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LENGTH–GIRTH RELATIONS OF FISHES FROM A MEDITERRANEAN LAGOON SYSTEM

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Abstract. We estimated the relations between total length (TL) and opercular (G_{ope}) and maximum (G_{max}) girths, for the eight most representative lagoon fish species in Mesolonghi–Etolikon lagoons within 2015–2017 (June through December). The following species were studied: *Chelon saliens* (Risso, 1810); *Chelon auratus* (Risso, 1810); *Chelon ramada* (Risso, 1827); *Mugil cephalus* Linnaeus, 1758; *Diplodus puntazzo* (Walbaum, 1792); *Diplodus sargus* (Linnaeus, 1758); *Sparus aurata* Linnaeus, 1758; *Dicentrarchus labrax* (Linnaeus, 1758). For five of these species (*C. saliens*, *C. auratus*, *C. ramada*, *S. aurata*, and *D. labrax*) LGR estimates were not available. Results showed that both G_{ope} and G_{max} increased significantly linearly with TL for all studied species with all r^2 values being higher than 0.862. When G_{max} values were plotted against TL for all species combined, two significant (ANCOVA, $P < 0.05$) length–girth relations were identified corresponding to different body shapes. The implications of girth measurements for lagoon gear selectivity estimates are also discussed.

Keywords: fish girth, fish morphology, barrier traps, Mesolonghi–Etolikon lagoons, Greece

Species-specific length–girth relations (LGR) allow the computation of girth from length measurements, the latter of which are easier and less expensive to be obtained. Such relations are important for quantifying:

- Biological components (e.g., condition and swimming capability: Wootton 1999)
- Ecological traits (e.g., predator–prey relations and trophic level estimation: Stergiou and Karpouzi 2003; feeding guilds: Pet et al. 1995)
- Fisheries assessment procedures (e.g. fishing gear efficiency: Reis and Pawson 1999, Stergiou and Erzini 2002)

LGR have been studied for numerous marine (i.e., Malaysia: Matsushita and Ali 1997; Portuguese coast: Mendes et al. 2006; southern Portugal: Santos et al. 2006; Aegean Sea: Stergiou and Karpouzi 2003) or freshwater (i.e., Iraq: Jawad et al. 2009; Colombia: Tobes et al. 2016) species and their estimates have been demonstrated for most fisheries compartments. For instance, trawl and gillnet selectivity estimates may benefit from girth data (Matsushita and Ali 1997, Stergiou and Erzini 2002, respectively), because these corresponding estimates are based on the opercular and maximum girth relation with length. However, very few girth data exist for fish species inhabiting periodically the lagoon systems (i.e., Patos Lagoon in Brazil: Reis and Pawson 1999; Szczecin Lagoon in Poland: Psuty et al. 2007) and none of them relates to the Mediterranean lagoons, where the gear efficiency is mostly based on maximum girth (fish width).

In the majority of the Mediterranean lagoons (Cataudella et al. 2015) fisheries exploitation is conducted using permanent fishing devices made of reinforced concrete, the barrier traps that are installed at the interface between the lagoon and open sea. Fisheries based on seasonal on-going migrations of fry and adult fish species for spawning, foraging, and shelter between open sea and lagoons (Franco et al. 2010) during June to February (Katselis et al. 2003). The multispecies nature of the lagoon fisheries, which in turn implied the exploitation of numerous species with different growth, maturity, behaviour, and body shape are increasing the uncertainty on the determination of gear-specific efficiency.

The aim of the presently reported study was the estimation of LGR for eight fish caught in the Mesolonghi–Etolikon lagoon system. The following species were studied: *Chelon saliens* (Risso, 1810); *Chelon auratus* (Risso, 1810); *Chelon ramada* (Risso, 1827); *Mugil cephalus* Linnaeus, 1758; *Diplodus puntazzo* (Walbaum, 1792); *Diplodus sargus* (Linnaeus, 1758); *Sparus aurata* Linnaeus, 1758; *Dicentrarchus labrax* (Linnaeus, 1758).

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The studied species (Table 1) contribute more than 90% to the fisheries landings in the studied area (Katselis et al. 2003). To our knowledge, LGR estimates have not existed worldwide for five of these species, the diadromous species of the family Mugilidae (*C. saliens*, *C. auratus*, and *C. ramada*), as well as for two sparids (*S. aurata* and *D. labrax*).

Sampling was conducted in the barrier traps of the Mesolonghi–Etolikon lagoon system within July–December of 2015 and 2016. The lagoon area covering 131.5 km^2 (38°30′N, 21°05′E–30°15′N, 21°35′E) consists one of the largest lagoon systems in the Mediterranean representing approximately 42% of the total surface of the Greek lagoons (Koutrakis et al. 2007). Total length (TL) and body girth were measured to the nearest millimetre for 1168 individuals. Girth measurements were obtained using a digital calliper and were measured from the height and width of opercular (G_{ope}) and of maximum (G_{max}) girths. The perimeter of the ellipse (where minor and major radii are the maximum height and width, respectively) was estimated for each of the above proxies using the formula proposed by Ramanujan in 1914 (Arfken and Weber 2000) and applied in similar studies (Tobes et al. 2016). This method is considered to be more accurate than the maximum circumference to estimate the true perimeter of the fish body (Arfken and Weber 2000). Then, LGR was estimated using least-square regression (Zar 1999). 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) (Zar 1999).

The relations of G_{ope} and G_{max} with TL for the eight species are summarised in Table 1. For all studied species, the slopes of all the regressions were significant ($P < 0.05$) and maximum girth increased fastest in length than opercular. Both G_{ope} and G_{max} were linearly related to TL and all r^2 values were higher than 0.862, with the latter minimum observed for *Mugil cephalus* in the case of G_{ope}–TL (Table 1). When G_{max} was plotted against TL for all studied species, two groups of species were significantly (ANCOVA, $P < 0.05$; $F = 89.57$) formed (Fig. 1A). In particular, the torpediforms of the family Mugilidae (i.e., *Chelon auratus*, *Chelon ramada*, *Chelon saliens*, and *M. cephalus*) and *Dicentrarchus labrax* clearly formed a separate group (group A, Fig. 1A) distinct from Sparidae species (i.e., *Diplodus puntazzo*, *Diplodus sargus*, and *Sparus aurata*: group B, Fig. 1A) that were characterised by deepest body height.

Due to the nature of the lagoons, which are acting as a nursery grounds for numerous fish species (Franco et al. 2010), data for the studied species usually did not include the very large-sized individuals (generally larger than 42 cm in our study). Thus, the use of the LGR presented here should be limited to the observed length ranges (Table 1). LGR is seasonally influenced by factors such as food availability, feeding rate, gonad development, and spawning frequency (Santos et al. 2006). Thus, the estimated relations should not be considered as mean annual values, as the samples were collected during the offshore species seasonal migration (June to January: Katselis et al. 2003).

Girth measurements are positively and linearly related to total body length (e.g., Karpouzi and Stergiou 2003) a fact that is in accordance with the LGR reported here. All species have shown a steeper relation for maximum, rather than for opercular girths, which is mostly occurred for such relations (e.g., Mendes et al. 2006), apart for few exceptions (e.g., *Liza abu* (Heckel, 1843): see Jawad et al. 2009). LGR are firstly presented for five out of the eight studied species, whereas LGR had previously been reported for *Diplodus puntazzo* and *D. sargus* in Portugal coasts (Santos et al. 2006) and for *Mugil cephalus* in south-western Australian estuaries (Yeoh et al. 2014).

Girth and length, along with other biological (e.g., fish behaviour) and technical (e.g., fishing techniques, gear construction and dimensions) components, strongly determine the size selectivity of passive fishing gears,

Table 1

Principal length–girth relations of eight fish species caught in the Mesolonghi–Etolikon lagoon system (2015–2016)

Family/Species	n	TL_{min}	TL_{max}	$G_{ope} = a + b$TL [cm]				$G_{max} = a + b$TL [cm]			
				Relation	SE_a	SE_b	r^2_{G1}	Relation	SE_a	SE_b	r^2_{G2}
Mugilidae											
Chelon saliens+	145	14.8	31.4	$y = -1.218 + 0.572x$	0.242	0.011	0.962	$y = -2.621 + 0.694x$	0.260	0.012	0.962
Chelon auratus+	205	23.1	37.7	$y = 0.007 + 0.560x$	0.231	0.008	0.958	$y = -3.161 + 0.716x$	0.310	0.011	0.952
Chelon ramada+	109	23.5	37.9	$y = -0.513 + 0.613x$	0.400	0.014	0.944	$y = -3.287 + 0.800x$	0.518	0.019	0.940
Mugil cephalus	80	16	59.3	$y = 5.509 + 0.453x$	0.761	0.020	0.862	$y = -3.303 + 0.731x$	0.548	0.015	0.969
Sparidae											
Diplodus puntazzo	156	10.0	22.0	$y = -2.501 + 0.975x$	0.217	0.017	0.963	$y = 1.765 + 1.045x$	0.201	0.015	0.971
Diplodus sargus	157	8.7	20.8	$y = 0.679 + 0.931x$	0.338	0.023	0.915	$y = 1.980 + 1.051x$	0.377	0.026	0.917
Sparus aurata+	176	9.6	33.6	$y = 0.139 + 0.906x$	0.302	0.014	0.967	$y = -0.349 + 1.016x$	0.445	0.021	0.944
Moronidae											
Dicentrarchus labrax+	140	13.3	42.4	$y = -1.427 + 0.724x$	0.285	0.012	0.967	$y = -1.917 + 0.778x$	0.315	0.013	0.965

G_{ope} = girth behind the gill-cover, G_{max} = girth in front of the first dorsal fin, TL = total length, TL_{min} = minimum length, L_{max} = maximum length, SE_a = standard errors of intercepts a, SE_b = standard errors of slopes b, R_{G1} and R_{G1} are coefficients of determination of both length–girth relations, respectively; + denotes species for which length–girth relations were firstly presented worldwide with respect to lagoon systems.

such as the barrier traps, which are mostly used in Greek lagoon fisheries (Koutrakis et al. 2007). These gears are harmonized to the multi-species nature of Greek lagoons (Koutrakis et al. 2007) with fish having different body shapes (i.e., Mugilidae, Sparidae, and Moronidae) and/or similar body shapes but different length at maturity estimates (*Chelon saliens* and *M. cephalus*: 20 and 32.5 cm, respectively: Froese and Pauly 2017). The identification of two significantly different (ANCOVA, $P < 0.05$) LGR (Fig. 1A) clearly revealed that the LGR of the studied fishes could be described by few generic LGR each corresponding to different body shapes (Karpouzi and Stergiou 2003).

The variability of the body shapes caught at the barrier traps hampers the efforts towards a multi-species management of the lagoon fishery. For instance, the maximum widths of *Dicentrarchus labrax* and *Diplodus sargus* (2.74 and 2.72 cm, respectively) that were corresponding to their enforced "minimum conservation reference size" as stipulated by the new Common Fisheries Policy (Anonymous 2013) were larger when compared with the aforementioned ones for the other lagoon species (Fig. 1B), because of the more pronounced cylindrical shape and deepest body width, respectively. Thus, managing the selectivity of the barrier traps for avoiding catching undersized individuals of the above-mentioned species would result in significant loss of commercial sizes of other fish species (Fig. 1B; Mugilidae and *Sparus aurata*). The existing problem concerns the concurrent presence of numerous species caught in the barrier traps at certain periods of the year, because for most species the time of the offshore migration is overlapped (September: *D. puntazzo*, *D. sargus*, *M. cephalus*; November: *Chelon auratus*, *C. ramada*, *S. aurata*; see Katselis et al. 2003).

In conclusion, girth estimates and more specifically the maximum width of a fish are expected to be equal to the width of the barrier traps than the total length in order to be caught in the traps. In this context, girth frequency distributions can be used as well for gear selectivity estimates, and thus both total length and girth parameters must be taken into account in gear size selectivity studies (for literature review see: Hamley 1975, Stergiou and Karpouzi 2003).

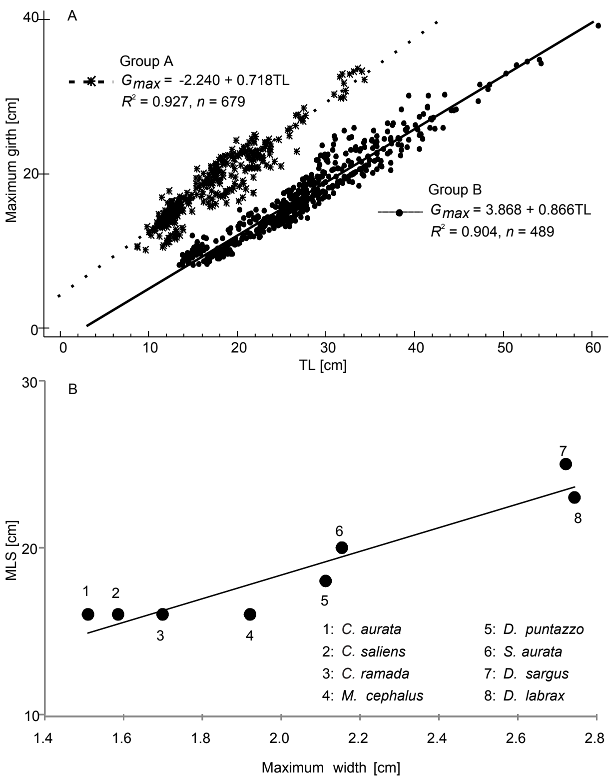

Fig. 1. Relations between TL and maximum girth (G_{max}); group A = *Chelon saliens*, *C. auratus*, *C. ramada*, *Mugil cephalus* and *Dicentrarchus labrax*; group B = *Diplodus puntazzo*, *Diplodus sargus*, and *Sparus aurata*; r^2 = coefficient of determination (**A**); relation between minimum landing size (MLS) and maximum width (**B**)

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