Intra-group growth variability of perch (*Perca fluviatilis* L., 1758) (Percidae) of Shalkar and Small Chebachye lakes

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Abstract. Perch (*Perca fluviatilis*) populations from Shalkar and Small Chebachye lakes were studied in terms of growth variability at the intragroup level. These reservoirs are quite similar in many respects of hydrology and hydrochemistry. In both reservoirs, perch is included in the group of dominant species. Growth was studied using the back-calculation method, followed by division within groups into alternative morphs using the K-clustering method. The obtained results showed that the population of Lake Shalkar grows, in general, faster than from Lake Small Chebachye. Generational growth variations were noted only for the sample from Lake Small Chebachye. In Lake Shalkar perch growth is more or less stable, regardless of generations, for almost the entire life span. For both populations, a high level of growth continuity was found, determined by the correlation of calculated lengths for adjacent ages. Also, the formation of "growth" forms was revealed, which significantly differ in growth rates, although they do not reach the level of differences between the well-known reed and pelagic forms of perch. This phenomenon is associated by the authors with the discrepancy in trophic niches to avoid intraspecific competition.
Key Words: analysis of variance, clusters, correlation, inverse calculation of growth, perch, variability.

Introduction. The growth of an organism must be considered as a change in time of its weight and linear dimensions (Mina & Klevezal 1976; Jobling 2002). From a physiological and biochemical point of view, the growth of an organism means primarily protein growth. And although the increase in mass occurs not only due to protein but the construction of the body is due to its dynamics (Shulman 1972). It goes without saying that the nature and rate of growth are adaptive functions. The organism reacts to changes in the environment and responds at the level of metabolic reactions. At the same time, most researchers agree that growth is one of the most variable properties of an organism (Mina & Klevezal 1976; Dgebuadze 2001; Kuznetsova 2003). That is, the adaptive response of an individual organism to changes in the environment is its own, although it can be classified as part of a general phenomenon.

The levels of growth variability are defined as an individual (growth of a discrete organism), or as a group - the sum of the growth dynamics of several organisms. The dynamics of group growth can be subdivided into intragroup and intergroup (Krainyuk 2021).

The importance of studying the growth of organisms is due to the fact that growth is closely related to the concepts of community productivity, their influence on the biotic environment and other economically important processes.

This study is devoted to the assessment of intragroup growth variability of perch (*Perca fluviatilis*) from Shalkar and Small Chebachye lakes. The main attention was paid to the division of a single group into the so-called "ecological (growth) morphs".

Material and Method. The material was collected in 2016-2020 during field work. Catching was carried out with fixed nets. The caught fish were measured for standard length (SL) of body, whole fish mass (M), and carcass mass (m). An operculum was used to determine the age and the back-calculation of height.

In total, the back-calculation of growth was carried out for 143 specimens of perch from Lake Shalkar and 153 specimens from Lake Small Chebachye. The use of the operculum to determine age in perch is described by Le Cren (1947). Specific methods of work on the determination of annual growth marks were described earlier (Krainyuk et al 2020). Based on a comparison of the distribution of annual and accessory rings in different parts, we came to the conclusion that more reliable results are obtained from measurements on thicker structures than on the operculum plate. In this regard, it is more convenient to use the vertical beam of the operculum, where the annual marks form straight lines, than the upper (horizontal) beam with Λ-shaped marks. This scheme is also convenient because the first annual marks are better visible on the bone ray, and additional formations are also less common. The point of convergence of bone rays projected onto the outer side and onto the vertical beam, proposed earlier (Le Cren 1947), was taken as the beginning of the vector. The back-calculation of growth was carried out using the Dahl-Lea simple proportions method (Francis 1990). Differences were assessed using ANOVA analysis of variance when assessed by Fisher's F-test.

In this study, the main attention was paid to the definition of intra-group clusters that differ in linear growth rates. Clusters were allocated for each generation separately. Data were used where calculated sizes are present for at least 5 years of life. These arrays undergo a K-clustering procedure (for example, using the IBM SPSS Statistics program), as a result of which each individual belongs to one of the groups (Bühl & Zöfel 2005).

One of the conditions for carrying out the procedure "K-means clustering" is the predetermination of the number of clusters. What is an inconvenience in other studies becomes a positive thing in this case, because there is no need to divide the sample into more than 2 groups. At this point, in the case of determining "growth" morphs, hierarchical clustering is inconvenient, dividing the sample into an unpredictable number of clusters in advance. Individual observations are aggregated according to their division into clusters and analyzed by standard methods (for example, F-test) with a high threshold of significance $\alpha \leq 0.01$.

The influence of the previous year on growth in the study year, as well as the dependence of body length in the first year of life on the final age, was estimated based on the Pearson correlation coefficient between years within the sample using the IBM SSPS Statistics v. 22 (Buhl & Zöfel 2005).

Results. The studied reservoirs are located in the northern half of Kazakhstan. Lake Shalkar - in the North Kazakhstan region, on the territory of the national park "Kokshetau" (53°12' N 68°23' E), Lake Small Chebachye - in the Akmola region, on the territory of the national park "Burabay" (53°06' N 70° 09' E).

Hydrological and hydrochemical indicators of reservoirs are shown in Table 1 (chemical analysis of water was carried out by an accredited laboratory of “EcoNus” LLP, Karaganda). Chloride ions predominate in both lakes, however, according to long-term data, sulfate ions also have a high proportion in Lake Small Chebache. In general, both reservoirs are quite close both in terms of the main hydrological and hydrochemical parameters. Increased mineralization is not a factor that inhibits growth and vital activity (to a certain extent), which can be seen at least in the case of perch from the Baltic Sea (Karås 1996; Tibblin et al 2012; Nelson et al 2018; Olsson 2019).

The bed of reservoirs is composed of rock yield and large (Lake S. Chebachye) and medium (Lake Shalkar) pebbles. Rigid emersed vegetation on both reservoirs forms insignificant border thickets. Soft underwater macrophytes are very rare.

The species composition of the ichthyofauna of the lakes does not have a high diversity and is largely composed of naturalized forms. In Lake Shalkar, two species are autochthonous: the perch itself and the silver carp (*Carassius gibelio* (Bloch, 1782)). Of the acclimatizers, carp (*Cyprinus carpio* L., 1758), spotted stone loach (*Triplophysa* *strauchii* (Kessler, 1874)) and the Aral stickleback (*Pungitius platygaster aralensis* (Kessler, 1877)). Perch is the dominant species here. Autochthonous species of Lake Small Chebachye are represented in addition to perch by roach (*Rutilus lacustris* (Pallas, 1814)). In 2022, one tench here (*Tinca tinca* (L., 1758)) was also caught. Acclimatizers include bream (*Abramis brama* (L., 1758)), goldfish (*Carassius auratus* (L., 1758)) and pikeperch (*Sander lucioperca* (L., 1758)). Perch, roach and bream predominate in catches in the reservoir. Thus, in the studied reservoirs, perch is a numerous species that plays a significant role in ichthyocenoses.

Perch growth in these lakes has a good rate compared to other populations of the region (Krainyuk et al 2020; Krainyuk 2021). Table 2 provides materials for the back-calculation of growth and their comparison. Simply put, perch from Lake Shalkar up to 8 years old grows significantly faster than individuals from Lake Small Chebachye. In the future, the differences are leveled.

Sex-related growth variability, as a rule, is either absent or weakly expressed in perch, which was noted by a number of authors (Shafi & Matland 1971; Nelson et al 2018; Krainyuk et al 2020; Krainyuk 2021) and also characteristic of the populations studied by us.

Generational variability of growth for perches from Lake Shalkar is uncharacteristic. The calculated lengths differ significantly only for yearlings ($\alpha \leq 0.05$). Most likely, this shows the relative stability of habitat conditions and the absence or insignificance of factors affecting growth rates. The reverse picture is typical for the population from Lake Small Chebachye. Here, up to the age of 8, there are significant differences between generations at $\alpha \leq 0.05$ (with the exception of two-year-olds). This is an indirect indicator of the heterogeneity of the habitat and the strengthening of factors affecting growth.

In this case, this heterogeneity or stability of the environment manifests itself in assessing the average indicators of internal discreteness at the group level and is characteristic of generations or the population as a whole. The evaluation of the intragroup impact initially at the individual level, using correlation indicators of adjacent ages, gives fairly stable growth stability (Table 3), which is possible against the background of the stability of the impact factors. For individuals with low starting rates, there is too little chance of subsequently reaching the first positions in terms of growth rates. This test is of a different nature than the analysis of variance of generational variability or the cluster analysis of "growth" morphs described below. But, in the end, they all complement each other, showing the presence of differences, factors of influence and their duration.

The studied generations born in 2011-2013 from Lake Shalkar showed the presence of two clusters that differ in growth rates (Table 4). These differences had a fairly high significance ($\alpha \leq 0.1$) and kept the general trend over the years. Conditionally slowly growing individuals in the total sample of three generations were about ¾ of the total number. Differences in the generation in 2014 no longer had high reliability and were in different directions: both clusters at different periods of the life cycle had predominant body length values.

In Lake Small Chebachye is dominated by conditionally fast-growing individuals (Table 5). Their share is equal to 2/3 of the total number of studied individuals of the generations of 2010 and 2011. The generation of 2013 continues the trend towards differentiation of individuals. However, the ratio of morphs in the sample was with a noticeable predominance of slowly growing ones.

One of the interesting features of this study is that in Lake Small Chebachye is dominated by a fast-growing cluster, in Lake Shalkar - individuals with low growth rates. But, at the same time, the growth of perch in Lake Shalkar is better than in Lake Small Chebachye.

Table 1

Hydromorphological indicators of lakes and their hydrochemical regime

Water body	Area, thousand ha	Depths		Year	pH	Basic ions						Min., $mg*dm^{-3}$	TWH, mg-eq*dm^{-3}
		Maximum, m	Average, m			Na^{+}+K^{+} $mg*dm^{-3}$	Ca^{+2} $mg*dm^{-3}$	Mg^{+2} $mg*dm^{-3}$	Cl^{-} $mg*dm^{-3}$	SO_3^{-2} $mg*dm^{-3}$	HCO_3^{-} $mg*dm^{-3}$		
Lake Shalkar	2.9	11.6	6.1	2019	8.93	1664	40	209	2570	120	671	5445	19.2
				2020	8.95	1651	32	219	2570	120	610	5397	19.6
				2021	8.88	1704	36	226	2482	360	598	5622	20.4
Lake Small Chebachye	1.7	10.0	5.0	2019	8.68	1007	60	328	1631	913	317	4372	30.0
				2020	8.63	1092	80	304	1064	1797	378	4811	29.0
				2021	8.80	1100	80	292	1560	1129	342	4620	28.0

Note: Min. = mineralization; TWH = total water hardness.

Table 2

Back-calculation of growth, cm (significant values are underlined at α ≤ 0.01)

Water body	Time frame													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lake Shalkar	6.1	9.7	12.5	15.0	17.4	19.6	21.4	23.3	25.6	27.4	30.3	31.4	32.5	-
Lake Small Chebachye	5.7	9.1	11.9	14.7	17.0	19.4	21.9	24.1	25.9	27.7	29.1	30.6	31.9	33.8
ANOVA, F	23.5	29.5	21.1	6.8	12.9	2.9	20.3	16.5	2.5	0.5	6.2	3.1	4.9	-
ANOVA, α	<0.001	<0.001	<0.001	0.011	<0.001	0.09	<0.001	<0.001	0.123	0.475	0.047	0.154	0.157	-

Table 3

Correlation of the calculated values of the body length of adjacent ages (significant values are underlined for α ≤ 0.01)

Samples	Pearson correlation measures											
	1/2	2/3	3/4	4/5	5/6	6/7	7/8	8/9	9/10	10/11	11/12	12/13
Lake Shalkar	0.573	0.665	0.742	0.759	0.742	0.708	0.608	0.425	0.944	-	-	-
Lake Small Chebachye	0.445	0.762	0.830	0.825	0.751	0.826	0.652	0.803	0.732	0.865	0.764	0.675

Table 4

Intragroup growth clusters in perch from Lake Shalkar (significant values are underlined for α ≤ 0.1)

Year of birth	Groups	Calculated body length by years of life, cm								Quantity
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	
2011	Cluster 1	5.9	9.7	12.3	14.7	17.1	19.2	21.3	23.1	11
	Cluster 2	6.0	10.2	13.0	16.2	18.3	20.0	22.2	23.8	5
	ANOVA, F	>0.1	1.8	<u>3.8</u>	<u>28.0</u>	<u>10.8</u>	<u>4.9</u>	<u>11.1</u>	<u>4.0</u>	-
2012	Cluster 1	5.9	9.5	12.2	14.6	17.0	19.4	21.1	-	46
	Cluster 2	6.5	10.5	13.6	16.3	18.4	20.3	21.7	-	20
	ANOVA, F	<u>13.8</u>	<u>30.3</u>	<u>65.7</u>	<u>84.3</u>	<u>109.2</u>	<u>34.3</u>	<u>18.1</u>	-	-
2013	Cluster 1	6.0	9.3	12.1	14.7	17.4	19.4	-	-	28
	Cluster 2	6.8	10.6	14.5	16.8	18.8	21.0	-	-	3
	ANOVA, F	<u>4.9</u>	<u>10.0</u>	<u>26.7</u>	<u>23.1</u>	<u>8.7</u>	<u>11.7</u>	-	-	-
2011-2013	Cluster 1	5.9	9.5	12.2	14.7	17.1	19.4	21.2	23.1	85
	Cluster 2	6.4	10.5	13.6	16.3	18.4	20.3	21.8	23.8	28
	ANOVA, F	<u>12.9</u>	<u>44.4</u>	<u>86.1</u>	<u>134.1</u>	<u>89.0</u>	<u>45.1</u>	<u>27.2</u>	<u>4.0</u>	-

Table 5

Intragroup growth clusters in perch from Lake Small Chebachye (significant values are underlined for α ≤ 0.1)

Year of birth	Groups	Calculated body length by years of life, cm						Quantity
		1	2	3	4	5	6	
2010	Cluster 1	4.9	7.8	10.2	13.2	16.1	18.8	5
	Cluster 2	5.5	9.5	12.5	15.5	17.6	19.5	15
	ANOVA, F	<u>3.9</u>	<u>24.0</u>	<u>37.0</u>	<u>34.9</u>	<u>14.9</u>	2.5	-
2011	Cluster 1	4.9	8.1	10.5	13.8	16.6	-	9
	Cluster 2	5.6	9.7	13.1	15.9	17.8	-	13
	ANOVA, F	<u>3.7</u>	<u>22.0</u>	<u>91.5</u>	<u>38.1</u>	<u>13.5</u>	-	-
2010-2011	Cluster 1	4.9	8.0	10.4	13.6	16.4	-	14
	Cluster 2	5.6	9.6	12.8	15.7	17.7	-	28
	ANOVA, F	<u>7.8</u>	<u>45.3</u>	<u>101.9</u>	<u>66.8</u>	<u>26.2</u>	-	-
2013	Cluster 1	5.8	8.7	11.2	13.8	-	-	18
	Cluster 2	6.8	10.9	13.8	15.9	-	-	2
	ANOVA, F	<u>4.4</u>	<u>33.7</u>	<u>20.6</u>	<u>9.6</u>	-	-	-

Discussion. In the process of growth assessment, there is a significant lack of techniques and methods for assessing differences, variability, and influence factors (Dgebuadze 2001). Sexual variability in perch is usually associated with the characteristics of the reproductive strategy, and the peculiarity of reproductive behavior (Henderson et al 2003; Marshall et al 2009; Pompei et al 2012; Bhatta et al 2012) or can be explained by a decrease in habitat quality (Nikolsky 1965). Although, the latter will concern individual generations more.

Intragroup forms with different growth rates in fish have long been well known (Nikolsky 1965, 1974). For perches, these are the so-called "pelagic" and "reed" forms (Berg 1949). These forms are observed not only in the perch *P. fluviatilis* L., but also in the Balkhash perch *P. schrenkii* Kessler, 1874, which replaces it in water bodies of the highland Asiatic subregion (Mitrofanov et al 1989). These forms differ quite strongly in terms of age range, fecundity, and some other reproductive indicators (Shatunovsky & Ruban 2013). The main reason for the differences in these morphs is the quantitative and qualitative characteristics of nutrition, which can be veiled by other reasons, for example, ethological ones, and can manifest themselves differently depending on the abiotic and/or biotic environment (Nikolsky 1965; Fontaine et al 1997; Craig 2000; Dgebuadze 2001; Krainyuk & Assylbekova 2013; Kestemont et al 2015; Nakayama et al 2017). The presence of these morphs indicates the existence of differences in the habitat of ecological niches with different characteristics and the attempt of the species to occupy them. These differences are especially clearly observed in large water bodies, where the habitat forms a mosaic of living conditions for quite natural reasons. For perch, for example, these morphs were noted for the Aral Sea in its best years (Nikolsky 1940); Balkhash (Mitrofanov et al 1989), and still in the delta of the Ile river (Tsoy & Assylbekova 2012). It is more difficult to identify these intragroup forms in small water bodies with high migratory abilities, although a high level of homing (Shaikin 1989) is not an obstacle to the appearance of discontinuities. Needless to say, the division within the groupings according to growth rates will not be observed in all water bodies.

Intragroup clusters of perches from the studied reservoirs show a significant, but numerically not very large, difference in growth. Probably, they should not be considered at the level of radical options (coastal and pelagic). Their spatial separation is also questionable, given the morphometry of the lakes which they inhabit. Here it is necessary to look for the cause elsewhere. And this is another quality characteristic of nutrition.

A high abundance of any age class (in this case, juvenile generations) leads to a decrease in their growth rates (Post & McQueen 1994; Boisclair & Rasmussen 1996; Hjelm et al 2000; Holmgren & Appelberg 2001; Bobyrev 2013; Rask et al 2014; Roloson et al 2016) due to the tension of trophic competition. Therefore, leaving part of the generation to feed on other suitable objects is quite justified. It makes it possible to reduce the intensity of intraspecific competition and develop new trophic and ecological niches. A similar microevolutionary algorithm was demonstrated in a model for this species (Bobyrev 2013).

Conclusions. As a result of the research, some features of the intragroup growth variability were found in perch from two lakes in Kazakhstan - Shalkar (North Kazakhstan region) and Small Chebachye (Akmola region). Sexual variability of growth in both populations was not noted. Differences in growth between the generations were typical only for Lake Small Chebachye. In both reservoirs, a single group of perch is divided into two clusters with significantly different growth. However, in this case, the level of differences does not imply a radical divergence in growth rates at the level of well-known coastal and pelagic forms of perch. The most logical explanation is that trophic niches are divided within populations to reduce intraspecific competition. Given the high degree of correlation of growth indicators in adjacent ages, belonging to a particular cluster is most likely lifelong (fatal).

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