Downstream Migration of Burbot (*Lota lota*) Larvae in the Subglacial Period

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Abstract. The research was carried out in the Ob-Irtysh basin on the Irtysh River. The studied section of the river is located in Western Siberia in the Tyumen region. The dynamics of the downstream migration of burbot larvae were assessed in the period preceding the spring ice melting. In the river flow, using a stationary trawl, larvae were caught at equal intervals in the morning, afternoon and evening. The research period was 2 weeks (31.03.2023-14.04.2023). As a result of the research, it was established that there were 2 peaks of migration activity and density of burbot larvae in the periods 3.04-8.04 – the first and 10.04-12.04 – the second. The average density values in the specified periods were 0.066 and 0.034 ind./m^3, with current speeds of 0.317 m/s and 0.450 m/s, respectively. The body length of the burbot larvae during the study period varied from 3.23 to 3.76 mm. Analysis of the dynamics during the migration period revealed a trend towards an increase in the body length of the larvae during the study period. Over the entire period of research, it was established that migration has a daily rhythm: it intensifies during the twilight period and slows down during the day.

1 Introduction

Migrations of organisms at various stages of their life cycle occur in various environments, including aquatic environments. The dispersal of hydrobionts by passive migrations in watercourses at early stages of development is of an adaptive nature.

2 Material and methods

The research was carried out on a section of the Irtysh River (Tyumen region, Uvat district) in the period 01.04.–13.04.2023. The section of the river bed where the control fishing was carried out has the following angular coordinates: 1 - 58.729250 N.L., 68.669813 E.L.; 2 - 58.725664 N.L., 68.663462 E.L.; 3 - 58.721748 N.L., 68.684329 E.L.; 4 - 58.725995 N.L., 68.684419 E.L.

For control fishing of larvae, daily trawling was carried out in the morning (9.00-10.00), afternoon (12.00-13.00) and evening hours (17.00-18.00) using a stationary trawl installation for 30 minutes, with subsequent recalculation for a period of 1 hour.

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The trawl for catching larvae during the fishing period was secured to the ice surface using two nylon braided cords (ropes) at least 10 m long (Fig. 1).

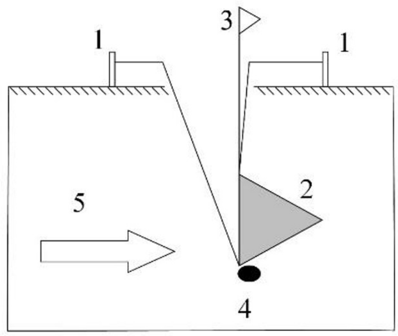

Fig. 1. Scheme of setting up the trawl for control fishing: 1 – Fixing posts; 2 – Trawl; 3 – Alignment flag; 4 – Weight; 5 – River current direction.

The trawl has the shape of a pyramid, its diagram and dimensions are shown in Fig. 2.

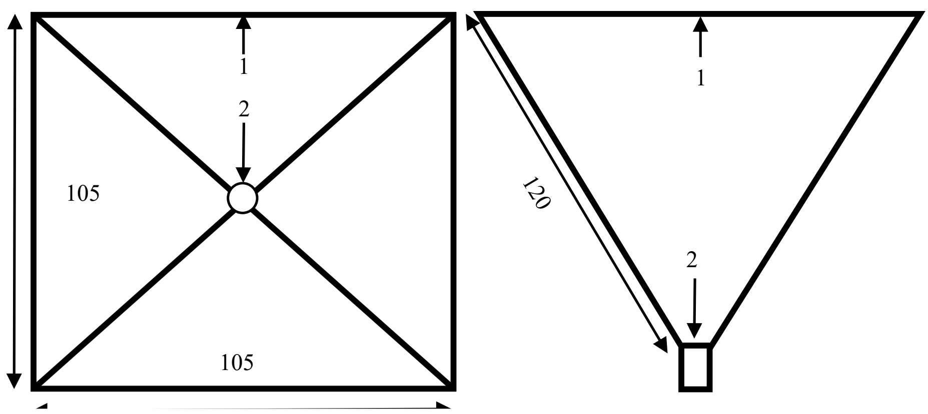

Fig. 2. Trawl design dimensions (cm): *1* – Metal frame; *2* – Cup and drain.

To consider the impact of environmental factors - water level and period of day on the dynamics of downstream migration of burbot larvae, regression statistical analysis (Multiple regression analyzes) and single-factor Anova-one way analysis were used. The response was considered as the number of downstream larvae caught in an equal period of time.

After the trawling time was over, the trawl was lifted upstream through the ice hole and the contents of the catch were poured into a container (basin) through a drain cup at its top. Then, in the laboratory, the catches were analyzed using Petri dishes, the volume of the catch was calculated and the larvae were fixed in 70% ethyl alcohol.

The body length was measured using a Levenhuk binocular camera and a special Levenhuk Lite 4.11.21835 software application with preliminary image calibration (mm/megapixel).

To determine the volume of water caught during trawling, measurements of the flow rate in the studied section of the river were taken using an flow rate meter (ISP-1M) and the volume of water passing through a permanently fixed trawl per unit of time was determined. The exposure duration was 30 minutes (0.5 hours). The number of larvae was determined using the formula:

$$N = \frac{n}{S * V * t} \quad (1)$$

where N is the concentration of larvae, n is the number of caught downstream larvae (ind./m^3) during fishing time t (s), V is the river flow velocity at the entrance to the stationary trawl (m/s), S is the area of the trawl entrance (m^2).

Statistical data processing was performed using the Statistica 10.0 software package (Statsoft Inc., USA).

3 Results and Discussion

As a result of statistical single-factor analysis, it was established that the illumination factor (light and twilight periods of the day), which determines the circadian rhythm of living organisms, significantly affects the intensity of migration of downstream burbot larvae (Fig. 3, Table 1).

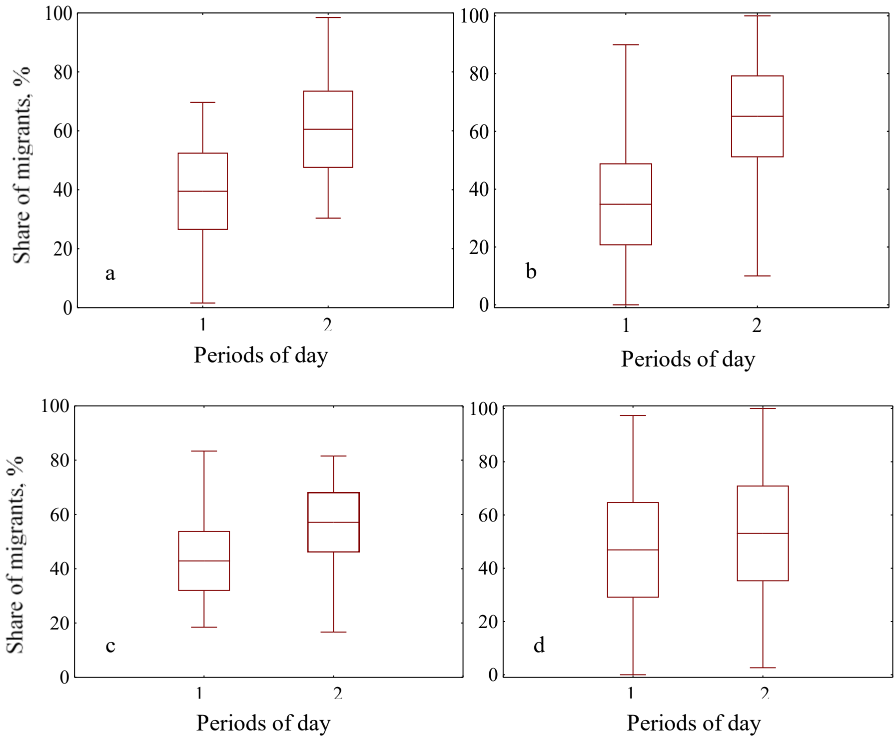

Fig. 3. Indicators of the proportion of downstream larvae in different periods of the day (line - mean, box - confidence interval, whiskers - min-max range): *a*. 1 – Afternoon; 2 – Evening; *b*. 1 – Morning; 2 – Evening; *c*. 1 – Morning- afternoon; 2 – Evening; *d*. 1 – Morning; 2 – Afternoon.

In a comparative analysis of the indicator of the share of migrants in the morning and evening periods, the average value of the indicator under consideration was 34.78 and 65.22%; afternoon and evening periods - 39.49 and 60.52, morning and daytime 46.90 and 53.10; the average value for the morning and afternoon periods in comparison with the evening 42.89 and 57.11%, respectively (Figure 3, Table 1).

Table 1. Results of the analysis of the significance of the impact of the illumination factor on the number of migrants (Anova one-way) and differences between periods of the day in terms of the proportion of migrants (burbot larvae) (Tukey Post-hoc HSD test).

No	Periods of the day (pair of variables)	Migrant share indicator (M±SE), %		Indicators of the hypothesis of the impact of the illumination factor *		Level of significance of differences in indicators **
				F	p	p
1	«Morning» x «evening»	34.78±6.51	65.22±6.51	7.326	**0.01**	**0.01**
2	«Afternoon» x «evening»	39.49±6.02	60.52±6.02	5.021	**0.03**	**0.03**
3	«Morning» x «Afternoon»	46.90±8.34	53.10±8,34	0.238	0.63	0.63
4	«Morning-Afternoon» x «evening»	42.89±5.06	57.11±5.06	3.939	0.06	0.06
*,**- bold italics indicate significance values						

Based on the Tukey test, significance differences were established in the proportion of migrants between the periods «morning» and «evening» ($p=0.01$), «afternoon» and «evening» ($p=0.03$). In the evening twilight period, the proportion of migrants is significantly higher. The increase in the number of downstream larvae reflects the evolutionarily developed mechanism of intensification of migration in the time interval during which the activity of predatory fish species decreases (Table 1).

The maximum number of caught larvae for 3 periods (morning, afternoon, evening) was noted in the period 5.04. - 6.04. at the level of 198-205 individuals (Fig.4).

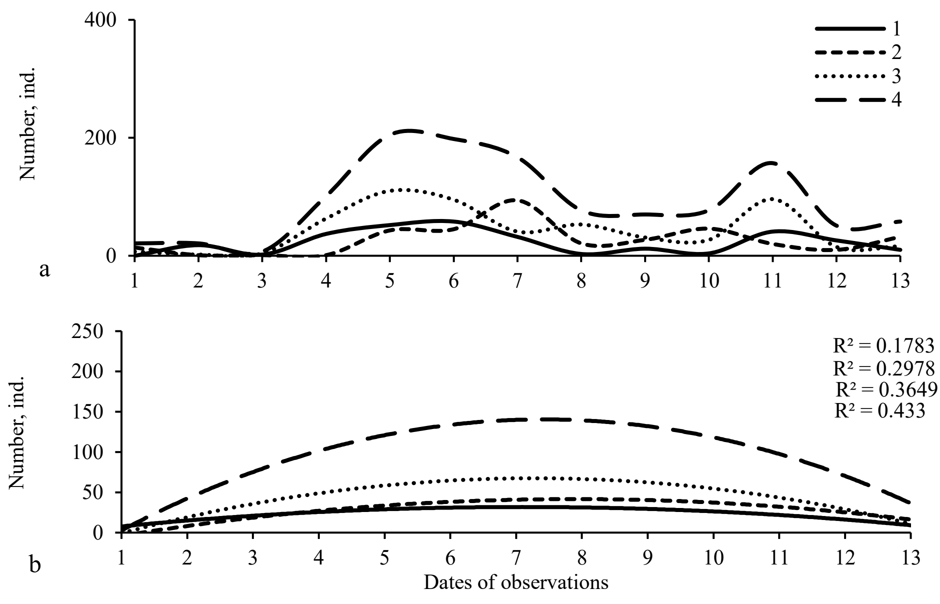

Fig. 4. Downstream migration of burbot larvae in conditions of ice cover of a watercourse (April, 2023). *a* – Dynamics of downstream migration: *1* – Morning; *2* – Afternoon; *3* – Evening; *4* – Generalized data (morning, afternoon, evening); *b* – Trend lines of downstream migration (polynomial function) and the value of its approximation (R^2).

The increase to this value of the indicator occurred from 1.04., then a trend towards a decrease in the indicator to 70 specimens was outlined by 09.04.2023. After this, a second increase in the intensity of the downstream migration and the indicator of the number of burbot larvae was recorded in the period up to 11.04 and a value of 157 individuals, then a decrease in the number of larvae to 58 specimens was again noted, up until the end of the observation period.

Thus, when analyzing the summarized data on the intensity of downstream migration of burbot larvae during the study period, 2 peaks with the highest values were noted – 05.04.2023 and 11.04. 2023, with values of 205 and 157 individuals, respectively.

Analysis of the dynamics of downstream migration of burbot larvae during the study period showed that its trend line at different periods of the day has the form of a polynomial function, i.e. the highest approximation coefficients are noted (Figure 4). The maximum approximation value R^2=0.433 was recorded for the indicator of generalized data on the number of migrant larvae. At the same time, the density of migrating larvae decreases with an increase in the flow rate and water level, respectively, in the period preceding the opening of the river from ice (Figure 4).

Statistical analysis of the dynamics of the density of migrating burbot larvae depending on the flow rate and water level revealed the presence of not significance relationship (R_S= -0.26 and -0.18, respectively), while a strong significance direct relationship was recorded between the water level and the flow rate (R_S=0.90) (Table 2).

Table 2. Correlation matrix of environmental factors in the analysis of the dynamics of the number of burbot larvae.

Indicators	Flow rate	Sum of water levels (cumulative total) *	Number of larvae
Flow rate	1.00	**0.90**	-0.26
Sum of water levels (cumulative total) *	-	1,00	-0.18
Number of larvae	-	-	1.00
*,**- bold italics indicate significance values			

Analysis of the density of larvae during the research period showed that the maximum density values of 0.109 ind./m^3 were noted on 5.04 with minimum values of current velocity - 0.317 m/s, and a rise in water level by 43 cm (the first peak). Then the density values gradually decreased to 10.04, while the density value was 0.026 ind./m^3, however, during this period the current velocity reached the maximum value for the period under consideration - 0.496 m/s, and the water level mark has increased by 99 cm since the beginning of the study.

The second peak of the density value with the indicator of 0.059 ind./m^3 was recorded on 11.04, at a flow rate of 0.450 m/s and a water level of 122 cm. During the study period, the minimum value of the density of burbot larvae - 0.004 ind./m3, was noted on 3.04, at a flow rate of 0.310 m/s and a water level rise of 23 cm.

Thus, during the study period, 2 peaks of the density of burbot larvae were noted in the periods 3.04-8.04 - the first and 10.04-12.04 - the second. The average density values in these periods were 0.066 and 0.034 ind./m^3, respectively (Figure 5).

The body length of the burbot larvae during the study period varied from 3.23 to 3.76 mm. During the first peak, the body length was 3.69 mm, and during the second peak, 3.62 mm (Figure 6). Analysis of the dynamics revealed a trend toward an increase in the body length of the larvae during the study period; the increase in the considered indicator is associated with the growth of previously born larvae.

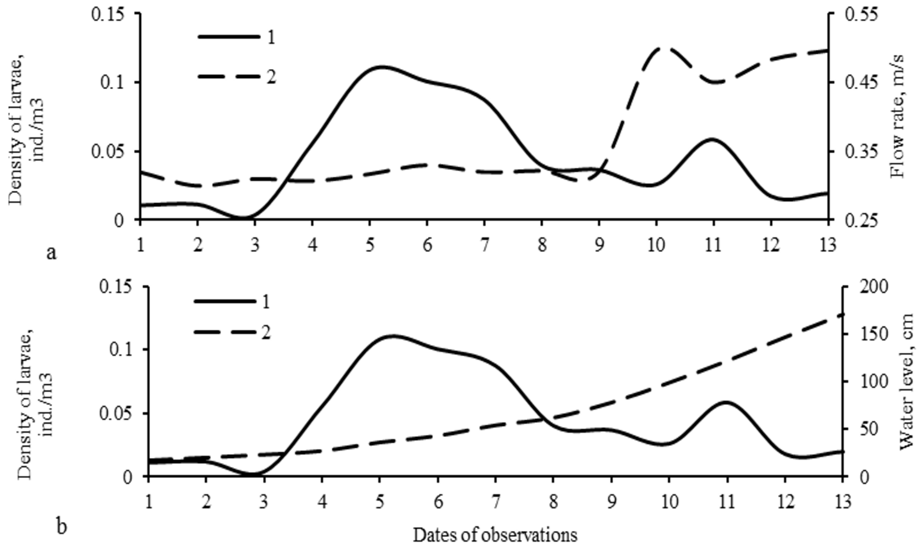

Fig. 5. Dynamics of burbot larval density, current velocity and water level under ice cover of the watercourse (April, 2023): a. *1* – Larval density, ind./m^3; *2* – Current velocity, m/s; b. *1* – Larval density, ind./m^3; *2* –Water level, cm.

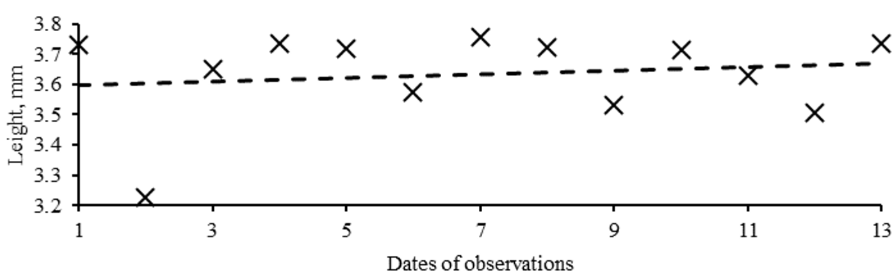

Fig. 6. Dynamics and trend of the body length indicator of migrating burbot larvae in conditions of ice cover of the watercourse (April, 2023).

The peaks of downstream migration of burbot larvae are short-lived, as noted by Koporikov A.R. [1] and last 1-2 days, while in our case, i.e. on the Irtysh River section, as well as on the Ob River, the mass downstream migration of larvae preceded the ice drift. Despite the fact that the larvae migrate passively in the flow [1], we noted a significance difference in the daily intensity of the downstream migration; in the twilight evening period, the proportion of downstream migrants is higher compared to the morning and afternoon periods. Such a pattern is revealed due to the manifestation of the daily rhythm of negative geotaxis and an active behavioral response to the change in the period of the day.

Apparently, even under ice conditions, daily dynamics of activity are evident, since adult fish have been experimentally shown to be most active during the night period [2]. Burbot larvae have also been observed [3] to migrate daily vertically for food items in the limnic system of Lake Constance, and the authors consider this to be a transitional phase from the pelagic to the benthic period of the life cycle.

Other authors have shown [4] that young burbot feed most intensively at twilight and dawn, and this feature helps reduce the expected risk of attack by predators. As a result, the triggers for burbot movements are considered to be [5] water temperature (interseasonal cycle) and illumination (daily cycle), and the greatest activity of individuals is noted [2-6] precisely in the twilight-night period of the day. The presence of a complex circadian rhythm in downstream burbot larvae is evident even in ice conditions, despite the fact that the daily rhythm of fish is determined by light-sensitive organs associated with the central nervous system [7]. We found in our earlier studies the manifestation of increased activity and movements of fish in the twilight-night period of various taxonomic and size groups in the absence of access to natural illumination (ice with a thick snow cover).

With the rise of the water level and the formation of water bodies with minimal flow rates zones, burbot larvae move to such areas for feeding, where zooplankton also develops and concentrates more intensively. At the same time [10], food availability is a limiting factor for survival, since an increase in zooplankton increases the survival rate of burbot juveniles at the larval stage, since it is the groups of cladocerans and copepods that are the main food for fish larvae [11]. In addition [12] a decrease in the density of larvae during their redistribution in the aquatic ecosystem contributes to their higher survival rate.

4 Conclusion

Thus, when the water level rises and the downstream larvae are redistributed from the lotic areas of the watercourse to the limnic areas, the number of downstream larvae in the channel decreases, while a daily rhythm of migration is observed - it intensifies in the twilight period, and slows down in the afternoon time. One of the main reasons for the predominant activity in the twilight-night period is, most likely, the avoidance of predators.

References

1. A.R. Koporikov, *Reproduction of semi-anadromous burbot (Lota lota L.) of the Ob River* (Ural Research Veterinary Institute of the Russian Academy of Agricultural Sciences, Yekaterinburg, 2009)
2. D. Eick, J. Appl. Ichthyol. **29** (2013)
3. O. Miler, P. Fischer, J. Fish Biol. **64** (2004)
4. W.N. Probst, R. Eckmann, Ecol. of Freshwater Fish. **18**, 4 (2009)
5. P.A. Cott, M.M. Guzzo, A.J. Chapelsky, S.W. Milne, P.J. Blanchfield, Hydrobiologia **757**, 1 (2015)
6. W.N. Probst, R. Eckmann, J. Fish Biol. **74**, 1 (2009)
7. I.V. Zhdanova, S.G. Reebs, *Fish physiology* (Elsevier Inc., Amsterdam, 2005)
8. A.A. Chemagin, Bull. of the Samara Scientific Center of the RAS **20**, 5-3 (85) (2018)
9. A.A. Chemagin, Bull. of the Astrakhan State Technical University. Series: Fisheries **3** (2021)
10. V.L. Paragamian, C. Laude, K.D. Cain, J.M. Barron, Jensen N.R. J. App. Ichthyology **27** (2011)
11. G. Furgała-Selezniow, A. Skrzypczak, D. Kucharczyk, R. Kujawa, A. Mamcarz, D. Żarski, K. Targońska, Aquaculture International **22**, 1 (2013)
12. J.M. Barron, N.R. Jensen, P.J. Anders, J.P. Egan, S.C. Ireland, K.D. Cain, Transactions of the American Fisheries Society **142** (2013)