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RESEARCH ARTICLE

Effect of environmental temperature on fecundity of *Rutilus rutilus* (L.) (Cypriniformes, Cyprinidae) in different types of water bodies in southern Western Siberia

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Abstract

The data on individual absolute and relative fecundity, and gonadosomatic index of roach *Rutilus rutilus* (L.) from different types of water bodies in southern Western Siberia: Lake Chany, the Novosibirsk Reservoir, and the Middle Ob are presented. The reproductive capacity of *R. rutilus* is vary widely and increase with age and size of female species. The roach from Lake Chany exhibit higher reproductive capacity compared to the Novosibirsk Reservoir and the Middle Ob. Furthermore, same-age roach specimens from Lake Chany and the Middle Ob have significant interannual differences in the reproductive indicators. The individual absolute fecundity of roach is statistically significantly related to water temperature at onset of oocytes trophoplasmic growth in the previous year, which occurs in mid-June in Lake Chany and mid-July in the Middle Ob.

Keywords

Roach, *Rutilus rutlius*, fecundity, natural resource management, Ob, Siberia

Introduction

Fecundity is a critical characteristic of fish species and individual populations that reflects their adaptive response to various habitat conditions. In many cases, fecundity variations can serve as an indicator for predicting the status of aquatic biological resources (Nikolsky 1963; Chen et al. 2022). *Rutilus rutilus* is a widespread species in Eurasia (Froese, Pauly 2025). Roach is a common native fish species to rivers and lakes in Western Siberia, it has historically held significant importance in the fisheries (Popov 2006). Currently, the total annual catch of roach in water bodies of southern Western Siberia amounts to 1.9 thousand tons, with the species accounting for 18–19% of the total fish catch in Lake Chany and the Middle Ob basin within Tomsk region (Interesova and Rostovtsev 2021; Abramov et al. 2023). The substantial role of roach in the fisheries boosts the need for deeper understanding of the factors and mechanisms that affect this economically valuable fish species in order to enhance the accuracy of its stock assessment.

Roach is a highly adaptable species characterized by significant variability in fecundity estimates (Ioganzen and Petkevich 1958; Liu 1963; Spanovskaya et al. 1966; Mann 1973; Vøllestad and L'Abée-Lund 1990; Lappalainen et al. 2008; Başkurt et al. 2015; Ivancheva and Ivanchev 2019). It is known that the fecundity estimates of *R. rutilus* are hereditary (Izyumov et al. 1983), they are closely related to growth rate, condition factor, and fatness index, which indicates that the species is highly dependent on feeding conditions (Ioganzen and Petkevich 1958; Volodin 1963; Kraynyuk et al. 2015). Interannual variability of roach fecundity has been described for several water bodies (Manadeeva 1953; Spanovskaya et al. 1966; Kulikova 1962; Nikonov 1977; Zhuravlev 2018). The reproductive capacity of roach is vary across different types of water bodies (Manadeeva 1953; Ioganzen and Petkevich 1958; Kulikova 1962; Mann 1973; Nikonov 1977; Vøllestad and L'Abée-Lund 1990; Zinoviev and Trenogn 2005; Lappalainen et al. 2008; Başkurt et al. 2015; Kraynyuk et al. 2015). The many researchers emphasize the hydrological regime as the primary predictor of interannual variability in roach fecundity – low water levels, particularly in spring, have an adverse effect on food supply, in particular for roach, leading to reduced fecundity (Ioganzen and Petkevich 1958; Nikonov 1977; Ivancheva and Ivanchev 2019). Siberian ecosystems are undergoing transformation due to climate change (Kirpotin et al. 2021), making analysis of the relationship between fecundity of fish and temperature particularly important, since little attention had been paid to this factor previously. This study aimed to conduct a comparative analysis of *R. rutilus* reproductive capacity indicators in the large water bodies of southern Western Siberia (Lake Chany, the Novosibirsk Reservoir and the Middle Ob) and assessment the relationship between the fecundity, water temperature and level regime.

Materials and methods

Fish specimens were collected from large water bodies of different types in southern Western Siberia during the early spring, pre-spawning period for roach. The sampling localities included Lake Chany near to Novorosino village (54°38' N; 77°46' E), Kupinsky district, Novosibirsk region; Novosibirsk Reservoir near to Beregovoye village (54°39' N; 82°30' E), Novosibirsk district, Novosibirsk region, and the Middle Ob near to Krivosheino village (57°20' N; 83°55' E), Krivosheinsky district, Tomsk region. These water bodies are situated in similar climatic conditions but differ significantly from one another. Lake Chany is located in the Ob-Irtysh interfluve and classified as an endorheic lake, primarily fed by water runoff from the Kargat and Chulym rivers, as well as precipitation and groundwater. The area of the lake varies greatly from year to year depending on water levels; in the long-term period, it tends to decrease, currently amounting to about 2000 km². The maximum lake depth reaches up to 8 m, with an average depth of 2 m. Increased water mineralization is observed in most of its reaches. In the Ob River, a dam of the Novosibirsk HEPP formed the Novosibirsk Reservoir in 1957–1959, with a maximum depth of 25 m and an average depth of 8 m. Its area is slightly more than 1000 km². The Middle Ob stretches from the estuary of the Tom River to the estuary of the Irtysh River. In this part, the river valley extends up to 50 km, with a floodplain reaching up to 30 km. The riverbed is divided into many branches and arms, and numerous lakes and oxbow lakes are situated within the floodplain. The riverbed depth can reach 4 to 8 m during low water period.

During sampling for fecundity, the standard length and weight of fish specimens were measured, scales were collected for determine age, and the gonad weight was estimated using conventional methods (Pravdin 1966; Petlina 1987). Eggs were collected from fish of different ages at maturity stage IV. The collection was conducted from several parts of the ovaries, with a total sample weight of 1.1–1.5 g. The samples were fixed in a 2% formalin solution for subsequent egg counting in the laboratory. A total of 116 specimens were collected in 2024 (Lake Chany – 50 specimens, Novosibirsk Reservoir – 22 specimens, Middle Ob – 44 specimens), and 113 specimens in 2025 (Lake Chany – 45 specimens, Middle Ob – 68 specimens). After counting the eggs, individual absolute fecundity (IAF), individual relative fecundity (IRF) and gonadosomatic index (GSI) were calculated. The GSI was calculated as the percentage of the gonad weight to fish weight (excluding entrails). In addition, archival data on roach fecundity in Lake Chany for 2004 (21 specimens) and in the Middle Ob for 2005 (20 specimens), 2006 (14 specimens), and 2007 (18 specimens) were used. Fish age was determined by one operator. The water level regime of the Middle Ob (Kargasok village) was characterized by estimating the inundation duration for 20% of the floodplain (the number of days when the water level exceeded 900 cm above the zero point), and for 60% of the floodplain (the number of days when the water level exceeded 1000 cm above the zero point). The water level regime of Lake Chany was characterized by the average water level in May–August.

Data on temperature and water level for the Middle Ob and Lake Chany were provided by the Federal State Budgetary Institution "West Siberian Department for Hydrometeorology and Environmental Monitoring".

The correlation between IAF, IRF, GSI and age, size characteristics of roach, the water level regime and temperature during the first half of summer in the year preceding sampling, was assessed through calculation of Pearson's correlation coefficients (r). The relationship between IAF and water temperature was determined using regression equations. To evaluate interannual differences in fecundity of same-age roach specimens (most abundant group of four- and five-year-old fish) from Lake Chany and the Middle Ob over the last decade, the analysis of variance (ANOVA) was employed. The normality of distribution was assessed using the Shapiro-Wilk test. To determine the significance of differences in the reproductive capacity of fish across different years, the Tukey's pairwise comparison test was used. The Kruskal-Wallis test was applied to assess differences in fecundity of roach across different types of water bodies. Statistical significance of differences and correlations was evaluated at $\alpha = 0.05$. All calculations were performed using Past 4.03 (Hammer 2024).

Results

The data obtained indicate significant differences in roach fecundity in water bodies of southern Western Siberia. In Lake Chany, IAF ranges from 9.98 to 81.82 thousand eggs (27.23 thousand on average), and IRF ranges from 125 to 363 eggs (213 on average). In the Novosibirsk Reservoir, IAF ranges from 4.12 to 29.93 thousand eggs (12.54 thousand on average), and IRF ranges from 89 to 232 eggs (136 on average). In the Middle Ob, IAF varies from 3.56 to 63.17 thousand eggs (15.59 thousand on average), and IRF ranges from 80 to 234 eggs (154 on average) (Tables 1, 2).

Table 1. Individual absolute fecundity of *Rutilus rutilus* in different types of water bodies in southern Western Siberia (thousand eggs)

Water body, year of material collection	Age				
	3	4	5	6	8
Lake Chany, 2004	–	21.20±1.59 17.49-25.77	31.49±0.47 28.16-32.93	35.83±1.31 33.47-39.45	–
Lake Chany, 2024	17.16±1.31 12.44-20.55	22.82±1.39 14.92-31.76	33.88±1.71 22.88-49.98	52.92±6.59 36.18-81.82	–
Lake Chany, 2025	16.41±0.76 9.98-25.65	21.65±1.50 12.94-29.64	34.62±3.06 24.39-54.17	–	–
Middle Ob, 2005	5.97±0.18 5.78-6.34	9.44±0.27 7.39-11.39	13.98±1.05 10.05-15.91	–	–
Middle Ob, 2006	6.02	10.01±0.53 7.45-11.57	16.24±1.09 13.26-20.52	–	–

Water body, year of material collection	Age				
	3	4	5	6	8
Middle Ob, 2007	9.17±0.54 8.10-9.74	11.295±0.285 10.06-12.73	15.90±0.39 14.07-17.15	–	–
Middle Ob, 2024	4.88±0.75 3.56-6.16	11.49±0.93 7.91-17.73	16.89±2.78 9.52-26.58	–	54.44
Middle Ob, 2025	7.62±0.69 5.89-10.67	10.88±0.50 6.90-14.59	18.89±0.78 13.09-30.57	32.66±1.74 20.88-43.17	63.17
Novosibirsk Reservoir, 2024	5.35±0.51 4.12-6.20	11.36±0.77 8.74-16.56	19.71±3.09 11.65-29.93	–	–

Note: in Tables 1-3, the mean and standard errors are shown above the line, the limits of fluctuations are shown below the line. Deviation for each age are indicated the average values and are shown above the line, and the limits of fluctuations of the indicators are shown below the line.

Table 2. Individual relative fecundity of *Rutilus rutilus* in different types of water bodies in southern Western Siberia (eggs/g)

Water body, year of material collection	Age				
	3	4	5	6	8
Lake Chany, 2004	–	195±14 163-246	209±09 165-271	210±18 174-253	–
Lake Chany, 2024	198±13 141-238	210±12 126-300	212±11 136-356	245±23 182-363	–
Lake Chany, 2025	199±08 125-276	217±16 129-330	250±10 189-286	–	–
Middle Ob, 2005	113±07 92-114	110±03 107-137	126±05 113-145	–	–
Middle Ob, 2006	114	121±03 109-133	149±04 140-168	–	–
Middle Ob, 2007	165±13 142-187	162±06 137-194	172±06 144-192	–	–
Middle Ob, 2024	98±10 81-116	134±10 80-212	149±19 103-218	–	190
Middle Ob, 2025	152±11 118-183	159±06 116-207	182±06 117-223	183±07 124-234	147
Novosibirsk Reservoir, 2024	107±07 93-121	132±10 89-213	161±16 126-232	–	–

GSI varies between 12.66 and 32.88 (22.13 on average) in Lake Chany, between 13.8 and 20.52 (15.92 thousand on average) in the Novosibirsk Reservoir, and between 11.48 and 26.01 (18.19 on average) in the Middle Ob (Table 3).

Table 3. Gonadosomatic index of *Rutilus rutilus* in different types of water bodies in southern Western Siberia (in percent)

Water body, year of material collection	Age				
	3	4	5	6	8
Lake Chany, 2004	–	22.48±1.86 15.62-26.22	25.03±0.98 20.06-31.42	24.58±2.27 21.62-31.27	–
Lake Chany, 2024	22.54±1.13 16.33-25.16	23.96±1.36 14.65-32.39	25.59±0.69 20.12-36.62	28.02±1.25 24.05-32.88	–
Lake Chany, 2025	16.32±0.53 12.66-22.10	17.39±0.61 13.46-21.70	20.82±1.02 16.98-27.46	–	–
Middle Ob, 2005	14.07±1.11 12.77-16.28	15.27±0.64 10.32-19.22	16.76±0.54 15.65-18.13	–	–
Middle Ob, 2006	15.75	14.51±0.85 11.45-17.16	17.02±0.20 16.40-17.79	–	–
Middle Ob, 2007	17.07±1.08 15.35-19.06	16.94±0.53 14.71-19.41	18.38±0.56 16.13-20.62	–	–
Middle Ob, 2024	15.08±0.64 13.80-15.73	15.95±0.71 11.33-20.52	17.96±0.67 16.67-20.35	–	18.72
Middle Ob, 2025	14.92±0.77 13.00-18.81	17.06±0.42 14.62-21.35	18.87±0.48 14.05-23.28	20.04±0.712 15.88-26.01	22.43
Novosibirsk Reservoir, 2024	14.76±0.55 13.80-15.73	15.38±0.81 11.33-20.52	17.79±0.57 16.67-20.35	–	–

Our data indicate a statistically significant increase in IAF with age ($r = 0.8751$, $p < 0.001$), standard length ($r = 0.9084$, $p < 0.001$), and weight ($r = 0.9429$, $p < 0.001$). IRF increases at a slower rate, yet the increase with age, standard length and weight is also statistically significant ($r = 0.4413$, $p < 0.001$; $r = 0.3104$, $p < 0.001$ and $r = 0.2882$, $p = 0.001$, respectively). GSI exhibits a similar trend ($r = 0.5569$, $r = 0.4721$, and $r = 0.4489$, respectively, at $p < 0.001$).

Comparison of the reproductive capacity indicators of same-age roach specimens across different years in the last decade revealed statistically significant differences in the Middle Ob (ANOVA: IAF $F = 5.713$, $p = 0.0004$; IRF $F = 22.113$, $p = 0.0000$; GSI $F = 5.791$, $p = 0.0003$). In 2005, IAF and GSI were significantly lower compared to 2025 (Tukey's test: IAF $p = 0.0038$; GSI $p = 0.0077$). IRF in 2005 was lower than in 2007 and 2025 (Tukey's test: $p = 0.0001$), and it was lower in 2006 compared to 2025 (Tukey's test: $p = 0.0124$). In 2007, IRF was higher than that in 2024 (Tukey's test: $p = 0.0046$), while in 2024, it was lower than that in 2025 (Tukey's test: $p = 0.0002$). For roach from Lake Chany, statistically significant interannual differences were observed only for GSI (ANOVA: $F = 19.690$, $p = 0.0000$), which was higher in 2025 compared to 2004 (Tukey's test: $p = 0.0003$) and 2024 (Tukey's test: $p = 0.0001$).

The predominant groups of roach with a standard length of 170 to 190 mm from Lake Chany, the Novosibirsk Reservoir and the Middle Ob were taken to compare

IAF, IRF and GSI in different types of water bodies. To exclude the impact of inter-annual variability, the comparison was conducted using data obtained during one year. The results revealed that roach from Lake Chany exhibit significantly higher reproductive capacity (Kruskal-Wallis test: IAF $H = 23.165$, $p = 0.0000$; IRF $H = 518.634$, $p = 0.0001$; GSI $H = 21.771$, $p = 0.0000$) (Fig. 1).

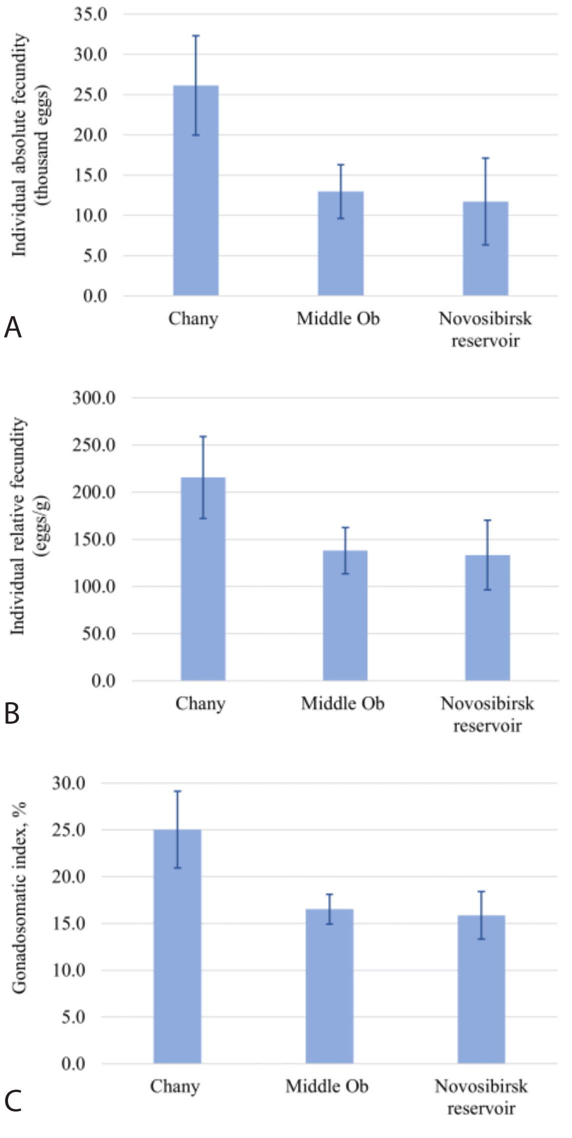

Figure 1. Reproductive capacity of *Rutilus rutilus* specimens with a standard length of 170 to 190 mm in Lake Chany, the Novosibirsk Reservoir, and the Middle Ob: IAF (**A**), IRF (**B**), and GSI (**C**). Average values and standard deviations.

Discussion

A statistically significant increase in IAF with age, standard length, and weight observed in roach from large water bodies in southern Western Siberia is consistent with the established patterns regarding the variability of this indicator in fish, specifically in roach (Ioganse and Petkevich 1958; Nikolsky 1965; Shatunovsky and Ruban 2010; Ivancheva and Ivanchev 2019; Kyritsi and Kokkinakis 2020; Chen et al. 2022). A slower increase in IAF, and in some cases a decrease in older age groups, is also characteristic of roach (Ivancheva and Ivanchev 2019). The higher reproductive capacity indicators of this species in Lake Chany were expected, as this shallow, stagnant water body is known for its greater productivity compared to other studied water bodies (Review… 2015; Gundrizer et al. 2000; Savkin et al. 2014), and it provides more favorable trophic conditions for roach. Comparison of our data on roach fecundity over the past decade with those obtained in the middle part of the 20th century (Ioganse and Petkevich 1958; Kulikova 1962) revealed a significant increase in IAF in recent years. IAF of four- and five-year-old roach in Lake Chany was, on average, 2.5 to 2.7 times lower in 1957–1958 compared to 2024–2025, while in the Middle Ob, it was 2.7 to 3.0 times lower in 1948 compared to 2024–2025 (Fig. 2).

The correlation between IAF, IRF, and GSI of the most abundant age groups (four- and five-year-old roach) in the Middle Ob, and the duration of spring floodplain inundation and water temperature in the first half of summer was analyzed in the year preceding sampling. The analysis revealed a statistically significant effect of water temperature in July on both IAF and GSI. No correlation was found with the duration of floodplain inundation (Table 4).

The dependence of IAF on water temperature during the second ten-day period of July is well described by the equations: y = 0.3676x + 17.227 (R^2 = 0.759) for four-year-old roach and y = 3.6545x – 61.134 (R^2 = 0.875) for five-year-old roach.

The correlation between IAF, IRF and GSI of same-age roach specimens from Lake Chany and the average water level in the lake from May to August and water temperature during the first half of summer was analyzed in the year preceding sampling. The analysis revealed a statistically significant effect of water temperature in June on IAF. No correlation with the water level in the lake was found (Table 5).

The dependence of IAF on water temperature during the second ten-day period of June is well described by the equations: y = 0.3167x + 14.371 (R2 = 0.823) (R^2 = 0.823) for four-year-old roach and y = 4.1212x – 55.796 (R^2 = 0.849) for five-year-old roach.

Apparently, higher temperatures of water at onset of oocytes trophoplasmic growth contribute to increased fecundity of the species in the following year. Interestingly, roach from Lake Chany and the Middle Ob exhibit different periods affecting to IAF: June for Lake Chany and July for the Middle Ob. This discrepancy likely reflects different timing of the life cycle stages and, consequently, oogenesis: in Lake Chany, roach spawns in late April to early May, whereas spawning in the Middle Ob occurs in the second half of May.

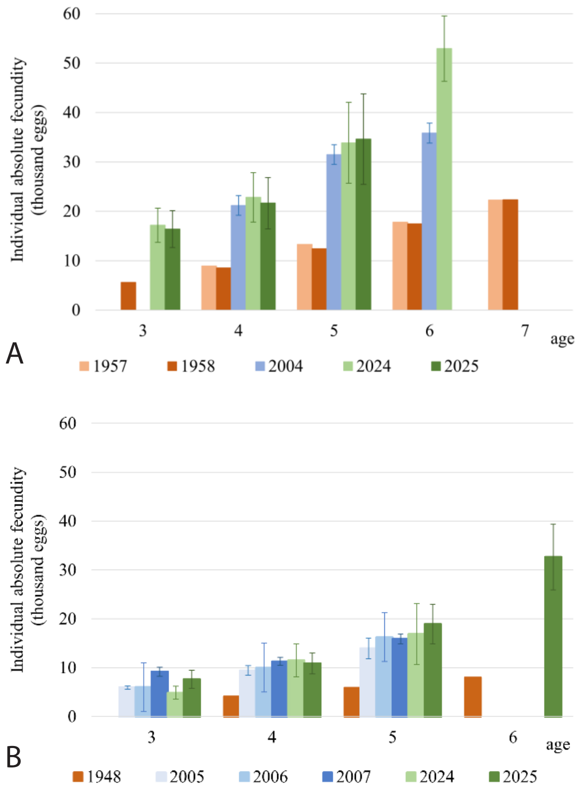

Figure 2. Long-term dynamics of absolute fecundity of *Rutilus rutilus* specimens of different ages in Lake Chany (**A**) and the Middle Ob (**B**). Average values and standard deviations. Data on roach fecundity obtained in the middle part of the 20th century by Kulikova (1962) for Lake Chany and by Iogansen and Petkevich (1958) for the Middle Ob.

Table 4. Pearson correlation between the reproductive capacity of *Rutilus rutilus* in the Middle Ob, water temperature and the duration of floodplain flooding (r, p-value)

Characteristics of the environment		**IAF at age**		**IRF at age**		**GSI at age**	
		4	**5**	**4**	**5**	**4**	**5**
Duration of flooding of 20 % of the floodplain area, days		-0.2490 0.634	-0.6540 0.902	0.4089 0.421	0.5096 0.302	0.5491 0.338	0.4972 0.94
Duration of flooding of 60 % of the floodplain area, days		-0.3948 0.439	-0.1988 0.706	0.3777 0.460	0.5927 0.215	0.5390 0.349	0.5351 0.353
Water temperature, June	first ten days	-0.2651 0.612	-0.4501 0.370	-0.4754 0.341	-0.3377 0.513	-0.4171 0.485	-0.4858 0.407
	second ten days	-0.1093 0.837	0.1162 0.826	0.392 0.941	0.1414 0.789	0.1013 0.871	0.1014 0.871
	third ten days	0.4172 0.410	0.4759 0.340	0.1847 0.726	-0.1416 0.789	0.3200 0.600	0.1442 0.817

Characteristics of the environment		IAF at age		IRF at age		GSI at age	
		4	5	4	5	4	5
Water temperature, July	first ten days	0.7442 0.90	0.7614 0.079	0.2994 0.564	-0.1074 0.840	0.1491 0.811	0.2882 0.638
	second ten days	**0.8712** **0.024**	**0.9351** **0.006**	0.4947 0.318	0.0053 0.992	0.7605 0.136	**0.9136** **0.030**
	third ten days	**0.9143** **0.011**	**0.9330** **0.007**	-0.0960 0.856	-0.5650 0.243	-0.0242 0.969	0.1098 0.861

Table 5. Pearson correlation between the reproductive capacity of *Rutilus rutilus* in Lake Chany, water temperature and the duration of floodplain flooding (r, p-value)

Characteristics of the environment		IAF at age		IRF at age		GSI at age	
		4	5	4	5	4	5
Average water level in May–August		0.4633 0.432	0.5030 0.388	0.8037 0.101	0.6632 0.222	-0.3326 0.784	0.4330 0.715
Water temperature, June	first ten days	0.7813 0.119	0.7289 0.162	0.5250 0.364	0.1393 0.823	0.9210 0.255	0.8733 0.324
	second ten days	**0.9070** **0.034**	**0.9214** **0.026**	0.6944 0.193	0.7557 0.140	-0.7049 0.502	-0.6237 0.571
	third ten days	0.4787 0.415	0.5296 0.359	0.4898 0.402	0.7622 0.134	-0.8355 0.370	-0.7709 0.440
Water temperature, July	first ten days	0.4417 0.0456	0.4508 0.446	0.0011 0.999	0.3420 0.573	-0.2707 0.826	-0.1645 0.895
	second ten days	0.6421 0.243	0.6834 0.203	0.8092 0.097	0.7774 0.122	-0.4398 0.710	-0.5348 0.641
	third ten days	0.5907 0.294	0.6277 0.257	0.6861 0.201	0.9890 0.198	-0.3686 0.760	-0.4674 0.690

Conclusion

The reproductive capacity indicators of *Rutilus rutilus*, including individual absolute fecundity, relative fecundity, and gonadosomatic index, exhibit considerable variability across large water bodies in southern Western Siberia. These indicators increase with age and size of female species, which is consistent with the established fecundity patterns. We found, the roach fecundity in Lake Chany is higher than that observed in the Novosibirsk Reservoir and the Middle Ob. Significant interannual differences in the reproductive capacity indicators were found among same-age roach specimens in Lake Chany and the Middle Ob. Currently the roach individual absolute fecundity is 2.5–3.0 times higher than in the mid-20th century. The individual absolute fecundity of roach statistically significantly correlates with water temperature at onset of oocytes trophoplasmic growth in the previous year: in Lake Chany – in mid-June, whereas in the Middle Ob – in mid-July.

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