Bulgarian Journal of Agricultural Science, 31 (No 3) 2025, 621–629

Comparison of length-weight relationships and condition factors among Czech Carp (ALxDOR70) and Lithuanian Carp (Bubiai) strains grown in ponds

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Abstract

Zibiene, G. & Zibas, A. (2025). Comparison of length-weight relationships and condition factors among Czech Carp (ALxDOR70) and Lithuanian Carp (Bubiai) strains grown in ponds. *Bulg. J. Agric. Sci., 31*(3), 621–629

This study was conducted to evaluate the adaptability of the hybrid mirror carp strain ALxDOR70 (Mirror) from the University of Bohemia in the Czech Republic. Larvae were injected into three ponds. The Bubiai carp larvae (Scaled) were also injected into the same ponds as the control group. Twenty-five thousand larvae of both carp varieties were injected into each pond. The initial mean weight of injected larvae was 4 mg. Measurements started from autumn 2020 to spring 2022. Fish measurements were carried out in the autumn and spring seasons, like a routine of fish farms. Length-weight relationship, Fulton's condition factor (K_F) and Relative condition factor (K_R) from standard length (L) and body weight (W) were analysed in different years and seasons. The results suggest that the lengths and weights of Scaled carp were lower than those of Mirror, and these differences were statistically significant ($P < 0.05$) throughout the study. The values of the coefficient of determination r^2 between the length and weight ratio for both species were determined to be significant ($r^2 > 0.60$, $P < 0.001$). A weaker but significant relationship was obtained in autumn 2021 for Mirror carp ($r^2 < 0.59$).

Cube law results showed that the regression coefficient $b < 3.0$ was obtained for both studied species, although a higher value of b was obtained for Scaled carp throughout the study period. Average values of Fulton's and relative condition factor were obtained higher than 1 in every season, reflecting good living conditions. At the same time, Mirror carp adapted well enough to live in new conditions. Survival in autumn 2020 and spring 2021 was better for Mirror carp than Scaled, but in autumn 2021 and spring 2022, better survival rates were obtained for Scaled carp. It was concluded that there was a significant difference in survival, growth parameters, length, weight, and condition factors between Scaled and Mirror carp in different seasons. The results obtained in the study can be used to understand the frameworks related to domestication and management for the adaptation of new carp breeds and breeding in fish farms.

Keywords: Cyprinus carpio; Scaled carp; Mirror carp; Length-weight relationship; Condition factor

Introduction

Information on fish growth patterns and body forms required for the conservation and domestication of newly introduced carp varieties. The weight-length ratio (WLR) is a useful tool for fish biology, physiology, ecology and stock assessment. Indeed, this relationship is widely used as a fisheries management method as information on the status of fish stocks in an aquatic ecosystem (Bagenal & Tesch, 1978). In addition, the WLR is often used by researchers to predict fish weight when fish length is known, as well as to estimate fish yields (Froese, 2006; Froese et al., 2014). According to Santos et al. (2013), WLR is generally more important than age because several ecological and physiological factors are more size-de-

pendent than age-dependent. The determination of WLR allows the estimation of seasonal variations in fish growth and the calculation of condition indices (Richter et al., 2000), which are often used to analyse ontogenic changes among fish species reared in different regions or habitats. WLRs are used in a variety of ways in fisheries research, including estimating weight-for-length fish (Froese, 2006; Froese et al., 2014) and weight-for-age (Petrakis & Stergiou, 1995).

The condition factor (*K*) provides information on the overweight condition of the fish. It is an instrument often used to compare the physiological condition of populations during a seasonal cycle or in watersheds with similar or different ecological conditions (LeCren, 1951). The Bubiai carp is a Lithuanian local carp strain grown on fishery farms since the beginning of the 20th century, with a beautiful exterior and good growth rate. However, when adverse conditions arise, they are not resistant and are easily infected with some diseases. Not resistance to diseases may be due to a small, isolated herd or interbreeding, which may have resulted in inbreeding. In order to improve local carp breeds, carp larvae were brought from the Czech Republic in the spring of 2020. In cooperation with Czech scientists, hybrids have been selected that are suitable for growing in Czech farms located as high as possible in the mountains, where the climate is significantly cooler and the carp feeding period is shorter than in Lithuania. The larvae of Czech carp hybrids were released to grow in the ponds of the Šilavotas Division of the Fisheries Service of the Ministry of Agriculture of the Republic of Lithuania.

The research aims to find out whether hybrids of Czech carp hybrids can adapt to grow, feed and winter in the climatic conditions of Lithuania. For that purpose, comparative studies of carp strains' length-weight ratio, specific growth rate and condition factor were conducted.

Materials and Methods

Study area and fish sampling

The research has been carried out since the summer of 2020 when carp larvae from the Czech University of South Bohemia were brought to the Šilavotas subdivision in June. A hybrid breed of mirror carp ALxDOR70 (starting now – Mirror) was purchased, the larvae of which were injected into three separate ponds (Figure 1).

Lithuanian carp larvae of the Bubiai (starting now -Scaled) breed was also released into the same ponds as the control breed. Twenty-five thousand larvae of both carp varieties were injected into each pond. The initial mean weight of injected larvae was 4 mg. 0.9 ha breeding ponds of the same size, arranged parallel to each other, with an identical

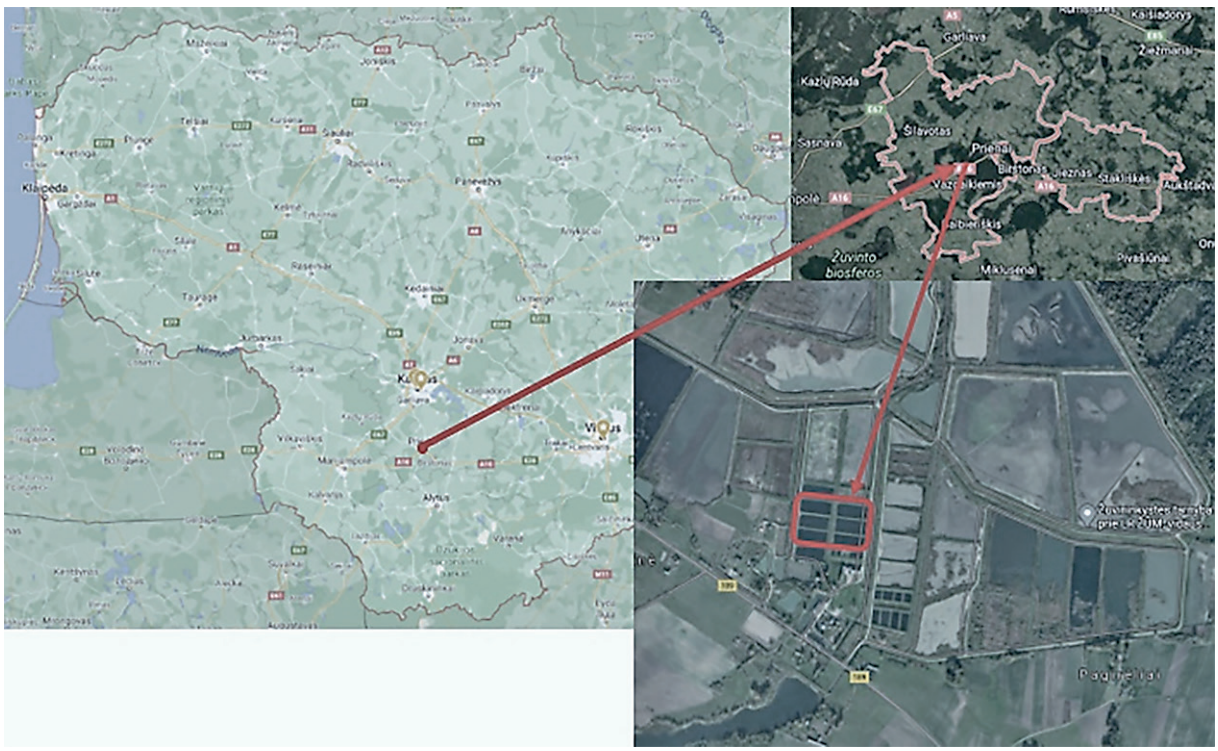

Fig. 1. Map of the study area

water supply and discharge system, were designated for the research. Investigations carried out: 2020, October 16–20, 2021, April 11–13 and October 1–3 and 2022, on April 29–May 1, during the regular carp breeding routine in fish farms.

During the study, the fish were fed with 3 groups of feed. Feeds were selected based on age groups of carp. Organic wheat is used for reared carp larvae. Flour was ground from the grains, which was mixed with a small amount of water and after forming lumps of about 10 cm in diameter, were introduced into the larval rearing ponds. Carps of one summer old were fed a specialized complete fish feed, which was made from wheat, soybean meal, corn, soybean concentrate, vegetable oil, sunflower meal, peas, vitamins, etc. This feed contains 25% protein. The pellets of such combined feed are 2–3 mm in size. Carps of other age groups were fed specialized complete feeds for two-year-old fish, which are made from wheat, soybean meal, corn, soybean concentrate, vegetable oil, sunflower meal, peas, vitamins, etc. This feed contains at least 20% protein. The pellets of such combined feed are 4–5 mm in size.

Fish were fed once a day. The amount of feed was calculated based on the amount of fish in the pond. Knowing the weight of the fish injected into the rearing pond and the standard feed ratio, the amount of feed needed to be fed is divided by the average number of feeding days. Feed rates are also affected by water temperature, dissolved oxygen in the water, disease, etc., so the amount of feed given can vary. During the entire study period, 830 kg of feed was used to feed Scaled carp and 1243 kg to feed Mirror carp.

Carps overwintered in identical conditions into 0.15 ha, 2.5 meters deep, parallel wintering ponds. Thirty individuals are taken randomly for measurements of carp of the same breed from each pond. The dimensions of each carp were measured with a marked measuring tape. The fishes were weighed with a metrologically tested scale with an accuracy of 0.01 g. The survival rate of larvae and juveniles of carp strains was also determined. Identical feeds were used for feeding the fish according to the age groups of the carp.

Temperature and dissolved oxygen were measured every day and the average monthly values were calculated.

Length-weight relationship data

The body length in centimetres and weight in grams of each carp strain were measured immediately after capture. The fish growth patterns were determined by equation (LeCren, 1951; Ricker, 1973):

$$W = a \times L^b, \tag{1}$$

where: W – body weight (g), L – total body length (cm), a – the intercept, b – the regression slope

Parameters a and b were determined according to the linear regression relationship between total length and weight to determine whether the growth pattern was similar or the same for the studied carp varieties. Therefore, the logarithmic transformation of equation (1) was used:

$$log_{10}W = log_{10}a + b \times log_{10}L, \tag{2}$$

where: W is the weight of the fish (g), and L is the length of the fish (cm). Parameter a is the intercept of the regression curve, and parameter b (slope of the regression curve) indicates the growth type: when $b = 3$, then isometric growth; when $b \neq 3$, then allometric growth (Ricker, 1973; Froese, 2006).

Specific growth rate (*SGR*) was calculated:

$$SGR = (lnW_F - lnW_0)/t \cdot 100, \tag{3}$$

where: SGR – specific growth rate (% in a day), W_F – Weight at the end of the experiment (g); W_0 – Weight at the start of the experiment (g), t – duration of the experiment (in days).

Condition factor (K) and relative condition factor (K_R)

The Condition Factor was used to determine the fish's condition and compare the investigated strains. Fulton's condition factor (K) was determined according to the formula (Fulton, 1902):

$$K = (\frac{W}{L^3}) \times 100, \tag{4}$$

where: K – Fulton's condition factor; W and L – are observed weight in g and length in cm. In this formula, b is equal to 3, which means that fish grow isometrically, i.e., the shape of the fish does not change as its length increases.

The Relative Condition factor (K_R) was determined according to (LeCren, 1957):

$$K_R = \mathrm{W}/aL^b \tag{5}$$

The formula members are the same as in formula (1).

Wintering yields were calculated as a percentage:

$$I = (N_c \times 100\%)/N_I, \tag{6}$$

where: I – wintering yield (%), N_C – the number of fishes caught (indiv.), N_I – the number of fishes injected to the pond (indiv.).

Statistical analysis

The growth model comparing the slope of the regression curve (b) was analysed according to (Froese, 2006; Okgerman, 2005): if $b < 3$, fish growth is negative allometry (body length grows faster than weight); if $b = 3$, isometric growth

(there is a balance between length and weight growth); if $b > 3$, positive allometry (weight grows faster than body length). A 95% confidence interval (level) (CL) was also determined for parameters *a, b*, *KF, KR* and *WR* (Froese, 2006). The correlation of Fulton's coefficient, Relative Condition coefficient and Relative Weight was tested using Spearman's rank correlation test. Regression analysis and line parameters *a* (intercept) and *b* (slope) were performed with log-transformed measurement. Statistical analysis for *a* and *b* was considered significant at $P < 0.001$; for Fulton's condition factor, Relative condition factor and Relative weight were considered significant at $P < 0.05$. To determine the isometric or allometric growth pattern, the exponent (*b*) of LWR was tested for significance by Fisher's t-test ($P < 0.05$). All data were checked for homogeneity of variance by the Levene test. ANOVA ($P < 0.05$) was performed using IBM SPSS software (version 20.0) to check whether the averages of length, weight, SGR and Fulton's condition factor between the two carp strain are statistically similar or different.

Results

Fluctuations in water temperature are typical for Lithuanian conditions, i.e. winter and summer seasons are distinguished. The oxygen content did not fall below the minimum concentration suitable for carp throughout the study period (Figure 2).

The survival rate of carp larvae is also related to the winter seasons. During the autumn weighing in 2020, it was determined that a small number of carp larvae (0+) of both varieties survived: only 20.84% of the individuals of the Scaled survived, while 37.90% of the individuals of the Mirror survived. In the spring of 2021, the Mirror carp had a high survival rate of 83.70%. In the meantime, only 23.49% of carp fry of the Scaled carp survived. Therefore, by observing the results of the autumn of 2021 and the spring of 2022, it can be conducted that the scaled carp had better survival rates (Figure 3). It should be emphasized that when analysing the number of carp individuals that survived throughout the study period, however, a more significant number of Mirror strain carp survived.

The first table shows the minimum, maximum and average length and weight data. Analysing the results, mirror carp brought from the Czech Republic were characterized

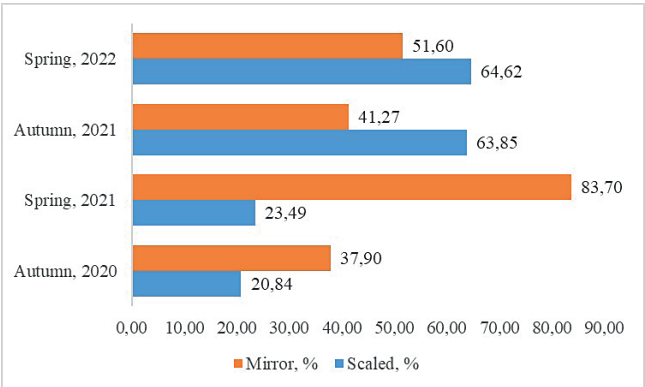

Fig. 3. Percentage of survival of Scaled and Mirror carp strains in different study periods

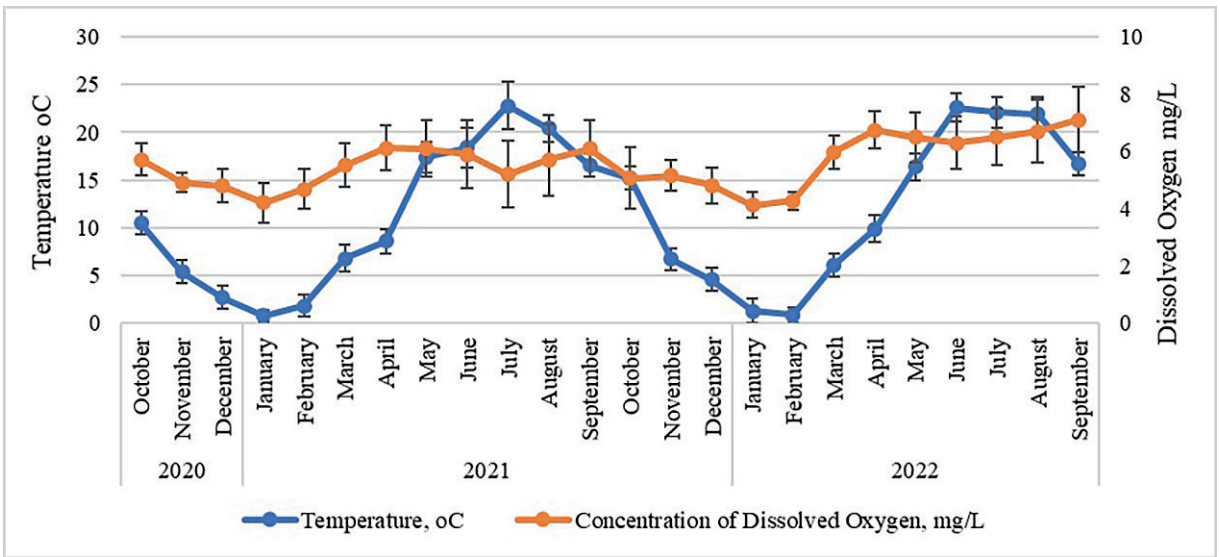

Fig. 2. Average monthly pond water temperature and dissolved oxygen content

by greater length and weight throughout the study period (Table 1). It should be noted that from the fall of 2020 to the spring of 2021, the average weight of the Scaled carp larvae decreased by 6.5%, while the average weight of the Mirror carp strain decreased by 2.2%. When measurements were measured in the fall of 2021, it was found that the average weight and length of both strains increased significantly. During the summer, the average weight of the Scaled carp increased almost 30 times, and the length increased almost three times; for the Mirror carp – the weight increased almost 16 times, and the length was 2.5 times. After the winter of 2022, the average weight of both varieties decreased by 3.2% and 7.2% for Scaled and Mirror carp, respectively. During the entire period of the study, carp of the Scaled carp had a low average weight compared to the average weight of mirror carp. The differences between length and weight were statistically significant ($P < 0.05$) (Table 2).

SGR values depended on the winter-summer seasons. After the winter season, weight loss was observed in both groups. Scaled carp lost less weight, but they gained less during the summer season. Differences in SGR values between strains were statistically significant ($P < 0.05$) during the entire study period. A positive SGR value was obtained in the period Spring, 2021 – Autumn, 2021. For Scaled carp, this value is 20% higher than for the Mirror carp strain.

The logarithmic transformation of LWR parameters, a (intercept), *b* (slope), 95% confidence limit (CL) of a and *b*, the determination coefficient r^2 and fish growth type are shown in Table 3. Examining the slope (*b*) values, the smallest b value was determined for carp of both varieties in the fall of 2021 (2.394 Scaled and 2.136 Mirror), while the highest values of parameter *b* were obtained in the spring of 2021 (2.951 Scaled and 2.704 for Mirror carp). Sufficiently high coefficient of determination for both species of carp throughout the study period (for Scaled carp – r^2 from 0.819 to 0.945 and for Mirror carp r^2 from 0.789 to 0.840), except for autumn 2021, when the coefficient of determination was the lowest for both species: 0.690 for Scaled and 0.568 for Mirror carp.

Fulton's condition factor (K_F), Relative condition factor (K_R), Relative weight (W_R) and 95% confidence level (CL) are shown in Table 4. Fulton's condition factor for carp of the Scaled strain ranged from 3.04±0.13 to 2.79 ± 0.21, and for carp of the Mirror carp, it varied from 2.87±0.17 to 2.65±0.10 throughout the study period. The mean Fulton's condition factor was higher throughout the study period in Scaled carp. This difference was statistically significant in Fall 2020, Spring 2021, and Spring 2022. In the fall of 2021, no statistically significant difference was found between the carp varieties in Fulton's condition factor. The average value

Table 1. The statistical description of length (L, cm) and body weight (W, g) of Scaled and Mirror carp strains during the study period

Season, year	The strain of Common carp	Length, cm			Weight, g		
		Min	Max	Mean ± SD	Min	Max	Mean ±SD
Autumn, 2020	Scaled	8.47	10.6	9.51* ± 0.57	18.33	36.00	26.45[a] ± 4.58
	Mirror	13.06	15.2	14.28[b] ± 0.59	63.00	103.67	83.85[b] ± 10.27
Spring, 2021	Scaled	8.67	10.37	9.40[a] ± 0.41	16.00	31.67	24.75[a] ± 3.42
	Mirror	13.40	15.30	14.29[b] ± 0.58	66.33	102.67	82.01[b] ± 10.02
Autumn, 2021	Scaled	27.23	31.07	29.51[a] ± 1.01	560.33	870.00	741.12[a] ± 71.74
	Mirror	34.03	37.67	35.72[b] ± 0.79	1117.33	1453,33	1280.91[b] ± 80.69
Spring, 2022	Scaled	26.87	35.33	29.45[a] ± 1.68	590.00	1166.67	717.33[a] ± 124.11
	Mirror	32.73	37.20	35.56[b] ± 1.01	980.00	1396.67	1193.00[b] ± 85.07

SD – Standard deviation; Values with different letter superscripts in a column are statistically different (P <0.05)

[a, b] Means with different superscript are significantly different at the $P < 0.05$

Table 2. Specific growth rate (SGR) of Mirror and Scaled carp during the experimental period

Season, year	The strain of Common carp	Days	Weight gain, W g	SGR
Autumn, 2020 – Spring, 2021	Scaled	243	-1.70 ± **0**.78[a]	-0.027[a] ± 0.045
	Mirror	243	-1.84 ± **0**.98[b]	-0.009[b] ± 0.006
Spring, 2021 – Autumn, 2021	Scaled	142	716.37[a] ± **3**7.58	2.394[a] ± 0.96
	Mirror	142	1198.90[b] ± **4**5.35	1.936[b] ± 0.56
Autumn, 2021 – Spring, 2022	Scaled	243	-23.790[a] ± 7.58	-0.013[a] ± 0.009
	Mirror	243	-87.910[b] ± 11.38	-0.029[b] ± 0.011

[a, b] Means with different superscript are significantly different at the $P < 0.05$

of the Relative condition factor for both breeds was similar and was about 1.00. The average values of Relative weight and Relative condition factor were obtained similarly for both breeds during the entire study period.

Spearmen's rank correlation showed a significant correlation ($P < 0.05$) between length with weight (L–W) and Fulton's condition factor with Relative condition factor throughout the study period (Table 5). For Mirror carp, the relationship between length and Fulton's condition factor was significant only in the spring of 2022. In comparison, weight relationships with Relative condition factors were significant in the fall of 2021 for both varieties and in the spring of 2022 only for Scaled carp.

Discussion

Whole-year fish breeding activities can be divided into two main categories: an active growing season in the sum-

Table 3. Length-weight relationships parameters of Scaled and Mirror carps during the study period

Season, year	Strain of Common carp	Regression equation	*a*	95% CL *a*	*b*	95% CL *b*	r^2	*p*-value	Growth type
Autumn, 2020	Scaled	LogW=2.816LogL-1.337	0.046	0.027 to 0.056	2.816	2.553 to 3.080	0.945	< 0.001	I
	Mirror	LogW=2.613LogL-1.096	0.080	0.066 to 0.084	2.613	2.091 to 3.135	0.789	< 0.001	A-
Spring, 2021	Scaled	LogW=2.951LogL-1.482	0.033	0.024 to 0.040	2.951	2.414 to 3.488	0.819	< 0.001	I
	Mirror	LogW=2.704LogL-1.211	0.061	0.048 to 0.077	2.704	2.247 to 3.160	0.840	< 0.001	A-
Autumn, 2021	Scaled	LogW=2.394LogL-0.652	0.222	0.214 to 0.363	2.394	1.774 to 3.015	0.690	< 0.001	A-
	Mirror	LogW=2.136LogL-0.210	0.616	0.436 to 0.908	2.136	1.415 to 2.856	0.568	< 0.001	A-
Spring, 2022	Scaled	LogW=2.521LogL-0.851	0.141	0.133 to 0.153	2.521	2.063 to 2.978	0.819	< 0.001	A-
	Mirror	LogW=2.249LogL-0.412	0.387	0.377 to 0.401	2.249	1.825 to 2.673	0.808	< 0.001	A-

a- intercept (parameter of the equation); 95% CL *a* – 95% confidence level of a parameter; *b* – slope (parameter of the equation); 95% CL *b* – 95% b confidence level of *b* parameter; r^2 – coefficient of determination; I – Isometric; A- – negative allometric

Table 4. Fulton's condition factor (K_F), Relative condition factor (K_R) and Relative weight (W_R) of the Scaled and Mirror carp during the study period

Season, year	The strain of Common carp	K_F	*p-value*	K_F 95% CL	K_R	K_R 95% CL	W_R	W_R 95% CL
Autumn, 2020	Scaled	$3.04^a \pm 0.13$	<0.05	2.99 – 3.09	1.00 ± 0.04	0.985 – 1.01	100.30 ± 4.21	98.73 – 101.87
	Mirror	$2.87^b \pm 0.17$		2.81 – 2.93	1.00 ± 0.05	0.980 – 1.02	100.36 ± 5.59	98.27 – 102.44
Spring, 2021	Scaled	$2.96^a \pm 0.17$	< 0.05	2.89 – 3.02	1.00 ± 0.05	0.978 – 1.02	100.04 ± 5.95	97.82 – 102.26
	Mirror	$2.80^b \pm 0.14$		2.74 – 2.85	1.00 ± 0.05	0.982 – 1.02	100.83 ± 4.89	99.00 – 102.66
Autumn, 2021	Scaled	$2.85^a \pm 0.25$	>0.05	2.76 – 2.94	1.00 ± 0.08	0.971 – 1.03	100.53 ± 7.86	97.59 – 103.46
	Mirror	$2.81^a \pm 0.13$		2.76 – 2.86	1.00 ± 0.04	0.985 – 1.02	100.15 ± 4.09	98.62 – 101.67
Spring, 2022	Scaled	$2.79^a \pm 0.21$	< 0.05	2.71 – 2.87	1.00 ± 0.07	0.975 – 1.02	100.02 ± 6.86	97.46 – 102.56
	Mirror	$2.65^b \pm 0.10$		2.61 – 2.68	1.00 ± 0.03	0.989 – 1.01	100.07 ± 3.16	98.89 – 101.26

Values with different letter superscripts in a column are statistically different ($p < 0.05$)

Table 5. Spearman rank correlation for Length (L), body Weight (W), Fulton's condition factor (K_f) and Relative condition factor (K_R) of Scaled and Mirror carp during the study period

Season, year	The strain of Common carp	*L-W*	L-K_F	L-K_R	W-K_F	W-K_R	$K_F - K_R$
Autumn, 2020	Scaled	0.967*	-0.268	0.069	-0.062	0.279	0.900*
	Mirror	0.931*	-0.286	-0.015	0.049	0.320	0.936*
Spring, 2021	Scaled	0.937*	-0.077	-0.001	0.190	0.270	0.991*
	Mirror	0.922*	-0.222	-0.015	0.102	0.306	0.964*
Autumn, 2021	Scaled	0.643*	-0.431	0.225	0.272	0.792*	0.704*
	Mirror	0.807*	-0.298	0.075	0.256	0.609*	0.867*
Spring, 2022	Scaled	0.857*	-0.161	0.187	0.199	0.552*	0.857*
	Mirror	0.851*	-0.547*	-0.077	-0.099	0.385	0.853*

*Correlation is significant at the $P < 0.05$ level

mer and an inactive period in winter (Horvâth et al., 2022). Therefore, one of the most critical indicators in pond fisheries is fish wintering yield (survival). According to Horvâth et al. (2022), the standard one-summer fry survival is 5–30%, one-year-old – 50–70%, and the survival rate of second-year carp grown in ponds is about 60–80% during the winter season. The survival results obtained in this study are similar to those reported in the previously mentioned source. In autumn 2020 and spring 2021, the survival rate was higher for Mirror carp. The survival rate of the Mirror carp (83.70%) in the spring of 2021 stands out. It can be said that the high survival rate of Mirror carp in the spring of 2021 was due to a hot summer and relatively high-water temperature. The Lithuanian carp breed is adapted to grow at lower water temperatures. However, the better survival rate for autumn 2021 and spring 2022 is for Scaled carp, although it is lower than that reported by Horvâth et al. (2022). In some scientific articles, second-year survival rates are higher than in our study. For example, in the study conducted by Mocanu et al. (2015), the survival of carp reached 67-70%, and in the article by Petrea et al. (2017), it is stated that the survival of carp in ponds reached 73–84%. Several factors can contribute to the low survival rate. Differences in the density and average weight of individual fish species, the amount of oxygen dissolved in the water, the availability of feed, or possible diseases could have influenced the studied breeds in winter. Also, during winter, with favourable temperatures, a layer of ice does not form on the water's surface. As a result, birds and predatory animals can feed on wintering fish and cause considerable damage (Hurst, 2007).

According to the technological norms of fish breeding in fishponds in Lithuania, carp larvae should reach an average weight of 25 g during the summer. Based on these norms, it can be concluded that carp of the Mirror carp strain reached an extremely high weight, exceeding these norms several times. Meanwhile, there were carp of the Scaled carp that did not reach the weight limit of 25 g. The high mortality and low weight gain of Scaled carp could have happened because the water temperature during incubation in the spring of 2020 was 16–17°C, while the recommended incubation temperature for carp eggs is 26°C (Sapkale et al., 2011); another article claims that incubation was carried out at a water temperature of 22–25°C (Cho et al., 2015). Therefore, the health status of the larvae could have been better.

During the winter, carp lose some of their body mass. After wintering, both types of carp did not lose more than 10% of their body mass: Scaled lost 3.3%, Mirror – about 6.9%. Therefore, carp were not fed additionally during the winter. As in the previous measurements, in the spring of 2022, Scaled carp had a lower weight. Their body mass was 40% lower than the mass of Mirror carp hybrids (Table 1). Scaled carp may have gained less weight for several reasons: due to the higher number of Mirror carps, which could dominate the feeding time.

As recommended (Froese, 2006), when selecting individuals for weight and length data collection, the size range of the fish to which the length–weight relationship will be applied should be included. It is not recommended to include fry and fingerlings in the overall calculations because fish at these age stages do not yet have the body shape characteristic of an adult fish. If necessary, the same author suggests evaluating the length-weight ratio for different growth phases, which was done in this study. The LWR results were similar to many other studies of carp growth parameters (Eljasik et al., 2022; Andrabi et al., 2021; Sánchez-González et al., 2020; Massod et al., 2022; Varga et al., 2021), although the r^2 values obtained in this study are lower than in the cited studies. In the cited studies, LWRs were determined in warm climate zones in carp living in natural water bodies or cultured in fibreglass or concrete tanks, such as, e. g. Gümüş et al. (2022).

The slope parameter b is used to describe the growth pattern of the fish: allometric growth, when $b \neq 3$, means either an increase in fish length ($b < 3$) or an increase in fatness ($b > 3$). Isometric growth describes the growth of fish when weight and length increase proportionally ($b = 3$) (Ricker, 1958; Ricker, 1973; Froese, 2006). Of course, during the study, it was expected that the value of the parameter b would be close to 3. Throughout the study period, the parameter b values of the Scaled carps were higher than those of the Mirror carps. Similar results were obtained when studying the growth parameters of Scaled and Mirror carp, which were grown in fibreglass and concrete pools (Gümüş et al., 2022). The spring 2021 results showed that the value of b was not statistically different (t-test, $p < 0.05$) from the value of 3. Therefore, the model of growth parameters was isometric. Sufficiently high coefficient of determination for both carp species throughout the study period (for Scaled carp – r^2 from 0.819 to 0.945 and for Mirror carp r^2 from 0.789 to 0.840), except for autumn 2021, when the coefficient of determination was the lowest for both species, shows that length increases with increasing for weight. However, the b value was less than 3 (Fisher's t-test, $p < 0.05$). Thus, fish growth shows negative allometry that does not follow the cube law. It can be concluded that the weight of the carp under study increases in a smaller proportion than its length cubed. LWR can be influenced by many factors, such as the season of the year, feeding (feeding), living environment (habitat), health, and availability of food (Cox & Hinch, 1997; Horváth et al., 2022). Fish weight depends on fish well-being, affecting the length-weight ratio (Froese, 2006).

For the interpretation of the parameter *b* values, one can refer to Froese (2006), who states that it is best when the parameter b is between 2.5 and 4.0. Scaled carp growth parameter b during the study was more than 2.5 (from 2.521 to 2.951). Meanwhile, in the fall of 2021 and the spring of 2022, the Mirror carp growth parameter b was lower than 2.5 (2.136 and 2.249, respectively). In this case, Scaled carp perform better than Mirror carp.

Fulton's condition factor is widely used in fisheries. This ratio is calculated as the ratio of fish weight to length to describe the quality of life of individuals (Nash et al., 2006). Fulton's condition factor is used to compare and explain differences in the growth of different fish populations. As stated in the article (Lemma et al., 2015), this factor is like an indicator that reflects the interaction between biotic and abiotic factors and the physiological condition of fish. Other authors (Nehemia et al., 2012) claim that Fulton's condition factor shows the suitability of the living environment for fish. A Fulton's condition factor greater than 1 means that the living conditions of the fish are relatively good (Wade, 1992). However, after the wintering period or spawning, as well as in case of lack of feed, Fulton's condition factor values may be lower than 0.8.

According to 2020, the results of the measurements obtained during the autumn and spring 2021 harvesting, the values of Fulton's condition factors between Scaled and Mirror differed significantly ($p < 0.05$). However, in 2021 in the results obtained during the autumn study, the similarity of the values of Fulton's condition factors between the research groups was observed, as the differences in the values of these factors are statistically insignificant. During the entire study period, the value of the Fulton coefficient was more significant than 1; therefore, according to Wade (1992), Nehemia et al. (2012), it can be said that the habitat conditions of the fish are good. However, too high a condition factor can affect the health of the fish and the improper ratio of proteins and fats in the body. These reasons can lead to lower disease resistance, growth rate and winter yield. The results obtained in this study are similar to those reported in Andrabi et al. (2021) article but different from those published by (Massod et al., 2022). This can be explained by the fact that many studies were carried out in warm climate zones, where the ambient and water temperatures change little in individual seasons.

Average values of the relative condition factor (K_R) were obtained around 1 for both species, which suggests that these species are in good condition and the biotope is suitable for them to live. These results correlate well with the results published by Sánchez-González et al. (2020).

In autumn 2020 and spring 2021, the mortality was higher for Scaled carp, but later mortality was higher for mirror carp varieties. However, the Mirror carp's length and weight were significantly higher than the Scaled carp. Comparing the values of Fulton's condition factor, higher values were obtained for Scaled carp than for Mirror during the entire study period. Despite the apparent differences between Scaled and Mirror carp, Mirror carp juveniles have adapted well to live in the Lithuanian climate. They can be used to improve carp breeds grown in Lithuania.

Conclusions

Survival in the first year was higher in the Mirror carp strain, but in the second year of the study, the higher survival percentage was in the Scaled carp. However, the Mirror carp dominated in terms of weight and length. The results obtained during the study indicate a negative allometric growth pattern for both Scaled and Mirror carp. However, Scaled carp growth parameter *b* was more significant than 2.5 throughout the study. In addition, the Condition factor was found to be greater than one throughout the study period, indicating that the living conditions are suitable and that the Mirror carp have adapted to the new conditions.

The vital information provided in this study is related to the growth parameters and Condition factors of Mirror (ALXDOR70) and Scaled (Bubiai) carp in the Šilavotas breeding farm. The results obtained in the study can be used to understand the frameworks related to domestication and management for the adaptation of new carp breeds and breeding in fish farms (stakeholders).

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Received: **July, 23, 2023**; *Approved*: **June, 01, 2024; *Published:*** **June, 2025**