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Research advances emerging from SEFS11: The 11th Symposium for European Freshwater Sciences

Editorial to the Special Issue in Fundamental and Applied Limnology

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Introduction

This Special Issue of Fundamental and Applied Limnology shares research presented at the 11th Symposium for European Freshwater Sciences (SEFS11), which was organized by the Croatian Association of Freshwater Ecologists in Zagreb, Croatia, from 30 June to 5 July 2019. Building on a 20-year tradition, the goal of this international conference was to bring together freshwater scientists from across and beyond Europe to share emerging knowledge, exchange the newest research advances and have productive scientific discussions – while also enjoying the hospitable atmosphere. SEFS11 welcomed contributions from both early career researchers and established scientists, and provided many networking opportunities that created new collaborations to support the next generation of freshwater scientists. The conference attracted participants from a breadth of complementary disciplines, enabling the development of innovative, interdisciplinary approaches that transcend boundaries within freshwater research.

More than 450 delegates from 41 countries participated in the meeting. Most travelled from within Europe, with important representation from other countries including the USA, Australia, Canada and China, and countries within South and Central America and Africa (Sertić Perić et al. 2019). Four plenary lectures, 23 regular sessions, 11 special sessions, seven workshops and a taxonomy fair were delivered. In total 321 oral and 126 poster presentations were delivered, and this Special Issue includes the research shared in nine of them. The studies report a wide range of topics within freshwater science, including hydrochemistry, species and habitat conservation, primary and secondary production dynamics, structural and functional community responses to disturbances, and biotic regulation of nutrient cycling. These papers have common strengths including the analysis of long-term data to support conservation and management strategies in changing European climates (Carosi et al. 2020; Maximov et al. 2020; Vurnek et al. 2020), and use of both traditional and genetic identification methods to characterize biodiversity – again supporting species conservation, in particular within the protected waters of the SEFS11 host nation, Croatia (Buj et al. 2020; Ivić et al. 2020; Piria et al. 2020). Other studies bring new insight into structural and functional invertebrate responses to disturbance (Lencioni et al. 2020; Šumanović et al. 2020), and Zandonà et al. (2020) are unique in exploring the stoichiometry of nutrient excretion by consumers with contrasting diets and body elemental composition. Below we briefly summarize each of these papers, which collectively make a significant contribution to freshwater science.

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Analysis of long-term data to support species and habitat conservation

Three papers use insights from long-term datasets to advance our understanding of freshwater ecosystems. **Vurnek et al. (2020)** analyse long-term trends in water quality of springs, streams and cascading lotic habitats in the karstic Plitvice Lakes National Park, Croatia. At weekly intervals for 12 years (2006–2017), the physicochemical parameters that influence tufa deposition were recorded, revealing increasing interannual trends in dissolved oxygen, conductivity, water hardness, alkalinity, chemical oxygen demand and nitrites, whereas temperature, pH and most nutrients (nitrates, ammonia and orthophosphates) decreased. The long-term analyses of spatial and temporal variability indicated annual fluctuations in hydrochemistry, correlations between hydrological and physicochemical variables, and differences among habitat types – despite which, tufa deposition processes were stable. The decreasing temperatures represented springs and streams but not cascading habitats and contrasted with increasing regional air temperatures, indicating the need for further research. Vurnek et al. (2020) highlight the value of insights gained from long-term, continuous monitoring data in planning of future ecosystem management in a context of ongoing climate change.

Second, **Carosi et al. (2020)** examine the effects of an exceptional drying event on the population of *Chirocephalus marchesonii* (Anostraca: Chirocephalidae), a fairy shrimp endemic to a single, temporary, high-elevation lake in the Central Apennines, Italy. By analysing an air temperature data series spanning 67 years from 1951 to 2018, Carosi et al. (2020) identified higher temperatures as the key driver of water loss, refuting a previous hypothesis that hydrogeological alteration triggered by a strong earthquake caused the lake to dry. Although *C. marchesonii* population densities were lower after the drying event, Carosi et al (2020) provide convincing evidence that the species completed its life cycle. This knowledge is crucial to inform extinction risk assessments and associated management strategies that support the persistence of this threatened endemic species, despite the vulnerability of its sole habitat to anthropogenic pressures including climate change.

Finally, **Maximov et al. (2020)** analysed long-term monitoring data from a small oligotrophic lake in northwestern Russia, comprising biological (benthic macroinvertebrate communities) and meteorological (air temperature, precipitation) data collected between 2002 and 2017, as well as 2002–2009 chlorophyll-*a* data first published by Maximov et al. (2009). Lagged positive correlations were identified between winter temperatures and chlorophyll-*a* concentrations, and these climate-driven changes in primary production were in turn positively correlated with benthic macroinvertebrate biomass in littoral sediments, suggesting winter temperatures as a key control of interannual community dynamics. However, benthic communities inhabiting different lake depths showed contrasting responses to climatic variability, leading Maximov et al. (2009) to suggest intra- and interspecific biotic interactions as important regulators of sublittoral and profundal communities. In addition, abiotic controls were locally important influences on benthic communities, with oxygen depletion linked to low biomass at the deepest site in late winter.

Fish diversity and distribution in the Danube River basin

Three papers explore the biodiversity, habitat preferences, distribution, and population status of fish species in the Danube River basin in Croatia, including both native and non-native invasive species. **Buj et al. (2020)** used both morphological and genetic analyses to determine the taxonomic identity of loaches (Cypriniformes: Cobitidae) in the Plitvice Lakes National Park. Previous research has suggested *Cobitis elongatoides* as the sole loach in these waters, but Buj et al. (2020) identified one species from each of two genera, neither of which has previously been reported in the Plitvice Lakes: *C. bilineata* and *Sabanejewia larvata*. As a result of this study, both are now listed as Natura 2000 target species for the National Park, to promote their protection (Kovačević, 2019). For both fish species, gene sequences were sufficiently different from Italian populations to suggest their natural colonization (via an undetermined pathway), rather than anthropogenic translocation.

With insights again supported by genetic analyses, **Ivić et al. (2020)** resolved taxonomic controversies regarding the diversity and structure of trout populations (*Salmo* sp., Cypriniformes: Salmonidae) within the Žumberak-Samoborsko Gorje Nature Park, Croatia. Specifically, Ivić et al. (2020) analysed the distribution, taxonomic status, intrapopulation diversity and effective population sizes of all species within the genus *Salmo*. Phylogenetic reconstruction revealed three evolutionarily independent and genetically distinct lineages, characterized by 26 haplotypes. Most samples and haplotypes belonged to the native *S. labrax*,

contributing to the moderately high genetic diversity of this species, which is widespread in the park. Ivić et al. (2020) also found haplotypes of non-native *S. trutta* and *S. marmoratus*, and native trout populations may be threatened by these non-native species, as well as habitat fragmentation and other anthropogenic pressures. The new insights from this study will thus support the setting of conservation priorities in this protected area.

Finally, **Piria et al. (2020)** used monitoring data collected across 108 sites on the Croatian Danube and its tributaries between 2014 and 2018 to determine the current distribution of the invasive Ponto-Caspian racer goby, *Babka gymnotrachelus* (Cypriniformes: Gobiidae). Piria et al. (2020) found 72 gobies including 61 juveniles, indicating the establishment of a self-sustaining population in the Croatian Danube mainstem and one of its tributaries, the Baranjska Karašica River. However, no individuals were recorded in the Drava and Sava Rivers, which are considered to be key invasion routes for Ponto-Caspian gobies. Piria et al. (2020) thus call for future surveys to focus on potentially suitable habitats in the region, to confirm the species' current distribution and to better understand the factors influencing its invasion success.

Structural and functional responses to disturbance

Two papers examine the functional responses of stream macroinvertebrates to contrasting environmental disturbances: shrinking alpine glaciers and hydromorphological degradation. First, **Lencioni et al. (2020)** used a combined structural and functional approach to investigate macroinvertebrate communities in Italian Alpine streams fed by shrinking glaciers and comparable non-glacial tributaries. Nine stream sites (five kryal, two glacio-rhithral and two krenal) and one proglacial pond were sampled in 2018, and eight sites had also previously been sampled between 1996 and 2014. Community composition was characterized in relation to environmental variables indicative of glacial influence, including water temperature and substrate stability. Both taxonomic diversity (as the Shannon index) and functional diversity (based on functional feeding groups) increased with decreasing glacial influence. Temporal changes in taxa distribution and community structure between 2018 and earlier years were also explained by environmental variables indicative of glacial influence. Notable changes in community composition over the 22-year study period reflected the loss of strict kryal species such as the chironomid *Diamesa steinboecki* (Diptera: Chironomidae) and upstream migration of generalist insects, with consequent changes in food web structure. Lencioni et al. (2020) thus suggest *D. steinboecki* as a 'flagship' species of kryal Alpine streams: a species that may be lost as sites pass 'tipping points' in response to rapid global warming.

Secondly, **Šumanović et al. (2020)** studied macroinvertebrate communities in 40 streams across a gradient of hydromorphological degradation in the Mediterranean part of Croatia. Reproductive strategies, functional feeding groups and substrate preferences were used to characterize functional community responses. Of two feeding groups, shredders were more affected by hydromorphological alteration than filter feeders, indicating the latter's higher tolerance of anthropogenic impacts. Smaller taxa with faster reproductive cycles were also relatively tolerant of hydromorphological degradation. Third, reduced substrate heterogeneity in degraded habitats decreased the occurrence of taxa favouring uncommon substrate types. These results allow Šumanović et al. (2020) to suggest that functional responses could complement current taxonomic approaches to macroinvertebrate-based bioassessment, and could also improve understanding of the mechanisms driving taxonomic responses.

Faunal contributions to nutrient bioavailability

Zandonà et al. (2020) make a unique contribution to this Special Issue by investigating how different freshwater faunas influence the bioavailability of inorganic nutrients. Studying a tropical stream in Brazil, Zandonà et al. (2020) are also our only Special Issue contribution from beyond the European continent. Here, excretion rates of nitrogen (N) and phosphorus (P) were determined for decapod shrimps and ray-finned fish, which have contrasting diets and body elemental composition. Zandonà et al. (2020) predicted that fish would excrete less P and have higher N:P ratios, due to the role of P in bone growth and maintenance. In contrast, shrimps and fish had comparable P excretion rates, and the N:P excretion ratio was highest for the herbivorous shrimp, *Potimirim brasiliana* (Decapoda : Atyidae). These results also indicate that diet was a poor predictor of nutrient excretion rates, which should be lower for organisms with nutrient-poorer diets, i.e. for herbivores compared to omnivores. Based on these differences between predicted

and observed patterns, Zandonà et al. (2020) suggest that factors other than bone tissue investment and diet affect consumer excretion rates, with consumption rates, assimilation efficiency, metabolic requirements and taxon-specific physiological mechanisms identified as potential controls.

Summary

Contributions to this Special Issue highlight the vibrancy of research activity within freshwater sciences across and beyond Europe. Much of the research presented focuses on freshwaters of conservation interest, from those within protected national parks (Buj et al. 2020; Ivić et al. 2020; Vurnek et al. 2020) to those in vulnerable areas of the Alpine region (Carosi et al. 2020; Lencioni et al. 2020). As European freshwaters continue to respond to climate change and other anthropogenic pressures, such research will underpin effective monitoring and management strategies that support biodiversity within functional ecosystems (Markovic et al. 2017). Conferences such as SEFS11 are vital opportunities to share such research, and to embark on new collaborations that seek to safeguard European freshwaters. As the editors of this exciting volume of Fundamental and Applied Limnology, we therefore thank SEFS11 organizers including Mirela Sertić Perić and Marko Miliša, as well as Andreas Naegele for his considerable editorial support during preparation of this Special Issue. We hope that the papers herein will guide and inspire future research activity spanning multiple scientific disciplines, as well as informing effective management of European freshwater ecosystems.

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