LONG-TERM MONITORING OF FISH ABUNDANCE DYNAMICS IN THE MIDDLE STRETCH OF THE MESHA RIVER (TATARSTAN)

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ABSTRACT

The study area is located in the middle reaches of the Mesha River on the territory of the Republic of Tatarstan and is characterized by strong temporal variability in environmental factors and fish populations. The impact of environmental factors on fish species and communities was analyzed with regression and ordination methods. The dominant species were bleak, dace, chub, and roach, which together accounted for 60.7% of the total fish species. Over 15 years of research, there have been significant decreasing trends in overall density, species richness and density of individual fish species. The main factors determining the size of both the fish population and individual species were fishing effort and temperature during different months. The index of long-term similarity of fish populations was only 7.5%.

ZUSAMMENFASSUNG: Langzeitüberwachung der Fischfauna im mittleren Abschnitt des Mesha-Flusses (Tatarstan).

Es wurde der mittlere Abschnitt des Mesha-Flusses (Tatarstan) untersucht, der durch starke zeitliche Variabilität der Umweltfaktoren und der Fischpopulationen gekennzeichnet ist. Die Auswirkungen der Umweltfaktoren auf die Fischgemeinschaft wurde mithilfe von Regressions- und Ordinationsmethoden analysiert. Die dominanten Fischarten waren Ukelei, Hasel, Döbel und Plötze, die zusammen 60,7% des Gesamtbestands ausmachten. Während der 15 Jahre der Langzeitüberwachung sank der Gesamtbestand der Fische deutlich, ebenso der des Artenreichtum die Bestände der einzelnen Fischarten. Die Hauptfaktoren hierfür waren jeweils die Fischerei und die Temperatur in verschiedenen Monaten. Der Index der langzeitigen Ähnlichkeit der Fischpopulationen lag lediglich bei 7,5%.

REZUMAT: Monitorizarea pe termen lung a dinamicii abundenței peștilor în partea de mijloc a râului Mesha (Tatarstan).

Zona de studiu este situată în cursul mijlociu al râului Mesha pe teritoriul Republicii Tatarstan și se caracterizează printr-o variabilitate temporală puternică a factorilor de mediu și a populațiilor de pești. Impactul factorilor de mediu asupra speciilor și comunităților de pești a fost analizat prin metode de regresie și ordonare. Speciile dominante au fost: obletele, cleanul mic, cleanul comun și babușca. Împreună, ponderea lor a reprezentat 60,7% din inventarul total al speciilor peștilor. În peste 15 ani de cercetare, există o tendință semnificativă de scădere a densității globale, a bogăției speciilor și a densității speciilor individuale de pești. Principalii factori care determină dimensiunea atât a populației de pești, cât și a speciilor individuale au fost: efortul de pescuit și temperatura în diferite luni. Indicele similitudinii pe termen lung a populațiilor de pești a fost de numai 7,5%.

INTRODUCTION

The abundance, occurrence, distribution, and composition of individual groups of living organisms can change significantly over historical processes in aquatic ecosystems (Matthews, 1998). Temporal differences in environmental factors can have a strong impact on aquatic ecosystems (Birzaks, 2012). Changes in environmental conditions, in turn, also significantly affect species compositions (Bănăduc et al., 2024; Cianfaglione and Bănăduc, 2024; Askeyev et al., 2017) and fish population dynamics (Jeppesen et al., 2012). In modern times, ecosystems of small rivers and the organisms living in them, especially fish, which are the final ecological link and important commercial animals, are of significant interest for studying long-term population dynamics. Inland fisheries, in particular, are of general and important socio-economical interest (Lynch et al., 2016; Suuronen and Bartley, 2014). Small rivers, on the one hand, serve as a reserve for the conservation of rare and endangered species (Askeyev et al., 2021, 2017, 2015a), as well as a place for spawning grounds and the formation of biological diversity and possible corridors for invasion of alien species. On the other hand, they are subject to a whole range of stressors, from various forms of anthropogenic activities of both local and regional nature to climate warming, which can have a detrimental effect on certain groups of fish (Bănăduc et al., 2021; Buisson et al., 2013; Comte and Grenouillet, 2013) and lead to improved conditions for the existence of individual species (Daufresne and Boet, 2007). At the same time, the main focus in studying the long-term dynamics of fish abundance has been on large rivers (Bennett and Kozak, 2016; Solomon et al., 2016), reservoirs (Loures and Pompeu, 2018; Říha et al., 2009; Kuznetsov, 2005; Pivnička and Švátora, 2001; Sály at al. 2011), and lakes (Jeppesen et al., 2012), while there are practically no studies on small rivers from a temporal perspective (Askeyev et al., 2015b).

Our current study of fish populations along the Mesha River is a continuation of work by Askeyev et al. (2015b), which showed that even over a relatively short period, significant changes can occur in fish assemblages. The selected section is located 35 km east of Kazan, the capital of the Republic of Tatarstan, and is currently subject to increasing anthropogenic and fishing pressure. The climate in the Republic of Tatarstan continues to change toward warming (Askeyev et al., 2022, 2020). For example, 2020 was the warmest year in the history of meteorological observations in the Republic of Tatarstan and caused serious nonlinear reactions in phenology (Askeyev et al., 2022). Therefore, it is very important to understand the changes occurring in species composition and population dynamics, both at the population level and for individual fish species.

In this work, we set several goals: 1) To study the species composition and structure of the fish population in the Mesha River site over 15 years; 2) to assess patterns and trends in long-term dynamics of both the total number of fish and individual species; 3) to identify environmental factors influencing changes in the long-term dynamics of fish populations; and 4) to analyze the long-term variability of fish populations.

MATERIAL AND METHODS

Study area

The studied area is located in the lower part of the middle stretch of the Mesha River in the extreme east of the European continent, within the territory of the Russian Federation, on the border of two regions of the Republic of Tatarstan – Pestrechinsky and Laishevsky, near three settlements – Karpovka, Bima, and Togashevo, which are 35 km east of Kazan, the capital of the Republic of Tatarstan (Fig. 1). The elevation is 54 m above sea level (Minnikhanov, 2005). The current speed at the site is 0.1 m/s in the reaches and up to 0.5 m/s in the rifts. The depth of the river in the study area averages 1-1.2 m. The average width of the river in the study area is 25 m. The trees and bush cover 20-25% the left bank and 65-70% the right bank. The right bank section of the floodplain is significantly swampy. The composition of woody coastal vegetation is dominated by various species willows (*Salix* sp.). A few trees are also present on the site, including elms (*Ulmus* sp.) and black alder (*Alnus glutinosa)* ((L.) Gaertn., 1791). The bottom of the river section under study is primarily covered with fine-grained sand and, in places, with soft muds.

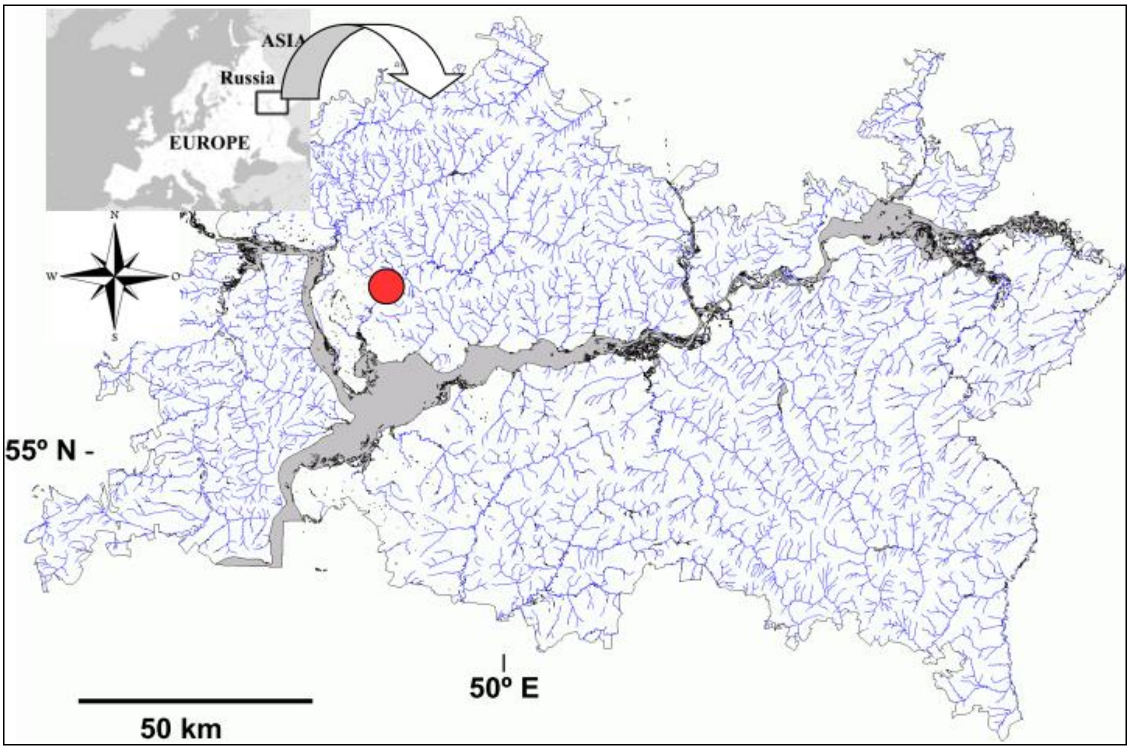

Figure 1: Map of the Republic of Tatarstan.
The red circle shows the study area on Mesha River. (inset shows location within Europe).

Fish assemblage data

Ichthyological material was collected annually for 15 years (2009-2023) from May to August, twice a month, on a 400 m long section of the Mesha River. Fish were captured using a large-mesh fry drag net 5-15 m long (with a mesh in the wings of 5 x 5 mm, in the codend 3 x 3 mm) and fishing nets (net diameter 40-50 cm, with mesh 4 x 4 mm). This set of fishing gear was selected due to significant overgrowth of the banks, the presence of rifts and the rapid change of fish biotopes. Local and short-term changes in the hydrological regime, increasing the river flow speed and water level, also influenced the choice of fishing gear (Matthews, 1998). The abundance of fish species in the area was assessed by the number of caught specimens during the fishing period, which lasted 2-3 hours in all cases. The total abundance of each species captured in a given year was then expressed as density (number of individuals per hectare). For each individual year, species richness and the Shannon index of biological diversity (H') were calculated. For each individual fish species, the mean density ± SE and the percentage from total density in the fish population were also calculated for all 15 years of study. To assess the relative abundance of a species in catches, the following classification was used: rare species – 0.01-0.50%, small – 0.51-4.99%, common – 5.0-9.9%, numerous (dominant) – 10.0-49.9%, very numerous (superdominant) – >50% of the total number in catches. Ecotopic characteristics based on abundance data are provided to describe fish population structure (Noble and Cowx, 2002). The following eight environmental factors were selected as the main variables influencing the long-term population dynamics in the selected section of the Mesha River: water temperatures for individual months (April, May, June, July, and August), the average temperature of the summer period (from April to August), spring flood levels (in m), and fishing effort, which was estimated by the number of fishermen (fishermen km^{-2}) each week throughout the entire study period. Meteorological parameters (water temperatures) were obtained from the Laishevo station.

Data analysis

Changes in densities of each species, total density, Shannon Index values, ecotopic groups of fish, and species richness over time were assessed using linear regression. The nature and strength of relationships between total density, species richness, ecotopic groups of fish and the eight environmental parameters were examined using a generalized linear model with a normal error structure. The best-fit model was selected based on the Akaike Information Criterion (AIC), with the model having the lowest AIC value considered the best fit.

We used Principal Component Analysis (PCA) to determine the similarity of long-term fish population dynamics across species. Redundancy Analysis (RDA) was then employed to study the factors influencing fish species density. In this analysis, we studied the effect of the following environmental variables on long-term abundance of fish species. Only species comprising more than 0.5% of the fish population were included in the analysis. Thus, the data matrix consisted of eight environmental factors and 16 fish species. In prior work (Askeyev et al., 2021), the occurrence of predatory fish was found to depend strongly on the species richness and abundance at the sites. Therefore, for three rare predatory fish species (asp, pikeperch, and pike), as well as three rare species (volga nase, amur bitterling, and spirlin) listed in the Red Book of the region (2016), we analyzed their populations using a generalized linear model with a normal error structure with the inclusion of total abundance and species richness of species as additional factors. The best-fit model was selected based on Akaike Information Criterion (AIC), where the model with the lowest AIC value considered the best fit. Long-term variability in the fish population was analyzed using similarity indices, calculated according to the Jaccard and Koch formulas, using the principle of minimum quantitative indicators (Chernov, 1971). Calculation and visualization were performed using PAST version 4.12 (Hammer et al., 2001), MINITAB 19 and XLSTAT 2021.

RESULTS

General information about fish populations for 15 years

In total, thirty species of fish were caught during the study period (species Latin and common names of fish are given in table 1). Of these, three species – common spirlin, Volga nase and Amur bitterling – are listed in Red Book of Republic of Tatarstan (2016). Species richness varied across the years, ranging from 16 to 25 species (with an average of 19.2 ± 0.68). The density of fish in the study area ranged from 360 to 3,640 individuals per hectare (with an average of 1,749.1 ± 276.9). The Shannon index for the site ranged from 1.818 to 2.598 (with an average of 2.13 ± 0.06). The dominant species in the studied area were bleak, common dace, chub, and roach (Fig. 2), with together accounted for 60.7% of the total number of fish in the Mesha River section over the entire 15 years of the study. Common species in terms of densities included silver bream and white-finned gudgeon. Fish species with smaller densities included perch, common bream, common gudgeon, common ruffe, gibel, ziege, rudd, ide, Volga nase, spirlin, stone loach, and blue bream. All other fish species were classified as rare.

Table 1: A – common and Latin species names of fish, as well as abbreviations in figure 2 and 3; B – mean density ± SE; C – proportion of the species in % of the total density of fish caught.

A	B	C
Northern pike – *Esox lucius* (Linnaeus, 1758)	8.8 ± 2.4	0.50
Common bream – *Abramis brama* (Linnaeus, 1758) – Abbr	78.1 ± 27.7	4.50
White-eye bream – *Ballerus sapa* (Pallas, 1814)	1.3 ± 0.7	0.10
Blue bream – *Ballerus ballerus* (Linnaeus, 1758) – Bala	8.9 ± 4.4	0.51
Silver bream – *Blicca bjoerkna* (Linnaeus, 1758) – Blbj	156.8 ± 44.7	8.90
Crucian carp – *Carassius carassius* (Linnaeus, 1758)	0.8 ± 0.4	0.05
Gibel – *Carassius gibelio* (Bloch, 1782) – Carg	40.0 ± 25.5	2.31
Gudgeon – *Gobio gobio* (Linnaeus, 1758) – Gogo	45.3 ± 12.3	2.59
White-finned gudgeon – *Romanogobio albipinnatus* (Lukasch, 1933) – Roma	93.6 ± 39.8	5.35
Spirlin – *Alburnoides bipunctatus* (Bloch, 1782)	11.5 ± 2.9	0.66
Common bleak – *Alburnus alburnus* (Linnaeus, 1758) – Alal	430.9 ± 79.3	24.6
Sunbleak – *Leucaspius delineatus* (Heckel, 1843)	7.7 ± 3.7	0.44
Asp – *Leuciscus aspius* (Linnaeus, 1758)	7.7 ± 2.2	0.44
Volga nase – *Chondrostoma variabile (volgensis*) (Jakovlev, 1870)	12.5 ± 8.1	0.71
Ide – *Leuciscus idus* (Linnaeus, 1758) – Leid	18.1 ± 7.1	1.04
Common dace – *Leuciscus leuciscus* (Linnaeus, 1758) – Lele	238.1 ± 67.8	13.6
Roach – *Rutilus rutilus* (Linnaeus, 1758) – Ruru	181.9 ± 38.8	10.4
Rudd – *Scardinius erythrophthalmus* (Linnaeus, 1758) – Scer	18.7 ± 7.2	1.05
Common chub – *Squalius cephalus* (Linnaeus, 1758) – Sqce	212.0 ± 46.6	12.1
Ziege – *Pelecus cultratus* (Linnaeus, 1758) – Pecu	24.5 ± 20.7	1.43
Tench – *Tinca tinca* (Linnaeus, 1758)	0.3 ± 0.3	0.02
Amur bitterling – *Rhodeus amarus* (Bloch, 1782)	2.1 ± 1.5	0.12
Eurasian carp – *Cyprinus carpio* (Linnaeus, 1758)	2.1 ± 1.9	0.12
Siberian spined loach – *Cobitis melanoleuca* (Nichols, 1925)	6.4 ± 1.2	0.36
Spined loach – *Cobitis taenia* (Linnaeus, 1758)	5.9 ± 2.5	0.33
Stone loach – *Barbatula barbatula* (Linnaeus, 1758) – Baba	10.1 ± 3.8	0.57
European perch – *Perca fluviatilis* (Linnaeus, 1758) – Pefl	78.4 ± 22.5	4.50
Ruffe – Gymnocephalus cernuus (Linnaeus, 1758) – Gyce	43.5 ± 23.0	2.50
Pikeperch – *Sander lucioperca* (Linnaeus, 1758)	4.0 ± 2.2	0.22
Amur sleeper – *Perccottus glenii* (Dybowski, 1877)	0.5 ± 0.5	0.03

Figure 2: Dominant fish species
(from top to bottom: common chub, roach, common dace)
on the Mesha River section.

Long-term dynamics of fish density

Significant changes in the density of eight fish species were observed over the 15-years period (Tab. 2). Six species – common bream, white-eye bream, silver bream, crucian carp, rudd and perch – showed a trend of a significant decrease in numbers (Tab. 2). While the most numerous species on the site, such as bleak, chub, and roach, also exhibited a strong downward trend, these trend were masked by annual fluctuations in their abundance. Overall, the total density of fish and species richness during the study period showed a significant downward trend. In contrast, two species of rare fish in the Republic of Tatarstan – spirlin and bitterling – displayed a significant increase in abundance.

Table 2: Changes in fish populations in 2009-2023. Regression coefficients (b ± SE) represent changes in fish density per year. Statistically significant changes are shown in bold.

Species	B ± SE	P
Northern pike	-0.01 ± 0.57	0.78
Common bream	**-16.2 ± 4.9**	**0.005**
White-eye bream	**-0.3 ± 0.12**	**0.01**
Blue bream	1.8 ± 0.94	0.07
Silver bream	**-18.1 ± 7.3**	**0.002**
Crucian carp	**-0.2 ± 0.09**	**0.05**
Gibel	-5.8 ± 3.9	0.34
Gudgeon	3.0 ± 2.43	0.31
White-finned gudgeon	-3.5 ± 9.49	0.71
Spirlin	**1.3 ± 0.59**	**0.04**
Common bleak	-21.9 ± 9.90	0.08
Sunbleak	-0.50 ± 0.27	0.61
Asp	-0.51 ± 0.52	0.39
Volga nase	2.28 ± 1.83	0.22
Ide	-1.30 ± 0.60	0.44
Common dace	20.61 ± 7.49	0.21
Roach	-15.80 ± 8.20	0.08
Rudd	**-4.01 ± 1.3**	**0.01**
Common chub	-20.31 ± 9.69	0.06
Ziege	-3.90 ± 2.91	0.44
Amur bitterling	**0.75 ± 0.29**	**0.02**
Eurasian carp	-0.44 ± 0.41	0.32
Siberian spined loach	0.02 ± 0.29	0.92
Spined loach	-0.33 ± 0.59	0.59
Stone loach	0.10 ± 0.92	0.92
European perch	**-9.92 ± 4.67**	**0.05**
Ruffe	-7.10 ± 5.17	0.19
Pikeperch	-0.80 ± 0.47	0.09
Species richness	**-0.31 ± 0.14**	**0.04**
Value of Shannon index	-0.01 ± 0.01	0.43
Total density	**-121.4 ± 57.35**	**0.05**

Interannual similarities and differences in long-term dynamics

The first two components of the PCA analysis explained 60.5% of the total variance in the long-term population dynamics of 16 fish species. The first axis, which explained 41.1% of the matrix variation, was significantly correlated with 12 fish species (Fig. 3). The second axis explained 19.4% of the variation and seven fish species were significantly associated with this axis. The arrangement of years (left to right) along the first axis clearly showed the change in fish abundance over time. On the left side we see years with small abundances, and on the right side we see years with large abundances for most of the studied fish species (Fig. 3). The second axis reflects the species-specific preferences in response to the environmental factors.

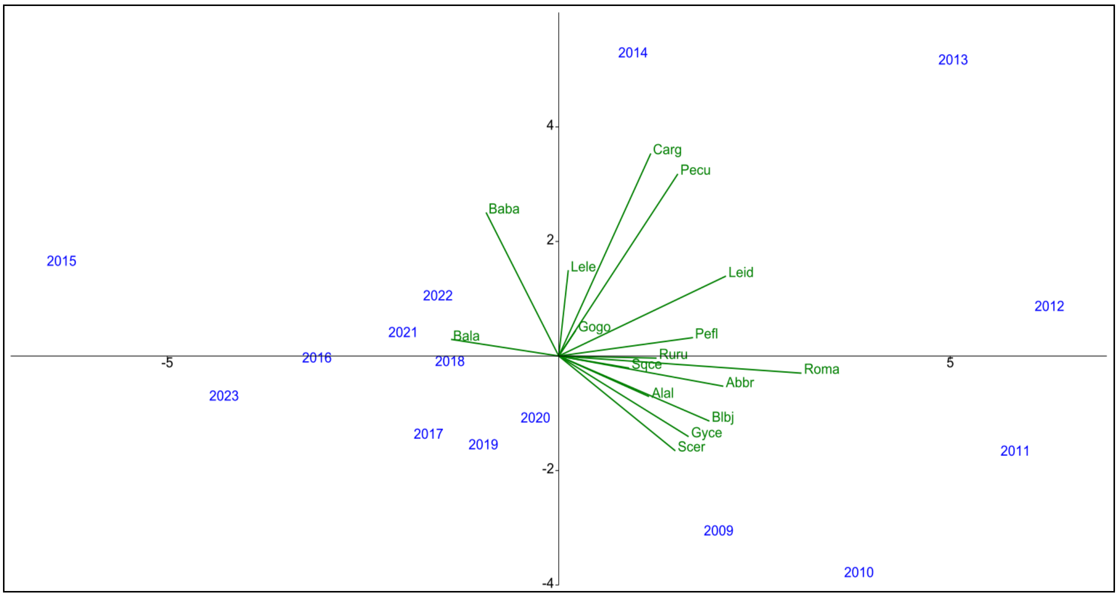

Figure 3: Biplots of Principal Component Analysis (PCA) a performed-on time series of 16 the fish species abundance in 2009-2023 years on Mesha River. Species presented as vectors and abbreviation (Tab. 1).

Compositions of fish species across environmental gradients

The first two axes of the RDA ordination explained 76.16% of the variation in the distance matrix. The first axis of ordination explained 46.83% of the variations in the researched fish assemblage's composition and was significantly related to the gradient of fishing effort and the month of July temperature ($p < 0.001$), with a lesser contribution from the overall summer (Fig. 4). The second axis explained 29.33% of the variations and was predominantly associated with spring months ' floods and May and June temperatures ($p < 0.05$).

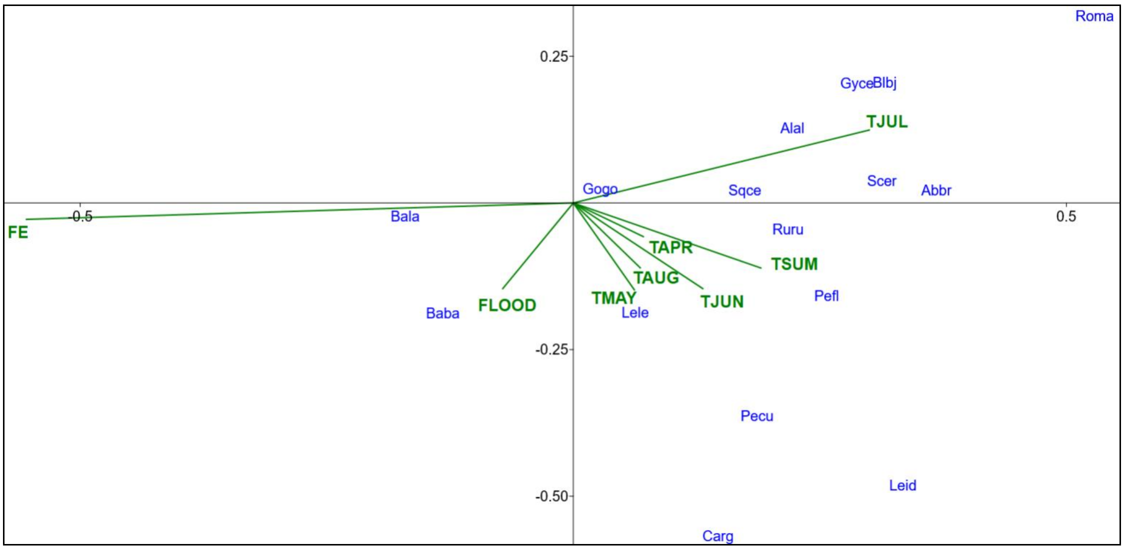

Figure 4: Biplot of first versus second axes of Redundancy Analysis (RDA), showing the relative influence on 16 fish species abundance in Mesha River of each variable. Variable represented as vectors and abbreviation: mean Summer (April-August) temperature (TSUM), temperature of April (TAPR), temperature of May (TMAY), temperature of June (TJUN), temperature of July (TJUL), temperature of August (TAUG), water flood in spring (FLOOD), fishing effort (FE). Species presented as abbreviation (Tab. 1).

In general, moving from right to left along the first axis shows a decrease in July and summer temperatures and an increase in fishing effort. The species that favored strong fishing effort was the blue bream. In contrast, whitefin gudgeon, perch, ruffe, rudd, roach, ide, bleak, silver bream, and common bream tended to avoid strong fishing effort. For bleak, ruffe, silver bream, and whitefin gudgeon, elevated July temperatures had a significant positive effect, and for roach and perch the temperature of the entire summer period had a positive effect (Fig. 4).

The second axis primarily reflected the influence of spring flood levels, as well as May and June temperatures (Fig. 4). Separate positions on this axis were identified for the stone loach, which favors years with high floods, whereas the whitefin gudgeon avoided years with high water levels in the spring. The dace showed preference for high floods and warmer May temperatures. Ziege, gibel and idefavored warmer water in both May and June.

Relationship between predatory and rare fish species and factors

Five out of ten factors significantly influenced the long-term dynamics of six rare species in the studied section (Tab. 3). Asp, Volga nase and bitterling, showed a significant positive association with temperature in May, indicating that higher temperatures corresponded to increased numbers of these species. Two species, pike and asp, were associated with fishing effort, total abundance, and species richness at the site, demonstrating that the number of pike and asp is greater in years with a higher total number of fish species. Conversely, spirlin had the opposite preference. The abundance of pikeperch also had a strong connection with human impact, indicating that the higher the human impact, the lower the abundance of this species. The abundance of bitterling, however, was higher in years with high human impact. Additionally, July temperatures significantly influenced the long-term dynamics of the asp population, with higher the temperatures leading to greater numbers of this species (Tab. 3).

Table 3: Coefficients and model summary for the relationship between abundance of six fish species and environmental variables. Environmental factors included in models are abbreviated as follows: Temperature of May (Tmay); Temperature of July (Tjul); Total density (Dens); Species richness (Spec); fishing effort (FE).

Species	Const	FE	Dens	Spec	Tmay	Tjul	AIC	p
Pike	–1.66	–	–	0.23	–	–	31.13	0.02
Asp	–6.28	–	–	0.31	0.25	0.21	45.41	0.001
Pikeperch	26.43	–0.8	0.2	–	–	–	49.83	0.01
Volga nase	–11.3	–	–	–	0.3	–	43.33	0.04
Spirlin	–4.1	–	–0.8	–	–	–	51.42	0.05
Bitterling	–6.13	1.7	–	–	0.21	–	43.08	0.005

Relationship between total abundance, species richness and environmental variables

Total abundance and species richness were strongly and significantly negatively associated with fishing effort. The greater the fishing effort on a river site, the lower the total abundance and species richness (Tab. 4).

Table 4: Coefficients for models summarizing the relationship between total abundance, total number of fish species and environmental factors. The environmental factors included in the models are abbreviated as: fishing effort (FE).

	Const	FE	AIC	p
Total abundance	9.8	–0.7	13.82	<0.001
Species richness	26.3	–1.9	45.41	0.008

Ecotopic groups of fish and their relationship with environmental factors

In the Mesha River section, three ecotopic guilds were identified: rheophiles, eurytopes, and limnophiles. Across most year of the study, except for four, the fish population was dominated by representatives of the eurytopic guild – together their share was 58.5 ± 4.7% (mean ± SE) of the total abundance. Rheophiles accounted for 39.3 ± 3.8% (mean ± SE), while limnophiles represented only 2.2 ± 0.7% (mean ± SE) and never exceeded 10% in any year. Despite the dominance of eurytopes in the population, their proportion significantly decreased over the years ($B \pm SE = –4.1 \pm 0.9$, $p < 0.001$), while the proportion of rheophiles significantly increases ($B \pm SE = 3.9 \pm 0.9$, $p = 0.005$).

Fishing effort had a significant impact on both groups (Tab. 5), though its influence was strictly opposite. In years with high fishing effort, the proportion of eurytopes decreased, while the proportion rheophiles increases. Another factor that greatly influences the abundance of rheophiles is floods. In years with high floods, the proportion of rheophiles is higher. The proportion of limnophiles was positively associated with May temperature. The higher the temperature in May, the higher the relative abundance of these group (Tab. 5).

Table 5: Coefficients for models summarizing the relationship between fish ecotopic groups and environmental variables. The environmental factors included in the models are abbreviated as: spring flood (Flood), Temperature of May (Tmay) and fishing effort (FE).

Ecotopic group	Const	FE	Flood	Tmay	AIC	p
Rheophiles	–17.9	8.9	8.6	–	130.12	0.01
Eurytopes	118.8	–9.7	–	–	139.21	0.009
Limnophiles	–8.1	–	–	3.5	124.91	0.04

Long-term similarity of fish populations

The index of long-term similarity in the fish population over the 15-year study was just 7.5%. Among the 30 species of fish recorded, only bream, silver bream, bleak, dace, chub, roach, common gudgeon, pike, and perch were recorded consistently during all 15 years of research.

DISCUSSION

Our study aims to address the gap in knowledge about the long-term dynamics of fish abundance in small rivers, highlighting strong processes of population fluctuations over a relatively short period due to climatic and anthropogenic factors. Many fish species are experiencing a strong negative impact, leading to decline in the total number of fish and individual species.

During the study period, a total of 30 species of fish were caught in the Mesha River section, representing 75% of the species richness of all small rivers in the Republic of Tatarstan (Askeyev et al., 2015a). The composition of dominant fish species, in terms of abundance, is atypical for small rivers of Tatarstan (Askeyev et al., 2015a). In particular, the shares of common gudgeon and stone loach are small and do not exceed 3%. Additionally, in a section of the Mesha River there is a complete absence of common minnow, which is the most numerous species of small rivers in the extreme eastern European subcontinent (Askeyev et al., 2017, 2015a) and Great Britain (Pretty et al., 2003). We attribute this absence to the low elevation of the location of the site and to the lack of stone substrates necessary for the species to reproduce. Comparing the species composition and dominant fish species abundance with other parts of the European continent, we see that they vary greatly in different river basins. So, it is interesting to note that similar species and numerical composition of fish to our data was obtained in the middle reaches of the Elbe River in the Czech Republic (Jurajda et al., 2010). The composition of dominant species was also similar. In particular, bleak, chub, and roach dominate in abundance. This contrasts from long-term data in the reservoir (Pivnička and Švátora, 2001), where only roach dominate in abundance. In the rivers of Hungary (Sály et al., 2011), on the one hand, there are high numbers of chub, roach, and silver crucian carp, similar to our findings. However, in the Hungarian rivers, there are numerous minnows and stone moroko (*Pseudorasbora parva* Temminck and Schlegel, 1846), which are absent in the section of the Mesha River. Conversly, Hungrary lacks dace, which is a dominant species in Mesha.

The species composition of dominant species in the section of the Mesha River differs significantly from small rivers in Latvia (Birzaks, 2012), where the dominant species are stone loach, common gudgeon, minnow, and brown trout (the latter two which are not found at all in the section of the Mesha River). Similarly, the composition of the dominant species in the Mesha River also differs from the rivers in Finland (Sutela et al., 2010), where the dominant species are bullhead and brown trout, which are both absent in our study area. Such differences between river basins indicate that to identify reliable trends in dynamics of the numbers of both individual species and fish populations, data must be collected from different parts of the species' range.

In general, the studied section of the Mesha River consistently exhibited higher numbers of fish species and Shannon Index values than in small rivers of the Republic of Tatarstan (Askeyev et al., 2015). The Shannon index in the Mesha River section in all years of the study was higher than that observed in different sections of the Elbe River (Jurajda et al., 2010), where it ranged from 1.49 to 1.71. The Shannon index was also lower than the Mesha at various sites in small rivers in Britain (Pretty et al., 2003), where it ranged from 1.61 to 1.82. The highest value of the Shannon Index was higher than the highest value in all small rivers in Latvia (Birzaks, 2012). The elevated value of species in the Mesha River section can be attributed to the mixing of fish from different guilds and the large number of microhabitats within a relatively short distance.

The PCA analysis showed synchronicity in population dynamics for the most numerous fish species, such as bleak, chub, roach, silver bream, bream, whitefin gudgeon, and perch. Based on these findings, we propose that in years when the density of silver breamis is high, the density of roach will be equally elevated. However, not all fish species experienced similar dynamics over the 15-year period. For example, blue bream exhibited the opposite trend in abundance compared to the above species, while dace (one of the most numerous fish species in the area), gibel, ziege, gudgeon, and stone loach held intermediate positions between these patterns.

A key question remains: what factors explain these changes in the many population dynamics. Redundancy analysis (RDA) can help address this question. Over the 15-years, multiple factors influenced the fish species in the area of the small Mesha River. The main factor influencing abundance of individual fish species was the fish effort on the site, which which had a negative impact, leading to a strong decrease populations. Human pressure could lead to a tenfold decline in abundance compared to that observed in the most productive year.

The prevalence of fishing effort over other factors has been described for lakes in Finland (Ranta et al., 1992), further supporting our thesis that excessive inland fishing (Post et al., 2008) can severely undermine the stocks of key species. This rasises serious concern, since it is shown (Daupagne et al., 2021) that the main measures to restore numbers are ineffective. In particular, stocking with non-native species can ultimately lead to an imbalance in the system (Hickley and Chare, 2004), and even stocking native species does not always provide a restoration effect or an increase in abundance (Argillier et al., 2002).

While some studies, such as Arlinghaus and Mehner (2005), highlight the selectivity of catching and reducing only species that are commercially valuable, our data suggests a reduction of, in addition to these species, less valuable and smaller-sized species. In this regard, we urge our colleagues to take a more careful and serious look at the issues of reducing even relatively insignificant species for fishing.

Contrary to fears that climate warming could lead to additional declines in fish population abundance (Buisson et al., 2013; Comte and Grenouillet, 2013), our results suggest that warming could actually contribute to an increase in the abundance of many fish species if not for the strong pressure of human activity on the site. Most fish species thrive in months with higher temperatures. These temperatures contribute to better survival of juveniles and an increase in food supply for adults. However, the importance of temperature for specific months varies for different fish species

We observed a significant decrease in abundance for perch, as well as three other less common predatory fish species. This decrease in abundance is directly associated with over-fishing, as well as a decrease in the overall abundance of species and a decrease in the number of non-predatory fish populations. The effect of a decrease in perch abundance in low abundance years has been shown in the Czech Republic (Pivnička and Švátora, 2001).

Interestingly, it was unexpected that less common species in Tatarstan, such as bitterling and spirlin, significantly increased in abundance. We believe this is related to a strong decline in the total abundance of other species of competitors and predators. Another rare species, the Volga nase, also saw an increase in numbers, but the main reason for its growth was elevated temperatures in May, coinciding with its breeding month.

The overall abundance and species richness show a significant decreasing trend, primarirly due to determining factors such as the strong fish effort. More intense floods and high river water levels in spring favor the rheophilic group of fish to spawn more efficiently, as well as the elimination of representatives of the eurytopic group due to high human pressure.

The low level of interannual similarity over the 15-year period points to strong fluctuations among the fish population, indicating that the fish are experiencing a range of stresses, which greatly influence the population dynamics of each species causing constant disruptions within fish species compositions. Such changes raise serious concern for the conservation of species diversity and rare and endangered species in this unique site of the small river, despite recent increases in abundance.

CONCLUSIONS

Unlike well-established monitoring schemes for long-term dynamics of the number of birds operating on different continents (Lehikoinen et al., 2016; Prince and Zuckerberg 2015), there are virtually no long-term monitoring schemes for fish. Our research demostates that even within the same region, the dynamics of different vertebrate groups can vary. In contrast to the number of birds in Tatarstan (Askeyev et al., 2023, 2020), which is rapidly growing in different groups, the density of fish is falling. Despite the increasing anthropogenic pressure, this section of the Mesha River is a spawning ground for many valuable commercial fish species and serves as a refugium for the conservation of three “Red Book” fish species in the Republic of Tatarstan. Thus, we see that in the extreme eastern European subcontinent, modern climate warming is having beneficial effects on different groups of vertebrates in different habitats, but for fish, this trend is masked by strong fish efforts. Notably, 2023 was the warmest year on record in the study area, emphasizing the need for careful monitoring of the state of aquatic ecosystems and the number of individual species of living.

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