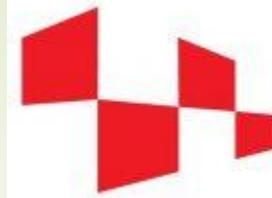




Universidad de Oviedo
Universidá d'Uviéu
University of Oviedo



HrZZ
Croatian Science
Foundation

An overview of the project activities during the second project period (1st January 2021 to 30th June 2022)

Zrinka Dragun

HrZZ METABIOM – 2nd project meeting
Zagreb, May 2022

Changes to project team

2. New associates



Zoran Kiralj, mag. biol. exp.
– PhD student on the project

Tomislav Kralj, mag. oecol. et prot. nat.
– PhD student



Ivana Karamatić, grad. eng. of food techn.
– professional assistant



1. Associates that left the project

Dr. Nesrete Krasnići
– professional assistant



Field activities



Sampling sites at the Mrežnica River:

- reference site (REF), Duga Resa factory (DRF) and Karlovac industrial zone (Mala Švarča) (KIZ)

Bioindicator organisms:

- fish – northern pike (*Esox lucius*) at REF and DRF
- bivalves (*Unio crassus*) – at REF and KIZ

Sampling dates:

- spring sampling: 22-23 April, 1 May 2021 (fish, water and sediments), 6 June 2021 (bivalves)
- autumn sampling: 22-23 September 2021 (fish, water and sediments), 3 October 2021 (bivalves)

In situ analyses:

- physico-chemical parameters of river-water by portable probes
- general fish health assessment



Laboratory analyses

Water and sediment in both seasons at all three sites:

- physico-chemical parameters and nutrients in water
- dissolved trace and macro elements in water
- trace and macro elements in sediments
- grain size distribution in sediments
- + particulate trace and macro elements in water
- + screening for organic contaminants in water

Fish in both seasons at REF and DRF sites:

- bacteriological, virological and parasitological analyses on northern pike
- histological examination of northern pike liver
- homogenisation of northern pike liver
- isolation of cytosolic fractions from the hepatic tissue
- trace and macro element measurement in the digested homogenates and cytosols of fish liver (total and cytosolic concentrations)
- biomarker analyses in fish liver (TP, MT, tGSH, CAT, AChE, MDA)
- trace and macro element measurement in the digested fish muscles (total concentrations)
- + biomarker analyses in fish muscles (TP, tGSH, AChE, MDA)

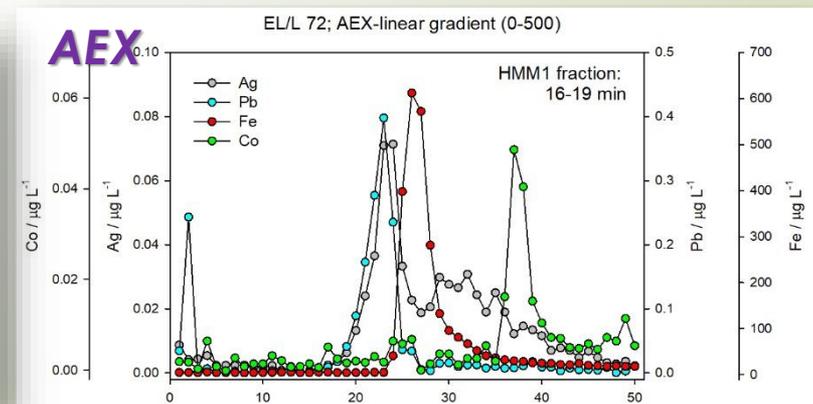
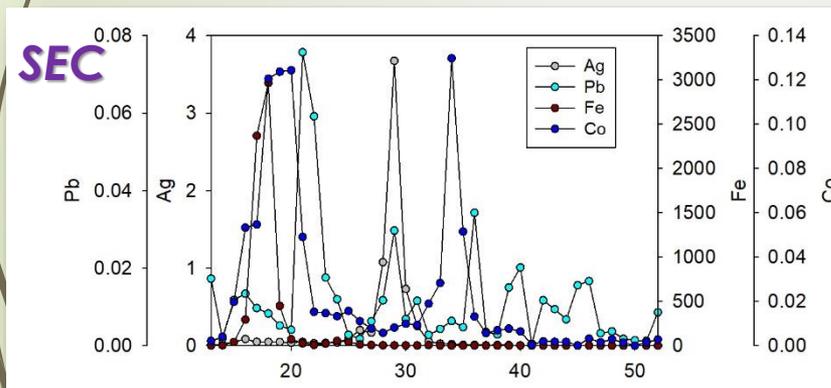
Laboratory analyses

Bivalves in both seasons at REF and KIZ sites:

- homogenisation of *U. crassus* digestive glands
- isolation of cytosolic fractions from the digestive gland tissue
- trace and macro element measurement in the digested homogenates and cytosols of *U. crassus* digestive glands (total and cytosolic concentrations)
- biomarker analyses in *U. crassus* digestive glands (TP, MT, tGSH, CAT, AChE, MDA)

Two dimensional HPLC separations of cytosolic fractions of organs of fish and bivalves with subsequent HR ICP-MS measurement:

- SEC-HPLC separations of cytosolic metal-binding proteins with subsequent HR ICP-MS measurement
- optimization of additional AEX-HPLC separation of SEC-HPLC separated proteins with subsequent HR ICP-MS measurement
- preparation for CEX-HPLC separations of SEC-HPLC separated proteins



Conferences

1. International Conference of Trace Elements and Minerals (ICTEM21; online meeting)

2-6 August 2021
Aachen, Germany

1. Kiralj, Z., Dragun, Z., Lajtner, J., Mandić, A., Trgovčić, K., Krasnići, N., Mijošek, T., Filipović Marijić, V., Ivanković, D., 2021. Metal accumulation in the digestive gland of mussel *Unio crassus* as an indicator of metal contamination in freshwater ecosystems: total vs. cytosolic metals. (poster presentation)

Metal accumulation in the digestive gland of mussel *Unio crassus* as an indicator of metal contamination in freshwater ecosystem: total vs. cytosolic metals

Zoran Kiralj^{1*}, Zrinka Dragun¹, Jasna Lajtner², Antonela Mandić², Krešimira Trgovčić³, Nesrete Krasnići¹, Tatjana Mijošek¹, Vlatka Filipović Marijić¹, Dušica Ivanković¹

¹Ruder Bošković Institute, Division for Marine and Environmental Research, Zagreb, Croatia; ²Faculty of Science, Department of Biology, University of Zagreb, Zagreb, Croatia; ³Vodovod i kanalizacija d.o.o., Karlovac, Croatia

Introduction

- High metal contamination of aquatic ecosystems can have a huge impact on aquatic environment.¹
- Freshwater mussels from family Unionidae are benthic, filter-feeding organisms which are very susceptible to any changes of water chemistry.²
- In addition, these bivalves live relatively long and are therefore suitable for monitoring long-term metal exposure.

Aim

- Aim of this study was to compare concentrations of twenty eight metals in the digestive gland of *Unio crassus* from two different locations of Mežnica River.
- An additional aim was to determine whether total or cytosolic metal concentrations in digestive gland of *U. crassus* are better indicators of metal exposure in freshwater ecosystems.

Sampling area and organism

- Two sampling sites at Mežnica River: upstream from the town of Duga Resa as the reference site (REF) and the industrial zone of Karlovac (KAR), as contaminated site.
- For this investigation we have selected *U. crassus* because this species has very abundant populations in Mežnica River.



Unio crassus, Philipsson 1788

Methods

```

graph TD
    A[Tissue homogenisation] --> B[Centrifugation 50 000g]
    A --> C[TISSUE HOMOGENATE]
    B --> D[S50 FRACTION (CYTOSOL)]
    C --> E[Digestion with mixture of HNO3 and H2O2]
    D --> F[Determination of metal/metalloid concentrations on ICP-MS]
    E --> F
        
```

Results

	REF	KAR
Bi ng/g	2.6±0.4	3.5±0.5
Cs ng/g	1.4±0.4	2.9±0.5
Cu µg/g	1.5±0.2	3.0±0.5
Mo ng/g	167±11	188±14
Pb ng/g	47±7	72±19
Sb ng/g	2.3±0.3	3.6±0.4
U ng/g	35±3	60±8

Table 1. Comparison of total metal concentrations between KAR and REF sites.

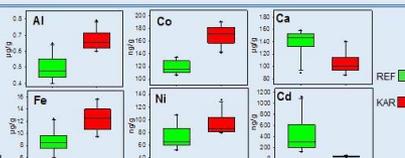


Fig.1. Comparison of cytosolic metal concentrations between KAR and REF sites.

Conclusion

- Results suggest that *U. crassus* is a good indicator of water quality, which provides information of different bioavailable metal species and forms in aquatic environments, especially by analysing cytosolic (potentially toxic) metal concentrations in their digestive glands.

Acknowledgements

- The Croatian Science Foundation is acknowledged for the financial support of the METABION project (IP-2019-04-2636).

References

- Herbert E. Allen et al. (1980) *Environ. Sci. Technol.* 14(4): 441-443
- Havlik, Marian E., Marking, Leif L. (1987) *U.S. Fish and Wildlife Service* (USA)

Conferences

2. 6th Croatian Congress of Toxicology with international participation (CROTOX 2020)

3-6 October 2021
Rabac, Croatia

1. Dragun, Z., Fiket, Ž., Stipaničev, D., Repec, S., Šošтариć Vulić, Z., Ivanković, D., Krasnići, N., Filipović Marijić, V., Mijošek, T., Barac, F., Valić, D., 2021. **Characterization of the water and sediment quality of the lower course of the Mrežnica River: the effect of long-term historical contamination.** (poster presentation)
2. Dragun, Z., Krasnići, N., Valić, D., Barac, F., Ivanković, D., Fiket, Ž., Filipović Marijić, V., Mijošek, T., Matanović, K., Kužir, S., Gjurčević, E., 2021. **Bioaccumulation and intracellular distribution of trace elements in the liver of northern pike (*Esox lucius* L., 1758) from the Mrežnica River: THE METABIOM PROJECT.** (poster presentation)
3. Ivanković, D., Mandić, A., Krasnići, N., Lajtner, J., Trgovčić, K., Mijošek, T., Filipović Marijić, V., Dragun, Z., 2021. **Comparison of metal accumulation, intracellular metal distribution and metal-binding biomolecules in the digestive gland of two freshwater bivalve species from the Mrežnica River.** (poster presentation)

3. 9th International Congress „Veterinary Science and Profession“ (VSP2021; online meeting)

9 October 2021
Zagreb, Croatia

1. Koutis, I., Gjurčević, E., Kužir, S., Benko, V., Valić, D., Barac, F., Dragun, Z., Ivanković, D., Mijošek, T., Filipović Marijić, V., Matanović, K., 2021. Health assessment of northern pike (*Esox lucius*) from the Mrežnica River, Croatia. (poster presentation)

Health assessment of northern pike (*Esox lucius*) from the Mrežnica River, Croatia

Irish Koutis¹, Emil Gjurčević¹, Snježana Kužir¹, Valerija Benko¹, Damir Valić¹, Fran Barac¹, Zrinka Dragun¹, Dušica Ivanković¹, Tatjana Mijošek¹, Vlatka Filipović Marijić¹, Krešimir Matanović¹

¹Department for Biology and Pathology of Fish and Bees, Faculty of Veterinary Medicine, University of Zagreb, Zagreb, Croatia
²Department of Aquatics, Biology and Entomology, Faculty of Veterinary Medicine, University of Zagreb, Zagreb, Croatia
³Division for Marine and Environmental Research, Ruđer Bošković Institute, Zagreb, Croatia

Northern pike (family Esocidae) is an important fish for aquaculture and the fishing industry in Croatia. Despite its commercial significance, there is only limited information on the health status of this species in natural waters (Rata, 1980). Here we report the results of an initial evaluation of the health status of wild northern pike collected from 3 locations along the Mrežnica River.

In the spring of 2020, a total of 9 specimens (30 – 67 cm in length, average body weight of 925 g) were captured by electrofishing and examined as part of a fish health and ecotoxicological study, conducted under the Croatian Science Foundation project, "Metal-binding biomolecules and health disturbances of freshwater organisms exposed to industrial wastes" (IP-2019-04-2636). For each pike, the presence of gross external and internal lesions were documented, and samples were processed for virological, bacteriological and parasitological examination. For the virological examination a routine culture-based procedure was carried out as recommended in the OIE Manual of Diagnostic Tests for Aquatic Animals (Anonymous, 2019). General purpose media were used for the isolation of bacteria (Austin and Austin, 2007). In addition to a routine parasitological examination, Giemsa-stained blood smears were examined for the presence of blood parasites. For the histological examination, small samples of liver and kidney were fixed in 10% neutral-buffered formalin, fixed material was embedded in paraffin and 5-µm thick sections were prepared. Sections were stained with haematoxylin and eosin (H&E), periodic acid-Schiff (PAS) and Mallory's trichrome.

No viruses or pathogenic bacteria were detected. However, a number of protozoan and metazoan parasites were observed, including ciliates (*Trichostema* sp.), myxosporeans (*Myxidium lieberknehti*), monogeneans (*Dactylogyrus* sp. and *Gyrodactylus* sp.), intestinal nematodes, leeches (*Hemiclepsis marginata*) and crustaceans (*Argulus foliaceus*). Histologically, different changes were evident in the liver and kidney of several fish. In the liver, changes of unknown aetiology were mostly characterized by hydropic degeneration, vascular congestion, granuloma formation, lymphocytic and necrosis of single hepatocytes (Fig. 1). Histopathological changes in the kidney were associated with *Myxidium* infection and were characterized by tubular dilation and glomerular destruction (Fig. 2).

This preliminary study suggests that special attention should be given to the health status of wild northern pike.

REFERENCES
Anonymous (2019): OIE Manual of Diagnostic Tests for Aquatic Animals.
Austin, B., D. A. Austin (2007): Bacterial Fish Pathogens - Diseases of Farmed and Wild Fish, Fourth Edition. Praxis Publishing Ltd, Chichester, UK.
Rait, A. J. P. (1988): Synopsis of biological data on the northern pike *Esox lucius* Linnaeus, 1758. FAO Fisheries Synopsis, No. 30, rev. 2.

ACKNOWLEDGEMENT
This study has been supported by Croatian Science Foundation under the project METABIOM (IP-2019-04-2636).



Figure 1. a) Pale liver in northern pike (*Esox lucius*); b-e) Histopathology of northern pike liver: b) Hydropic degeneration (HE); c) Vascular congestion (Mallory's trichrome); d) Granuloma formation (PAS); e) Necrosis of single hepatocytes (HE).

Figure 2. a) Darkening of the posterior kidney due to *Myxidium lieberknehti* infection in northern pike; b) Histological section of a northern pike kidney showing dilation of a tubule (HE); c) Lumen of affected tubules containing plasmodia of *M. lieberknehti* (Mallory's trichrome).

Conferences

4. 21st European Meeting on Environmental Chemistry (EMEC21)

30 November - 3 December 2021
Novi Sad, Serbia

1. Mijošek, T., Ivanković, D., Kiralj, Z., Cvitanović, M., Valić, D., Barac, F., Filipović Marijić, V., Gjurčević, E., Matanović, K., Kužir, S., Dragun, Z., 2021. **Multibiomarker responses in the liver of the northern pike (*E. lucius*) from the Mrežnica River as an indication of water contamination.** (poster presentation)
2. Kiralj, Z., Dragun, Z., Krasnići, N., Lajtner, J., Trgovčić, K., Mijošek, T., Mandić, A., Filipović Marijić, V., Valić, D., Ivanković, D., 2021. **Deeper insight into the metallome of the digestive glands of *Unio crassus* mussels at different metal exposures: Distribution of metals among cytosolic biomolecules.** (poster presentation)



Conferences

5. Scientific school on the environment 2021 at Institute Ruđer Bošković (online meeting)

7-10 December 2021
Zagreb, Croatia

1. Kiralj, Z., Dragun, Z., Lučić, M., Lajtner, J., Trgovčić, K., Mijošek, T., Filipović Marijić, V., Valić, D., Fiket, Ž., Ivanković, D., 2021. **Assessment of heavy metals contamination in water and biota of the Mrežnica River.** (oral presentation).



Conferences

6. 2nd Online ACE Seminar on Chemistry and the Environment Led by Early-Career Scientists: Environmental Chemistry Towards Global Change – CHEM2CHANGE

15-16 March 2022

1. Kralj, T., Stipaničev, D., Repec, S., Barac, F., Kiralj, Z., Ivanković, D., Mijošek, T., Filipović Marijić, V., Valić, D., Dragun, Z., 2022. **Assessment of drug contamination of Mrežnica River water in Croatia during COVID pandemic (2020-2021).** (oral presentation)



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Hrvatska Voda

CHEM 2
CHANGE

ASSESSMENT OF DRUG CONTAMINATION OF MREŽNICA RIVER WATER
IN CROATIA DURING COVID PANDEMIC (2020-2021)

Tomislav Kralj
Rudjer Bošković Institute
Laboratory for Biological Effects of Metals

Conferences

7. 6th PhD Student Symposium at Faculty of Science

23-24 April 2022
Zagreb, Croatia

1. Kiralj, Z., Dragun, Z., Krasnići, N., Mandić, A., Lajtner, J., Trgovčić, K., Mijošek, T., Filipović Marijić, V., Valić, D., Ivanković, D., 2022. **Differences in the subcellular distribution of the toxic metals Ag and Cd in the digestive glands of three mussel species from the family Unionidae.** (oral presentation)



Conferences

15-19 May 2022
Copenhagen, Denmark

8. SETAC Europe 32nd Annual Meeting

1. Kiralj, Z., Dragun, Z., Lajtner, J., Trgovčić, K., Mijošek, T., Filipović Marijić, V., Valić, D., Ivanković, D., 2022. **Analysis of molecular biomarkers in the digestive glands of *Unio crassus* as a useful tool for assessing pollution of aquatic ecosystems: a study in the Mrežnica River (Croatia).** (poster presentation)



The award for the best poster presentation



Dr. Tatjana Mijošek was awarded by Princ Sultan Bin Abdulaziz for the best poster presentation, titled:

"Multi-biomarker responses in the liver of the northern pike (*E. lucius*) from the Mrežnica River as an indication of water contamination.,,"

She was presented with the award at 21st European Congress of Environmental Chemistry in Novi Sad.

1. Journal of Fish Diseases - published

Bekavac, A., Beck, A., Dragičević, P., Dragun, Z., Maguire, I., Ivanković, D., Fiket, Ž., Gračan, R., Hudina, S., 2021. Disturbance in invasion? Idiopathic necrotizing hepatopancreatitis in the signal crayfish *Pacifastacus leniusculus* (Dana, 1852) in Croatia. *Journal of Fish Diseases*, 00:1-16.

Received: 15 July 2021 | Revised: 19 October 2021 | Accepted: 21 October 2021

DOI: 10.1111/jfd.13552

RESEARCH ARTICLE

Journal of
Fish Diseases  WILEY

Disturbance in invasion? Idiopathic necrotizing hepatopancreatitis in the signal crayfish *Pacifastacus leniusculus* (Dana, 1852) in Croatia

Ana Bekavac^{1,2} | Ana Beck³ | Paula Dragičević¹ | Zrinka Dragun⁴ | Ivana Maguire¹ | Dušica Ivanković⁴  | Željka Fiket⁴ | Romana Gračan¹  | Sandra Hudina¹ 

¹Department of Biology, Faculty of Science, University of Zagreb, Zagreb, Croatia

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⁴Division for Marine and Environmental

Abstract

As the most successful crayfish invader and possible vector for infectious agents, signal crayfish *Pacifastacus leniusculus* is among the major drivers of the native crayfish species decline in Europe. We describe histopathological manifestation and frequency of newly detected idiopathic necrotizing hepatopancreatitis along the invasion range

2. Comparative Biochemistry and Physiology Part C - Toxicology and Pharmacology – published

Dragun, Z., Ivanković, D., Krasnići, N., Kiralj, Z., Cvitanović, M., Karamatić, I., Valić, D., Barac, F., Filipović Marijić, V., Mijošek, T., Gjurčević, E., Matanović, K., Kužir, S., 2022. Metal-binding biomolecules in the liver of northern pike (*Esox lucius* Linnaeus, 1758): the first data for the family Esocidae. *Comparative Biochemistry and Physiology Part C - Toxicology and Pharmacology*, 257:109327.

Comparative Biochemistry and Physiology, Part C 257 (2022) 109327

Contents lists available at ScienceDirect

 **Comparative Biochemistry and Physiology, Part C**

journal homepage: www.elsevier.com/locate/cbpc





Metal-binding biomolecules in the liver of northern pike (*Esox lucius* Linnaeus, 1758): The first data for the family Esocidae

Zrinka Dragun^{a,*}, Dušica Ivanković^{a,*}, Nesrete Krasnići^a, Zoran Kiralj^a, Marita Cvitanović^b, Ivana Karamatić^a, Damir Valić^a, Fran Barac^a, Vlatka Filipović Marijić^a, Tatjana Mijošek^a, Emil Gjurčević^c, Krešimir Matanović^c, Snježana Kužir^c

^a Ruđer Bošković Institute, Division for Marine and Environmental Research, Laboratory for Biological Effects of Metals, Bijenička c. 54, Zagreb, Croatia
^b Faculty of Science, Department of Biology, University of Zagreb, Rooseveltov trg 6, Zagreb, Croatia
^c Faculty of Veterinary Medicine, University of Zagreb, Heinzelova 55, Zagreb, Croatia

ARTICLE INFO

Edited by Martin Grosell

Keywords:
Cytosol
Freshwater fish
Green liver syndrome
HPLC
ICP-MS

ABSTRACT

Metal-handling strategies of various fish species are known to vary significantly in association with their intracellular metal behaviour. Thus, to better understand the possible consequences of increased metal exposure in fish it is important to perform comparative studies on metal-binding biomolecules in organs of different species. This study was the first of this kind on a liver of an esocid fish (northern pike, *Esox lucius*), and the gathered information were compared to fish belonging to three other families, Leuciscidae, Cyprinidae and Salmonidae. Distributions of ten elements among cytosolic biomolecules of different molecular masses were studied by size exclusion HPLC combined offline with high resolution ICP-MS. The results indicated predominant association of Co, Fe and Mn to high molecular mass biomolecules (>100 kDa), of Zn and Bi to both high and

3. Water Research – in preparation

Dragun, Z., Stipaničev, D., Fiket, Ž., Lučić, M., Udiković Kolić, N., Puljko, A., Repec, S., Šošarić Vulić, Z., Čerkez, T., Ivanković, D., Krasnići, N., Filipović Marijić, V., Mijošek, T., Barac, F., Kiralj, Z., Kralj, T., Valić, D., (2022) Yesterday's contamination – a problem of today? The case study of discontinued historical contamination of the Mrežnica River. *Water Research*, in preparation.

Submission – by the end of June 2022

The screenshot displays the journal's website interface. At the top, there are logos for ScienceDirect, Elsevier, and Nature-Based Solutions. The main header features the journal title 'Water Research' with a CiteScore of 15.6 and an Impact Factor of 11.236. Below the header, there is a navigation menu with options for 'Articles & Issues', 'About', 'Publish', and a search bar. The 'About the journal' section is visible, providing information about the journal's open access companion journal, *Water Research X*, and its focus on anthropogenic water.

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1 July 2022

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Graduation theses

1. Toni Čerkez

- graduate programme of Environmental Sciences
Faculty of Science, University of Zagreb
- supervisors: prof. dr. Gordana Medunić and **assist. prof. dr. Željka Fiket**
- title: Geochemical characteristics of water and sediment of the Mrežnica River
- date of defense: 21st April 2021

2. Antonela Mandić

- graduate programme of Environmental Sciences
Faculty of Science, University of Zagreb
- supervisors: **dr. Dušica Ivanković and assoc. prof. dr. Jasna Lajtner**
- title: Accumulation and intracellular distribution of metals in the digestive glands of two freshwater bivalve species from the Mrežnica River
- date of defense: 21st September 2021

Graduation theses

3. Lucija Runje

- integrated undergraduate/graduate program in veterinary medicine
Faculty of Veterinary Medicine, University of Zagreb
- supervisors: **assist. prof. dr. Krešimir Matanović and assoc. prof. dr. Jasna Lajtner**
- title: Investigation of frequency of trematodes of the genus *Aspidogaster* in freshwater fish and molluscs
- date of defense: 29th October 2021

4. Ema Omrčen

- graduate programme of Environmental Sciences
Faculty of Science, University of Zagreb
- supervisors: **dr. Dušica Ivanković and assoc. prof. dr. Jasna Lajtner**
- title: Biomarker responses and accumulation of metals in the muscles of northern pike (*Esox lucius*) from the Mrežnica River as indicators of water pollution
- in progress

Graduation theses

5. Marita Cvitanović

- graduate programme of Environmental Sciences
Faculty of Science, University of Zagreb
- supervisors: **dr. Zrinka Dragun and assoc. prof. dr. Jasna Lajtner**
- title: Impact of environmental exposure and physiological factors on metal bioaccumulation in the liver of northern pike (*Esox lucius*)
- in progress



Other activities - dissemination

- Lecture at the Faculty of Veterinary Medicine, University of Ljubljana held by prof. dr. Snježana Kužir



- Lecture at Science Festival 2022 in Čabar held by dr. Damir Valić



Z. Dragun, D. Ivanković¹ i D. Valić^{2,3}
 Institut Ruder Bosković
 Bijenčka 54
 HR-10 000 Zagreb

Biomolekule koje vežu metale i zdravstveni poremećaji kod slatkvodnih organizama izloženih industrijskom otpadu (METABIOM)

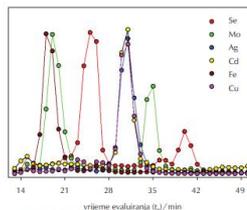
Šifra: IP-2019-06-2636

Prijavitelji: Institut Ruder Bosković

Partneri: Veterinarski fakultet Sveučilišta u Zagrebu; Prirodoslovno-matematički fakultet Sveučilišta u Zagrebu; Kemijski fakultet Sveučilišta u Oviedu, Španjolska

Izvor financiranja: Hrvatska zaklada za znanost

Osnovna je zamisao projekta METABIOM primijeniti metalomiku u području okolišnih istraživanja u Hrvatskoj. Znanstvena disciplina metalomik razvijena je početkom 21. stoljeća s ciljem uvođenja sustavnog i opsežnog pristupa sučeljavanju metala ili metaloida u biološkom kontekstu (Izobinski i sur., 2010). Primjena načela metalomike u rasvjetljavanju sudbine metala u tkivima i stanicama akvatičnih organizama, poput riba i školjaka, još uvijek je slabo zastupljena diljem svijeta. U skladu s tim, cilj je projekta primijeniti ovu HPLC tehniku (izvođenju po veličini (šikla 1)) te anionske i kationske izmjene) u kombinaciji s HR ICP-MS-om odrediti raspodjele metala među citosolnim biomolekulama različitih veličina i naboja za dva biotransformacijska organizma: školjku (*Eux Iucius*) kao predstavnika slatkvodnih ribljih vrsta te *Unio crassus* kao predstavnika slatkvodnih školjaka. Odabrane biomolekule koje vežu metale izolirane iz tihvih metaloidičkih i de-



Šikla 1 – Profili raspodjele metaloidno odabranih metala među molekulama različitih molekularnih masa dobiveni razdvajanjem citosolnih proteina jeta školjke (*Eux Iucius*) te riblje Mezotrice na koloni *Incom*™ Superdex 200 10/300 GL (GE Healthcare Bioscience, SAD) raspon razdvajanja: od 10 do 600 kDa pomoću HPLC sustava Perkin Elmer, SAD.

- Short review on METABIOM project in the journal *Chemistry in Industry*



Thank you for your attention 😊