DISTRIBUTION OF COMMON CHUB, COMMON DACE AND ROACH ACROSS ENVIRONMENTAL GRADIENTS ON THE EAST EDGE OF EUROPE

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ABSTRACT The probability of occurrence, optimums, niche breadth, and distribution of three fish species in 559 small rivers on the eastern edge of Europe were studied. Roach was the most abundant species, while common chub was the most frequent by occurrence. The probability of occurrence of common chub, common dace, and roach differs significantly between our studies in the extreme east of Europe and those in river basins in the west of the continent. Cohabitation of all three species was noted in 13.1% of rivers. The highest percentage (22.9%) of cohabited fish was observed for chub and dace. Elevation and river depth were the main environmental factors influencing the distribution of all the selected fish species. Our research on the eastern edge of Europe shows that fish niche widths can vary significantly between species for some environmental factors, while being similar for others.

ZUSAMMENFASSUNG: Verbreitung von Döbel, Hasel und Plötze über Umweltgradienten am östlichen Rand Europas.

Die Vorkommenswahrscheinlichkeit, die Optimums und die Nischenbreite sowie – verteilung von drei Fischarten wurden in 559 kleinen Flüssen im östlichen Randgebiet Europas untersucht. Plötze war die am häufigsten vorkommende Art; Döbel war die häufigste. Die Vorkommenswahrscheinlichkeit von Döbel, Hasel und Plötze unterscheidet sich in unseren Untersuchungen im äußersten Osten Europas und in Flussgebieten im Westen des Kontinents erheblich. Das Zusammenleben aller drei Arten wurde in 13,1% der Flüsse festgestellt. Der höchste Prozentsatz kombinierter Fische wurde für Döbel und Hasel beobachtet – 22,9. Höhenlage und Flusstiefe waren die wichtigsten Umweltfaktoren, die Verteilung aller ausgewählten Fischarten beeinflussten. Unsere Untersuchungen am östlichen Rand Europas zeigen, dass die Breite der Fischnischen bei manchen Umweltfaktoren zwischen den Arten erheblich variieren kann, bei anderen jedoch ähnlich ist.

REZUMAT: Distribuția cleanului, cleanului mic și a babuștei de-a lungul unor gradienți de mediu la marginea de est a Europei.

A fost studiată probabilitatea de apariție, optimul și lățimea nișei și distribuția a trei specii de pești în 559 de râuri mici din marginea Europei de Est. Babușca a fost cea mai abundentă specie; cleanul a fost cel mai comun în funcție de frecvență. Probabilitatea de apariție a cealnului, cleanului mic și a babuștei diferă semnificativ în studiul nostru în estul extrem al Europei și in bazinele hidrografice din vestul continentului. Coabitarea tuturor celor trei specii a fost observată pentru 13,1% din râuri. Cel mai mare procent (22,9%) de pești care conviețuiesc a fost observat la clean și cleanul mic. Altitudinea și adâncimea râurilor au fost principalii factori de mediu care au influențat distribuția tuturor speciilor de pești selectate. Cercetările noastre de la marginea de est a Europei arată că lățimea nișei peștilor poate varia semnificativ între specii pentru unii factori de mediu, în timp ce este similară pentru altele.

INTRODUCTION

Among vertebrates, the fish class is a large taxonomic group that form the final ecological link in water bodies (Matthews, 2012). Fishes have been objects of recreational fishing and important food sources for humans (Askeyev et al., 2023a; Wheeler and Jones, 1989). Inland fisheries are of general socio-economic interest (Suuronen and Bartley, 2014). Traditionally, the main fishing efforts in freshwater reservoirs have been concentrated in the deltas of large rivers, big lakes, and reservoirs. However, due to the destruction of habitats, pollution, eutrophication, climate warming, changes in the hydrological balance, overfishing, etc. (Bănăduc et al., 2024, 2022; Moss et al., 2011; Gregory, 2006; Allan et al., 2005) in these basins, there is a need to look for alternative fishing locations, including small rivers due to their abundance. Under the conditions of modern climate warming, these watercourses are a place of conservation of many rare species in the selected study region (Askeyev et al., 2023b, 2022, 2021, 2017) and can also serve as a base for catching some fish species.

In this study, our focus is on the small rivers of the extreme east of Europe, despite the fact that the most numerous fish species here are small-sized fish (Askeyev et al., 2022), and the abundance of predatory fish, with the exception of perch, is low (Askeyev et al., 2021b). Among the potential species we have focused on in this study are the following: common chub (*Squalius cephalus*, Linnaeus, 1758), common dace (*Leuciscus leuciscus*, Linnaeus, 1758), and roach (*Rutilus rutilus*, Linnaeus, 1758). These species are quite numerous, have a high reproductive potential, and are capable of reaching large sizes (for example, the maximum standard length of the caught chub reached 50 cm, and the weight was more than 1.5 kg). As long-term studies in the Republic of Tatarstan have recently shown (Askeyev et al., 2024), these species may be among the dominant species in some areas of small rivers, which makes them potential commercial targets in these waters. The study area represents an extremely wide range of diverse environmental conditions (Askeyev et al., 2017, 2015). For the rational use of these potentially resourceful species over time, it is important to understand their preferences for environmental conditions, optimal habitats, niche width, and morphological size.

The main goals of the study were: 1) to calculate the probability of occurrence of each species in small rivers in the extreme east of Europe and compare these values with similar data from other European river basins; 2) to identify the preferences of dace, chub and roach in relation to environmental factors; and 3) to identify the optimal habitats and widths of the ecological niche for these species in small rivers in the study area.

MATERIAL AND METHODS

Study area and fish assemblage data

The study area is located in the extreme east of Europe (eastern Ponto-Caspian region) (Fig. 1) and covers the territory of Tatarstan and the mountainous part of Bashkortostan. We focused on the fish assemblages of small rivers (up to 500 km in length) and excluded rivers strongly impacted by large reservoirs. Fish sampling was conducted at 559 locations. Fieldwork was carried out from May to October between 2012 and 2024 during reduced summer flows. We used three different lengths of nets, depending on the width of the river. The three seining net were 5-15 m in length, 1.2-1.5 m high, 5x5 mm mesh in the wings, 3x3 mm in bags. Dip nets had a diameter of 50-70 cm, with 4x4 mm mesh. River sites between 200 m (smaller rivers) and 400 m (larger rivers) were sampled. To determine the length of the site, we followed the recommendations for fish sampling by FAME CONSORTIUM (2004). Caught fish were placed in a plastic basin, identified, counted, and measured at the end of each session, after which ≥ 90% of the fish were returned to the water. Fish identification was carried out according to Makeeva et al. (2011) and Maitland and Linsell (2009).

The following six environmental variables were obtained for each site: elevation (altitude) above sea level (from 53.2 to 720 m, mean 234.8 m, standard deviation (SD) 182.9 m), mean width (from 0.5 to 55 m, mean 8.1 m, SD 15.5 m), mean depth (from 0.10 to 1.82 m, mean 0.63 m, SD 0.35 m), water velocity (from 0 to 1 m/s, mean 0.34 m/s, SD 0.16 m/s), tree/bush cover along banks (from 0 to 100%, mean 55.1%, SD 27.7%), and dominant bottom substrate (1 – mud, 2 – clay or peat, 3 – sand, 4 – gravel, 5 – small pebbles, 6 – large stones up to 150 mm, 7 – large stones 150-300 mm, 8 – boulders > 300 mm).

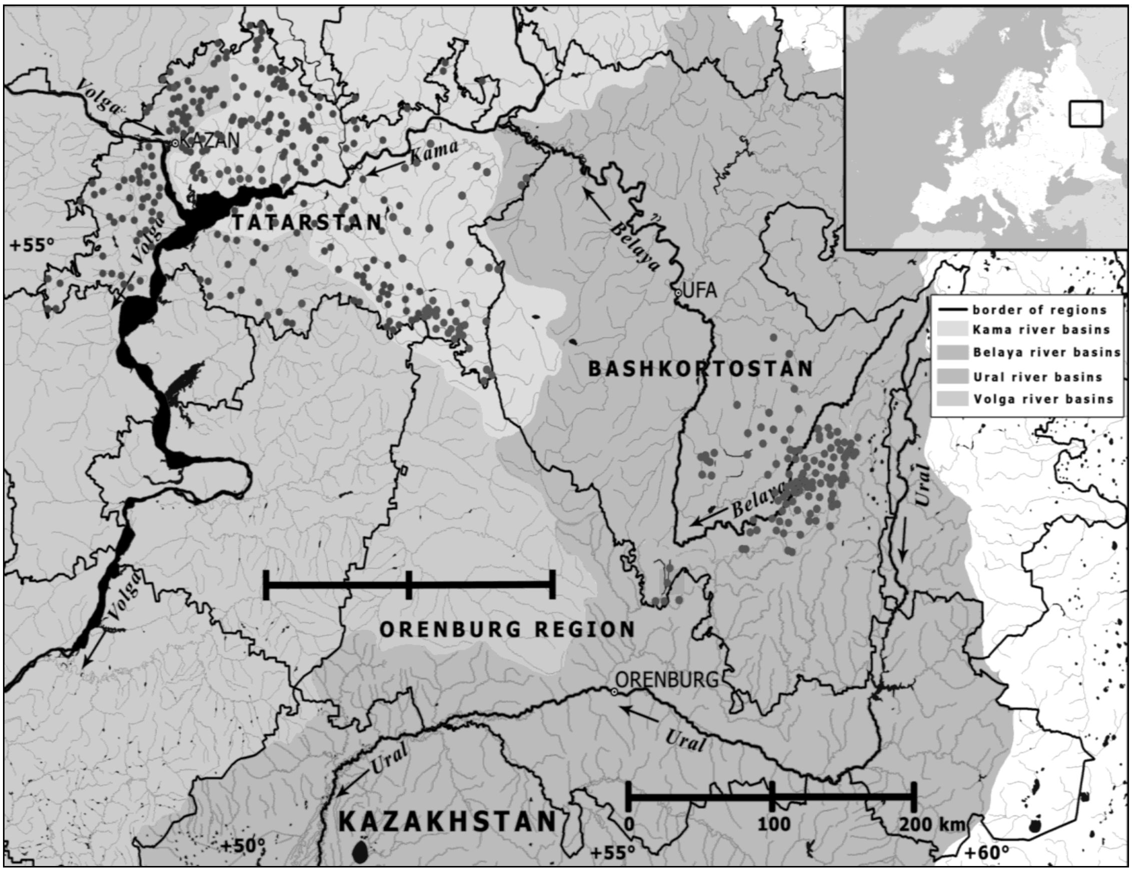

Figure 1: Distribution of the sampling sites
(inset shows location within Europe).

Data analysis

Relationship between fish species and environmental variables

For each studied fish species, the nature and strength of relationships with the six environmental parameters were examined using binary logistic regression, with the environmental variables as predictors. Only statistically significant variables were selected and retained in these regressions. In order to assess the accuracy of the final models, we used the area under the ROC curve (AUC), which indicates predictive performance expressed as an index ranging from 0.5 to 1. The accuracy of the model was interpreted after Swets (1988) as follows: 0.90-1.00 excellent; 0.80-0.90 good; 0.70-0.80 fair; 0.60-0.70 poor; and 0.50-0.60 fail.

Species optimums and niche breadth

Species optima in terms of fish numbers for each environmental variable were calculated to rank species by habitat preferences. This model fits Gaussian response models to species abundances along an environmental gradient. The fitted parameters are optimum (i.e., average) and niche breadth/tolerance (i.e., standard deviation). The algorithm is based on weighted averaging (ter Braak and van Dam, 1989).

In this research the calculation and visualization were performed in PAST version 4.12 and MINITAB 19.

RESULTS AND DISCUSSION

General information about fish species

Common chub was the most common among selected fish species in study area (Tab. 1), the probability of occurrence reaching 35.1%. Dace was recorded in approximately a third of the watercourses, and the probability of occurrence for roach was 23.3%. However, roach was the most numerous species in our study (Tab. 1). High numbers of roach, with relatively low occurrence compared to other fish species, have also been noted in rivers in Great Britain (Pretty et al., 2003) and lakes in the Republic of Tatarstan (Askeyev et al., 2023c). Comparing the probability of occurrences of the selected fish species with those values from other parts of Europe, we can say that they vary greatly. For example, in general, the probability of occurrence of chub in Eastern Europe is lower than in its western regions. In the Czech Republic, in the Bylina River basin, the frequency of chub encounters is 70% (Jurajda et al., 2010). In the territory covering most of France (Maire et al., 2016), the probability of occurrence of this species is 57%. In Latvia (Birzaks, 2012), in the river basins of southwestern France (Santoul et al., 2005), in the rivers of Hungary (Saly et al., 2011), and in Tatarstan (Askeyev et al., 2015), the probability of occurrence of chub is 45-46%. On the other hand, in most small rivers of Finland (Sutela et al., 2020), the probability of occurrence of chub does not exceed 10%, and in rivers of northeastern Germany (Fieseler and Wolter, 2006), the probability of occurrence of chub is only 10%.

Unlike chub, the probability of occurrence for common dace is higher in the east of the continent. For example, this species was absent from the rivers of Hungary (Saly et al., 2011). In the Bylina River basin, the probability of finding dace is 7% (Jurajda et al., 2010). In the rivers of northeastern Germany, the probability of encountering dace is 12% (Fieseler and Wolter, 2006). In river of Sweden, the probability does not exceed 20%. In France (Maire et al., 2016; Pont et al., 2005) it is 23%. In Finland (Sutela et al., 2020), only in the largest catchments does the probability of occurrence of dace reach approximately 25%, while in smaller ones it does not exceed 10%. In Romania, over the last century as a whole, dace has remained a rather rare species, inhabiting a limited number of watercourses (Păpuc, 2023; Kottelat and Freyhof 2007; Bănărescu, 1964). In Switzerland, in the Thur River, dace has been a rare species for several centuries (Weber et al., 2009). In Ireland, the dace is an invasive species that appeared in the late 19th century and, for almost 100 years, lived only in one basin, beginning to spread throughout the country only in the late 20th century (Caffrey et al., 2007). In the southwestern river systems of France (Santoul et al., 2005), the probability of occurrence of dace, as in our studies, is 33%. The probability of occurrence of dace in the territory of eastern Europe is higher than in the western European countries, as the range boundaries of this species are located in Western Europe. In addition, in our opinion, the relatively low occurrence of common dace in the rivers of Europe is due to the widespread reaclimatization of brown trout and its high abundance.

The probability of occurrences of roach in small rivers in the extreme east of Europe is 22.3%, which is significantly lower than in many river basins in Western Europe. For example, the frequency of roach occurrence in the rivers of France is 56% (Maire et al., 2016), in the watercourses of Latvia it is 54% (Birzaks, 2012), in the rivers of Hungary (Saly et al., 2011) it is 52%, in the river basins of southwestern France it is 39% (Santoul et al., 2005), and in the rivers of northeastern Germany, under potamal conditions, the probability of occurrence of roach is 45%. In ritral conditions, it is the same as in our study. In our opinion, such differences in the probability of detecting roach are associated with a larger number of ponds in the rivers of Western Europe and less amateur fishing pressure.

Table 1: Common species names of fish, probability of occurrence, total number caught and mean number ± SD on site. Species arranged in decreasing order of frequency.

Species	Probability of occurrence (%)	Total number caught	Mean ± SD
Common chub	35.2	2637	4.7 ± 15.1
Common dace	33.1	2560	4.6 ± 17.1
Roach	23.3	2994	5.4 ± 19.9

Table 2: The proportion (%) of sites where two species coexisted.

Species	Dace	Chub	Roach
Dace	•	22.9%	16.5%
Chub	22.9%	•	16.8%
Roach	16.5%	16.8%	•

Table 3: Coefficients and model summary for models summarising the relationship between presence/absence of fish and environmental variables. Species arranged in decreasing order of frequency.

Species	Constant	Cover	Elevation	Depth	Substratum	Velocity	Width	AUC
Common chub	–0.84	–0.11	–0.39	1.53	–0.19		0.60	0.841
Common dace	0.98		–0.31	1.88		1.21		0.886
Roach	–1.22		–0.97	2.11	–0.69		0.95	0.904

Figure 2: Mesha River – cohabitating place for common chub, common dace and roach.

Distribution of fish species in environmental gradients in rivers of east edge Europe; relationship between fish species and environmental variables

The probability of occurrence for each species had statistically significant relationships with three or more of the environmental variables (Tab. 2). All final models had satisfactory predictive power (AUC), varying from 0.841 to 0.904 (Tab. 2). All six variables had a major effect on at least one of the three fish species (Tab. 2). The probability of occurrence of all species was negatively associated with elevation (Fig. 3) and positively associated with the depth of rivers (Fig. 4). Two species, chub and roach, preferred "soft" substrates and wide streams. Common chub also had a strong connection with forest cover, avoiding areas with heavy cover (Fig. 5), and common dace preferred areas with high flow (Tab. 2).

Comparison of the species preferences in the studied rivers and in the rivers of other European basins shows differences and similarities. For example, in the rivers of the Elbe River basin (Humpl, 2006) and in the Udava River basin in Slovakia (Pekarik et al., 2011), as in our study, chub and common dace mainly live in areas with low altitudes. In the rivers of Finland (Sutela et al., 2020) and the Czech Republic (Lusk and Pivnicka, 2009), chub, dace, and roach primarily prefer large rivers. In the work by Takács et al. (2008), for the rivers of Hungary, it is reported that the frequency of occurrence of chub increases in areas with high flow velocity, but in our study, this species shows indifference to this environmental factor. In the rivers of the Czech Republic (Vlach et al., 2005), as in the Republic of Tatarstan, chub prefers deep sections of watercourses with "soft" bottom substrates (clay-sand), avoiding hard stone substrates, and inhabits mainly in the middle and lower sections of rivers.

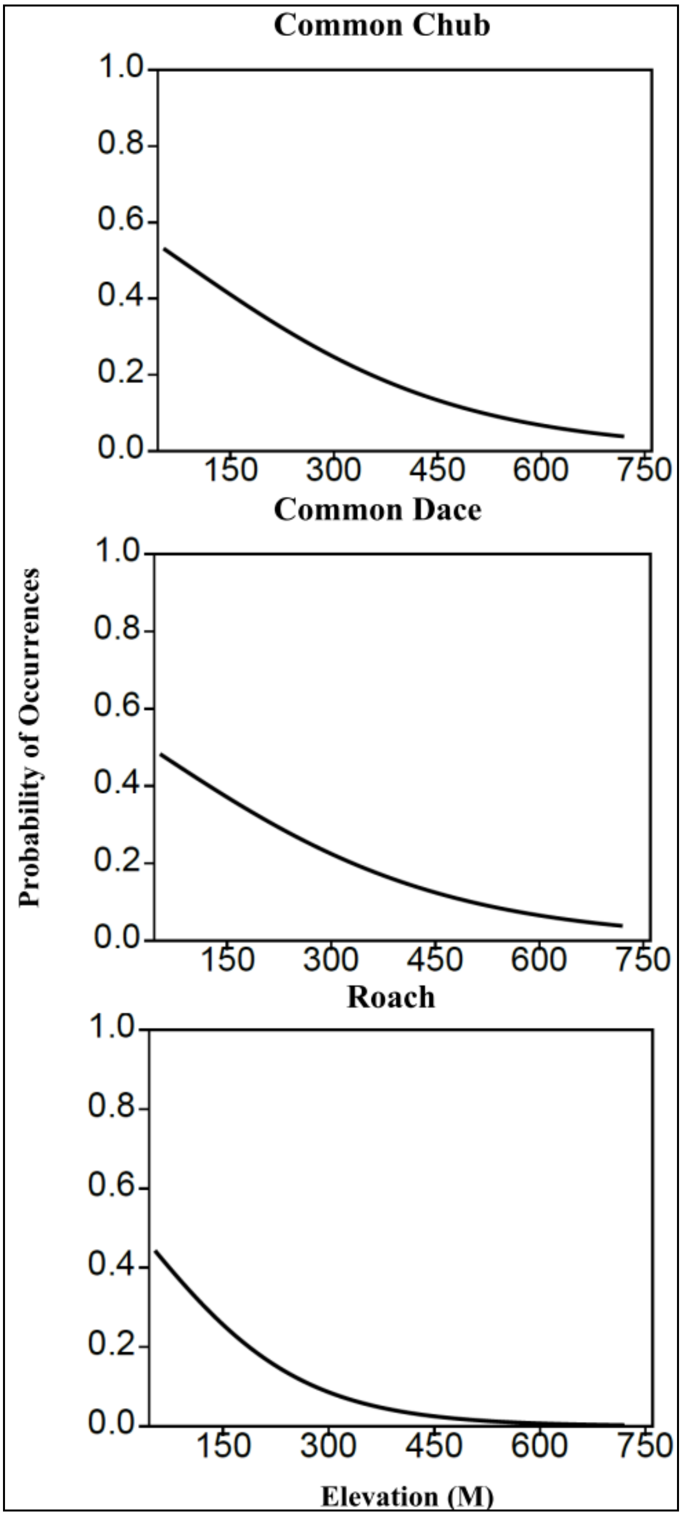

Figure 3: Relationship between the probability of occurrence of fish and elevation.

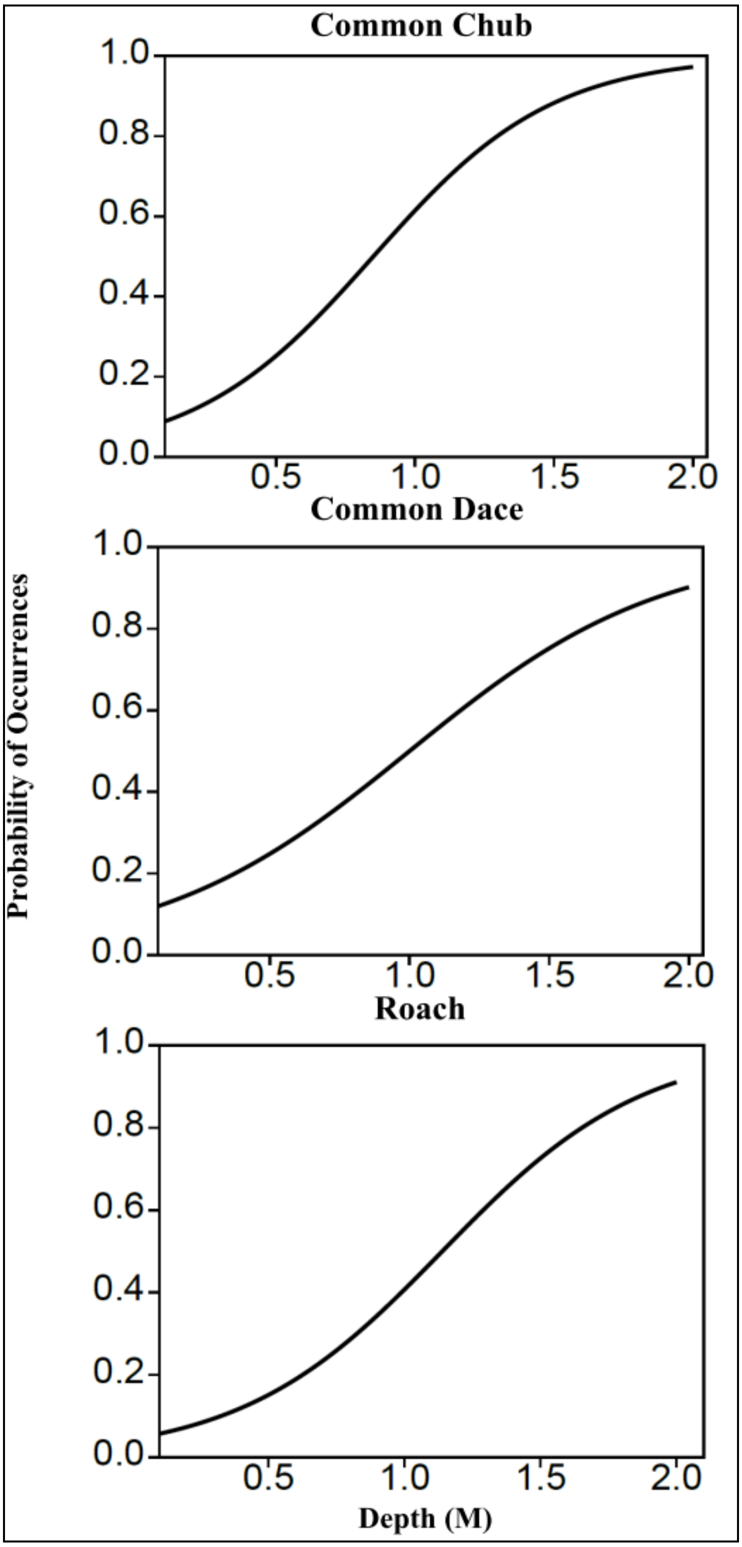

Figure 4: Relationship between the probability of occurrence of fish and depth.

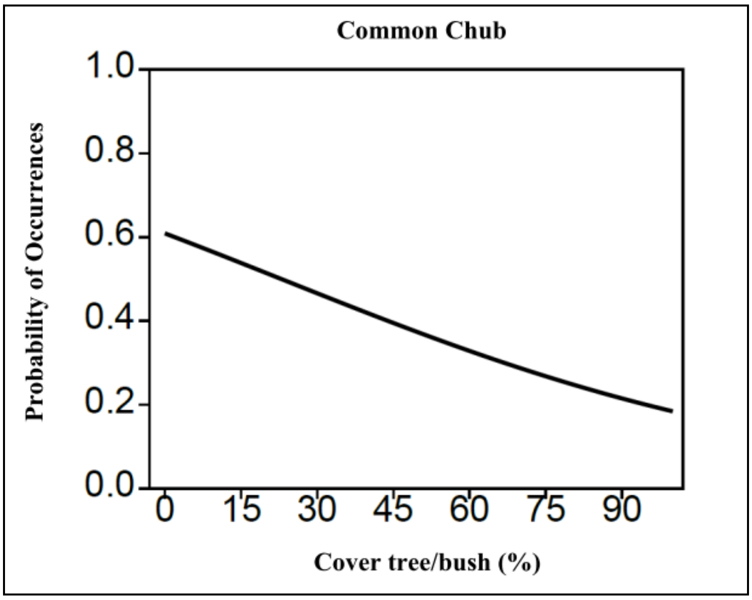

Figure 5: Relationship between the probability of occurrence of common chub and cover tree/bush cover.

Species optimums and niche breadth

Table 4 shows the optimal points and breadths in the gradient of the four environmental variables; values for elevation are presented in the work by Askeyev et al. (2017). The value of the optimal points generally varies for some factors across different fish species. Thus, in terms of width, the optimal points varied by more than six meters, and in terms of tree/bush coverage, by more than 10%. Studying the width of the fish niche by environmental factors, we can say that, in general, chub is the most tolerant. In our opinion, this is one of the reasons why this species is more common among the species in our study. We observe significant variability according to the river width factor, while for the cover tree/bush cover and velocity factors, the selected species have practically similar values. This shows that species' niche preferences and positions cannot be explained by one or two simple factors but can be determined by a combination of all environmental factors.

Table 4: Fish species optimum values and tolerance (niche breadth) against five environmental variables (based on abundance data); species arranged in decreasing order of frequency.

Fish species	Width (m)	Cover tree/bush (%)	Depth (m)	Velocity (m/s)
Optimum values				
Common chub	21.2	36.2	0.96	0.28
Common dace	14.7	40.3	0.83	0.33
Roach	16.3	46.8	1.00	0.26
Tolerance (niche breadth)				
Common chub	20.3	24.7	0.42	0.16
Common dace	9.9	25.9	0.38	0.14
Roach	11.6	24.3	0.36	0.15

CONCLUSIONS

Some sections of small rivers in the extreme east of Europe (Tatarstan) may indeed be potential sources for the extraction of these three valuable fish species. The calculated optimum points and the width of ecological niches may be used in further development of future fish farming operations.

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