Ecological Questions 37(2026)3 http://dx.doi.org/10.12775/EQ.2026.044

Microplastics in the water column and stomach contents of European perch (*Perca fluviatilis*) in a temperate lowland dam reservoir: a case study from the lower Vistula River

Dominika Parda, Tomasz Kakareko

Department of Ecology and Biogeography, Faculty of Biological and Veterinary Sciences, Nicolaus Copernicus University, Lwowska 1, 87-100 Toruń, Poland

Corresponding author e-mail: domiparda@wp.pl

Received: 25 May 2026 / Accepted: 31 August 2026

Abstract. Microplastics are of environmental concern because they are ubiquitous, persistent, and readily ingested by aquatic organisms. This study investigated the occurrence and characteristics of microplastics in the water column and in stomachs of juvenile European perch (*Perca fluviatilis*) in the Włocławek Reservoir, a large dam reservoir in Central Europe. Samples were collected in June 2024 from the nearshore zone in the central part of the reservoir. Water samples were filtered through 11 μm filters, and the retained material was digested with 30% hydrogen peroxide to remove organic matter. The samples were then re-filtered and examined under a stereomicroscope. Fish digestive tracts were dissected and analysed stereomicroscopically. For each identified microplastic particle, shape (fibres, ovals, flakes), colour, number, and size range were recorded. Ivlev's electivity index was used to assess selective ingestion of microplastics by fish. Microplastics were detected in reservoir water (188.7 particles per litre), in 25% (13 of 52) of the examined perch, and in the procedural blank (distilled water processed in the same way as reservoir water), where 24 particles per litre were found. Among fish containing microplastics, the mean number of particles per stomach was 2.08. Fibres dominated in the water column and were mostly blue, whereas only fibres were found in biological samples, where red fibres predominated. The results indicate a substantial microplastic contamination of the Włocławek Reservoir and demonstrate the presence of microplastics in the fish. However, the observed selectivity of microplastic uptake by fish from the water column remains unclear. The predominance of red fibres in stomach contents may indicate selective ingestion and/or differential retention of fibres in the digestive tract.

Keywords: freshwater pollution, plastic debris, dam reservoir, microplastic identification, microplastic ingestion, pelagic fish

1. Introduction

Microplastics (MPs), defined as plastic particles ranging in size from 1 μm to 5 mm (Winiarska et al. 2024), pose a significant threat to the environment, affecting both living organisms and the functioning of entire ecosystems (Özgenç et al. 2024). Due to their relatively small size and low density, they are easily transported by water and wind (Ryan 2015) and can be mistakenly ingested by organisms as food and incorporated into food webs

(Lusher 2015). Plastics are mainly composed of polymers, most of which are organic and highly resistant to biodegradation, which makes plastic particles a long-lasting source of environmental contamination (Ryan 2015, Verla et al. 2019). Research indicates their ability to accumulate persistent organic pollutants and heavy metals found in the environment, which are hazardous to potential consumers (Verla et al. 2019). Microplastics most commonly take the form of fibres, ovals, although particles of other shapes are also found, including ellipses, triangles, rods, and asymmetrical structures that are difficult to identify (Liu et al. 2023). The shape of microplastics in the environment depends mainly on the original form of the material and the environmental conditions, which directly influence degradation processes (Yang et al. 2022b). However, MPs in the environment are characterised by great diversity not only in terms of shape: particles also differ in size, colour, chemical composition, and origin (Galgani et al. 2015, Quinn et al. 2016). Microplastic pollution is widespread in inland water ecosystems, and its concentrations sometimes exceed those observed in the seas, a phenomenon closely linked to human activity (Wu et al. 2018, Ritambhara et al. 2025). Rivers flowing through urban areas carry significant amounts of plastic waste, originating from domestic and industrial wastewater, material washed off streets by rain, litter left on the banks of rivers and lakes, and direct losses from boats and other floating objects (Kay et al. 2018, Wagner et al. 2019, Wong et al. 2020, Ritambhara et al. 2025). Reservoirs are particularly vulnerable to microplastic contamination; due to their hydrological characteristics and physical barriers in the form of water-retaining structures, they can act as sites for the accumulation of pollutants, including microplastic particles (Zhang et al. 2015, Nocoń et al. 2020, Gao et al. 2025). This phenomenon results, among other things, from restricted flow and intensified sedimentation of bottom sediments. Suspended matter, including the waste it contains, settles on the bottom of the reservoir as a result of this sedimentation; however, due to resuspension, it may re-enter the water column, constituting a secondary source of pollution.

Microplastics affect not only water quality in water bodies, but also the organisms living in them. Their presence has been recorded in fish, birds, crustaceans, and mussels, among others (Verla et al. 2019, Ritambhara et al. 2025). They pose a threat to animals because of their potential ingestion, whether intentional or accidental, via the food chain. Intentional consumption of plastic particles is likely linked to their colour, foraging strategy, and the age of individuals (Teuten et al. 2007, Kuhn et al. 2015). Many predators inhabiting aquatic environments rely on sight when hunting, which creates the possibility of ingesting plastic fragments of specific colours and shapes that are mistaken for their intended prey

(Ivar do Sul et al. 2018). Research suggests that ingested microplastics may accumulate in the digestive tracts of animals and thus lead to functional disorders (Qiao et al. 2019), as well as exert toxic effects (Verla et al. 2019, Mao et al. 2022). Furthermore, digestion may cause microplastics to break down into even smaller particles, known as nanoplastics, which are capable of penetrating the intestinal wall and accumulating in other tissues of the body, resulting in functional abnormalities (Kahane-Rapport et al. 2022).

The study was conducted in the Włocławek Reservoir, the largest dam reservoir in Poland by surface area (Tutro et al. 2023) and the only reservoir on the lower Vistula. Because it is located on a large lowland river with an extensive catchment, the reservoir may accumulate sediment from a substantial part of the country. It is also characterised by high water dynamics and resuspension of bottom sediments (Gierszewski 2018), which may favour the presence of secondary pollutants in the water column.

European perch (*Perca fluviatilis* Linnaeus, 1758) was selected as a model species because it inhabits the water column and relies largely on visual cues during foraging (Ning et al. 2025). It is one of the most abundant fish species in European inland waters, and is common in dam reservoirs (Kubečka 1993, Hladík et al. 2008), including the Włocławek Reservoir, where it is relatively abundant in the littoral zone (Kakareko & Pawlikowska 2009, Błażejewski et al. 2022). These characteristics make the species a suitable model, particularly its juvenile, plankton-feeding individuals that penetrate the water column of reservoirs, for assessing microplastic ingestion by fish.

This study aimed to determine whether microplastics occur in the water column of the Włocławek Reservoir on the lower Vistula and in the stomachs of juvenile perch. We hypothesised that microplastic concentrations in the reservoir would be high compared with other inland water bodies in Poland and worldwide, and that microplastics would be detectable in perch fry. We further expected fibrous particles to dominate both in the water column and in stomach contents because their elongated shape increases resistance to sinking and may prolong their residence time in suspension. Finally, because the particles are small, we hypothesized that particle colour might have a limited influence on their ingestion by perch, however, this assumption should be treated with caution.

2. Materials and methods

2.1. Study area

The Vistula River is 1,047 km long and has a basin area of nearly 200,000 km² (Yang et al. 2022a). The Włocławek Reservoir was created between 1962 and 1970 on the lower Vistula (author's note: location of the dam - 52°39'25.1"N 19°08'01.9"E) in central Poland. It covers 70 km² (volume: 376 mln m^3) and extends for 55 km. The reservoir has an average width of 2 km and depth of 5.5 m (maximum 13 m), respectively (Kaczmarek et al. 2015, Yang et al. 2022a). Samples were collected near the left bank, in the floodplain zone of the central reservoir, close to the Nicolaus Copernicus University (NCU) field station in Dobiegniewo (52°37'03.5"N 19°19'39.5"E). Sampling was conducted in the littoral zone, between the shoreline and a macrophyte stands composed mainly of yellow water lily (*Nuphar lutea* (L.) Sm., 1809), located approximately 10 m offshore, at a depth of 0.5–1.2 m, over a sandy–silty bottom.

2.2. Sample collection and preservation

Sampling was conducted on 21 June 2024. Three litres of surface water were collected in three 1-litre containers that had been thoroughly rinsed with reservoir water before use to minimise contamination from particles adhering to the container walls. Fifty-two juvenile perch were then caught using a beach seine net with bag (length 10 m, bag height 2.5 m, wing height 1 m, mesh size 2/5 mm). The age of the fish was not determined, but their small body size (approx. 3-4 cm) suggests that they were first-year individuals (age 0+), because perch in Polish inland waters typically increase in body length by at least 5-6 cm during this period (Terlecki 2000). Fish were euthanised with an overdose of MS-222 and preserved in 70% ethanol (Lusher et al. 2017). Water samples and ethanol-preserved fish were placed in 1-litre containers previously rinsed with reservoir water. The material was transported to the NCU laboratory, where the water samples were frozen (temperature -18°C) and the preserved fish were refrigerated.

2.3. Preparation of environmental samples and control sample

Environmental water samples were analysed for microplastics following the methods described by Prata et al. (2019). After thawing, samples were filtered with a vacuum pump (KNF Neuberger D-79112 Freiburg, type N022 AN.18, Germany) equipped with 11 µm filters (Cytiva Whatman Grade 589/3). Microplastics were then separated by density: the retained suspension was transferred to 50 ml glass beakers, flooded with saturated sodium chloride solution, stirred for 10 s with a glass rod, and left for 12 h. The mixture was subsequently digested with 30% hydrogen peroxide (H_2O_2) for 24 h to remove organic matter. The purified samples were filtered again through 11 μm filters; only the upper water layer was decanted, assuming prior separation of the microplastics. The retained material was examined under a binocular microscope (Motic SMZ-168) at 7.5-50× magnification and assessed qualitatively and quantitatively for MPs. Particles were selected when they met the criteria of Shaw Institute (2019), namely: (1) did not split into smaller pieces under pressure from the needle; (2) did not contain any discernible organic structures; (3) were of uniform thickness across their entire surface; (4) were of a uniform colour. The identified microplastics were classified into categories based on shape (ovals, fibres, and flakes) and colour. Both the shape and colour of the particles were determined by visual assessment. Ovals were defined as compact, non-fibrous particles with a roughly rounded morphology; fibres as elongated, thread-like particles; and flakes as irregularly shaped particles. The size range of the identified microplastic particles was estimated by randomly measuring the largest and smallest particles under a binocular microscope, with an accuracy of 0.5 mm.

In order to assess potential contamination introduced during sample processing, a procedural blank was prepared using distilled water. The distilled water was filtered using the same vacuum pump and filtration materials as those used for the environmental samples and was processed under identical laboratory conditions. This allowed to estimate the background level of microplastic contamination associated with the laboratory environment, equipment, containers, and handling procedures. The results of the procedural blank were used as a reference for interpreting the microplastic particles detected in the environmental samples.

2.4. Processing of biological samples and assessment of perch selectivity in microplastic uptake

In the laboratory, fish were removed from the preservative solution and rinsed with distilled water. Body length and total length were measured to the nearest 1 mm with a ruler, and body weight was measured to the nearest 0.1 g with a balance (RADWAG WPT 3/6, Radom, Poland). Mean values and ranges were as follows: body length, 33 mm (23-44 mm); total length, 40 mm (28-53 mm); body weight, 0.6 g (0.1-1.3 g). To minimise environmental contamination, samples were prepared under the cleanest possible conditions, synthetic materials were avoided, and the work surface was regularly wiped with 70% ethanol. The digestive tract of each specimen was dissected, the stomach was opened, and the contents were gently scraped from the stomach walls with a dissecting needle. Stomach contents were placed on a microscope slide with 2-3 drops of distilled water and examined under a binocular microscope (Bresser Science ETD-101, Rhede, Germany) at 7-45× magnification. Microplastics were identified using the same criteria as for the water samples.

To assess the dietary selectivity of the studied *P. fluviatilis* specimens in relation to the microplastics ingested, Ivlev's electivity index was used (Lechowicz 1982):

$$E_i = \frac{r_i - p_i}{r_i + p_i}$$

where:

ri - the percentage share of a given component in the diet, i.e. among the microplastics identified in the digestive contents

pi - the percentage share of that component in the environment, i.e. among all microplastic particles identified in the water column samples.

The results obtained were interpreted as follows:

- when $E_i > 0$ – the component is selected
- when $E_i < 0$ – the component is avoided.

3. Results

3.1. Microplastics in the water column of the Włocławek Reservoir and in the control sample

Three types of microplastic were identified in samples taken from the water column: ovals, fibres and irregular shapes, subsequently referred to as flakes (Fig. 1). Fibres had the highest concentration, 139.3 particles L^{-1} (73.9% of all particles), followed by grains at 31.7 particles L^{-1} (16.8%) and flakes at 17.7 particles L^{-1} (9.4%). The total microplastic concentration in the analysed material was 188.7 particles L^{-1} (Table 1). Colour composition differed among forms: grains were mainly orange (33.7%) and transparent (29.5%); threads were predominantly blue (50.2%), with lower proportions of black (20.8%) and red (15.1%); and flakes were mostly red (37.7%) or black (32.1%) (Fig. 2). In the control sample, 24 microplastic particles in the form of fibres were found in 1 litre of distilled water, in the following colours: black (10), blue (5), grey (5), and orange (4 particles).

3.2. Microplastics in the digestive tracts of perch and their feeding selectivity

Microplastic particles were observed in 13 of the 52 fish examined (25%), and a total of 27 particles were found in their stomachs. Fibres were the only microplastic form identified in the stomach contents. The colour composition of ingested plastic fibres was 32% red, 24.04% black, 15.38% transparent, 10.58% blue, 8.65% pink, 5.77% grey, and 2.88% green (Fig. 3). Among individuals containing microplastics, red fibres were the most frequent (38.5% of stomachs), followed by black fibres (30.8%). Blue, green, and transparent flakes each occurred in 15.4% of these samples, whereas green and white fibres occurred in 7.7% each. Ivlev's electivity index indicated that blue fibres were the only microplastic type avoided by fish; all other fibre colours were selected (Table 2).

4. Discussion

The results confirmed the hypothesis that microplastics occur both in the water column of the Włocławek Reservoir and in the digestive tracts of juvenile perch.

The microplastic concentration in reservoir-water samples was 188.7 particles L^{-1}. However, the procedural blank indicates that approximately 12% of the identified particles may have originated from the surrounding environment, and contamination during sampling or processing cannot be excluded. Even after accounting for this potential background contamination, the observed concentration remains substantially higher than values reported for the Vistula Lagoon and the Gulf of Gdańsk (1.39 and 1.24 particles L^{-1}, respectively; Winczek et al. 2025) and for three Vistula sites near Warsaw (1.6-2.55 particles L^{-1}; Sekudewicz et al. 2021). It is also high compared with other European watercourses, including the Danube in Austria (0.00032 particles L^{-1}; Scholz-Lechner et al. 2014) and the Seine in France (approximately 0.03 particles L^{-1}; Dris et al. 2015). Nava et al. (2023), analysing 38 lakes and reservoirs located in 23 countries, identified a total of 9425 plastic particles, with a mean concentration of 0.00182 ± 0.00037 particles L^{-1}. The highest concentration, only 0.0115 particles L^{-1}, was recorded in Lake Lugano. However, the differences between these results and those obtained in our study may be partly attributable to differences in sampling and analytical methods, particularly in mesh or filter pore size, as we used 11 µm filters, whereas Nava et al. (2023) used 250 µm nets. Comparable or higher concentrations have been reported from the urban rivers of Chengdu, China (5-10.5 particles L^{-1}; Chen et al. 2022), the lowland River Nida, a tributary of the upper Vistula (245 particles L^{-1}; Bhat & Janaszek 2024), and the Saigon River in Vietnam (mean 172 ± 519 particles L^{-1}; Lahens et al. 2018). These comparisons support the hypothesis that the Włocławek Reservoir, as a dam reservoir on large lowland river, can accumulate substantial quantities of microplastic particles and may reach concentrations comparable to those of highly polluted river systems described in the literature. The findings of Nava et al. (2023) also indicate that reservoirs characterized by a large catchment area and high levels of anthropogenic influence are particularly vulnerable to plastic pollution, which is consistent with the characteristics of the Włocławek Reservoir.

As expected, fibrous particles predominated in the samples. Their persistence in the water column may be promoted by intense resuspension, a characteristic feature of the Włocławek Reservoir, especially in shallow floodplain areas (Gierszewski 2011) such as the sampling site. Fibre morphology is also relevant: the elongated shape of fibres likely makes them sink more slowly than ovals or flakes. Laboratory studies by Waldschläger and Schüttrumpf (2019) showed that, among different microplastic forms, fibres have the lowest settling velocities (e.g. 0.39 cm s^{-1} for polyamide fibres, compared with 18.4 cm s^{-1} for large PVC ovals). According to these authors, fibres adopt a stable horizontal orientation in water, and their diameter strongly affects their settling rate. Relative to grains and asymmetrical particles, fibres are also more easily slowed by turbulence and lateral water movement, which may extend their residence time in the water column. Guo et al. (2021) found that fibres were the dominant form in water-column samples from 43 reservoirs worldwide (65% of all identified forms), and in the study of Nava et al. (2023), fibres accounted for nearly half the identified particles (49.5%). Similarly, Winczek et al. (2025) reported fibres as 73% and 82% of all particles at two sites in northern Poland, and Sekudewicz et al. (2021) found that fibres constituted 97% of particles in Vistula water samples. The dominance of fibres in the Włocławek Reservoir may therefore reflect both their environmental prevalence and their physical tendency to remain suspended.

Microplastics were also present in the stomachs of perch, consistent with the second hypothesis. Nevertheless, the frequency of occurrence of microplastics in perch from the Włocławek Reservoir was lower than that reported by Kuśmierek and Popiołek (2020) for the Widawa River reservoir in south-western Poland. Those authors detected plastic particles in more than 50% of digestive tracts of gudgeon (*Gobio gobio*) and roach (*Rutilus rutilus*), whereas in the present study only 25% of perch contained microplastics. The number of fibres per contaminated fish was similar, however: 2.08 particles per perch in the present study compared with 2.13 particles per gudgeon and roach in Kuśmierek and Popiołek (2020). The lower frequency of occurrence of microplastics in perch may indicate that this species is less susceptible to their accidental ingestion. The feeding ecology of juvenile perch may help explain this pattern. In field observations and laboratory experiments, Peterka and Matěna (2009) found that perch selected primarily mobile prey, and their selectivity depended more on the visibility of prey movement than on prey evasiveness. They were also effective predators of copepods (Copepoda), which they preferred even when copepods became less abundant in the food mixture, indicating a strong response to dynamic movement stimuli. In the present study, a preliminary analysis of perch diet showed dominance, by estimated volume proportion (% of field of view), of chironomid larvae (Chironomidae), copepods, and cladocerans (Cladocera), with substantial contributions from ostracods (Ostracoda) and gammarids (Gammaridae). This predominance of mobile organisms supports the importance of prey movement in the foraging strategy of juvenile perch. Because microplastic particles do not move like live prey, their attractiveness to perch is probably reduced, which may explain the low frequency of accidental ingestion despite their high concentration in the water column.The microplastics identified in perch stomachs were consistent with those reported by Pozo et al. (2019) for fish from the Bío Bío region of central Chile: in both studies, all particles were thread-like and predominantly red. Red particles also dominated in fish collected from the Gulf of Thailand and the Andaman Sea (Klangnurak & Chunniyom 2020). In contrast, Piskuła et al. (2023; 2025) reported a predominance of blue fibres, although red fibres were also present. Fish have been shown to selectively ingest microplastic particles of specific colours, which may be mistaken for food (Santos et al. 2016). The red colour and elongated form of the fibres detected here may visually resemble chironomid larvae, which were frequent in the stomach contents of the examined perch, suggesting possible mistaken ingestion. This hypothesis requires further qualitative analyses of environmental microplastics considered together with fish feeding ecology. The red fibres observed in perch stomachs were 1.5-5 mm long, which overlaps with reported sizes of early Chironomidae larval stages: 1.16-2.79 mm in stage I and 2.9-7.0 mm in stage II (Montaño-Campaz et al. 2022). Żbikowski (2006) reported high densities of pelophilic macrofauna, including chironomid larvae, in the Włocławek Reservoir: 6,000 individuals m^{-2} in the former riverbed channel and 7,500 individuals/m^2 in the floodplain. Żbikowski (2000) also noted that pelophilic chironomid larvae dominate in some reservoir zones. Resuspension of bottom sediments may therefore introduce both chironomid larvae and microplastic fibres into the water column, increasing the chance that perch fry mistake fibres for chironomids.

Perch may also acquire fibres through mechanisms other than active prey selection. Because of their elongated shape, fibres may be more likely than other microplastic forms to become lodged in the gills and/or stomach after accidental intake during feeding. In addition, digestive processes may alter the colour of ingested fibres, so colour-based selectivity should be interpreted cautiously. Recording the colours of microplastic particles does not allow their sources to be determined but may help identify preferences related to the ingestion of plastic waste by fish (Nava et al. 2023). In the present study, the colours of particles in the water samples were diverse, with blue (39%), black (19%), red (17%) and transparent (10%) being the most common. In the study by Nava et al. (2023), the most common colour was black (30%), followed by transparent (24%), blue (18%), and white (13%). Similarly, Winczek et al. (2025) reported that black, blue, and transparent were the predominant colours in samples from the Vistula Lagoon. In both studies, relatively few red particles were identified. These differences in colour composition may be partly related by the phenomenon of crypsis, i.e. the camouflage of particles with colours such as blue, white, and transparent in the aquatic environment, whereas red microplastics are more visible and therefore more likely to be detected by aquatic organisms (Martí et al. 2020). In the present study, blue microplastics were the most abundant in the water samples. However, they were the only colour avoided by perch, whereas red was the most frequently selected. This pattern may indicate that colour-dependent differences in the detectability of microplastic particles could influence their ingestion by fish. Differences in the presence of individual fibre colours in perch stomachs and in water-column samples may also have resulted from the use of H_2O_2 to digest biological material (Karami et al. 2015), whereas the former were not subjected to chemical digestion. However, this conclusion should be approached with caution, as the authors reported changes in PET fragments during digestion at 50°C. In the present study, the chemical composition of the identified microplastics is unknown, and digestion was performed at room temperature. Further research is needed to distinguish between active mistaken ingestion, passive intake, and possible post-ingestion changes in particle colour.

References

Bhat M. A. & Janaszek A., 2024, Delving into river health: unveiling microplastic intrusion and heavy metal contamination in freshwater, *Discover Environment* 2: 61.

Błażejewski M., Król J., Kakareko T., Mierzejewska K. & Hliwa P., 2022, Daily and seasonal dynamics of littoral zone fish communities in the lowland Włocławek Reservoir (central Poland), with a special emphasis on alien invasive gobies, *Journal of Limnology* 81: 2059.

Chen J., Deng Y., Chen Y., Peng X., Qin H., Wang T. & Zhao C., 2022, Distribution Patterns of Microplastics Pollution in Urban Fresh Waters: A Case Study of Rivers in Chengdu, China, *International Journal of Environmental Research and Public Health* 19: 8972.

Dris R., Gasprei J., Rocher V., Saad M., Renault N. & Tassin B., 2015. Microplastic contamination in an urban area: a case study in Greater Paris. Environmental Chemistry 12. 592-599.

Galgani F., Hanke G. & Maes T., 2015, Global Distribution, Composition and Abundance of Marine Litter, [in:] *Marine Anthropogenic Litter*, M. Bergmann, M. Klages, L. Gutow (eds), Springer, Cham: 29-56.

Gao W., Zhang P., Wang H., Yang X. & An C., 2025, From water to sediment: A meta-analysis of microplastic distribution and the impact of dams in reservoir ecosystems, *Eco-Environment & Health* 4: 4.

Gierszewski P., 2011, Impact of the Włocławek Reservoir on the conditions for the transport of suspended load, *Geomorphologia Slovaca et Bohemica* 11(1): 28-41.

Gierszewski P., 2018, Hydromorfologiczne uwarunkowania funkcjonowania geoekosystemu Zbiornika Włocławskiego [Hydromorphological conditions of the functioning of the Włocławek Reservoir geosystem]. Wydawnictwo Instytutu Geografii i Przestrzennego Zagospodarowania PAN.

Guo Z., Boeing W. J., Xu Y., Borgomeo E., Mason S. A. & Zhu Y.-G., 2021, Global meta-analysis of microplastic contamination in reservoirs with a novel framework, *Water Research* 207: 117828.

Hladík M., Adámek Z., Jurajda P. & Valová Z., 2008, Effects of the construction of a reservoir on the fish assemblage in an inflow river, *Czech Journal of Animal Science* 53: 537-547.

Ivar do Sul J. A., Tagg A. S. & Labrenz M., 2018, Exploring the common denominator between microplastics and microbiology, *Scientometrics* 117: 2145-2157.

Kaczmarek H., Tyszkowski S. & Banach M., 2015, Landslide development at the shores of a dam reservoir (Włocławek, Poland), based on 40 years of research, *Environmental Earth Sciences* 74: 4247-4259.

Kahane-Rapport S. R., Czapanskiy M. F., Fahlbusch J. A., Friedlaender A. S., Calambokidis J., Hazen E. L., Goldbogen J. A. & Savoca M. S., 2022, Field measurements reveal exposure risk to microplastic ingestion by filter-feeding megafauna, *Nature Communications* 13: 6327.

Kakareko T. & Pawlikowska K., 2009, Relative abundance of Ponto-Caspian gobiids in seine net catches in the flooded area of the Włocławek Reservoir (the Vistula River, Poland) 2-3 years after the first appearance, *Limnological Papers* 4: 69-77.

Karami A., Golieskardi A., Choo C. K., Romano N., Ho Y. B. & Salamatinia B., 2017, A high-performance protocol for extraction of microplastics in fish, *Sci Total Environ*. 1:578:485-494.

Kay P., Hiscoe R., Knez E. & Grembecka M., 2024, Food and human safety: The impact of microplastics, *Critical Reviews in Food Science and Nutrition* 64(11): 3502-3521.

Klangnurak W. & Chunniyom S., 2020, Screening for microplastics in marine fish of Thailand: the accumulation of microplastics in the gastrointestinal tract of different foraging preferences, *Environmental Science and Pollution Research* 27: 27161-27168.

Kubečka J., 1993, Succession of fish communities in reservoirs of Central and Eastern Europe, [in:] *Comparative Reservoir Limnology and Water Quality Management*: 153-168.

Kuhn S., Bravo Rebolledo E. L. & van Franeker J. A., 2015, Deleterious Effects of Litter on Marine Life, [in:] *Marine Anthropogenic Litter*, M. Bergmann, M. Klages, L. Gutow (eds), Springer, Cham: 75-116.

Kuśmierek N. & Popiołek M., 2020, Microplastics in freshwater fish from Central European lowland river (Widawa R., SW Poland), *Environmental Science and Pollution Research* 27: 11438-11442.

Lahens L., Strady E., Kieu-Le T. C., Dris R., Boukerma K., Rinnert E., Gasperi J. & Tassin B., 2018, Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity, *Environmental Pollution* 236: 661-671.

Lechowicz M. J., 1982, The sampling characteristics of electivity indices, *Oecologia* 52: 22-30.

Liu F., Rasmussen L. A., Klemmensen N. D. R., Zhao G., Nielsen R., Vianello A., Rist S. & Vollertsen J., 2023, Shapes of Hyperspectral Imaged Microplastics, *Environmental Science & Technology* 57: 12431-12441.

Lusher A., 2015, Microplastics in the Marine Environment: Distribution, Interaction and Effects, [in:] *Marine Anthropogenic Litter*, M. Bergmann, M. Klages, L. Gutow (eds), Springer, Cham: 245-307.

Lusher A. L., Welden N. A., Sobral P. & Cole M., 2017, Sampling, isolating and identifying microplastics ingested by fish and invertebrates, *Analytical Methods*, 9 (9): 1346-1360.

Martí E., Martin C., Galli M., Echevarría F., Duarte C. M. & Cózar A., 2020, The colors of the ocean plastics, *Environ. Sci. Technol.* 54, 6594-6601.

Mao X., Xu Y., Cheng Z., Yang Y., Guan Z., Jiang L. & Tang K., 2022, The impact of microplastic pollution on ecological environment: a review, *Frontiers in Bioscience – Landmark* 27(2): 46.

Montaño-Campaz M. L., G.-Dias L. & Toro-Restrepo B., 2022, *Chironomus columbiensis* (Diptera: Chironomidae) as test organism for aquatic bioassays: Mass rearing and biological traits, *Anais da Academia Brasileira de Ciências* 94: e2022XXXX.

Nava V., Chandra S., Aherne J., Alfonso M. B., Antão-Geraldes A. M., Attermeyer K., ... & Leoni B. (2023). Plastic debris in lakes and reservoirs. Nature, 619(7969), 317–322.

Ning N., Barlow C., Baumgartner L. J., Bretzel J. B., Doyle K. E., Duffy D., Price A. & Vu A. V., 2025, A global review of the biology and ecology of the European perch, *Reviews in Fish Biology and Fisheries* 35: 587-618.

Nocoń W., Moraczewska-Majkut K. & Wiśniowska E., 2020, Microplastic upstream and downstream dam-reservoirs, *Desalination and Water Treatment* 199: 263-272.

Ozgenc E., Keles E. & Yildiz T., 2024, Assessment of biomarker-based ecotoxic effects in combating microplastic pollution – A review, *Global NEST Journal* 26(1): 1-24.

Peterka J. & Matěna J., 2009, Differences in feeding selectivity and efficiency between young-of-the-year European perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*) – field observations and laboratory experiments on the importance of prey movement apparency vs. evasiveness, *Biologia* 64: 786-794.

Piskuła P. & Astel A. M., 2023, Microplastics in Commercial Fishes and By-Catch from Selected FAO Major Fishing Areas of the Southern Baltic Sea, *Animals* 13: 458.

Piskuła P., Astel A. & Pawlik M., 2025, Microplastics in seawater and fish acquired from the corresponding fishing zones of the Baltic Sea, *Marine Pollution Bulletin* 211: 117485.

Pozo K., Gomez V., Torres M., Vera L., Nunez D., Oyarzun P., Mendoza G., Clarke B., Fossi M. C., Baini M., Pribylova P. & Klanova J., 2019, Presence and characterization of microplastics in fish of commercial importance from the Biobío region in central Chile, *Marine Pollution Bulletin* 140: 315-319.

Prata J. C., da Costa J. P., Duarte A. C. & Rocha-Santos T., 2019, Methods for sampling and detection of microplastics in water and sediment: A critical review, *TrAC Trends in Analytical Chemistry* 110: 150-159.

Qiao R., Sheng C., Liu Y., Zhang Y., Ren H. & Lemos B., 2019, Microplastics induce intestinal inflammation, oxidative stress and disorders of metabolome and microbiome in zebrafish, *Science of the Total Environment* 662: 246-253.

Quinn B., Murphy F. & Ewins C., 2016, Validation of density separation for the rapid recovery of microplastics from sediment, *Analytical Methods* 8: 14-19.

Ritambhara, Prajna, Parida P., Behera B. & Das B., 2025, Microplastics as Emerging Contaminants: Challenges in Inland Aquatic Food Web, *Water* 17: 201.

Ryan P. G., 2015, A Brief History of Marine Litter Research, [in:] *Marine Anthropogenic Litter*, M. Bergmann, M. Klages, L. Gutow (eds), Springer, Cham: 1-25.

Santos R. G., Andredes R., Fardim L. M. & Martins A. S., 2016, Marine debris ingestion and Thayer's law – the importance of plastic color, *Environmental Pollution* 214, 585-588.

Sekudewicz I., Dąbrowska A. M. & Syczewski M. D., 2021, Microplastic pollution in surface water and sediments in the urban section of the Vistula River (Poland), *Science of the Total Environment* 762: 143111.

Scholz-Lechner A., Keckeis H., Lumesberger-Loisl F., Zens B., Krusch R., Tritthart M., Glas M. & Schludermann E., 2014, The Danube so colourful: A potpourri of plastic litter outnumbers fish larvae in Europe's second largest river, *Environmental Pollution* 188.

Shaw Institute, 2019, *Guide to Microplastics Identification: A Comprehensive Methods Guide for Microplastics Identification and Quantification in the Laboratory*, Shaw Institute.

Terlecki J., 2000, Okoń *Perca fluviatilis*, [in:] *Ryby słodkowodne Polski*, M. Brylińska (red.), Wydawnictwo Naukowe PWN, Warszawa: 455-461.

Teuten E. L., Rowland S. J., Galloway T. S. & Thompson R. C., 2007, Potential for plastics to transport hydrophobic contaminants, *Environmental Science & Technology* 41: 7759-7764.

Tutro M., Hachaj P. S., Szlapa M., Gierszewski P., Habel M., Juśkiewicz W. & Mączka N., 2023, Implementation of the AdH hydrodynamic model on the Włocławek Reservoir. *Geographia Polonica* 95: 371-386.

Verla A. W., Enyoh C. E. & Verla E. N., 2019, Microplastic–toxic chemical interaction: a review study on quantified levels, mechanism and implication, *SN Applied Sciences* 1: 1400.

Wagner S., Klöckner P., Stier B., Römer M., Seiwert B., Reemtsma T. & Schmidt C., 2019, Relationship between discharge and river plastic concentrations in a rural and an urban catchment, *Environmental Science & Technology* 53(17): 10082-10091.

Waldschläger K. & Schüttrumpf H., 2019, Effects of particle properties on the settling and rising velocities of microplastics in freshwater under laboratory conditions, *Environmental Science & Technology* 53: 1958-1966.

Winczek M., Romanowski J., Radwańska A., Kurzydłowski D. & Kaliszewicz A., 2025, Microplastic pollution of the Vistula Lagoon and Baltic Sea: A comparison study, *Environmental Pollution and Management* 2: 133-141.

Winiarska E., Jutel M. & Zemelka-Wiącek M., 2024, The potential impact of nano- and microplastics on human health: Understanding human health risks, *Environmental Research*.

Wong J. K. H., Lee K. K., Tang K. H. D. & Yap P. S., 2020, Microplastics in the freshwater and terrestrial environments: Prevalence, fates, impacts and sustainable solutions, *Science of the Total Environment* 719: 137512.

Wu C., Zhang K. & Xiong X., 2018, Microplastic Pollution in Inland Waters Focusing on Asia.

Yang R., Wu S., Wu X., Ptak M., Li X., Sojka M., Graf R., Dai J. & Zhu S., 2022a, Quantifying the impacts of climate variation, damming, and flow regulation on river thermal dynamics: a case study of the Włocławek Reservoir in the Vistula River, Poland, *Environmental Sciences Europe* 34: 3.

Yang X., Man Y. B., Wong M. H., Owen R. B. & Chow K. L., 2022b, Environmental health impacts of microplastics exposure on structural organization levels in the human body, *Science of the Total Environment* 825: 154025.

Zhang K., Gong W., Lv J., Xiong X. & Wu C., 2015, Accumulation of floating microplastics behind the Three Gorges Dam, *Environmental Pollution* 204: 117-123.

Żbikowski J., 2000, Macrozoobenthos of the Vistula in the section from Wyszogród to Toruń, *AUNC, Limnological Papers* 21: 75-84.

Żbikowski J., 2006, Struktura populacji pelofilnego makrozoobentosu Zbiornika Włocławskiego, [in:] *Hydrobiologia Toruńska: Monografia dorobku prac doktorskich Zakładu Hydrobiologii w latach 1978–2003*, Wydawnictwo Uniwersytetu Mikołaja Kopernika, Toruń: 92-98.

Table 1. Concentration and percentage composition of microplastic particles by shape and colour in the water column of the Włocławek Reservoir

	Concentration (n / l)			**% n**		
Colour	Ovals	Fibres	Flakes	Ovals	Fibres	Flakes
Yellow	4.7	0.3	3.0	14.7	0.2	17.0
Red	3.7	21.0	6.7	11.6	15.1	37.7
Black	0.3	29.0	5.7	1.1	20.8	32.1
Transparent	9.3	9.3	0.0	29.5	6.7	0.0
Orange	10.7	0.3	0.0	33.7	0.2	0.0
Green	0.7	1.3	0.0	2.1	1.0	0.0
Blue	2.3	70.0	1.0	7.4	50.2	5.7
Grey	0.0	5.0	1.3	0.0	3.6	7.5
Brown	0.0	1.0	0.0	0.0	0.7	0.0
Purple	0.0	2.0	0.0	0.0	1.4	0.0
Total	31.7	139.3	17.7			

Table 2. Selectivity of perch for microplastic fibres of different colours, calculated using Ivlev's electivity index (E_i)

Colour	**Fish (%)**	**Water (%)**	E_i	**Interpretation**

black	24.04	15.37	0.22	selected
blue	10.58	37.1	-0.56	avoided
green	2.88	0.71	0.60	selected
pink	8.65	0.0	1.0	selected
white	5.77	0.0	1.0	selected
red	32.69	11.13	0.49	selected
transparent	15.38	4.95	0.51	selected

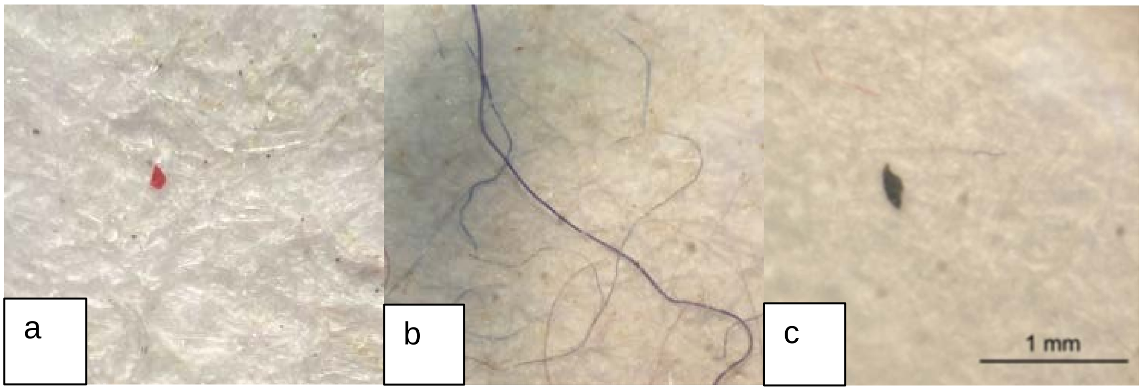

Figure 1. Examples of microplastic particles identified in water samples from the Włocławek Reservoir: (a) ovals, (b) fibres, and (c) flakes.

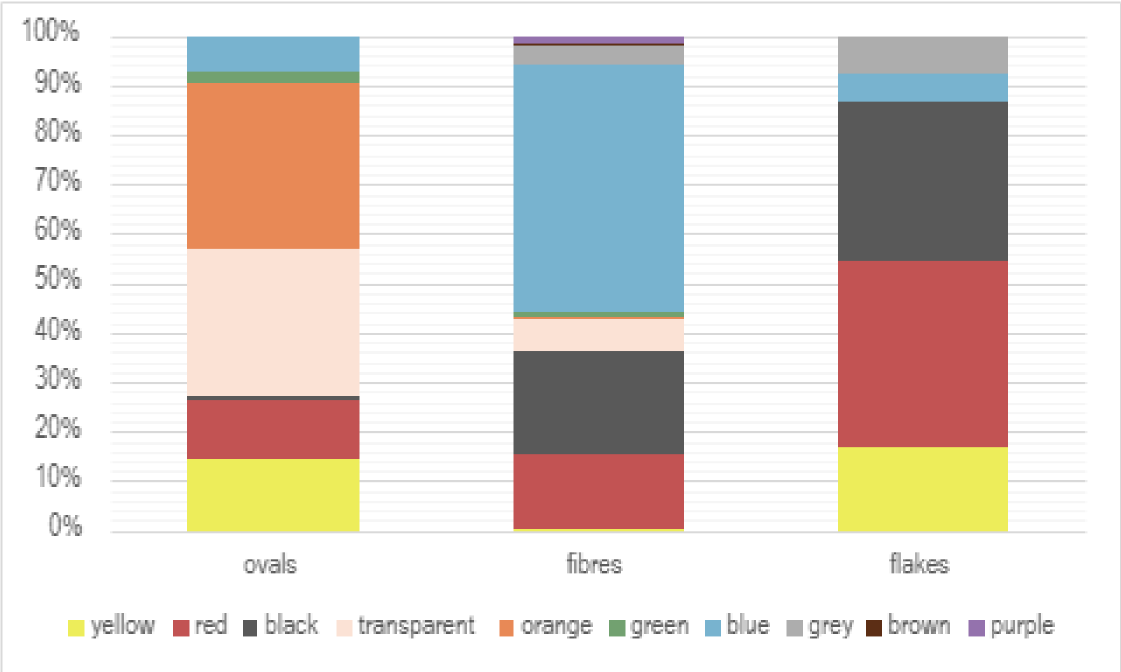

Figure 2. Colour composition of microplastic particles within each shape category identified in the water column of the Włocławek Reservoir

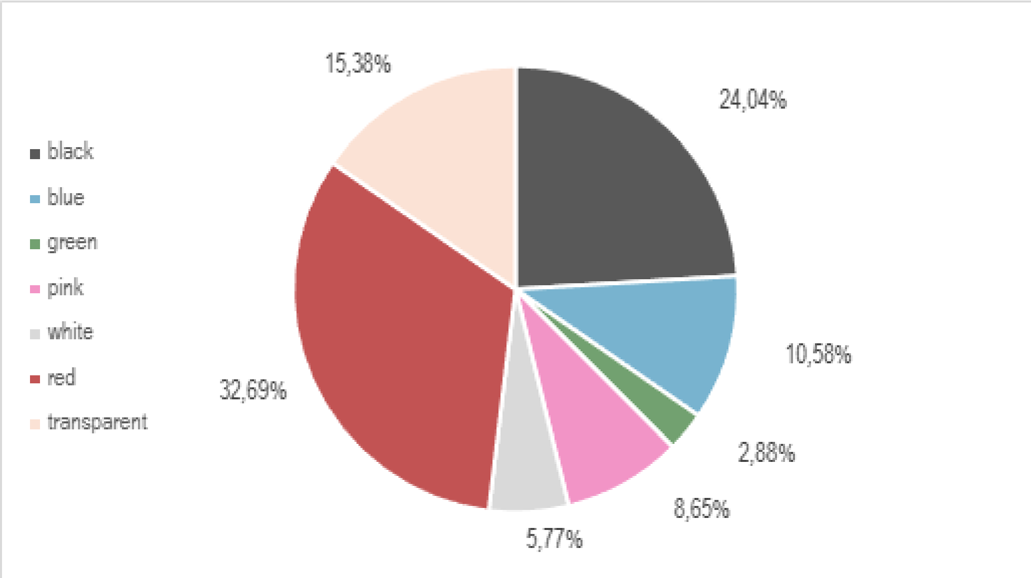

Figure 3. Colour composition of microplastic fibres found in the stomachs of perch specimens from the Włocławek Reservoir