwater reservoir**

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Freshwater reservoirs are highly modified ecosystems created by damming rivers, where their inhabitants suddenly find themselves in a completely different ecosystem. The first option is to stay in the upper parts, which still resemble rivers. The other option is to adapt to the lacustrine environment, either using the pelagic habitat or staying in the littoral zone, which is rather scarce in a canyon-shaped reservoir. Perch, among others (freshwater bream, *Abramis brama*, and roach, *Rutilus rutilus*), is one of the most commonly distributed species in Europe that has adapted to the lacustrine environment. Cyprinid species (freshwater bream and roach) have become accustomed to pelagic zooplankton as a food source and were observed to have a particular type of filter-feeding called "gulping" (Peterka *et al.*, 2006); these species very often form large schools that help them find zooplankton patches while using a sinusoidal swimming pattern (Čech and Kubečka, 2002). Perch, on the other hand, do not form schools in adulthood, but have been observed in small groups usually consisting of two or three individuals. Perch are not abundant in pelagic habitats, but underwater camera data (SplashCam Delta Vision HD B/W; Everett, Washington, USA) showed that they are very active, searching for prey and swimming in zigzagging trajectories to effectively find prey. Unlike cyprinids, which locate the prey patch and suck it in, perch, as particulate feeders, must first visually locate the individual prey, which was confirmed by the camera footages. It is common for fish to be attracted to floating objects. Perch was the only one of the species we observed (out of 7 total) that was interested in the camera. The fish were apparently attracted to silver parts and sometimes stayed near the camera for several minutes.

## **Distribution patterns, annual density changes, and mortality of pikeperch (*Sander lucioperca* L.) fry in a shallow, well-mixed reservoir**

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Until 2006, the Lipno Reservoir was the best place for recreational fishery for pikeperch in the Czech Republic, with usual catches exceeding 15,000 kilograms per year. Since 2007, there has been a partial collapse of pikeperch population, and the annual catch dropped below 2,500 kilograms. This collapse was preceded by oligotrophication of the reservoir when phosphorus concentrations declined by a quarter. Protective measures from 2009 to 2017 partly reversed the declining trend, but pikeperch population remained relatively low. Apart from overfishing, unsuccessful spawning and low survival of pikeperch fry were suspected reasons. Pelagic trawling for pikeperch early juveniles in June and older juveniles in August indicated that extreme mortality in the first year of life, rather than limited spawning, was the reason for low pikeperch recruitment, as mortality exceeded 99 % in all years. An insignificant correlation between spring and summer pikeperch densities was observed in the surface layer, but a significant positive correlation was observed for spring and summer pikeperch densities in the deeper layer. High inter-annual variability in pikeperch fry density was observed in spring and summer, and growth was slow, with the usual standard length in August being less than 50 mm. In both terms, pikeperch fry density followed the trophic gradient with the highest densities in the eutrophic upper reservoir parts. No clear trend was observed in fish size along the longitudinal profile of the reservoir. In spring, neither density nor size of pikeperch fry differed significantly between the two depth strata sampled in the dam part. In summer, significantly higher density was observed in the surface layer (0-3 m) than in the deeper layer (3-6 m), but significantly larger juveniles were caught in the deeper layer than in the surface layer in the dam part. Pikeperch fry density in summer was positively correlated with water temperature during the growing season, while the correlation between pikeperch size in summer and water temperature was surprisingly negative. Oligotrophication of the reservoir in recent years is likely responsible for the extreme mortality and slow growth of pikeperch fry that are still zooplanktivorous, resulting in a lower probability of surviving their first winter of life. Survival of the more stable older year classes is therefore limited and the overall population dynamics of the species are disrupted. Given the changing conditions in the reservoir, measures should be taken to strictly protect pikeperch by reducing fishing pressure and stopping poaching to maintain self-sustaining pikeperch populations in Lipno Reservoir.



**Interactions between populations of ruffe (*Gymnocephalus cernua*) and round gobies (*Neogobius melanostomus*) in the Biesbosch reservoirs (Netherlands)**

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The native ruffe (*Gymnocephalus cernua*), which was the dominant species in benthic gillnets and littoral beach seine catches before the invasion of the round goby (*Neogobius melanostomus*), disappeared almost completely after the 2012 invasion in three Biesbosch reservoirs, whose fish community is dominated by percids. The competitive superiority of the round goby over the ruffe was so strong that populations of the once dominant species of the entire benthic fish community collapsed after only two years of coexistence. In one of the Biesbosch reservoirs (De Gijster), gillnet sampling in 2016 and 2019 showed a declining trend in round goby numbers and an increasing trend in ruffe densities. Densities of both species were clearly negatively correlated, and approximate theoretical thresholds for coexistence of both species at the same densities were estimated to be 750 ind/ha in seine and 120-140 ind/1000 m<sup>2</sup> in standard CEN gillnets. Following a natural decline in invasive species density, a recovery of the native fish population occurred in De Gijster Reservoir, which could be important for invasive species management.

## **Rise of European perch (*Perca fluviatilis*) – insights from the northern distribution edge of subarctic Europe**

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Climate change is progressing in northern Europe much faster than on global average and benefiting the warmer water adapted species. Northern Finnish Lapland provides excellent region to study fish community change along climatic and productivity gradient from cold water salmonid towards warmer murky lakes dominated by first percids and later cyprinid fish. Previously long-winters and short summers have restricted the number of year-classes and distribution of percid fishes, but last 20 years have been much warmer supporting successful reproduction and survival. European perch (*Perca fluviatilis*) is actively expanding its northern most distribution range with establishment in new lakes previously dominated by benthivorous European whitefish (*Coregonus lavaretus*) and partly by ruffe (*Gymnocephalus cernua*). In these subarctic lakes, all three species are preferring benthic habitats and diets, but resource competition and predation by perch is moving whitefish towards more pelagic habitat use. In lakes with polymorphic whitefish, perch will have the most severe impact on benthivorous whitefish that need to compete both with other whitefish morphs and perch. At wider landscape, perch has increased its share of fish communities and is the dominant species in many lakes. In warmer conditions, individual specialization of perch increase, while the opposite is true for whitefish. Collectively, results from subarctic lakes suggest a clear shift from cold water adapted and autumn spawning salmonid communities towards warmer adapted and spring spawning fish communities where percid fish are the first to take advantage on changing environmental conditions.

## **Allochthony and the fatty acid and mercury contents of Eurasian perch (*Perca fluviatilis*) along boreal environmental gradients**

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Environmental change, including browning [increasing dissolved organic carbon (DOC) concentration] and eutrophication [increasing phosphorous (TP)], in boreal northern lakes potentially affects food web energy sources and the biochemical composition of organisms. These environmental stressors are enhanced by anthropogenic land-use, putatively decreasing the quality of polyunsaturated fatty acids (PUFA) in consumable seston and zooplankton, and possibly cascading up to fish. In contrast, the content of harmful mercury in fish supposedly increases with lake browning potentially amplified by intensive forestry practises. However, there is little evidence on how these environmental stressors simultaneously impact beneficial omega-3 fatty acid (n3-FA) and total mercury (THg) content of fish muscle for human consumption. We conducted a space-for-time substitution study to assess whether environmental stressors affect Eurasian perch (*Perca fluviatilis*) allochthony and muscle nutritional quality [PUFA, THg, and their derivative, the hazard quotient (HQ)]. We collected perch samples from 31 Finnish lakes along pronounced lake size (0.03–107.5 km<sup>2</sup>), DOC (5.0–24.3 mg L<sup>-1</sup>), TP (5–118 µg L<sup>-1</sup>) and land-use gradients (forest: 50.7–96.4%, agriculture: 0–32.6%). These environmental gradients were combined using principal component analysis (PCA). Allochthony for individual perch was modelled using source and consumer δ<sup>2</sup>H values. Perch allochthony increased with decreasing lake pH and increasing forest coverage (PC1), but no correlation between lake DOC and perch allochthony was found. Perch muscle THg and n6-FA content increased with PC1 parallel with allochthony. Perch muscle DHA (22:6n3) content decreased, and ALA (18:3n3) increased towards shallower murkier lakes (PC2). Perch allochthony was positively correlated with muscle THg and n6-FA content but did not correlate with n3-FAs content. Hence, the quality of perch muscle for human consumption decreases (increase in HQ) with increasing forest coverage and decreasing pH, by increasing the THg burden derived from these fish, potentially mediated by increasing fish allochthony.

## Walleye (*Sander vitreus*) length influences reproductive phenology

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Fish stocks generally exhibit high interannual variability in recruitment, and past research has suggested the truncation of a stock's size- and age-distribution may exacerbate such variability. Individual female fish often differ in reproductive traits like fecundity, offspring size and annual spawn timing. These traits are thought to be related to maternal size and age, suggesting that a more demographically diverse stock will display increased variation in reproductive phenology and offspring traits, which may temper recruitment variability. There are many anecdotal reports that larger, older female fish spawn relatively earlier in the year. However, such phenological patterns have generally not been quantitatively evaluated, especially for male fish. In our study, we synthesized the effects of both male and female walleye (*Sander vitreus*) length on their annual spawn timing. We obtained multi-year data on walleye sex, length, and capture date from state natural resource agency spawning collections throughout the Laurentian Great Lakes Region. We analyzed three effects using this large dataset: 1) the effect of walleye length on capture date during fishery-independent spawning surveys, 2) the effect of walleye length on capture date by anglers during the spawn, and 3) the effect of female walleye length on date of capture based on spawning ripeness status (i.e., "green", "ripe", and "spent"). Overall, we found that the longest walleye of both sexes were captured earliest in both spawning surveys and by anglers. The effect of length on reproductive phenology was stronger in females than in males. The pattern was also consistent among females grouped by ripeness. Although our study broadly supports an expected trend in females, it also uncovers an effect of length on annual spawn timing in males. The finding of differential reproductive phenology based on length suggests that

selective harvest of the longest individuals may shorten a population's spawning period duration.

## Comparison of the effects of different fishing methods on the food web and fish size structures

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It is commonly acknowledged that fishing can have effects on the size distributions of the fish populations. The effects could be plastic phenotypic effects or evolutionary changes. Different fishing methods have different selectivity so their catch consists of different fish species, fish with different traits (like size) and fish with different ages.

Here, we used Allometric Trophic Network model with Evolutionary application (ATNE-model) to see how different fishing methods affected the size composition of fish species and what were the effects at the level of a food web. ATNE-model was build at the base of previous ATN-model. In ATNE-model the fish inherit their growth parameters from the parental population and grow according to it. Model uses metabolic rates as its basement, and here the metabolic rates also changed during a growth season (difference from the ATN-model). Fishing methods studied were trawl and gill nets with different knot sizes. The theoretical food web was based on Lake Oulujärvi data. This presentation considers especially the percid fish, pikeperch (*Sander lucioperca*) and looks at the effects of fishing on pikeperch or fishing on its prey species vendace (*Coregonus albula*), smelt (*Osmerus eperlanus*) and whitefish (*Coregonus lavaretus*).

## **Changes in perch populations are indicating deteriorating water quality in four Danish brackish lakes with varying degrees of eutrophication**

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On a global scale many shallow brackish lakes have become eutrophic during the past century. How fish and particularly perch populations are responding to this development in brackish systems is not well studied. In the present study we investigated decadal changes in fish populations from 1999/2000 to 2017/2018 in four shallow Danish brackish lakes subject to varying degrees of eutrophication, using standardized Lundgreen gill nets. In two of the four lakes (Glombak and Selbjerg Vejle) a slight increase in N concentration and a significant increase in P concentration was observed. In the third macrophyte dominated lake (Han Vejle) there was a non-significant tendency for a nutrient increase, and the fourth lake (Lund Fjord) had no difference between the two periods. In the two lakes with a significant P increase, but also in the lake with a tendency to an increase we observed a 4-10 times reduction in percentual perch abundance by numbers, and a 2-10 times reduction in percentual biomass. Thus, the fish and perch communities are responding to the changes in nutrient concentration, and based on the Han Vejle results, the perch population seems to respond even before we find significant increases in the P concentrations. Looking across lakes and time there are strong correlations between perch and TN, TP and Chlorophyll, and it is concluded that in the given shallow (mean depth = 0.75 m), brackish systems, CPUE (by number) for roach and perch should be <30 and >20 individuals, respectively, for maintaining systems with macrophyte dominance. The results will be used for upscaling on Danish brackish lakes.

## **Reconstruction of the demographic history of Eurasian perch (*Perca fluviatilis*) on the basis of whole genome data**

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The demographic analysis is an essential tool to reveal intra- and interspecific genetic diversity and determine the phylogeographic patterns of species distribution. So far, the evolutionary history of Eurasian perch (*Perca fluviatilis*) is not well characterized. Here we infer the contemporary population structure of *P. fluviatilis* based on both whole mitochondrial (mtDNA) and nuclear genome data, consisting of 125 and 40 individuals, respectively. In addition to individual genomes, we included in the analyses whole-genome sequencing data from multiple individuals (Pool-seq) and published RNA-seq data. FigTree was used to visualize both split time dendrogram constructed in BEAST and the phylogenetic tree generated in iqtree-2.1.3. Haplotype network was represented using PopART. By applying PCMS analysis for whole-genome nuclear data, we observed different patterns of historical  $N_e$  fluctuations for European and Siberian populations reflecting contrasting glacial history. Based on the whole mtDNA genome analysis, we identified four highly diverged mitochondrial lineages, three of which were found in the Baltic Sea basin. Altogether, our findings support the idea of “melting pot” of evolutionary diverged lineages of perch at Baltic Sea area and demonstrate the power of whole genome analysis to infer evolutionary history of the species.



## Whole-genome sequencing of pooled DNA for the detection of genomic signatures underlying humic adaptation in Eurasian perch

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Organisms face environmental heterogeneity through time and space, which can impose highly variable selection pressures on populations. Terrestrial loads of dissolved organic carbon (DOC) have increased in recent years in lakes and rivers of many regions, which can greatly alter the chemical, physical, and biological traits of aquatic ecosystems, altering planktonic and benthic primary production due to changes in light and nutrient availability. Lakes with high levels of DOC usually also have acidic pH, high oxygen and temperature stratification, and extremely low visibility, which impose challenges to the adaptation of species that inhabit these circumstances. Eurasian perch (*Perca fluviatilis*), is one of the few fish species able to live in such environments, and is abundant in both humic and clear-water lakes. Here we use whole-genome sequencing of pooled DNA from multiple individuals (Pool-seq) to uncover the genomic regions involved in humic adaptation. We discovered approximately 1.5 million SNPs using DNA pools from nearly 50 humic and clear-water lakes in northern Europe and Siberia. Subsequently, we applied allele frequency-based analysis to study selective sweeps among populations, followed by genome–environment association (GEA) analysis to investigate the presence of outliers SNPs associated to humic adaptation. Our study demonstrates high potential and cost-efficiency of pool-seq to understand the genome-wide patterns of diversity and to shed some light on molecular mechanisms of adaptation to extreme environmental conditions.

## **The long-term trends in fish yields of percid species in central Europe with respect to fisheries management actions**

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We studied the long-term trends in the yields of percid species (European perch *Perca fluviatilis* and pikeperch *Sander lucioperca*) in connection to fisheries factors. To do this, we used secondary data from mandatory angling logbooks collected by the Czech Fishing Union in central Bohemia over years 2005–2020. We used mixed models to assess the long-term trends and the effects of fisheries factors on the yields of both percid species. We found that the overall percid yield has decreased by 60–70 % over the 15 years. This decrease could not be explained by lower intensity of fish stocking. However, the yield was closely correlated to the angling effort (the number of anglers who fished in the study area). In addition, the fishing sites that were under the highest angling pressure displayed the highest fish yields per hectare but also the lowest yield per one angler, suggesting strong competition between anglers.

## **Humic-substance-associated changes in eye size and whole eye transcriptome in Eurasian perch (*Perca fluviatilis* L.)**

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Populations exposed to similar environmental challenges are expected to undergo parallel changes in relevant phenotypes. Yet, this process can be better described as a continuum ranging from parallel to non-parallel changes driven by both genetic and environmental factors. Here, we investigated relative eye size and whole eye transcriptome in Eurasian perch (*Perca fluviatilis* L.) in relation to visual environment shaped by humic substances. In aquatic habitats, humic substances lead to strong light filtering creating an extreme visual environment, where the increased eye size or adaptation at molecular level might be beneficial. To test this, firstly, we analyzed phenotypic variation in multiple clear-water and humic lakes (>50) across substantial part of the species range. While there was a large inter-population and regional variation, humic lake populations had significantly larger relative eye size. Subsequently, we used the whole eye RNAseq to elucidate what genes are differentially expressed between humic and clear-water populations ( $N_{\text{lakes}}=14$ ). We have identified >200 differentially expressed genes including genes related to eye size, lens size, lens and corneal opacity (e.g., APOA1), as well as up-regulation of red long wavelength sensitive opsin (OPN1LW) and down-regulation of short wavelength sensitive opsin (OPN1SW) in humic lakes. Lastly, in order to assess to what extent phenotypic variation in the eye morphology is influenced by the genetic and environmental factors, we conducted a common garden experiment where fry, originating from three clear-water and three humic lakes in Sweden, were grown in clear-water and humic enclosures. Results showed that response to the treatment was population and habitat dependent. Taken together, here we show how humic substances may shape visual system in a teleost fish at morphological and molecular levels and that results are not uniformly parallel.

## **Four decades of pikeperch (*Sander lucioperca*) stock monitoring in Finnish coastal area - effects of fishing, predation and climate change**

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Pikeperch is one of the most valuable and targeted freshwater fish species in Finland. Pikeperch stocks have been evaluated by catch statistics, catch samples and VPA since 1980s in the Finnish coastal areas. The main fishing area has been the Archipelago Sea where pikeperch stock was at highest in 1990s and 2000s and has decreased after that despite the steep reduction in the gillnet fishing effort. Only in the latest years the pikeperch stock has been growing again. The evolutionary changes have been assumed to be one reason for the slow recovery of the pikeperch stock, as a decrease in maternal size and age has been observed. The increased cormorant and seal populations are an unlikely reason since they cover only a small proportion of the natural mortality. Climate change has probably leveled down the year-class strength as only moderate year-classes have appeared in 2-3 yr. consecutive warm summers that were not observed before 2000s. Individual growth has accelerated especially in young pikeperch enhancing the production of the stock. Pikeperch catches have rapidly increased in northern coastal areas likely reflecting the warming of waters. The recent fishing regulations are predicted to positively affect the state of the pikeperch stock and catches.

## **Application of genetic fingerprinting in fish stock management: lessons from Atlantic salmon and Eurasian perch**

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Genetic fingerprinting is applied in fish stock management for over forty years to solve multiple questions, such as revealing stock structure, monitoring of population status and identification of fish origin. One of the species group, where the progress of integration of genetics in fish stock management has likely been the fastest, are salmonids. Here, we summarize the applicability of genetic fingerprinting in Atlantic salmon management based on several international projects (e.g. Kolarctic salmon KO197, CoASal KO4178), where assessment of large- and fine-scale genetic structure allowed to refine management units and to identify the origin of the salmon caught at sea with high accuracy. Moreover, we describe the application of genetic tools in forensics to investigate unregulated and illegal fishing in Eurasian perch. Earlier studies showed that application of microsatellites allowed to discriminate between freshwater and marine perch in Estonia with ca. 85% accuracy. Recent studies of perch genome, using next generation sequencing, revealed hundreds of thousands polymorphic SNPs. A pilot study based on DNA pools showed that few hundreds SNPs provide much higher level of accuracy in discrimination between freshwater and marine populations compared to microsatellites. Also this has a potential to reduce the costs of genetic analyses by employing custom SNP-arrays, thus likely promoting the development of routine genetic monitoring of fish trade.

## **Qualitative diet analysis of two coexisting piscivores – pikeperch (*Sander lucioperca*) and asp (*Aspius aspius*)**

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Pikeperch belongs to the most valued game-fish species naturally occurring particularly in shallow eutrophic waters. Because it relatively soon, most often during the second year of life, switches to an exclusively piscivorous way of foraging, it is also a species often used for biomanipulation of fish communities in drinking water supply reservoirs. Unlike shallow eutrophic waters, in the conditions of deep canyon-like reservoirs of mesotrophic character the cohort strength of pikeperch is quite variable and the factors behind are not fully known. One of the possible factors of variable success of pikeperch in waters with lower than high productivity is the competition with other predatory fish species, especially the conspecific asp. Therefore, in order to clarify the possible diet overlap and hence competition between the two species, 124 digestive tracts of pikeperch with the body length of 95 to 770 mm and 292 digestive tracts of asp with a body length of 115 to 660 mm were examined in the Římov Reservoir using various capture techniques (gillnetting, beach seining, purse seining, trawling) over the period of five years.

## **Year-round changes in fish community mercury content and bioaccumulation in a seasonally ice-covered boreal humic lake**

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Northern latitude lakes demonstrate pronounced seasonality, where the warm open-water season and subsequent cold and ice-covered season dominate natural cycles. While fish muscle mercury content is well documented in open-water summer months, we have limited knowledge on year-round mercury dynamics in fish from various foraging, thermal and spawning guilds. Climate change continually elevates temperatures above the global average in northern regions, generating warmer winters and shorter periods of ice-cover. A holistic understanding is lacking from how mercury dynamics vary in fish species from various guilds along seasonal gradients in thermal attributes, light and lake productivity. Here, we conducted a year-round study to test how seasonal variability may influence total mercury content (THg) and bioaccumulation of the whole fish community in mesotrophic boreal humic Lake Pääjärvi in southern Finland. We sampled the fish community (n= 12 species), including three percids, ruffe (*Gymnocephalus cernua*), pikeperch (*Sander lucioperca*) and perch (*Perca fluviatilis*), and tested for THg content in dorsal muscle. THg was the highest in piscivores, followed by profundal benthivores and planktivores, and the lowest values were in littoral benthivores and omnivores. THg was the highest in the winter and spring, due to condensing, starvation and spawning effort, but the lowest in summer and autumn, due to recovery and somatic growth dilution. Bioaccumulation regression slopes between THg and fish length were the most elevated near spawning time and the lowest in the autumn and summer after the growing season. THg in fish muscle was best described by fish total length and a combination of seasonally relevant environmental factors (ice thickness, total carbon, total nitrogen, and oxygen saturation) and biotic factors (gonadosomatic index, and sex). Seasonal variation found in fish THg content and bioaccumulation supports the need for a standardized monitoring programme to include sampling in both winter and summer to understand seasonal changes.

## Comparison of an efficiency and profitability of juvenile pikeperch *Sander lucioperca* production under RAS with or without using of rotifers *Brachionus plicatilis* as first exogenous feeding during larval culture

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This study compared an efficiency (specific growth rate – SGR in  $\% \cdot d^{-1}$ , survival, cannibalism and deformity rates – SR, CR, and DR in %) and production cost for juvenile pikeperch (*Sander lucioperca* L.) with TL= 36 – 41 mm and W= 0.34 – 0.47 g. Mentioned juvenile production was based on two different the first exogenous larval feeding during period 5<sup>th</sup> – 12<sup>th</sup> days post hatching (DPH). The first group (R) was fed with rotifers (*Brachionus plicatilis*) 10 ind.ml<sup>-1</sup> and the second (A) with artemia (*A. salina*) 5 ind.ml<sup>-1</sup>. Both groups of larvae (TL =  $5.7 \pm 0.2$  mm and W =  $0.7 \pm 0.15$  mg) were cultured under same RAS: water temperature  $20 \pm 1.5$  °C; oxygen saturation  $85 \pm 10$  %; pH  $6.8 \pm 0.3$ ; light regime 12L:12D;  $80 \pm 15$  lux in three repetitions (black tanks with volume 333 litres) with initial density 100 larvae per litre. After 12 DPH, larvae in group R were fed till 17 DPH with the combination of rotifers and artemia 5+5 ind.ml<sup>-1</sup>. During this period, larvae of group A were fed with artemia 5 ind.ml<sup>-1</sup>. Both groups were fed with the combination of artemia and artificial starter Otohime (150 – 250  $\mu$ m) from 18 DPH. Larvae of both groups were weaned at 26 DPH when larvae received only Otohime starter 250 – 1400  $\mu$ m till the end of this experiment, *i.e.* 65 DPH (after 60 days intensive culture).

Results of this study showed higher growth rate in larvae of group A (SGR =  $6.9 \% \cdot d^{-1}$ ) compared to group R (SGR =  $6.6 \% \cdot d^{-1}$ ). However, larvae in group R achieved higher survival rate (SR = 37 % compared to 16 %), lower cannibalism rate (CR = 7 % compared to 20 %) and lower deformity rate (DR = 15 % versus 33 %). Generally, group R significantly produced higher number of high-quality juveniles 31,5 % compared to group A (10,7 %). Three times higher production of high-quality pikeperch juveniles was also connected with lower production cost on one produced pikeperch juvenile in group R (4.8 CZK.pcs<sup>-1</sup>) compared to 10.1 CZK.pcs<sup>-1</sup> in group A.

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## Effect of sexual size dimorphism on the distribution and diet of European perch *Perca fluviatilis* and ruffe *Gymnocephalus cernua*

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Many fish species exhibit female-biased size dimorphism that may lead to spatial segregation of sexes. We selected two common European percids (Percidae, European perch *Perca fluviatilis* and ruffe *Gymnocephalus cernua*) differing in total body size, reproduction mode, habitat use and diurnal activity, to test whether they display size dimorphism and its effect on habitat use and diet. Females were significantly larger than equally old males (by 76% in perch, 23% in ruffe). No differences in habitat use by sexes were found along depth and longitudinal gradients of reservoir or between inshore and offshore habitats. Perch females had fuller guts, but both sexes were equally likely to consume same prey items (*Leptodora kindtii*, *Daphnia* spp., Chironomidae larvae, fish). Both sexes of ruffe had similar stomach fullness, but females preferred *L. kindtii* and males *Asellus aquaticus*. In summary, perch and ruffe show strong female-biased size dimorphism, but sexes do not segregate spatially. Their unequal sex-specific dietary demands are satisfied by higher feeding rate of female perch and by preference for different prey items in ruffe. The magnitude of dimorphism was related to species body size and reproduction mode being larger in larger species and in total spawner (perch).

## **The invasion history of European perch (*Perca fluviatilis* L.) in mainland Portugal: Options for its management**

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The European perch *Perca fluviatilis* has recently invaded Portuguese watersheds (Iberian Peninsula, southwestern Europe), being first detected in a small reservoir of the Tagus river basin. This new non-indigenous fish has raised deep concerns about its putative impacts on freshwater communities given its strong invasive potential, tied to its broad ecological niche and particular life history traits. Here, we reconstruct the history and putative invasion pathways of this species in Portugal and discuss management options. Newly collected molecular genetic data (e.g., microsatellites) indicate that the origin of the Portuguese population resulted from an introduction from its northwestern native range (putatively from France or Belgium), and is distinct from the origin of neighbouring Spanish non-native populations. Current species distribution in Portugal is also presented from data obtained from an ongoing monitoring program, integrated with recreational fishermen records (e.g., citizen science) and environmental DNA metabarcoding data. We show that the European perch has spread to other reservoirs and drainages since its first record, likely due to its high interest for recreational fisheries, and greatly restricting the available options to manage this invasive fish in Portuguese watersheds.

## **Diets of age-0 walleye reflect food web changes in western lake Erie**

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In Lake Erie, walleye are king. However, their year-class strength can fluctuate widely. Young walleye growth and survival is directly affected by their diet during the first year of life. In the last few decades, Lake Erie has experienced several unintentional introductions of aquatic invasive species (AIS) that have likely led to environmental and food web changes, potentially impacting age-0 walleye diet and growth. To determine how the diet of age-0 walleye has changed in western Lake Erie, we compared diet composition during late spring, summer, and early fall using data from 1994 and 2019. We found that calanoid copepods dominated diets of pelagic larval walleye in spring 1994, differing from 2019 when cyclopoid copepods were more frequently consumed. From summer to early fall 1994, demersal juvenile walleye diets contained mostly fish, whereas large cladoceran species and benthic invertebrates dominated diets during 2019. Additionally, two of the most recent AIS, the spiny water flea and round goby, were commonly found in 2019 diets but absent in 1994, confirming that age-0 walleye are adapting to food web changes brought about by AIS. Our results suggest that copepods remain important food for pelagic walleye larvae, although a switch in species from calanoids to cyclopoids was observed. For demersal age-0 fish, cladocerans and benthic invertebrates may have become important prey items for age-0 walleye in Lake Erie, especially in the later months, which could have implications for slower growth rates.

## **Invasive *Bythotrephes longimanus* are selected by Age-0 Yellow Perch and do not negatively affect perch growth**

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*Bythotrephes longimanus*, a predatory zooplankton native to Eurasia known for its large caudal spines, is known to negatively impact several zooplankton species important to age-0 fish growth, and decrease growth rates of native planktivorous fish including Yellow Perch (*Perca flavescens*). Oneida Lake is a eutrophic, polymictic lake located in New York, USA that supports a large Yellow Perch population frequently targeted by anglers. *Bythotrephes* was first discovered in Oneida Lake in 2019 and reached densities close to 100 individuals/m<sup>3</sup> in both 2020 and 2021. Here, we investigate the diet selection of age 0 and older Yellow Perch to evaluate if perch select *Bythotrephes* and if feeding on *Bythotrephes* depends on the size of age-0 perch. Then, we use the extensive monitoring data from Oneida Lake to investigate if age-0 perch growth is decreasing as a consequence of feeding on *Bythotrephes*. Age-0 Yellow Perch as small as 27mm fed on *Bythotrephes* and age-0 fish consistently selected for *Bythotrephes* at lengths larger than 40 mm (Ivlev's Electivity Index 0.71 to 0.99). *Bythotrephes* was found in 46% of age-0 and 36% of age 1+ Yellow Perch from June through October. Contrary to our prediction, age-0 Yellow Perch growth rates were higher in the three years with *Bythotrephes* present (2019-2021) than the nine years before the establishment of *Bythotrephes* (2010-2018).

## **From margin to frontline – pikeperch stocks and their management in Finnish lakes**

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The pikeperch (*Sander lucioperca* L.) stocks of Finnish lakes collapsed in 1960's because of a period of cool summers unfavourable to reproduction and simultaneous increase in fishing mortality due to emerging use of monofilament gillnets. The re-establishment of pikeperch populations was started in 1980's with a widespread stocking of fingerlings. The yield obtained from the stocked fingerlings was profitable only in minority of lakes, but gradually stocked pikeperch established self-sustaining populations. The importance of pikeperch in fish catches increased and more sustainable management options, including elevated minimum size limit (MSL) and mesh-size of gillnets were applied in many lakes. New fishing act (2016) raised the MSL of pikeperch to 42 cm with possibility to +/-20% adjustment locally. The act prescribed natural reproduction of fish populations as the most important criteria to sustainable fisheries, and stockings should be done only if the population is not able to reproduce. At present, pikeperch is the most targeted species in many Finnish lakes. Annual catches have increased to 3-4 Mkg during last years compared to less than 1 Mkg in 1990's and earlier.

Pikeperch was introduced to Lake Vesijärvi in 1980's as a tool of biomanipulation and to improve the value of fish catches. Eutrophication had changed the lake more favourable to pikeperch. First lake-hatched strong year-class was 1992. The need of elevated MSL (42 cm) and mesh-size of gillnets was noticed and the mesh-sizes under 50 mm were forbidden, first in 1997 in southern basin of the lake and in 2008 in the entire lake. Since 2002, the annual pikeperch catches have been variable, 18-30 tonnes. Further studies suggested even higher MSL (50 cm) and mesh size of 60 mm to criteria of sustainable fishing and these have been applied since 2014, but only in half of the southern basin of the lake.

## The effect of littoral complexity on the diel distribution of early juvenile fish communities in temperate freshwater reservoirs

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The occupation of deep waters as a daytime shelter has been broadly documented in early juvenile fish communities from artificial water bodies where the littoral zone is spatially poorly structured. In contrast, utilization of diel refuges, where littoral aquatic vegetation is well developed, remains poorly described. In this study, the diel distribution of early juvenile fish communities, from two temperate freshwater reservoirs that strongly differed in cover of submerged aquatic vegetation, was investigated.

In the daytime, 99.96 % of the juvenile fish community from the plant-rich water body was found in the near shore belt of submerged aquatic vegetation reaching an average abundance of 37,982 inds.1000 m<sup>-3</sup>. In contrast, in the pelagic habitat, close to zero abundance was found in the daytime. In the plant-poor water body, 98.9 % of juveniles occupied the pelagic habitat during the day and reached an average abundance 333 inds.1000 m<sup>-3</sup>. Fish vertical distribution in the pelagic habitat in both water bodies was affected by steep thermal and oxygen stratification and no individuals were found below 6m depth.

At night, 88.8 % of the juvenile fish community from the plant-rich water body predominated in the pelagic habitat and reached an average abundance 1423 inds.1000 m<sup>-3</sup>. Their diel horizontal shifts were much more pronounced compared to the community from the plant-poor water body that reached an average night pelagic abundance of 523 inds. 1000 m<sup>-3</sup>. About 1.1 % of the latter juvenile fish community was found in the littoral during the day and 0.7 % at night reaching an average day time abundance of 1688 inds.1000 m<sup>-3</sup> and night time abundance 1664 inds.1000 m<sup>-3</sup>.

At night, the juvenile pelagic fish community from the plant-poor water body was composed of percids, 66.2 %, and cyprinids, 33.8 %. This was reversed in the plant-rich water body with percids, 34.4%, and cyprinids, 65.6 %.

Pelagic zooplankton density in the plant-rich water body was 35 inds. L<sup>-1</sup> and littoral density was 1.14 inds. L<sup>-1</sup>. In the plant-poor water body, pelagic zooplankton density was 85 inds. L<sup>-1</sup> and littoral density was 9.7 inds. L<sup>-1</sup>.

The study indicates that if a well developed littoral cover of aquatic vegetation is present (plant-rich water body), early juvenile fish communities prefer extensive diel horizontal shifts. In a plant-poor water body the absolute majority of juvenile fishes stays in the pelagic habitat both in the day and at night, *i.e.* the exchange of fishes between the pelagic and littoral is rather limited. The overall absence of apparent diel vertical migration seems to be amplified by the steep thermal stratification of the water body, extremely low temperature in the hypolimnion and oxygen depletion in the metalimnion.

## Effects of quercetin and rutin as feed additives on pikeperch (*Sander lucioperca* L.) in recirculating aquaculture

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European pikeperch (*Sander lucioperca*) is a popular food fish and a promising aquaculture species, but it is highly sensitive to environmental and handling stressors. This limits the intensification of its farming in recirculating aquaculture and aquaponic systems, which are production systems of growing interest for this species and for the sustainable upscaling of its cultivation. Plant bioactive compounds can be effective feed ingredients that reduce stress and improve fish growth and immunity, but no specific compounds have been identified and tested on pikeperch. An 84 day experiment investigated the effect of incorporating either quercetin or rutin, two plant flavonols previously found to have beneficial effects on different fish species, at 2 g kg<sup>-1</sup> into the diet of pikeperch of an average initial weight of 356 ± 90 g (mean ± SD). The fish were cultured in closed recirculating systems with tank volumes of 2m<sup>3</sup> at a water temperature of 24°C. Growth, stress and immune parameters were compared to a control group and accumulation of the phytomolecules in the cultivation system was monitored. While the addition of quercetin did not have a significant effect, rutin addition resulted in a significantly lower growth rate, final condition factor and a higher feed conversion ratio. Physiological parameters indicate toxic effects of rutin, possibly due to concentration or exposure time, and highlight the need of species-specific research as improved formulated feed is developed for pikeperch in intensive aquaculture.

## **Yellow perch (*Perca flavescens*) mortality bottleneck restricts recruitment**

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Historically Saginaw Bay, Lake Huron in North America sustained both an abundant Walleye and Yellow Perch population and fisheries. Walleye have recently recovered and now prey heavily on young Yellow Perch. Perch reproduce very well in Saginaw Bay but mortality between age-0 and age-1 averages 83% and has been as great as 99%. Lost from the bay is an annual influx of pelagic predators from the main basin of Lake Huron that were thought to offer a buffer on predation for Perch. Recently that was from invasive Alewives and historically from native Cisco. This predation mortality constitutes a bottleneck that is preventing recruitment to the local recreational and commercial fisheries. Both have greatly contracted and are virtually collapsed by historical standards. Attempts to bio-manipulate Walleye (liberalized harvest in hopes to reduce abundance) to benefit Perch has largely failed. Cisco reintroduction in the bay is taking place, hoped as a long-term solution. Yellow Perch availability is a major driver of recreational fishing participation in the bay. A new management plan is in development with stakeholder involvement. Consultation indicates that Perch restoration remains a high priority, but the problem seems to defy any easy solutions. What few perch do survive, grow very fast helping to compensate some for the loss of abundance.



## **Assessing the contribution of artificially stocked fish to the population using otolith microelemental composition**

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Stocking is a common management practice applied to help mitigate the effects of over-fishing or other threats to wild fish populations. This activity is largely employed in freshwater ecosystems, but with complex and temporally variable strategies (different timing, fish lengths and origins), and hence its effectiveness is not easily understood. In order to assess the prevalence of artificially stocked individuals in a population with complex management history (pikeperch - *Stizostedion lucioperca* – from Lipno reservoir, Czechia), we investigated the microelemental composition of sagitta otoliths of wild and stocked individuals. Five out of seven chemical elements analyzed (barium, magnesium, potassium, rubidium and strontium) were found to differ between stocked and wild pikeperch. The machine learning classification algorithm was trained with data from fish of known origin (42 individuals) to classify the origin of fish of unknown origin captured in the lake (60 individuals). The model had an overall accuracy of 83.3 %, with the accuracy for wild fish being 89.5 %, while the accuracy for each stocking facility ranged from 60 to 100 %. The model identified that the fish of unknown origin were predominantly autochthonous (80 %), with the contribution of stocked fish being smaller (20 %). Due to the relatively small contribution of stocked fish into the pikeperch stock, the efficacy of the stocking program should be further scrutinized in order to avoid the pursuing of management strategies that are neither efficient nor healthy for the fish stock.

## **Eurasian perch (*Perca fluviatilis*) and rainbow trout (*Onchorhynchus mykiss*) culture in pond multitrophic system – a case study from Ireland**

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Water quality, duckweed, and fish productivity of the given commercial-sized innovative multitrophic aquaculture system are characterized using two-year data (2019 and 2020). The system converts nutrients originating from aquaculture units into microalgae and duckweed biomass and removes residual ammonium or/and nitrite to ensure recycled water quality for fish rearing. The findings showed that following system maturation, total ammonia nitrogen (TAN), free ammonia, nitrite (NO<sub>2</sub>-N), nitrate (NO<sub>3</sub>-N), pH, chlorophyll, and turbidity were all maintained at optimum levels for fish in the system (second year of study). The removal of TAN, NO<sub>2</sub>-N, NO<sub>3</sub>-N, and TN was facilitated by duckweed and a variety of microalgae and bacteria. Over the course of two years, net yields of Eurasian perch (*Perca fluviatilis*) and rainbow trout (*Oncorhynchus mykiss*) reached 4 325 kg/year and 9 674 kg/year, respectively, at the described facility. The multitrophic farm shown here is an efficient method of growing European perch and rainbow trout, as well as duckweed co-culture. The duckweed's value could help cover some of the costs of fish production.

## **The European Percid Fish Culture Core Group as a knowledge sharing group**

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In 2012 the European Percid Fish Culture (EPFC) was founded as a thematic group within the European Aquaculture Association (EAS). This EPFC was meant to bring researchers in contact with their target group, being the upcoming pikeperch (*Sander lucioperca*) and European perch (*Perca fluviatilis*) producers. From the founders' point of view, research needs to solve, clear-out, the bottlenecks in the industry and to push this new sector forward.

The first EPFC workshop was held in 2012 during the EAS congress in Prague, Czech Republic. Year by year the network of researchers and fish producers expanded, and the contacts and exchange of knowledge and insights became more valuable. All with one common topic: percid fish culture. In 2017 the idea grew to evolve from a knowledge exchanging platform towards a knowledge sharing group.

Beginning 2019 the EPFC Core Group was founded as a knowledge sharing group within the EAS thematic group EPFC. All 26 members paid a membership fee and signed a cooperation agreement for 3 years. A Short overview of the first 3 years activities and future activities is given in the presentation.

## **Biological parameters of an imperilled pike-perch (*Sander lucioperca* L.) population in Central Europe**

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Freshwater ecosystems are sensitive indicator to anthropogenic and natural changes. Assessing the response of fish populations to past environmental changes helps to understand their future development patterns. However, this is often hampered by the lack of long-term biological data. Scales and otoliths from pike-perch collected over the past 17 years (2003-2020) were used as proxy for individual somatic growth. Of five different models used for back-calculation (Dahl-Lea, Fraser-Lee, Biological Intercept, Monastyrsky, and Modified fry), the Fraser-Lee model for scales and the Modified fry model for otoliths were selected based on the fit to our dataset ( $r^2=0.83$  and  $r^2=0.90$ , respectively). Mean standard length at different ages was calculated and showed significant variation among cohorts. Growth increment between successive age groups of individual fish in each cohort was computed. The best growth model (von Bertalanffy) for our dataset was selected based on the values of residual sum of squares. The estimated vital growth parameters  $L_\infty$ ,  $K$ , and  $\Phi$  varied from 42.8 cm to 79.3 cm, 0.133 to 0.45, and 2.57 to 2.97 among cohorts, respectively. The growth rate at the first decade of this century was very slow and together with high exploitation rates it was likely cause of pikeperch population collapse. Later length-at-age data show partial recovery of the growth rate.

## **Alternative protein and lipid sources for percid feed: A meta-analysis study**

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Aquaculture production of European percid fishes, pikeperch (*Sander lucioperca*) and European perch (*Perca fluviatilis*), has significantly increased since the 1990s and is expected to move towards an established freshwater aquaculture sector in Europe. The aquaculture production of these fishes is mainly operated under a recirculating aquaculture system, employing high-quality compound feeds. Over the last twenty years, many studies have sought alternative ingredients for fishmeal and fish oil in feed for percid aquaculture. In the present study, we employed a meta-analysis approach to investigate the effect of these alternative sources on production performance and meat quality of both perch and pikeperch. Overall, alternative ingredients have a detrimental impact on Hedges' effect sizes of special growth rate, feed conversion ratio, and fillet quality, specifically the fatty acid profile of fed fish. The meta-regression analysis demonstrated that, at plausible thresholds, dietary novel ingredients maintain those variables similar to the control group. According to our findings, diversifying feed components in percid feed might reduce feed price volatility and ensure the sector's future growth.

## Exploring the food web and fish dietary niches in a deep, eutrophic reservoir: Does biogenic methane contribute to fish production?

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Eutrophication of lentic waters leads to higher algal productivity, organic matter accumulation and lack of oxygen, which stimulates methane production. Biogenic methane has recently been identified as an important energy source that partially supports some freshwater food webs. However, no research has yet explored the role of biogenic methane in food webs of deep, eutrophic reservoirs, although these systems provide particularly favourable conditions for methanogenesis and methane oxidation. Using carbon and nitrogen stable isotopes ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ), we therefore investigated the food web and fish dietary niches in the Římov Reservoir, a stratifying and eutrophic artificial lake (max. depth: 43 m, mean depth: 16 m, total phosphorus concentration:  $\sim 30 \mu\text{g L}^{-1}$ ) in southern Bohemia. Our main goal was to evaluate how much carbon in the diet of common fish species could derive from biogenic methane. We found that profundal chironomid larvae were strongly depleted in  $^{13}\text{C}$  relative to littoral macroinvertebrates and pelagic crustacean zooplankton. Using  $\delta^{13}\text{C}$  values measured for primary producers and methane in the Římov Reservoir, we estimated that profundal chironomid larvae assimilated  $\sim 50\%$  of their carbon from biogenic methane. Of the five fish species studied (perch *Perca fluviatilis*, ruffe *Gymnocephalus cernua*, bleak *Alburnus alburnus*, bream *Abramis brama*, and roach *Rutilus rutilus*), the ruffe population had the largest isotopic niche size and the lowest mean  $\delta^{13}\text{C}$ . Outputs of isotopic mixing models indicated that  $\sim 8\%$  of the carbon biomass of ruffe population in the Římov Reservoir eventually came from methane. At an individual level, the maximum contribution of methane-derived carbon to ruffe biomass was  $\sim 25\%$ . Other fish species showed a negligible reliance on methane-derived carbon. In summary, our study illustrates the flexible feeding behaviour of ruffe in a deep, eutrophic ecosystem and provides evidence that biogenic methane may partially support the production of this species.

## Unlocking the genome of perch – adaptation, parasites and glacial history

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Life from microbes to vertebrates has evolved countless solutions to colonize practically every crevice of Earth. Among the less known evolutionary innovators is a sturdy fish, Eurasian perch, which thrives in acidic and dark humic freshwater lakes, where other fish species perish. Here, we describe the results of joint research effort, which aims to generate and apply genomic information to better understand how ecological, physiological and evolutionary processes shape genetic variation on this keystone species. We describe the sequencing and annotation of the first whole genome assembly of perch, followed by resequencing of over thirty whole nuclear genomes to better understand the molecular mechanisms of adaptation to humic and acidic environment. Subsequently, we show how gene expression analysis can reveal unexpected links between parasites and environment, and challenge old dogmas, such as immunoprivilege. Next, we describe the development and application of high-throughput metabarcoding to reveal cryptic diversity in perch eye parasites. Finally, based on whole mitochondrial and nuclear genome analysis of perch collected from Europe and Siberia, we decipher the glacial history and colonisation routes of current day waterbodies. Our work illustrates the power of whole genome analysis and provides the foundation to resolve intricate links between genetic variation, ecology, evolution and climate change.

## Niche width and diet specialization of Eurasian perch (*Perca fluviatilis*) compared to three other fish species

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A stable isotope analysis from four body tissues (fin, muscle, blood, plasma) differing in isotopic half-lives was provided to reveal a feeding behaviour of Eurasian perch (*Perca fluviatilis*). Specifically, the position of Eurasian perch in the food web, the width of individual and population niche, and the individual specialization. The results were compared with three other species, European catfish (*Silurus glanis*), Northern pike (*Esox lucius*) that are typical predators, and rudd (*Scardinius erythrophthalmus*) that is an herbivorous to omnivorous species. Eurasian perch appears to be a very generalist species, without inclining to strict specialization in contrast to Northern pike. Eurasian perch switches between food sources seasonally, thus both individual niche and population niche are wide. In contrast to the two large predators (European catfish, Northern pike), individual specialization of perch was not dependent on the trophy of the site. An interesting phenomenon was observed for large individuals of perch. Their foraging behaviour was very similar to the behaviour of the apex predators.



## **Utilizing otolith thin sections in age validation of Perch (*Perca fluviatilis* L.) in coastal areas of Finland**

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Perch is one of the most common species in Finnish coastal areas and it has also an important role as catch for both commercial and recreational fisheries. In Finnish coastal areas more than 3000 Perch are aged and their growth calculated annually from operculum bones. As the former age reader was retired without a change to have a proper intercalibration with new, less experienced reader we used a set of samples that had both operculum and otoliths collected. The new reader aged the samples first only from operculum and then compared the results with previous reader. After the comparison the reader used also thin sections of otoliths to help checking the age from previously read operculum and also to give some help to understand the individual growth patterns.

The results showed that having both samples did not only improve the agreement between readers but also helped to detect more reliably the first annuli from operculums and detect false rings. It seems like even the more experienced reader had some troubles in detecting the first annuli in some individuals and also separating some false rings from actual annuli. If this bias causes some problems in assessment on stock level remains to be studied as the data has not yet been fully analysed and effects of bias has not yet been modelled.

This study proves the importance of doing some validation of aging between readers and using different structures and methods to gain more reliable aging results

## **Taurine supplement improved growth performance and digestive activity of pikeperch larvae**

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Pikeperch (*Sander lucioperca*) intensive aquaculture development has been slowed down by high mortality rates (>70%) during larval rearing. The use of taurine during larval development in other species has been reported to improve survival as well as growth. This trial aims to find out whether supplementation of taurine during the larval stage will benefit pikeperch larval performance and if digestive enzymes production can be promoted. A twenty-one-day trial was carried out, in which taurine live feed enrichment for pikeperch larvae was tested. Overall, growth parameters such as total length, myomere height and eye diameter were significantly higher and survival between treatments remained equal. Specific activities of digestive enzymes in the control group were low compared to taurine group during the first seven days post hatching (dph) but reached peak values for alkaline proteases, lipase and pepsin at 14 dph. Taurine supplementation increased specific pepsin, alkaline proteases, and lipase activities in early larval stages where larvae presented enhanced levels of alkaline proteases and pepsin activities at 7 dph, while that of lipase tended to be higher although not significantly. Such enhancement of enzyme activity can improve nutrient availability, which has had a direct effect in improving pikeperch larvae growth and development. However, these differences in digestive activity were compensated at the end of the experimental period (21 dph).

## **Variable growth and feeding of *Perca fluviatilis* in five pristine bog lakes in Latvia**

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The Teici Nature Reserve in Latvia includes 18 lakes. Some of the lakes are known to host a perch population. The few previous studies from Northern Europe suggest fish growth in brown water, low pH and low productivity bog lakes to be stunted and size classes limited to small fish.

We hypothesized that bog lake fish populations are spatially uniform in the terms of length frequency distribution, feeding and growth because of the abiotic environment.

Four lakes were studied. Samples for phytoplankton and invertebrate communities; fish abundance, diversity and biomass and fish diet and growth were collected and analysed.

Two of the lakes had stunted populations with largest individuals of 20 cm total length (TL), while in two other lakes individuals of up to 42cm were found. Invertebrate communities were of low biomass and dominated by a few abundant species of terrestrial insect larvae. Smaller fish (5-12cm TL) fed on zooplankton. Larger individuals (13-18 cm TL) showed high feeding variability across the study lakes. Insect larvae were the dominant prey in one lake. Adult terrestrial insects dominated the stomach contents from three lakes. Fish growth was variable – size of 3+ age fish varied from 10.3 cm to 15.3 cm TL across the lakes.

Statistical analysis indicates that changing environmental variables determine fish growth in the study lakes. We found that water transparency is a key driver leading to faster growth rates in clearer lakes. We suggest that the low zoobenthos availability forces perch to switch to feeding on terrestrial insects. Better visibility in its turn makes it easier to forage on the water surface increasing feeding efficiency.

We are looking to explain the finding that only some lakes have stunted perch populations. Changing spring influx of low pH water leading to low egg survival as well as winter hypoxia are among the possible explanations.

## **Modelling annual fish recruitment using a zero-inflated Poisson regression on Lake Erie walleye (*Sander vitreus*)**

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Fishery independent surveys provide important information about fish population dynamics. However, environmental factors often influence fish abundance and distribution and thus create difficulties to accurately estimate survey parameters. In this study, we use a zero-inflated Poisson regression to process the fish catch and environmental variables collected from the Interagency Fall Trawl Surveys in Lake Erie. The abundance of walleye (*Sander vitreus*) larvae collected from the surveys was the dependent variable and water temperature, dissolve oxygen, and water transparency (Secchi depth) were environmental covariates or independent variables. A negative binomial model was also tested to compare with the Poisson model. The Akaike information (AIC) criterion was used for model selection among the covariates and models.

**Poster presentations**  
(alphabetic in order of presenters)

## **High mobility and flexibility in habitat use of pikeperch (*Sander lucioperca*) based on mark-recapture experiment in a deep reservoir**

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Detection of stocked fish is crucial for assessment of the stocking success. Mark-recapture experiments of sensitive fish larvae are rare. In this study, early hatched pikeperch (*Sander lucioperca*) were marked by oxytetracycline hydrochloride in a hatchery and stocked in a semi-closed bay, close to the dam part of a deep reservoir in 2007 and 2008. Pikeperch were monitored by a fix-frame trawl for 43 and 51 days after stocking, respectively. In both years, marked pikeperch were recaptured in the bay and closed dam part of the reservoir during the whole study period. After a month, individuals were captured in the middle part of the reservoir approximately 5 km from the stocking place. During the last sampling in 2007, four individuals were recaptured in the tributary zone of the reservoir approximately 10 km from the stocking place. During the day-time sampling, marked pikeperch were captured in both epipelagic layer above the thermocline and bathypelagic layer below the thermocline. The later represented a community of vertically migrating individuals which was originally believed to be composed of reservoir-born and reservoir-experienced fish only. This study demonstrates high mobility and flexibility of pikeperch early juveniles as well as their unexpected behavioural plasticity.

## **The influence of fluorescing lure color on catch outcomes in European perch (*Perca fluviatilis*) angling**

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Anglers use different lure colors in the hopes of increasing the vulnerability of fishes to their lure. Anecdotal evidence, especially within angler communities, suggests that the usage of fluorescent lure colors increases the catch rate in dim light conditions or at high turbidities by increasing the conspicuousness of the lure. A fully controlled field study was conducted in three waterbodies assessing the European perch (*Perca fluviatilis*) catch-per-unit-effort (CPUE) and the probability of deep hooking or bleeding of two lure colors (one fluorescent, one non fluorescent) with equal reflective spectra, in relation to the light intensity above the water level, cloud cover, water depth, Secchi depth, daytime, lure size and position on a twolure fishing rig. In total, 400 fish were captured of which over 80 percent were perch. Lure color did not affect the perch catch rate, hooking depth or the probability of catching bleeding perch. Instead, the perch CPUE was significantly related to light intensity, cloud cover, water depth, lure size and position on a fishing rig. Based on the results of the present field experiment there is no catch enhancing effect of a fluorescent lure color in perch angling in the observed water bodies.

## Stock assessment of Pikeperch (*Sander lucioperca*) from catch in three Tunisian reservoirs: Application of the CMSY model

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The Common Fisheries Policy around the world requires effective management of the different exploited fish stocks in order to achieve the Maximum Sustainable Yield (MSY). In this study, we applied, for the first time, the CMSY++ (state-space Bayesian method) on the Tunisian freshwater fish data. This advanced method allows to assess the stock status through the fisheries reference points' estimation as well as the relative stock size and the exploitation ratio from catch. The aim of this study is to evaluate the pikeperch "*Sander lucioperca*" stock in three Tunisian reservoirs (Kasseb, Siliana and Lahjar) based on catch data of a 15-year period (2005-2020).

Application of CMSY++ model in Kasseb Reservoir revealed that the increase of the fishing pressure on stocks allows the recovering of the low exploitation and catch levels. Catches relative to MSY as estimated by CMSY, with indication of 95% confidence limits, shows that the exploitation state of pikeperch is slightly under the MSY. In Lahjar Reservoir, the analyses indicated a sustainable fishing pressure and a healthy stock size of pikeperch capable of producing high yields close to MSY. Additionally, the evaluation made in this area shows that the time series of predicted total biomass relative to Bmsy and relative exploitation (F/Fmsy) confirm the optimal status of exploitation. Contrariwise, in Siliana Reservoir, we detected an overexploitation of the pikeperch population. The correlation between the time series of pressure (F/FMSY) and the state (B/BMSY) indicated that there is an 83.5 % probability that the stock is in the yellow area which means that the reduced fishing pressure on stocks allows the recovering for the low biomass levels. The monitoring of the median exploitation rate (F/Fmsy) between 2005 and 2020 for *S. lucioperca* in this reservoir indicated that the 2.5<sup>th</sup> and 97.5<sup>th</sup> percentiles were above MSY between 2008 and 2017. These results point to the urgent need to re-assess fisheries reference points in Siliana Reservoir for biomass recovery and to implement regulations regarding sustainable fishing pressure and healthy stock sizes of Pikeperch. For Kasseb and Lahjar the Pikeperch stocks need a rigorous monitoring in order to avoid an overbalance in a state of overexploitation.



## **The role of percid scales in the external appearance of fish-eating birds: an example of the flying diamond, the common kingfisher (*Alcedo atthis*)**

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The humped body shape of percid fishes like ruffe (*Gymnocephalus* spp.) or perch (*Perca* spp.) as well as the arsenal of hard, sharp rays in fins and mighty thorns on opercular bones make these fish not easy to swallow for many fish-eating birds. Also a number of rough, ctenoid scales make the process of prey swallowing difficult and extend the handling time. Ctenoid scales, however, play one more role in the life of fish-eating birds. They also grind off the ceratin of the beak as a nail file causing significant beak abrasion especially in the central part of both jaws. Such a peculiar defect in external appearance is typical in the situation when percids represent a dominant/superdominant prey. In Slapy Reservoir (Vltava River basin, Central Bohemia, Czech Republic), percids and especially European perch (*Perca fluviatilis*) compose 60-90 % of the diet of common kingfisher (*Alcedo atthis*). At this reservoir, adult kingfishers show significant beak abrasion caused by perch ctenoid scales. At other localities in Central Bohemia, where cyprinids like roach (*Rutilus rutilus*), gudgeon (*Gobio gobio*), bleak (*Alburnus alburnus*) or European chub (*Squalius cephalus*) strongly dominate the diet of common kingfishers, the beak of these fish-eating predators has its usual shape (no abrasion recorded).

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## **Brackish water has no positive effect on European perch (*Perca fluviatilis*) growth and behaviour at low temperatures**

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Annual perch migration from freshwater to the Baltic Sea during the warm water season has been a well-known phenomenon. Superior growth promotion in brackish compared with fresh water was considered to be the main our hypothesis explaining the migration, but this does not explain why perch return to freshwater during autumn for overwintering. To rule out one of the hypotheses and gain a better understanding of the phenomenon of perch migration between the fresh and brackish waters, we performed (1) a laboratory experiment to test the effect of salinity on the growth of perch reared at low temperatures (< 14 °C), (2) behavioural experiment when perch were able to choose between different temperature and water salinity combinations.

Laboratory experiments revealed that brackish water (3 and 7 ppt) has no significant effect on growth rates among perch young-of-the-year, if compared to freshwater effect at low temperature (7 °C). The differences in relative growth rate (RGR) of perch reared under different salinity conditions were too small to be significant, however slightly higher RGR was observed for perch reared in brackish water comparing to freshwater. Results of behavioural experiments demonstrated that perch prefer to stay in brackish water (6 ppt) when can choose between brackish and freshwater, and in warm water (15 °C) compared to cold water (12 °C). However, the most important factor is temperature as perch clearly avoided cold and brackish water compared to warm and fresh.

In conclusion, growth and behavioural experiments allow to assume that brackish water has no growth or behavioural promoting effect on European perch at low temperatures. Thus, this may explain the autumn migration from brackish to fresh water, given that the lagoons often provide greater food availability and offer protection from harsh winter storms that generate rough sea conditions in exposed coastal areas.

## Exploring data-limited stock assessment approaches: pikeperch stocks in Lithuania

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Inland and coastal fisheries of pikeperch (*Sander lucioperca*) are important to local communities and recreational fishing. Yet usually are data limited which impedes application of common quantitative stock assessment methods. As a result, the status of many pikeperch stocks remains almost entirely unknown and unassessed, which increases the possibility of stock depletion and poor management. In this study we applied surplus production and length-based stock assessment models to two pikeperch stocks in Lithuania. These stocks are regularly monitored using scientific surveys. The first one is a stock in coastal Curonian Lagoon which currently sustains a commercial pikeperch fishery shared between Russia and Lithuania. The second stock is in Kaunas Water Reservoir, an inland artificial water body, in which all commercial fishery has been banned in 2013, but recreational fishery is intensive. We explore a range of common issues with data limited stocks, such as uncertain catch data and limited samples for length-based models. Our results show that data limited stock assessment methods can provide reasonably good estimates of likely stock status, especially if scientific catch per unit effort series is relatively long and regular. We show that Curonian Lagoon, pikeperch stock is severely depleted with the current fishing mortality greatly exceeding the mortality for maximum sustainable yield. In Kaunas Water Reservoir, despite the closure of commercial fishery, pikeperch show only minor recovery signs, due to high recreational fishing pressure.

**Growth performance and fatty acid composition of juvenile pikeperch (*Sander lucioperca* Linnaeus, 1785) derived from cultured and wild broodstock fed with chironomid and *Artemia* biomass**

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The effects of feeding with different live feeds on growth performance, viability and fatty acid profile of juvenile pikeperch (*Sander lucioperca*) derived from cultured (C) and wild (W) broodstocks were studied. For this purpose, fish in two groups with an initial body weight of  $3.76 \pm 0.01$  g and total length of  $8.61 \pm 0.22$  cm were fed with three diets *ad libitum*, including CH: frozen larvae of *Chironomus* sp., A: frozen *Artemia* (*Artemia franciscana*) biomass and M: a combination of CH (50%) and A (50) in triplicate groups. After ten days, growth indices including weight gain, body weight increase, specific growth rate, condition factor, survival rate and fatty acid profile were compared among different groups. The results showed that final weight, WG and SGR in treatments CHW and MW were significantly lower than CHC ( $P < 0.05$ ). Moreover, the survival rate in AC was significantly lower than the other groups ( $P < 0.05$ ). Additionally, a difference was observed in fatty acid composition between the whole body of cultured and wild groups in some cases. Hence, our results suggest the differences between the performance of cultured and wild groups of juvenile pikeperch fed with various live feed.

## **Oocyte maturation and changes in steroid levels in the wild and domesticated pikeperch *Sander lucioperca* following hormonal treatments**

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This study was designed to compare plasma steroid levels and spawning success between wild and cultured female pikeperch after induction of ovulation by different hormones. Two groups of wild or domesticated fish were treated with common carp pituitary extract (CPE), human chorionic gonadotropin (hCG) and luteinizing hormone releasing hormone analogue (LHRHa2), and saline solution as control group. All females received those agents in a priming (10% of body weight) and resolving (90% of body weight) dosages. The blood samples were taken before hormonal treatment and after ovulation. Plasma levels of sex steroids (17 $\beta$ -estradiol, testosterone and progesterone) and stress indices (cortisol, glucose and lactate) were measured. The results showed that all wild females responded to CPE and LHRHa2, while in wild female which injected with hCG and farmed females which injected with hCG and pituitary extract, 75% responded to hormone injection and no farmed fish responded to LHRHa2. According to reproductive parameters including the number of eggs/g and working fecundity, no significant differences were observed in different treatments. All hormonal treatments induced an elevation in plasma cortisol and glucose levels after ovulation in cultured fish. In contrast, plasma cortisol levels declined significantly after ovulation in wild groups. Considering the obtained results from the present study, it seems that CPE and hCG have a high reproductive performance and recommend for induction of controlled reproduction in both wild and domesticated pikeperch. In addition, the results demonstrated that wild fish is more sensitive than the cultured fish.

## **Embryology and allometry of body growth during early development of pikeperch (*Sander lucioperca*)**

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The embryology, morphological characteristics and allometric growth pattern during the early ontogeny of pikeperch were studied. Developmental stages in embryos were identified as zygote, post-fertilization, gastrula stages, segmentation stages and hatching based on morphological features. The newly fertilized eggs diameter and weight were  $1.2 \pm 0.03$  mm and  $1.2 \pm 0.02$  mg, respectively. According to external morphology of larvae, four different phases during early growth stages of pikeperch were known as: yolk-sac larvae in the first stage (occurred right after hatching until the depletion of the yolk-sac), preflexion larvae in the second stage (happened from mouth opening to the start of the flexion of the caudal tip of notochord), flexion larvae in the third stage (started from the flexion of the notochord to the appearance of hypural plate), and postflexion larvae in the fourth stage (showed from the appearance of the hypural plate to observation of a pigmentation pattern similar to the adults). From hatching to final stage of development, total length of pikeperch increased from 3.6 mm to 27.0 mm. The results indicated that less drastic changes were observed over the initial 6th day. A lowest growth coefficient was observed in preflexion larvae for the features of trunk, mouth length, tail depth, body depth and head depth with less than 0.5. A highly growth coefficient between 1.4-1.6 was found in flexion and postflexion larvae for the features of body depth, head depth and eye diameter. All body measurements inflection points showed during the preflexion stage between 6th-10th day post hatch, corresponding to the total length from 9 to 12.5 mm. Knowledge on the embryo development and larvae growth and development acquired through this study will contribute to the improvement of larval rearing techniques. The obtained results demonstrate the differentiation in the growth pattern of pikeperch embryonic and early larval stages and create a document for pikeperch normal development and aquaculture management.

## **Pikeperch (*Sander lucioperca*) adaptive or maladaptive reactions to environmental stressors: A review**

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Some features such as greatly priced and delicious meat, soft and white tissue with few intermuscular bones, appropriate growth performance, and good market acceptance made pikeperch as a worth species in aquaculture industry. Nevertheless, it is an extremely susceptible species to environmental changes and other aquaculture activities. Admittedly, the optimal rearing condition is an inevitable necessity for pikeperch development and survives in aquaculture. In this regard, the aquaculture stressors (e.g. handling, transport, fishing, stocking density) and environmental conditions (e.g. photoperiod, temperature, oxygen status, oxidative stress) are the inescapable factors in pikeperch aquaculture industries that affect on entire life cycle rearing. Meanwhile, there is still a gap in knowledge about pikeperch adaptive or maladaptive reactions to these stressors. Hence, the effects of environmental stressors on pikeperch physiological changes deserve further investigation. In order to help the ameliorate management methods in pikeperch culture, the current review tried to discuss and consider the adaptive or maladaptive reactions of this species to various environmental stressors.

## Evaluation of biomass and abundance of three percid species using electrofishing, gillnetting, seining, trawling, and environmental DNA metabarcoding (eDNA) in three reservoirs

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The objective of this study was to compare percid species distribution and abundance using conventional sampling methods, such as electrofishing at day and night (DE and NE), standard benthic and pelagic gillnets (SBG and SPG), large benthic and pelagic gillnets (LBG and LPG), fry seine nets at day and night (DFS and NFS), and trawling (FT) and environmental DNA metabarcoding (eDNA) during two summer campaigns in three reservoirs. Data were quantified as biomass per unit effort (BPUE) and catch per unit effort (CPUE). Three percid species were caught or detected: *Gymnocephalus cernua*, *Perca fluviatilis*, and *Sander lucioperca* in the reservoirs. The latter two shared an identical sequence amplified for eDNA. In Římov reservoir, the highest biomass of *Perca fluviatilis* + *Sander lucioperca* and *Gymnocephalus cernua* was obtained using NFS and DFS methods in 2018 and 2019, respectively. Abundance of *Perca fluviatilis* + *Sander lucioperca* and *Gymnocephalus cernua* was higher in 2018 sampling of Římov reservoir using NE and NFS, while this trend was higher in 2019 sampling in DE and NFS methods. The highest biomass of *Perca fluviatilis* + *Sander lucioperca* and *Gymnocephalus cernua* in Klíčava reservoir was observed with DE and NE in 2018 and 2019 sampling times. In Klíčava reservoir, abundance of *Perca fluviatilis* + *Sander lucioperca* and *Gymnocephalus cernua* was higher using the DE and SBG sampling methods in 2018 and 2019, respectively. In Žlutice reservoir, the highest biomass of *Perca fluviatilis* + *Sander lucioperca* and *Gymnocephalus cernua* was found using the NE and eDNA methods. Abundance of *Perca fluviatilis* + *Sander lucioperca* and *Gymnocephalus cernua* was higher in 2018 in Římov reservoir using DE and SBG, while this trend was higher with NE and SBG in 2019 sampling. This pattern of percids distribution in reservoirs showed a trade-off between sampling methods in predicting abundance/biomass based on conventional and eDNA sampling methods.



## **Effects of environmental conditions on the annual density of juvenile perch, *Perca fluviatilis*, in peri-alpine lakes**

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In many aquatic ecosystems, the abundance of young of the year (YOY) fish fluctuates greatly in response to environmental factors and climatic conditions (e.g. wind and temperature) but also the availability and quality of food resources. High variations of YOY perch, *Perca fluviatilis*, are regularly observed in the oligotrophic Lake Annecy and the meso-oligotrophic Lake Bourget. The YOY fish densities vary by a factor of 10 and can exceed 100 kg.ha<sup>-1</sup>. Perch is the numerically dominant species and is of major economic interest, exploited by commercial fishermen and anglers. The objective of this study was to determine which environmental factors explain the interannual fluctuations in perch abundance in these two lakes. The densities of perch, in late summer, were obtained using hydroacoustics, a non-invasive and standardized method, over a period of 10 years. The YOY densities are related to climatic indices, mainly the surface temperature during the embryonic and larval phases, as well as the abundance of prey during the larval stage. The results are in agreement with previous studies and support that climatic conditions during the embryonic development phase are the main factor for the recruitment of perch in lakes and account for more than 60 % of the variations of YOY perch density, regardless of the trophic status of the lake considered.

## **Elemental accumulation and histopathology of two age groups of pikeperch (*Sander lucioperca*) from Garaši reservoir (Serbia)**

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Distributed throughout all temperate European inland waters, pikeperch (*Sander lucioperca* L.) is one of the most interesting fish species for angling and in high demand for human consumption. There is also a growing interest in pikeperch aquaculture. Pikeperch as a freshwater predator has high tendency to accumulate metals in its tissues. Eight individuals of 3+ age class and twelve 4+ individuals were caught at Garaši reservoir during summer of 2017. Concentrations of 26 elements (Ag, Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Si, Sr, and Zn) were determined in gills, liver and muscles. Metal pollution index (MPI) was used to record the total metal content in different tissues. Apart from this, histopathological lesions in gills and liver were also assessed. Correlation tests between fish condition and element concentration as well as between HP scores for gills and liver were conducted. Aim of the present study was to investigate whether there are differences between element concentrations and HP alterations in the age classes. Results showed that the gills were exposed to the highest pressure of metal pollution in both age classes. There were no significant differences in elemental accumulation and histopathological changes between 3+ and 4+ age classes, nor between the elemental accumulation and condition of fish and between HP indices.

## **Accumulation of 17 organochlorine pesticides in muscle of pikeperch (*Sander lucioperca*) from Garaši reservoir (Serbia)**

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Samples of pikeperch (20 in total) were caught at Garaši reservoir during the summer of 2017. The objectives of this research was to analyse the concentrations of 17 organochlorine pesticides (aldrin,  $\alpha$ -HCH,  $\beta$ -HCH,  $\gamma$ -HCH,  $\delta$ -HCH, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, heptachlor, heptachlor epoxide, and metoxychlor) in fish muscle by gas chromatography with mass spectrometric (GC-MS) detection. QuEChERS method was used for extraction and clean-up of pesticide residues from muscle tissue. Three phenyl phosphate (TPP) was used as an internal standard. Concentrations of 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, heptachlor and heptachlor epoxide in fish muscle were compared with the maximum allowed concentrations (MAC) in fish meat set by the national legislation of Serbia. This reservoir is used as a drinking water source. Therefore, the hypothesis was that it was exposed to low organic pollution. The concentrations of all analyzed pesticides were below the detection limits. In conclusion, there is no health risk for consumption of pikeperch from Garaši reservoir.

## **Standard gillnet monitoring revealed remarkable differences in the size-structure of pikeperch (*Sander lucioperca*) populations in Finnish and Swedish lakes**

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Pan-European standard gillnet monitoring enables comparisons of species relative abundance and population structure in different countries and environmental circumstances. In Sweden and Finland, pikeperch is very popular target for especially recreational but also commercial fisheries. In Finland however, the use of gillnets in recreational fishing is far more common, increasing the risk for truncated size structure. We studied 75 Swedish and 64 Finnish lakes with standard gillnet and environmental data, aiming to compare the pikeperch relative abundance and size structure. The lakes were similar in size and nutrient conditions, but the Swedish lakes were located more south and were warmer. We found remarkable between-country differences in pikeperch size-structure - especially the low abundance of large ( $\geq 50$  cm) individuals in Finnish lakes compared to the Swedish lakes. According to the preliminary analyses, the environmental differences between the Swedish and Finnish lakes were not the only reason for the differences in pikeperch size-structure, but the deviations in fishing pressure and size selection also had an effect.

## **Elevated water temperature applied during juvenile development affects the morphometric features, but not the sex ratio of European perch**

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In this study, we investigated potential effects of increased water temperature applied during larviculture on the sex ratio and morphometric features of the European perch (*Perca fluviatilis*). Perch juveniles, originating from a mass cross of a farm stock were used for our investigation. At 23 days post-fertilization, half of the perch fingerlings were subjected to elevated temperature (25 °C) for 22 days (treated group), whereas the rest were grown at 19 °C (control). At the end of the treatment period, the water of the treated group was allowed to cool down to 19 °C. At the age of eight month, all survivors (n=154) were euthanized and dissected to determine their sex that was later confirmed by aceto-carmin staining of squashed gonads. Digital photographs were taken before the autopsy from all the studied individuals and 18 morphometric variables were recorded to reveal the differences in body shape. The results show, that the temperature increase had a statistically significant effect on survival (treated n=56, control n=98), however, it did not significantly affect the female/male ratio in the two groups [treated (1:1.15) and control (1:1.08)]. Based on the morphometric characteristics examined, the treated and control female groups and the two male groups were significantly different. The results of the PERMANOVA analysis showed that the morphometric differences induced by the juvenile heat treatment within the two sexes were more considerable than the differences due to sexual dimorphism of the perch.

## **Coping with tapeworms: gene expression response of Eurasian perch (*Perca fluviatilis*) to *Triaenophorus nodulosus* infection**

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Understanding the physiological effects of parasite infection and host immune response are essential to improving our understanding of host-parasite interactions and their ecological and evolutionary consequences. Here, we analyze variations in transcript abundance across multiple organs (liver, spleen) in the Eurasian perch (*Perca fluviatilis*) as they relate to infection status by the widespread and antagonistic helminth *Triaenophorus nodulosus*. We characterize the differentially expressed genes between infected and uninfected Eurasian perch and describe the molecular pathways involved in host response. We investigated host response to infection from samples that were collected from three lakes within Estonia, finding increases in transcripts associated with immune response in one of the tissues examined. Differences in life history, concurrent infection, and environment effects may all be factors contributing to the immune response of *P. fluviatilis* to infection by *T. nodulosus*. Future research targeting a larger number of tissues, and the temporal aspects of the pathogen's life cycle are expected to provide insights into the physiological cost and defense mechanisms of the European perch to *T. nodulosus* infection.

## Diet specialization in a trophic generalist, European perch as a model example

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Every consumer depends on the energy obtained from its diet. In more detail, the relationship between an individual or population and its diet is reflected in the trophic niches of an individual, population or species. Depending on the extent to which an organism uses a given spectrum of resources, generalists and specialists can be distinguished. In generalist species, the overall trophic generalism can be reached either by sum of individual generalistic trophic behaviours or by sum of differently specialized trophic behaviours. In our study, the main goal was to determine the degree of individual trophic specializations in European perch (*Perca fluviatilis* Linnaeus, 1758) – important meso-predator of palearctic aquatic ecosystems. The determination of the trophic spectrum was performed by gut contents analyses in 2,515 perch individuals from Milada and Most post-mining lakes, North Bohemia, Czech Republic. These unique lakes were chosen because all manifestations of perch foraging behaviours, i.e. zooplanktivory, invertivory and piscivory, are possible to observe there; perch has a high share in their fish communities, hence having an important role in these systems; and strong long-term data were available from these localities. Consistently with general knowledge on trophic ecology of perch, we found perch to utilize a wide range of diet sources from zooplankton to fish, with changes occurring particularly in relation to ontogenetic development and sex. On the other hand, we found a high degree of individual trophic specialization (83,6 % individuals in Most Lake and 93,2 % individuals in Milada Lake utilising zooplankton, macroinvertebrates or fish only), relatively stable during ontogeny and depending on the composition of the fish community.

## **Hypoxic pelagic zone as a refuge for small fish in a freshwater ecosystem**

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Hypoxic zones in the freshwater ecosystems are often observed phenomenon that is related to a trophic increase induced human industry. Research of hypoxic zones revealed several interesting findings. Use of hypoxic littoral zone by small fish as a refuge from predation is one of them. Our study proved that also hypoxic pelagic zone can be used by small fish as a refuge from predation. It is demonstrated on a distribution of juvenile perch (*Perca fluviatilis*). Juvenile perch often inhabit deeper zones of deep lakes or reservoirs from the metalimnion to the hypolimnion. It was proved the hypoxic conditions of these zones occurred in Vír Reservoir, Czech Republic, (oxygen concentration  $\leq 3.5 \text{ mg L}^{-1}$ ) offered a refuge due to a small number of predators and sufficient amounts of zooplankton prey. Large predators avoid deep hypoxic waters and prefer the warmer epilimnion where few or no juvenile perch were observed. Sampling by fry trawl and hydroacoustics revealed a heterogeneous depth distribution of juvenile perch, with the highest abundance in the hypoxic pelagic zones.



## **PREDATOR: European catfish (*Silurus glanis*) as a voracious predator of percids and other freshwater and brackish biota**

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LIFE PREDATOR aims at contrasting the spread and further introductions of the invasive European catfish (*Silurus glanis*) contributing to the application of the EU IAS Regulation n. 1143/2014 in southern European lakes. An early detection system based on environmental DNA will be tested and developed in 50 lakes (23 in Italy, 25 in Portugal and 2 in Czech Republic) and integrated with citizen science records. In 10 selected lakes where the species is widespread and abundant, different capture methodologies are tested to select the best selective and effective capture method, which will be then applied to reduce the catfish biomass by 90 % in 5 small and isolated Natura 2000 lakes, at least 10 % in large lakes and reservoirs, 50 % in small reservoirs and involving in these activities at least 130 commercial fishermen and 100 anglers. Massive awareness-raising campaigns are organized targeting specifically anglers (at least 400,000) but also the general public, expecting to reach 1 million people at the end of the project, including 12,000 school children. Protocols and best practices are transferred to at least 15 management authorities to be integrated into their management plans, particularly of Natura 2000 sites. For the replication of the project results, a South European catfish Management Group (SEMG) is created. Additionally, to sustain the project goals where the catfish invasion is more advanced (i.e., northern Italy), the creation of a local circular economy is proposed, looking for the best solution to make the catfish more palatable and thus increasing the fishing pressure on catfish by encouraging its consumption as food. The catfish removed during control campaigns will be used for the preparation of meals sold at fair prices by social cooperatives to at least 1,000 people facing socioeconomic challenges.

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## Live feed enrichments using algae technology for pikeperch (*Sander Lucioperca*) larval culture

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The use of *Chlorella vulgaris* and *Trachidiscus minutus* as live feed enrichments for rotifer and artemia fed to Pikeperch (*Sander lucioperca*) larvae was tested during this trial. Larvae were fed a combination of rotifers (until day 15 post hatching) and artemia (from day 12 post hatching) under seven different enrichments: a) *Nannochloropsis oculata* (Nanno 3600 reed Mariculture), b) *Chlorella vulgaris* cultured at 20 degrees Celsius in BG117 media, c) *Chlorella vulgaris* cultured at 30 degrees Celsius in BG117 media, d) *Chlorella vulgaris* cultured at 20 degrees Celsius in Urea media, e) *Chlorella vulgaris* cultured at 30 degrees Celsius in Urea media, f) *Trachidiscus* cultured at 15 degrees Celsius and g) *Trachidiscus* cultured at 25 degrees Celsius. After 21 days from the trial initiation significant differences were found between treatments on total length (TL), myomere height (MH), and fatty acid composition. In terms of growth parameters, larvae from treatment c had significantly higher values in total length (11.48 mm) and myomere height (2.04 mm). Furthermore, larvae from treatment c) showed significant higher concentration of Docosahexaenoic acid (DHA) (%), and Linoleic acid (LA) (%) and larvae from treatment g) had significant higher concentration of Eicosapentaenoic acid (EPA) (%) and Arachidonic acid (ARA) (%).

Overall, larvae from treatments c and g, performed better than the other treatments, likely due to the difference in Essential Fatty Acids (EFA) concentration. The results from this trial, will help to optimize the pikeperch larvae nutritional requirements and diversify the live feed enrichments used during first feeding.

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