Ph.D. thesis topics 2026/2027

DSP Rybářství / Fishery and DSP Ochrana vodních ekosystémů / Protection of aquatic ecosystems

Výzkumný ústav rybářský a hydrobiologický / Research Institute of fish Culture and Hydrobiology

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Functional diversity of ovarian fluid in freshwater fish fertilization: effects on sperm performance, fertilization success, and species specificity

Funkční diverzita ovariální tekutiny při oplození sladkovodních ryb: vliv na vlastnosti spermií, úspěšnost oplození a druhovou specificitu

DSP: Rybářství / Fishery

Annotation

Successful fertilization in externally fertilizing freshwater fish depends on highly coordinated interactions between spermatozoa, eggs, and the surrounding reproductive environment (Kholodnyy et al, 2020). Ovarian fluid (OF), the biologically active medium surrounding fish eggs during spawning, has traditionally been considered mainly as a protective or supportive substance. Recent studies indicate that OF may actively influence sperm motility parameters, longevity, swimming behavior, fertilization success, sperm longevity, and gamete interactions (Alonzo et al, 2016; Johnson et al, 2020) in a species-specific manner. Despite increasing interest in these processes, the biological functions and diversity of OF roles among freshwater fish species remain insufficiently understood.

Freshwater fish species differ markedly in their reproductive strategies, spawning environments, and susceptibility to natural or artificial hybridization. These differences may be reflected in the biochemical composition and physiological functions of OF (Gasparini, Evans 2018). Understanding these mechanisms is important not only for basic reproductive biology, but also for aquaculture, conservation programs, artificial reproduction, and the management of endangered or economically important fish species.

The proposed Ph.D. project will investigate how OF modulates sperm performance and fertilization processes in selected freshwater fish species, with particular focus on interspecific differences and intraspecific variability among females. The study will combine reproductive physiology, sperm motility analyses, in vitro fertilization experiments, and comparative biological approaches. Biochemical and molecular characterization of OF will be incorporated to identify factors associated with specific functional effects.

The main hypothesis

- Ovarian fluid actively modulates sperm motility patterns, swimming performance, and fertilization success in freshwater fish.
- The functional effects of ovarian fluid differ among fish species and among females within species.
- Ovarian fluid preferentially supports conspecific sperm and may contribute to species-specific fertilization and reproductive isolation.
- Functional differences in ovarian fluid are associated with biological, ecological, and biochemical variability among freshwater fish species.

Aim(s) of the Ph.D. thesis

- To characterize the effects of ovarian fluid on sperm performance parameters in selected freshwater fish species.

- To determine the influence of ovarian fluid on fertilization success under different experimental conditions.
- To investigate species-specific interactions between ovarian fluid and spermatozoa in conspecific and heterospecific combinations.
- To compare functional variability of ovarian fluid among fish species with different reproductive strategies.
- To identify selected biochemical or molecular characteristics associated with functional effects of ovarian fluid.

Possible approaches to reach the aims / to verify the hypotheses

- Collection of ovarian fluid, eggs, and sperm from selected freshwater fish species under controlled conditions.
- Evaluation of sperm motility and swimming behavior using Computer Assisted Sperm Analysis (CASA) systems under different activation conditions including ovarian fluid treatments.
- Performing fertilization experiments using homologous and heterologous ovarian fluid combinations under controlled laboratory conditions.
- Analysis of sperm longevity, swimming trajectories, velocity parameters, and fertilization outcomes in relation to ovarian fluid exposure.
- Comparative analysis of ovarian fluid effects among species differing in reproductive ecology and hybridization potential.
- Application of selected biochemical and molecular analyses of ovarian fluid including protein concentration measurements, ion composition analyses, metabolomic and proteomic approaches, or fractionation methods.
- Statistical analyses using generalized linear models (GLM), mixed-effects models, ANOVA, multivariate analyses, and correlation analyses.

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Czech Science Foundation (GAČR) project: “Decoding the Role of Female Reproductive Fluids in Freshwater Fish Fertilization”

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"Adult stem cells" and regeneration: The role of neural crest-derived Schwann cell precursors during the bone regeneration

„Dospělé kmenové buňky" a regenerace: Role prekurzorů Schwannových buněk odvozených z neurální lišty během regenerace kosti

DSP: Rybářství / Fishery

Annotation

The evolution of vertebrates is closely linked to the emergence of the neural crest, a migratory and multipotent stem cell population that gives rise to many vertebrate-specific features, including the craniofacial skeleton, peripheral neurons and glia, and numerous other cell types. However, it remains unclear whether neural crest stem cells persist in postnatal tissues and, if they do, whether they contribute to the regeneration of neural crest-derived tissues.

Among the neural crest-derived cell types present in postnatal tissues, Schwann cells and their precursors (SCPs) retain developmental properties similar to those of their embryonic maternal cells, neural crest stem cells. These cells are associated with peripheral nerves and, because of the extensive branching of the peripheral nervous system, are widely distributed throughout the body. Their regenerative roles following peripheral nerve injury are well documented, as Schwann cells are key contributors to nerve repair. However, peripheral nerves are not the only tissues in which neural crest-derived cells play important regenerative roles. It has been demonstrated that they are important for the regeneration of heart tissue, skin or teeth.

The bodies of sturgeons are covered by dermal bony scutes, neural crest-derived structures that represent an evolutionary remnant of the ancestral dermoskeleton of early vertebrates. Because these scutes retain a clear neural crest origin and possess regenerative capacity, sturgeons provide a unique opportunity to investigate whether SCPs contribute to the regeneration of neural crest-derived dermal bone.

The main hypothesis

- Schwann cell precursors represent an essential source of stem cell-like cells for the regeneration of dermal bones.

Aim(s) of the Ph.D. thesis

- To contribute to our understanding of Schwann cell precursors role in the regeneration of sturgeon bony scutes but also in general aspects of regeneration.

Possible approaches to reach the aims / to verify the hypotheses

- Analyses of bulk RNA-seq and scRNA-seq datasets.
- Validation of candidate genes using hybridization chain reaction in situ hybridization, immunohistochemistry.

- Functional validation using CRISPR/Cas9 mutagenesis.

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Deep Learning-Based Analysis of Feed Palatability in Aquaculture Species

Analýza Chutnosti Krmiva U Akvakulturních Druhů Založená Na Hlubokém Učení

DSP: Rybářství / Fishery

Annotation

Over the past decade, the aquafeed industry has undergone a substantial transition from fishmeal and fish oil derived from marine forage fish to terrestrial protein sources and, more recently, to alternative and novel protein ingredients (Cottrell et al., 2020; Froehlich et al., 2018; Liu et al., 2025). This shift has reduced pressure on marine resources while supporting the expansion of aquaculture to meet the increasing global demand for seafood driven by population growth (Hua et al., 2019; Panteli et al., 2025).

Although alternative ingredients have been shown to maintain the production performance of aquaculture species at certain inclusion levels (Cottrell et al., 2020; Mugwanya et al., 2023; Qian et al., 2024; Tran et al., 2022), the palatability of these materials remains a challenge for feed acceptance in some fish species. Feed ingredients of aquatic animal origin, such as fishmeal, are rich in chemical compounds including free amino acids, nucleotides, amines, and nucleosides, which are readily detected by the chemosensory systems of aquatic animals during food detection and ingestion. In contrast, alternative protein sources are generally lower levels of these compounds, limiting their capacity to fully replace fishmeal in aquaculture feeds (Dong et al., 2016; Soengas et al., 2025; Suresh et al., 2011; Terrey et al., 2021). Therefore, improving the inclusion of unconventional protein sources in aquafeeds while maintaining feed acceptance requires the selection of suitable ingredients for specific species, additional ingredient processing, or the incorporation of feed attractants (Alves et al., 2020; Dong et al., 2016; Hossain et al., 2024; Terrey et al., 2021).

Feed palatability in aquaculture species has been evaluated using various assessment methods, including manual observation in multi-chamber tanks (Suresh et al., 2011), Y-maze systems (Jingting et al., 2020), self-feeding approaches (Roy et al., 2020), and hydrophone-based monitoring (Araujo et al., 2026). More recently, deep-learning-based techniques have emerged as valuable tools for investigating feed palatability in aquatic animals (Janssens et al., 2026; Tran et al., 2026). These approaches enable the analysis of behavioural indicators such as swimming speed, pellet ingestion dynamics, movement heatmaps, and feeding responses. However, the palatability of feeds containing alternative proteins and attractants has so far been insufficiently investigated using precise and lightweight deep learning approaches in the context of unconventional feed ingredients.

The main hypothesis

- The palatability of unconventional feed ingredients varies considerably in aquatic species.
- The use of attractants may enhance the palatability of feed ingredients with low acceptability.
- Free amino acids, nucleotides, and amines are the primary drivers of feed palatability.

Aim(s) of the Ph.D. thesis

- To evaluate feed palatability through fish behavior while fed unconventional protein sources, using a deep learning technique.
- To assess different commercial feed attractants on fish behavior using a deep learning technique
- To evaluate whether a specific attractant enhances the palatability of a low-palatability feed ingredient.

Possible approaches to reach the aims / to verify the hypotheses

- Three experiments will be conducted.
    - Experiment 1: A feeding trial will evaluate three protein sources, insect meal, fungal meal, and bacterial meal, as replacements for fishmeal in comparison with a control diet.
    - Experiment 2: A second feeding trial will evaluate three feed attractants in comparison with a control diet without attractants.
    - Experiment 3: One of the low-palatability diets identified in Experiment 1 will be used as a reference diet, while the remaining diets will be supplemented with a promising candidate identified in Experiment 2.
- In these experiments, the tested animals will be maintained under both normal and stressful conditions, such as hypoxia and crowding. Tank designs will range from conventional tanks to Y-maze and multi-chamber systems. Feed intake and fish behavior will be analyzed using a deep learning approach as previously described (Tran et al., 2026). Diets and ingredients will be analyzed for nutritional composition and specific palatability-related compounds. Fish will also be evaluated for physiological responses, including neurotransmitters, taste receptors, and related parameters.

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Funding

Collaboration with Feed ingredient and Aquafeed Producers and laboratory sources.

CENAKVA Research program

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Sustainable Recovery and Valorization of Pond Sediment in Circular Bioeconomy

Udržitelné využití a zhodnocení rybničního sedimentu v podmínkách cirkulární bioekonomiky

DSP: Rybářství / Fishery

Annotation

In Central Europe, fishpond management is associated with the long-term accumulation of organic matter, nutrients, suspended solids, and various contaminants originating from fish production, agricultural runoff, and surrounding catchments. Regular sediment removal is necessary to maintain pond functionality, water quality, and ecological stability. However, dredged pond sediments are frequently classified as waste materials, creating economic and environmental burdens related to their disposal and management. At the same time, these sediments contain substantial amounts of organic carbon, nitrogen, phosphorus, and micronutrients, indicating significant potential for reuse within circular bioeconomy systems (Drozdz et al., 2020).

Increasing environmental pressure, stricter European legislation, and the need to reduce dependency on mineral fertilizers highlight the urgent necessity to develop safe and sustainable strategies for sediment valorization. Current knowledge concerning the environmental risks, treatment efficiency, and long-term impacts of sediment application on soil and aquatic ecosystems remains fragmented and insufficiently standardized. Furthermore, there is limited understanding of how treatment technologies such as composting, anaerobic digestion, pyrolysis, hydrothermal carbonization, or biochar stabilization influence contaminant mobility, nutrient availability, and the overall environmental footprint of sediment utilization (Drozdz et al., 2020; Marval et al. 2020)).

Within this framework, pond sediments could become an important source of bio-based fertilizers, soil amendments, substrates for ecological restoration, or raw materials for industrial applications (Drozdz et al., 2020). However, successful implementation requires comprehensive evaluation of sediment quality, environmental safety, treatment technologies, economic feasibility, and stakeholder acceptance.

The main hypothesis

- Appropriately treated pond sediments can serve as a safe and effective secondary resource for nutrient recovery and agricultural applications within circular bioeconomy systems.
- Advanced sediment treatment technologies (e.g., composting, pyrolysis, hydrothermal carbonization, or biochar stabilization) significantly reduce the environmental risks associated with pond sediments, including contaminant mobility.
- The valorization of pond sediments through circular bioeconomy approaches provides measurable environmental and economic benefits compared to conventional sediment disposal, including reduced waste generation, improved nutrient recycling efficiency, and lower environmental footprint.

Aim(s) of the Ph.D. thesis

- To characterize the physicochemical, microbiological, and contaminant profile of pond sediments originating from different aquaculture management systems, with emphasis on nutrient content, heavy metals, and micropollutants.
- To evaluate and optimize sustainable treatment and valorization technologies for pond sediments, including biological, thermochemical, and stabilization approaches, in order to improve nutrient availability and reduce environmental and health risks.
- To assess the environmental, agronomic, and economic potential of treated pond sediments within circular bioeconomy applications using integrated sustainability indicators, including nutrient recovery efficiency, ecotoxicological safety, and life cycle assessment (LCA).

Possible approaches to reach the aims / to verify the hypotheses

- Collection of sediment samples from different aquaculture systems followed by physicochemical, microbiological, and contaminant analyses, including nutrients, organic matter, heavy metals, micropollutants.
- Testing of treatment and stabilization technologies: Evaluation and optimization of sustainable sediment treatment methods such as composting, vermicomposting, anaerobic digestion, pyrolysis, hydrothermal carbonization, and biochar-based stabilization to reduce environmental risks and improve nutrient recovery.
- Assessment of agronomic and environmental safety: Performance of germination, phytotoxicity, and plant growth experiments to evaluate nutrient availability, soil improvement potential, contaminant mobility, and possible ecological risks associated with sediment application.
- Sustainability and circular bioeconomy evaluation: Application of life cycle assessment (LCA), nutrient flow analysis, and economic assessment to compare conventional sediment disposal with circular valorization pathways and identify sustainable utilization strategies.

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Carbohydrates in the pond food web, their interactions with fish nutrition and water quality

Sacharidy v potravní síti rybníka, jejich interakce s výživou ryb a kvalitou vody

DSP: Rybářství / Fishery

Annotation

Carbohydrates constitute one of the major macronutrient fractions of natural food web components in pond aquaculture, including algae, zooplankton and benthic invertebrates. Their nutritional value depends not on total abundance but on carbohydrate typology, digestibility and fermentability. The composition, availability, digestibility and bioenergetic significance of aquatic carbohydrates in pond food web remain largely unexplored from a fish nutritional point of view, limiting the development of precision pond feeds. Natural food organisms frequently contain large proportions of recalcitrant carbohydrates, collectively termed non-starch polysaccharides (NSPs), including chitin, cellulose, hemicellulose, pectin, lignin and β-glucans, which are generally resistant to digestion by fish. For example, carbohydrates in zooplankton and benthic invertebrates are often dominated by chitin, whereas aged algal and microbial biomasses may contain substantial quantities of cellulose and hemicellulose. This creates a mismatch between carbohydrate abundance and digestible non-protein energy availability within pond food webs. Such mechanisms partly explain the long-standing success of traditional grain-fed European carp ponds, where supplementary cereals provide readily digestible carbohydrates and non-protein energy that was otherwise limited in natural food/ pond ecosystem. Under conditions where lipid-rich natural food resources do not dominate carp diets, digestible carbohydrates do represent an important source of non-protein energy. The pond-reared common carp (*Cyprinus carpio*) may break down complex NSP fractions through synergistic digestibility effect of pond ecosystem and extract energy. But beyond energy supply, the interplay of carbohydrates type may strongly influence excretion, gut fullness, lipid digestibility, protein sparing, feed intake regulation, grazing pressure on natural food and nutrient cycling within pond ecosystems.

The main hypothesis

- Carbohydrate types including their stoichiometries represent an overlooked determinant of fish growth, supplementary feed efficiency, natural food grazing pressure and water quality in pond aquaculture.

Aim(s) of the Ph.D. thesis

- To investigate the seasonal dynamics of carbohydrate fractions and non-protein energy supplied by carp gill-filterable plankton communities and zoobenthic organisms throughout the vegetative season in temperate European fishponds.

- To investigate the interactions between different non-starch polysaccharide (NSP) fractions and the digestion/ absorption of other nutrients in fish, with particular emphasis on highly demanding digestion process of lipids.
- To determine the optimal carbohydrate composition of supplementary feeds for enhancing zooplankton abundance, improving fish bioenergetic efficiency, and reducing eutrophication risk in pond ecosystems.
- To quantify the capacity of pond aquaculture systems to convert recalcitrant carbohydrate inputs into human-edible fish biomass without increasing eutrophication or harmful algal bloom risk, relative to traditional grain-feeding systems.

Possible approaches to reach the aims / to verify the hypotheses

- Fish digestibility and nutritional bioenergetics trial in Guelph-RAS system.
- Pond trial with plankton net, Eckman grab operation.
- Pond water mesocosms, aquaponic sludge digestors (bioreactors).
- FOSS FibreTec analyses (for NDF, ADF, ADL analyses).
- LC-MS, UV-VIS spectrophotometry (for glycogen, sugar, starch analyses)
- Knowledge of using specialized GPTs (OpenAI Data analyst) and Rstudio in tandem.

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Spatiotemporal dynamics of fish movement: The role of orientation, temperature, and hydrology in habitat selection

Časoprostorová dynamika pohybů ryb: role orientace, teploty a hydrologických poměrů na výběru habitatu

DSP: Rybářství / Fishery

Annotation

River fragmentation caused by dams, weirs, and hydropower plants represents one of the most critical threats to freshwater biodiversity globally (Birnie-Gauvin et al., 2017). While engineering solutions such as fishways and bypass channels are widely implemented to restore longitudinal connectivity, their biological effectiveness is often surprisingly low (Birnie-Gauvin et al., 2017). A major reason for this failure is the discrepancy between hydraulic design and fish behavior. Traditional management focuses on "swimming performance" (can the fish physically swim through?) (Castro-Santos & Haro, 2010), ignoring the critical aspect of "orientation and navigation" (can the fish find the entrance?). Without understanding the mechanisms determining how fish select and utilize their environment (Nathan et al., 2008), conservation efforts in regulated rivers like the Danube remain inefficient.

To improve passage efficiency, we must first understand the baseline spatial strategies of fish in unfragmented or semi-natural environments. Current knowledge of how fish perceive space, maintain headings, and select specific habitats is limited, often relying on coarse-scale data (Hussey et al., 2015). This thesis utilizes high-resolution telemetry from lentic systems (reservoirs) to establish a fundamental understanding of how navigation underpins habitat selection (Rodríguez et al., 2021). By analyzing fine-scale trajectories of model species (e.g., pikeperch Sander lucioperca, wels catfish Silurus glanis, pike Esox lucius), it is possible to define the natural rules of habitat use (how fish search for resting or foraging sites and respond to environmental cues), which serves as a necessary control for understanding their behavior in anthropogenically altered systems (Edelhoff et al., 2016; Říha et al., 2022).

In regulated rivers, these natural selection strategies confront artificial barriers. The complex hydro-morphology of the Danube (Gabčíkovo-Čunovo system) creates a "sensory trap" where altered flow regimes and depth profiles disrupt migration routes (Kubala et al., 2019). Here, the challenge shifts from theoretical orientation to practical passability. Rheophilic fish species must not only possess the motivation to migrate but also the ability to select the correct path towards bypass entrances amidst turbulent tailraces. The problem is exacerbated by the lack of knowledge regarding vertical microhabitat selection; a fish preferring near-bottom structures may simply miss a surface-oriented fishway, regardless of its motivation.

This doctoral research addresses the urgent need to integrate behavioral ecology into river management. By combining the study of fundamental navigation principles with applied telemetry of barrier crossing success, the project aims to identify the specific behavioral bottlenecks limiting connectivity. The analysis of depth selection, thermal habitat preferences, and passage efficiency at key obstacles will provide direct recommendations for optimizing fishway attraction flows. Ultimately, the thesis demonstrates that

successful restoration of migration corridors requires a holistic approach that considers not just the physical permeability of barriers, but the spatiotemporal dynamics of habitat selection of the species attempting to cross them.

The main hypothesis

- In featureless lentic environments, fish rely on allocentric cognitive maps. We hypothesize that navigation towards known habitats is precise and goal-directed regardless of the starting position, significantly exceeding the efficiency of random walk or simple beaconing models.
- In lotic systems, vertical space use is determined by species-specific ecomorphological traits. We hypothesize strict vertical niche partitioning: while pelagic predators as asp (Leuciscus aspius) utilize the upper water column, benthic species as starlet (Acipenser ruthenus) or barbell (Barbus barbus) are obligatorily bound to the riverbed boundary layer, causing them to approach migration barriers at significantly different depth strata. It can caused species-specific differences in barrier permeability.

Aim(s) of the Ph.D. thesis

- To characterize fine-scale movement trajectories and homing precision of different fish species in reservoirs, aiming to confirm the existence of map-like navigation and identify the behavioral rules used for orientation in the absence of flow.
- To assess the spatiotemporal dynamics of rheophilic species (Acipenser ruthenus, Leuciscus aspius, Barbus barbus) in the Danube, with a specific focus on how vertical space use (depth selection) changes in response to discharge, temperature, and migration phase.
- To quantify the passability of the Gabčíkovo-Čunovo waterworks for the target species and identify behavioral bottlenecks (e.g., depth mismatch at fishway entrances) that limit successful migration.
- To quantify the passability of the Gabčíkovo-Čunovo waterworks in relation to species-specific vertical distribution, and to identify behavioral bottlenecks caused by the mismatch between the preferred swimming depths and the vertical position of fishway entrances.

Possible approaches to reach the aims / to verify the hypotheses

- Data Acquisition: Combine high-resolution 3D telemetry (reservoirs) with large-scale linear arrays equipped with depth and temperature sensors (Danube).
- Statistical Framework: Perform all analyses in R (e.g., actel, moveHMM) using Hidden Markov Models to segment behavioral states, circular statistics for navigation precision, and GLMMs to test abiotic drivers.
- Habitat Modelling: Apply Habitat Selection Models (HSM), specifically Resource Selection Functions (RSF) or Step Selection Functions (SSF), to quantify the selection of microhabitats (depth strata, flow classes) relative to their availability.
- Barrier Assessment: Evaluate passage efficiency using event-time analysis and compare fish vertical profiles with fishway hydraulics to identify migration bottlenecks.

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