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Length–girth relationships for freshwater fishes from Lake Volvi (Northern Greece)

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Abstract
We estimated the relationships between total length (TL) and opercular (G_{ope}) and maximum (G_{max}) girths, for the seven most important freshwater fish species in Lake Volvi during 2016-2017. Both G_{ope} and G_{max} increased significant linearly with TL for all studied species with all r^2 values being greater than 0.83. When G_{ope} and G_{max} were plotted against TL for all species combined, four general length–girth relationships were identified, the slopes of which differed significantly (ANCOVA, $P< 0.05$) and corresponded to three general body shapes. Twenty-nine out of 52 species-season combinations showed that the intercept a and/or slope b values differed significantly among seasons, with more than half of which are attributed to the effect of spring and summer. The implications of girth measurements for selectivity estimates are also discussed.

Keywords: Length–girth relationships, Fish girth, Fish morphology, Lakes

1. Introduction

Length-Girth Relationships (LGR), those between fish body length and girth dimensions, are an important component for biological (e.g. condition and swimming capability) [1], ecological (e.g. predator–prey relationships, trophic level estimation) [2, 3] and fisheries (e.g. quantifying the catching efficiency of a fishing gear) [4, 5] assessments. Species-specific LGR also allow the computation of girth from length measurements, the latter of which are easier to be obtained. In Mediterranean waters LGR have been studied on multi-species fisheries (for more than 10 species) from marine systems (i.e., Spanish Reservoirs, Portugal, southern Portugal, Aegean Sea) [6, 7, 8, 3], whereas such studies are generally lucking for Mediterranean freshwater systems.
The aim of the present study deals with the estimation of LGR for seven freshwater fish species from Lake Volvi (Northern Greece): *Abramis brama* (Linnaeus, 1758), *Alosa macedonica* (Vinciguerra, 1921), *Carassius gibelio* (Bloch, 1782), *Cyprinus carpio* Linnaeus, 1758, *Esox lucius* Linnaeus, 1758, *Perca fluviatilis* Linnaeus, 1758 and *Rutilus rutilus* (Linnaeus, 1758). For *A. brama*, *A. macedonica* and *E. lucius* no LGR estimates existed worldwide. The studied species contribute more than 90% of the fisheries landings in the studied area [9]. Lake Volvi (68 Km^2) located in Northern Greece (40°41'N 23°28'E) consists the second largest natural lake of Greece with significant fisheries exploitation (68 recorded professional fishermen) and high fisheries landings [10].

Materials and Methods

Sampling was conducted from September 2016 to October 2017 (14 seasonal fishing trials), in Lake Volvi with a small-scale fishing vessel (5.80 m of length) using gillnets of different mesh sizes (from 24 mm to 80 mm measured from knot to knot) depending on targeted species. The fishing grounds were selected by the fisherman to ensure the highest possible catches of the main species.
Total length (TL) and body girth were measured to the nearest millimeter for 1229 individuals. Girth measurements were measured to the nearest 0.01 cm with a caliper and were obtained from the height and width behind the gill-cover (G_{ope}) and in front of the first dorsal fin (G_{max}). These measurements were used for the estimation of LGR for the studied species, using least-square regression [11]. The perimeter of ellipse (where minor and mayor radii are the maximum height and width, respectively) was estimated for each of the above proxies using the formula

proposed by Ramanujan in 1914 [12] and applied in similar studies [13].

This method is considered to be more accurate than the maximum circumference to estimate the true perimeter of the fish body [12]. For each species, the intercepts and the slopes of the LGR for G_{ope} and G_{max} were compared for between-species differences using analysis of covariance (ANCOVA) [11]. In addition, for the most abundant species the intercepts and the slopes of the LGR were separately compared for between-season (i.e., autumn 2016-2017, winter 2016-2017, spring 2017 and summer 2017) differences using analysis of covariance (ANCOVA) [11].

Results and Discussion

The relationships of G_{ope} and G_{max} with TL for the seven studied species are summarised in Table 1. For all species the slopes of the regressions were significantly different from 0 ($P< 0.05$), r^2 values were higher than 0.83 (for *A. macedonica* for G_{max}-TL) and both G_{ope} and G_{max} was linearly related to TL (Table 1). Apart from *E. lucius* and *P. fluviatilis* G_{max} increased more with length than did G_{ope} in the remaining five species (Table 1). This is in agreement with LGR estimated from [7] Mendes *et al*. (2006), for open sea species, and from [14] Jawad *et al*. (2009), for estuarine and riverine species. Differences are also observed for slope comparisons among this study and other areas. In fact, significantly (t-test: $P<0.05$) lower slope values were estimated among the study area and Iraque estuarine and riverine waters (i.e.) [14] for the relationships between length and G_{ope} for *C. auratus gibelio* and between length and G_{max} both for *C. auratus gibelio* and *C. carpio*. In contrast, no significant (t-test: P>0.05) difference was found for the between-areas comparison for the relationships between length and G_{ope} for *C. carpio*. Area differences might have been the cause for such variation [7].

When G_{ope} and G_{max} were plotted against TL for all studied species three group of species were significantly (ANCOVA; $P<0.05$) formed according to differences in b values of LGR pair-comparisons among the studied species (Fig. 1). Group A: *A. bramis* and *C. carpio*; Group B: *E. lucius*; and Group C: *A. macedonica*, *C. gibelio*, *R. rutilus* and *P. fluviatilis*. In particular, the torpediform *E. lucius* (group B: Fig. 1) separated from the remaining laterally flattened species, from which, those characterized by the deepest body height (i.e. group C: *C. gibelio*, *R. rutilus* and *P. fluviatilis*) formed a distinct group from those with strongly spherical body cross-sectional shape (i.e. group A: *A. brama* and *C. carpio*). Such relationships might be useful as tools to separate species or genera within families.

Table 1: Relationship between girth behind the gill-cover (G_{ope}, cm) and in front of the first dorsal fin (G_{max}, cm) and total length (TL, cm; TL_{min} and TL_{max} are the minimum and maximum TL, respectively) of seven fish species caught in lake Volvi (September 2016 to October 2017). a and b = parameters of the length-girth relations, SE indicates the standard error of the relations and R^2 denotes coefficient of determination.

Family/Species	N	TL_{min}	TL_{max}	TL_{me}	SE_{TLme}	G_{ope}=a+bTL	SE_a	SE_b	R^2_{G1}	G_{max}=a+bTL	SE_a	SE_b	R^2_{G2}
Cyprinidae													
Abramis brama	119	24.5	52.5	40.5	5.67	Y= 5.913+0.595X	0.96	0.02	0.85	Y= 5.691+0.787X	1.08	0.03	0.88
Carassius auratus gibelio	173	21.0	37.8	29.6	3.68	Y=-1.560+0.976X	0.56	0.02	0.94	Y=-0.753+1.094X	0.82	0.03	0.90
Cyprinus carpio	224	36.0	91.0	51.4	9.33	Y= 6.977+0.595X	0.60	0.01	0.92	Y= 2.581+0.783X	0.88	0.02	0.91
Rutilus rutilus	216	16.1	35.0	18.8	2.45	Y=-5.656+0.883X	0.45	0.02	0.87	Y=-5.835+1.079X	0.44	0.02	0.91
Clupeidae													
Alosa macedonica	244	13.2	26.5	18.6	1.73	Y=-2.981+0.790X	0.39	0.02	0.85	Y=-5.320+0.957X	0.53	0.03	0.83
Esocidae													
Esox Lucius	132	33.0	85.5	62.6	10.2	Y=-6.797+0.586X	0.99	0.02	0.92	Y=-1.436+0.481X	0.99	0.02	0.88
Percidae													
Perca fluviatilis	121	21.0	49.0	27.3	4.55	Y=-2.065+0.977X	0.84	0.03	0.90	Y=-2.228+0.941X	0.82	0.03	0.89

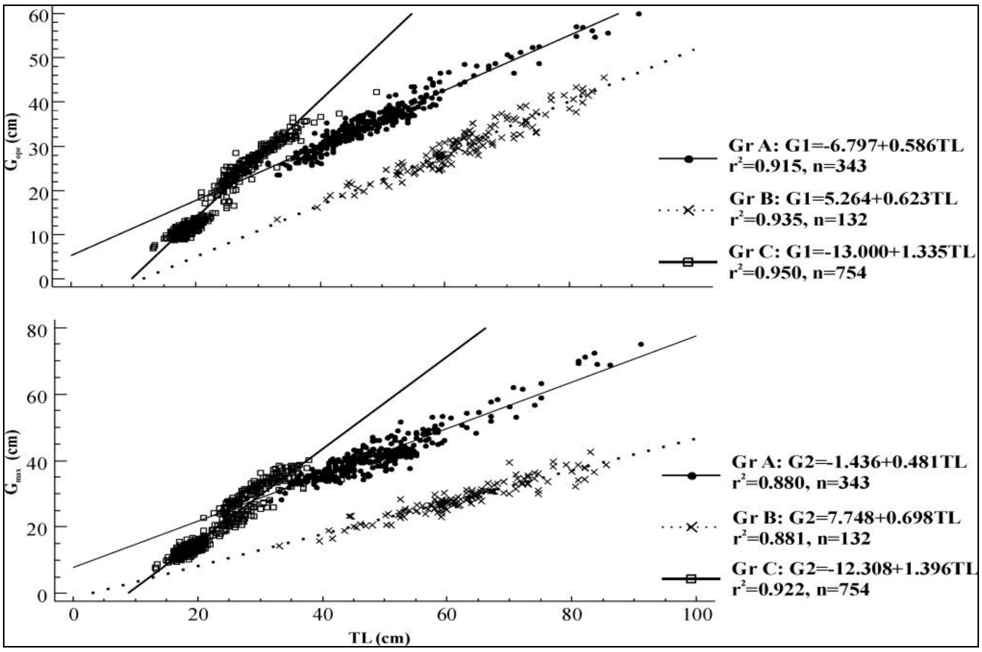

Fig 1: Relationships between TL and (a) girth behind the gill-cover (G1) and (b) girth in front of the first dorsal fin (G2). Group A: *Abramis bramis* and *Cyprinus carpio*; Group B: *Esox lucius*; Group C: *Alosa macedonica*, *Carassius gibelio*, *Rutilus rutilus* and *Perca fluviatilis*. R^2 denotes coefficient of determination.

Between-season comparisons of the LGR were done separately for the five most abundant species (Table 2). Exceptions were the specimens of *A. brama* and *P. fluviatilis*, because the specimens caught in spring and in spring-summer, respectively, were less than 10. Comparisons between all pairs of species-season combinations (Table 2) showed that for 23 out of 52 species-season combinations intercept a and/or slope b values did not differ significantly (ANCOVA: $P > 0.05$) with season. In particular, for 10 out of the 23 non-significant combinations both the intercept a and the slope b did not differ with season, whereas for 4 and 9 combinations the intercept a or the slope b, respectively, showed non-significant differences with season. For the remaining 29 species-season combinations, LGR estimates showed significant (ANCOVA: $P < 0.05$) differences with season, from which 16 are attributed to the effect of spring and summer (Table 2).

Table 2: Results of the analysis of covariance (ANCOVA, $P < 0.05$) for pairs of LGR (girth behind the gill-cover, G_{ope} in cm, and in front of the first dorsal fin, G_{max} in cm) for the most abundant fish species caught in lake Volvi (September 2016 to October 2017) for different species–season combinations. a and b are the parameters of the LGR; ns = non-significant difference ($P > 0.05$), * significant difference ($P < 0.05$).

Species	Season	Autumn		Winter		Spring	
G_{ope}		P of a	P of b	P of a	P of b	P of a	P of b
Rutilus rutilus	Winter	*	*				
	Spring	*	*	*	*		
Esox lucius	Winter	*	ns				
Alosa macedonica	Winter	*	*				
	Summer	*	*	ns	*		
Carassius gibelio	Winter	ns	ns				
	Summer	*	*	*	*		
Cyprinus carpio	Spring	ns	ns				
	Summer	*	ns			*	ns
G_{max}							
Rutilus rutilus	Winter	*	*				
	Spring	*	ns	ns	*		
Esox lucius	Winter	*	ns				
Alosa macedonica	Winter	ns	*				
	Summer	ns	*	ns	ns		
Carassius gibelio	Winter	*	ns	*	ns		
	Summer	*	ns				
Cyprinus carpio	Spring	ns	ns				
	Summer	ns	ns			*	ns

Seasonal differences in LGR can be attributed to biological (e.g., reproduction, sex, food availability) and/or abiotic (e.g., water temperature) factors [1]. The effects of abiotic factors and those of sex and food availability are not examined in the present study. Yet, the spawning and gonad activity could cause seasonal variations in the LGR for certain species as shown by the significant differences of LGR with season for more than half of species-season combinations (Table 2). In particular, these differences on LGR were marked in spring and summer seasons, which consist the main reproductive period of the studied species [15]. Thus, given that LGR are not constant over the year, the estimated LGR could be considered as mean annual values and the use of the LGR estimated here should be limited to the observed length ranges (Table 1). For instance, length ranges did not include the very small-sized individuals (generally smaller than 9 cm) that frequently caught by smaller mesh sizes of the nets (mesh sizes smaller than 24 mm: [16]), and did not represent the commercial part of the professional fisheries catches. The gears used in the present study are girth-specific rather than species-specific gears [5] and thus, girth is expected to be more closely related to mesh size than length [4].

Conclusions

Concluding, girth-length data and girth frequency distributions can be considered crucial in gear selectivity studies, particularly for netter (gillnets: [17]; and trammel nets: [18]), for which the strategy on the suitable mesh size ranges need to be taken. In addition, the estimated relations are of great importance, because they determine fish growth patterns, which in turn are essential for developing of ecosystem-based models for fisheries.

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