Aquatic Ecology
Research Article

ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., 67 (1), 2015: 97-103

Growth and Weight-Length Relationship of Burbot *Lota lota* (L.) (Lotidae) in the Danube River at Bačka Palanka (Serbia)

Marija M. Smederevac-Lalić[1]*, Stefan B. Skorić[1], Željka V. Višnjić-Jeftić[1], Vesna Dj. Djikanović[2] and Branislav M. Mićković[1]

[1] Institute for Multidisciplinary Research, University of Belgrade, 1 Kneza Višeslava, Belgrade, Serbia;
E-mail: marijasmederevac@imsi.rs
[2] Institute for Biological Research "Siniša Stanković", University of Belgrade, 142 Despota Stefana Blvd., Belgrade, Serbia

Abstract: The basic life history data of the burbot inhabiting the Danube River at the Bačka Palanka locality were studied. Totally, 124 specimens (45.2% males, 48.4% females and 6.4% of undeterminable sex) were collected from commercial landings. The total length and weight ranges were 22.5-63 cm and 92-1709 g, respectively, while the age range was 1-6 years (otolith readings). For each age class, there were no differences in the average length and weight between sexes. The average length-at-age and weight-at-age were 26.97 cm, 32.35 cm, 38.34 cm, 52.5 cm and 139.8 g, 225.2 g, 371.8 g and 1041 g for the age classes 1, 2, 3 and 6, respectively. The weight-length relationship was described as $W = 0.01\ TL^{2.861}$ ($r^2 = 0.9566$). The von Bertalanffy growth parameters were $L_\infty = 66.58$ cm, $k = 0.17$, $t_0 = -2.01$, and the phi-prime index was calculated as $\Phi' = 2.88$. The obtained data were compared with available results from elsewhere.

Keywords: Danube River, burbot, weight-length relationship, growth

Introduction

Burbot, *Lota lota* (L.), is the only freshwater gadiform fish, which is widely distributed throughout the northern hemisphere above 40° N (Stapanian *et al*. 2010, Worthington *et al.* 2011, Lahnsteiner *et al.* 2012). Due to many threats, including habitat loss and fragmentation, exploitation, pollution, invasive species impact and climate change, the species is endangered or extinct in many regions throughout its geographical range, especially in western Europe and some parts of USA (Stapanian *et al*. 2010, W orthington *et al.* 2011, Lahnsteiner *et al.* 2012). On the global scale, the burbot is considered as an excellent indicator species for habitat degradation and as an early indicator of climate change (Stapanian *et al*. 2010, Edwards *et al*. 2011). Additionally, it is envisaged as a promising candidate species for cold-water aquaculture (Wocher *et al*. 2011).

In Serbia, the burbot inhabits rivers of the Danube River basin, in both the lowland (cyprinid) and the highland (salmonid) waters (Simonović 2006). Despite of the worldwide ecological importance of the species, its status in the Serbian waters is largely unknown and little information has been collected concerning its biological characteristics (Janković 1986, Nikčević *et al*. 1995, Skorić *et al.* 2013). In the past, the burbot was not commercially harvested and catches by local fishermen were of negligible economic interest. Because of that low importance of the species, both in the game and commercial context, the life history data of the burbot populations in the Serbian waters have not been well documented. However, recent reports indicated that the interest in fishing the burbot, both in commercial and recreational fishery, has grown in the last decade, especially in the upper part of the Danubian course in Serbia and in the Belgrade region. The rising popularity as a commercial species and the awareness of its value as an indicator organism emphasise the

*Corresponding author

need for research of all segments regarding the life history of this species.

The growth pattern, because of its importance for management and conservation, is one of the key parameters in studies on fish life history. The growth of fish is accompanied and influenced by both endogenous and exogenous factors, and must be studied through actual observation of the growth of a given species or population (Royce 1972). The aim of this study is to present information on the age and growth of the burbot population from the upper part of the Danube River course in Serbia, at the Bačka Palanka locality.

Material and Methods

Burbot samples were collected by commercial fishermen between 27 December 2006 and 25 January 2007. The fish were caught in the Danube River at the Bačka Palanka locality (45°13', 19°23'; 75 m a.s.l.) by using hoop nets (mesh size 30 mm), which were deployed in the river mid-channel at approximately 4-5 m depth (Fig. 1). The fishing gears were deployed in the evening hours and checked next morning. The total lengths (TL) and weights (W) of 124 individuals were measured to the nearest 0.5 cm and 1.0 g, respectively. Both sagittae were extracted from each specimen, cleaned and stored dry in paper envelopes. In order to make the annuli more distinct for age reading, the otoliths were ground with sandpaper and examined under a dissecting stereomicroscope in whole view with reflected light. The otoliths were read three times, and only in the case of the largest fish (TL = 63 cm, W = 1709 g), the age could not be determined. After dissection of the ventral cavity, the sex was determined macroscopically according to Evenson (2000). Student's t-test was used for comparison of average total length and weight of different age classes of males and females.

The weight-length relationship was expressed using the formula $W = a\ TL^b$ (Ricker 1975), where W = weight (g), TL = total length (cm), while *a* and *b* are parameters. The parameters *a* and *b* were estimated by linear regression on the transformed equation: $\log_{10}W = \log_{10} a + b \log_{10}TL$. To test the isometric pattern hypothesis (b = 3), the t-test was applied. The statistical analyses and calculations were performed using Statistica 6.0 package (StatSoft).

The growth in length was described using the von Bertalanffy growth equation: $L_t = L_\infty \{1 - e^{[-k (t - t_0)]}\}$ (Sparre, Venema 1998), where L_t is the total length at age *t*; L_∞ is the length that the fish would reach at an infinitely high age; *k* is the curvature parameter; and t_0 is the theoretical age when the fish has zero length. The von Bertalanffy plot was used for estimating the growth parameters by applying the Powell-Wetherall method for L_∞ estimate (Sparre, Venema 1998).

Chi-square test(χ^2) was used for comparison of the observed and predicted length-at-age data. The phi-prime (Φ') index was used to study overall growth performance: $\Phi' = \log_{10}k + 2\log_{10} L_\infty$ (Sparre, Venema 1998). Additionally, our results were compared with available data on other growth studies of the species.

Results

Totally, 124 fish were examined. The ranges of body measurements were 22.5-63.0 cm for total length and 92-1709 g for wet weight. In terms of the sex structure, the sample consisted of 56 (45.2%) males and 60 (48.4%) females, while 8 (6.4%) specimens were of macroscopically undeterminable sex. The ages ranged from 1 to 6 years. However, ages 4 and 5 were absent, and the largest fish (female, TL = 63 cm) was not aged. All specimens of undetermined sex belonged to the 1 year age class. The contribution of the males and females in age classes 1 and 2 was equal (sex ratio 0.93:1 and 1.07:1 for age class 1 and 2, respectively), while in age class 3 dominance of females was recorded (sex ratio 0.65:1). Both individuals 6 years old were males. The three largest fish individuals were spent, while the others were not matured.

The mean length and weight of the examined fish by age classes and sex (Table 1) did not exhibit sex differences. The statistical comparison between the mean lengths and weights in the males and females of the same age showed that there were no statistically significant differences (Student's t-test; $P > 0.05$); therefore, sex was not considered as a separate variable in the subsequent analysis.

The weight-length relationship (Fig. 2) was described by the equation $W = 0.01\ TL^{2.861}$. The relationship was significant ($r^2 = 0.9566$), demonstrating that weight varied as a power of length. The value of regression coefficient (b = 2.861) was significantly different from 3 ($P < 0.05$), pointing to a negative allometric weight growth.

Irrespectively of their sex, the examined fish were combined by age, mean length and weight (corresponding ranges in brackets, Table 2). Regarding the age contribution in the sample, it was 28.4 %, 47.2 %, 22.8 %, and 1.6 % for age classes 1, 2, 3 and 6, respectively.

The mean lengths of the individuals of the age classes 1-3 were used to fit the von Bertalanffy

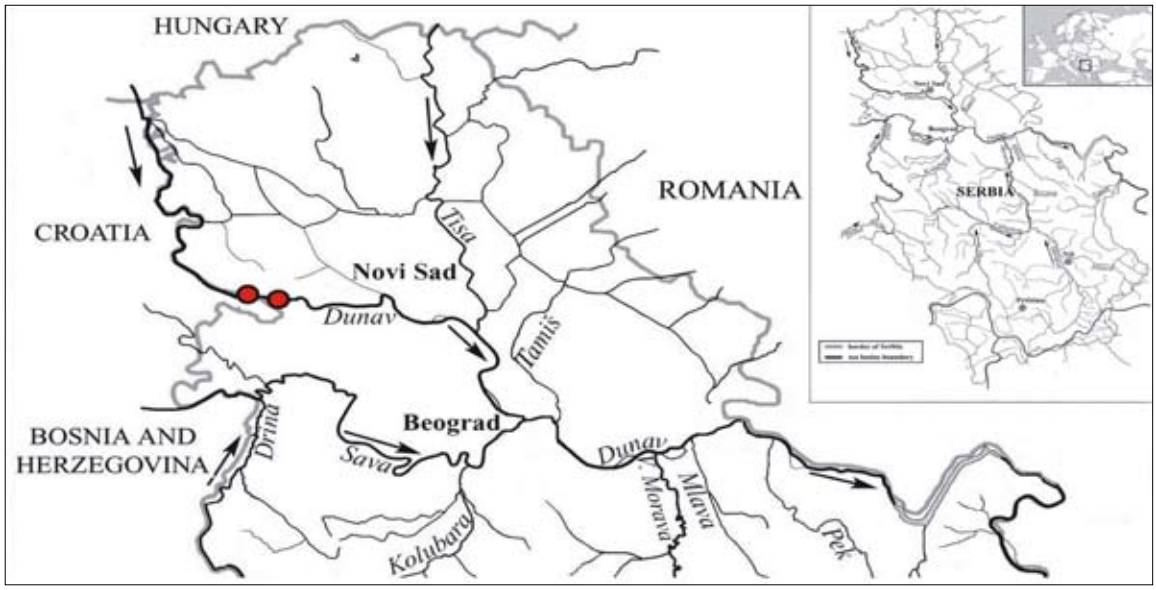

Fig. 1. Fishing sites

Table 1. Mean lengths and weights of burbot (*L. lota*) caught in the Danube at the Bačka Palanka locality according to age and sex and their comparison (Student's t-tests, P = 0.05): n – sample size, SD – standard deviation, ns – not significant

AGE	MALES			FEMALES			
(years)	n	Mean	SD	n	Mean	SD	Significance
Total length (cm)							
1	13	27.54	2.503	14	27.96	3.00	ns
2	30	32.12	1.596	28	32.61	1.822	ns
3	11	37.64	2.026	17	38.79	1.795	ns
6	2	52.50	2.121				
Weight (g)							
1	13	145.77	32.286	14	154.64	46.216	ns
2	30	222.47	39.021	28	228.14	47.644	ns
3	11	346.363	48.063	17	388.24	64.489	ns
6	2	1041.0	35.355				

growth model parameters. According to Powell-Wetherall method, the estimated asymptotic length (L_∞) was 66.58 cm. The length growth rate of the burbot population studied (Fig. 3) did not reveal statistically significant differences between the observed and predicted lengths ($\chi^2 = 0.182$; $P > 0.05$). Based on the estimated parameters of the von Bertalanffy equation, the approximate maximum age of the burbot from the population studied was calculated as 15.6 years.

The computed overall growth performance index Φ' was 2.88. The comparison between the growth-in-length parameters and index of growth performance recorded in this study were compared (Table 3) with those available in the database FishBase (Froese, Pauly 2014).

Table 2. Mean total length and weight (ranges of observed values in brackets) of age classes concerning total sample size: n – number of fish, TL – total length, W – weight, SD – standard deviation

Age (years)	n	TL ± SD (cm)	W ± SD (g)
1	35	26.97 ± 2.846 (22.5 – 33.0)	139.8 ± 40.08 (87 – 221)
2	58	32.35 ± 1.712 (28.0 – 36.0)	225.2 ± 43.11 (147 – 325)
3	28	38.34 ± 1.939 (35.0 – 43.0)	371.8 ± 61.27 (282 – 519)
6	2	52.5 ± 2.121 (51 – 54)	1041 ± 35.36 (1016 – 1066)

Table 3. Comparative overview of burbot (*L. lota*) growth parameters from different regions across its distribution area: (*) – data source FishBase; bolded data – this study; TL – total length; SL – standard length; (-) – no data in database.

Location	Length type	L_∞ (cm)	k	t_0	Φ'
Russia, Ilmen Lake*	TL	66.1	0.21	-	2.96
Germany, Spree River*	TL	74.0	0.11	-	2.78
Russia, Petschora River*	TL	84.4	0.17	-	2.98
Germany, Oderhaff*	TL	88.0	0.24	-	3.27
Russia, Lake Vygozero*	SL	104.0	0.05	-3.42	2.77
Finland, Bay of Bothnia*	TL	104.0	0.08	-1.94	2.95
Russia, Enisey River*	TL	126.4	0.11	1.10	3.24
Russia, Enisey River*	TL	160.0	0.06	-0.28	3.21
Serbia, Danube	TL	66.6	0.17	-2.01	2.88

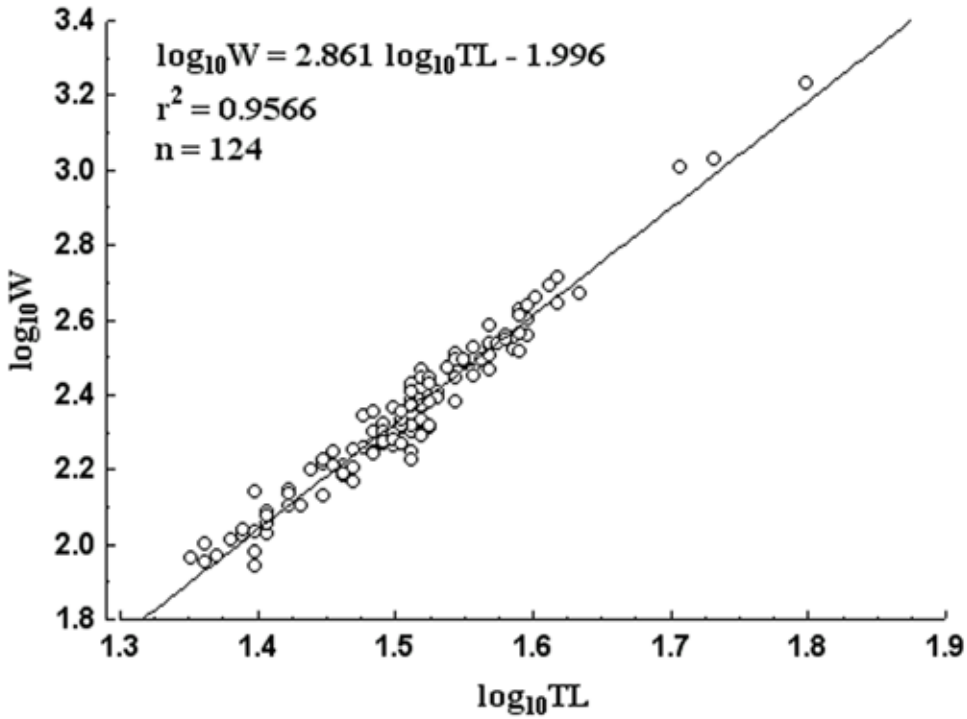

Fig. 2. Weight-length relationship as found for 124 burbot individuals at Bačka Palanka, Serbia

Discussion

Burbot spawns at low temperatures (1-4°C) in winter or early spring and the spawning season is relatively short (up to 20 days) and highly synchronised (McPhail, Paragamian 2000, Evenson 2000). Janković (1986) reported that in the Danube River in Serbia the peak of the burbot spawning took place during January and early February. Therefore, the fish in our study were collected in the period of high reproductive activity. The observed age structure was most likely related to the spawning season. Burbots are mass spawners, which form aggregations at the spawning sites located in the shallows of the inshore area (McPhail, Paragamian 2000, Evenson 2000) and, thus, mature individuals are not available at the fishing grounds (depths of the main river channel). Further support for the previous assumption is provided by the sex ratios within particulate age classes. Burbots in the southern part of the range reach maturity at age of 3-4 years and most authors agree that males mature about a year earlier than females (Janković 1986, McPhail, Paragamian 2000, Arndt, Hutchinson 2000). The numbers of the males and females in the age classes 1 and 2 were almost identical, while the sex ratio in the age class 3 is 0.65:1 in favour of females, giving an indication that males after attaining maturity migrate to spawning area.

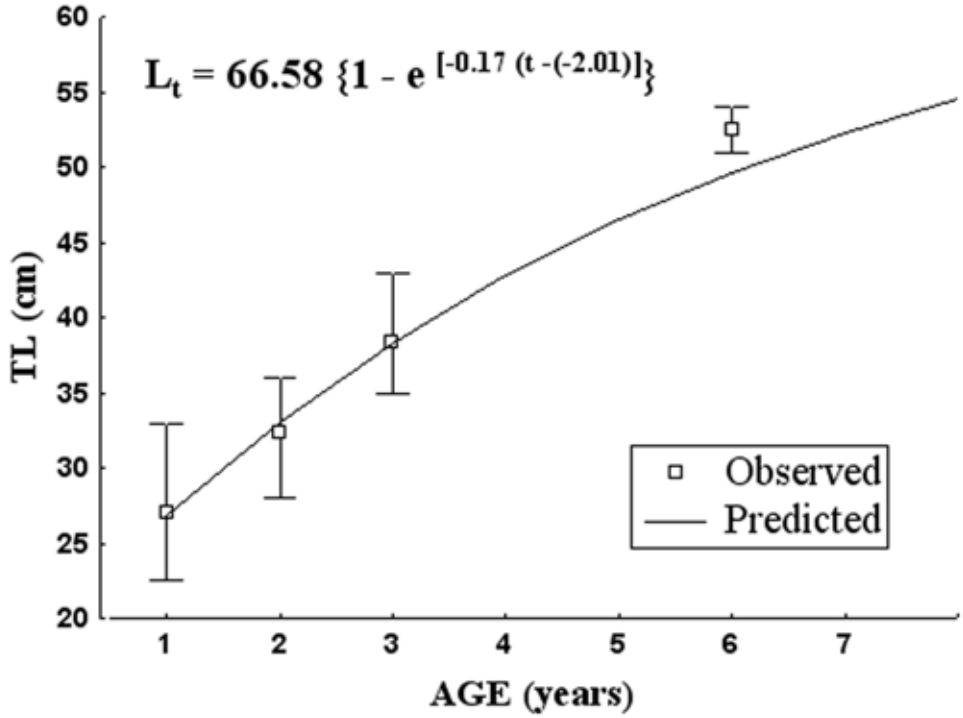

Fig. 3. The growth rate in length of the burbot caught in the Danube River at Bačka Palanka described by the von Bertalanffy equation: (□) – represents the means; vertical bar represents the range

There are no differences in growth between the sexes in the particular age classes. Differences in growth rates of fish species are more pronounced in the older age groups (Žiliukienė, Žiliukas 2010). Therefore, our results could be a reflection of the investigated age range. However, it should be noted that in the studies on growth of burbot populations, which have been conducted on wider age ranges, other authors have not considered sex as a separate variable (Arndt, Hutchinson 2000, Katzman, Zale 2000, Schram 2000, Švagdžys 2002, Polacek *et al*. 2006, Hensler *et al.* 2007, Rohtla *et al*. 2013).

The estimated exponent of the weight-length relationship (b = 2.861) is statistically different from 3 indicating negative allometric growth patterns, which means that the larger fish become more elongate than smaller ones. Verreycken *et al*. (2011) have reported a similar value of b (2.875) for the burbot in waters of Flanders and characterised it as an elongated species. In fishery and ichthyological studies, weight-length relationships are useful tools for comparison of populations. The obtained results are within the expected range of 2.5-3.5 (Froese 2006) and are based on a sufficient number of individuals and the large size range of the examined fish. Moreover, the correlation coefficient has been 0.96, while the value of 0.8 is recommended as a threshold for result validity (Verreycken *et al*. 2011). Our results may serve for comparison in future studies of burbot populations inhabiting other localities in the Danube or other waters and habitats.

The length of the smallest caught specimen (22.5 cm) indicates that, due to the net mesh size and fishing locations, the smaller individuals are not susceptible to the fishing gear. The recorded average body lengths measured at a particular age, falls within the range reported on other burbot populations from large water bodies in North America (Katzman, Zale 2000, Schram 2000, Polacek *et al*. 2006, Hensler *et al.* 2008) and Europe (Švagdžys 2002, Rohtla *et al*. 2013). Two burbot subspecies are described: *L. l. maculosa* (Le Sueur) occurring exclusively in North America from the Great Slave Lake (Canada) to the southern limit of the species' distribution, and the nominotypical subspecies *L. l. lota* distributed across the remaining part of the Nearctic range and the entire Eurasian range (Stapanian *et al.* 2010). In the quoted literature concerning American populations, authors have not distinguished subspecies, which may mean that there are no differences between subspecies in respect to the growth in length. Such an assumption is supported by the findings of Elmer *et al.* (2012), who have noted for the burbot from the Great Slave Lake and the Mackenzie River drainage area, although the two subspecies are parapatric and genetically distinct, a difference in body length between the subspecies has not been determined. In general, burbot grows rapidly until the on-

set of sexual maturity (McPhail, Paragamian 2000), which is also confirmed by our study. At the age of 3, the burbot reach 57.6% of asymptotic length. The most remarkable feature of the studied population is the rapid growth of fish during their first year. Katzman, Zale (2000) have reported that the age-0 burbot in Upper Red Rock Lake (USA) averaged 236 mm TL and achieved 265 mm TL by the third week of October, and apparently, they continue to grow throughout the winter. According to the available literature, the average total lengths of the 1-year burbot in different waters vary from 129 to 267 mm (Schram 2000, Katzman, Zale 2000). Based on the back-calculated values at the time of annulus formation, the latter authors have reported a length range of 191-415 mm for a given age, which means that the ratio between the largest and smallest individual is 2.2. In this study, the corresponding ratio is 1.5, and may probably be attributed to the selectivity of the gear. Consequently, further studies are needed for collection of more detailed data on the length range within the 1-year age class. It is generally believed that growth intensity reflects the suitability of particular environment to the species. The fast growth during the first year, as reported here, seems to indicate that for this age class the favourable environmental conditions prevailed at the investigated locality.

The theoretical maximal length (66.58 cm) appears to be realistic, since it is greater than the length of the largest specimen collected. Sparre, Venema (1998) stated that the von Bertalanffy plot is more robust in comparison to other methods in the sense that it nearly always gives a reasonable estimate of the curvature parameter (k). Given that a reasonable estimate of the asymptotic length is used in computations, perhaps the best way of estimating it is the Powell-Wetherall method. The von Bertalanffy equation is thought to describe properly the growth pattern if the maximum observed length is approximately 95% of the estimated asymptotic length (Taylor 1962). The ratio between the maximum observed length of the sample and the estimated asymptotic length (0.946) suggests the validity of the reported results.

The growth parameters obtained in this study are within the ranges reported by other authors (Table 3). A comparison of the available data reveals a high variability of the growth parameters in the burbot populations across its distribution area, which can be attributed to temporal and geographical variations. Sparre, Venema (1998) have suggested that comparison of fish growth based on a single parameter from the von Bertalanffy equation is misleading, and that the phi-prime index, due to its minimum variance, is the most appropriate index of overall growth performance for fish growth comparison. The obtained phi-prime (2.88) index for the Danubian burbot population is in the mid-range in comparison with available data. More specifically, the obtained phi-prime index among the reported locations is higher than two (2.77, 2.78), and close to three (2.95-2.98), being considerably lower than three corresponding values (3.21-3.27). This indicates a moderate growth of the burbot in the Danube River on comparing to other populations elsewhere as reported by Froese, Pauly (2014).

The present study provides some basic information on the life history traits of the burbot from the upper part of the Danube River course in Serbia. Having in mind the great differences between the ecosystems and habitats inhabited by burbot, our results may be valid only for the examined population. However, these results may serve for comparison in future studies of burbot populations that inhabit other localities.

Acknowledgments: The reported work is supported by the Ministry of Education, Science and Technological Development (Project number TR37009), and the Serbian Academy of Sciences and Arts.

References

Arndt S. K. A. and J. Hutchinson 2000. Characteristics of burbot spawning in a tributary of Columbia Lake, British Columbia, over a four-year period. – In: Burbot biology, ecology, and management. V. L. Paragamian and D. H. Willis (Eds.). American Fisheries Society, Fisheries Management Section, Publication No. 1, Bethesda. MD, 48-60.

Edwards W. H., M. A. Stapanian and A. T. Stoneman 2011. Precision of two methods for estimating age from burbot otoliths. – *Journal of Applied Ichthyology*, **27** (Suppl. 1): 43-48.

Elmer K. R., H. Recknagel, A. Thompson and A. Meyer 2012. Asymmetric admixture and morphological variability at a suture zone: parapatric burbot subspecies (Pisces) in the Mackenzie River basin, Canada. – *Hydrobiologia,* **683**: 217-229.

Evenson M. J. 2000. Reproductive traits of burbot in the Tanana River, Alaska. In: Burbot biology, ecology, and management. V. L. Paragamian and D. H. Willis (Eds.). American Fisheries Society, Fisheries Management Section, Publication No. 1, Bethesda. MD, 61-70.

Froese R. 2006. Cube low, condition factor and weight-length relationships: history, meta-analysis and recommendations. – *Journal of Applied Ichthyology*, **22**: 241-253.

Froese R. and D. Pauly 2014. Fish base. World Wide Web electronic publication. Available at: http://www.fishbase.org (last accessed March 2014).

Hensler S. R., D. J. Jude and J. He 2008. Burbot growth and diets in lakes Michigan and Huron: an ongoing shift from native species to round gobies. American Fisheries Society Symposium, **59**: 91-107.

Janković D. 1986. Taxonomical and ecological characteristics of burbot *Lota lota* (Linnaeus), 1758 from the Danube River (Yugoslavia). – *Ichthyologia*, **18**: 23-39.

Katzman L. M. and A. V. Zale 2000. Age and growth of an unexploited burbot population in Upper Red Rock Lake, Montana. – In: Burbot biology, ecology, and management. V. L. Paragamian and D.H. Willis (Eds.). American Fisheries Society, Fisheries Management Section, Publication No. 1, Bethesda. MD, 139-146.

Lahnsteiner F., M. Kletzl and T. Weismann 2012. The effect of temperature on embryonic and yolk-sac larval development in the burbot *Lota lota*. – *Journal of Fish Biology*, **81**: 977-986.

McPhail J. D. and V. L. Paragamian 2000. Burbot biology and life history. – In: Burbot biology, ecology, and management. V. L. Paragamian and D. H. Willis (Eds.). American Fisheries Society, Fisheries Management Section, Publication No. 1, Bethesda. MD, 11-23.

Nikčević M., A. Hegediš, B. Mićković, A. Baković and R. K. Andjus 1995. The burbot (*Lota lota* L.) in Yugoslavia: Habitats and thermal acclimation capacity. – *Ichthyologia,* **27** (1): 5-11.

Polacek M. C., C. M. Baldwin and K. Knuttgen 2006. Status, distribution, diet and growth of burbot in Lake Roosevelt, Washington. – *Northwest Science*, **80** (3): 153-164.

Ricker W. E. 1975. Computation and interpretation of biological statistics of fish populations. – *Bulletin Fisheries Research Board of Canada*, **191**, 1-382.

Rohtla M., M. Vetemaa, I. Taal, R. Svirgsden, K. Urtson, L. Saks, A. Verliin, M. Kesler and T. Saat 2013. Life history of anadromous burbot (*Lota lota*, Linnaeus) in the brackish Baltic Sea inferred from otolith microchemistry. – *Ecology of Freshwater Fish*, Vol. **23**. No 2. 141-148.

Royce W. F. 1972. Introduction to the fishery sciences. Academic Press, New York, London, 351 pp.

Schram S. T. 2000. Seasonal movement and mortality estimates of burbot in Wisconsin waters of western Lake Superior. – In: Burbot biology, ecology, and management. V. L. Paragamian and D. H. Willis (Eds.). American Fisheries Society, Fisheries Management Section, Publication No. 1, Bethesda. MD, 90-95.

Simonović P. 2006. Ribe Srbije. NNK International, Zavod za zaštitu prirode Srbije, Biološki fakultet Univerziteta u Beogradu, Beograd, 247 p.

Skorić S., M. Smederevac-Lalić, Ž. Višnjić-Jeftić, A. Hegediš and B. Mićković 2013. Relationships of otolith size to total length of the burbot (*Lota lota*) from the Danube River. VI International Conference "Water & Fish", Belgrade, Serbia, Conference Proceedings, 158-163.

Sparre P., S. C. Venema 1998. Introduction to tropical fish stocks assessment. Part I, Manual. FAO Fish Technical Paper. No 306/1. FAO, Rome, 407 p.

Stapanian M. A., V. I. Paragamnian, C. P. Madenjian, J. R. Jackson, J. Lappalainen, M. J. Evenson and M. D. Neufeld 2010. Worldwide status of burbot and conservation measures. – *Fish and Fisheries*, **11**: 34-56.

Švagdžys A. 2002. Growth and abundance of burbot in the Curonian Lagoon and determinatives of burbot abundance. – *Acta Zoologica Lituanica*, **12**: 1, 58-64.

Taylor C. C. 1962. Growth equation with metabolic parameters. – *Journal du Conseil international pour l'exploration de la Mer*, **27**: 279-286.

Verreycken H., G. Van Thuyne and C. Belpaire 2011. Length-weight relationships of 40 freshwater fish species from two decades of monitoring in Flanders (Belgium). – *Journal of Applied Ichthyology*, **27**: 1416-1421.

Wocher H., A. Harsányi and F. J. Schwarz 2011. Husbandry conditions in burbot (*Lota lota* L.): Impact of shelter availability and stocking density on growth and behaviour. – *Aquaculture*, **315**: 340-347.

Worthington T., P. S. Kemp, P. E. Osborne, C. Howes and K. Easton 2011. A review of the historical distribution and status of the burbot (*Lota lota*) in English rivers. – *Journal of Applied Ichthyology*, **27** (Suppl. 1): 1-8.

Žiliukienė V., V. Žiliukas 2010. Growth of pike *Esox lucius* in Lake Rubikiai (Lithuania). – *Journal of Applied Ichthyology*, **26**: 898-903.

Received: 29.05.2014
Accepted: 08.10.2014