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RESEARCH PAPER

Age and growth of the European catfish (*Silurus glanis*) in a Turkish Reservoir and comparison with introduced populations

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Abstract The European catfish, *Silurus glanis*, is native to eastern Europe and western Asia and is among the largest freshwater fish in the world. Despite its increasing economic importance and its frequent introductions, the ecology and life-history of this species is poorly known due to the difficulty of sampling such a large species in large rivers and standing waters. Our study provides the first data on age and growth of this species in Turkish waters, where it is native. We report the length-weight relationships and age and size structure of this population, which were significantly different between females and males. A marginal increment analysis indicated that annulus formation occurred between May and June. The estimates of three growth functions (von Bertalanffy, logistic and Gompertz) are reported, with the von Bertalanffy growth providing a better fit and more realistic parameter estimates. Growth rates were significantly higher in males than in females and were overall higher compared to other native populations but similar to introduced populations of similar latitude.

Keywords Growth models · Invasive species · Life history · Freshwater fish

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Introduction

The European catfish, *Silurus glanis*, also known as wels or sheatfish, is among the largest freshwater fish worldwide, with a maximum record of 5 m of total length and body mass of 306 kg (Copp et al. 2009) and individuals over 50 kg being regularly angled (Slavík et al. 2007). It is characterized by its rapid growth and large body size (Brzuska and Adamek 1999). Two *Silurus* species, *S. glanis* and *S. aristotelis*, inhabit European inland waters, the latter being endemic to Greece while *S. glanis* is native to eastern Europe and western Asia but has been introduced to many European countries, including France, Italy, the

Netherlands, Spain and the UK due to its popularity among anglers (Banarescu 1989; Krieg et al. 2000; Britton and Pegg 2007; Carol et al. 2007, 2009; Copp et al. 2009). *Silurus glanis* and *S. triostegus* inhabit Turkish inland waters; the former species has a wide distribution that includes Manyas, Apolyont, İznik, Gölhisar lakes and Sakarya, Kura, Aras, Kızılırmak, Yeşilırmak, Seyhan and Ceyhan rivers in Turkey (Geldiay and Balık 1996) while *S. triostegus* is endemic to the Euphrates basin (Ünlü and Bozkurt 1996).

The European catfish has an economic importance in commercial and recreational fisheries as well as in aquaculture. Its aquaculture production has increased from 600 tonnes in 1993 to 2,000 tonnes in 2002 in ten European countries (Linhart et al. 2002; Copp et al. 2009). However, the total production of European catfish by aquaculture and the captive fisheries in all Europe and former USSR countries decreased from 17,459 tonnes in 1990 to 11,286 tonnes in 1999 primarily due to lower catches in the Volga River delta and in other rivers of the former Soviet Union (Linhart et al. 2002). In contrast to Europe and although there are no aquaculture facilities of European catfish in Turkey, its commercial catches increased from 300 tonnes in 1993 to 1,000 tonnes in 2000, probably due to the large increase of reservoirs in recent years.

Because of its economic importance, European catfish has attracted recent interest as a potential species for aquaculture, and a number of studies have been carried out for its artificial reproduction and aquaculture production (Haffray et al. 1998; Brzuska and Adamek 1999). However, the ecology of its wild populations both in its natural and introduced ranges is poorly known, probably because of the difficulty of sampling such a large species in large rivers or lentic ecosystems (Carol et al. 2007, 2009; Copp et al. 2009). European catfish shows maximal movement during the warmest season and has strictly nocturnal feeding activity (Slavík et al. 2007) and during day time it is located in the littoral zone and spends extended periods of the day hidden in concealed habitats (Carol et al. 2007). European catfish inhabits the lower reaches of large rivers and muddy lakes and tends to prey on smaller fish than could be expected for its size and mouth gape (Adamek et al. 1999; Dogan Bora and Gül 2004; Wysujack and Mehner 2005; Carol et al. 2009). In the Menzelet Reservoir, females mature at 860 mm of length and 4.4 kg body mass and males mature at 830 mm and 3.7 kg (Alp et al. 2004).

Growth parameters of fish populations are important data for fisheries management and vary among populations. Age and growth of different European catfish populations were reviewed by Copp et al. (2009) and its geographical variation is still poorly known. The objectives of the present study are to provide growth data from a native *S. glanis* population and to compare them with the invasive and native populations in other region. European catfish is an important invasive species and its ecological impacts are poorly understood (Carol et al. 2009; Copp et al. 2009) in part because of the absence of data before introductions. Hence, these results form a native *S. glanis* population will help to understand the life history variation in their introduced range.

Methods

Data collecting and age determination

Menzelet Reservoir, located at 37°43′8″N, 36°51′59″E and 700 m altitude in River Ceyhan at the eastern Mediterranean region of Turkey, has a surface area of 4,200 ha. The maximum depth is ca. 100 m and total water volume is about 12×10^9 m^3. Water temperatures range 9–30°C and other water quality parameters of the reservoir are given by Tanrıverdi et al. (2010). Annual commercial catch of the reservoir is ca. 40 tonnes, 15 of which were of European catfish (Alp et al. 2004).

Samples of European catfish were collected using trammel nets and hooklines or from commercial fishery catches. Total length (TL) and total weight (*W*) of the fish were measured and individuals were dissected and then their sexes were recorded. All procedures involving fish were approved by the University of Kahramanmaraş Animal Care and Use Committee.

The age of *S. glanis* is generally estimated by the analysis of vertebrae, otoliths (Planche 1987a, 1987b; Rossi et al. 1991) and pectoral fin rays (Harka 1984; Harka and Bíró 1990; Horoszewicz and Backiel 2003). Pectoral fin rays are often used for aging because they are easily sampled without reducing the economic value of the fish. However, the growth of the haemal tube of the ray may damage the first annuli and some fish may display juvenile rings that are not true annuli (Harka and Bíró 1990; Horoszewicz and Backiel 2003). In contrast, vertebrae are more difficult to obtain and are thus less frequently used to age European catfish, although might be more accurate for ageing and were used in this study. Yılmaz et al. (2007) compared vertebrae, pectoral fin spines, and otoliths (utricular (lapillus) and lagenar (asteriscus)) to age of 128 *S. glanis* and found vertebrae as superior.

The first 3–5 vertebrae from the beginning of the head were removed of each individual and were cooked and excess muscle and tissue were removed. Vertebrae were also rinsed in 8–10% NaOH for 3–4 h to remove connective tissue. Cleaned vertebrae were washed in water, dried and their centrums were longitudinally sectioned by an Isomet low speed saw. Sectioned centrum was soaked in 5–10% sodium hypochlorite solution for up to 15–20 min (depending on their size) and then rinsed in freshwater and glycerol. The total radius of the each vertebra (VR_c) was measured using a micrometer on a projector and sectioned vertebrae were photographed. Images of vertebrae sections were then analysed with a computer. Growth band pairs (defined as a narrow translucent band adjacent to a wide opaque band) were independently counted and the radius of each band pair measured from the centre of the vertebra to the distal edge and the measurements were used for back-calculations (Fig. 1). Two readers independently aged all vertebrae three times. Age estimates were accepted only if counts by both readers were in agreement or if a third independent analysis matched one of the previous readings.

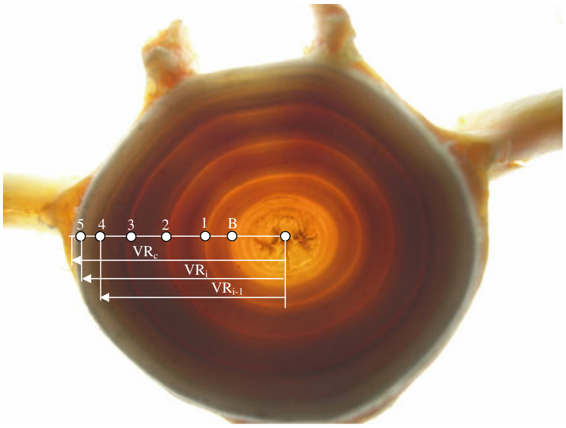

Fig. 1 Growth bands formed on the vertebral centrum of European catfish. *B* birth mark

Marginal increment analysis was used to validate the periodicity of band formation in the vertebrae. Marginal increment analysis is one of the most commonly employed age validation techniques in fish and typically consists in comparing the width of the ultimate, developing band to the width of the last fully formed band pair in different months of capture (Cailliet et al. 2006). We estimated the marginal increment ratio (MIR) as:

$$\mathrm{MIR} = \frac{\mathrm{VR_c} - \mathrm{VR}_i}{\mathrm{VR}_i - \mathrm{VR}_{i-1}}$$

where VR_c is the centrum radius, and VR_i and VR_{i-1} are the radii of the ultimate and penultimate bands, respectively (Fig. 1) (Cailliet et al. 2006).

The relationship between vertebrae radius and total length was approximately linear and was estimated by linear regression. The regression in both sexes did not pass through the origin, thus suggesting that Fraser-Lee method was appropriate for back-calculation (Ricker 1969), and the back-calculated total length of the fish (L_i) at age *i* was estimated as:

$$L_i = \frac{\mathrm{VR}i}{\mathrm{VR_c}}(L_c - a) + a$$

where L_c is the total length of the fish at capture, VR_c is the vertebrae radius at capture, VR_i is the vertebrae radius at ring *i*, and *a* is the intercept of the regression.

Growth functions

Three of the most commonly used growth functions, namely the von Bertalanffy growth function (VBGF), the logistic growth function, and the Gompertz growth function (see e.g. Cailliet et al. 2006) were used to fit the length at age of the European catfish. The NLIN procedure of the statistical package SAS 8.2 (SAS Institute Inc., Cary, NC, USA, 2001) was used to estimate the parameters of each function. The three growth functions are described as follows:

(1) von Bertalanffy growth function

$$L_t = L_\infty[1 - e^{-k(t-t_0)}]$$

(2) the logistic growth function

$$L_t = \frac{L_\infty}{1 + e^{-k(t-t_0)}}$$

(3) Gompertz growth function $L_t = L_\infty e^{-e^{-k(t-t_0)}}$,

where L_t is the length at age t, L_∞ is the asymptotic length, k is the growth coefficient, t is the age (year) and t_o is a constant.

The goodness of fit of the three growth functions was compared based on the ratio of L_{max}/L_∞, the coefficient of determination (r^2) and Akaike's information criterion (AIC; Haddon 2001). AIC was used to compare the goodness of fit of different growth functions (Chen et al. 2007; Chiang et al. 2004; Liu et al. 2009), however, when $n/k < 40$, AIC_c should be used instead of AIC (Franklin et al. 2001). Therefore, AIC_c was used in the present study. AIC and AIC_c were expressed as;

$$AIC = n \ln(MSE) + 2k$$

$$AIC_c = AIC + \frac{2k(k+1)}{n-k-1}$$

where n is the total sample size, MSE is the error mean square, and k is the number of parameters estimated in the growth function. The growth model with the smallest AIC_c value is most likely to be correct.

Results

Length and weight

A total of 257 European catfish (142 females and 115 males) from Menzelet Reservoir were obtained from the fisheries catch or by sampling with trammel nets and hook lines. The total length of the specimens ranged from 30.9 cm (220 g) to 148.1 cm (24,260 g) for females and from 38.5 cm (330 g) to 187.0 cm (42,500 g) for males. The mean size of female and male individuals were 92.7 ± 23.4 cm (6578.2 ± 4964.1 g) and 101.8 ± 29.2 cm (9041.1 ± 7868.9 g), respectively.

The relationships between total weight (W) and total length (TL) were described as $W = 0.0104\ TL^{2.9133}$ ($n = 110$; $r^2 = 0.9664$; $p < 0.0001$) for males and $W = 0.0038\ TL^{3.1295}$ ($n = 135$; $r^2 = 0.9845$; $p < 0.0001$) for females (Fig. 2). Statistical analysis

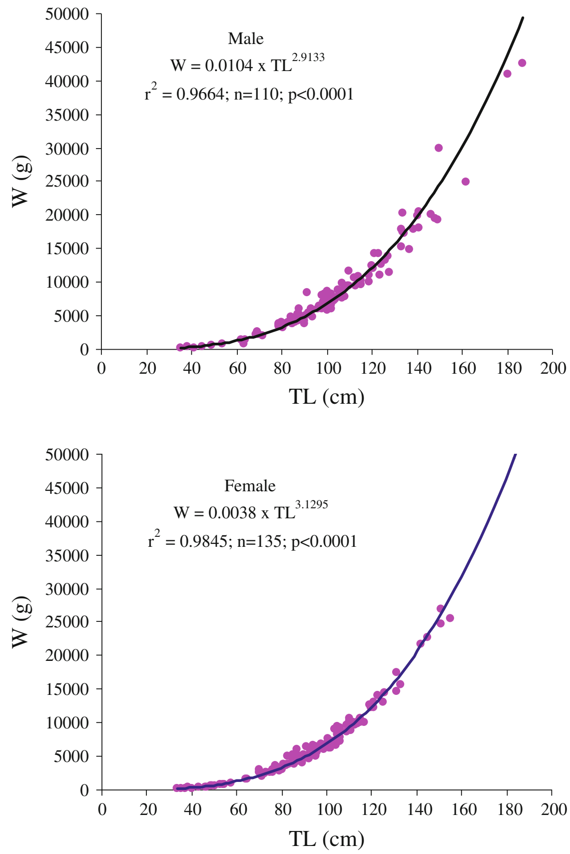

Fig. 2 Length-weight relationship of the European catfish caught at Menzelet Reservoir

revealed no significant differences in length–weight relationships between females and males (ANCOVA, $p > 0.05$).

Age estimation and validation

In total, 245 of the 257 fish were aged successfully and 12 vertebral sections (4.67%) were rejected because the third band reading did not agree with the previous two analyses. The vertebral sections of the female individuals showed up to 11 age groups from 2 to 12 years old. However, the male individuals had 14 age groups from 2 to 17 years old. The percent agreement (PA) between readers was 76.3% overall, 90.2% for 1 band, and 95.4% for 2 bands.

Significant linear relationships were found between the vertebral centrum diameter (VR) and total length (TL) for 135 females and 110 males, which differed significantly (ANCOVA, $p < 0.01$) (Fig. 3). The monthly means of marginal increment ratio (MIR) for females with all ages combined, declined from the maximum of 1.395 in May to minimal of 0.556 in June and 0.612 in July and then increased to 0.795 in August (Fig. 4). Similarly, the monthly means of MIR for males dropped from the maximum of 1.339 in May to 0.598 and 0.591 in June and July and then increased to 0.855 in August. The MIR monthly means during the period from October to February were not significantly different (ANOVAs: females, $p = 0.36$; males $p = 0.874$), but monthly means of MIR in March, April and May were significantly higher than those in June, July and August (two sample *t* test, $p < 0.001$). Also the mean MIR in July was significantly lower than in August (females: *t* test, $p < 0.001$). The MIR monthly means indicated that annulus formation occurred between May and June.

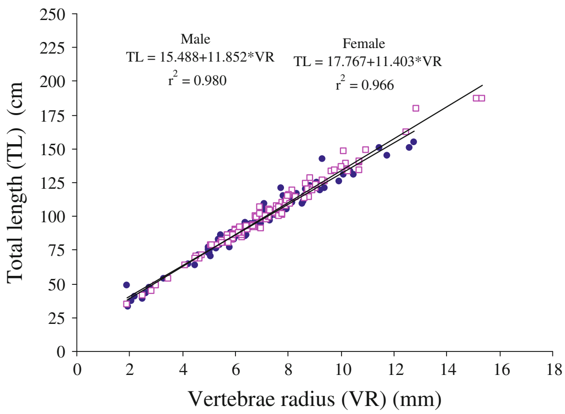

Fig. 3 Relationship between vertebral radius and total length of the European catfish (*S. glanis*) from Menzelet Reservoir. *Filled circles* correspond to females and *open squares* to males

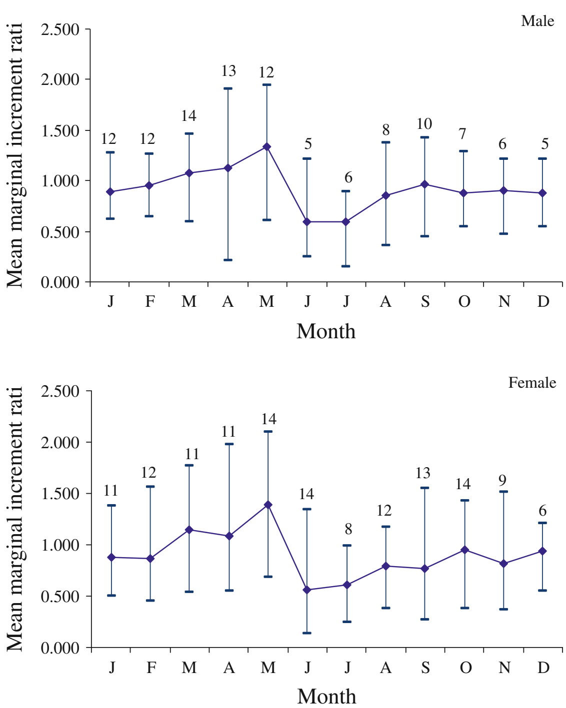

Fig. 4 Monthly changes in marginal increment ratio of male and female European catfish (*S. glanis*) from Menzelet Reservoir. *Vertical lines* are minimum and maximum MIR, *numbers* on the *top of vertical lines* are sample sizes

Growth

The observed and back-calculated mean lengths at age are reported separately for females (Table 1) and males (Table 2). Growth rates of both sexes were lower in older fish. Back-calculated lengths were lower than those observed. The differences between back-calculated and observed lengths did not change with age. The mean back-calculated lengths of older fish in early years were quite similar to the observed mean lengths of individuals of the corresponding age, suggesting that Lee's phenomenon was not important.

The maximum likelihood ratio test suggested that the growth functions between sexes were significantly different ($p < 0.05$). The estimates of the three growth models were as follows:

(1) von Bertalanffy growth function (VBGF): Male: $L_t = 303.2\left[1 + e^{-0.051(t+1.593)}\right]$ ($n = 110$, $r^2 = 0.999, p < 0.0001$) (Fig. 5a); Female: $L_t = 260.0\left[1 + e^{-0.064(t+1.332)}\right]$ ($n = 135, r^2 = 0.999$, $p < 0.0001$) (Fig. 5b).

(2) logistic growth function Male: $L_t = \frac{198.8}{1+e^{-0.222(t-6.529)}}$ ($n = 110, r^2 = 0.992, p < 0.0001$); Female: $L_t = \frac{168.6}{1+e^{-0.287(t-4.967)}}$ ($n = 135$, $r^2 = 0.995, p < 0.0001$).

(3) Gompertz growth function Male: $L_t = 219.4e^{-e^{-0.138(t-4.698)}}$, ($n = 110$, $r^2 = 0.996$, $p < 0.0001$); Female: $L_t = 186.8e^{-e^{-0.177(t-3.577)}}$, ($n = 135$, $r^2 = 0.998, p < 0.0001$).

The VBGF had the smallest AIC_c and highest r^2 among the three growth functions (Table 3) for both sexes. The highest male length (187 cm) in the study was 61.7% of the L_∞ in the VBGF, 94.1% in the logistic growth function and 85.2% in the Gompertz function. The highest female length (148.1 cm) was

Table 1 Back-calculated and observed length-at-age data (cm) for female European catfish (*Silurus glanis*) from Menzelet Reservoir

Age	*N*	1 (135)	2 (135)	3 (131)	4 (124)	5 (112)	6 (89)	7 (51)	8 (26)	9 (11)	10 (6)	11 (2)	12 (1)
Back-calculated													
2	4	33.19	42.95										
3	7	32.84	40.54	52.40									
4	12	31.87	40.80	55.13	71.25								
5	23	32.48	43.87	59.19	72.68	85.86							
6	38	32.74	43.82	56.73	70.04	83.13	94.37						
7	25	33.59	45.24	58.80	71.11	84.15	94.81	105.88					
8	15	32.03	43.34	57.15	69.99	81.27	91.78	102.44	112.50				
9	5	30.12	42.85	55.45	68.12	82.31	93.45	104.65	114.11	126.80			
10	4	33.05	42.97	58.31	71.87	83.02	96.82	103.89	113.93	122.37	131.49		
11	1	28.91	38.44	55.35	64.98	79.84	94.61	100.12	109.87	118.54	129.54	140.21	
12	1	33.97	44.24	54.47	65.43	78.88	93.13	103.00	110.72	119.59	128.10	136.30	145.05
Mean		32.25	42.64	56.30	69.50	82.31	94.14	103.33	112.22	121.82	129.71	138.26	145.05
SD		2.862	3.60	5.23	6.23	7.65	8.89	9.84	6.22	4.61	7.64	2.81	
Observed													
Mean			45.95	59.62	74.32	87.96	99.45	107.17	116.65	128.41	135.50	142.10	148.10
SD			5.540	8.568	9.771	8.181	10.831	12.130	9.343	7.214	14.870		

Numbers in parantheses are the number of individuals examined for each category of band count

57.0% of the L_∞ in VBGF, 87.8% in the logistic and 79.3% in the Gompertz growth function. The VBGF of European catfish as a function of age indicated higher growth rates in males than in females (maximum likelihood ratio test: $p < 0.01$).

The length at age of eight native *S. glanis* populations from different regions and 13 invasive populations from Spain, Italy, France and England are given in Fig. 6. Growth rates of the native populations including Menzelet significantly differed from each other (ANCOVA: population × age, $F_{7,83} = 11.4, p < 0.001$). Growth rates of the invasive populations were also significantly different (ANCOVA: population × age, $F_{11,59} = 18.83$, $p < 0.001$). The differences among growth rates of native and invasive populations were also significant (ANCOVA: population × age, $F_{19,142} = 18.47$, $p < 0.001$). Growth rates in southern populations such as in Turkey, Spain and Italy, were higher than in northern countries such as England and Russia.

Discussion

The largest *S. glanis* reported in the literature was caught in the River Dnepr, where a maximum record of 5 m TL and 306 kg was recorded near Krementchug (Berg 1949). In our study the largest fish was 187 cm in total length. However, larger specimens (TL > 2.5 m) are caught every year in the commercial catch at Menzelet reservoir. Male catfish of Menzelet reservoir were larger than females of the same age, in agreement with previous studies (Ciocan 1979; Carol et al. 2009; Copp et al. 2009). Differences in total length between male and female were of ca. 5–6 cm before age 9, but decreased to 2–3 cm afterwards.

Total lengths at age in the present study were higher than the overall means of the 30 native populations of a previous review (Table 4) but were within the mean ranges among the total of 51 populations. Growth in *S. glanis* is highly variable (Harka 1984), depending on several factors such as habitat, water temperature, and food abundance (Copp et al. 2009). Menzelet reservoir is located in the eastern Mediterranean region and has abundant cyprinid prey species and a water temperature that ranges between 9–30°C and is above 20°C over 6–7 months during the year and likely explains the higher growth rates in Menzelet reservoir. Similar length at age were reported for the invasive populations in Spanish reservoirs (Carol et al. 2009).

Table 2 Back-calculated and observed length-at-age data (cm) for male European catfish (*Silurus glanis*) from Menzelet Reservoir

Age	*N*	1 (110)	2 (110)	3 (108)	4 (103)	5 (97)	6 (81)	7 (67)	8 (35)	9 (23)	10 (17)	11 (10)	12 (6)	13 (3)	14 (2)	15 (2)	16 (2)	17 (1)
Back-calculated																		
2	2	30.05	38.30															
3	5	36.25	45.31	53.50														
4	6	38.59	45.72	54.23	63.50													
5	16	38.53	51.48	65.32	76.99	88.56												
6	14	40.47	54.46	67.42	79.80	93.41	106.30											
7	32	37.31	48.82	62.96	78.49	94.08	109.12	121.83										
8	12	43.09	57.68	71.40	85.93	101.45	116.40	126.92	137.49									
9	6	42.60	55.61	65.40	75.55	90.06	102.70	112.87	124.60	133.80								
10	7	37.77	51.77	66.60	78.38	86.98	96.36	104.67	113.81	122.84	131.40							
11	4	33.60	42.40	56.70	67.80	80.88	93.45	102.84	110.87	119.87	128.41	137.50						
12	3	36.40	48.90	61.10	72.30	82.45	94.71	106.42	117.96	126.84	136.14	143.84	150.87					
13	1	34.50	45.32	57.30	69.45	78.54	91.13	100.89	110.12	123.54	135.87	146.78	154.12	159.60				
16	1	37.60	45.30	56.69	68.62	81.24	95.09	106.79	116.38	125.36	135.50	144.34	154.07	162.03	168.41	175.86	183.49	
17	1	39.20	50.37	64.21	75.85	84.20	92.96	102.19	111.25	119.64	126.27	133.29	141.21	150.93	159.04	168.91	176.90	186.40
Mean		37.57	48.67	61.76	74.39	87.44	99.82	109.49	117.81	124.56	132.26	141.15	150.07	157.52	163.73	172.38	180.20	186.40
SD		3.439	5.355	5.614	6.248	6.932	8.403	9.213	9.273	4.855	4.242	5.572	6.097	5.833	6.625	4.911	4.659	
Observed																		
Mean			52.41	67.81	77.12	89.31	105.40	113.41	123.61	130.21	138.40	147.80	154.61	162.30			182.80	187.00
SD			6.18	7.98	10.26	9.75	10.45	9.74	11.25	8.63	6.88	5.46	3.15					

Numbers in brackets are the number of individuals examined for each category of band count

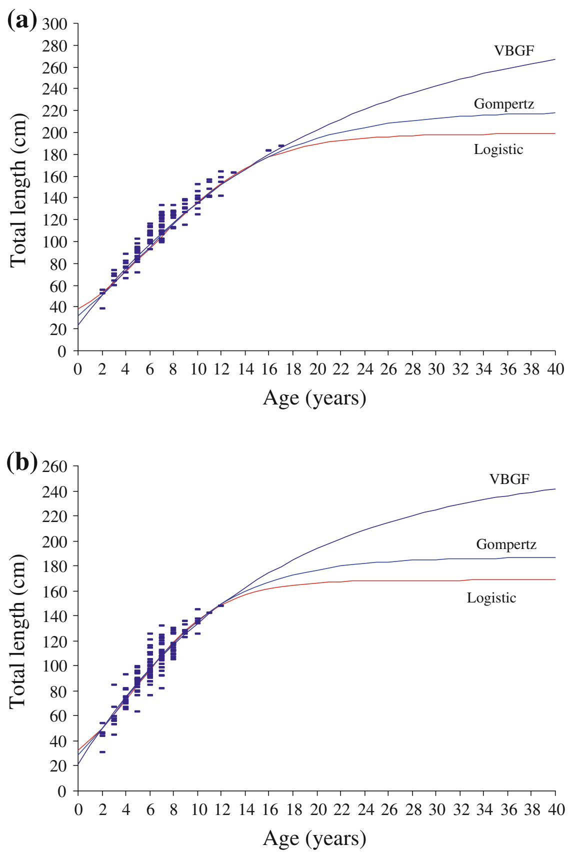

Fig. 5 Growth curves generated from **a** males and **b** females European catfish (*S. glanis*) from Menzelet Reservoir

Average total length of *S. glanis* of age 7 were: 110 cm in Spanish reservoirs (Carol et al. 2009); 70.3 cm in the Vag River, Slovakia; 80.4 cm in the Tizsa River, Hungary; and 102 cm in the Danube River, Serbia (Harka 1984). In the present study, the observed length of 7 years old female *S. glanis* was estimated as 107.2 cm (back-calculated length is 103.3 cm) for female and 113.4 cm (back-calculated is 109.5 cm) for male. These findings are similar to Spanish invasive populations located in the Mediterranean region.

Higher r^2 and smaller AIC_c suggested that the VBGF was a better model to describe the growth of the European catfish. Froese and Binohlan (2000) reported a high correlation between asymptotic length and maximum length of fish in general, and they suggested that asymptotic length should be about 5% higher than the maximum observed length. Although the L_∞ estimate of the VBGF was much larger than those of the logistic and Gompertz models and did not fit Froese and Binohlan's 5% criterion, the much larger catfish caught in the commercial fisheries actually suggest that the logistic and Gompertz models yielded too low L_∞ estimates. L_∞ estimates of the different *S. glanis* populations from Spain (Carol et al. 2009), Poland (Horoszewicz and Backiel 2003), Hungary (Harka 1984) and England (Britton and Pegg 2007) varied from 125.3 to 357.0 cm and the results of populations from Hungary and Spanish were more consistent with our results. Growth model estimates are greatly affected by the lack of very young or old individuals (Cailliet and Goldman 2004).

The marginal increment analysis conducted for European catfish suggested that annulus formation occurred from May to June. Spawning for European catfish in Menzelet Reservoir lasts from June through August (Alp et al. 2004). Similar findings about MIR for European catfish have been reported by Horoszewicz and Backiel (2003).

In the present study, life spans were 12 years for females and 17 years for males. These life spans are higher than those of the majority of the populations in Tables 4 and 5. Life span of the native populations

Table 3 Estimated growth parameters and comparation of goodness of fit among von Bertalanffy, logistic and Gompertz growth functions for European catfish

Growth function	Sex	L_∞	k	t_o	r^2	AIC_c	L_{max}/L_∞
von Bertalanffy	Male	303.2 (15.774)	0.051 (0.004)	−1.593 (0.287)	0.999	27.624	0.62
	Female	260.0 (14.446)	0.064 (0.007)	−1.334 (0.168)	0.999	19.768	0.57
Logistic	Male	198.8 (6.599)	0.222 (0.016)	−6.529 (0.383)	0.992	59.092	0.94
	Female	168.6 (5.212)	0.287 (0.019)	−4.967 (0.274)	0.995	36.725	0.88
Gompertz	Male	219.4 (7.705)	0.138 (0.009)	−4.698 (0.287)	0.996	46.842	0.85
	Female	186.8 (6.102)	0.177 (0.011)	−3.577 (0.205)	0.998	26.741	0.79

Values in parentheses indicate the SE

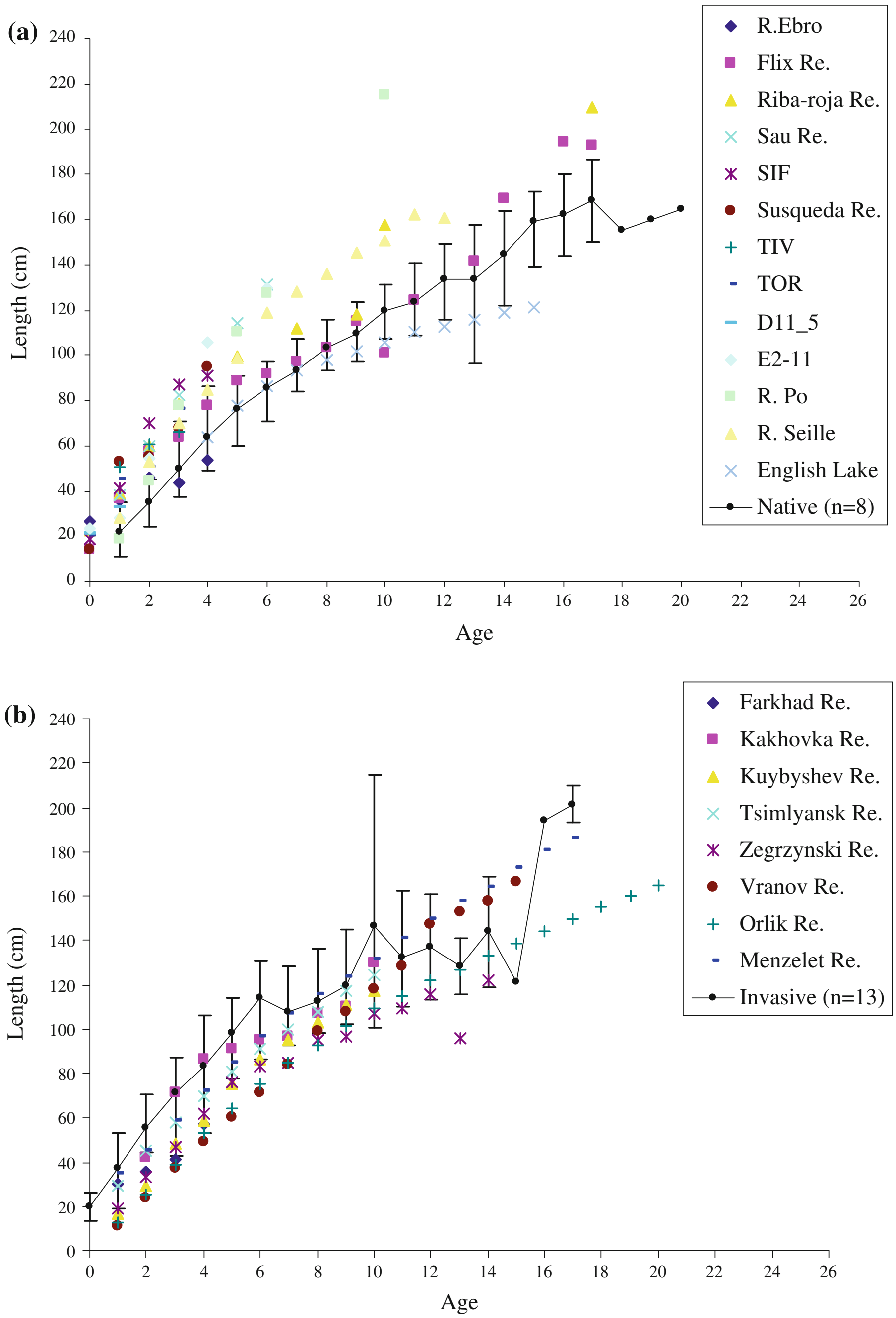

Fig. 6 Comparison of the length at age of different *Silurus glanis* populations **a** invasive populations and native mean, **b** native populations and invasive mean

was reported as 22 years for males and 16 years for females in the Volga Delta, with specimens of 26 years old having been observed in Danube delta (Copp et al. 2009). Life spans for this species introduced to Spain were 17 years for Flix and Riba-roja reservoirs, 7 years for Sau reservoir, 4 years for Susqueda reservoir and 5 years for Ebro channels in Spain (Carol et al. 2009).

In conclusion, this study provides detailed estimates of age and growth for the European catfish, which can be used to improve the management and conservation of native populations of this species and to understand the ecological response of its introduced populations.

Table 4 Back-calculated total lengths (TL) at age of native *S. glanis* populations in a previous review of 30 studies (Copp et al. 2009) and comparison with the results of the present study

Native populations	TL (cm) at age									
	1	2	3	4	5	6	7	8	9	10
Overall mean	20	36	51	62	72	81	88	97	106	113
Minimum population mean	11	22	33	43	52	60	70	72	78	80
Maximum population mean	41	58	90	96	106	118	129	138	153	155
Menzelet Reservoir, Female	32	43	56	70	82	94	103	112	122	130
Menzelet Reservoir, Male	38	49	62	74	87	100	109	118	125	132

Native populations	TL (cm) at age										
	11	12	13	14	15	16	17	18	19	20	25
Overall mean	120	130	130	138	147	166	177	190	193	192	198
Minimum population mean	92	99	96	111	121	140	150	155	160	165	180
Maximum population mean	165	175	180	190	194	197	208	212	216	227	207
Menzelet Reservoir, Female	138	145									
Menzelet Reservoir, Male	141	150	158	164	172	180	186				

Table 5 Total lengths at age of the invasive *S. glanis* populations and their comparisons with the results of the present study

Invasive populations	TL (cm) at age												
	Country	0	1	2	3	4	5	6	7	8	9	10	11
River Ebro	Spain	26	36	46	43	53							
Flix Reservoir	Spain	14	37	58	64	78	89	92	97	103	115	101	124
Riba-roja Reservoir	Spain	23	39	60	78		100		112		118	158	
Sau Reservoir	Spain		38	59	82	91	114	131					
Ebro channel 1	Spain	19	41	70	87	91							
Susqueda Reservoir	Spain	14	53	55	68	95							
Ebro channel 2	Spain		51	61	66								
Ebro channel 3	Spain	20	45	50	77								
Ebro channel 4	Spain	21	32										
Ebro channel 5	Spain	23	28	55		106		130					
River Po	Italy		19	44	78		110	127				215	
River Seille	France		28	53	70	85	99	119	128	136	145	151	162
An English Lake	UK					64	78	86	93	98	102	106	110
Mean		20	37	56	71	83	98	114	108	112	120	146	132
Menzelet Re. Female	Turkey		32	43	56	70	82	94	103	112	122	130	138
Menzelet Re. Male	Turkey		38	49	62	74	87	100	109	118	125	132	141

Table 5 continued

Invasive populations	TL (cm) at age										
	Country	12	13	14	15	16	17	18	19	20	Ref.
River Ebro	Spain										1
Flix Reservoir	Spain		141	169		194	193				1
Riba-roja Reservoir	Spain						210				1
Sau Reservoir	Spain										1
Ebro channel 1	Spain										1
Susqueda Reservoir	Spain										1
Ebro channel 2	Spain										1
Ebro channel 3	Spain										1
Ebro channel 4	Spain										1
Ebro channel 5	Spain										1
River Po	Italy										2
River Seille	France	161									3
An English Lake	UK	113	116	119	121						4
Mean		137	129	144	121	194	202				
Menzelet Re. Female	Turkey	145									(P)
Menzelet Re. Male	Turkey	150	158	164	172	180	186				(P)

Ref: (1) Carol et al. (2009); (2) Rossi et al. (1991); (3) Planche (1987a, b); (4) Britton et al. (2007); (P) Present study

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