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Short communication

Age and growth of bream *Abramis brama* (Linnaeus, 1758) in the downstream section of Irtysh River in China

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Introduction

The European bream (*Abramis brama*) was introduced into Lake Zaysan from Russia in the 1950s, gradually spreading into China along the Irtysh River. The species became one of the most popular sport and commercial fish in the downstream section of the Irtysh River (Adakbek et al., 2003).

The age and growth of *A. brama* has been widely studied by many scientists (e.g. Goldspink, 1981; Kompowski, 1982, 1988; Lammens, 1982; Kangur, 1996; Tierney et al., 1999; Kakareko, 2001; Adakbek et al., 2003; Treer et al., 2003; Ziliukiene and Ziliukas, 2011). Most information has been gathered from Europe. However, there is no information on *A. brama* populations in the Irtysh River. The method employed for fish growth rate assessment affects the results considerably, this being particularly true in the case of back-calculations (Francis, 1990). Scale was the only material used for age-growth study of *A. brama,* except that Goldspink (1981) used the opercula to study the growth rate of *A. brama* in three eutrophic lakes in England. Sentiakova (1969) demonstrated (using *A. brama* as an example) that the hypothesis assuming a constant species-specific relationship between fish length and scale radius was erroneous. Therefore, it might be not appropriate to use scales when back-calculating the growth rate of *A. brama*. However, otoliths are widely accepted as the most appropriate structure for age determination of fish (Phelps et al., 2007; Ma et al., 2011). The idea of predicting age from other variables, e.g. fish length and/or otolith measurements, has quite a long history that began with the research of Boehlert (1985), who showed that age prediction can be obtained with different otolith size parameters (primarily weight).

In this study we attempted to estimate the age of *A. brama* by counting increments on ground otoliths, and describing relationships of otolith dimensions with fish length and age. The study also aimed to compare parameters of fitted von Bertalanffy growth equations with those obtained by other authors.

Materials and methods

The Irtysh River is transnational and originates on the southwestern slope of the Altai Mountains, then flows through China, Kazakhstan and Russia, before flowing into the Arctic Ocean. The total river length is 4248 km, with the section in China of 633 km. Preliminary site investigations showed that the bulk of the *Abramis brama* population in China is restricted to only the downstream section. The winter in this area always lasts for circa 150 days, with about 120 days of ice and a mean water temperature of 0~3.0°C. Summer is only for about 45 days, with a mean water temperature of 15–18°C.

A total of 635 specimens were collected from the downstream section of Irtysh River in China (47°96′~48°07′N; 85°51′~85°62′E) during monthly samplings conducted from April to October 2013 and April 2014. A minimum of 30 fish was collected each month using trammel nets (inner mesh size 10 cm, outer mesh size 23 cm), gillnets (mesh size 2.5 cm) and purse nets (mesh size 1 cm). For each individual, the standard length (*SL*) and fork length (*FL*) were measured to the nearest 1 mm and body weight (*BW*) to the nearest 0.01 g. Specimens were macroscopically classified as male, female, or unsexed. Lapillus otoliths were extracted from each fish and stored in labeled tubes for age analysis.

SL-BW relationship was calculated by applying exponential regression: $BW = a\ SL^b$. The allometric index value (b) obtained was compared to the theoretical value of isometric growth (b = 3) by a t-test (Pauly, 1984).

Paired otoliths were similar in size and shape, therefore only the left otolith was used. Common anatomical terminology was used to identify the position of the otoliths corresponding to its original orientation in the fish (Reñones et al., 2007). The measurements taken were: otolith length (*OL*): maximum anterior-posterior distance; otolith breadth (*OB*): dorsal-ventral distance at the widest point; otolith thickness (*OT*): distal-proximal maximum distance, and otolith weight (*OW*): measured after being dried over 24 h at 60°C.

Annuli were counted independently by two experienced readers without prior information regarding length or sex, and only coinciding estimates were accepted. Each fish was assigned to an age-class assuming 1 June as the designated birth date, which approximately corresponds to the peak spawning season. A new ring mark found on the otolith of a fish captured before 1 June was not considered to be an

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Table 1
Abramis brama in lower reaches of Irtysh River, October 2013–April 2014

	Female			Male			Unsexed			Overalll		
Age (yr)	n	Mean ± SD (mm)	Range (mm)	n	Mean ± SD (mm)	Range (mm)	n	Mean ± SD (mm)	Range (mm)	n	Mean ± SD (mm)	Range (mm)
1							10	45.8 ± 3.0	29–55	10	45.8 ± 3.0	29–55
2							32	80.7 ± 8.4	62–105	32	80.7 ± 8.4	62–105
3	3	113.0 ± 7.9	105–136	5	115.6 ± 14.3	102–132	79	116.0 ± 12.5	100–135	87	113.8 ± 12.9	100–136
4	13	139.6 ± 12.2	105–143	19	135.4 ± 15.1	105–156	75	141.8 ± 15.4	103–162	107	140.4 ± 15.1	103–162
5	10	162.9 ± 32.3	131–216	9	162.7 ± 26.4	125–201	10	164.5 ± 15.2	138–211	29	163.4 ± 22.8	125–216
6	22	186.8 ± 36.5	157–266	20	185.3 ± 26.5	152–249	5	188.6 ± 27.9	155–237	47	186.4 ± 31.3	152–266
7	44	204.3 ± 29.7	170–279	67	203.9 ± 23.7	164–266				111	204.1 ± 28.0	164–279
8	57	220.0 ± 36.4	179–289	71	218.9 ± 28.3	166–286				128	219.4 ± 33.3	179–289
9	29	234.0 ± 43.6	177–314	27	233.6 ± 32.7	178–305				56	233.8 ± 39.3	177–314
10	7	247.9 ± 26.5	193–323	10	247.3 ± 24.5	187–311				17	247.5 ± 25.0	187–323
11	10	261.8 ± 45.7	191–317	8	259.1 ± 30.8	201–315				18	260.6 ± 38.8	191–317
12	9	270.6 ± 35.5	236–344	2	267.5 ± 21.9	245–286				11	270.0 ± 30.8	236–326
13	1	289		4	280.3 ± 31.8	261–333				5	282.5 ± 26.5	261–317
14	1	296								1	289.0 ± 8.08	282–296
15	3	293.5 ± 40.3	241–326							3	293.5 ± 40.3	241–336
Total	209			242			169			620		

Data represent numbers of specimens (n), means and standard deviation (±SD) as well as range of standard length-at-age.

annulus in the age assignment, whereas when a fish sampled after the assumed birth date had no new ring mark, an annulus that was supposed to have formed was considered in the age estimation (Grandcourt et al., 2006). The index of average percent error (*IAPE*) was calculated to determine the precision between the two readings (Beamish and Fournier, 1981):

$$\mathrm{IAPE}_j = \frac{1}{N}\sum_{j=1}^{N}\left(\frac{1}{R}\sum_{i=1}^{R}\frac{\left|X_{ij}\quad X_j\right|}{X_j}\right)\times 100\%$$

where N is the number of fish aged, R is the number of readings, X_{ij} is the ith age determination of the jth fish, and X_j is the mean age calculated for the jth fish.

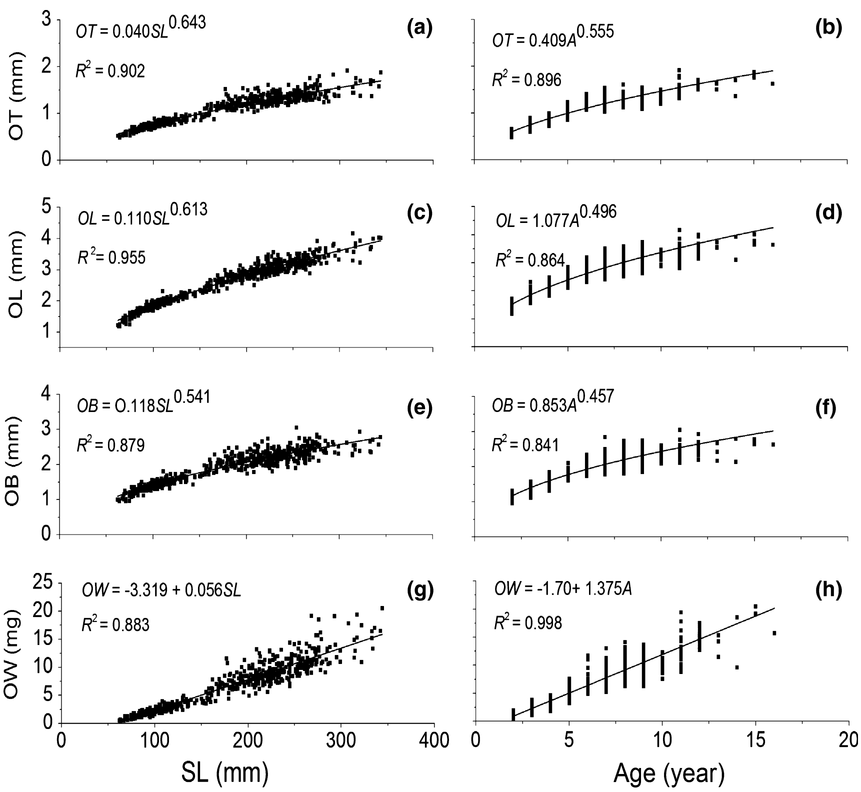

Fig. 1. Relationships between otolith dimensions (otolith length OL, otolith breadth OB, otolith thickness OT, and otolith weight OW) and fish length/age of *A. brama* (n = 635)

The relationship between SL and otolith radius (R, mm) was examined and the power regression ($SL = a\ R^b$) found to have the best fit. Both the back-calculated and observed length-at-age data were fitted to the traditional von Bertalanffy growth function (*VBGF*): $L_t = L_\infty(1 - e^{-k(t-t_0)})$, where L_t is the length at age t, L_∞ is the asymptotic length, k is the growth coefficient, t is the age, and t_0 is the hypothetical age at zero length. Growth performance index ($\text{Ø} = \log_{10} k + 2 \log_{10} L_\infty$) was estimated to compare growth parameters obtained in the present study with those reported by other authors (Pauly and Munro, 1984).

Results

Of the 635 individuals, 245 were males at 102–333 mm SL, 215 were females at 105–344 mm SL, and 175 were unsexed at 29–237 mm SL. The mean SL of females (228.1 ± 50.76 mm) was significantly longer than males (213.2 ± 40.78 mm) (t-test, $t = 3.444$, $P < 0.05$). The regression equation of FL on SL was: $FL = 1.13\ SL + 3.00$ ($R^2 = 0.998$, n = 635).

The *IAPE* was quite low (2.6%) between the two independent readers, reflecting concordance in the two readings. Overall, 242 males, 209 females, and 169 unsexed specimens were successfully aged. The estimated age ranges were 3–13 years for males, 3–15 years for females, and 1–6 years for unsexed. Mean and standard deviations of the observed lengths-at-age for age classes 1–15 are shown in Table 1.

SL-BW regression equations were described as $BW = 1.560 \times 10^{-5}\ SL^{3.076}$ ($R^2 = 0.973$, n = 245) for males; $BW = 2.135 \times 10^{-5}\ SL^{3.025}$ ($R^2 = 0.976$, n = 215) for females; and $BW = 5.759 \times 10^{-6}\ SL^{3.263}$ ($R^2 = 0.988$, n = 175) for unsexed. No significant differences were detected for the *SL-BW* relationship between sexes (ANCOVA, $F = 0.399$, $P > 0.05$), and the regression equation derived from pooled date was: $BW = 1.556 \times 10^{-5}\ SL^{3.092}$ ($R^2 = 0.986$, n = 635). The allometric index value (b) showed no significant differences from 3 (t-test, $t = 0.728$, $P > 0.05$). Therefore, *SL-BW* relationships indicate a tendency of isometric growth in *A. brama*.

The goodness of fit between (OL, OB and OT) and fish length/age were high for the power function (Fig. 1). The

Table 2
Back-calculated mean standard length-at-age and annual length increment of *A. brama*, Irtysh River, China, October 2013–April 2014

Age (yr)	n	SL_1	SL_2	SL_3	SL_4	SL_5	SL_6	SL_7	SL_8	SL_9
2	32	47.9								
3	87	46.2	81.3							
4	107	45.9	81.1	108.6						
5	29	44.6	80.2	108.8	132.0					
6	40	49.1	85.9	116.9	145.0	171.5				
7	116	48.3	85.5	117.9	142.2	166.8	192.6			
8	130	48.7	85.7	116.2	141.8	163.5	185.5	207.7		
9	56	47.5	85.6	116.2	142.5	163.6	181.7	200.7	220.4	
10	17	47.6	87.0	118.8	147.0	168.0	186.8	203.0	218.4	234.3
a		47.4	84.0	114.7	141.8	165.7	187.5	205.4	220.0	234.3
$\triangle L$		47.5	36.6	30.7	27.1	23.9	21.8	17.9	14.6	14.3

a: weighted average (mm); SL: annual standard length increment (mm).

Table 3
Published comparisons of *A. brama* growth studies applying von Bertalanffy growth equation and using different structures commonly employed in age determination

Region	Structures used for aging	Sex	L_∞(mm)	k	t_0	Ø	Authors
Lake Tatton Mere (England)	Opercular	Total	476	0.114	−0.056	4.412	Goldspink (1981)
Lake Cole Mere (England)		Total	394	0.119	−0.097	4.266	
Lake Ellesmere (England)		Total	494	0.118	−0.107	4.459	
Lake Dabie (Poland)	Scale	Total	544	0.113	−0.033	4.524	Kompowski (1982)
River Regalica (Poland)	Scale	Total	515	0.108	−0.059	4.457	
Lake Dabie and Szczecin Lagoon (Poland)	Scale	Total	541	0.136	−0.200	4.600	Kompowski (1988)
Lake Volvi (Greece)	Scale	Male	397	0.102	−0.351	4.207	Valoukas and Economidis (1996)
		Female	446	0.094	−0.406	4.272	
Wloclawek Reservoir (Poland)	Scale	Total	546	0.185	0.015	4.742	Kakareko (2001)
Międzyodrze waters (Poland)	Scale	Total	593	0.099	−0.037	4.546	Neja and Kompowski (2001)
Lake Ulungur (China)	Scale	Total	566	0.122	−0.131	4.592	Adakbek et al. (2003)
Danube (Croatia)	Scale	Total	577	0.087	−0.885	4.462	Treer et al. (2003)
Curonian Lagoon (Lithuania)	Scale	Total	716	0.076	−0.576	4.591	Stankus (2006)
Lake Rubikiai (Lithuania)	Scale	Total	65.7	0.085	−0.582	4.565	Ziliukiene and Ziliukas (2011)
Irtysh River (China)	Otolith	Total	349	0.123	−0.205	4.176	Present study

OL, *OB* and *OT* increased at a fixed rate up to 200 mm *SL* and/or age 7, and at a slightly slower rate thereafter. Linear relationships were detected between *OW* and fish length/age, indicating an isometric increase between *OW* and fish length/age over the range of ages sampled. Otolith dimensions were more highly correlated with fish length than age, with the exception of *OW*.

The power regression of *SL* on *R* (otolith radius) for the pooled data was: $SL = 257.5\ R^{1.674}$ ($R^2 = 0.900$). Back-calculated length-at-age and annual length increment of *A. brama* are reported in Table 2. Results show that the annual standard length increment was decreasing year by year. The von Bertalanffy functions fitted to the back-calculated and observed length-at-age are: $L_t = 348.6\ (1-e^{-0.123(t\ +\ 0.205)})$ ($R^2 = 0.933$) and $L_t = 338.5\ (1-e^{-0.139(t\ +\ 0.473)})$ ($R^2 = 0.857$). Parameters were calculated in age groups 2-10, and the older groups disregarded because the sample size was too small. The growth performance index (*Ø*) was 4.176 obtained from the back-calculated data.

Discussion

In recent years the otolith weight (*OW*) was reported to be correlated with the age of some fish (Pino et al., 2004), and may be a useful, simple tool for rapidly estimating the age of individuals (Araya et al., 2001). Cardinale et al. (2000) reported that there was no significant difference between the results of using *OW* and the traditional method of annuli counts to estimate age of *Gadus morhua* and *Pleuronectes Platessa*. Yan et al. (2009) showed that *OW* overlaps only occasionally among age groups, and to individuals with similar standard length, the older and slower-growing fishes have heavier otoliths because of the continued otolith material deposition. In the present study the relationships between *OW* and fish standard length/age were both linear, indicating isometric growth between *OW* and fish standard length/age. It is suggested that the *OW* analysis is a useful technique for validating the accuracy of age determination of *A. brama* by annuli counts, even for individuals of similar size.

Some authors indicated different growth rates between males and females, whereas others stated the absence of such difference. Female *A. brama* in the Curonian Lagoon grow more rapidly than males (Stankus, 2006), however, the author did not indicate at what significance level. Goldspink (1978) found no differences between growth rates of males and females of the same age in Lake Tjeukemeer, which agrees with the present study where growth rates of both sexes were comparable. However, the data indicate that females live longer and are grow larger than males.

Stankus (2006) reported that the *A. brama* growth rate is related to the latitude. He compared growth rates of *A. brama* in different waterbodies and found that growth rate decreased with an increasing latitude. Growth is influenced not only by the geographical location of the waterbody, but also by the abundance of food. Kakareko (2001) and Stankus (2006) indicated that *A. brama* growth rates depend upon abundance of benthic organisms, in particular chironomids. Both the growth rate ($Ø = 4.176$) and $L_\infty = 349$ mm obtained in the present study were much lower than those in previous studies (Table 3), although it is one of the two southernmost waterbodies (the other being Lake Ulungur). A slow growth rate might be related to the low supply of food resources in the Irtysh River. And according to Wang et al. (2014), the biomass of zoobenthos in the downstream section was lower than 3.6 g m^{-2} for the sand substrate. Whereas a relatively higher *A. brama* growth rate ($Ø = 4.591$) and $L_\infty = 566$ mm was observed in Lake Ulungur (similar in latitude to the Irtysh River) with high productivity of zoobenthos (9.83 g m^{-2}) in the silt (Zhao et al., 2011). Kangur (1996) also reported an especially high growth rate of *A. brama* in Lake Peipsi, a high-latitude lake in Estonia, and pointed out that Lake Peipsi had the highest biomass of zoobenthos (15.56 g m^{-2}) among the large lakes of northern Europe. Hence, for a coldwater fish such as *A. brama*, the abundance of benthic organisms might be a more important influencing factor of growth rate compare to the latitude. In addition to the above two reasons, a smaller size might be also attributed to the *A. brama* inhabiting the Irtysh River, being under a greater fishing pressure. Our investigations revealed that the overfishing of *A. brama* was very serious, especially during the spawning season from April to June, making it difficult for the fish to grow larger. It is essential therefore essential to establish sound management strategies for this species to allow for its sustainability, with the strategies focused on a sustainable fishing intensity, a minimum catch size, and proper fishing methods to prevent overfishing. Specifically, prohibiting fishing during the spawning season could be an effective way to protect the sustainability of the *A. brama* population as a resource.

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