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HISTORICAL AND CURRENT DISTRIBUTION OF THE BROWN TROUT, EUROPEAN GRAYLING AND VOLGA NASE IN SMALL RIVERS IN THE REPUBLIC OF TATARSTAN

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ABSTRACT

We have studied the historical and current distribution of brown trout, European grayling, and Volga nase in the Republic of Tatarstan. The influence of environmental variables on the current distribution of these fish was assessed using regression methods. The probability of occurrence in small rivers of all three fish species is currently low, ranging from 2.8 to 5.3%. Each of the recorded environmental variables had statistically significant relationships with presence/absence of at least one fish species, but only two variables (elevation and human impact) significantly affected the probability of occurrence of all species in the study.

RÉSUMÉ: Répartition historique et actuelle de la truite commune, de l'ombre commun et de la Volga nase dans les petites rivières de la République du Tatarstan.

Nous avons étudié la répartition historique et actuelle de la truite commune, de l'ombre commun et de la Volga nase dans la République du Tatarstan. L'influence des variables environnementales sur la répartition actuelle des poissons a été évaluée à l'aide de méthodes de régression. La probabilité d'occurrence dans les petites rivières des trois espèces de poissons est actuellement faible et varie de 2,8 à 5,3 %. Chacune des variables environnementales enregistrées avait des relations statistiquement significatives avec la présence/l'absence d'au moins une espèce de poisson, mais seules deux variables, l'altitude et l'impact humain, affectent de manière significative la probabilité d'occurrence de toutes les espèces dans l'étude.

REZUMAT: Distribuția istorică și actuală a păstrăvului indigen, a lipanului și a scobarului de Volga în râurile mici din Republica Tatarstan.

Am studiat distribuția istorică și actuală a păstrăvului indigen, a lipanului și a scobarului de Volga în Republica Tatarstan. Influența variabilelor de mediu asupra distribuției curente a peștilor a fost evaluată folosind metode de regresie. Probabilitatea de apariție în râurile mici a tuturor celor trei specii de pești este în prezent scăzută și variază de la 2,8 la 5,3%. Fiecare dintre variabilele de mediu înregistrate au avut relații semnificative statistic cu prezența/absența a cel puțin a unei specii de pești, dar doar două variabile, altitudinea și impactul uman, au afectat semnificativ probabilitatea de apariție a tuturor speciilor din studiu.

INTRODUCTION

The distribution, occurrence, and abundance of animals changes over time, caused by many factors. Rivers are characterized by spatial and temporal differences in environmental factors (Birzaks, 2012; Askeyev et al., 2017, 2021a). Environmental conditions, which include geomorphological, physical, and chemical factors in river systems, have a great influence on the distribution of freshwater fish species (Matthews, 1998). However, over the past two centuries it has been human activity that has been the main variable affecting the distribution of most fish species, including in the Republic of Tatarstan. The creation of large reservoirs in the middle of the 20th century put even more pressure on river ecosystems and led to a change in the hydrological balance of small and medium-sized rivers. The discovery and development of oil fields in the southeast of Tatarstan as well as the use of chemicals in oil production have had a detrimental effect on the ichthyofauna of the rivers of this region, leading to the partial or complete disappearance of fish from watercourses (Askeyev et al., 2015, 2016). Another negative aspect of human activity lies in the ecologically unjustified introduction or re-introduction of certain animal species. For example, the release of Eurasian beaver (*Castor fiber* Linnaeus, 1758) led to extremely negative consequences for small rivers in Tatarstan. A decrease in the flow rate, and eutrophication of small rivers, due to the construction of dams by beavers has had a detrimental effect on the abundance of a number of rheophilic fish species.

We focused on the following fish species: brown trout (*Salmo caspius morpha fario,* Kessler, 1877); European grayling (*Thymallus thymallus,* Linnaeus, 1758), and Volga nase (*Chondrostoma variabile,* Yakovlev, 1870). All these species are native representatives of the rheophilic complex with limited distribution and low abundance (all are listed in the Red Book of the Republic of Tatarstan, 2016). Modern climatic changes (IPCC, 2019; Askeyev et al. 2020, 2022) can have an additional negative impact on the state of fish populations (Comte and Grenouillet, 2013; Buisson et al., 2013; Bănăduc et al., 2021). Therefore, their ecological parameters require especially careful monitoring, and their habitats deserve strong protection.

The main aims of the study were to compare historical and current distributions of brown trout, European grayling, and Volga nase and identify their preferences on environmental gradients in rivers in Tatarstan in current time.

MATERIAL AND METHODS

Study area

The Republic of Tatarstan is located in the eastern part of the Russian Plain, at the confluence of the largest rivers in Europe: the Volga, Kama, Belaya, and Vyatka. Traditionally, this area is considered to be within the historical and geographical provinces of European Russia – the Middle Volga and the Pre-Ural region and includes two natural zones – forest and forest-steppe. The largest rivers divide Tatarstan into three clearly separated natural and geographical parts: the Predvolga region (to the west and south of the Volga River valley), the Predkamye region (to the north of the Volga and Kama river valleys), and the Zakamye region (to the south of the Kama River valley). Predkamye, in turn, is divided by the valley of the Vyatka River into Western and Eastern Predkamye; Zakamye is divided by the valley of the Sheshma River into Western (low) and Eastern (high) Zakamye (Stupishin, 1964).

The Predvolga region, bounded to the east and north by the Volga River, is the northeastern part of the Volga Upland, with elevations of about 200-260 m above sea level. The elevated plain has a general slope to the north and is drained by the Sviyaga River. The eastern part of the interfluve of the Volga and Sviyaga rivers is higher and abruptly breaks off to the Volga River, forming the Uslonsky Mountains. The relief surface is heavily dissected by erosion (Stupishin, 1964). In figures 1-3 this region is shaded pink.

Western Predkamye occupies a vast area of the north-west of Tatarstan, bounded in the west by the Volga River, in the south by the Kama River, and in the east by the Vyatka River. In relief, it is a ridged plain with a general slope to the southwest, towards the valley of the Volga River. The undulating surface of the interfluves of the Ashit-Kazanka, Kazanka-Mesha, and Mesha-Kama rivers in the valleys are dissected by numerous small tributaries, ravines, and gullies (Stupishin, 1964). In figures 1-3 this region is shaded green.

Eastern Predkamye, in the northeastern Tatarstan, in relief is the southern spurs of the Mozhginskaya and Sarapulskaya uplands 150-220 m heights, drained by Vyatka, Toima, and Izhem rivers. Slightly undulating interfluve areas are characterized by asymmetry: the western and northeastern slopes are gentler (Stupishin, 1964). This region is shaded blue in figures 1-3.

Western Zakamye occupies a low-lying plain with heights of 100-150 m above sea level, located east of the Volga River, south of the lower reaches of the Kama River and up to the Sheshma River in the east, the prevailing slopes are to the southwest and west, to the valley of the Volga River. The region is drained by the Bolshoi Cheremshan and Malyi Cheremshan rivers and their tributaries (Stupishin, 1964). In figures 1-3 this region is shaded red.

Eastern Zakamye contains the Bugulma-Belebeevskaya upland with the highest point in the central parts of the interfluves in the south (up to 380 m above sea level). The northern slope is rather gentle; the height of the surface of the basins of the lower reaches of the Sheshma, Zaya, and Ika rivers is 100-200 m, and only in the interfluves reaches up to 230-250 m (Stupishin, 1964). In figures 1-3 this region is shaded brown.

Fish assemblage data

Historical information

Information about the historical distribution of the studied species was taken from literary sources (Pallas 1773; Varpakhovsky 1886; Ruzsky 1887; Berg 1906, 1948-49; Meisner 1907; Pokrovsky 1909; Logashev 1933; Tikhiy 1933; Zhdanov and Muratova 1935; Lukash 1940; Popov and Lukin 1949; Platonova 1952; Kirikov 1966; Kuznetsov 2005).

Current research

Fish sampling was conducted at 318 locations in the 11 years from 2012-2022. We focused on the fish assemblages of small rivers (length up to 500 km). We excluded rivers strongly impacted by large reservoirs. Detailed information on the method of catching fish and the distribution of study sites was presented in earlier work (Askeyev et al., 2015, 2021b)

For each site, we calculated the occurrence and abundance of each fish species. The following nine variables were obtained for each site: elevation above sea level (range from 53.2 to 270 m, mean 105.3 m, SD-standard deviation 39.0 m), mean width (0.5 to 55 m, mean 7.7 m, SD 10.3 m), mean depth (0.15 to 1.7 m, mean 0.71 m, SD 0.31 m), water velocity (0 to 1 m/s, mean 0.31 m/s, SD 0.16 m/s), tree/shrub cover along banks (0% to 100%, mean 48.0%, SD 27.5%), dominant bottom substrate (1 – mud, 2 – clay/peat, 3 – sand, 4 – gravel, 5 – pebbles, 6 – stones up to 150 mm, 7 – stones 150-300 mm, 8 – boulders > 300 mm), human impacts (as a 7 point scale: 0 – no agriculture or forestry; 1 – light agricultural impact – hay meadows, light grazing, and forestry within 250 m of the river bank; 2 – moderate agricultural impact – average grazing within 250 m of the river bank, the presence of a ford and a watering hole for livestock; 3 – strong agricultural impact – strong grazing with cattle driving trails visible, arable land, and shelter for animals within 250 m of the river bank; 4 – moderate agriculture impact and oil pollution – average grazing and exploitation of oil and gas within 250 m of the river bank; 5 – urban impact – river site in town or large village; 6 – strong oil and chemical pollution – chemical or oil odour is smelt or spots seen), latitude, and longitude.

Data analysis

Relationship between fish species and environmental variables

For each of the three fish species the nature and strength of relationships with the nine environmental variables was examined using binary logistic regression with the environmental variables as predictors on presence-absence data. Only statistically significant variables were 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 the 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.

Calculation and visualization were done in PAST version 4.04 and XLSTAT 2021.

RESULTS AND DISCUSSION

Historical and current distribution for brown trout, European grayling, and Volga nase

Our current study estimated the probability of occurrence of brown trout as 5.3%, but all the occupied sites of this species fall in Eastern Zakamye in the southeast of Tatarstan (Fig. 1). Compared to historical data, the number of sites of brown trout has decreased by almost 80%; in particular, the populations north of the Kama River and in the Predvolga region have been completely lost (Fig. 1).

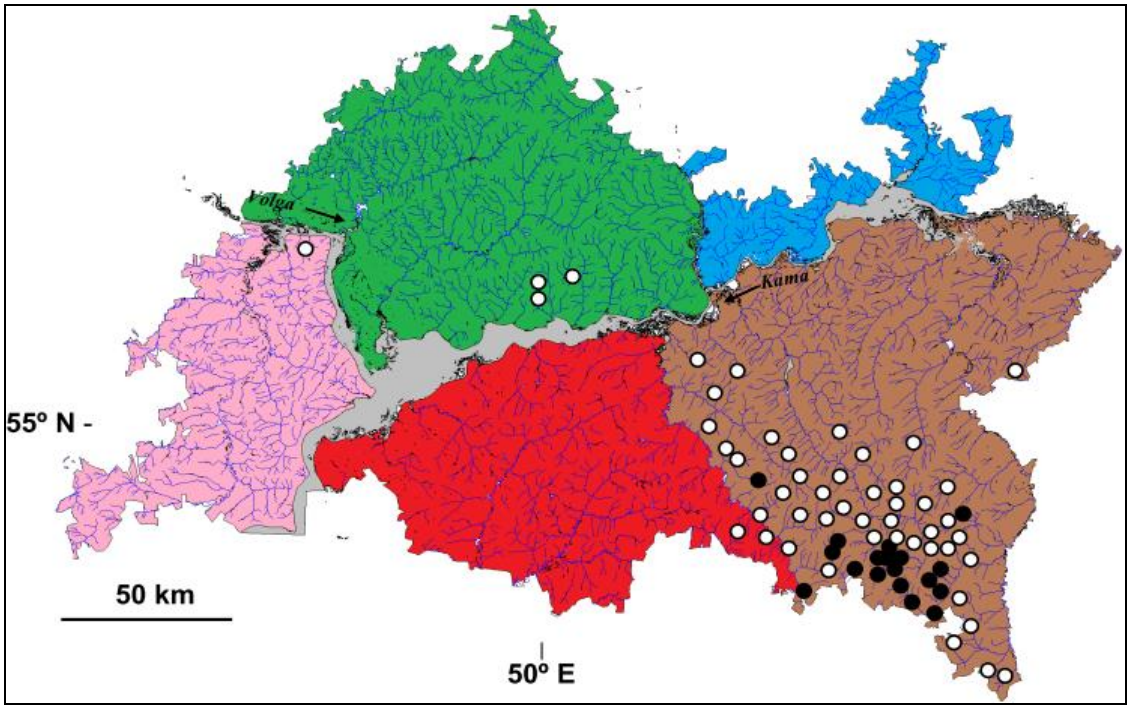


Figure 1: Historical and current distribution of brown trout in the Republic of Tatarstan. White circles show historical locations now absent, black circles historical locations which are still occupied.

In current times, the probability of occurrence of European grayling in the small rivers of Tatarstan is 2.8%. The few locations of European grayling are now very fragmented and can be divided into two clusters (Fig. 2). The first cluster is located in two sites in Western Predkamye: in tributaries of the Kama River (in the Bersut and Karmalka rivers which have been occupied by European grayling since the 19th century (Varpakhovsky 1886)), and one site in Eastern Predkamye in a tributary of the Vyatka River (the Lubyanka River – also a known historical site (Lukash, 1940)). Three others historical sites in this cluster for European grayling have been lost. Thus, compared to historical data, the number of sites for European grayling in these clusters has halved (Fig. 2). Another historical location in Western Predkamye for European grayling was the upper Kazanka River, located in the northwest of Tatarstan. A European grayling in this place was caught by Gontserovsky at the end of the nineteenth century (Meisner 1907).

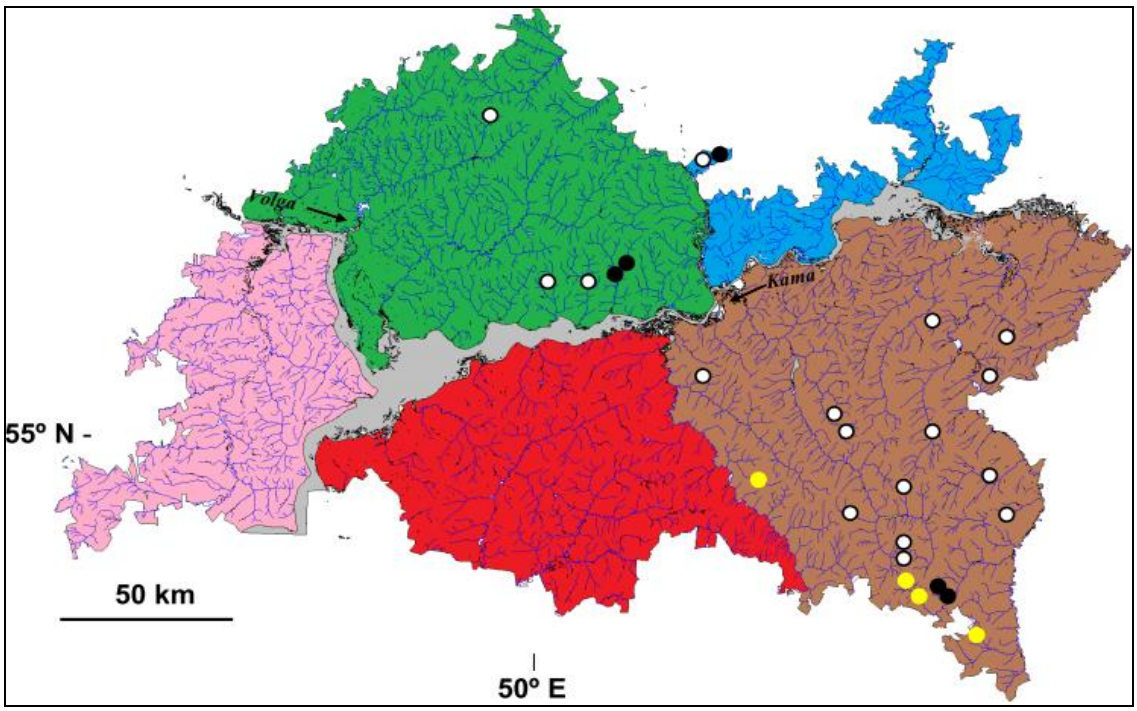


Figure 2: Historical and current distribution of European grayling in the Republic of Tatarstan. White circles show historical locations now absent, black circles – historical locations still occupied, yellow circles – new locations discovered in the current study.

The second cluster in current time is located in the southeast of Tatarstan, in Eastern Zakamye – in the basin of the Ik River – the Sula River and its tributary (the Lipovka River), the Dymka River and its tributary (the Shaitanka River), where this species was recorded in the 18th century (Pallas 1773). At present, European grayling has also been noted in the basin of the Sheshma River (the Bagryazhka River) (Fig. 2). Compared to the historical distribution, several locations have now been lost in the basins of the Zai, Ik, and Sheshma rivers. In general, despite the discovery of new sites of the European grayling, the total number of sites in Tatarstan has decreased markedly (Fig. 2).

Presently, the probability of occurrence for Volga nase is 4.7%. Populations of the Volga nase are distributed in Tatarstan in a scattered pattern, in separate river basins in all three orographic zones (Fig. 3).

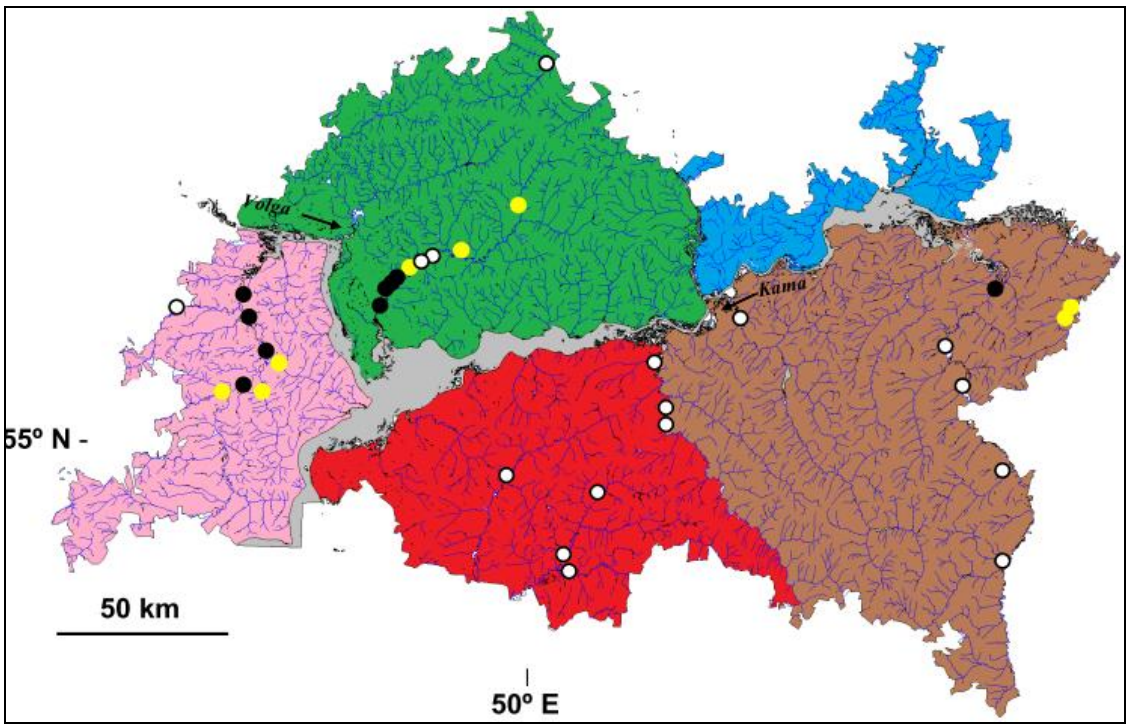


Figure 3: Historical and current distribution of Volga nase in the Republic of Tatarstan. White circles show historical locations now absent, black circles – historical locations still present, yellow circles – new locations discovered in the current study

The largest number of Volga nase locations is now in the Predvolga region, in the basin of the Sviyaga River (Sviyaga, Suhaya Ulema, Ulema, and Bula rivers). In Predkamye, Volga nase were noted in the Mesha River basin. There were only three locations in Zakamye (two in the Syun River basin and one in the Ik River basin). According to historical data, the Volga nase was a relatively common species, but mainly in large rivers (such as the Volga, Kama, and Vyatka), as well as in the lower parts of their tributaries, currently flooded by reservoirs. Compared with the modern distribution of Volga nase, the historical distribution was smaller in the Predvolga region, but significantly greater in Zakamye. In Western Zakamye, the Volga nase is now no longer observed (Fig. 3).

Environmental variables influencing the distribution of the fish species

Each of the selected environmental variables had statistically significant relationships with the presence/absence of at least one fish species (Tab. 1). All species were associated with elevation and human impact, two with width of the river, one with each of water velocity, tree and shrub cover, depth, longitude, latitude, and bottom substrate. All final models had satisfactory predictive power (AUC) varying from 0.87 to 0.98 (Tab. 1).

Table 1: Coefficients and summary for models of the relationship between presence/absence of brown trout, European grayling and Volga nase, with environmental variables. Environmental variables included in the models are abbreviated as follows: elevation above sea level (Elev); mean width (Width); mean depth (Depth); water velocity (Vel); tree/shrub cover along banks (Cover); dominant bottom substrate (Substrate); human impacts (Human); latitude (Lat); longitude (Long).

Species	Equation of the model	AUC
Brown trout	Y = 4.41 +2.81*Elev –0.32*Width +3.83*Vel –1.41*Human –1.62*Lat +0.53*Long	0.984
European grayling	Y = –2.94 +2.49*Elev +4.31*Cover +0.47*Substrate –1.10*Human	0.869
Volga nase	Y = –1.87 –3.87*Elev +3.35*Width –1.12*Human +1.71*Depth	0.932

In Europe, brown trout is a widespread species and inhabits various types of watercourses (Logez et al., 2012). However, in the studied region, brown trout is a rare species that prefers narrow, fast flowing rivers at high elevation, with a low anthropogenic load and with a gravel-stone substrate. A similar distribution of brown trout in the rivers of Western Europe was typical for the first half of the 20th century. At that time the occurrence of brown trout was quite low; the species predominantly occupied areas in the headwaters of rivers at high elevation (Huet, 1959). Currently, in the rivers of Europe, due to different types of human activity, brown trout populate rivers from source to mouth, and its distribution is essentially independent of elevation (Grenouillet et al., 2007; Buisson et al., 2008). In our study, there was a strong decrease in the occurrence of brown trout in rivers with a high anthropogenic impact. This species prefers “clean” rivers little touched by humans. A similar decline in numbers with increased agricultural pressure on rivers has been noted in Finland (Sutela and Vehanen, 2010). Similar trends were also noted in Tatarstan. At the end of the 19th century, Ruzksky (1887) noted a reduction of brown trout in the Sviyaga Basin, while Zhdanov and Muratova (1935) noted a strong decrease in the number of brown trout locations due to intensive human activity in the rivers. All these facts indicate that man has a serious impact on aquatic ecosystems and it is impossible to ignore this influence. For brown trout, the probability of occurrence decreased with increasing river width. Similar preferences for this variable were noted in the rivers of Latvia, where brown trout inhabits narrow sections of watercourses (Birzaks, 2012). The nature of the bottom substrate has a significant impact on the presence of brown trout. This species avoids areas with “soft” substrates, preferring gravel and areas with small and medium-sized pebbles. This is due to the ecological preferences of this species; in particular, brown trout is more conservative in terms of breeding substrate, spawning only on “hard” substrates (Greenberg et al., 1996). Brown trout are more likely to populate areas of watercourses with relatively high water velocity, preferring places with a powerful flow and high oxygen content. Similar preferences by brown trout have also been noted elsewhere in Europe (Greenberg et al., 1996; Logez et al., 2012). The absence of a significant relationship between brown trout and river depth is explained by the fact that different age groups of this species have contrasting preferences for this variable (Greenberg et al., 1996). An increase in the probability of occurrence of brown trout in the southeastern regions of Tatarstan is associated with the historical distribution of the species, as well as more suitable environmental conditions.

In Tatarstan, European grayling is a rare species and is found in rivers at higher elevations with a high percentage of tree cover, low human impact, and hard substrates. The frequency of occurrence of European grayling in European river basins varies greatly. The probable reason for these differences lies in genetic and historical differences in European grayling populations from different regions of Europe (Marić et al., 2014). In the rivers of Europe, European grayling also prefers rivers with tree cover (Logez et al., 2012; Maire et al., 2016). In this regard, a serious reason for the decrease in the number and distribution of European grayling in Tatarstan is that forest area has decreased by two thirds over the past 200 years. The deterioration of the state of European grayling populations as a result of the destruction of bank vegetation has also been noted in Romania (Curtean-Bănăduc and Bănăduc, 2016). Anthropogenic pressure has a significant negative impact on the probability of finding European grayling in rivers. Household and agricultural emissions, waste, and products of the petrochemical industry entering the rivers directly or indirectly have led to a decrease in numbers, and elimination of, European grayling from the rivers. In boreal Europe (Sutela and Vehanen, 2010), a significant relationship has been found between agricultural pollution and a decrease in the number of European grayling in rivers.

The main limiting factors for European grayling and brown trout are the marked fragmentation and geographic isolation of populations, oil and chemical pressure on the rivers, and a low percentage of riparian forests. Poaching of these species may be a further contributory factor. It is also important to note that in addition to humans, beavers also have a negative effect on the populations of these species, since their activity leads to a reduction in habitats and the number of suitable biotopes for spawning of brown trout and European grayling. In addition, for brown trout and European grayling, it should be noted that climate change will probably create additional negative pressure, reducing their numbers.

The Volga nase, in contrast to the other two species in our study, is characterized by an increase in the probability of occurrence on larger rivers at low elevation; but, as for brown trout and European grayling, it avoids sites with high anthropogenic impact. Unfortunately, it is difficult to compare the ecological preferences of the Volga nase in Tatarstan with those from other European regions due to the unclear genetic status of the species in different parts of the continent. The main limiting factors for the Volga nase are river flow regulation, and water pollution by industrial, domestic, and agricultural effluent (Red Book of Republic of Tatarstan, 2016).

CONCLUSIONS

The changing distribution of brown trout, European grayling, and Volga nase raises serious concerns for their future conservation, especially in the context of sharp and rapid climate change.

Based on the results of our work, a specially protected natural area “Rychkovskaya Forest-Steppe” has been formed, which includes a number of sites on small rivers which are characterized by a high number of brown trout and European grayling.

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