Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XV, 2026
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

MOISTURE, LIPID CONTENT, AND MERCURY IN FRESHWATER FISH MUSCLE: INDICATORS OF ECOLOGICAL CONDITION IN THE LOWER DANUBE RIVER

Andreea-Miruna CODREANU[1], Ștefania-Adelina MILEA[1], Cristina Mihaela LUNTRARU[2], Alin Constantin DÎRȚU[3], Cătălina ITICESCU[1, 4]

[1]"Dunărea de Jos" University of Galați, REXDAN Research Infrastructure,
98 George Coșbuc Street, Galați, Romania
[2]SC Hofigal Export Import SA, 2 Intrarea Serelor Street, District 4, Bucharest, Romania
[3]"Alexandru Ioan Cuza" University of Iași, Faculty of Chemistry, 11 Carol I Blvd, Iași, Romania
[4]"Dunărea de Jos" University of Galați, Faculty of Sciences and Environment,
111 Domnească Street, Galați, Romania

Corresponding author email: miruna.codreanu@ugal.ro

Abstract

The composition of fish muscle is influenced by environmental factors and can be used to assess the status of the aquatic ecosystems. This study explores the relationship between moisture and lipid content in the muscle tissue of selected freshwater fish species from the Lower Danube River, aiming to evaluate their potential as ecological indicators. Eight edible fish species, asp, vimba bream, perch, wels catfish, zander, pontic shad, common roach, and common carp, were included in the analysis. Moisture content was determined by freeze-drying and total lipid content was assessed on the dry fish using the Soxhlet extraction method. Lipid content was expressed both as dry and wet weight to allow an extensive interpretation in a biological and environmental context. Total mercury concentrations were also determined in fish samples, ranging from 0.15 ± 0.02 mg/kg in pontic shad to 1.04 ± 0.62 mg/kg in wels catfish. The results for moisture content ranged from 73.67 ± 2.52 % to 81.25 ± 1.06%, while lipid content (expressed as wet weight) showed high variability among species (0.4 ± 0.00% to 17.67 ± 5.42%). A strong inverse correlation was observed between moisture and lipid content (r ≈ -0.929), which suggests that fish muscle composition reflects differences in energy storage and environmental conditions. The findings of this study support the use of biochemical parameters as complementary indicators in aquatic environmental assessment, particularly in freshwater systems subject to environmental variability.

Key words: *Danube River, freshwater fish, freeze-drying, lipids, mercury.*

INTRODUCTION

Aquatic ecosystems evaluation is based on the integration of physicochemical and biological indicators that show both natural diversity and environmental stresses. This evaluation is closely linked to water quality monitoring, which provides essential information regarding the environmental status and the anthropic pressures, especially for the large rivers like Danube (Iticescu et al., 2014). In addition, environmental monitoring is strongly connected to broader sustainability goals and policy frameworks (Georgescu et al., 2025). Moreover, recent studies emphasize the importance of conventional and emerging pressures on water ecosystems, highlighting their role in supporting water security and the socio-economic development (Goswami & Bisht, 2017; Wang et al., 2024; Zlati et al., 2024; Cadieux, 2026; Moon et al., 2026).

Within this perspective, identifying complementary indicators capable of evaluating the ecosystem regarding the environment quality and trophic dynamics remains a key objective in environmental research and monitoring.

Even though physicochemical characteristics provide an overview of water quality and biological communities are an indicator of long-term responses to ecological changes, biochemical parameters of fish tissues can reflect environmental changes over time and contribute to the assessment of the physiological state of the aquatic organisms. Therefore, fish are considered relevant bioindicators of

ecological condition in water environments due to their sensitivity to environmental pressures and can be complementary to physicochemical and biological monitoring by integrating trophic interactions and environmental quality (Maceda-Veiga & De Sostoa, 2011; Wannas & Mohammed, 2025). The principal constituents of fish muscle are generally water, lipids and proteins, while carbohydrates and ash are present in low levels. Since the protein concentrations tend to vary less than the lipid content, fluctuations in fat content are linked to interchanges between water and lipid fractions. As a consequence, an inverse relationship between moisture and lipid content in fish species was reported, with greater lipid depositions corresponding to lower water content (Naeem & Salam, 2010; Ahmed et al., 2022; Warret Rodrigues et al., 2023). Lipid and moisture content can offer valuable insight about energy storage and other physiological characteristics and may reflect the adaptive response to environmental conditions in freshwater ecosystems like the Lower Danube River (Petricorena, 2014; Martin et al., 2017; Ahmed et al., 2022).

Furthermore, the assessment of total mercury can be included alongside fish muscle composition, as mercury is known for its persistence in the aquatic ecosystems, and for its bio-accumulative and bio-magnification character across the trophic chain (Tolkou et al., 2023; Rock et al., 2025). Therefore, monitoring total mercury in fish from different trophic levels can give additional data on the ecosystem quality (Zillioux, 2015; Bernal-Alviz et al., 2025).

The selected fish species are representative for different trophic positions and feeding habits within the lower Danube River, and permit a more extensive evaluation of the biochemical interspecific variation in fish muscle. The study includes omnivorous species such as common carp (*Cyprinus carpio carpio*) and common roach (*Rutilus rutilus*); benthic-omnivorous vimba bream (*Vimba vimba*); predatory species including perch (*Perca fluviatilis*), pontic shad (*Alosa immaculata*), asp (*Leuciscus aspius*), zander (*Sander lucioperca*), and wels catfish (*Silurus glanis*) (Okgerman et al., 2013; Gerasimov & Strel'nikova, 2016; Mazlum & Akgumus, 2019; Olsson, 2019; Pfauserová et al., 2019; Nahon et al., 2020; Santos et al., 2025).

The aim of the present study was to evaluate the relationship between moisture and lipid content in muscular tissue of selected freshwater fish species from the Lower Danube River and to investigate their potential as indicators of ecological status. Furthermore, mercury concentrations were assessed to provide supplementary information on the extent of metal contamination in the aquatic environment. This work highlights the importance of fish muscle composition in ecological evaluation. It also provides preliminary data for the Lower Danube River, contributing to the relatively limited research regarding the use of simple compositional analysis in freshwater monitoring.

MATERIALS AND METHODS

Fish samples were collected in spring 2023 from local fishermen in the Lower Danube and Danube Delta regions. The biometric characteristics of the analysed fish were as follows: asp, total length 37.00 cm and body weight 386.00 g (n=1); vimba bream, 44.40 ± 31.89 cm and 265.70 ± 34.02 g (n=3); perch, 22.33 ± 1.51 cm and 169.33 ± 22.05 g (n=3); wels catfish, 74.83 ± 3.67 cm and 2916.67 ± 633.11 g (n=2); zander, 23.35 cm and 151.50 g (n=1); pontic shad, 25.93 ± 1.40 cm and 167.67 ± 21.94 g (n=3); common roach, 30.00 cm and 290.00 g (n=1); common carp, 59.10 ± 4.45 cm and 2800 ± 1255.99 g (n=3). Two of the eight analysed species are represented in Figure 1. All specimens were eviscerated immediately after collection. Muscle samples were collected from the dorsal white muscle. The fish muscles were frozen, and stored at –20°C until analysis.

Ten grams of each muscle sample were first pre-frozen at −80°C for 24 hours, then freeze-dried for 24 hours at a condenser temperature of −80°C and a vacuum pressure of 200 Pa to remove all water content, allowing accurate determination of the moisture level in the fish tissues (Figure 2); the lyophilization was performed on a Table Top Freeze Dryer BK-FD10PT (BioBase, Shandong, China).



Figure 1. Examples of analysed species: perch and Pontic shad

Moisture was calculated by the gravimetric method using the formula:

$$\text{Moisture (\%)} = \frac{wet\ weight - dry\ weight}{wet\ weight} \times 100$$

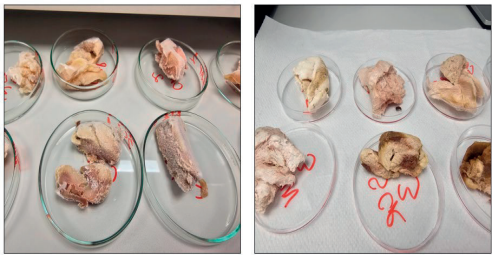


Figure 2. Fish muscle before and after freeze-drying

Subsequently, lipid determination was carried out on the dried samples. The total lipids were analysed by the modified Soxhlet method, with 30 minutes of hot extraction, 60 minutes of rinsing time and 30 minutes of solvent recovery. The samples were extracted with 150 mL n-hexane, with the heating block set to 180°C. The samples were weighed in the cellulose thimble. Each extraction beaker contained 2 boiling stones to ensure constant boiling. The extract was evaporated to dryness, permitting the gravimetric determination of fat content. The total lipid content was determined using a Soxtherm SOX414 (C. Gerhardt Analytical Systems, Königswinter, Germany) fully automated extraction unit. Lipids were expressed on dry weight, using the gravimetric method:

$$\text{Lipids (dry weight, \%)} = \frac{final\ mass - initial\ mass}{sample\ mass} \times 100$$

The results were further used for conversion to wet weight:

$$\text{Lipids (wet weight, \%)} = \text{Lipids (dry weight, \%)} * (1 - \text{Moisture}/100)$$

The data have been statistically processed and interpreted in Python (version 3.12) using the pandas, matplotlib, and SciPy libraries within the Spyder IDE.

Pearson's Correlation analysis was used to evaluate the relationship between lipids content and moisture.

Approximately 50 milligrams of fresh, non-lyophilized muscle was weighed in nickel sample boat and submitted to the analysis using DMA-80 evo Direct Mercury Analyzer (Milestone, Sorisole, Italy). Samples were analysed directly without previous digestion. Total mercury (THg) was assessed by thermal decomposition of the sample, followed by catalytic removal of by-products, gold amalgamation and quantification by atomic absorption spectroscopy (AAS).

One-way statistical analysis (ANOVA) was performed using Data Analysis ToolPak in Microsoft Excel (Microsoft Corporation, WA, USA) to evaluate differences among species regarding total mercury concentrations, lipids content and moisture. Only fish with duplicate or triplicate measurements were included in the analysis. Statistical significance was accepted at $p<0.05$.

RESULTS AND DISCUSSIONS

Results for moisture and lipid content in freshwater fish from the Danube River are presented in Table 1.

Moisture content was fairly constant among the species, ranging from 73.67 ± 2.52 % to 81.25 ± 1.06 %; these results are in accordance with a study conducted by Xia (2025) on freshwater fish. However, Pontic shad showed lower levels of 65.70 ± 8.00%, consistent with its high lipid content.

One-way ANOVA indicated significant differences in moisture content among fish species ($F = 5.09$; $p = 0.024$).

The differences in total lipid content observed between the analysed fish species can indicate different feeding behaviour, distinct habitats and environmental characteristics in the Lower Danube River ecosystem. Lipids can be used as an indicator of energy storage and fish physiological characteristics and can be

influenced by food resource availability and trophic interactions. Fish species that have increased lipid concentrations have access to more energy-rich food resources, whereas decreased lipid levels can indicate accelerated metabolism or environmental pressures.

Pontic shad showed the highest lipid levels, 17.67 ± 5.42% wet weight (ww), which can reflect energy reserves for migration (Misir et al., 2016). Common carp also showed relatively high lipid concentrations of 7.57 ± 2.34% ww, due to their omnivorous feeding behaviour and efficient accumulation of energy reserves (Ayalew et al., 2025). Lower lipid levels were exhibited by perch (0.4 ± 0.00% ww), zander (0.6% ww) and asp (0.7% ww), which can be explained by their predatory feeding character, intense swimming activity or habitat conditions. These species use most of their energy for locomotion, resulting in lower lipid deposition in their fish muscle tissue. Intermediate lipid values were obtained for common roach, wels catfish and vimba bream (2.1% ww, 2.35 ± 0.35% ww, 3.13 ± 0.91% ww, respectively). These results indicate species-specific feeding behaviour and resource management (Łuczyńska et al., 2020; Simeanu et al., 2022). Lipid levels remained highest in Pontic shad when expressed on a dry weight basis, suggesting that inter-species differences were present even after normalising for moisture content.

These findings suggest that fish muscle composition, especially lipid and moisture content, indicate species-specific adaptive response and can represent useful information on energy usage, availability of food resources, and ecological stress, supporting its use as a bioindicator within the Lower Danube River ecosystem.

One-way ANOVA revealed significant differences in lipid content between fish species ($F = 14.33$; $p = 0.001$).

Table 1. Moisture and lipid content in freshwater fish from the Danube River

Fish species	Abbreviation	Number of specimens	Moisture (%)	Total lipids (% dry weight)	Total lipids (% wet weight)
common carp (*Cyprinus carpio carpio*)	CRP	3	73.67 ± 2.52	28.77 ± 8.93	7.57 ± 2.34
perch (*Perca fluviatilis*)	BIB	3	78.90 ± 1.04	1.87 ± 0.15	0.4 ± 0.00
vimba bream (*Vimba vimba*)	MOR	3	76.77 ± 2.05	13.33 ± 2.95	3.13 ± 0.91
pontic shad (*Alosa immaculata*)	SCR	3	65.70 ± 8.00	51.03 ± 5.67	17.67 ± 5.42
wels catfish (*Silurus glanis*)	SMN	2	81.25 ± 1.06	12.65 ± 1.06	2.35 ± 0.35
zander (*Sander lucioperca*)	SL	1	79.9	3.0	0.6
common roach (*Rutilus rutilus*)	BAB	1	77.7	9.6	2.1
asp (*Leuciscus aspius*)	AVAT	1	78.0	3.0	0.7

The negative correlations between moisture and lipid content across the analysed muscles (wet weight basis; r=-0.929, n=17, $p<0.001$) are represented in Figure 3. The linear regression equation was y=-1.020x+82.550, R^2=0.864, indicating a statistically significant inverse relationship. As lipid levels increase, moisture content decreases as a result of intracellular water being replaced by high-energy lipidic deposits (Huss, 1995). The obtained results align with the well-documented moisture-lipid relationship described for muscle (Zhang et al., 2014; Matos et al., 2019; Ahmed et al., 2022).

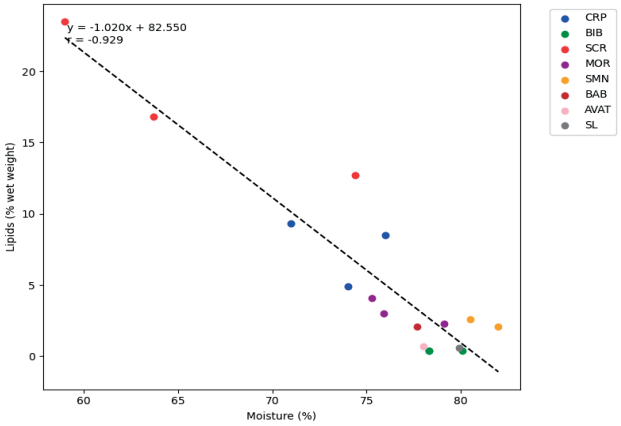


Figure 3. Correlations between lipids content and moisture

Mercury (Hg) is a widespread environmental pollutant that is extremely toxic and bioavailable. It accumulates in aquatic food chains and poses serious health concerns to consumers who eat seafood (Fioravanti et al., 2025). In all fish samples (Figure 4), the total mercury concentration varied between 0.15 ± 0.02 to 1.04 ± 0.62 mg/kg. Catfish recorded the highest concentration of 1.044 ± 0.62 mg/kg and at the opposite pole, the pontic shad determination recorded values of 0.15 ± 0.02 mg/kg.

Catfish from Danube are predator species which can accumulate high mercury levels by consuming other fish species. They are freshwater omnivores and consume substrate that is found at the bottom of water bodies (Cadieux, 2026).

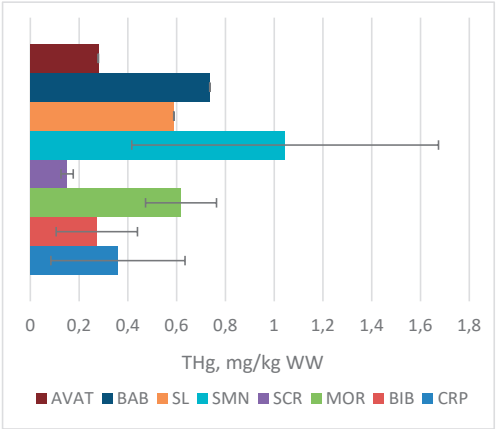


Figure 4. Total mercury (THg) concentrations (mg/kg) in fish muscle

Moreover, they have a potential to bioaccumulate this toxic element in time. Usually, the mercury level within the catfish reflects very well the degree of pollution from that environment. Pontic shad usually feed with smaller plankton, so their position into the food chain is lower and has a much shorter average lifespan compared to catfish. According to Brodziak-Dopierała & Fischer (2023), mercury levels in catfish from river Po ranged from 0.51 to 1.43 mg/kg. The observed levels are similar, which means that support the comparability between studies. Milea (2023) measured the mercury in pontic shad and obtained 0.21 mg/kg DW and Brodziak-Dopierała & Fischer (2023) stated that fish from the Danube, which passes through Croatia, have approximately 0.191 mg/kg (omnivorous species) and 0.441 mgHg/kg (plankton eaters). Regarding the other analysed samples, common roach, vimba bream, and zander exhibited high concentrations of mercury, followed by smaller concentrations in common carp, asp, and perch. Excepting pontic shad, all fish samples presented an increased intra-species variability in terms of mercury concentration. All these differences could be due to specific environmental factors, diet, age, size of each individual fish (Rock et al., 2025). Mercury levels in fish are important because for humans, eating fish is typically the main source of mercury (Dang & Wang, 2012). Additionally, they are indicators for the environmental pollution status (Tolkou et al., 2023).

One-way ANOVA showed a statistically significant difference in total mercury

concentration among fish species at the 0.05 significance threshold ($F = 3.70$; $p = 0.050$).

CONCLUSIONS

The present study showed interspecific variability for moisture and lipid content in muscle tissue of freshwater fish species from the Lower Danube River. The highest lipid accumulation was observed in Pontic shad and common carp, while perch, zander, and asp exhibited lower lipid reserves, highlighting differences in feeding strategies, metabolic activity, and habitat adaptations.

A strong inverse relationship between moisture and lipid content was identified ($r=-0.929$), confirming that lipid deposition is associated with lower tissue moisture across the investigated samples.

After determining the concentration of mercury in all fish species, it can be concluded that the highest levels were observed in the predatory species, in catfish. The presence of mercury in fish from the Danube highlights the need for continuous monitoring in order to preserve the quality of the aquatic ecosystem, but also to control the possibility of human exposure to contaminated food.

The findings of this study represent baseline data for the Lower Danube River area and reinforce the use of biochemical parameters as ecological indicators in aquatic environmental assessment in freshwater ecosystems. However, sampling was limited to a single season, and annual variations could not be accounted for. Seasonal changes in the lipid reserves and tissue moisture content can influence the mercury bioaccumulation. Future research should include seasonal sampling and the assessment of other pollutants and stressors to better understand the determinants of biochemical variations. These investigations would consolidate the use of these biomarkers in ecological monitoring programs and would contribute to the Water Framework Directive implementation, while contributing to broader freshwater management and sustainability strategies.

ACKNOWLEDGEMENTS

This work was supported by the Fondo Proserpina S.R.L., grant number 2506/2022, "The impact of heavy metals and microplastics from aquatic organisms on human health", and by the project "HORIZON-MISS-2021-OCEAN-02, DANUBE REGION WATER LIGHTHOUSE ACTION," Project No. 101094070 - DALIA, funded by the European Union's Horizon Europe programme.

REFERENCES

Ahmed, I., Jan, K., Fatma, S., & Dawood, M. A. O. (2022). Muscle proximate composition of various food fish species and their nutritional significance: A review. *Journal of Animal Physiology and Animal Nutrition*, *106*(3), 690–719. https://doi.org/10.1111/jpn.13711

Ayalew, T., Teshome, M., & Aemro, D. (2025). Food and feeding habits of the introduced common carp (*Cyprinus carpio* L. 1758) in Lake Ardibo, Ethiopia. *Heliyon*, *11*(4), e42596. https://doi.org/10.1016/j.heliyon.2025.e42596

Bernal-Alviz, J., Córdoba-Tovar, L., Pastrana-Durango, D., Molina-Polo, C., Buelvas-Soto, J., Cruz-Esquivel, Á., Marrugo-Negrete, J., & Díez, S. (2025). Influence of environmental and biological factors on mercury accumulation in fish from the Atrato River Basin, Colombia. *Environmental Pollution*, *366*, 125345. https://doi.org/10.1016/j.envpol.2024.125345

Brodziak-Dopierała, B., & Fischer, A. (2023). Analysis of the Mercury Content in Fish for Human Consumption in Poland. *Toxics*, *11*(8), 717. https://doi.org/10.3390/toxics11080717

Cadieux, J. (2026). *What Do Catfish Eat? A Pond Owner's Guide to Feeding & Management*. Midwest Ponds. https://midwestponds.com/blogs/midwestponds-blog/what-do-catfish-eat-a-pond-owner-s-guide-to-feeding-management

Dang, F., & Wang, W.-X. (2012). Why mercury concentration increases with fish size? Biokinetic explanation. *Environmental Pollution*, *163*, 192–198. https://doi.org/10.1016/j.envpol.2011.12.026

Fioravanti, R., Muzzioli, L., Maurel, E., Palma, G., Calabrese, G., Angioni, A., La Rocca, C., Mantovani, A., Pezzana, A., & Donini, L. M. (2025). Bioaccumulation and Biomagnification of Mercury Along the Seafood Chain in Europe: A Systematic Review. *Foods*, *14*(21), 3752. https://doi.org/10.3390/foods14213752

Georgescu, P.-L., Barbuta-Misu, N., Zlati, M. L., Fortea, C., & Antohi, V. M. (2025). Quantifying the Performance of European Agriculture Through the New European Sustainability Model. *Agriculture*, *15*(2), 210. https://doi.org/10.3390/agriculture15020210

Gerasimov, Yu. V., & Strel'nikova, A. P. (2016). Specific features of feeding in underyearlings of zander (Sander lucioperca) (Percidae) of the Rybinsk reservoir in various years. *Journal of Ichthyology*, *56*(3), 390–396. https://doi.org/10.1134/S0032945216030036

Goswami, K. B., & Bisht, P. (2017). The Role of Water Resources in Socio-Economic Development. *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, *5*(12), 1669–1674.

Huss, H. H. (1995). *Quality and quality changes in fresh fish—4. Chemical Composition*. Food and Agriculture Organization of the United Nations. https://www.fao.org/4/v7180e/v7180e05.htm

Iticescu, C., Georgescu, L., Topa, M.C. & Murariu, G. (2014). Monitoring the Danube water quality near the Galati city. *Journal of Environmental Protection and Ecology*, *15*, 30–38.

Łuczyńska, J., Paszczyk, B., Łuczyński, M. J., Kowalska-Góralska, M., Nowosad, J., & Kucharczyk, D. (2020). Using *Rutilus rutilus* (L.) and *Perca fluviatilis* (L.) as Bioindicators of the Environmental Condition and Human Health: Lake Łańskie, Poland. *International Journal of Environmental Research and Public Health*, *17*(20), 7595. https://doi.org/10.3390/ijerph17207595

Maceda-Veiga, A., & De Sostoa, A. (2011). Observational evidence of the sensitivity of some fish species to environmental stressors in Mediterranean rivers. *Ecological Indicators*, *11*(2), 311–317. https://doi.org/10.1016/j.ecolind.2010.05.009

Martin, B. T., Heintz, R., Danner, E. M., & Nisbet, R. M. (2017). Integrating lipid storage into general representations of fish energetics. *Journal of Animal Ecology*, *86*(4), 812–825. https://doi.org/10.1111/1365-2656.12667

Matos, Â., Matos, A., & Moecke, E. (2019). Polyunsaturated fatty acids and nutritional quality of five freshwater fish species cultivated in the western region of Santa Catarina, Brazil. *Brazilian Journal of Food Technology*, *22*. https://doi.org/10.1590/1981-6723.19318

Mazlum, R., & Akgumus, S. (2019). Stomach content analysis and length-weight relationship of the Pontic shad *Alosa immaculata* Bennett, 1835 (Pisces: Clupeidae), from the eastern Black Seacoast of Turkey. *Indian Journal of Fisheries*, *66*, 39–45. https://doi.org/10.21077/ijf.2019.66.4.79747-05

Milea, Ș.-A., Lazăr, N.-N., Simionov, I.-A., Petrea, Ș.-M., Călmuc, M., Călmuc, V., Georgescu, P.-L., & Iticescu, C. (2023). Effects of cooking methods and co-ingested foods on mercury bioaccessibility in pontic shad (*Alosa immaculata*). *Current Research in Food Science*, *7*, 100599. https://doi.org/10.1016/j.crfs.2023.100599

Misir, G., Tufan, B., & Köse, S. (2016). Variations in Total Lipid and Fatty Acid Contents of Edible Muscle, Liver, and Roes of Spotless Shad, Alosa Immaculata, During Catching Season in Black Sea. *Journal of Aquatic Food Product Technology*, *25*(1), 2–14. https://doi.org/10.1080/10498850.2013.816402

Moon, S. R., Rahman, M. M., Rahman, A., Khan, A. A., Nazir, M. A., Islam, M. A., & Abdulla-Al-Mamun, M. (2026). Water Resources and Environmental Sustainability: Current Challenges and Future Perspectives. *Resources*, *15*(2), 31. https://doi.org/10.3390/resources15020031

Naeem, M., & Salam, A. (2010). Proximate composition of fresh water bighead carp, *Aristichthys nobilis*, in relation to body size and condition factor from Islamabad, Pakistan. *Afr. J. Biotechnol.*, *9*, 8687–8692.

Nahon, S., Roussel, J.-M., Jaeger, C., Menniti, C., Kerhervé, P., Mortillaro, J.-M., & Aubin, J. (2020). Characterization of trophic niche partitioning between carp (*Cyprinus carpio*) and roach (*Rutilus rutilus*) in experimental polyculture ponds using carbon (δ13C) and nitrogen (δ15N) stable isotopes. *Aquaculture*, *522*, 735162. https://doi.org/10.1016/j.aquaculture.2020.735162

Okgerman, H., Yardimci, C., Dorak, Z., & Yilmaz, N. (2013). Feeding ecology of vimba (*Vimba vimba* L., 1758) in terms of size groups and seasons in Lake Sapanca, Northwestern Anatolia. *Turkish Journal of Zoology*, *37*, 288–297. https://doi.org/10.3906/zoo-1107-1

Olsson, J. (2019). Past and Current Trends of Coastal Predatory Fish in the Baltic Sea with a Focus on Perch, Pike, and Pikeperch. *Fishes*, *4*(1), 7. https://doi.org/10.3390/fishes4010007

Petricorena, Z. C. (2014). *Chemical Composition of Fish and Fishery Products*. In Handbook of Food Chemistry (pp. 1–28). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-41609-5_12-1

Pfauserová, N., Slavík, O., Horký, P., Kolářová, J., & Randák, T. (2019). Migration of Non-Native Predator Asp (*Leuciscus aspius*) from a Reservoir Poses a Potential Threat to Native Species in Tributaries. *Water*, *11*(6), 1306. https://doi.org/10.3390/w11061306

Rock, K. D., Bhoothapuri, S., Lassiter, E., Segedie, L., & Belcher, S. M. (2025). Variability of Mercury Concentrations Across Species, Brand, and Tissue Type in Processed Commercial Seafood Products. *Toxics*, *13*(6), 426. https://doi.org/10.3390/toxics13060426

Santos, G. S., Ribeiro, F., Pereira, E., Silva, A. F., Almeida, P. R., Ribeiro, D., & Quintella, B. R. (2025). Behaviour of the Apex Predator European Catfish (Silurus glanis) on a Recently Invaded Reservoir. *Ecology of Freshwater Fish*, *34*(1), e12817. https://doi.org/10.1111/eff.12817

Simeanu, C., Măgdici, E., Păsărin, B., Avarvarei, B.-V., & Simeanu, D. (2022). Quantitative and Qualitative Assessment of European Catfish (*Silurus glanis*) Flesh. *Agriculture*, *12*(12), 2144. https://doi.org/10.3390/agriculture12122144

Tolkou, A. K., Toubanaki, D. K., & Kyzas, G. Z. (2023). Detection of Arsenic, Chromium, Cadmium, Lead, and Mercury in Fish: Effects on the Sustainable and Healthy Development of Aquatic Life and Human Consumers. *Sustainability*, *15*(23), 16242. https://doi.org/10.3390/su152316242

Wang, Z., Liu, X., Liu, T., Wang, W., & Liu, J. (2024). Towards the sustainable development of water security: A new copula-based risk assessment system. *Ecological Indicators*, *166*, 112489. https://doi.org/10.1016/j.ecolind.2024.112489

Wannas, A., & Mohammed, S. (2025). The role of environmental stress in fish health: A review. *GSC Biological and Pharmaceutical Sciences*, *32*, 017–027. https://doi.org/10.30574/gscbps.2025.32.2.0304

Warret Rodrigues, C., Armstrong, D., Wang, F., & Roth, J. D. (2023). Tissue composition and storage duration affect the usefulness of generic wet-to-dry mass conversion factors in toxicology studies. *Environmental Research*, *236*, 116727. https://doi.org/10.1016/j.envres.2023.116727

Xia, B., Zhang, J., Li, C., Wu, S., Huang, L., Qin, D., Hao, Q., & Gao, L. (2025). Texture, Nutrition, and Flavor of Different Freshwater Fish Muscles: Comparative Study and Molecular Docking. *Foods*, *14*(13), 2258. https://doi.org/10.3390/foods14132258

Zhang, Z., Liu, L., Xie, C., Li, D., Xu, J., Zhang, M., & Zhang, M. (2014). Lipid Contents, Fatty Acid Profiles and Nutritional Quality of Nine Wild Caught Freshwater Fish Species of the Yangtze Basin, China. *Journal of Food and Nutrition Research*, *2*, 388–394. https://doi.org/10.12691/jfnr-2-7-10

Zillioux, E. (2015). Mercury in Fish: History, Sources, Pathways, Effects, and Indicator Usage. *Environmental Indicators*, *Environmental Indicators, RH Armon&O Hänninen, eds.DOI 10.1007/978-94-017-9499-2_42, Springer, New York.* https://doi.org/10.1007/978-94-017-9499-2_42

Zlati, M. L., Antohi, V.-M., Ionescu, R.-V., Iticescu, C., & Georgescu, L. P. (2024). Quantyfing the impact of the water security index on socio-economic development in EU27. *Socio-Economic Planning Sciences*, *93*, 101912. https://doi.org/10.1016/j.seps.2024.101912