

Influence of hydrochemical factors on morphometric variability of *Scardinius erythrophthalmus* in a freshwater river system

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Article info

Received 28.06.2022

Received in revised form
21.07.2022

Accepted 22.07.2022

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Klymenko, M., Gandziura, V., Biedunkova, O., & Statnyk, I. (2022). Influence of hydrochemical factors on morphometric variability of *Scardinius erythrophthalmus* in a freshwater river system. *Biosystems Diversity*, 30(3), 244–254. doi:10.15421/012226

Studying fish growth is a complex task because growth depends on many factors. The process of fish growth is influenced by ecological factors of the water environment. Each species of fish has growth characteristics and characteristic changes in this process as a result of the action of natural and anthropogenic factors. We investigated the morphometric features of *Scardinius erythrophthalmus* in the hydroecosystem conditions of the Horyn River. Fish were caught by amateur fishing methods during 2018–2021 in the section of the hydrographic system of the Horyn River within the Rivne Plateau, which is the northern part of the Volhynian Upland, namely the Horyn River and its tributaries – the Zamchysko River, the Ustia River, and the Stubelka River. The catches included fish aged from 0+ (one-year-olds) to 5+ (five-year-olds). Growth variability was studied for fish aged 1+ to 4+ because their numbers were sufficient for statistical evaluation. We noticed clear features of the morphometric variability of the fish. According to the coefficient of variation for the general populations of *S. erythrophthalmus* from different rivers, there was mostly significant variability of such growth characteristics as the largest and smallest fish body height, total length, Smith length and short body length of fish. We also noticed the similarity of the morphometric variability of fish of different ages for the Horyn River and Stubelka River and Zamchysko River and Ustia River. The analysis and evaluation of the surface water quality of these rivers was also similar. Thus, Horyn and Stubla districts had a transitional state from II to III quality class, and the Zamchysko River and Ustya River districts had a transitional state from III to IV quality class. We conducted a multivariate regression and it revealed statistical significance and a close correlation between the coefficients of variation of the growth characteristics of fish with the phosphate content in the water (with an average value of the weighting coefficients of 0.50 ± 0.06), nitrite nitrogen (0.39 ± 0.10) and nitrate nitrogen (0.84 ± 0.34). The calculation of the specific growth of fish by full length revealed that the intensity of growth is the highest between the first and second year of life of fish for small rivers (Zamchysko River, Ustya River, Stubelka River) and between the second and third year for the Horyn River. The results presented in the article are valuable and describe the local variation in the morphometric variability of *S. erythrophthalmus*. This expanded the understanding of the influence of ecological factors of the aquatic environment on the formation of growth characteristics of this species of fish. In the future, our research will continue and study the linear growth of natural fish populations against the background of changes in the ecological and hydrological conditions of the studied region.

Keywords: fish growth; age of fish; coefficient of variation; growth rate; influence of environmental factors; surface water quality.

Introduction

Morphometry, as a method of taxonomic identification, is extremely important for assessing the variability of fish growth, their ontogenesis, and population formation. This importance is reflected in the large amount of scientific literature that presents multiple datasets on the size differentiation of fish in water bodies of different natural and climatic zones under the influence of biotic and abiotic factors. Such studies always attract attention as they combine physiological and environmental fields of study and, therefore, develop new methodological approaches to the systematization of modern ideas about real changes in fish growth under the influence of various factors at different ontogenesis stages.

It is known that growth rate changes in fish, like in all vertebrates, occur as a result of metabolic regulation (Norris & Carr, 2013). At the same time, the growth process significantly depends on the conditions of existence of the fish organism and is a total reflection of the lifestyle peculiarities of both individuals and populations as a whole (Dgebuadze, 2001). The researches regarding the natural and artificial groups of fish show that their appearance is influenced by such physical and chemical factors of the water environment as depth (Guo et al., 2019), current speed (Dudgeon, 2000), salinity (Yu et al., 2021), transparency, temperature regime (Saha et al., 2022), the presence of toxic elements (Mahmoud et al., 2020), etc. Furthermore, the nature of fish growth is closely related to inter-organism interaction in water bodies (Jeffres et al., 2020). The study of morphome-

tric features of fish has proven to be useful for understanding such a complex and dynamic process as the formation of dimensional diversity of single-species fish groups. Most of such information is presented for those species of fish that have industrial importance (Resende et al., 2016; Khalil et al., 2022; Xavier et al., 2022). In such cases, morphometric features reflect the conditions of fish cultivation in artificial conditions (Liu et al., 2022), or their development in their wild populations (O'Connor & Booth, 2021). Similar studies in the scientific literature are less common for fish from natural water bodies that do not have significant industrial value. One of these species is the rudd *Scardinius erythrophthalmus* (Linnaeus, 1758), which is very common in freshwater habitats (Fieseler & Wolter, 2006). The natural range of this species is located in the middle latitudes of the temperate climate zone (Kennedy & Fitzmaurice, 1974). It is also known that this species is often found in the rivers of New Zealand, Italy, Ireland, Canada, Finland (Kennedy & Fitzmaurice, 1974; Grossman et al., 1992; Neilson, 2004; Horppila & Numminen, 2009; Maceda-veiga & De Sostoa, 2011).

Scientists often use the rudd to study the general physiological characteristics of fish (Muntz & Northmore, 1973; Knapp & Wieser, 1981; Teien et al., 2021). Also, there are known interesting studies on morphometric and meristic features of this species with different goals. Thus, using the example of differences in morphometric characteristics, statistical significance was proven for the species *S. erythrophthalmus* and *S. elmaliensis* (Bogutskaya, 1997) in the rivers of Turkey (Ilhan, 2019).

In other studies, it was shown that the species related to the rudd in the water bodies of Montenegro had noticeable differences in several morphological features. In particular, *Scardinius knezevici* from Lake Skadar differs from *S. erythrophthalmus* from the Neretva and Krka rivers, as they have a noticeably slimmer body, fewer lateral line scales, and less branched anal fin rays (Bianco & Kottelat, 2005). Using the example of the rudd in Greek water bodies, it is shown that the measurement of the pharyngeal bone is a sensitive characteristic for the successful identification of different species. This approach has proven effective within the same *Scardinius* genus with identical tooth types and dental formulas (Iliadou & Anderson, 1998). It is worth giving an example of detailed studies of morphometric measurements of otoliths of the *S. erythrophthalmus*. The coefficient of variation established at that time showed that otoliths were the most reliable structures for determining fish age (Gumus et al., 2007). The morphometric description of the rudd in the combined type of hydroecosystem showed a difference in the set of analyzed characteristics of fish in the river and lakes. The authors of this study assume that the morphological characteristics of the rudd depend on the development speed of its growth at an early stage of life (Mavrin et al., 2017).

There is an overwhelming amount of current scientific evidence that monitoring fish growth, including the species *S. erythrophthalmus*, in natural water bodies contributes to obtaining important information about ecological speciation, dimensional variability and stability of fish populations (Scharbert & Borcherding, 2013). Thus, in the reservoirs of Poland, the redfin from warm waters had a longer head, lower and narrower body, shorter pre-dorsal and post-dorsal distances (Szlachciak, & Strakowska, 2010). There are studies that use the morphometric features of *S. erythrophthalmus* for the purpose of preserving the species and managing its fishing in rivers (Gürsoy Gaygusuz, 2018). In the studies carried out during 1963–1995 in the Klicava Reservoir (Czech Republic), in the forecasts of the growth of the number of rudd, the most indicative morphometric parameter turned out to be the total length of the fish, which explained the changes in growth (Pivnička & Švátora, 2010). The morphometric variability of fish is also used in studies of the geographical distribution of populations. For example, body length variation of *S. erythrophthalmus* from European populations at age 1+ was more pronounced at southern latitudes in the northern ones (Tarkan et al., 2010).

Morphometric characteristics are one of the main instruments in analyzing the peculiarities of fish growth and population structure. For example, the study of the rudd from Lake Ladik population during the years 2009–2010 established that among 1329 specimens, the average length of the body of fish ranged 9.8–21.4 cm. At the same time, the ratio of length-weight in the average for age category from 0+ to 7+ was higher in males than in females (Yazici et al., 2015). Interestingly, when studying morphometric characteristics of rudd in Lake Vrana (Croatia) in 2008, one specimen of rudd, which was caught by a fishing athlete, had a total length of 617 mm, a small length of 541 mm and weight of 3623 g, which is a record now (Šprem et al., 2010). And although morphometric data has long been used in the classification of different types of fish, as well as in environmental practice (Iliadou & Anderson, 1998), the study of morphometry of the rudd is limited to certain regions. This knowledge, along with the study of the environmental position of water bodies, contributes to the understanding of the influence of water quality on growth processes, the formation and maintenance of biodiversity, and the distribution of fish species in aquatic ecosystems (Cordoleani et al., 2022).

The foremost objective of our research was to track the morphometric variability of *Scardinius erythrophthalmus* (Linnaeus, 1758) in the middle course of the hydrographic system of the Horyn River within the Rivne Plateau in order to find out local variations in the dependence of the fish size characteristics on the hydrochemical factors of their habitat. We have formulated our working hypothesis as follows: fish growth features depend primarily on species characteristics, but within the limits of local variations their variability depends on environmental conditions of the water environment.

Materials and methods

Scardinius erythrophthalmus is a typical stout-bodied freshwater fish of the carp family (Cyprinidae). It's phytophile (plant spawner) and eury-

phage, spawns for the first time in the third year of life, in the early stages of ontogenesis it prefers to stay in shallow water zones. It has a small industrial value in aquaculture, although there is evidence of the appropriateness of using the species in the human diet because of the saturation of its muscle tissue with omega-3 fatty acids (Bayar et al., 2020). Regulation of populations of this species is used to optimize the number of phytoplankton in water (Ravera & Jamet, 1991; Venugopal & Winfield, 1993). Within the Horyn River basin, this species is one of the most widespread representatives of the ichthyofauna and accounts for about 21% of the total number of fish in the hydrological network of small and medium rivers.

The research was conducted during 2018–2021 in the section of the hydrographic system of the Horyn River within the Rivne Plateau, which is the northern part of the Volhynian Upland. Fish catches were carried out in July–August every year by amateur fishing methods using rods and landing nets. The coordinates of the control catch site points where the fish was caught are shown below: (1) Horyn River – 50°46'37" N, 26°07'23" E; (2) Zamchysko River – 50°51'03" N, 26°29'05" E; (3) Ustia River – 50°44'27" N, 26°07'25" E; (4) Stubelka River – 50°47'07" N, 25°58'26" E (Fig. 1). The distance between the places of control catch sites was determined relative to the main river – Horyn River. The distance between the first and second sections was 26.63 km; the distance between the first and third sections was 5.0 km; the distance between the first and fourth sections was 9.64 km. The areas of riverbeds where the researchers collected ichthyological material were characterised by the absence of the waste water impact and absence of violations of the boundaries of water protection protective zones.

The Horyn River according to the EU WFD (European Communities WFD CIS Common Implementation Strategy for the Water Framework Directive (2000/60/EC) (2003). Guidance document No. 5. Transitional and Coastal Water: typology, reference conditions and classification systems. Luxembourg) is classified as a large river, the Zamchysko River, Ustia River and Stubelka River according to the size of the catchment area and the length of the riverbed belong to the category of small rivers.

While evaluating the morphometric measurements and ratios of fish, the researchers measured linear features according to the carp measurement scheme (Shevchenko & Pylypenko, 2018) using a ruler and a beam with tammel head and fine adjustment (Fig. 2).

The sample included 231 fish (*S. erythrophthalmus*), particularly: n = 49 fish for the Horyn River; n = 61 fish for the Ustia River; n = 62 fish for the Zamchysko River; n = 59 fish for the Stubelka River. The age of the fish (Fig. 3) was determined by the scales taken in the central part of the body under the dorsal fin, above the lateral line from each fish.

The scale samples were fixed by immersing them in acidic formalin and examined under a light biological trinocular microscope (Microton-400) at a total 8 x 40 magnification (Dgebuadze & Chernova, 2003). The data were systematised for each of the studied morphometric features for the general aggregate of the obtained samples and separately by age categories of fish from 1+ to 4+ (which number allowed for descriptive statistics) in order to compare growth features at different stages of fish ontogenesis.

The specific growth rate of different age categories of fish was calculated according to the Schmalhausen-Brody equation (Dgebuadze, 2001):

$$C = \frac{\lg l_n - \lg l_0}{0.4343(t_n - t_0)}$$

where l_0 is the initial fish length in the initial time period; t_0 ; l_n is the final fish body length in the final time period t_n .

Water samples of the investigated rivers were selected in the places of fishing, in each year of research, according to the standardized method (DSTU ISO 5667-6:2009 Water quality. Sampling of samples. Part 6. Guidelines for taking samples from rivers and streams. Ukrainian Research Institute of Environmental Problems, 2011). On the same day, samples were delivered to the laboratory of Rivne Regional Environmental Inspection. The assessment is based on the results of the chemical and analytical control for 12 hydrochemical indicators, which were grouped into three blocks, namely: salt composition (sulphates, chlorides), trophic saprobity (suspended solids, ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, phosphates, BOD5, dissolved oxygen) and specific toxic substances (iron, copper, zinc).

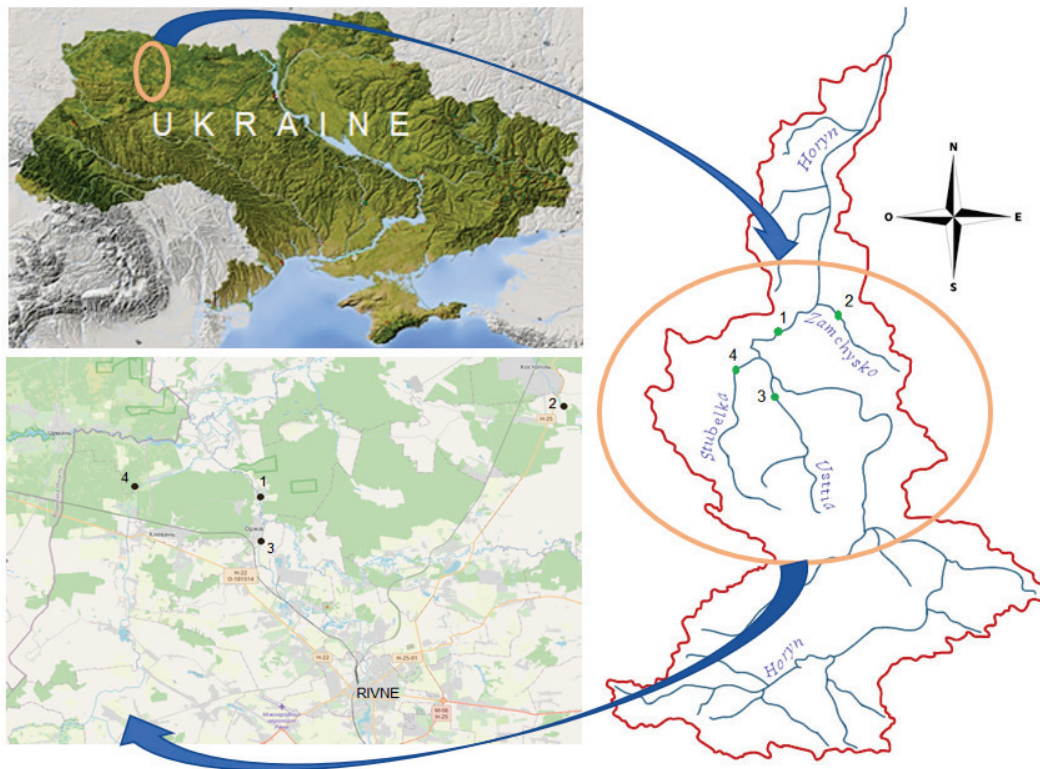


Fig. 1. Location of control catch sites in the investigated part of the hydrographic system of the Horyn River

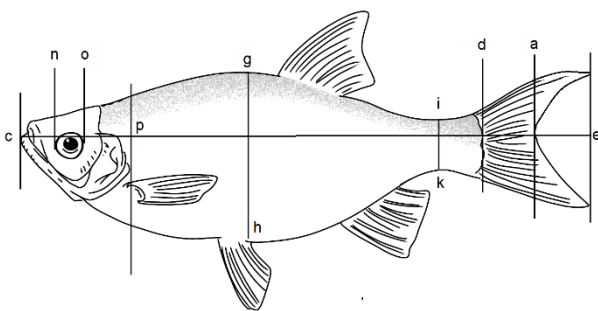


Fig. 2. Morphometric fish measurement scheme: ce is total (zoological) body length, mm; ca is body length from the tip of the snout to the end of the middle caudal fin rays (according to Smith or fork length), mm; cd is standard (ichthyological) body length excluding the length of the caudal (tail) fin, mm; no is the diameter of the eye (horizontal), mm; cp is head length, mm; gh is the greatest height of the body, mm; ik is the smallest height of the body (height of the caudal peduncle), mm

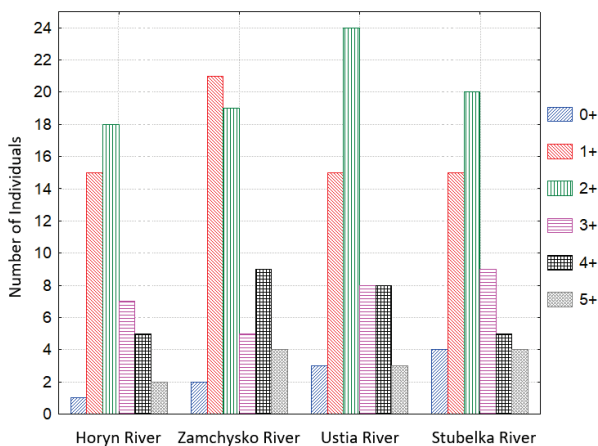


Fig. 3. Age structure of *S. erythrophthalmus* given the hydrological connectivity of the Horyn River within the Rivne Plateau Area

The researchers carried out the environmental assessment of the surface water quality in the research areas of rivers in line with the "Methods ... according to the relevant categories" (Romanenko et al., 1998). The method includes assessment of hydrochemical parameters of water according to three blocks of parameters: 1 – salt composition (I_1), 2 – trophic saprobity composition (I_2), 3 – specific toxic substances (I_3). The raw data were grouped together in blocks: the average values were calculated, the minimum and maximum (worst) values were determined, which all together characterized the variability of values of each of the water quality indicators in real conditions of performance and analysis of the results of researches.

The values of the categories of water quality have been determined by the method algorithm for all indicators of each block. The average values for the three blocks of water quality indices were determined by calculating the average category number according to all indicators of this unit. The phase of the joint water quality assessment consisted in the calculation of the ecological index (I_e):

$$I_e = \frac{I_1 + I_2 + I_3}{3}$$

The names given to classes and categories of water quality by their ecological condition have been determined by the scale: the I class with one category (1) – excellent; the II class is good, with two categories: very good (2) and good (3); the III class is satisfactory, with two categories: satisfactory (4) and intermediate (5); the IV class with one category (6) is bad; the V class with one category (7) is very bad. The names given to classes and categories of water quality by their degree of purity (pollution) have been determined by the scale: the I class with one category (1) is very clean; the II class is clean, with two categories: pure (2) and fairly clean (3); the III class is dirty, with two categories: poorly polluted (4) and moderately contaminated (5); the IV class with one category (6) is dirty; the V class with one category (7) is very dirty.

The obtained data were given statistical processing by means of single-factor dispersion analysis (Akritas et al., 1997) and multifactor correlation regression (Camargo, 1996) by means of packages ANOVA, Basic Statistic and Multiple Regression, Honestly Significant Difference test (McDonald, 2014) using the statistical program Statistica 8.0 (Corain & Salmaso, 2007). Illustrations were formed and processed with Adobe Photoshop version 21.2.9 2020. A fragment of the topographic map that is shown in Figure 1 was obtained with the help of a cartographic underlay Open Street Maps (Zohar, 2021).

Results

The results of the conducted morphometric assessments of the general aggregate of the *S. erythrophthalmus* from the Horyn River indicate that such growth characteristics as the largest and smallest body height of fish had significant variability. The corresponding coefficients of variation (CV) for these characteristics within the age categories from 0+ to 5+

were equal to 36.4% and 41.6%. Total length (CV = 28.7%), fork length (CV = 28.9%) and standard length of fish (CV = 28.8%) also showed significant variability. According to the horizontal diameter of the eye and the head length, the variability of the features was average (the corresponding coefficients of variation were equal to 21.5% and 24.6%).

The morphometric assessment of individual age categories of fish revealed slightly different variability in their growth characteristics (Table 1).

Table 1

Descriptive statistics of morphometric size features of *S. erythrophthalmus* in the Horyn River by particular age categories

Age of fish	Statistical parameters	Morphometric size features						
		total body length (ce)	length according to Smith (ca)	standard body length (cd)	diameter of the eye (no)	head length (cp)	greatest height of the body (gh)	smallest height of the body (ik)
1+ (n = 14)	x ± SE	100.28 ± 1.93	88.64 ± 2.06	71.28 ± 3.24	6.00 ± 0.18	21.86 ± 0.68	26.64 ± 0.79	8.92 ± 0.38
	Min–Max	86.0–109.0	78.0–100.0	59.0–88.0	5.00–8.00	20.00–32.00	20.00–32.00	7.00–13.00
	CV	7.25	8.7	17.01	11.32	11.61	11.08	16.12
2+ (n = 19)	x ± SE	112.66 ± 4.00	99.00 ± 2.94	87.95 ± 2.39	6.58 ± 0.12	22.95 ± 0.97	29.73 ± 1.79	9.6 ± 0.57
	Min–Max	86.00–145.00	77.00–123.00	72.00–110.00	6.00–7.00	16.00–31.00	18.00–44.00	7.00–14.00
	CV	15.49	12.93	11.84	7.71	18.40	26.26	25.77
3+ (n = 7)	x ± SE	165.71 ± 5.12	147.71 ± 4.49	124.00 ± 6.65	9.00 ± 0.31	33.28 ± 1.36	47.86 ± 2.79	18.86 ± 1.64
	Min–Max	150.00–184.00	131.00–164.00	106.00–151.00	8.00–10.00	27.00–38.00	37.00–58.00	12.00–24.00
	CV	8.17	8.05	14.19	9.07	10.79	15.42	22.99
4+ (n = 5)	x ± SE	199.00 ± 2.34	178.20 ± 3.26	143.80 ± 3.64	10.00 ± 0.00	35.80 ± 0.58	57.80 ± 3.39	18.60 ± 1.17
	Min–Max	193.00–206.00	166.00–185.00	138.00–158.00	10.00–10.00	34.00–37.00	47.00–66.00	15.00–22.00
	CV	2.62	4.09	5.66	0.00	3.64	13.14	14.09

Note: n is number of individuals in the sample; x is the arithmetic mean value in the sample; SE is the standard error; Min–Max is minimum and maximum values of features in the sample; CV is the coefficient of variation for values features.

Hence, the age category 1+ had insignificant variability of features for total length and fork length (coefficients of variation <11%). The rest of the features revealed medium variability, with coefficients of variation ranging from 11.1% to 17.0%. At the same time, the greatest range of variation was in the standard length (71.3 ± 3.2 mm) with the minimum and maximum values of 59 mm and 88 mm, respectively. Within the category 2+, the greatest and smallest fish body heights were characterised by significant morphometric variability (corresponding coefficients of variation were equal to 26.3% and 25.8%). The variability of the eye diameter was insignificant (CV = 7.7%). The rest of the features revealed medium variability, with coefficients of variation ranging from 11.8% to 26.3%. The greatest body height (29.7 ± 1.8 mm) manifested the most significant range of variation within this age category with a minimum and maximum value of 18 and 44 mm, respectively. Within the category 3+, the morphometric features in the sample of *S. erythrophthalmus* were characterised by weak (CV from 8.0% to 10.8% for the total body length, the length according to Smith, the diameter of the eye, the head length) and medium (CV from 14.2% to 22.9% for the standard body length, the greatest height of the body, the smallest height of the body) variability, with the largest range of variation in the standard body length (124.0 ± 6.7 mm) given the minimum and maximum of 106 and 151 mm, respec-

tively. The age category 4+ demonstrated mainly high variability of features (total body length, length according to Smith, standard body length, greatest height of the body, smallest height of the body) with a coefficient of variation ranging from 28.7% to 41.6%. At the same time, the greatest range of variation was in the smallest body height (11.8 ± 0.7 mm) with the minimum and maximum values of 7 and 24 mm, respectively. Within this age category, morphometric features such as eye diagonal and head length had moderate variability (respective coefficients of variation were equal to 21.5% and 24.6%).

The general aggregate of the sample of *S. erythrophthalmus* in the Zamchysko River demonstrated the most noticeable variability for the greatest and smallest body height (corresponding coefficients of variation were equal to 43.8% and 39.9%). Total length (CV = 33.0%), fork length (CV = 34.3%) and standard length of fish (CV = 36.3%) also showed significant variability. According to the diameter of the eye and the head length, the variability of the features was average (the corresponding coefficients of variation were equal to 21.9% and 24.0%).

The vast majority of the estimated growth characteristics of individuals aged 1+ had a coefficient of variation ranging from 11.5% (eye diameter) to 17.8% (the smallest body height), which indicated their average variability (Table 2).

Table 2

Descriptive statistics of morphometric size features of *S. erythrophthalmus* in the Zamchysko River by particular age categories

Age of fish	Statistical parameters	Morphometric size features						
		total body length (ce)	length according to Smith (ca)	standard body length (cd)	diameter of the eye (no)	head length (cp)	greatest height of the body (gh)	smallest height of the body (ik)
1+ (n = 20)	x ± SE	95.95 ± 1.91	85.30 ± 1.88	71.20 ± 2.54	5.95 ± 0.15	20.35 ± 0.63	24.70 ± 0.72	9.10 ± 0.36
	Min–Max	82.00–113.00	74.00–99.00	57.00–89.00	5.00–8.00	16.00–28.00	19.00–31.00	7.00–12.00
	CV	8.92	9.88	15.94	11.54	13.83	13.08	17.79
2+ (n = 19)	x ± SE	116.53 ± 3.63	102.32 ± 2.88	86.79 ± 3.27	7.00 ± 0.15	24.26 ± 0.85	32.26 ± 1.46	10.47 ± 0.44
	Min–Max	85.00–144.00	78.00–122.00	58.00–109.00	6.00–8.00	19.00–31.00	23.00–44.00	8.00–14.00
	CV	13.58	12.25	16.43	9.52	15.23	19.71	18.11
3+ (n = 5)	x ± SE	162.20 ± 4.85	143.80 ± 5.51	119.80 ± 5.94	9.00 ± 0.32	31.80 ± 1.71	45.80 ± 3.51	17.40 ± 2.11
	Min–Max	151.00–174.00	128.00–161.00	106.00–140.00	8.00–10.00	26.00–35.00	36.00–57.00	11.00–22.00
	CV	6.69	8.57	11.08	7.86	12.06	17.15	27.14
4+ (n = 9)	x ± SE	208.22 ± 2.89	189.56 ± 3.11	150.78 ± 4.02	9.89 ± 0.11	34.22 ± 0.40	67.56 ± 0.73	20.67 ± 0.67
	Min–Max	194.00–220.00	175.00–199.00	137.00–177.00	9.00–10.00	33.00–36.00	65.00–71.00	16.00–23.00
	CV	4.16	4.92	8.00	3.37	3.51	3.24	9.68

Note: see Table 1.

Total fish body length and fork length demonstrated low variability with CV = 8.9% and CV = 9.8%, respectively. The greatest range of variation was in the standard fish body length (71.2 ± 11.3 mm) with the minimum and maximum values of 57 and 89 mm, respectively. In the age category 2+, among all features no significant variability was observed,

and insignificant variability in eye diameter (CV = 9.5%). The variability of the rest of the growth characteristics in the examined individuals was average, with the coefficient of variation ranging from 12.3% to 19.7%. The most significant range of variation was in the total body length of the 2-year-old individuals (116.5 ± 3.6 mm) with the minimum and maxi-

mum values of 85 and 144 mm, respectively. The age category 3+ had significant variability for such a feature as the smallest body height of fish (CV = 27.1%), and insignificant variability for the total length (CV = 6.7%), fork length (CV = 8.6%), and eye diameter (CV = 7.9%). The rest of the features revealed medium variability, with coefficients of variation ranging from 11.1% to 17.2%. The most notable range of variation was in the standard length (119.8 ± 5.9 mm) with the minimum and maximum values of 106 and 140 mm, respectively. The age category 4+ had little variability for all growth characteristics of the examined individuals of *S. erythrophthalmus*, with the coefficients of variation ranging from 3.2% for the greatest body height to 9.7% for the smallest body height.

Table 3
Descriptive statistics of morphometric size features of *S. erythrophthalmus* in the Ustia River by particular age categories

Age of fish	Statistical parameters	Morphometric size features						
		total body length (ce)	length according to Smith (ca)	standard body length (cd)	diameter of the eye (no)	head length (cp)	greatest height of the body (gh)	smallest height of the body (ik)
1+ (n=15)	M ± SE	77.47 ± 2.41	68.80 ± 2.43	56.13 ± 3.15	5.20 ± 0.11	16.87 ± 0.52	20.53 ± 0.68	7.60 ± 0.34
	Min–Max	65.00–104.00	59.00–94.00	45.00–85.00	5.00–6.00	15.00–21.00	15.00–26.00	6.00–10.00
	CV	12.03	13.66	21.72	7.96	11.83	12.87	17.08
2+ (n=24)	M ± SE	119.88 ± 3.21	105.46 ± 2.52	91.96 ± 2.15	6.71 ± 0.15	24.38 ± 0.79	32.83 ± 1.50	10.50 ± 0.41
	Min–Max	90.00–152.00	82.00–130.00	69.00–116.00	5.00–8.00	18.00–33.00	21.00–50.00	7.00–15.00
	CV	13.12	11.71	11.43	11.19	15.95	22.39	19.05
3+ (n=8)	M ± SE	162.63 ± 3.32	143.00 ± 3.49	122.13 ± 5.26	8.38 ± 0.26	30.75 ± 0.98	44.50 ± 2.29	16.75 ± 1.49
	Min–Max	152.00–175.00	129.00–162.00	103.00–141.00	8.00–10.00	26.00–34.00	36.00–57.00	11.00–22.00
	CV	5.77	6.91	12.19	8.88	8.99	14.56	25.08
4+ (n=8)	M ± SE	206.00 ± 2.82	185.50 ± 2.95	155.63 ± 6.18	9.25 ± 0.25	34.63 ± 0.50	69.13 ± 0.69	19.38 ± 1.07
	Min–Max	194.00–217.00	175.00–198.00	137.00–178.00	8.00–10.00	33.00–37.00	65.00–71.00	16.00–23.00
	CV	3.87	4.49	11.23	7.64	4.07	2.83	15.59

Note: see Table 1.

Thus, the growth characteristics of fish aged 1+ had mostly average variability, with coefficients of variation ranging from 11.8% for head length to 21.7% for standard length. Simultaneously, eye diameter demonstrated insignificant variability (CV = 7.9%). The most notable range of variation was in the standard body length (56.1 ± 3.1 mm) with the minimum and maximum values of 45 and 85 mm, respectively. The assessed individuals of *S. erythrophthalmus* at the age of 2+ showed average variability in all growth characteristics, with the coefficient of variation ranging from 11.4% for eye diameter to 22.4% for the greatest body height of fish. At the same time, the most notable range of variation was in the total length (119.9 ± 3.2 mm) with the minimum and maximum values of 90 and 152 mm, respectively. Within the category 2+, the smallest fish body heights was characterised by significant morphometric variability (corresponding coefficient of variation was equal to 25.1%). The standard body length (CV = 12.2%) and the largest body height of fish (CV = 14.6%) had the average variability. The rest of the features demonstrated insignificant variability. The most notable range of variation for the growth features of the 3-year-old individuals was in the standard body

The most significant range of variation was in the standard fish body length (150.8 ± 4.0 mm) with the minimum and maximum values of 137 and 177 mm, respectively.

The results of the conducted morphometric assessments of the general aggregate of the *S. erythrophthalmus* from the Ustia River show that almost all growth characteristics exhibited significant variability (the coefficients of variation ranged from 27.4% for head length to 45.5% for the longest body length of fish. Only the diameter of the eye had an average variability of the feature (the corresponding coefficient of variation was equal to 22.3%). The variability of morphometric features within different age categories had some differences (Table 3).

length (122.1 ± 5.3 mm) with the minimum and maximum values of 103 and 141 mm, respectively. The age category 4+ demonstrated insignificant (total body length, length according to Smith, diameter of the eye, head length, greatest height of the body) and average (standard body length, smallest height of the body) variability of the features. The most notable range of variation was in the standard body length (155.6 ± 6.2 mm) with the minimum and maximum values of 137 and 178 mm, respectively.

The general aggregate of the sample of *S. erythrophthalmus* in the Stubelka River demonstrated the most significant variability for the greatest and smallest body height (corresponding coefficients of variation were equal to 38.6% and 37.3%). Total length (CV = 27.5%), fork length (CV = 28.2%) and standard length of fish (CV = 28.5%) also showed significant variability. According to the diameter of the eye and the head length, the variability of the features was average (the corresponding coefficients of variation were equal to 17.9% and 22.6%). The variability of morphometric features within different age categories had its peculiarities (Table 4).

Table 4
Descriptive statistics of morphometric size features of *S. erythrophthalmus* in the Stubelka River by particular age categories

Age of fish	Statistical parameters	Morphometric size features						
		total body length (ce)	length according to Smith (ca)	standard body length (cd)	diameter of the eye (no)	head length (cp)	greatest height of the body (gh)	smallest height of the body (ik)
1+ (n=15)	M ± SE	95.53 ± 3.47	85.00 ± 3.71	71.07 ± 4.90	5.60 ± 0.21	20.13 ± 0.70	24.93 ± 0.76	9.07 ± 0.40
	Min–Max	75.00–117.00	68.00–109.00	34.00–98.00	5.00–7.00	17.00–25.00	21.00–29.00	7.00–13.00
	CV	14.05	16.92	26.69	14.79	13.39	11.79	16.92
2+ (n=19)	M ± SE	128.47 ± 2.95	114.16 ± 2.25	99.26 ± 2.10	7.47 ± 0.12	25.63 ± 0.82	34.79 ± 1.48	11.05 ± 0.46
	Min–Max	112.00–160.00	100.00–135.00	86.00–121.00	7.00–8.00	21.00–35.00	25.00–49.00	8.00–15.00
	CV	10.01	8.58	9.20	6.86	14.02	18.57	17.96
3+ (n=9)	M ± SE	164.89 ± 2.93	146.89 ± 3.43	120.00 ± 4.41	7.89 ± 0.26	31.89 ± 1.10	47.22 ± 2.37	18.22 ± 1.37
	Min–Max	152.00–176.00	130.00–163.00	107.00–141.00	6.00–9.00	25.00–35.00	36.00–58.00	11.00–22.00
	CV	5.33	7.00	11.02	9.91	10.33	15.08	22.59
4+ (n=)	M ± SE	205.00 ± 3.61	185.60 ± 3.79	150.60 ± 7.55	8.80 ± 0.20	34.60 ± 0.51	69.60 ± 1.03	20.00 ± 1.14
	Min–Max	197.00–218.00	177.00–199.00	138.00–179.00	8.00–9.00	33.00–36.00	66.00–72.00	16.00–23.00
	CV	3.93	4.57	11.22	5.08	3.30	3.31	12.75

Note: see Table 1.

Within the category 1+, only the standard fish body length was characterised by significant morphometric variability (corresponding coefficient of variation was equal to 26.7%). The rest of the growth features demonstrated average variability with the coefficients of variation ranging

from 11.8% for the greatest body height to 16.9% for the fork length and the smallest body height of the fish. The most notable range of variation was in the standard body length (71.1 ± 4.9 mm) with the minimum and maximum values of 34 and 98 mm, respectively. 2-year-old individuals of

S. erythrophthalmus had average variability for such features as the head length (CV = 14.0%), the greatest (CV = 18.6%) and the smallest (CV = 17.9%) body height of fish. The rest of the features demonstrated insignificant variability with the coefficients of variation ranging from 6.9% for the eye diameter to 10.0% for the total length of the fish body. The most notable range of variation was in the total length (128.5 ± 2.9 mm) with the minimum and maximum values of 112 and 160 mm, respectively. The individuals of the studied species of fish within the age category 3+ also had average and insignificant variability of growth characteristics. In particular, they had average variability for such features as the standard length (CV = 11.0%), the greatest (CV = 15.1%) and the smallest body height of fish (CV = 22.6%). The rest of the features demonstrated insignificant variability with the coefficients of variation ranging from 5.3% for the total length to 10.3% for the fish head length. The most notable range of variation was in the total length (120.0 ± 4.4 mm) with the minimum and maximum values of 107 and 141 mm, respectively. The age category 4+ demonstrated the average variability for standard length (CV = 11.2%) and for the smallest body height of fish (CV = 12.7%). The rest of the features demonstrated insignificant variability with the coefficients of variation ranging from 3.3% for the head length to 5.1% for eye diameter. The most notable range of variation was in the standard body length (150.6 ± 7.6 mm) with the minimum and maximum values of 138 and 179 mm, respectively. The cluster analysis of the calculated coefficients of variation with regard to the growth characteristics of *S. erythrophthalmus* allowed the researchers to compare their similarity within the boundaries of the studied rivers (Fig. 4).

According to the general aggregate of the samples, which had individuals aged from 1+ to 4+, the values of the coefficients of variation for

growth characteristics were higher for fish that were caught in the Horyn River and the Stubelka River. For the fish caught in the Zamchysko River and the Ustia River the values of the coefficients of variation for growth characteristics were comparatively lower. A separate analysis of each morphometric characteristic of fish for all studied rivers was carried out by the method of pairwise comparisons of group means using the Tukey test (Table 5).

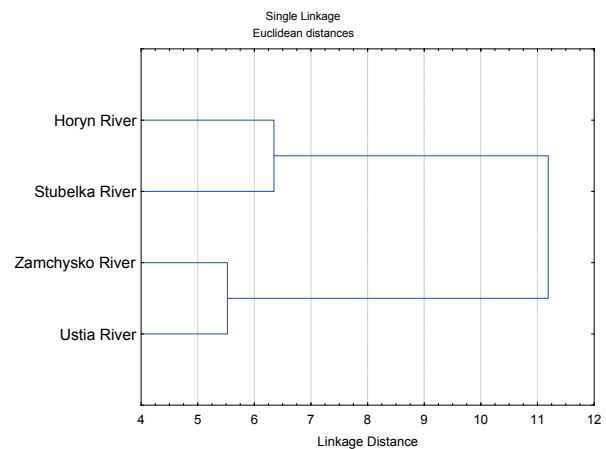


Fig. 4. Clustering of dimensional features of *S. erythrophthalmus* by coefficients of variation in the section of the hydrographic system of the Horyn River within the Rivne Plateau Area

Table 5

The value of the Tukey test in pairwise comparisons of the morphometric characteristics of *S. erythrophthalmus* in the studied rivers ($P < 0.05$)

Morphometric size features	Location of control catch sites			
	Horyn River (n = 45)	Zamchysko River (n = 53)	Ustia River (n = 55)	Stubelka River
Total body length (ce)	126.72 ± 5.42 ^a	128.64 ± 5.83 ^a	127.05 ± 5.98 ^a	132.98 ± 5.28 ^a
Length according to Smith (ca)	112.16 ± 4.84 ^a	114.62 ± 5.39 ^a	112.56 ± 5.38 ^a	118.63 ± 4.83 ^a
Standard body length (cd)	94.58 ± 4.06 ^a	94.89 ± 4.33 ^a	95.83 ± 4.73 ^a	99.69 ± 4.11 ^a
Diameter of the eye (no)	7.16 ± 0.23 ^a	7.28 ± 0.22 ^a	6.91 ± 0.21 ^a	7.10 ± 0.18 ^a
Head length (cp)	25.64 ± 0.94 ^a	25.19 ± 0.83 ^a	24.75 ± 0.91 ^a	26.02 ± 0.85 ^a
Greatest height of the body (gh)	34.71 ± 1.88 ^a	36.68 ± 2.21 ^a	36.45 ± 2.23 ^a	37.67 ± 2.09 ^a
Smallest height of the body (ik)	11.83 ± 0.73 ^a	12.34 ± 0.68 ^a	11.91 ± 0.65 ^a	12.71 ± 0.68 ^a

Note: for indicators, the arithmetic mean and standard deviation is given.

Table 6

Summarized results of hydrochemical control of the quality of surface waters at control catches (2018–2021)

Substance	Statistical parameters*	The value at control catch sites			
		Horyn River	Zamchysko River	Ustia River	Stubelka River
SO ₄ ²⁻ , mg/dm ³	Min-Max (n)	20.78–38.93 (8)	32.20–92.15 (8)	30.50–50.22 (8)	27.50–41.60 (8)
	x ± SE	27.38 ± 0.89	59.23 ± 4.46	35.65 ± 1.13	35.08 ± 3.04
Cl ⁻ , mg/dm ³	Min-Max (n)	6.38–34.74 (8)	8.41–55.10 (8)	12.63–53.51 (8)	7.90–39.15 (8)
	x ± SE	24.43 ± 0.99	21.65 ± 3.02	30.65 ± 2.54	23.61 ± 6.57
Suspended solids, mg/dm ³	Min-Max (n)	3.60–10.40 (8)	12.40–28.20 (8)	13.60–14.80 (8)	7.0–13.40 (8)
	x ± SE	5.48 ± 0.32	18.73 ± 3.48	13.93 ± 0.13	10.31 ± 0.69
NH ₄ ⁺ , mg/dm ³	Min-Max (n)	0.00–1.20 (12)	0.25–0.92 (12)	0.48–1.10 (12)	0.36–0.78 (12)
	x ± SE	1.19 ± 0.08	0.55 ± 0.06	0.81 ± 1.15	0.53 ± 0.09
NO ₃ ⁻ , mg/dm ³	Min-Max (n)	0.19–0.55 (12)	0.33–0.78 (12)	0.63–0.82 (12)	0.88–1.53 (12)
	x ± SE	0.27 ± 0.02	0.57 ± 0.03	0.70 ± 0.04	1.25 ± 0.14
NO ₂ ⁻ , mg/dm ³	Min-Max (n)	0.001–0.044 (12)	0.02–0.10 (12)	0.06–0.14 (12)	0.01–0.022 (12)
	x ± SE	0.008 ± 0.003	0.06 ± 0.01	0.10 ± 0.08	0.14 ± 0.003
PO ₄ ³⁻ , mg/dm ³	Min-Max (n)	0.02–0.20 (12)	0.06–0.28 (12)	0.06–0.25 (12)	0.05–0.21 (12)
	x ± SE	0.05 ± 0.01	0.15 ± 0.01	0.13 ± 0.04	0.12 ± 0.04
Dissolved oxygen (DO), mgO ₂ /dm ³	Min-Max (n)	8.90–7.20 (12)	8.40–6.80 (12)	8.30–6.90 (12)	8.00–8.50 (12)
	x ± SE	7.90 ± 0.10	7.34 ± 0.19	7.83 ± 0.32	8.2 ± 0.12
BOD ₅ , mgO ₂ /dm ³	Min-Max (n)	0.50–1.80 (12)	4.30–12.40 (12)	4.80–10.20 (12)	2.90–3.30 (12)
	x ± SE	1.06 ± 0.10	8.95 ± 0.57	7.85 ± 1.16	3.10 ± 0.09
Fe ²⁺ , mkg/dm ³	Min-Max (n)	160.00–230.00 (6)	310.00–560.00 (6)	280.00–420.00 (6)	150.00–180.00 (6)
	x ± SE	183.65 ± 4.43	400.82 ± 18.57	350.00 ± 32.91	167.50 ± 6.29
Cu ²⁺ , mkg/dm ³	Min-Max (n)	0.40–2.00 (6)	12.00–21.00 (6)	8.00–15.00 (6)	12.50–39.00 (6)
	x ± SE	0.98 ± 0.11	15.35 ± 0.58	11.25 ± 1.49	23.38 ± 5.59
Zn ²⁺ , mkg/dm ³	Min-Max (n)	3.00–12.00 (6)	15.00–28.00 (6)	17.00–22.00 (6)	16.00–21.00 (6)
	x ± SE	6.47 ± 0.67	19.22 ± 1.31	19.50 ± 1.04	18.50 ± 1.19

Note: see Table 1.

It can be stated that there are no significant differences between the morphometric features of *S. erythrophthalmus* in the studied rivers. However, for such morphometric features as full body length and the smallest body height, were established. This indicates that the dimensions of these features differed for individual pairs of comparisons. These pairs were made up by the Horyn River with all its tributaries: Horyn River – Zamchysko River; Horyn River – Ustia River; Horyn River – Stubelka River. That is, according to the total length and the smallest height of the body, the analyzed samples of fish had certain features in the main river of the hydroecosystem and in its tributaries. Perhaps these features are the most sensitive and their formation could be influenced by the peculiarities of the ecological conditions of the aquatic environment, including water quality indicators.

This fact gave grounds for the comparison of the environmental position of the investigated sections of the rivers as well as for the analysis of the influence of the hydrochemical quality indicators of their surface waters on the formation of variability in the dimensional features of *S. erythrophthalmus*. The averaged results of hydrochemical control of the studied rivers over the years of observation demonstrate differences in quantitative values in different rivers (Table 6).

The qualitative characteristics of the ecological state of the water in the control catches shows the change in the quality of surface water over the years of observation, mainly within the fourth and sixth categories of the III and IV classes (Fig. 5).

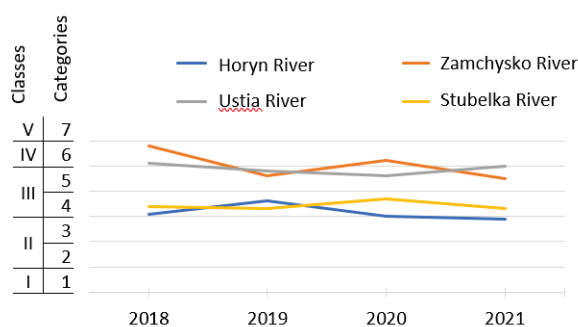


Fig. 5. Time dynamics of the comprehensive water quality identification index for environmental quality assessment of surface water in the section of the hydrographic system of the Horyn River within the Rivne Plateau Area

Consequently, the dynamics of the comprehensive water quality identification index for the environmental quality assessment of surface water, determined by the worst average annual indicators, reflect a better situation for the surface waters of the Horyn River and the Stubelka River. It fluctuated within the categories III and IV, which corresponded to the transition class of surface water quality from class II ("good"), degree of purity – "clean water" to class III ("satisfactory"), degree of purity – "moderately polluted water". Compared to 2018–2021 the ecological status of the Zamchysko River and the Ustia River was significantly worse. It fluctuated within the categories V and VI, which corresponded to the transition class of surface water quality from class III ("satisfactory"), degree of purity – "moderately polluted water" to class IV ("bad"), degree of purity – "dirty water". If we talk about the contribution of individual substances to the formation of the water quality class, then in all cases, the substances of the trophic saprobity block demonstrated the highest categories.

Taking into account the general array of data obtained, the analysis of the influence of the surface water quality indicators in the rivers on the formation of the variability of dimensional features of *S. erythrophthalmus* made it possible to notice certain dependences of the fish growth processes on the conditions of their habitat. Thus, we applied multivariate regression and obtained model equations that describe the influence of the absolute values of the concentrations of the hydrochemical water quality indicators on the morphometric variability of fish expressed using the coefficients of variation of their growth features (Table 7).

The presented regression models were obtained based on the results of the water quality analysis of all four rivers, which was conducted for three years in a row ($n = 12$). Although the obtained models are relatively

simple mathematical dependencies, they have confirmed statistical significance ($P < 0.01$) and close correlation ($R^2 = 0.96-0.99$). Hence they clearly demonstrate that not only hydrological conditions and genetic factors influence the morphometric variability of single-species populations of fish, but also quality characteristics of the habitat. In the majority of the presented regression equations, it is obvious that there is a correlation between the coefficients of variation for growth characteristics and the content of phosphates (for ce, ca, cd, gh, ik), nitrite-nitrogen (for cd, no, gh, ik) and nitrate-nitrogen (for ca, cd, cp) in water. However, the weight coefficients of dependencies had differences in individual regressions: for PO_4^{3-} they were 0.50 ± 0.06 ; for NO_3^- they were 0.84 ± 0.34 ; and for NO_2^- they were 0.39 ± 0.10 . Based on the set of parameters in the equations, it is possible to distinguish sensitivity to the combined effects of the substances, first of all, such growth characteristics as standard length (cd) and the smallest body height of fish (ik).

Table 7

Results of the multivariate regression analysis for the influence of the hydrochemical water quality indicators on the morphometric variability of fish (expressed using the coefficients of variation of their growth features)

Features	Regression Equations	Statistical parameters		
		r	F	p
ce	$C_v = -4.03 + 0.52(PO_4^{3-}) + 0.66(Cl^-)$	0.98	155.74	$1.9 \cdot 10^{-5}$
ca	$C_v = 0.91 + 0.60(NO_3^-) + 0.55(PO_4^{3-})$	0.97	241.64	$2.4 \cdot 10^{-4}$
cd	$C_v = -11.72 + 0.55(SS) + 0.86(O_2) - 0.53(NO_3^-) - 0.23(NO_2^-) - 0.34(SO_4^{2-}) + 0.52(PO_4^{3-})$	0.98	196.06	$0.7 \cdot 10^{-5}$
no	$C_v = -0.81 - 0.47(NO_2^-)$	0.96	45.45	$7.5 \cdot 10^{-5}$
cp	$C_v = 1.14 + 1.39(NO_3^-) + 0.45(SO_4^{2-})$	0.98	90.91	$1.4 \cdot 10^{-4}$
gh	$C_v = 12.12 - 0.59(NO_2^-) + 0.31(PO_4^{3-})$	0.99	444.44	$1.7 \cdot 10^{-4}$
ik	$C_v = -11.77 - 0.55(BOD_5) + 1.18(O_2) - 0.25(NO_2^-) - 0.47(SO_4^{2-}) + 0.61(PO_4^{3-})$	0.98	146.95	$0.6 \cdot 10^{-5}$

In order to expand the understanding of the growth rates of fish we used the calculation of the specific growth rate for different age categories according to the Schmalhausen-Brody equation. We also graphed a de Finetti diagram, which allowed us to determine the contribution of the fish growth rates in the time intervals within their four-year age that had been analysed separately, using the principle of the equation $a + b + c = K$ (Fig. 6).

The presented graphic images demonstrate that the specific growth rate of fish between the first and second year of life was noticeably higher for individuals that were caught in the tributaries of the Horyn River (Fig. 8a). In particular, it turned out that the highest rate was in the Ustia River (0.44); a somewhat lower and almost identical rate was in the Stubelka and Zamchysko Rivers (0.30 and 0.29, respectively) despite the fact that the specific growth rate of *S. erythrophthalmus* for the Horyn River at this time stage was only 0.12. The growth of fish between the second and third year of life was the highest in the Horyn River (0.39). We assume that in this case it was the hydrological factors that influenced the growth of the fish, because taking into account the energy costs for fish swimming in the conditions of increased current, the intensity of growth of young may be complicated. At the same time, in the third year of life the fish reach linear sizes which correspond to their age via accelerated growth rates. Remarkably, in the Zamchysko River the specific growth of fish in the third year of life, although insignificant, was also greater, compared to the second year. Perhaps, there may be a measurement error, or the effect of certain ecological and hydrological factors of the river. At the same time, for all rivers within the research, the growth rates of fish in the fourth year of life turned out to be significantly lower, compared to earlier periods. It is quite obvious that as the fish reach puberty and after spawning, the fish growth rate slows down.

The analysis of the contribution of fish growth rates for the time intervals within their four-year age that had been analysed separately (Fig. 8b) allowed us to estimate the importance of linear features (ce) in the formation of the fish growth intensity according to the following linear expression: $X = 2.2506 \cdot (X_1) + 1.6202 \cdot (X_2) - 2.214 \cdot (X_3)$, where X – full body length of the fish at the age of 4 years (mm); X_1 – full body length of the fish at the age of 1 year (mm); X_2 – full body length of the fish at the age of 2 years (mm); X_3 – full body length of the fish at the age of 3 years (mm). Explicitly, according to the obtained weight coefficients from the equation, it can be stated that the total body length of the 4-year-old indi-

viduals of *S. erythrophthalmus*, in the middle part of the hydrographic system of the Horyn River, was formed as a result of significant growth intensity between the first and second year of life with a noticeable manifestation of linear growth between the second and third year and a certain slowdown between the third and fourth year of the fish's life.

Discussion

The presented research results provide a unique opportunity to analyze local variations in the morphometric variability of the indigenous species rudd *S. erythrophthalmus* in the conditions of the freshwater hydro-

ecosystem of the Horyn River. Detailed studies of this species have not yet been carried out for this region, although in modern conditions of rapid reduction of biodiversity in freshwater rivers, studies of various fish species are important (Zhang et al., 2021; Ahmed et al., 2022; Santos et al., 2022). Studying the influence of environmental factors on the morphometry of fish helps in the restoration of fish communities and contributes to better management of the ecological state of rivers (Stoffers et al., 2022; Tsavdaridou et al., 2022). And the fact that each species of fish has its own life strategies and specific variability of development indicators necessitates careful research for individual species of fish within local scales (Bedunkova, 2016; Bergström et al., 2016; Wynia et al., 2022).

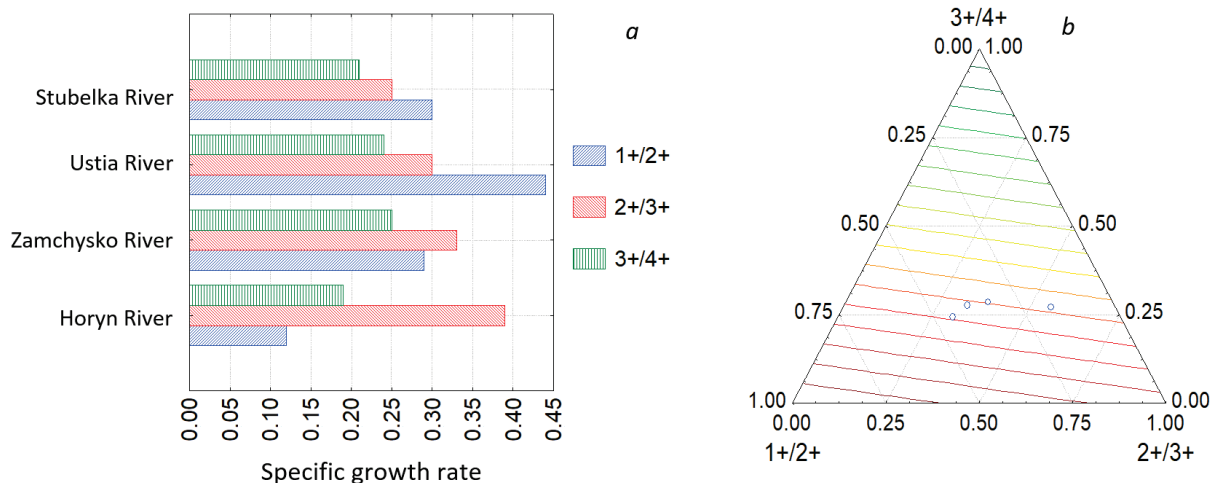


Fig. 6. Analysis of the *S. erythrophthalmus* Growth Rates: *a* – specific growth of fish according to the total length in time intervals 1+/2+, 2+/3+, 3+/4+; *b* – contribution of fish growth rates in the time intervals within their four-year age that had been analysed separately

We noticed that in the conditions of the studied hydroecosystem, namely in the sections of the main Horyn River and its tributaries the Zamchysko River, Ustia River, Stubelka River, the variability of morphometric features of *S. erythrophthalmus* has some differences at different stages of ontogenesis. At the same time, not all of the analyzed features were evaluated with a significant coefficient of variation.

The analysis of individual morphometric characteristics of rudd for all age groups (from 1+ to 4+) by the method of pairwise comparison in the control sections of the rivers did not reveal any differences. We assume that all representatives of this species belong to the same population, which was formed in the conditions of the hydroecosystem of the Horyn River. It is known that most species of fish, with the exception of passing fish, have their life cycle within specific river systems and form separate populations within these areas (Wolter et al., 2015). For rudd, migratory movements do not differ across long distances and are primarily associated with daily changes in light and water temperature, as well as spawning migrations from open areas of the river to shallow thickets (Hohausova et al., 2003). But on the example of phylogeographical studies, the differentiation of populations of *S. erythrophthalmus* in Italian and Central European river systems is shown (Stefani et al., 2004). Genetic variability of 7 populations of rudd from Greece, Slovenia, Northern and Central Italy showed that the Greek population of *S. erythrophthalmus* had a certain degree of genetic differentiation, and the Northern and Central Italian populations were almost indistinguishable (Ketmaier et al., 2003). That is, the formation of separate populations of *S. erythrophthalmus* can occur under conditions of significant spatial separation of its single-species populations. In our region of research, the distance between the river sections (control catch sites) was insignificant and was 5.00–26.63 km. It is obvious that in this case the local type of rudd is represented by one population.

The distribution of coefficients of variation of fish growth characteristics that we found was divided into two clusters, although one of the clusters included rivers of different sizes and with different hydrological conditions. We are talking about the Horyn River, which belongs to large rivers, and the Stubelka River, which, according to the size of the catchment basin and the length of the channel, belongs to the category of small rivers.

It is well known that hydrological conditions, in particular the speed of the current, are one of the main factors that affect the growth rates of fish, since the energy expenditure for swimming can be quite significant – up to 4 J/g/km and even higher (Boisclair & Tang, 1993).

However, in our studies, attention is drawn to the measured difference of such morphometric features as the full length of fish and the lowest height of the fish body with a pair comparison of values for the Horyn River with its tributaries for the significance of the Tukey criterion. Our explanation for this situation is that there is a difference in environmental conditions in the small rivers (Zamchysko River, Ustia River, Stubelka River) and ecological conditions of the large Horyn River. This particularly concerns the different speed of the current and the presence of the shoreline growth of the higher water vegetation. In the Horyn River, the average value of the total length of rudd is higher than their value in tributaries, and the average value of the lowest height of the body of fish is lower. Perhaps this is due to the level of activity of the type and strategies of food search (Winfield, 1986). Due to the higher energy costs of swimming against the water flow and the search for shelter or places of spawning in the Horyn River the fish acquire a more elongated body shape. There is also an interspecific competition that can affect the growth characteristics of the rudd (Johansson, 1997), as well as reproductive activity of fish and availability of food (Gumus et al., 2007). It is proved that the peculiarities of food, in particular, the change of the diet of rudd at different stages of life affects the growth processes of fish (Horppila & Nurminen, 2009). It has been established that in the early stages of development rudd consume phytoplankton, young individuals give preference to microcrustaceans, and adults to macrocrustaceans; *S. erythrophthalmus* eat more zooplankton in spring and autumn and less in summer (García-Berthou & Moreno-Amich, 2000).

In general, for freshwater species of fish, including for rudd, a high degree of variations of growth features is usual (Zivkov et al., 2003; Martins et al., 2014). This variation is often attributed to environmental conditions, from which researchers especially distinguish temperatures (Gumus et al., 2007; Lappalainen et al., 2008; Tarkan et al., 2010) and the general manifestation of stress (Chakraborty et al., 2017; Abdel-Tawwab et al., 2019; Roy et al., 2022).

Our attempt to analyze how the quality of surface waters affects the formation of the size variability of *S. erythrophthalmus* has shown that variations of the dimensions have regressive dependencies with a whole set of hydrochemical parameters. First of all, the regression dependence of the coefficients of morphometric variations combined the substances of the trophic saprobity block. We assume that this is connected not with the influence of pollution, but with the level of river trophicity, which affects the availability of fish food resources. Such assumptions are based on the analysis of scientific literature on study of the tolerance of the rudd to various ecological characteristics of the water environment. It is shown that *S. erythrophthalmus* is a species tolerant to moderate organic pollution and preserves a sufficient population and frequency of occurrence (Maceda-Veiga & De Sostoa, 2011). Other studies have shown that the number of rudd has a direct correlation with the trophism of the water body (Virbickas & Stakėnas, 2016). Also, the body development of *S. erythrophthalmus* can be manifested in response to inappropriate diet (Kamler & Sikorska, 2008).

We have also seen the difference between the specific growth rate of *S. erythrophthalmus* for different age categories in small rivers and large rivers. In general, we know about the gradual acceleration of growth in the older age groups of *S. erythrophthalmus* (Pivnička & Švátora, 2010). Therefore, we assume that within the limits of the rivers we have studied there are local variations which are formed due to different ecological conditions in the main river of the hydroecosystem and its tributaries (Zalewski, 2013; Painter et al., 2020).

Among all possible reasons, one should recall the trophic saprobity block of hydrochemical substance. In tributaries it has worse quality characteristics. This may affect the deteriorating sanitary condition of the rivers. As a result rudd can be affected by helminths (Shukerova & Kirin, 2008; Chunchukova et al., 2019; Kvach, 2021). And as is known, the presence of parasites in the body of fish can affect their growth and morphological features (Timi & Poulin, 2020; Oikonomou et al., 2022).

The above facts prove that many factors influence the growth of fish in natural conditions. It is often difficult to separate them from each other. However, the questions that we consider demonstrate the variability of the growth characteristics of *S. erythrophthalmus* within local variations. This confirms our hypothesis about the influence of ecological conditions of the aquatic environment on the features of fish growth. The perspective of these studies is to expand knowledge about the patterns of variability in the number of single-species fish communities, as well as to promote the preservation of biodiversity in natural water bodies.

Conclusions

Given the hydrological connectivity of the Horyn River within the Rivne Plateau area the age structure of *S. erythrophthalmus* caught by recreational fishing methods during 2018–2021 was represented by age categories from 0+ to 5+. The main core of the obtained samples consisted of individuals aged from 1+ to 4+.

The variability of morphometric features estimated by the coefficient of variation for the general aggregate of the obtained samples of *S. erythrophthalmus* from different rivers is most significant for such growth features as the greatest ($41.08 \pm 2.47\%$) and smallest body height of fish ($41.35 \pm 2.69\%$), total length ($31.00 \pm 1.99\%$), fork length ($32.13 \pm 2.23\%$) and standard body length of fish ($32.55 \pm 2.60\%$). The individual age categories of fish demonstrate clear features of morphometric variability, with common patterns that divide the studied rivers into subcluster 1 (Horyn and Stubla Rivers) and subcluster 2 (Zamchysko and Ustia Rivers). Similarly, the rivers are divided according to the environmental class of water quality. Accordingly, the first subcluster corresponded to the transition from class II to III of surface water quality ("good – satisfactory", degree of purity: "clean water – moderately polluted water"), while the second subcluster corresponded to the transition from class III to IV ("satisfactory – bad", degree of purity: "moderately polluted water – dirty water").

Multivariate regression analysis confirmed statistical significance ($P < 0.01$) and close correlation ($r = 0.96–0.99$) between the coefficients of variation for fish growth features with the content of phosphates in water (for ce, ca, cd, gh, ik) given that the average weighting coefficient is equal

to 0.50 ± 0.06 ; with the content of nitrite-nitrogen in water (for cd, no, gh, ik) – 0.39 ± 0.10 ; and with the content of nitrate-nitrogen in water (for ca, cd, cp) – 0.84 ± 0.34 .

The determined specific fish growth based on the total length reveals that for small rivers (Zamchysko, Ustia, Stubelka Rivers) the highest intensity of the fish growth is observed between the first and second year of life and for the main river of the studied hydrological network (Horyn River) it is observed between the second and third year. The results of this research are very valuable in understanding the local variations in the morphometric variability of single-species populations of fish and in expanding the comprehension of the impact of the environmental factors of the aquatic environment on the formation of growth features of *S. erythrophthalmus*. In the future it may lead to further studies of the linear growth of natural fish populations while taking into account the changes in the environmental and hydrological conditions of the studied region.

References

- Abdel-Tawwab, M., Monier, M. N., Hosenifar, S. H., & Faggio, C. (2019). Fish response to hypoxia stress: Growth, physiological, and immunological biomarkers. *Fish Physiology and Biochemistry*, 45(3), 997–1013.
- Ahmed, S. F., Kumar, P. S., Kabir, M., Zuhara, F. T., Mehjabin, A., Tasannum, N., Hoang, A. T., Kabir, Z., & Mofijur, M. (2022). Threats, challenges and sustainable conservation strategies for freshwater biodiversity. *Environmental Research*, 214, 113808.
- Akritas, M. G., Arnold, S. F., & Brunner, E. (1997). Nonparametric hypotheses and rank statistics for unbalanced factorial designs. *Journal of the American Statistical Association*, 92(437), 258–265.
- Bayar, İ., İnci, A., Ünübol Aypak, S., & Bildik, A. (2021). Büyük Menderes Nehri'nde (Aydın) yaşayan iki tatlı su balığı türünün kas dokularındaki total yağ asidi kompozisyonunun araştırılması [Investigation of total fatty acid composition in muscle tissues of two freshwater fish species living in Büyük Menderes River (Aydın)]. *Kahramanmaraş Sütçü İmam Üniversitesi Tarm ve Doğa Dergisi*, 24(2), 260–266 (in Turkish).
- Bedunkova, O. O. (2016). Homeostaz ryb yak instrument otsinky krytychnykh navantazhen na hidroekosystemy malykh rihok [Homeostasis in fishes as an instrument for assessment of critical loads on hydroecosystem of small rivers]. *Hydrobiological Journal*, 52(5), 25–33.
- Bergström, L., Bergström, U., Olsson, J., & Carstensen, J. (2016). Coastal fish indicators response to natural and anthropogenic drivers – variability at temporal and different spatial scales. *Estuarine, Coastal and Shelf Science*, 183, 62–72.
- Bianco, P. G., & Kottelat, M. (2005). *Scardinius knezevici*, a new species of rudd from Lake Skadar, Montenegro (Teleostei: Cyprinidae). *Ichthyological Exploration of Freshwaters*, 16(3), 231–238.
- Boisclair, D., & Tang, M. (1993). Empirical analysis of the influence of swimming pattern on the net energetic cost of swimming in fishes. *Journal of Fish Biology*, 42(2), 169–183.
- Camargo, J. A. (1996). Comparing levels of pollutants in regulated rivers with safe concentrations of pollutants for fishes: A case study. *Chemosphere*, 33(1), 81–90.
- Chakraborty, B., Bhowmick, A. R., Chattopadhyay, J., & Bhattacharya, S. (2017). Physiological responses of fish under environmental stress and extension of growth (curve) models. *Ecological Modelling*, 363, 172–186.
- Chunchukova, M., Kirin, D., & Kuzmanova, D. (2019). Biodiversity of the helminth communities of *Scardinius erythrophthalmus* (Linnaeus, 1758) from Maritsa River, Bulgaria. *Scientific Papers, Series D, Animal Science*, 62(1), 445–450.
- Corain, L., & Salmaso, L. (2007). A critical review and a comparative study on conditional permutation tests for two-way ANOVA. *Communications in Statistics – Simulation and Computation*, 36(4), 791–805.
- Cordoleani, F., Holmes, E., Bell-Tilcock, M., Johnson, R. C., & Jeffries, C. (2022). Variability in foodscapes and fish growth across a habitat mosaic: Implications for management and ecosystem restoration. *Ecological Indicators*, 136, 108681.
- Dgebuadze, Y. (2001). *Ekologicheskie zakonomosti izmenchivosti rosta ryb* [Environmental patterns of fish growth variability]. Nauka, Moscow (in Russian).
- Dgebuadze, Y., & Chernova, O. (2009). *Cheshuia kostistykh ryb kak diagnosticheskaia i registrirovushchaia struktura* [The scales of teleosts as a diagnostic and recording structure]. KMK, Moscow (in Russian).
- Dudgeon, D. (2000). Large-scale hydrological changes in tropical Asia: Prospects for riverine biodiversity. *BioScience*, 50(9), 793–806.
- Fieseler, C., & Wolter, C. (2006). A fish-based typology of small temperate rivers in the northeastern lowlands of Germany. *Limnologia*, 36(1), 2–16.
- García-Berthou, E., & Moreno-Amich, R. (2000). Rudd (*Scardinius erythrophthalmus*) introduced to the Iberian Peninsula: Feeding ecology in Lake Banyoles. *Hydrobiologia*, 436, 159–164.
- Grossman, E. J., Holm, E., Cholmondeley, R., & Tuininga, K. (1992). First record for Canada of the Rudd, *Scardinius erythrophthalmus*, and notes on the intro-

- duced Round Goby, *Neogobius melanostomus*. Canadian Field-Naturalist, 106(2), 206–209.
- Gumus, A., Bostanci, D., Yilmaz, S., & Polat, N. (2007). Age determination of *Scardinius erythrophthalmus* (Cyprinidae) inhabiting Bafra Fish Lakes (Samsun, Turkey) based on otolith readings and marginal increment analysis. *Cy-bium: International Journal of Ichthyology*, 31(1), 59–66.
- Guo, A., Yuan, J., Chu, T., & Lian, Q. (2019). Hydroacoustic assessment of fish resources in three reservoirs: The effects of different management strategies on fish density, biomass and size. *Fisheries Research*, 215, 90–96.
- Gürsoy Gaygusuz, C. (2018). Age and growth of rudd, *Scardinius erythrophthalmus* (Linnaeus, 1758), in Ömerli Reservoir (Istanbul, Turkey). *Aquatic Sciences and Engineering*, 33(1), 25–31.
- Hohausova, E., Copp, G. H., & Jankovsky, P. (2003). Movement of fish between a river and its backwater: Diel activity and relation to environmental gradients. *Ecology of Freshwater Fish*, 12(2), 107–117.
- Horpilla, J., & Numminen, L. (2009). Food niche segregation between two herbivorous cyprinid species in a turbid lake. *Journal of Fish Biology*, 75(6), 1230–1243.
- Ilhan, A. (2019). Morphometry comparison between *Scardinius erythrophthalmus* (Linnaeus, 1758) and *Scardinius elmalienis* (Bogutskaya, 1997). *Fresenius Environmental Bulletin*, 28(5), 3824–3828.
- Iliadou, K., & Anderson, M. J. (1998). Morphometric comparative analysis of pharyngeal bones of the genus *Scardinius* (Pisces: Cyprinidae) in Greece. *Journal of Natural History*, 32(6), 923–941.
- Jeffres, C. A., Holmes, E. J., Sommer, T. R., & Katz, J. V. E. (2020). Detrital food web contributes to aquatic ecosystem productivity and rapid salmon growth in a managed floodplain. *PLoS One*, 15(9), e0216019.
- Johansson, L. (1987). Experimental evidence for interactive habitat segregation between roach (*Rutilus rutilus*) and rudd (*Scardinius erythrophthalmus*) in a shallow eutrophic lake. *Oecologia*, 73(1), 21–27.
- Kamler, E., Wolnicki, J., Kamiński, R., & Sikorska, J. (2008). Fatty acid composition, growth and morphological deformities in juvenile cyprinid, *Scardinius erythrophthalmus* fed formulated diet supplemented with natural food. *Aquaculture*, 278, 69–76.
- Kennedy, M., & Fitzmaurice, P. (1974). Biology of the rudd *Scardinius erythrophthalmus* (L.) in Irish waters. *Proceedings of the Royal Irish Academy*, 74(18), 245–303.
- Ketmaier, V., Bianco, P. G., Cobolli, M., & De Matthaes, E. (2003). Genetic differentiation and biogeography in Southern European populations of the genus *Scardinius* (Pisces, Cyprinidae) based on allozyme data. *Zoologica Scripta*, 32(1), 13–22.
- Khalil, H. S., Momoh, T., Al-Kenawy, D., Yossa, R., BadrEldin, A. M., Roem, A., Schrama, J., & Verdegem, M. (2022). Metabolic growth, plankton selectivity, haemato-biochemical and intestinal morphometry of Nile tilapia (*Oreochromis niloticus*) fed a lysine-deficient diet in earthen ponds. *Aquaculture Reports*, 24, 101122.
- Knapp, E., & Wieser, W. (1981). Effects of temperature and food on the free amino acids in tissues of roach (*Rutilus rutilus* L.) and rudd (*Scardinius erythrophthalmus* L.). *Comparative Biochemistry and Physiology, Part A: Physiology*, 68(2), 187–198.
- Kvach, Y., Tkachenko, M. Y., Seifertová, M., & Ondračková, M. (2021). Insights into the diversity, distribution and phylogeny of three ergasilid copepods (Hexanauplia: Ergasilidae) in lentic water bodies of the Morava River basin, Czech Republic. *Limnologia*, 91, 125922.
- Lappalainen, J., Tarkan, A. S., & Harrod, C. (2008). A meta-analysis of latitudinal variations in life-history traits of roach, *Rutilus rutilus*, over its geographical range: Linear or non-linear relationships? *Freshwater Biology*, 53(8), 1491–1501.
- Liu, F., Zhan, W., Xie, Q., Lou, B., Han, M., Xu, W., & Tao, S. (2022). First genetic evaluation of growth traits in *Larimichthys polyactis* to guide the formulation of selective breeding programs. *Aquaculture*, 554, 738141.
- Maceda-Veiga, A., & De Sostoa, A. (2011). Observational evidence of the sensitivity of some fish species to environmental stressors in Mediterranean rivers. *Ecological Indicators*, 11(2), 311–317.
- Mahmoud, H. K., Reda, F. M., Alagawany, M., & Farag, M. R. (2021). The stress of abamectin toxicity reduced water quality, growth performance, immunity and antioxidant capacity of *Oreochromis niloticus* fish: Modulatory role of *Simmondsia chinensis* extract as a dietary supplement. *Aquaculture*, 534, 736247.
- Martins, Y. S., Melo, R. M. C., Campos-Junior, P. H. A., Santos, J. C. E., Luz, R. K., Rizzo, E., & Bazzoli, N. (2014). Salinity and temperature variations reflecting on cellular PCNA, IGF-I and II expressions, body growth and muscle cellularity of a freshwater fish larvae. *General and Comparative Endocrinology*, 202, 50–58.
- Mavrin, A. S., Kasyanov, A. N., & Goroshkova, T. V. (2017). Morphological characteristics of the rudd *Scardinius erythrophthalmus* (Linnaeus) from small waterbodies of the upper Volga and Oka basins. *Inland Water Biology*, 10(4), 436–439.
- McDonald, J. H. (2014). *Handbook of biological statistics* (third edition). Sparky House Publishing, Baltimore.
- Muntz, W. R. A., & Northmore, D. P. M. (1973). Scotopic spectral sensitivity in a teleost fish (*Scardinius erythrophthalmus*) adapted to different daylengths. *Vision Research*, 13(2), 245–252.
- Neilson, K., Kelleher, R., Barnes, G., Speirs, D., & Kelly, J. (2004). Use of fine-mesh monofilament gill nets for the removal of rudd (*Scardinius erythrophthalmus*) from a small lake complex in Waikato, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, 38(3), 525–539.
- Norris, D. O., & Carr, J. A. (2013). Chapter 1 – An overview of chemical bioregulation in vertebrates. In: Norris, D. O., & Carr, J. A. (Eds.). *Vertebrate endocrinology* (Fifth edition). Academic Press. Pp. 1–22.
- O'Connor, C., & Booth, D. J. (2021). Response of estuarine fishes to elevated temperatures within temperate Australia: Implications of climate change on fish growth and foraging performance. *Journal of Experimental Marine Biology and Ecology*, 544, 151626.
- Oikonomou, S., Kazlari, Z., Papapetrou, M., Papanna, K., Papaharisis, L., Manousaki, T., Loukovitis, D., Dimitroglou, A., Kottaras, L., Gourzioti, E., Pagonis, C., Kostandis, A., Tsigenopoulos, C. S., & Chatziplis, D. (2022). Genome Wide Association (GWAS) analysis and genomic heritability for parasite resistance and growth in European seabass. *Aquaculture Reports*, 24, 101178.
- Painter, K. J., Brua, R. B., Chambers, P. A., Culp, J. M., Chesworth, C. T., Cormier, S. N., Tyrrell, C. D., & Yates, A. G. (2021). An ecological causal assessment of tributaries draining the Red River Valley, Manitoba. *Journal of Great Lakes Research*, 47(3), 773–787.
- Pivnická, K., & Svátora, M. (2000). Cyclic changes and synchrony of fish growth in the Klicava Reservoir (1963–1995). *Folia Zoologica*, 49(3), 231–240.
- Ravera, O., & Jamet, J. L. (1991). The diet of the rudd (*Scardinius erythrophthalmus* L.) in relation to the possible consequences for the removal of this species from an eutrophic lake. *Archiv für Hydrobiologie*, 123(1), 99–109.
- Resende, S. V., Kavalco, K. F., & Pazza, R. (2016). Morphological and genetic divergence of a small stream fish species along a watershed. *Biochemical Systematics and Ecology*, 68, 66–73.
- Romanenko, V., Zhukinskii, V., & Oksiuk, O. (1998). Metodika ekologicheskoy otsenki kachestva poverkhnostnykh vod po sootvetstviushchim kategorijam [Methodology of environmental assessment of the surface water quality in relevant categories]. *Symvol-T, Kyiv* (in Russian).
- Roy, T., Ghosh, S., & Bhattacharya, S. (2022). A new growth curve model portraying the stress response regulation of fish: Illustration through particle motion and real data. *Ecological Modelling*, 470, 109999.
- Saha, S., Chukwuka, A. V., Mukherjee, D., Saha, N. C., & Adegun, A. O. (2022). Hydrological connectivity, surface water quality and distribution of fish species within sub-locations of an urban Oxbow Lake, East India. *Watershed Ecology and the Environment*, 4, 44–58.
- Santos, R., Astruc, G., Poulet, N., & Besnard, A. (2022). Spatially structured freshwater fish population dynamics at the River Basin District scale: Implication for environmental management and fish conservation. *Journal of Environmental Management*, 317, 115180.
- Scharbert, A., & Borcherding, J. (2013). Relationships of hydrology and life-history strategies on the spatio-temporal habitat utilisation of fish in European temperate river floodplains. *Ecological Indicators*, 29, 348–360.
- Shevchenko, P., & Pylypenko, Y. (2018). Spetsialna ikhtiolohiia [Special ichthyology]. Volume 1. Oldi Plus, Kherson (in Ukrainian).
- Shukerova, S. A., & Kirin, D. (2008). Helminth communities of the rudd *Scardinius erythrophthalmus* (Cypriniformes, Cyprinidae) from Srebarna Biosphere Reserve, Bulgaria. *Journal of Helminthology*, 82(4), 319–323.
- Smetanin, M. (2003). Statisticheskie metody v ekologii ryb [Statistical methods in fish ecology]. IBVV RAN, Borok (in Russian).
- Šprem, N., Matulić, D., Treer, T., & Aničić, I. (2010). A new maximum length and weight for *Scardinius erythrophthalmus*. *Journal of Applied Ichthyology*, 26(4), 618–619.
- Stefani, F., Galli, P., Crosa, G., Zaccara, S., & Calamari, D. (2004). Alpine and Apennine barriers determining the differentiation of the rudd (*Scardinius erythrophthalmus* L.) in the Italian Peninsula. *Ecology of Freshwater Fish*, 13(3), 168–175.
- Stoffers, T., Buijse, A. D., Geerling, G. W., Jans, L. H., Schoor, M. M., Poos, J. J., Verreth, J. A. J., & Nagelkerke, L. A. J. (2022). Freshwater fish biodiversity restoration in floodplain rivers requires connectivity and habitat heterogeneity at multiple spatial scales. *Science of The Total Environment*, 838(4), 156509.
- Szlachciak, J., & Strakowska, E. (2010). Morphological characteristics and variation of rudd *Scardinius erythrophthalmus* (L.) from the Łuknajno Lake, Poland. *Aquaculture, Aquarium, Conservation and Legislation*, 3(2), 91–101.
- Tarkan, A., Lappalainen, J., Numminen, L., & Horppila, J. (2010). Life history strategies of fish: Patterns in growth and lifespan of rudd *Scardinius erythrophthalmus* (L.) in Europe. *Polish Journal of Ecology*, 58(1), 191–196.
- Teien, H.-C., Kashparova, O., Salbu, B., Levchuk, S., Protsak, V., Eide, D. M., Jensen, K. A., & Kashparov, V. (2021). Seasonal changes in uptake and depuration of ¹³⁷Cs and ⁹⁰Sr in silver prussian carp (*Carassius gibelio*) and common rudd (*Scardinius erythrophthalmus*). *Science of the Total Environment*, 786, 147280.

- Timi, J. T., & Poulin, R. (2020). Why ignoring parasites in fish ecology is a mistake. *International Journal for Parasitology*, 50, 755–761.
- Tsavdaridou, A. I., Almpanidou, V., & Mazaris, A. D. (2022). Novel climates in European river sub-basins pose a challenge for the persistence of freshwater fish. *Science of the Total Environment*, 830, 154696.
- Venugopal, M. N., & Winfield, I. J. (1993). The distribution of juvenile fishes in a hypereutrophic pond: Can macrophytes potentially offer a refuge for zooplankton? *Journal of Freshwater Ecology*, 8(4), 389–396.
- Virbickas, T., & Stakėnas, S. (2016). Composition of fish communities and fish-based method for assessment of ecological status of lakes in Lithuania. *Fisheries Research*, 173, 70–79.
- Winfield, I. J. (1986). The influence of simulated aquatic macrophytes on the zooplankton consumption rate of juvenile roach, *Rutilus rutilus*, rudd, *Scardinius erythrophthalmus*, and perch, *Perca fluviatilis*. *Journal of Fish Biology*, 29, 37–48.
- Wolter, C., Buijse, A. D., & Parasiewicz, P. (2015). Temporal and spatial patterns of fish response to hydromorphological processes. *River Research and Applications*, 32(2), 190–201.
- Wynia, A. G., Tetreault, G. R., Clark, T. W., Cunningham, J. L., Ussery, E. J., & McMaster, M. E. (2022). Fish assemblage monitoring in Alberta's Ells River: Baseline fish and habitat variability prior to major development. *Global Ecology and Conservation*, 34, e02007.
- Xavier, M. J., Navarro-Guillén, C., Lopes, A., Colen, R., Teodosio, R., Mendes, R., Oliveira, B., Valente, L. M. P., Conceição, L. E. C., & Engrola, S. (2022). Effects of dietary curcumin in growth performance, oxidative status and gut morphology and function of gilthead seabream postlarvae. *Aquaculture Reports*, 24, 101128.
- Yazici, R., Yilmaz, S., Yazicioglu, O., & Polat, N. (2015). Population structure and growth of rudd *Scardinius erythrophthalmus* (L., 1758) from a eutrophic lake in Northern Anatolia. *Croatian Journal of Fisheries*, 73(3), 94–102.
- Yu, J., Wen, X., You, C., Wang, S., Chen, C., Tocher, D. R., & Li, Y. (2021). Comparison of the growth performance and long-chain polyunsaturated fatty acids (LC-PUFA) biosynthetic ability of red tilapia (*Oreochromis mossambicus* ♀ × *O. niloticus* ♂) fed fish oil or vegetable oil diet at different salinities. *Aquaculture*, 542, 736899.
- Zalewski, M. (2013). Ecohydrology: Process-oriented thinking towards sustainable river basins. *Ecohydrology and Hydrobiology*, 13(2), 97–103.
- Zhang, C., Zhu, R., Sui, X., Li, X., & Chen, Y. (2021). Understanding patterns of taxonomic diversity, functional diversity, and ecological drivers of fish fauna in the Mekong River. *Global Ecology and Conservation*, 28, 01711.
- Zivkov, M., Belomachevo, T., & Trichkova, T. (2003). Growth rate and condition of rudd (*Scardinius erythrophthalmus* L.) in two Bulgar-Ian Reservoirs as compared to other European water bodies. *Acta Zoologica Bulgarica*, 55, 93–105.
- Zohar, M. (2021). Geolocating tweets via spatial inspection of information inferred from tweet meta-fields. *International Journal of Applied Earth Observation and Geoinformation*, 105, 102593.