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The Effect of Environmental Conditions of the Open Channel Period on the Relative Body Condition of Semianadromous Burbot, *Lota lota* L. (Lotidae), in the Ob River

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Abstract—The results of long-term observations on changes in the relative body conditions of burbot (*Lota lota* L.) in the Lower Ob basin during the open channel period (June–September) are analyzed. Statistically significant strong positive dependence of the hepatosomatic index of spawners on the maximum flood level is revealed. An equation predicting the value of the hepatosomatic index of spawners from instrumentally measurable environmental parameters is constructed.

Keywords: burbot, hepatosomatic index, environmental conditions, water levels, water temperature

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The physiological state of the organism strongly depends on environmental conditions. The idea that environmental conditions affect the relative size of internal organs (the method morphophysiological indicators) was introduced by S.S. Shvarts as early as the mid-20th century (Shvarts, 1956, 1958; Smirnov et al., 1972; etc.).

In contrast to most other freshwater fishes, burbot deposits fat in the liver (Bull, 1928; Mittel'man, 1932) and has a fat content of less than 1% in muscles (Sorokin, 1976). Depending on the amount of accumulated fat, burbot liver can become several times as large and shrink again. In our previous study (Koporikov and Bogdanov, 2013) we analyzed changes in the liver size of semianadromous burbot (*Lota lota* L.) depending on the physiological state of the fish, feeding intensity, morphological aberrations, etc. In this study we show that changes in liver size (i.e., accumulation of fat in the body) of semianadromous burbot in the Ob River basin depends on the environmental conditions of the open channel period (i.e., during the summer phase of living in the floodplain).

The morphophysiological parameter characterizing the relative liver weight is named the hepatosomatic index. Determining this index makes it possible to minimize measurement error in the assessment of fat reserves in gadiform fishes, compared to the results obtained using absolute parameters of liver size.

The purposes of this study were to reveal the environmental parameters that affect the relative body conditions of burbot during the open channel period and predict values of the hepatosomatic index of burbot spawners by calculating these values from parameters of the environment measured during the summer period, when the fish live in the floodplain.

MATERIAL AND METHODS

The material was collected in 2000, 2004–2007, and 2010–2012 (a total of 8 years) during the periods of spring–summer foraging migration of burbot upstream from the Gulf of Ob in the Ob River and autumn foraging–prespawning migration upstream in Ural tributaries of the Ob. The study area (Fig. 1) included the lowermost segment of the Ob (Aksarka village) and the Voikar River. The material was collected using various fishing gear: seines, stake and drift nets, and hook-and-line gear. A total of 340 burbot specimens were examined.

Values of the hepatosomatic index considerably change in spawners in spring and summer during their long (up to several thousand kilometers) anadromous migration in the channel of the Ob, depending both on the length of this migration and on particular environmental conditions in each part of the floodplain. Using material collected in autumn from only one spawning tributary (the Voikar River) made it possible to assess the effect of environmental conditions on fat accumulation during the open channel period more precisely, since it excluded the effects of migration length and differences in conditions encountered by the fish in different parts of the floodplain. The environmental conditions were characterized by data provided by the nearest weather station, situated in Muzhi village, Yamalo-Nenets autonomous okrug (33 km from the mouth of the Voikar).

Fig. 1. Schematic map of the study area.

The fish and their organs were weighed using Kern digital scales (models CH15K20 and 442-51). The age of the fish was determined by examining otoliths and vertebrae. The hepatosomatic index was calculated as the percent ratio of liver weight to carcass weight (*Instruktsii...*, 2001).

This study required determining the effect of a set of abiotic factors (flood level and sum of daily average water temperatures) on changes in accumulated fat (hepatosomatic index) in spawners during the open channel period. Since the study covered a total of 8 years (one unit of measurement corresponding to one year of study), we used the method of median quantile regression, a nonparametric counterpart of multiple regression (Koenker and Bassett, 1978). The data on the maximum flood level (m) and sum of daily average water temperatures over the open channel period (°C) are given as percentage of the highest values of these parameters recorded over the study period.

The level of dependence of the hepatosomatic index on environmental conditions encountered by burbot spawners was evaluated using Spearman's rank correlation coefficient (Sidorenko, 2003). The degree of uniformity in hepatosomatic index values for different fish samples was determined using the Lehmann–Rosenblatt test (Orlov, 2003; Lemeshko and Lemeshko, 2005).

Mathematical data processing was performed using programs SPSS Statistics 17.0, Matrixer 5.1, and a package for statistical analysis of interval-censored observations on one-dimensional continuous random variables, version 4.2.41.21.

RESULTS AND DISCUSSION

The intensity of digestion in burbot is known to be strongly dependent on water temperature (Ananichev and Gomazkov, 1960). We have shown earlier (Koporikov and Bogdanov, 2010) that maximum flood level and sum of daily average water temperatures over the open channel period affect values of the hepatosomatic index in spawners during the autumn prespawning period. New data confirm the conclusions of that study. The correlation of the hepatosomatic index and annual maximum flood level is strong, positive, and statistically significant ($r_s = 0.71$, $p \le 0.05$). The association of the hepatosomatic index with sum of daily average water temperatures over the open channel period (June–September) is somewhat weaker ($r_s = -0.6$).

The following dependence was hypothesized (Koporikov and Bogdanov, 2010): the higher is flood level, the lower is temperature in the water column, and vice versa (the initial assumption was that high flood levels result in slower heating of the water). However, in some years this pattern was broken: in 2006 low water temperature coincided with low flood level, and in 2007 high water temperature coincided with high flood level. This anomaly was caused by strong deviations of air temperature from long-term average values. The difference between 2006 and 2007 in sum of daily average air temperatures over the open channel period of the Ob River was 10.5%.

Figs. 2 and 3 show that similar values of the hepatosomatic index can be observed under different summer conditions encountered by the fish in the floodplain. Thus, the difference in values of this index between 2006 and 2007 was 0.7%, while the differences in sum of daily average water temperatures and maximum flood level in the Ob were 9.4 and 6%, respectively. This scatter in the measured environmental parameters in combination with the relatively uniform hepatosomatic index suggests that using only one of these parameters (flood level or water temperature) is insufficient for predicting the level of accumulated fat in the body of spawners. Therefore, a new method of predicting body fat accumulation is required.

The value of the hepatosomatic index in spawners during the foraging period can be affected by several factors (Koporikov and Bogdanov, 2010): conditions of winter foraging (which determine the initial amount of accumulated fat at the start of the open channel period) and conditions of living in the floodplain in summer (when fat deposits mostly decrease).

The conditions of winter foraging in the Gulf of Ob (prey accessibility, oxygen and temperature regime) can be rather safely assumed constant. This assumption is confirmed by the absence of significant differences in values of the hepatosomatic index among fish migrating in spring from the Gulf of Ob in different

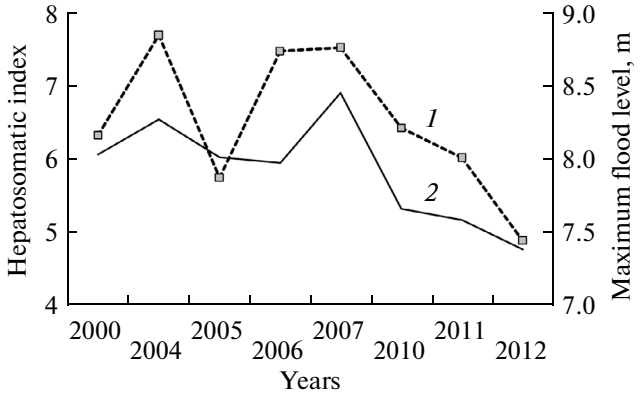

Fig. 2. Long-term changes in (*1*) hepatosomatic index values in burbot spawners in Ural spawning tributaries of the Ob in autumn and (*2*) maximum flood levels of the Ob.

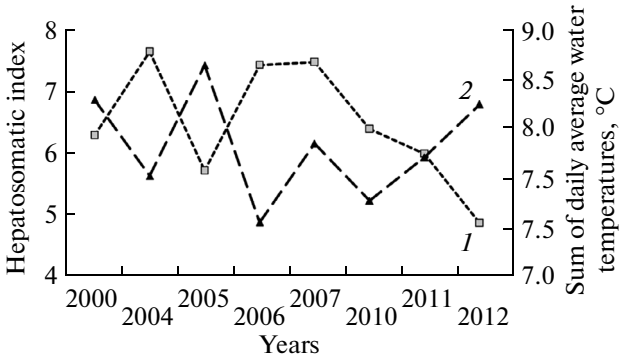

Fig. 3. Long-term changes in (*1*) hepatosomatic index values in burbot spawners in Ural spawning tributaries of the Ob in autumn and (*2*) sum of daily average water temperatures over the open channel period (June–September).

years. For instance, no statistically significant differences have been found between burbots during spring–summer foraging migrations in 2010 and 2012 (average values of the index 12.1 and 11.5, respectively; Lehmann–Rosenblatt test 0.27, $p > 0.1$). However, by autumn the hepatosomatic index invariably decreases below the level typical of the start of spring–summer migration. The difference in the amounts of accumulated fat between burbots of the same year measured in spring and autumn is highly statistically significant (for 2010 and 2012, Lehmann–Rosenblatt test 3.26 and 1.45, respectively, $p \le 0.001$). This difference may be caused by high water temperature during the open channel period and the resulting decrease in locomotor and feeding activities of burbot. The intensity of decrease in amount of accumulated fat in the body is determined by environmental conditions of the open channel period. The values of the hepatosomatic index of spawners measured in autumn in 2010 and 2012 (both years of record low flood levels, but different in temperature regimes) were statistically significant (average values of the index 6.4 and 4.9, respectively; Lehmann–Rosenblatt test 0.47, $p \le 0.05$).

Relatively favorable conditions for burbot living in summer in the floodplain require low water temperatures and coincidence of habitats for burbot and its potential prey. Higher flood levels provide burbot with more biotopes in which potential prey forage (lowermost reaches of tributaries, deep pits in floodplain water bodies, etc.), whereas at lower flood levels burbot lives mainly in the channel, where the amounts of potential prey are quite small. However, at high water temperatures, even if potential prey is accessible, burbot is passive and does not feed (our observation). As a result, the summer conditions of living in the floodplain largely determine the value of the hepatosomatic index measured at the start of the autumn prespawning migration.

The equation for calculating the predicted hepatosomatic index of spawners was constructed using median quantile regression, with relative maximum flood level and relative sum of daily average water temperatures over the open channel period as regressors. The resulting equation describes the changes in the predicted hepatosomatic depending on these environmental parameters with a high degree of determination ($R^1 = 0.90$):

$$HEP = 0.179\ Hmax\% + (-0.112)\ SumT\%,$$

where HEP is predicted value of the hepatosomatic index of spawners; Hmax% is relative maximum flood level as percentage of the highest recorded value; SumT% is relative sum of daily average water temperatures over the open channel period as percentage of the highest recorded value; and 0.179 and –0.112 are regression coefficients (confidence level $p \le 0.001$) for maximum flood level and sum of daily average water temperatures, respectively.

Fig. 4 graphically represents predicted and actual values of the hepatosomatic index for burbot at the start of the autumn foraging–prespawning migration. The equation describes most (90.3%) of the measured

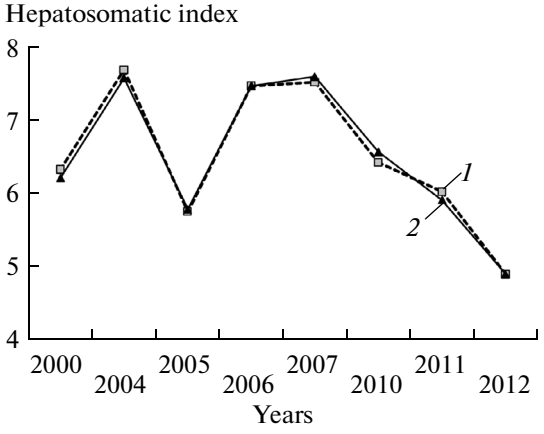

Fig. 4. Long-term changes in (*1*) actual and (*2*) predicted hepatosomatic index values in burbots migrating to Ural spawning tributaries of the Ob for breeding.

empirical data and makes it possible to predict from instrumentally measurable environmental parameters (maximum flood level and sum of daily average temperatures over the open channel period) values of the hepatosomatic index of burbot migrating into Ural spawning tributaries of the Ob for spawning.

CONCLUSIONS

(1) It is determined that the relative body conditions of the burbot migrating into Ural spawning tributaries of the Ob is higher at higher flood levels and at lower values of the daily average water temperature over the open channel period.

(2) Using median quantile regression, we have constructed an equation that makes it possible to predict with a high degree of determination ($R^1 = 0.90$) values of the hepatosomatic index of burbot during the autumn prespawning migration from instrumentally measurable environmental parameters (maximum flood level and sum of daily average temperatures over the open channel period).

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