ISSN: 0001-5113
AADRAY

ACTA ADRIAT.,
62 (2): 219 - 236, 2021

ORIGINAL SCIENTIFIC PAPER

Length-girth relationships of 24 marine fishes in the northern Aegean Sea (eastern Mediterranean Sea)

Angeliki ADAMIDOU[1,2*], Konstantinos TOULOUMIS[1] and Athanassios C. TSIKLIRAS[2]

[1] Fisheries Research Institute, ELGO-DIMITRA, 64007 Nea Peramos, Kavala, Greece

[2] Laboratory of Ichthyology, School of Biology, Aristotle University of Thessaloniki, Thessaloniki, Greece

Corresponding author, e-mail: adamidou@inale.gr

The knowledge of morphological relationships and particularly of those concerning fish body girth (G) with total length (TL) is necessary in gear selectivity and specifically the technical measures to avoid capture of undersized individuals. This study concerns 24 marine species exploited by the small-scale coastal fleet in the Aegean Sea (eastern Mediterranean Sea), for 6 of which, the TL-G relationships are mentioned for the first time in the Mediterranean Sea and the adjacent seas. Samples were collected seasonally, from April 2016 to February 2017. The coefficients of the linear regression of body girth in three body positions, (G_{eye}, posterior to the eye; G_{head} at the posterior end of the operculum; G_{max} at the maximum body depth), with the total length were estimated for each species and for the groups formatted when G_{eye}, G_{head} and G_{max} were plotted against total length for all the species combined. Statistically significant differences among the three groups were detected (ANCOVA, $P<0.001$). Comparison of the total length-body girth relationships for 18 species previously studied in different geographic areas of the Mediterranean and the adjacent seas, showed differences mainly with the results from Portuguese waters for certain species populations. Based on the resulted equations, the maximum girth (G_{max}) corresponding to the Minimum Conservation Reference Size (MCRS) and to the total length at maturity (L_m) were calculated for each species. Identified mesh sizes respective to G_{max} values were quite larger than the minimum legal mesh size for gillnets and the inner sheet of trammel nets, indicating that the relevant current fisheries regulations cannot meet the requirements for sustainable exploitation of fish resources.

Key words: fish morphology; fisheries management; gillnets; length at maturity (L_m); Minimum Conservation Reference Size (MCRS); trammel nets

INTRODUCTION

The morphometric relationships of fish provide basic information on their populations, since morphology is strongly related to the functional role of a species within a community and thus, to their evolutionary history (WAINWRIGHT & REILLY, 1994). The relationship between fish total length and body girth (LGR) is useful for the comparison of life history and morphology among species or populations (SANTOS *et al.*, 2006), the explanation of predator–prey relationships and the estimation of trophic level (HAMBRIGHT, 1991; PAULY, 2000), the determination of gear selectivity, as both length and girth have significant effect in the retention of fish by different fishing gears (gillnets: REIS & PAWSON, 1999; FUJIMORI, 2018; trammel nets: SANTOS *et al.*, 2006) as well as for the estimation of girth from length measurements, that are easier obtained onboard and are more readily available (STERGIOU & KARPOUZI, 2003).

Despite their importance in fisheries research and management, studies focusing on total length - body girth relationships for marine fish species in the Mediterranean Sea and the adjacent seas are limited (Greece: STERGIOU & KARPOUZI, 2003; Portugal: MENDES *et al.*, 2006; SANTOS *et al.*, 2006; Saudi Arabia /Red Sea: GABR & MAL, 2018). More often, LGRs are used as a mean to assess fishing gear selectivity (FABI *et al.*, 2002; ÖZEKINCI, 2005; MOUTOPOULOS *et al.*, 2017; ILKYAZ, 2018), since length-based selectivity models are justified when a linear relationship between fish girth and fish length is established (KURKILAHTI *et al.*, 2002). Occasionally, the estimation of LGRs is included in morphometric-biometric analyses of single species (GARCIA-RODRIGUEZ & ESTEBAN, 1998) and in the estimation of girth by applying different models (RAGONESE & BERTOLINO, 1994).

Total length - body girth relationships are important in fisheries management especially in the Mediterranean Sea where most fisheries are managed by controlling the fishing effort and by technical measures (closed areas and seasons, minimum landing size, minimum mesh sizes for nets). A meaningful relationship between related technical measures (such as gear mesh size and fish minimum landing size) is necessary to ensure the effectiveness of any regulation and fisheries management. In this context, the correlation of the mesh size regulations with the Minimum Conservation Reference Sizes (MCRS; in the EU Regulation 2019/1241 the term MCRS replaced the term Minimum Landing Size of the EC Council Regulation 1967/2006) is necessary aiming towards the reduction of the undersized (and mostly immature) individuals in the catch. The MCRS have been defined for a limited number of species, and in some cases are not in accordance with their size at first maturity (L_m, the length at which 50% of a population are sexually mature) (LUCCHETTI *et al.*, 2020) indicating that a large number of undersized individuals are being caught by fishing gears (TSIKLIRAS & STERGIOU, 2014).

The aim of the present study is the estimation of the LGRs of 24 marine fish species from the northern Aegean Sea. Based on this information and by taking into consideration the L_m and the MCRS of each species, we indicate mesh sizes that would be more appropriate for the multi gear and multi species coastal fishery of the area, and could contribute to mitigate the capture of undersized individuals for some of the species studied.

MATERIAL AND METHODS

The fish samples used were collected during a gillnet and trammel net selectivity survey in the northern Aegean Sea (eastern Mediterranean). The sea trials were carried out seasonally, from April 2016 to February 2017 onboard a commercial small-scale fishing vessel. Three fleets of nets were fished, each made up of two net-types (trammel and gillnets) mounted alternately and ten different mesh sizes placed in random order. The mesh sizes of the gillnets and the inner sheets of the trammel nets ranged from 32 to 140 mm stretched mesh (32, 38, 44, 52, 60, 72, 84, 100, 120, 140 mm) while the outer sheets of trammel nets ranged from 190 to 540 mm stretched mesh (190, 200, 220, 260, 300, 320, 350, 400, 480, 540). Nets were linked together to form 1000 m long fleets that were deployed at three depth zones (0-20 m, 20-40 m, 40-60 m), one fleet in each depth zone, as the coastal fishery in the area usually exploits the depths from the coastline to 60m. The taxonomy and nomenclature of the species is according to FishBase (FROESE & PAULY, 2019).

The total length (TL) and body girth (G) was measured to the nearest 0.1 cm for all fish species. The body girth was measured using a thin non-elastic thread (monofilament PA twine) that was afterwards extended on a measuring board.

Girth measurements were recorded at three positions along the fish body: the eye girth (G_{eye}) was measured just posterior to the eye, the head girth (G_{head}) at the posterior end of the operculum and the maximum girth (G_{max}) at the maximum body depth (MOUS *et al.,* 1995). For small red scorpionfish *Scorpaena notata,* black scorpionfish *Scorpaena porcus,* greater weever *Trachinus draco* and stargazer *Uranoscopus scaber,* the G_{head} was measured at the end of pre-operculum since the end of operculum coincided with the maximum girth. All girth measurements were taken from the same person in order to minimize the measurement bias. The body positions where the girths were measured are related to the three most common ways fishes are caught by gillnets (BARANOV, 1914): i) tangled: caught in the net by maxillaries and teeth, no penetration of fish's body in the mesh, ii) gilled: caught behind the gill cover, penetration of fish head in the mesh, iii) wedged: caught by a mesh around the body, penetration of a considerable part of the body in the mesh.

The total length and body girth measurements were used to calculate the LGRs for 24 species based on a linear regression model (SOKAL & ROHLF, 1995):

$$G_x = a + b \times TL$$

where G_x is the girth (G_{eye}, G_{head}, G_{max}) (cm), TL is the total length (cm) and *a* and *b* are the intercept and the slope of the linear regression. The degree of association between the variables was measured by the determination coefficient (r^2). The standard error (*SE*) was determined for the regression parameters *a* and *b*.

Whenever the necessary information was available, a Z-test (KLEINBAUM & KUPPER, 1978) was applied to compare the slope *b* of LGRs of the present study with similar studies in the Mediterranean Sea and the adjacent seas (Sea of Marmara, Black Sea, Red Sea, Gulf of Cádiz, west Portuguese coast), using the general form:

$$z = b1 - b2/SE_{b1\text{-}b2}$$
$$SE_{b1\text{-}b2} = \sqrt{(SE_{b1}^2 + SE_{b2}^2)}$$

where *b1* and *b2* are the slopes and $se_{b1\text{-}b2}$ is the standard error of the difference between the slopes. In the studies where the standard error of *b* was not available, the results of other studies were compared with the confidence intervals of the present study. In order to investigate any possible grouping among species, the G_{eye}, G_{head}, G_{max} were plotted against TL for all the species combined. General G-TL relationships for each group were estimated for all girth types, and the existence of statistically significant differences of the slopes among the groups of each girth type was examined (ANCOVA, $P < 0.001$).

To associate the total length -girth relationships with management actions aiming to minimize the capture of undersized and immature individuals, the estimated species-specific LGR equations were applied to calculate G_{max} at MCRS (according to EU regulation and the national legislation) as well as G_{max} at length at maturity (L_m) that obtained from the literature. When more than one studies were available, the median record of L_m was used. These G_{max} values were used to calculate indicative mesh sizes per species (MCRS mesh size and L_m mesh size). Finally, to identify any inconsistencies among the applied technical measures, the indicative mesh sizes were associated with the minimum legal mesh size (20 mm, stretched mesh for gillnets and the inner sheet of trammel nets), according to national legislation.

RESULTS

Overall, 3380 individuals representing 24 fish species from 14 families were collected and used for the calculation of the LGRs for G_{eye} (Table 1), G_{head} (Table 2) and G_{max} (Table 3). The G_{eye}, G_{head}, G_{max} were plotted against to TL for each species separately, along with the respective regression lines (Fig. 1). For six species, the snake blenny *Ophidion barbatum*, the sand sole *Pegusa lascaris*, the round sardinella *Sardinella aurita*, the brown comber *Serranus hepatus*, the *U. scaber* and the picarel *Spicara flexuosa*, the TL-G_{eye}, TL-G_{head} and TL-G_{max} relationships are calculated for the first time in the Mediterranean Sea and the adjacent seas. For additional six species the spotted flounder *Citharus linguatula*, the common dentex *Dentex dentex* the blackspot seabream *Pagellus bogara-*

Table 1. Descriptive statistics and estimated parameters of total length-eye girth relationships for 24 species fished from April 2016 to February 2017 in northern Aegean Sea, (eastern Mediterranean Sea). a, intercept; b, slope; b, b values from previous LGR studies in the Mediterranean and the adjacent Seas; G_{eye}: eye girth, cm; n, sample size; r^2: determination coefficient; SD: standard deviation; SE: standard error of a, b; TL: total length, cm. The references of the previous studies are in the end of the table while in the table are indicated as a superscript number of b*.*

Family/Species name	n	*TL* (cm) (mean±*SD*)	*TL* (cm) min-max	G_{eye} (cm) (mean±*SD*)	G_{eye} (cm) min-max	Length–girth equation Y=*a*+*b*X	*SE* (*a*)	*SE* (*b*)	r^2	*b** range of other studies
Carangidae										
Trachurus mediterraneus (Steindachner, 1868)	37	18.54±2.13	14.9-22.2	6.98±0.83	5.4-8.4	G_{eye}=0.085+0.372*TL	0.362	0.019	0.910	(0.357)[1]
Centracanthidae										
Spicara maena (Linnaeus, 1758)	86	16.34±1.36	12.5-19.2	6.96±0.61	5.2-8.3	G_{eye}=0.734+0.381*TL	0.406	0.025	0.735	
Spicara flexuosa Rafinesque, 1810	147	14.93±1.68	10.4-17.8	6.13±0.72	4.4-7.8	G_{eye}=0.651+0.367*TL	0.273	0.018	0.736	
Citharidae										
Citharus linguatula (Linnaeus, 1758)	79	14.32±2.90	8.0-21.6	5.3±1.04	3.4-7.7	G_{eye}=0.386+0.343*TL	0.183	0.013	0.906	
Clupeidae										
Sardinella aurita Valenciennes, 1847	271	20.48±1.26	16.7-24.1	6.86±0.44	5.4-7.8	G_{eye}=1.743+0.249*TL	0.315	0.015	0.494	
Gadidae										
Trisopterus capelanus (Lacepède, 1800)	38	14.52±1.74	12.2-20.7	5.96±0.83	4.8-9.2	G_{eye}=-0.629+0.454*TL	0.365	0.025	0.899	
Merlucciidae										
Merluccius merluccius (Linnaeus, 1758)	143	30.22±4.66	21.3-44.8	10.13±1.64	6.8-15.2	G_{eye}=0.153+0.333*TL	0.276	0.009	0.904	(0.301)[1]
Mullidae										
Mullus barbatus Linnaeus, 1758	342	16.38±2.26	12.0-23.9	7.31±1.13	5.2-10.8	G_{eye}=-0.487+0.477*TL	0.144	0.009	0.898	
Mullus surmuletus Linnaeus, 1758	223	17.81±2.21	11.7-22.5	7.99±1.08	5.3-10.5	G_{eye}=-0.081+0.453*TL	0.211	0.012	0.870	(0.513)[1]
Ophidiidae										
Ophidion barbatum Linnaeus, 1758	26	20.65±1.22	17.5-23-8	5.62±0.38	5.0-6.8	G_{eye}=0.835+0.232*TL	0.873	0.042	0.538	
Scorpaenidae										
Scorpaena notata Rafinesque, 1810	63	12.69±1.51	9.3-15.8	7.94±1.02	5.5-9.6	G_{eye}=-0.159+0.638*TL	0.371	0.029	0.886	
Scorpaena porcus Linnaeus, 1758	544	13.09±1.90	8.5-21.8	7.94±1.30	5.1-14.1	G_{eye}=-0.588+0.651*TL	0.124	0.009	0.900	(0.658)[1]
Serranidae										
Serranus hepatus (Linnaeus, 1758)	29	10.13±0.54	8.8-11.1	5.22±0.33	4.3-5.9	G_{eye}=0.023+0.513*TL	0.659	0.065	0.686	
Serranus scriba (Linnaeus, 1758)	97	14.53±2.07	11.6-21.7	6.18±0.86	4.6-9.0	G_{eye}=0.573+0.386*TL	0.188	0.013	0.905	(0.391)[1]
Soleidae										
Pegusa lascaris (Risso, 1810)	106	17.65±2.21	13.8-26.1	7.22±0.98	5.6-10.7	G_{eye} =-0.226+0.421*TL	0.237	0.013	0.905	
Sparidae										
Boops boops (Linnaeus, 1758)	88	15.87±1.84	9.3-21.7	5.94±0.81	3.5-8.7	G_{eye}=-0.509+0.406*TL	0.292	0.018	0.850	(0.345)[1]
Dentex dentex (Linnaeus, 1758)	20	18.29±3.52	11.8-24.2	8.79±1.61	5.5-11.8	G_{eye}=0.670+0.444*TL	0.480	0.026	0.940	
Diplodus annularis (Linnaeus, 1758)	507	13.34±1.92	8.3-18.1	7.45±1.15	4.5-10.5	G_{eye}=-0.131+0.569*TL	0.115	0.009	0.899	(0.619)[1]
Diplodus vulgaris (Geoffroy Saint-Hilaire, 1817)	107	11.39±2.90	7.8-22.0	6.37±1.71	4.0-12.6	G_{eye}=-0.172+0.575*TL	0.162	0.014	0.943	
Pagellus acarne (Risso, 1827)	32	12.10±2.33	7.4-16.5	5.65±1.14	3.2-7.9	G_{eye}=0.087+0.460*TL	0.362	0.029	0.887	
Pagellus bogaraveo (Brünnich, 1768)	51	10.11±1.44	7.3-12.4	5.05±0.83	3.3-6.3	G_{eye}=-0.567+0.556*TL	0.207	0.020	0.938	
Pagellus erythrinus (Linnaeus, 1758)	78	13.67±2.54	10.7-21.7	7.03±1.36	5.5-11.2	G_{eye}=-0.165+0.526*TL	0.153	0.011	0.968	(0.540)[1]
Trachinidae										
Trachinus draco Linnaeus, 1758	217	23.93±4.87	9.9-34.0	7.67±1.43	3.0-10.8	G_{eye}=0.874+0.284*TL	0.128	0.005	0.931	
Uranoscopidae										
Uranoscopus scaber Linnaeus, 1758	49	20.58±4.24	10.5-30.9	12.15±2.52	6.5-18.9	G_{eye}=0.308+0.575*TL	0.443	0.021	0.939	

STERGIOU & KARPOUZI, 2003[1]

Table 2. Descriptive statistics and estimated parameters of total length-head girth relationships for 24 species fished from April 2016 to February 2017 in northern Aegean Sea, (eastern Mediterranean Sea). a, intercept; b, slope; b, b values from previous LGR studies in the Mediterranean and the adjacent Seas; G_{head}, head girth, cm; G_{head}β, head girth measured at pre-operculum, cm; n, sample size; r^2: determination coefficient; SD: standard deviation; SE: standard error of a, b; TL: total length, cm. The references of the previous studies are in the end of the table while in the table are indicated as a superscript number of b*.*

Family/Species name	n	*TL* (cm) (mean±SD)	*TL* (cm) min-max	G_{head} (cm) (mean±*SD*)	G_{head} (cm) min-max	Length–girth equation Y=*a*+*b*X	*SE* (*a*)	*SE* (*b*)	r^2	*b** range of other studies
Carangidae										
Trachurus mediterraneus (Steindachner, 1868)	37	18.53±2.14	14.9-22.2	7.87±0.88	6.7-9.5	G_{head}=0.969+0.372*TL	0.564	0.030	0.80)	(0.487)[4]
Centracanthidae										
Spicara maena (Linnaeus, 1758)	86	16.34±1.36	12.5-19.2	8.23±0.79	6.4-10.2	G_{head}=-0.017+0.505*TL	0.504	0.031	0.760)	(0.687)[4]
Spicara flexuosa Rafinesque, 1810	146	14.89±1.65	10.4-17.8	7.10±0.91	5.2-8.8	G_{head}=-0.225+0.492*TL	0.305	0.020	0.801	
Citharidae										
Citharus linguatula (Linnaeus, 1758)	79	14.25±2.87	8.0-21.6	7.03±1.66	3.9-11.3	G_{head}=-0.963+0.561*TL	0.223	0.015	0.945	(0.342-0.370)[6;7]
Clupeidae										
Sardinella aurita Valenciennes, 1847	269	20.54±1.26	16.9-24.1	8.02±0.47	6.2-9.6	G_{head}=2.010+0.293*TL	0.293	0.014	0.612	
Gadidae										
Trisopterus capelanus (Lacepède, 1800)	37	14.52±1.76	12.2-20.7	6.89±1.01	5.5-10.7	G_{head}=-0.956+0.541*TL	0.451	0.031	0.895	(0.365)[6]
Merlucciidae										
Merluccius merluccius (Linnaeus, 1758)	104	29.46±4.72	21.3-44.8	11.50±2.13	7.7-18.0	G_{head}=-1.204+0.431*TL	0.401	0.013	0.909	(0.364-0.441)[4;6;7]
Mullidae										
Mullus barbatus Linnaeus, 1758	340	16.37±2.26	12.0-23.9	7.98±1.27	5.7-11.8	G_{head}=-0.803+0.536*TL	0.150	0.009	0.911	(0.540)[3;6]
Mullus surmuletus Linnaeus, 1758	224	17.79±2.22	11.7-22.7	8.92±1.31	5.8-12.3	G_{head}=-0.860+0.550*TL	0.254	0.014	0.871	(0.517-0.589)[4;6;7]
Ophidiidae										
Ophidion barbatum Linnaeus, 1758	26	20.65±1.22	17.5-23.8	6.30±0.38	5.4-7.4	G_{head}=0.557+0.278*TL	0.591	0.029	0.790	
Scorpaenidae										
Scorpaena notata Rafinesque, 1810	63	12.69±1.51	9.3-15.8	8.91±1.11	6.3-11.0	$G_{head}^{\$}$=0.290+0.679*TL	0.467	0.037	0.847	(0.631-0.782)[6;7]
Scorpaena porcus Linnaeus, 1758	546	13.09±1.91	8.5-21.8	8.90±1.45	5.6-15.7	$G_{head}^{\$}$=-0.504+0.718*TL	0.137	0.010	0.898	
Serranidae										
Serranus hepatus (Linnaeus, 1758)	29	10.13±0.54	8.8-11.1	6.19±0.34	5.3-6.7	G_{head}=0.373+0.575*TL	0.502	0.046	0.827	
Serranus scriba (Linnaeus, 1758)	72	14.41±1.88	11.6-21.7	8.01±1.17	5.5-10.8	G_{head}=-0.658+0.601*TL	0.294	0.020	0.926	(0.608)[4]
Soleidae										
Pegusa lascaris (Risso, 1810)	106	17.57±2.06	13.8-25.0	9.76±0.92	7.8-13.1	G_{head}=2.072+0.437*TL	0.173	0.010	0.950	
Sparidae										
Boops boops (Linnaeus, 1758)	86	15.86 ±1.85	9.3-21.7	6.90±1.02	4.0-10.2	G_{head}=-1.438+0.526*TL	0.309	0.019	0.897	(0.325-0.439)[4;6;7]
Dentex dentex (Linnaeus, 1758)	20	18.29±3.52	11.8-24.2	10.60±2.03	7.0-14.4	G_{head}=0.227+0.567*TL	0.460	0.025	0.965	(0.608)[8]
Diplodus annularis (Linnaeus, 1758)	500	13.32±1.91	8.3-18.1	8.87±1.44	5.3-12.7	G_{head}=-0.743+0.722*TL	0.136	0.010	0.911	(0.620-0.725)[2;3;4;5;7]
Diplodus vulgaris (Geoffroy Saint-Hilaire, 1817)	106	11.30±2.77	7.8-22.0	7.46±1.97	5.0-15.2	G_{head}=-0.432+0.698*TL	0.157	0.014	0.963	(0.630-0.651)[6;7]
Pagellus acarne (Risso, 1827)	33	12.08±2.30	7.4-16.5	6.45±1.31	3.5-9.2	G_{head}=-0.116+0.544*TL	0.387	0.032	0.903	(0.637-0.676)[1;6;7]
Pagellus bogaraveo (Brünnich, 1768)	53	10.07±1.38	7.3-12.4	5.62±0.96	3.6-7.2	G_{head}=-1.140+0.672*TL	0.243	0.024	0.938	(0.622)[6]
Pagellus erythrinus (Linnaeus, 1758)	78	13.67±2.54	10.7-21.5	7.85±1.62	5.9-12.3	G_{head}=-0.690+0.625*TL	0.210	0.015	0.957	(0.636-0.697)[1;4;6;7]
Trachinidae										
Trachinus draco Linnaeus, 1758	220	23.98±4.87	9.9-34.7	9.12±1.85	3.8-13.6	$G_{head}^{\$}$=0.212+0,371*TL	0.136	0.006	0.954	(0.302-0.384)[6;7]
Uranoscopidae										
Uranoscopus scaber Linnaeus, 1758	50	20.67±4.25	10.50-30.90	13.99±3.02	7.2-22.2	$G_{head}^{\$}$=-0.216+0.687*TL	0.551	0.026	0.934	

SANTOS *et al.*, 1995[1]; SANTOS *et al.*, 1998[2]; FABI *et al.*, 2002[3]; STERGIOU & KARPOUZI, 2003[4]; ÖZEKINCI, 2005[5]; MENDES *et al.*, 2006[6]; SANTOS *et al.*, 2006[70]; AYDIN & SÜMER, 2010[8]

Table 3. Descriptive statistics and estimated parameters of total length-maximum girth relationships for 24 species fished from April 2016 to February 2017 in northern Aegean Sea, (eastern Mediterranean Sea). a, intercept; b, slope; b, b values from previous LGR studies in the Mediterranean and the adjacent Seas; G_{max}, maximum girth, cm; n, sample size; r^2: determination coefficient; SD: standard deviation; SE: standard error of a, b; TL: total length, cm. The references of the previous studies are in the end of the table while in the table are indicated as a superscript number of b*.*

Family/Species name	n	*TL* (cm) (mean±SD)	*TL* (cm) min-max	G_{max} (cm) (mean±*SD*)	G_{max} (cm) min-max	Length–girth equation Y=*a*+*b*X	*SE* (*a*)	*SE* (*b*)	r^2	*b** range of other studies
Carangidae										
Trachurus mediterraneus (Steindachner, 1868)	34	18.37±2.15	14.9-22.2	8.49±0.84	7.2-10.4	G_{max}=1.709+0.369*TL	0.426	0.023	0.886	(0.580)[6]
Centracanthidae										
Spicara maena (Linnaeus, 1758)	86	16.34±1.36	12.5-19.2	9.38±0.91	7.1-11.8	G_{max}=-0.404+0,599*TL	0.522	0.032	0.806	(0.755)[6]
Spicara flexuosa Rafinesque, 1810	148	14.92±1.66	10.4-17.8	8.09±0.97	6.1-10.0	G_{max}=0.467+0.511*TL	0.347	0.023	0.769	
Citharidae										
Citharus linguatula (Linnaeus, 1758)	81	14.25±1.66	8.0-21.6	8.46±2.03	4.2-13.6	G_{max}=-1.436+0.688*TL	0.264	0.018	0.948	(0.667)[10]
Clupeidae										
Sardinella aurita Valenciennes, 1847	249	20.51±1.23	16.9-24.1	8.92±0.72	7.0-10.7	G_{max}=-0.964+0.482*TL	0.439	0.021	0.672	
Gadidae										
Trisopterus capelanus (Lacepède, 1800)	38	14.52±1.74	12.2-20.7	8.03±1.07	6.6-11.7	G_{max}=-0.369+0.579*TL	0.515	0.035	0.879	(0.375-0.620) [7;9]
Merlucciidae										
Merluccius merluccius (Linnaeus, 1758)	138	30.21±4.66	21.3-44.8	12.50±2.37	8.1-20.5	G_{max}=-2.061+0.482*TL	0.428	0.014	0.896	(0.426-0.620) [2;5;6;7;9; 10]
Mullidae										
Mullus barbatus Linnaeus, 1758	340	16.37±2.27	12.0-23.9	8.68±1.35	6.2-12.6	G_{max}=-0.633+0.569*TL	0.159	0.010	0.911	(0.514-0.600) [4;7;9]
Mullus surmuletus Linnaeus, 1758	225	17.81±2.24	11.7-22.7	9.72±1.39	6.4-13.7	$G_{max=}$-0.719+0.586*TL	0.245	0.014	0.892	(0.547-0.691) [6; 9;10]
Ophidiidae										
Ophidion barbatum Linnaeus, 1758	27	20.59±1.23	17.5-23-8	7.09±0.64	5.8-8.5	G_{max}=-2.140+0.448*TL	1.082	0.053	0,735	
Scorpaenidae										
Scorpaena notata Rafinesque, 1810	64	12.73±1.54	9.3-15.8	9.70±1.26	6.6-12.7	$G_{max=}$-0.062+0.767*TL	0.478	0.037	0.870	(0.748)[10]
Scorpaena porcus Linnaeus, 1758	544	13.08±1.90	8.5-21.8	9.60±1.53	6.1-16.5	$G_{max=}$-0.342+0.760*TL	0.153	0.012	0.889	(0.734)[6]
Serranidae										
Serranus hepatus (Linnaeus, 1758)	29	10.13±0.54	8.8-11.1	6.70±0.34	6.0-7.2	G_{max}=0.782+0.584*TL	0.420	0.041	0.876	
Serranus scriba (Linnaeus, 1758)	95	14.47±2.03	11.6-21.7	9.16±1.50	6.2-12.3	G_{max}=-0.932+0.698*TL	0.354	0.024	0.898	
Soleidae										
Pegusa lascaris (Risso, 1810)	107	17.58±2.14	13.8-26.1	12.48±1.58	9.6-19.3	G_{max}=-0.190+0.721*TL	0.276	0.016	0.953	
Sparidae										
Boops boops (Linnaeus, 1758)	89	15.88±1.83	9.3-21.7	7.88±1.22	4.4-11.8	G_{max}=-2.158+0.632*TL	0.362	0.023	0.898	(0.512-0.623) [6; 9;10]
Dentex dentex (Linnaeus, 1758)	20	18.29±3.52	11.8-24.2	11.71±2.32	7.3-15.5	G_{max}=-0.139+0.648*TL	0.488	0.026	0.970	(0.638)[11]
Diplodus annularis (Linnaeus, 1758)	500	13.34±1.92	8.3-18.1	10.37±1.78	6.0-14.6	$G_{max=}$-1.520+0.891*TL	0.156	0.012	0.922	(0.694-0.897) [3;4;6; 7;8;10]
Diplodus vulgaris (Geoffroy Saint-Hilaire, 1817)	106	11.35±2.88	7.8-22.0	8.60±2.44	5.8-17.4	G_{max}=-0.877+0.835*TL	0.148	0.013	0.976	(0.701-0.797) [9;10]
Pagellus acarne (Risso, 1827)	33	12.11±2.31	7.4-16.5	6.99±1.46	3.7-9.6	$G_{max=}$-0.242+0.597*TL	0.455	0.037	0.891	(0.598-0.752) [1;5;6;7;9; 10]
Pagellus bogaraveo (Brünnich, 1768)	52	10.04±1.38	7.3-12.4	6.00±1.05	3.9-7.9	$G_{max=}$-1.408+0.738*TL	0.246	0.024	0.948	
Pagellus erythrinus (Linnaeus, 1758)	75	13.63±2.56	10.7-21.5	8.51±1.75	6.2-13.3	G_{max}=-0.685+0.674*TL	0.191	0.014	0.970	(0.676-0.714) [1;6; 7;9;10]
Trachinidae										
Trachinus draco Linnaeus, 1758	213	23.98±4.92	9.9-34.7	9.93±2.13	4.0-15.0	G_{max}=0.102+0.410*TL	0.230	0.009	0.900	(0.420-0.424) [9; 10]
Uranoscopidae										
Uranoscopus scaber Linnaeus, 1758	50	20.67±4.25	10.5-30.9	14.23±3.29	7.4-23.3	G_{max}=-1.144+0.744*TL	0.659	0.031	0.920	

SANTOS *et al.,* 1995[1]; GARCIA-RODRIGUEZ & ESTEBAN, 1998[2]; SANTOS *et al.,* 1998[3]; FABI *et al.,* 2002[4]; CAMPOS & FONSECA, 2003[5]; STERGIOU & KARPOUZI, 2003[6]; TOSUNOĞLU *et al.,* 2003[7]; ÖZEKINCI, 2005[8]; MENDES *et al.,* 2006[9]; SANTOS *et al.,* 2006[10] ; AYDIN & SÜMER, 2010[11]

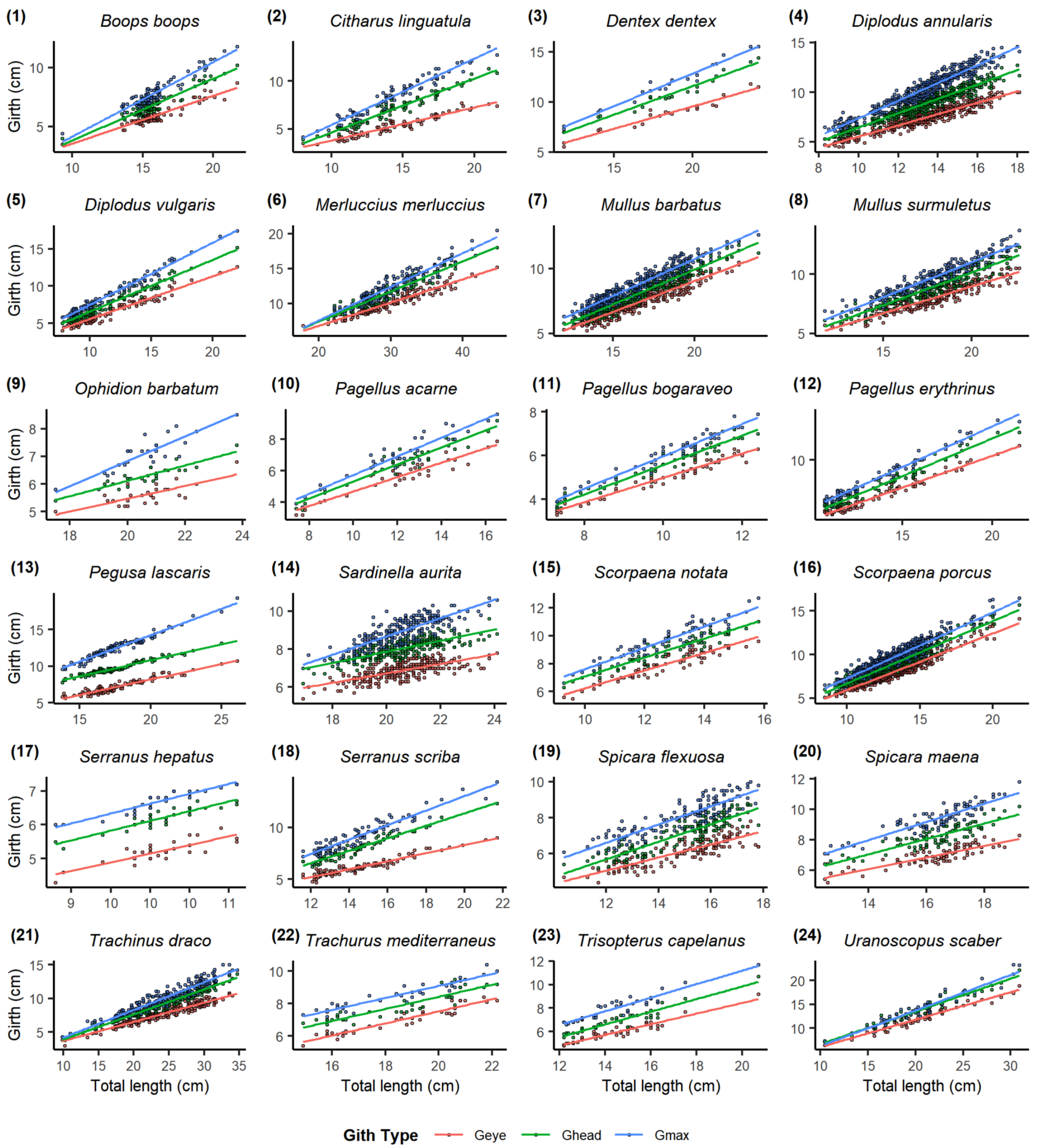

Fig. 1. Total length (TL, cm)-Eye girth (G_{eye}, cm), Total length (TL, cm)-Head girth (G_{head}, cm), Total length (TL, cm)-Maximum girth (G_{max}, cm) relationships per species for the 24 species fished from April 2016 to February 2017 in northern Aegean Sea, (eastern Mediterranean Sea)

veo, the *S. notata*, the *T. draco* and the poor cod *Trisopterus capelanus*, the TL-G_{eye} relationship is calculated for the first time.

A positive linear relationship between body girth (G) and total length (TL) was detected for all the species in all girth types (G_{eye}: Table 1; G_{head}: Table 2; G_{max}: Table 3). Linear regressions of TL with G_{eye}, G_{head}, G_{max} were statistically significant ($P < 0.001$) and most r^2 values were higher than 0.7, apart from those resulted for the length-girth regressions of the *S. aurita* (in all girth positions), *O. barbatum* (in G_{eye}) and *S. hepatus* (in G_{eye}). The highest r^2 values of G_{eye}, G_{head}, G_{max} to TL regressions were estimated for the common pandora *Pagellus erythrinus* (0.968), the *D. dentex* (0.965) and the

Table 4. General relationships between total length and girth (G_{eye}, G_{head}, G_{max}) for the different groups identified (A, B, C) according to body shape and results of the ANCOVA for between groups comparison. G_{eye}, eye girth, cm; G_{head}, head girth, cm; G_{max}, maximum girth, cm; n, number of specimens investigated; r^2, coefficient of determination; TL, total length, cm.

G_{eye}	Length–girth equation Y=*a*+*b*X	r^2	n
Group A	G_{eye}=0.7758+0.3017*TL	0.921	756
Group B	G_{eye}=-0.1803+0.4439*TL	0.840	1199
Group C	G_{eye}=-0.3657+0.6052*TL	0.890	1398
ANCOVA:	P<0.0001 r^2: 0.891 F value: 5490		
G_{head}	**Length–girth equation Y=*a*+*b*X**	r^2	n
Group A	G_{head}=0. 7206+0.3600*TL	0.932	716
Group B	$G_{head=}$-0.1829+0.5170*TL	0.839	1172
Group C	G_{head}=-0.5978+0.7097*TL	0.911	1396
ANCOVA:	P<0.0001 r^2: 0.901 F value: 6004		
G_{max}	**Length–girth equation Y=*a*+*b*X**	r^2	n
Group A	$G_{max=}$0.6146+0.3972*TL	0.912	634
Group B	G_{max}=0.6014+0.5186*TL	0.807	1311
Group C	G_{max}=0.4879+0.7116*TL	0.904	1372
ANCOVA:	P<0.0001 r^2: 0.894 F value: 5580		

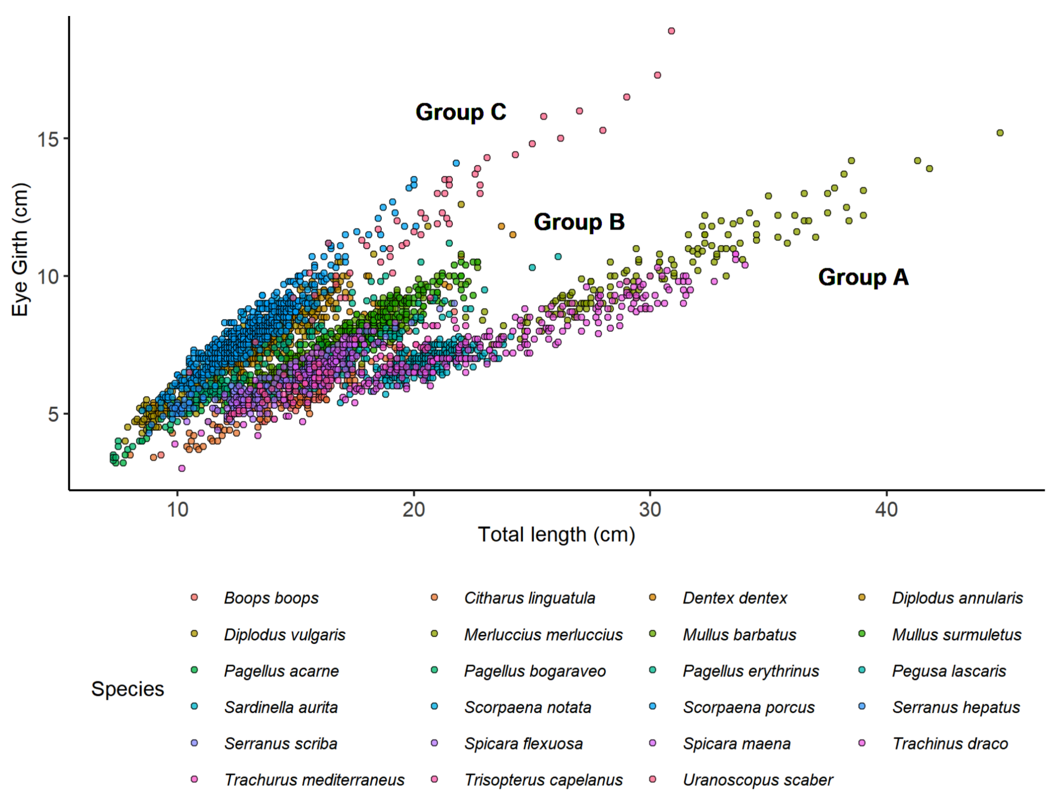

Fig. 2. Total length (TL, cm)-Eye girth (G_{eye}, cm) relationship for 23 species combined fished from April 2016 to February 2017 in northern Aegean Sea, (eastern Mediterranean Sea)
Group A: Boops boops, Merluccius merluccius, Sardinella aurita, Trachinus draco, Trachurus mediterraneus; Group B: Citharus linguatula, Dentex dentex, Mullus barbatus, Mullus surmuletus, Pagellus acarne, Pegusa lascaris, Serranus hepatus, Serranus scriba, Spicara flexuosa, Spicara maena, Trisopterus capelanus; Group C: Diplodus annularis, Diplodus vulgaris, Pagellus bogaraveo, Pagellus erythrinus, Scorpaena notata, Scorpaena porcus, Uranoscopus scaber.

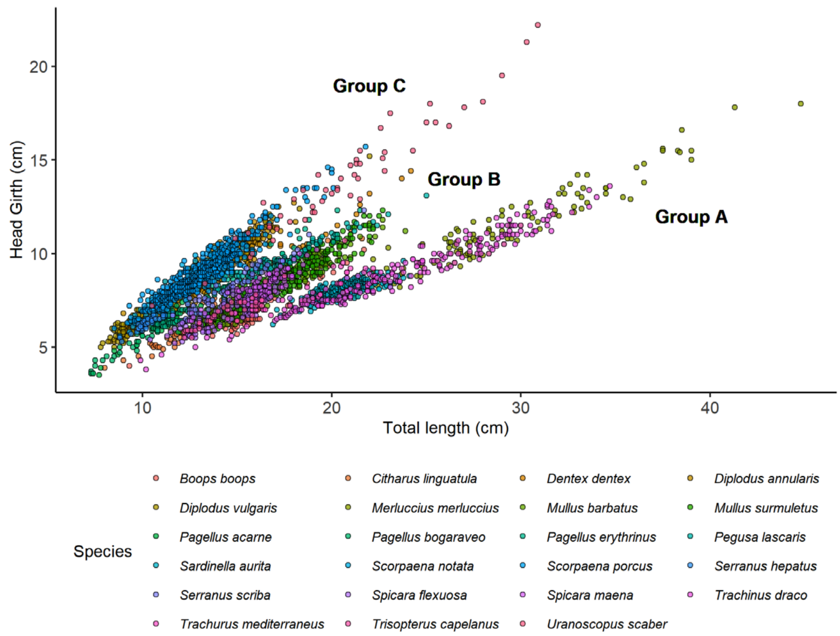

Fig. 3. Total length (TL, cm)-Head girth (G_{head}, cm) relationship for 23 species combined fished from April 2016 to February 2017 in northern Aegean Sea, (eastern Mediterranean Sea)
Group A: Boops boops, Merluccius merluccius, Sardinella aurita, Trachinus draco, Trachurus mediterraneus; Group B: Citharus linguatula, Dentex dentex, Mullus barbatus, Mullus surmuletus, Pagellus acarne, Pegusa lascaris, Serranus hepatus, Serranus scriba, Spicara flexuosa, Spicara maena, Trisopterus capelanus; Group C: Diplodus annularis, Diplodus vulgaris, Pagellus bogaraveo, Pagellus erythrinus, Scorpaena notata, Scorpaena porcus, Uranoscopus scaber

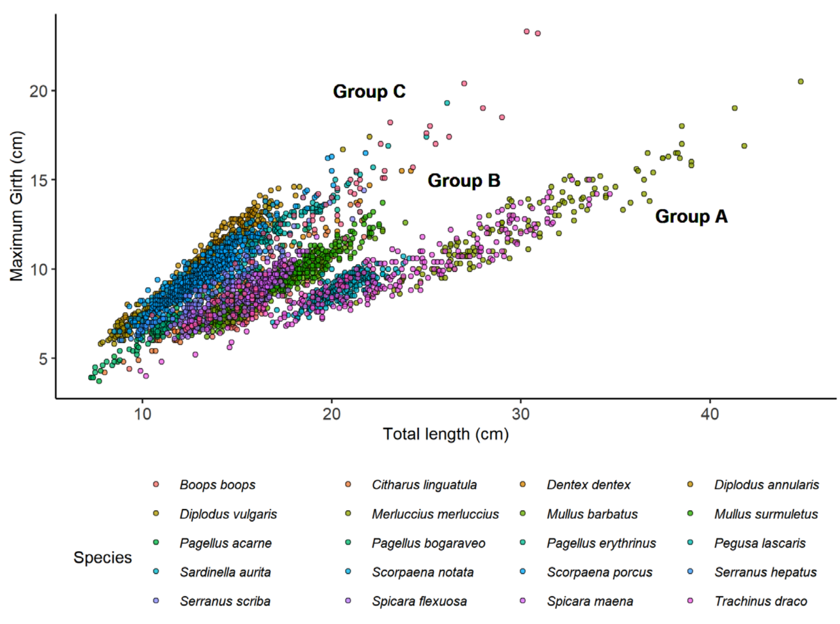

Fig. 4. Total length (TL, cm)-Maximum girth (G_{max}, cm) relationship for 23 species combined fished from April 2016 to February 2017 in northern Aegean Sea, (eastern Mediterranean Sea).
Group A: Merluccius merluccius, Sardinella aurita, Trachinus draco, Trachurus mediterraneus; Group B: Boops boops, Citharus linguatula, Dentex dentex, Mullus barbatus, Mullus surmuletus, Pagellus acarne, Pagellus bogaraveo, Pagellus erythrinus, Serranus hepatus, Serranus scriba, Spicara flexuosa, Spicara maena, Trisopterus capelanus; Group C: Diplodus annularis, Diplodus vulgaris, Pegusa lascaris, Scorpaena notata, Scorpaena porcus, Uranoscopus scaber

Table 5. Comparison of slope b of LGR from present study and previous ones from Mediterranean and adjacent seas for species in common (b: slope; S.E.:standard error; P: statistical significance level)

		Present study		Stergisou & Karpouzi (2003)			Santos et al. (2006)			Mendes et al. (2006)			Santos et al. (1998)			Santos et al. (1995)			Özekinci (2005)		
Species	**Girthtype**	**b**	**SEb**	**b**	**SEb**	**p**	**b**	**SEb**	**p**	**b**	**SEb**	**p**	**b**	**SEb**	**p**	**b**	**SEb**	**p**	**b**	**SEb**	**p**
Trachurus mediterraneus	Geye	0.372	0.019	0.357	0.015	0.542															
Merluccius merluccius	Geye	0.333	0.009	0.301	0.014	0.059															
Mullus surmuletus	Geye	0.453	0.012	0.513	0.014	**0.001**															
Scorpaena porcus	Geye	0.652	0.009	0.658	0.011	0.653															
Serranus scriba	Geye	0.386	0.013	0.391	0.02	0.841															
Boops boops	Geye	0.406	0.018	0.345	0.015	**0.009**															
Diplodus annularis	Geye	0.569	0.009	0.619	0.018	**0.011**															
Pagellus erythrinus	Geye	0.526	0.011	0.54	0.009	0.337															
Trachurus mediterraneus	Ghead	0.372	0.030	0.487	0.019	**0.001**															
Spicara maena	Ghead	0.505	0.031	0.687	0.022	**0.001**															
Citharus linguatula	Ghead	0.561	0.015				0.342	0.010	**0.001**	0.370	0.017	**0.001**									
Trisopterus capelanus	Ghead	0.541	0.031							0.365	0.034	**0.001**									
Merluccius merluccius	Ghead	0.431	0.013	0.441	0.021	0.689	0.366	0.003	**0.001**	0.364	0.004	**0.001**									
Mullus barbatus	Ghead	0.536	0.009							0.540	0.017	0.849									
Mullus surmuletus	Ghead	0.550	0.014	0.589	0.016	0.066	0.589	0.008	**0.014**	0.517	0.015	0.113									
Scorpaena notata	Ghead	0.679	0.037				0.631	0.025	0.276	0.782	0.072	0.202									
Serranus scriba	Ghead	0.601	0.020	0.608	0.038	0.873															
Boops boops	Ghead	0.526	0.019	0.435	0.016	**0.001**	0.325	0.016	**0.001**	0.439	0.007	**0.001**									
Diplodus annularis	Ghead	0.722	0.010	0.711	0.018	0.610	0.725	0.025	0.912				0.720	0.059	0.980				0.620	0.015	**0.001**
Diplodus vulgaris	Ghead	0.698	0.013				0.630	0.016	**0.001**	0.651	0.020	0.051									
Pagellus acarne	Ghead	0.544	0.031				0.676	0.008	**0.001**	0.637	0.007	**0.004**				0.676	0.742	0.865			
Pagellus bogaraveo	Ghead	0.672	0.024							0.622	0.046	0.337									
Pagellus erythrinus	Ghead	0.625	0.015	0.649	0.008	0.153	0.697	0.008	**0.001**	0.636	0.021	0.660				0.693	0.760	0.928			
Trachinus draco	Ghead	0.371	0.006				0.302	0.006	**0.001**	0.384	0.014	0.401									
Trachurus mediterraneus	Gmax	0.369	0.023	0.58	0.028	**0.001**															
Spicara maena	Gmax	0.599	0.032	0.755	0.025	**0.001**															
Citharus linguatula	Gmax	0.688	0.018				0.667	0.019	0.404												
Trisopterus capelanus	Gmax	0.579	0.035							0.375	0.041	**0.001**									
Merluccius merluccius	Gmax	0.482	0.014	0.426	0.026	0.060	0.463	0.004	0.201	0.434	0.006	**0.002**									
Mullus barbatus	Gmax	0.569	0.010							0.514	0.017	**0.005**									
Mullus surmuletus	Gmax	0.586	0.014	0.642	0.016	**0.008**	0.691	0.005	**0.001**	0.547	0.018	0.084									
Scorpaena notata	Gmax	0.770	0.037				0.748	0.029	0.631												
Scorpaena porcus	Gmax	0.760	0.012	0.734	0.012	0.121															
Boops boops	Gmax	0.632	0.023	0.579	0.017	0.063	0.623	0.030	0.818	0.512	0.009	**0.001**									
Diplodus annularis	Gmax	0.891	0.012	0.897	0.02	0.806	0.748	0.003	**0.001**				0.747	0.042	**0.001**				0.694	0.016	**0.001**
Diplodus vulgaris	Gmax	0.835	0.013				0.797	0.010	**0.016**	0.701	0.023	**0.001**									
Pagellus acarne	Gmax	0.597	0.037	0.598	0.024	0.988	0.752	0.007	**0.001**	0.690	0.007	**0.014**				0.749	0.662	0.818			
Pagellus erythrinus	Gmax	0.674	0.014	0.676	0.008	0.920	0.714	0.006	**0.009**	0.676	0.023	0.952				0.708	0.719	0.960			
Trachinus draco	Gmax	0.410	0.009				0.420	0.007	0.358	0.424	0.017	0.465									

*Table 6. Estimation of the maximum girth (G_{max}) and the indicative mesh size according to Minimum Conservation Reference Sizes (MCRS), and to length at maturity (L_m). The MCRS is according to EU regulation 2019/1241 and the national legislation (R.D.25/1954) *. The references of the maturity studies are in the end of the table while in the table are indicated as a superscript number of L_m.*

Family/Species name	MCRS (cm)	L_m, [median, (min-max)] (cm)	G_{max} at MCRS (95%CI) (cm)	G_{max} at L_m (95%CI) (cm)	Indicative mesh size according to MCRS (stretched mesh, mm)	Indicative mesh size according to L_m (stretched mesh, mm)
Carangidae						
Trachurus mediterraneus (Steindachner, 1868)	15	19.1[5]	7.2 (5.7-8.8)	8.8 (7.0-10.5)	36	44
Centracanthidae						
Spicara maena (Linnaeus, 1758)	8*	11.5 (10.5-13.1)[5]	4.4 (2.8-5.9)	6.5 (4.7-8.3)	22	32
Spicara flexuosa Rafinesque, 1810	8*	10.1 (9.5-10.7)[5]	4.6 (3.5-5.6)	5.6 (4.5-6.8)	23	28
Citharidae						
Citharus linguatula (Linnaeus, 1758)	8*	13.5 (12.0-16.9)[4,6,7]	4.1 (3.3-4.9)	7.9 (5.9-11.3)	20	39
Clupeidae						
Sardinella aurita Valenciennes, 1847	10*	14.7 (11.5-16.8)[5]	3.9 (2.6-5.1)	6.1 (4.6-7.6)	19	31
Gadidae						
Trisopterus capelanus (Lacepède, 1800)	8*	12.8 (10.5-14.5)[5]	4.3 (2.6-5.9)	7.0 (5.1-9.0)	21	35
Merlucciidae						
Merluccius merluccius (Linnaeus, 1758)	20	30.5 (21.5-42.5)[5]	7.6 (6.2-9.0)	12.6 (11.0-14.3)	38	63
Mullidae						
Mullus barbatus Linnaeus, 1758	11	12.9 (10.5-15.5)[5]	5.6 (5.1-6.2)	6.7 (6.2-7.3)	28	34
Mullus surmuletus Linnaeus, 1758	11	15.5 (11.9-17.8)[5]	5.7 (4.9-6.5)	8.4 (7.5-9.3)	29	42
Scorpaenidae						
Scorpaena notata Rafinesque, 1810	8*	11.6 (8.8-14)[5]	6.1 (4.5-7.6)	8.8 (7.0-10.7)	30	44
Scorpaena porcus Linnaeus, 1758	8*	15.3 (13.8-17.5)[5]	5.7 (5.3 -6.2)	11.3 (10.6-11.9)	29	56
Serranidae						
Serranus hepatus (Linnaeus, 1758)	8*	8.5[1]	5.5 (3.9-7.0)	5.8 (4.2-7.3)	27	29
Serranus scriba (Linnaeus, 1758)	8*	10.3 (9.3-11.2)[5]	4.7 (3.6-5.7)	6.3 (5.1-7.5)	23	31
Soleidae						
Pegusa lascaris (Risso, 1810)	8*	17.4 (17.2-17.7)[2]	5.6 (4.8-6.4)	12.4 (11.1-13.7)	28	62
Sparidae						
Boops boops (Linnaeus, 1758)	10*	13.5 (11.9-17.1)[5]	4.2 (3.0-5.3)	6.4 (5.0-7.7)	21	32
Dentex dentex (Linnaeus, 1758)	8*	34.6 (33.3-52.0)[5]	5.0 (3.6-6.5)	22.3 (19.3-25.2)	25	111
Diplodus annularis (Linnaeus, 1758)	12	10.1 (9.0-12.6)[5]	9.2 (8.6-9.8)	7.5 (7.0-8.0)	46	37
Diplodus vulgaris (Geoffroy Saint-Hilaire, 1817)	18	17.1 (15.5-19.5)[5]	14.2 (13.4-14.9)	13.4 (12.7-14.1)	71	67
Pagellus acarne (Risso, 1827)	17	18.0 (16.4-21.7)[5]	9.9 (7.7-12.1)	10.5 (8.2-12.8)	50	53
Pagellus bogaraveo (Brünnich, 1768)	33	32.9 (30.2-35.7)[5]	23.0 (20.9-25.0)	22.9 (20.8-25.0)	115	114
Pagellus erythrinus (Linnaeus, 1758)	15	16.4 (11.3-26.6)[5]	9.4 (8.6-10.2)	10.4 (9.6-11.2)	47	52
Trachinidae						
Trachinus draco Linnaeus, 1758	8*	18,5 (12.0-25.0)[1,3]	3.4 (2.78-3.98)	7,7 (6,9-8,5)	17	38
Uranoscopidae						
Uranoscopus scaber Linnaeus, 1758	8*	13.9 (11.0-1 8.0)[5]	4.8 (2.98-6.63)	9.2 (7.0-11.4)	24	46

BAGGE, 2004[1]; PAJUELO & LORENZO, 2008[2]; AK & GENÇ, 2013[3]; CENGIZ *et al.,* 2014[4]; TSIKLIRAS & STERGIOU, 2014[5]; PAPPA *et al.,* 2017[6]; ILKYAZ *et al.,* 2018[7] common two-banded sea bream *Diplodus vulgaris* (0.976), respectively. The slope (*b* values) gradually increased from the G_{eye} to the G_{max} for all the species (Fig. 1) indicating that G_{max} increases faster with length than the head girth and that the G_{eye} increases slower than all. The lower *b* values were estimated for *O. barbatum* for the G_{eye} (0.232) and the G_{head} (0.278) and for the Mediterranean horse mackerel *Trachurus mediterraneus* for the G_{max} (0.369). The higher *b* values were estimated for the *S. porcus* (0.651) for the G_{eye}, and the annular seabream *Diplodus annularis* for the G_{head} (0.752) and the G_{max} (0.891).

When G_{eye}, G_{head} and G_{max} were plotted against TL for all the species combined (except of *O. barbatum* because of its dissimilar body shape), three main groups of species with similar values were revealed (G_{eye}: Fig. 2; G_{head}: Fig. 3; G_{max}: Fig. 4). The general LGRs for each group of species and girth type are presented in Table 4. Among the three groups, Group A and C exhibited the highest r^2 (~0.9 consistently in the three LGR relationships), while r^2 of LGR relationships in Group B were generally lower (~0.8 in all LGR relationships). Statistically significant differences (ANCOVA, $P < 0.001$) in the slopes of the general LGRs were found among the three groups in each girth type (Table 4).

For 18 of the 24 species analyzed in the present study, LGRs have been estimated previously in other areas of the Mediterranean and adjacent seas. The range of the slopes of the previous estimations, per species and girth type is presented in Tables 1, 2 and 3. The comparison of the slope *b* from current analysis with the slopes of previous studies using the Z-test, showed significant differences for 5 species in the Mediterranean Sea, and for 11 species in the Gulf of Cádiz and west Portuguese coast (Table 5). Specifically, in the Mediterranean Sea differences detected for *D. annularis* in TL-G relationship for all girth types, *Mullus surmuletus* in TL- G_{eye} and TL-G_{max}, *Boops boops* in TL-G_{eye} and TL-G_{head}, *T. mediterraneus* and *Spicara maena* in TL-G_{head} and TL-G_{max}. Also, for *Merluccius merluccius* and *Mullus barbatus* the slopes estimated in previous studies were out of the confidence intervals of the slope estimated in the present study for TL-G_{max} relationship. The comparison with the results from studies in Portuguese waters showed differences for *M. surmuletus*, *B. boops*, *T. capelanus*, *M. merluccius*, *D. vulgaris*, *Pagellus acarne*, *P. erythrinus* in TL-G_{head} and TL-G_{max} relationships; *C. linguatula* and *T. draco* in TL-G_{head} relationship; *M. barbatus* and *D. annularis* in TL-G_{max} relationship. Comparing the L_m with the MCRS for the species examined in the present study, revealed that for the majority of the species the L_m was considerably higher than the MCRS imposed by European and national legislation (Table 6). For five species (*P. bogaraveo*, *P. acarne*, *S. hepatus*, *D. annularis*, *D. vulgaris*) the MCRS was very close or slightly higher than the L_m. The calculated mesh sizes according to MCRS were consistent with the minimum legal mesh size (20mm, stretched mesh) for nine species (*B.boops, C. linguatula*, *S. aurita*, *S.scriba S. flexuosa, S.maena, T. capelanus, T. draco*) considering a retention rate of 1.25. The calculated mesh sizes according to L_m were much higher from the minimum legal mesh size for all species (Table 6).

DISCUSSION

For all species analyzed in the present study, the estimated LGRs were linear for all girth types (G_{eye}: Table 1; G_{head}: Table 2; G_{max}: Table 3), which is in agreement with the results of similar studies in the Mediterranean and the adjacent Seas (SANTOS *et al.,* 1995, 1998, 2006; GARCIA-RODRIGUEZ & ESTEBAN, 1998; FABI *et al.,* 2002; CAMPOS & FONSECA, 2003; TOSUNOĞLU *et al.,* 2003; ÖZEKINCI, 2005, MENDES *et al.,* 2006, İLKYAZ, 2018). Log-linear relationships were reported only for *D. vulgaris*, *M. barbatus*, *P. acarne*, parrotfish *Sparisoma cretense*, *S. maena* and Atlantic lizardfish *Synodus saurus* in the Aegean Sea (STERGIOU & KARPOUZI, 2003). The LGRs estimated in the present study should be considered as the mean annual values, since samples were collected on a seasonal basis. Also, the results are relevant to a certain size range, not including individuals smaller than 7 cm in TL, as they depend on the size-selectivity of the gears/meshes used.

The faster increase of the G_{max} rather than the G_{head} with the total length (higher values of slope parameter *b*), observed for all species (see Tables 1, 2 and 3), was also in agreement with the results of the afore mentioned studies. This could be attributed to the non-uniform body shape changes, in relation to the body size, during the growth of a fish (LOY *et al.,* 1998). In adulthood most fish species experience greater increase in body depth that can be associated with the development of internal organs as well as predation and maturation. The abovementioned condition was not observed for *D. vulgaris*, *M. merluccius*, John dory *Zeus faber* in the Aegean Sea (STERGIOU & KARPOUZI, 2003), and *M. barbatus*, Atlantic mackerel *Scomber scombrus*, lesser spotted dogfish *Scyliorhinus canicula*, comber *Serranus cabrilla* in the west Portuguese coast (MENDES *et al.,* 2006).

The comparison of regression slope *b* from current analysis with previous ones from Mediterranean Sea and the adjacent seas, showed statistically significant differences in the Mediterranean Sea, and in the Gulf of Cádiz and west Portuguese coast. The differences detected in the Mediterranean Sea could be related with the fishing gear used during sampling. For example, the difference reported in *D. annularis* (FABI *et al.,* 2002; TOSUNOĞLU *et al.,* 2003; ÖZEKINCI, 2005) as well as in *M. barbatus* and *M. merluccius* (FABI *et al.,* 2002; TOSUNOĞLU *et al.,* 2003) could be attributed to different gears used for sampling (bottom trawl in TOSUNOĞLU *et al.,* 2003; gillnets and trammel nets in the present study), and to the netting material of the gear (monofilament in FABI *et al.,* 2002; ÖZEKINCI, 2005; multifillament in the present study) used in each study, which affected the length range used. The difference reported in *B. boops*, *T. mediterraneus* and *S. maena* (STERGIOU & KARPOUZI, 2003) could be the result of the sample size and length range that were greater than in the present study. The comparison of LGRs slope values with the studies from Portuguese waters (SANTOS *et al.,* 1998, 2006; MENDES *et al.,* 2006) can be attributed to the sample size and length range used for the estimation of the LGR in the two areas. In the majority of the cases greater number of individuals were used and larger specimens were fished in Portuguese waters. However, these differences are not necessarily related to sampling inconsistencies, since they could be the result of the generally smaller size, lower longevity and higher adult mortality rates reported for fish species in Greek seas (STERGIOU, 2000). Other factors that may also affect girth and thus LGR are differences in food availability, feeding rate, gonad development and spawning period of fish populations across areas (SANTOS *et al.,* 2006), elasticity of the netting material and compressibility of the fish body (LUCENA *et al.,* 2000)

Body shape seems to be a key factor that grouped the different species, when all the girth types were plotted against TL. The fusiform or elongated species (*B. boops*, *S. aurita*, *M. merluccius*, *T. mediterraneus*, *T. draco*) formed a compact group (group A) with low *b* values indicating that their girth increases slower with length. The strongly spherical and the deep-bodied species (*S. notata*, *S. porcus*, *U. scaber*, *D. annularis*, *D. vulgaris*, *P. bogaraveo*, *P. erythrinus*) formed a distinct group (group C) with much steeper slopes (the highest *b* values), indicating fast increase of girth with length. Group B, mainly laterally flattened fish, had higher variability (lower r^2 values) and formatted an intermediate group where girth increases more proportional to length. The species composition of each group per girth type was similar to those reported in the southern Aegean Sea (STERGIOU & KARPOUZI, 2003). The general regression equations determined, expressing LGRs based on the body shape of fish, can be used as empirical equations when girth data for certain species are absent.

In the Mediterranean the heterogeneity of small-scale fisheries as well as their multi species character pose obstacles to the implementation of large-scale and across species management measures. The main management measures usually followed by the Mediterranean Sea EU member states are fishing effort control, and specific technical measures such as spatial and temporal closures, minimum landing sizes (now known as MCRS), minimum legal mesh sizes for nets and regulation of technical characteristics of fishing gears. The effectiveness of technical measures and their contribution to the sustainable exploitation of fish stocks requires a meaningful relationship between the technical measure (such as the MCRS) and key population parameters, such as the size at first maturity, L_m (FROESE *et al.,* 2008). Based on this link, MCRS has been determined for 21 fish species in the Mediterranean Sea (EU Regulation 2019/1241). However, it has been reported that in Europe and particularly in the Mediterranean Sea the MCRS of several commercial species are much lower than their L_m (FROESE *et al.,* 2008; TSIKLIRAS & STERGIOU 2014). This could be attributed to an attempt by fisheries managers to compromise between the technical measures, the multispecies nature of fisheries and the need to ensure the economic viability of the sector (LUCCHETTI *et al.,* 2020). The total length-body girth relationships could be used as a first indication of setting appropriate mesh sizes that could contribute to reducing overfishing of undersized individuals. Robust selectivity studies are required to identify suitable mesh sizes per species or group of species that will be used in accordance with L_m.

CONCLUSIONS

Total length-body girth relationships can be considered as a useful tool that links the morphometric characteristics of the fish with the technical characteristics of the fishing gear; nets in the present case. These relationships are often used in net selectivity studies and consequently as indicative thresholds for technical measures aiming to minimize the capture of undersized and immature individuals. L_m is a crucial population parameter for the maintenance of stock biomass; thus, it should be considered the basis in setting the MCRS of the exploited stocks. It has been showed that the larger the gap between the length at first capture and the L_m, the more vulnerable the stock is to overfishing (MYERS & MERTZ, 1998). As overfishing the young and virgin individuals has severe effects on marine populations, MCRS should always be set to exceed L_m (TSIKLIRAS & STERGIOU, 2014). Combining these parameters together through LGRs will reduce overfishing of undersized individuals and will promote the sustainable exploitation of fish stocks.

ACKNOWLEDGEMENTS

The authors would like to thank Manos Koutrakis for his helpful comments and suggestions.

REFERENCES

AK, O. & Y. GENÇ. 2013. Growth and reproduction of the greater weever (*Trachinus draco* L., 1758) along the eastern coast of the Black Sea. J. Black Sea/Mediterranean Environment, 19: 95-110.

AYDIN, M. & Ç. SÜMER, 2010. Güney Ege'de sinarit (*Dentex dentex*) avciliğinda kullanilan fanyali uzatma ağlarinin seçiciliği (Selectivity of trammel nets used for common dentex (*Dentex dentex*) fishery in the South Aegean). J FisheriesSciences.com, 4(4): 446-454.

BAGGE, O. 2004. The biology of the greater weever (*Trachinus draco*) in the commercial fishery of the Kattegat. ICES J. Mar. Sci., 61: 933-943.

BARANOV, F.I. 1914. The capture of fish by gillnets. Mater. Poznoniyu Russ. Rybolov., 3: 56-99. (Partially transl. From Russian by W.E. Ricker).

CAMPOS, A. & P. FONSECA. 2003. Selectivity of diamond and square mesh cod ends for horse mackerel (*Trachurus trachurus*), European hake (*Merluccius merluccius*) and axillary seabream (*Pagellus acarne*) in the shallow groundfish assemblage off the south-west coast of Portugal. Sci. Mar., 67: 249–260.

CENGIZ, Ö., A. ISMEN & U. OZEKINCI. 2014. Reproductive biology of the spotted flounder, *Citharus linguatula* (Actinopterygii: Pleuronectiformes: Citharidae), from Saros Bay (northern Aegean Sea, Turkey). Acta

Ichthyol. Piscat., 44: 123–129.

FABI, G., M. SBRANA, F. BIAGI, F. GRATI, I. LEONORI & P. SARTOR. 2002. Trammel net and gill net selectivity for *Lithognathus mormyrus* (L., 1758), *Diplodus annularis* (L. 1758) and *Mullus barbatus* (L., 1758) in the Adriatic and Ligurian seas. Fish. Res., 54: 375–388.

FROESE R., A. STERN-PIRLOT, H. WINKER & D. GASCUEL. 2008. Size matters: How single-species management can contribute to ecosystem-based fisheries management. Fish. Res., 92: 231-241.

FROESE, R. & D. PAULY. (Editors) 2019. FishBase. World wide web electronic publication. www.fishbase.org, version (12/2019).

FUJIMORI, Y. 2018. A new approach of determining gillnet selectivity based on the relationship between fish length and girth to estimate the length distribution of fish encountering a net. Bull. Fish. Sci. Hokkaido Univ., 68: 1-6.

GARCIA-RODRIGUEZ, M. & A. ESTEBAN. 1998. Biometric relationships and growth of the Mediterranean hake (*Merluccius merluccius* L.) from the Santa Pola Bay (Spain). Rapp. Comm. int. Mer Médit., 35: 434-435

GABR, M.H. & A.O. MAL. 2018. Trammel net fishing in Jeddah: species composition, relative importance, length-weight and length-girth relationships of major species. Int. J. Fish. Aquat. Stud., 6: 305-313.

HAMBRIGHT, D.K. 1991. Experimental analysis of prey selection by largemouth bass: role of predator mouth width and prey body depth. Trans. Am. Fish. Soc., 120: 500–508.

İLKYAZ, A.T. 2018. Estimating gillnet selectivity of Bluefish (*Pomatomus saltatrix*) by morphology. EgeJFAS, 35: 89-94.

İLKYAZ, A.T., G. METIN, O. SOYKAN & H.T. KINACIGIL. 2018. Spawning season, first maturity length and age of 21 fish species from the central Aegean Sea, Turkey. Turk. J. Fish. Aquat. Sci., 18: 211-216.

KLEINBAUM, D.G. & L.L. KUPPER. 1978. Applied Regression Analysis and Other Multivariable Methods. Duxbury Press, North Scituate, MA.,787pp.

KURKILAHTI, M., M. APPELBERG, T. HESTHAGEN & M. RASK. 2002. Effect of fish shape on gill-net selectivity: a study with Fulton's condition factor. Fish. Res., 54: 153–170.

LOY, A., L. MARIANI, M. BERTELLETTI & L. TUNESI. 1998. Visualizing allometry: Geometric morphometrics in the study of shape changes in the early stages of the two-banded sea bream, *Diplodus vulgaris* (Perciformes, Sparidae). J. Morphol., 237: 137–146.

LUCCHETTI, A., V. VIRGILI, A. PETETTA & P. SARTOR. 2020. An overview of gill net and trammel net size selectivity in the Mediterranean Sea. Fish. Res., 230: 105677.

LUCENA, F.M., C.M., O'Brien, & E.G. Reis. 2000. The effect of fish morphology and behaviour on the efficiency of gill nets, their selectivity and by-catch: two examples from southern Brazil. International Council for the Exploration of the Sea, ICES CM 2000/J,11: 16.

MYERS, R.A. & G. MERTZ. 1998. The limits of exploitation: a precautionary approach. Ecol. Appl., 8: 165–169.

MENDES, B., P. FONSECA & A. CAMPOS. 2006. Relationships between opercula girth, maximum girth and total length of fish species caught in gillnet and trammel net selectivity surveys off the Portuguese coast. J. Appl. Ichthyol., 22: 209-213.

MOUS, P.J., P.C. GOUDSWAARD, F.B. KATUNZI E., Y.L. BUDEBA, F. WITTE & W. LIGTVOET. 1995. Sampling and measuring. In: F. Witte and W.L.T. van Densen (Editors). Fish stocks and fisheries of Lake Victoria. A handbook for field observations. Samara Publishing Ltd, Cardigan, pp. 55-82.

MOUTOPOULOS, D.K., N. DIMITRIOU, T. NYSTAS & C. KOUTSIKOPOULOS. 2017. Length–girth relations of fishes from a Mediterranean lagoon system. Acta Ichthyol. Piscat., 47 (4): 397–400.

ÖZEKINCI, U. 2005. Determination of the selectivity of monofilament gillnets used for catching the annular sea bream (*Diplodus annularis* L., 1758) by length-girth Relationships in Izmir Bay (Aegean Sea). Turk. J. Vet. Anim. Sci., 29: 375-380.

PAJUELO, B.J. & J.M. LORENZO. 2008. Reproductive characteristics of the sand sole *Pegusa lascaris* (Soleidae), from the eastern-central

Atlantic. J. Mar. Biolog. Assoc. U.K., 88: 629-635.

PAPPA, M., A. CHYCHYKALO, M. KOUTSIDI, N. MAVRAKI, E. LEFKADITOU, C. KOUTSIKOPOULOS & E. TZANATOS. 2017. Biology and fisheries of the spotted flounder (*Citharus linguatula*) caught by multiple gears with partial spatiotemporal overlaps. Aquat. Living Resour., 30, 32.

PAULY, D. 2000. Predator–prey ratios in fishes. In: R. Froese and D. Pauly (Editors.). FishBase 2000: concepts, design and data sources. ICLARM, Los Banos, Philippines, p. 201.

RAGONESE, S. & F. BERTOLINO. 1994. Estimating the girth of fish by applying an elliptic model. Naga ICLARM Q., 17: 41–46.

REIS, E.G. & M.G. PAWSON. 1999. Fish morphology and estimating selectivity by gillnets. Fish. Res., 39: 263-273.

SANTOS, M.N., C.C. MONTEIRO & K. ERZINI. 1995. Aspects of the biology and fisheries of the axillary seabream (*Pagellus acarne*, Risso) and the common pandora (*Pagellus erythrinus*, Linnaeus) from Algarve (south Portugal). Fish. Res., 23: 223–236.

SANTOS, M.N., C.C. MONTEIRO, K. ERZINI & G. LASSERRE. 1998. Maturation and gill-net selectivity of two small seabreams (genus *Diplodus*) from the Algarve coast (south Portugal). Fish. Res., 36: 185–194.

SANTOS, M.N., A. CANAS, P.G. LINO & C.C. MONTEIRO. 2006. Length– girth relationships for 30 marine fish species. Fish. Res., 78: 368-373.

SOKAL R. & F.J. ROHLF. 1995. Biometry: The principles and practice of statistics in biological research, W. H. Freeman, New York, N.Y., 887 pp.

STERGIOU, K.I. 2000. Life-history patterns of fishes in the Hellenic Seas. Web Ecol., 1: 1–10.

STERGIOU, K.I. & V.S. KARPOUZI. 2003. Length–girth relationships for several marine fishes. Fish. Res., 60: 161–168.

TOSUNOĞLU, Z., Y.D. ÖZBILGIN & H. ÖZBILGIN. 2003. Body shape and trawl cod end selectivity for nine commercial fish species. J. Mar. Biol. Ass. U.K., 83: 1309–1313.

TSIKLIRAS, A.C. & K.I. STERGIOU. 2014. Size at maturity of Mediterranean marine fishes. Rev. Fish Biol. Fisheries, 24: 219-268.

WAINWRIGHT, P.C. & S.M. REILLY. 1994. Ecological morphology: integrative organismal biology. University of Chicago Press, Chicago, IL., 376 pp.

Received:20 June 2021
Accepted: 11 November 2021

Odnos dužine i maksimalnog obujma za 24 riblje vrste u sjevernom Egejskom moru (istočno Sredozemno more)

Angeliki ADAMIDOU*, Konstantinos TOULOUMIS i
Athanassios C. TSIKLIRAS

SAŽETAK

Poznavanje morfoloških odnosa, a posebno onih koji se tiču maksimalnog obujma tijela ribe (G) s ukupnom dužinom (TL) potrebito je za određivanje selektivnosti alata, a posebno za tehničke mjere za izbjegavanje hvatanja nedoraslih jedinki. Ova studija se odnosi na 24 morske vrste koje se iskorištavaju u priobalnoj ribolovnoj floti u Egejskom moru (istočno Sredozemno more), za 6 od kojih se TL-G odnosi prvi put spominju u Sredozemnom moru i susjednim morima.

Uzorci su prikupljani sezonski, od travnja 2016. do veljače 2017. Koeficijenti linearne regresije obujma tijela u tri položaja tijela (G_{eye}, posteriorno od oka; G_{head} na stražnjem kraju operkuluma; G_{max} na maksimalnoj visini tijela), s ukupnom duljinom procijenjene su za svaku vrstu i za skupine oblikovane kada su G_{eye}, G_{head} i G_{max} ucrtani u odnosu na ukupnu duljinu za sve vrste zajedno.

Utvrđene su statistički značajne razlike između tri skupine (ANCOVA, P<0,001). Usporedba odnosa ukupne duljine i obujma tijela za 18 vrsta koje su prethodno istraživane u različitim geografskim područjima Sredozemlja i susjednih mora, pokazala je razlike uglavnom s rezultatima iz portugalskih voda za određene populacije vrsta. Na temelju dobivenih jednadžbi izračunat je maksimalni obujam (G_{max}) koji odgovara minimalnoj referentnoj veličini očuvanja (MCRS) i ukupnoj dužini pri zrelosti (Lm) za svaku vrstu. Identificirane veličine oka koje odgovaraju G_{max} vrijednostima bile su dosta veće od minimalne zakonske veličine oka za mreže stajačice i unutarnju ploču troslojnih mreža, što ukazuje da relevantni trenutačni propisi o ribarstvu ne mogu ispuniti zahtjeve za održivo iskorištavanje ribljih resursa.

Ključne riječi: morfologija ribe; upravljanje ribarstvom; mreža stajačica; dužina pri zrelosti (L_m);