Folia Zool. – 57(1–2): 155–161 (2008)

Age and growth of the karyologically identified spined loach *Cobitis taenia* (Teleostei, Cobitidae) from a diploid population

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Received 15 November 2006; Accepted 21 March 2008

A b s t r a c t . A total of 174 specimens of the spined loach *Cobitis taenia* Linnaeus, 1758, comprising 117 females, 45 males and 12 juveniles, from Lake Klawoj (Poland) were identified as *C. taenia* from their karyotype (2n = 48 chromosomes). The overall sex ratio (M:F = 1:2.6) showed that females dominated in the population, but this varied with increasing fish size. Age and growth were determined based on otolith measurements. Standard lengths were back-calculated from the regression of fish standard length on the otolith radius and the growth pattern was described using the von Bertalanffy model separately for males and females, which revealed a strong fit for both females ($Lt = 92.4(1 - \exp(-0.278\ (t - 0.456))$; $r^2 = 0.803$) and males ($Lt = 120.6\ (1 - \exp(-0.227\ (t - 0.558))$; $r^2 = 0.772$). Comparison of asymptotic length with maximum observed size of males and females revealed that all values were a bit overestimated (as per the Taylor criteria). The SL – weight equations for males ($W = 0.0003\ SL^{3.8377}$; $r^2 = 0.8961$) and females ($W = 0.0039\ SL^{3.1683}$; $r^2 = 0.9616$) indicated allometric growth in both sexes, though more so in males than in females.

Key words: otolith, Pisces, von Bertalanffy function**,** weight-length relationship

Introduction

There are relatively few studies that have examined the age and growth of the spined loach *Cobitis taenia* (R o b o t h a m 1981, B o r o ń 1992). Until recently, *C. taenia* was thought to be rare but widespread in Poland, occurring in all types of freshwaters. However, recent cytogenetical investigations (B o h l e n & R á b 2001, B o r o ń 2001) revealed that *C. taenia* is not so common, representing ≈ 13% of all *Cobitis* specimens collected (B o r o ń 2003). Most of the *Cobitis* populations in Poland consist of *C. taenia* and/or *C. elongatoides* and their polyploid hybrids (B o r o ń 2003). However, polyploid fish are not morphologically distinguishable from diploid specimens (K o t u s z 2000, J e l e ń 2006). All Cobitidae species have been protected under Polish law since 2004. The occurrence of diploid-polyploid *Cobitis* populations in Poland casts doubt on the results of any previous studies that did not provide cytogenetic identification of the specimens examined. According to karyological identification of spined loaches from the Great Ouse River basin (B o r o ń et al. 2003) at least R o b o t h a m (1981) studied age and growth of a population of pure diploid *C. taenia*. However, R o b o t h a m (1981) studied the species in a small flowing river, though it also occurs in lakes in a different environment. The aim of the study was to provide information on the age and growth of a pure population of *C. taenia* from a lake in Poland and to compare it with the data of R o b o t h a m (1981) as well as with data from mixed diploid-polyploid complexes.

Material and Methods

Using a seine net, 174 specimens of *C. taenia*, consisting of only diploid (2n = 48) individuals, were collected between April and September, biweekly in 2001 and monthly in 2002, from Lake Klawoj in northern Poland (Boroń 1999). Immediately after capture, the fish were anaesthetized, measured for standard length (SL) and total length (TL) to nearest 0.1 mm and weighed (to the nearest 0.1 g.), and dissected to determine sex (117 females, 45 males, 12 juveniles). Each fish was identified according to its karyotype, with chromosome slides made from kidney tissue as per Rába & Roth (1989) and Boroń (1995).

Sex was determined by gonad histology (Juchno et al. 2007) and the presence of the *lamina circularis*. Specimens possessing the *lamina circularis* and those characterized by gonads containing vitellogenetic oocytes were considered respectively as sexually mature males and females.

Age was determined from otoliths (Nagięć 1993), which were cleaned, immersed for 24 hours in glycerin (Robotham 1981) and then examined under a Nikon binocular microscope. Distances from the otolith's centre to each annual ring (r_n) and to the otolith's edge (R – total radius) were measured to the nearest 0.05 mm. Back-calculated fish SL for each year of life was by the direct proportion method (Francis 1990, Devries & Frie 1996), using the regression relationship between SL and total otolith radius (R): SL = 172.84×R + 7.674 (r^2 = 0.8705).

Back calculated SL at age were used to estimate the von Bertalanffy growth function (VBGF): $L_t = L_{inf}$ (1 – exp(–K(t – to))) where L_{inf} is the asymptotic length, K is the growth constant and t_0 is the hypothetical time at which the fish started to grow (Ricker 1975). The VBGF parameters were also used to calculate the overall growth index $\varphi' = \log_{10}(K)+2*\log_{10}(L_{inf})$ (Munro & Pauly 1983). All these parameters (and their standard errors) were calculated using the FiSAT software (Gayanilo et al. 1994). The SL–weight relationship ($W = aSL^b$) was used to determine whether growth was isometric (b = 3) or allometric (b ≠ 3). To test this pattern, the Student *t* – test was applied following the log-transformation of data (Zar 1984).

Results and Discussion

Females dominated the Lake Klawoj population of *C. taenia* (M:F = 1:2.6) in both 2001 (1:2.9) and 2002 (1:1.8). This ratio varied according to SL (Fig. 1) and age (Table 1). Robotham (1981) reported a male – female ratio of *C. taenia* of 1:1.3. The higher dominance of females in Lake Klawój may be caused by higher mortality risk by predation of the smaller males (Bohlen & Ritterbusch 2000). In mixed, diploid-polyploid populations, this ratio was 1:1.75 (Kostrzewa et al. 2003) and 1:22 (Bohlen & Ritterbusch 2000).

Maximum observed SL in males was 72.5 mm (specimen captured in June 2001) and 91.7 mm in females (specimen captured in May 2002). SL at age varied widely due to the combination of specimens collected over a two-year period, which introduced a seasonal growth effect (Rosenberg & Beddington 1988). The equation describing the TL to SL relationship was: TL = 0.22+1.14×SL, r^2 = 0.9930 (for females) and TL = 1.09+1.12×SL, r^2 = 0.9936 (for males).

C. taenia males from Lake Klawoj were smaller than females (Fig. 1), which is a fixed biological feature of all *Cobitis* species such as *C. paludica* (Przybylski & Valladolid 2000), *C. elongatoides* (Erős 2000), and *C. narentana* (Schneider

Table 1. Number of fish (n), proportion of total sample (%), standard length (SL in mm, with S.E.) and weight (W in g) of males and females by age group for *C. taenia* from Lake Klawój (Poland) in 2001 and 2002.

Age Group	Males				Females			
	n	%	mean SL min – max S.E.	mean W min – max S.E.	n	%	mean SL min – max S.E.	mean W min – max S.E.
1+	0	0	-	-	13	11.1	45.5 33.2–56.1 7.33	0.8 0.3–1.2 0.30
2+	12	26.7	52.9 49.6-56.3 2.23	1.2 0.9-1.6 0.24	13	11.1	59.5 41.4–66.6 7.34	1.7 0.6–3.1 0.69
3+	28	62.2	58.4 53.4-63.4 3.32	1.7 1.3-3.4 0.47	36	30.8	74.6 58.9–85.8 6.82	3.5 1.5–5.7 1.05
4+	5	11.1	69.6 65.3-72.5 2.70	3.7 2.4-4.9 0.97	52	44.4	81.3 70.3–88.5 4.25	4.6 2.8–7.3 0.87
5+	0	0	-	-	3	2.6	88.1 85.9–91.7 3.17	6.2 5.4–7.1 0.84

et al. 2000, Zanella et al. 2003), and was also found by Robotham (1981) in *C. taenia* from the Great Ouse River. Females achieved sexual maturity at about 53.3 mm SL and males at about 40 mm SL (Juchno et al. 2007). The 12 juveniles under the present study ranged in SL from 31.4 to 46.8 mm, and in weight from 0.15 to 0.7 g. The smallest loaches (SL from 31.4 to 36.4 and weight about 0.3 g) collected on 22 June 2001 were likely 1+ specimens, while fish collected one month later, with an SL from 20 to 25 mm, could represent the 0+ cohort. The lengths of the smallest fish, corresponding with fry, attained a length of 15 mm after 24 days given by Robotham (1981).

More than 60% of males in Lake Klawoj were age 3+ and ≈ 45% of females were age 4+, which is similar to the *C. taenia* population studied by Robotham (1981) and to that of other European species of *Cobitis* (Marconato & Rasotto 1989, Rasotto 1992, Przybylski & Valladolid 2000, Oliva-Paterna et al. 2002, Kostrzewa et al. 2003, Ekmekçi & Erk'akan 2003). Furthermore, the maximum age in Lake Klawoj females was age 5+ and age 4+ in males (they should die by the end of their sixth and fifth year of life respectively) (Table 1), which is similar to other *Cobitis* species (Lobon-Cervia & Zabala 1984, Przybylski & Valladolid 2000, Erős 2000, Schneider 2000, Ritterbusch & Bohlen 2000). One exception is *C. taenia* population from the Great Ouse River with the majority of females attained the age of 3+, and the males reached the age of 2+ (Robotham 1981).

Comparison of observed and back-calculated length showed good agreement (Table 2), with annual increments decreasing between age groups in the same magnitude for both sexes and the fastest growth was in the first year of life. The high coefficient of determination values (r^2 = 0.803 for females and 0.772 for males) indicate a strong fit of the von Bertalanffy equation to the observed data (Table 3). Although the largest male had 72.5 mm and female had 91.7 mm, the maximum asymptotic length (L_{inf}) was found to be

92.4 and 120.6 mm, respectively. Taking into account the Taylor's (1962) criterion of fitting the growth function to the observed data, the L_{inf} is overestimated for both sexes. Meanwhile, L_{inf} was found to be ≈1.3 times higher in females than in males, with similar results reported elsewhere for *C. paludica* (Przybylski & Vallado lid 2000) and *C. narentana* (Zanella et al. 2003).

A genetically determined characteristic, such as theoretical maximum length (L_{inf}), can be affected by varying environmental influences (Weatherley & Gill 1987). Therefore the asymptotic SL is considered to reflect growth capacity under particular environmental conditions (Bagenal & Tesch 1978). Growth constant *K* was only slightly larger in males (K = 0.278) than in females (K = 0.227), indicating a slightly faster growth rate. Because the inverse relationship between L_{inf} and K is an inherent property of the von Bertalanffy growth function (Moreau et al. 1985), further but reversed differences in growth between sexes are revealed by the index of growth (ϕ'), with a higher value (and faster growth) in females than males (Table 3).

The length-weight equation calculated for males was $W=0.0003SL^{3.8377}$, $r^2 = 0.8961$, while the similar equation for females was $W = 0.0039SL^{3.1683}$, $r^2 = 0.9616$. This indicated that at a similar SL, males achieved a greater weight than females ($t = 3.131$, df = 158, $P = 0.0021$). Moreover both sexes grew allometrically with $b>3$ ($t = 4.203$, df = 43, $P <0.001$ for males and $t = 2.961$, df = 115, $P <0.002$ for females). The similar pattern was also noted for a *C. taenia* population in England (Robotham 1981), a *C. paludica* population in

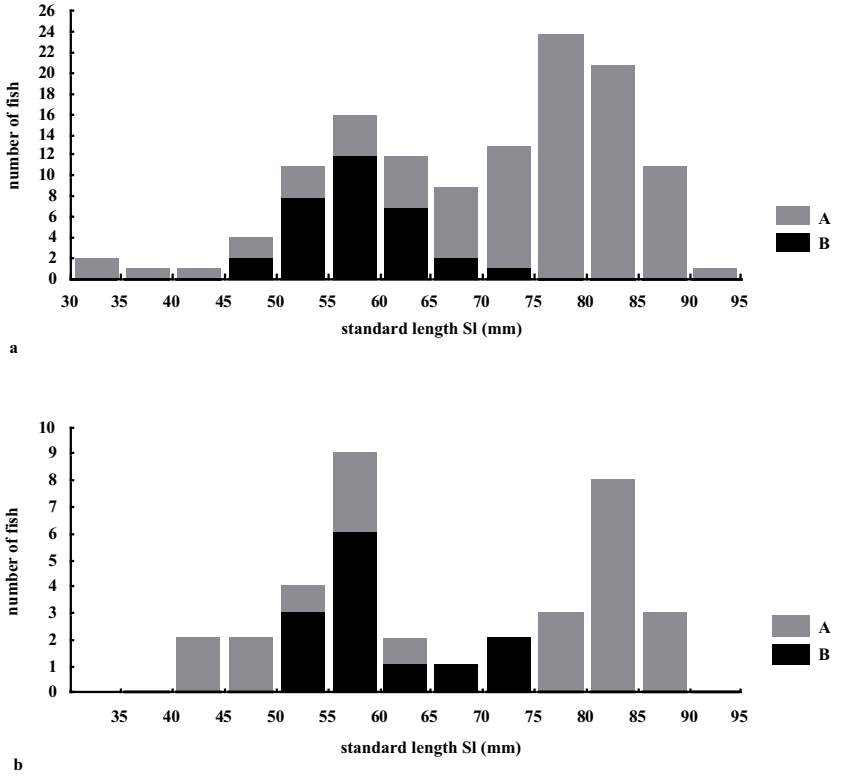

Fig. 1. Standard length-frequency distributions of female (A, grey) and male (B, black) *C. taenia* at capture from Lake Klawój (Poland) in 2001 (a) and 2002 (b).

Table 2. Mean back calculations of standard lengths (SL in mm) obtained from otoliths measurements of *C. taenia* from Lake Klawój (Poland) in 2001 and 2002.

Age Group	SL at capture			SL at age				
	n	mean	S.D.	l_1	l_2	l_3	l_4	l_5
Males								
1	-	31.1	5.97					
2	12	45.3	6.94	35.3	48.1			
3	28	55.9	5.89	29.1	43.9	55.6		
4	5	66.4	4.04	31.8	46.2	57.2	66.4	-
Mean length				32.1	46.1	56.4	66.4	
S.D.				3.1	2.1	1.1		
Annual increment					14.0	10.3	10.0	
Females								
1	13	35.1	7.87	38.7				
2	13	51.4	8.53	36.5	52.6			
3	36	66.6	7.40	37.7	55.1	69.9		
4	52	76.7	5.27	31.9	48.5	64.6	76.6	
5	3	82.8	0.75	36.4	50.9	60.7	75.9	82.8
Mean length				36.2	51.8	65.1	76.3	
S.D.				2.6	2.8	4.6	0.5	
Annual increment					15.5	13.3	11.2	6.6

Table 3. Parameters of the von Bertalanffy growth model and their standards errors S.E. for *C. taenia* from Lake Klawój (Poland).

Parameters	Males	S.E.	Females	S.E.
L_{inf}	92.4	21.1	120.6	15.6
K	0.278	0.127	0.227	0.056
t_o	-0.456	0.290	-0.558	0.171
φ‘	3.385	0.655	3.665	0.565
n	130		370	
r^2	0.7718		0.80297	
max. lifespan	4		5	

Iberia (P r z y b y l s k i & V a l l a d o l i d 2000) and a *C. narentana* population in Croatia (Z a n e l l a et al. 2003). Because the presented result concerns the pure diploid population of *C. taenia*, which is rare in Central Europe, the results could be used as references to compare, for example, how polyploidisation could affect the life history of loaches.

A c k n o w l e d g e m e n t

We would like to express our sincere thanks to S. B o r o ń for collecting the material and to G.H. C o p p for valuable comments and editing the English. This work was carried out within the grant no. 2 P04C00526 supported financially by the State Committee for Scientific Research and project no. 0208.805 of the University of Warmia and Mazury in Olsztyn, Poland. Spined loach as a protected species in Poland was collected according to the permit DLOPiKog.–4201–04–43/01 given by the Ministry of Environment and research was carried out with the Local Ethical Committee consent no. 28/02.

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