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Length-weight relationships of 107 osseous and 9 cartilaginous fish species on a shelf-break zone of the eastern Mediterranean Sea

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Abstract: Overall and spatiotemporal total length-weight relationships (LWR) were studied for the 116 fish composing of 107 osseous and 9 cartilaginous fish species collected by otter trawl in the shelf and upper slope of Gulf of Antalya in 2014-2015. Of the 89 abundant bony species, 38 species had isometric growth, 24 species positive allometry, and 27 species negative allometry. Growth type was significantly affected with the sample size. LWRs of osseous fish species which had their body condition factor CF ≤ 1 were significantly differentiated by factors region, season and depth, but none was for the fish having CF ≥ 1. The factorial differences were found in relation with the CF. The *b* values for the osseous fish decreased slightly with bottom depth from lower shelf to middle shelf. The highest *b* values occurred for the ubiquitous fish on the entire shelf while the *a* values increased. At greater depths, the *b* values shifted the allometry from the isometry to the negative allometry. Average *b* value of osseous fish was 2.962 ± 0.048 (isometric), and median was 2.992. LWRs of body width-weight of batoid fish showed a *b* value ≤ 3. Sexual dimorphism in the LWR occurred for 10 species.

Résumé : *Relations taille-poids de 107 poissons osseux et 9 poissons cartilagineux sur le rebord du plateau continental en Méditerranée.* Les relations taille-poids (LWR) ont été étudiées pour 116 poissons, dont 107 osseux et 9 cartilagineux, récoltés au chalut à panneaux sur le plateau et la partie supérieur de la pente du Golfe d'Antalya en 2014-2015. Sur 89 espèces de poissons osseux abondants, 38 présentaient une croissance isométrique, 24 une croissance allométrique positive et 27 une croissance allométrique négative. Le type de croissance était affecté par la taille de l'échantillon. Les LWR des poissons osseux ayant un indice de condition CF ≤ 1 étaient significativement différenciés par les facteurs région, saison et profondeur mais aucun de ceux ayant un CF ≥ 1 ne l'étaient. Les différences factorielles de l'analyse étaient liées à la valeur de CF. La valeur du coefficient *b* des LWR diminuait légèrement avec la profondeur. Les valeurs les plus élevées de *b* concernaient les les espèces ubiquistes sur la totalité du plateau alors que les valeurs du coefficient *a* augmentaient. Aux profondeurs les plus importantes, les valeurs de *b* basculaient de l'isométrie vers l'allométrie négative. La valeur moyenne de *b* des poissons osseux était 2,962 ± 0,048 (isométrie), la médiane était 2,992. Les LWR entre la largeur et le poids des Batoïdae ont montré une valeur de *b* ≤ 3. Un dimorphisme sexuel a été mis en évidence pour les LWR de 10 espèces.

Keywords: Osseous and cartilaginous fish • Length-weight • Spatio-temporal • Eastern Mediterranean Sea

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Introduction

Owing to two different growth dimensions between length (one dimension,1D) and weight (three dimensions, 3D or two dimensions, 2D in some species), the fish length-weight relationship (LWR) is expressed with multiplicative model (curve-linear) of the regression analyses, shows increment in weight by a degree of power of the length increment (FAO, 1991). Two constants of the power-fit regression equation are compounded with an initial weight, intercept (*a*), and power constant, slope (*b*). Equally 3D-growing species in term of weight across the length are expected (FAO, 1991) to have *b* value equal to 3 for torpedo-shape (fusiform) species, and mostly 2D-growing species such as highly dorso-ventrally or laterally flatted specimens are coursed to negative allometry ($b < 3$). Unequally 3D growing species go to positive allometry for such species growing in weight in one of the dimensions; dorsa-ventrally or laterally growth. Occurrence of weight growth at posterior or anterior derives deviations of the *b* from the isometry of equally 3D-growing species. Both constants suggest some comparable knowledge on size distribution, length range, sexual dimorphism in size, growth strength in weight versus length, specific growth rate, body shape, conditional factor, nutritional strength, feeding goodness/condition and metabolisms of species, and trophic level, ecological status and temperature changes of the environment inhabited by the fish (Anderson & Gutreuter, 1983; Pauly, 1993; Petrakis & Stergiou, 1995). The LWRs among the species and same species change depending on the environmental (water temperature, salinity, food availability), biological properties of the species (sexual dimorphisms, maturity, size of species, life strategy, migration and ontogeny), sampling strategies (depth range, catch gear type, number of specimens caught, area categorized by disturbed or undisturbed by trawl and season) and anthropogenic effects in space and time (Weatherley & Gill, 1987; Gonçalves et al., 1997; Pecuchet et al., 2017).

The LWR is benefited to estimate individual weight of specimens, hence total biomass (Beyer, 1991; Petrakis & Stergiou, 1995) even though there are spatiotemporal differences in the L and W besides the sexual dimorphism and ontogeny in size (Gonçalves et al., 1997; Moutopoulos & Stergiou, 2002). The LWR is needed for fish stock assessment, fish-based ecosystem model, stock management, estimation of conditional factor, weight-at-age, and growth-in-weight as function of growth in length (Pauly, 1993; Petrakis & Stergiou, 1995; Richter et al., 2000).

The Mediterranean Sea may be an example for the spatiotemporal dynamic of the organisms since it contains comparable different trophic levels from the west through the centre to east bearing the different seas. It is the largest intercontinental and peripheral sea in the world, which brings high biogeographical area into high levels of biodiversity (Coll et al., 2010). The study area, Gulf of Antalya, is the most ultra-oligotrophic region of the Levantine Sea. The study area was detailed by de Meo et al. (2018) and Mutlu et al. (2021) for spatiotemporal distribution of fish community and the biogeochemical environments under measured physical hydrography. The Levantine basin is characterized by a negative freshwater balance and high evaporative rates, rapid surface water warming, low production of organic matter and ultra-oligotrophic conditions (Sisma-Ventura et al., 2017). Furthermore, the ecosystem of the eastern Mediterranean Sea has been affected by significant changes due to the biological invasion of alien species through the Red Sea (Por, 1978), which may induce changes in spatiotemporal LWRs as a consequence of possible competition between species for the highly limited food availability in the study area. Of number of the present fish species, 35 alien fish species were found in the study area (de Meo et al., 2018), and as possible food for fish, 18 aliens of 59 megabenthic crustaceans (Patania & Mutlu, 2021) and 3 aliens of 90 megabenthic non-crustacean invertebrates (Garuti & Mutlu, 2021).

Many studies on the LWR from the Turkish coasts were already published and most of them were conducted in the Black Sea (e.g. Özdemir et al., 2015; Türker & Bal, 2018), Aegean and Marmara Sea (e.g. İşmen et al., 2009; Eronat & Özaydın, 2014) and partly in the Mediterranean Sea; the northern-easternmost bays, Iskenderun and Mersin Bay (e.g. Ergüden et al., 2009; Başusta et al., 2012; Gündoğdu et al., 2016). Studies were focused on targeted or captured species, regardless of seasonal and bathymetrical samplings.

However, most of the studies have been attended to the limited number of fish species in the moderately eutrophic regions (Iskenderun and Mersin Bay) of the Turkish Mediterranean waters, and a lesser extend to oligotropic region, Antalya Gulf with exception of few studies conducted at the greater depths (200-800 m) (Güven et al., 2012; Deval et al., 2014; Özvarol, 2014). The present study is scoped to outline the spatio (depth, fishing and non-fishing zone)-temporal (season) distribution of the LWR of all fish species captured mostly in the shelf of the Turkish waters in the eastern Mediterranean Sea. Regarding the historical lack of comprehensive information on LWR estimations, the aim of this study is to provide baseline information on overall, and regional, bathymetrical and seasonal LWR of abundant fish species in the most ultra-oligotrophic waters of the Mediterranean Sea.

Material and Methods

Fish samples were collected seasonally with the otter trawl (wing mesh size 88 mm in a diamond eye and the cod-end 44 mm, cover of codend 22 mm, float line 35 m long) in May 2014, August, October and February 2015. The study area was divided into sub-regions (R1: fishing zone and unvegetated soft bottoms, R2: the fishing zone and vegetated by a meadow, *Posidonia oceanica* (Linnaeus) Delile, 1813, R3: non-fishing zone and less vegetated and unvegetated bottoms; R1 fully and R2 partly fished outside 3 nautical miles far from the coast). The meadow was found at shallower bottoms than 30 m in the study area (Mutlu et al., 2021). Samples were collected along track lines at depths of 10, 25, 75, 125 and 200 m on the shelf. Furthermore, one shelf-break station in each of the fishing and non-fishing zone was conducted at 300 m to check an ontogenic succession and extension of the fishes from the shelf to shelf-break (Fig. 1). On board of R/V "Akdeniz Su", the trawl was towed on the bottom of each station at a speed of 2.5-3 knots for about 30 minutes.

The total length of bony fishes and sharks, and total body width of the batoids were measured in a precision of mm since tails of the batoids were cut off in some cases. Sexes of the specimens were determined looking at the gonads of bony, and claspers of cartilaginous fish. Individual weight was measured with a precision of 0.01 g, and 0.0001 g according to size of the fish species.

Total length and body width (cm) for cartilaginous fish (L, cm)-weight (W, g), Length-Weight relationships (LWR), which were established using the multiplicative power-fitted model of regression equations, $W = a \times L^b$, were tested by Analyses of CoVariance (ANCOVA) for differences in constants (intercept *a* and slope *b*) of the regression equations between the sexes. Small-size samples ($n < 30$, FAO, 1991) were previously involved into analyses of the LWR (Ozen et al., 2009; Robinson et al., 2010). Therefore, minimum sample size was kept 4 specimens for the LWR analyses to discuss shifts in growth type of fish depending on sample size. Pearson correlation coefficient between L and W was tested using t-test. Constant *b* was tested for significant differences from an isometric constant of $b = 3$ for the fish using student t-test. Effect of sample size on growth type (allometric and isometric) was tested using Generalized Linear Model (GLM) in distribution type of inverse Gaussian. The L and W data of only sample sizes $n > 14$ (so minimum sample size is ≥ 3 for each factor; i.e. 5 isobaths* sample size of 3 = 15 samples) were subjected to the ANCOVA for seasonal, regional, and depth wise difference of the regression constants. To interpret factorial LWRs Fulton's condition factor, CF of species was estimated for each of the spatiotemporal factors and was subjected to one-way ANOVA. All statistical analyses were performed using of the statistical tool with commands, "ttest", "corr", "fitglm", "aoctool", and "anovan" of MatLab (vers. 2021a, Matworks inc.). Furthermore, cluster analyses were performed to show interspecific relation of the osseous fish based on a set of data on the morphometry (mean

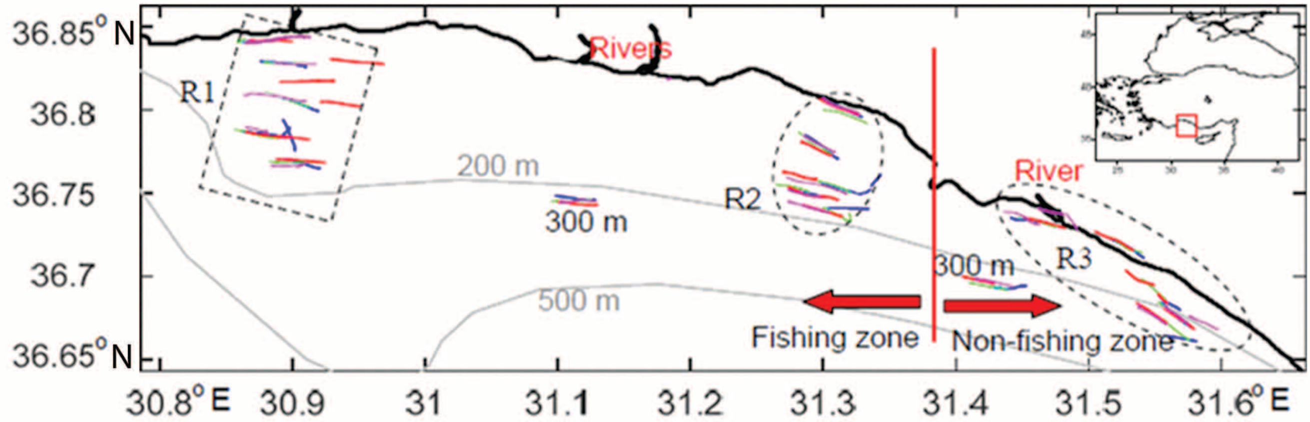

Figure 1. Study area in red frame and tracklines of the seasonal trawl towing during 2014-2015 (blue: May 2014, green: August 2014, red: October 2014 and magenta: February 2015). Standard fixed depths are in the order of the shallowest to the deepest bottom depths from the coast to open water seaward in each of regions (R1-R3).

length and mean weight), regression constants (*a* and *b*) and growth type (isometric, negative or positive allometric), and based on only regression constants as well. All data matrix of the variables was $\log_{10}$-tranformed to calculate the Euclidean distance (Anderson, 2001) before the cluster analyses as non-parametric analyses using PRIMER+6 (vers. 1.0.3). The Euclidean distance was used since the variables were dependent and each on similar scales (Anderson et al., 2008). Besides, the data set was subjected to 2-way PERMANOVA (999 permutations) for the differences in the variables among bottom depth classes, and size classes. Depending on the sampling depths, depth classes (lower shelf L: 10-25 m, middle shelf M: 75-125 m, upper shelf U: 125-200 m, shelf S: 10-200 m, deep bottom D: 200-300 m, and shelf break B: 300 m) were estimated referring the occurrence of the fish species in ranges of the bottom depth a year and description by the studies on megafauna (e.g. DeLaHoz et al., 2018; Demestre et al., 2000). This classification was also enhanced by de Meo et al. (2018) studying fish ecology and community with bottom depth using the density of the fish of the present study data. Size classes of the total length were determined by sorting the lengths of all osseous fishes in ascending order and then drawing the straight lines between points where the slope of the straight line changed. We fixed three size classes as small < 10 cm, medium 10-15 cm, and large size > 15 cm. All classes were performed to compare LWRs differentiated by interaction of different spatial ecosystem and growth strategies in size of the fish.

Results and Discussion

A total of 107 bony fish species belonging to 54 families and 9 cartilaginous fish species to 6 families were analyzed to establish their LWRs. Of a total of 66526 individuals, the number of individuals subjected to the statistical treatment varied between 4 and 3567 individuals. A total of 76 species had large sample size ($n > 30$), and additionally a total of 21 species with $n < 10$ (Suppl. Mat. Table S1). Small sample size down to 5 individuals was previously used to assess the LWRs of the fish (Ozen et al., 2009; Robinson et al., 2010).

Of the 89 bony species, 38 species had isometric growth, 24 species showed positive allometry in the growth, and 27 species were characterized with negative allometry. Overall, the growth type changed depending on the sex, and the sample size ($n < 21$ through $n = 53$, $n > 100$) deriving variation in S_{berr} (standard error of *b* values) and the statistical test for same *b* values (Suppl. Mat. Table S1 & Fig. S1-A) besides the environmental factors. Therefore, fish families whose species grow isometrically were Champsodontidae in range of $b = 2.754\text{-}3.365$, Clupeidae (2.725-3.087), Engraulidae (2.902-3.014), Gobiidae (2.913-3.375), Haemulidae (2.798-2.955), Labridae (2.422-2.914), Mugilidae (2.671-3.268), Scophthalmidae (2.930-3.071), Scorpaenidae (2.872-3.054), Synodontidae (2.973-3.107) and Uranoscopidae (2.855-3.025). Positive allometric growth was performed by the species of families; Carangidae (3.037-3.240), Centriscidae (3.299-3.372), Fistulariidae (3.272-3.337), Leiognathidae (3.206-3.215), Mullidae (3.007-3.115), Peristediidae (3.004-3.171), Sebastidae (3.134-3.165), Sillaginidae (3.114-3.128) and Trichiuridae (3.432-3.643). Weight increased negative allometrically with the length of species belonging to families Callionymidae (2.622-2.916), Citharidae (2.769-2.863), Cynoglossidae (2.331-2.667), Monacanthidae (2.658-2.882), Nemipteridae (2.886-2.909), Terapontidae (2.604-2.707), Tetraodontidae (2.699-2.932) and Zeidae (2.715-2.788), less ($b < 3$) than the species belonging to the families aforementioned. Rest of the families showed cosmopolite growth (Fig. 2 & Suppl. Mat. Table S1). Isometry of growth was significantly affected with the sample size (GLM, $F = 5.66$, $p = 0.018$) and confidence limits of the isometry increased in reverse trend compared to expected confidence limits with the sample size (Suppl. Mat. Fig. S1-B). Furthermore, the maximum length and length ranges of specimens were from the factors fating the LWRs for the small-scale demersal fisheries (Goncalves et al., 1997). Number of different growth types could change spatiotemporally and regionally in the eastern Mediterranean Seas (Kapiris & Klaoudatos, 2011; Evagelopoulos et al., 2017; Adamidou et al., 2020).

The *b* value of the same species changes to differ from geographical location, trophic level, hydrography, space, bathymetry and seasons (Weatherley & Gill, 1987; Wootton, 1990), and some anthropogenic effects (trawling, pollution, hypoxia, etc.) (Gonçalves et al., 1997; Pecuchet et al., 2017). The LWRs of 242 fish species were compiled from different studies conducted in the Turkish coasts by Gündoğdu et al. (2016), and of 84 same species, 28 species had not same *b* values, 21 species had similar *b* values, and 47 species were found within a narrow range of given *b* values due presumably to different methodology, e.g. space and time.

Of the ten cartilaginous fish species, total width-weight formulized the LWRs overall having $b \leq 3$ statistically proofed for the batoid fish. Only the shark *Scyliorhinus canicula* (Linnaeus, 1758) showed a

Table 1. 2-way PERMANOVA result table analyzed for the differences in the data matrix in figure 2 by two factors: bottom depth classes and size classes of the 78 osseous fish species (P is p value of the PERMANOVA test, and P-MC is p value of the Monte Carlo test).

Source	df	SS	MS	F	P	P-MC
Bottom	6	10.41	1.735	2.243	**0.042**	**0.015**
Size classes	2	34.986	17.493	22.615	**0.001**	**0.001**
Bottom x Size classes	11	8.0959	0.736	0.95149	0.515	0.532
Residuals	70	54.146	0.77352			
Total	**89**	**128.94**				

positive allometry with the total length (Suppl. Mat. Table S1). Average *b* value of the batoids was 2.763 ± 0.142 and median was 2.745.

Sexual dimorphism in the LWR occurred for several fish species, e.g. species of Centracanthidae, Gobiidae, Serranidae, Sparidae. *Anthias anthias, Argentina sphyraena, Arnoglossus rueppelii, Bothus podas, Callionymus filamentosus, Chlorophthalmus agassizi, Stephanolepis diaspros, Mullus barbatus, Upeneus pori* and *Boops boops* were sexually dimorphic osseous species, and *Dasyatis pastinaca* and *Gymnura altavela* cartilaginous species regarding the LWR (Suppl. Mat. Table S1). The LWR was differentiated by sexual maturity and sex (Wootton, 1990). Parker (1992) affirmed that the sexual dimorphism in the fish resulted from contrary relationships between costs and benefits in balance, attributed to that large female had high fecundity and small males were not needed to produce intense sperm during mating or spawning (Ragonese et al., 1997).

Factorial (regional, seasonal and depthwise) differences in the LWR occurred for most species whereas LWR was not significantly differentiated by these factors for four cartilaginous species and 17 osseous species (Suppl. Mat, Table S1). *Dasyatis pastinaca* was only one species from cartilaginous fish demonstrating regional (*b* values were less in non-fishing ground than fully fishing ground), seasonal (minimum *b* values in August, growing very less than in October, less than the remaining seasons) and depth-wise (as function of length increment, weight increment decreased relatively with the bottom depth) significant differences in the LWR (Suppl. Mat. Table S1). Özdemir et al. (2015) observed significant differences in the LWR by months. These spatiotemporal indifferences in most cases depended on the Fulton's condition factor CF of the fish, and were more pronounced for the fish having CF ≥ 1 (Suppl. Mat. Table S2).

LWRs of 13 osseous fish species were affected significantly by all of the regional, seasonal and depth-wise factors. Overall, the species occurred ubiquitously at all the seafloor depths of the shelf in addition to a few species overspreading from the middle shelf to shelf break (Suppl. Mat. Table S2). The species of which the LWRs were influenced only seasonally inhabited the bottom within a very narrow depth range; lower shelf, or middle or upper shelf. This was truly valid for species with the LWR differed only by the seafloor depth. Only regionally, some species differed in terms of the LWR between fishing zone and non-fishing zone, followed by meadow-vegetated and unvegetated grounds for the specific biological cycle of the fish species (Suppl. Mat. Table S2). There were the species having *b* values increasing with increasing seafloor depths as such there were species having *b* values decreasing by bottom depth (Suppl. Mat. Table S2). For instance, some species (*Callionymus filamentosus, Trachurus mediterraneus, Macroramphosus scolopax, Citharus linguatula, Equulites kluzingeri, Mullus barbatus, Upeneus moluccensis, Dentex maroccanus* and *Pagellus erythrinus*) had *b* values increasing and decreasing with bottom depths; i.e. the *b* values of *Pagellus acarne* (MA >, R3 <, D3 <, D6 >) decreased from the coastal depth to depth 3 (75 m) and then increased to depth 6 (Suppl. Mat. Table S2). In respect to regional differences, the species had lower *b* value in non-fishing zone (R3) than in fishing zones (R1 and R2). Seasonal differences for this species was characterized with *b* values expressing weight gain of individuals as a function of length, similar in May and August, but much more than in October and February. With the exception of the three sparid fish, such spatiotemporal differences in the *b* value were observed for fish which CF ≤ 1 (Suppl. Mat. Table S2). This seasonal shift could happen specifically for pelagic fish depending on food availability, water temperature and fish condition factor (Weatherley & Gill, 1987). At the year scale, the LWR varied with the number of specimens, the areal and seasonal effects (Moutopoulos & Stergiou, 2002) induced from differences in prevailing water temperature and salinity, sexual dimorphism, nutrition condition of the environments, length ranges of specimens and species (Goncalves et al., 1997; Froese et al., 2012). This difference was also truly valid for the cartilaginous fish species (İşmen et al., 2009).

Such factorial differences of the growth in weight versus length could be attributed to the biological demands of the population with season, characterization of the region and seafloor depth. Small individuals of the species grow more slowly than the larger individuals in weight by the length increment (Weatherley & Gill, 1987). In the study area, there was no significant seasonal differences in the fish assemblages (de Meo et al., 2018). Nevertheless, community structure of megabenthic crustaceans as possible food showed seasonal patterns along the depth gradient owing to the fishing disturbance between fishing and non-fishing zones (Patania & Mutlu, 2021).

Weatherley & Gill (1987) determined the factors to differ the LWR seasonally: temperature, salinity, food availability, and size which outlined the growth-selected strategies of species (K or r-selected). Some species lived in vegetated bottoms such as *Posidonia* forest for spawning, nutritional or refuge preferences (de Meo et al., 2018; Mutlu et al., 2021). Area disturbed and undisturbed by the bottom trawl induced differences in the length frequency of species hence the *b* values (Suppl. Mat. Table S3 and Fig. S2). For instance, differences in *b* values between fishing and non-fishing zone: fish species of genera of the Sparidae family between *Dentex*, *Pagrus* (K) and *Pagellus* species and of genera of the Serranidae family between *Epinephelus* (K) and *Serranus* since the trawl eliminated K-selected organisms more than r-selected organisms usually in numerous. Basically, Pecuchet et al. (2017) characterized traits for determining r and K-selected fish community in relation to the environmental parameters inducing growth, feeding and reproduction of the fish in response to natural and anthropogenic stressors, including fishing and climate change.

Based on a data matrix of morphometry (size classes small < 10 cm, medium 10-15 cm, and large size > 15 cm, Fig. 2 & Suppl. Mat. Table S1), regression constants and growth type, the cluster analyses showed that there were overall two main groups of the osseous fish with few sub-entities; small-middle sized, and large-sized species with few exceptions (Fig. 2). The first group was branched into two sub-entities; small and middle-sized fish species. In general, dominance of the allometric growth types changed with size classes of the fish species. Small-sized fish species had mostly negative-allometric and isometric growth, middle-sized fish were characterized with equal dominance within all growth types; and large-sized fish with isometric growth (Fig. 2). Weatherley & Gill (1987) recognized size of the fish as one of the factors differentiating the L and W in a year. The 2-way PERMANOVA showed that the variables of data matrix were overall significantly different among the bottom depth classes and size classes (Table 1). However, their interaction did not affect the variables at $p < 0.05$. Monte Carlo test significantly approved the differences (Table 1).

The *b* values decreased slightly with the bottom depth from lower shelf to middle shelf whereas the highest *b* values occurred for the ubiquitous fish on the entire shelf whereas the *a* values increased. At greater depths, the *b* values shifted the allometry from the isometry to the negative allometry whereas the *a* values changed variably (Fig. 3A). However, the greater depth did not show any difference owing presumably to inconsistency of the *a* values by the depth (Fig. 3A). Shelf and lower shelf inhabited the fish community similarly in terms of growth type owing to a reverse relationship between *b* and *a* values, and mid-shelf as well, but in higher variation owing to cosmopolite fish assemblage in this intermediate zone where the fish community changes to be adapted to greater depths (de Meo et al., 2018). This bathymetrical trend was related to the variation in the fish assemblage structure shifting along the bathymetric gradient; shallow waters were characterized by sandy bottom, higher zooplankton abundance, irradiance and suspended material compared to the deeper stations. Shelf-break fish assemblage was a group apart (de Meo et al., 2018). In the study area, the shelf-break was more oligotrophic than the shelf in terms of surface and near-bottom water chl-*a*, seston, bioseston and total suspended mater (Patania & Mutlu, 2021). Deep sea fish community was discriminated without the reverse relation compared to that at shallower waters. In general, reverse relationships occurred between *a* and *b* constants for many fish (Gündoğdu et al., 2016). Average *b* value was 2.962 ± 0.048 and median was 2.992 for the osseous fish, and average value was not significantly different from the isometric growth ($p > 0.05$). Besides, *a* values trended to decrease with the size classes of the fish (Fig. 3B). Medium-size fish seemed to have negative allometric growth (Fig. 3b). However, the *b* values of the alien (Indo-Pacific) species seemed to relate to age referring date of their first occurrence report in the Mediterranean Sea and increased (*b* values ≥ 3) with time (Suppl. Mat. Table S1). Overall, alien fish introduced in last few decades had *b* values < 3 (Suppl. Mat. Table S1).

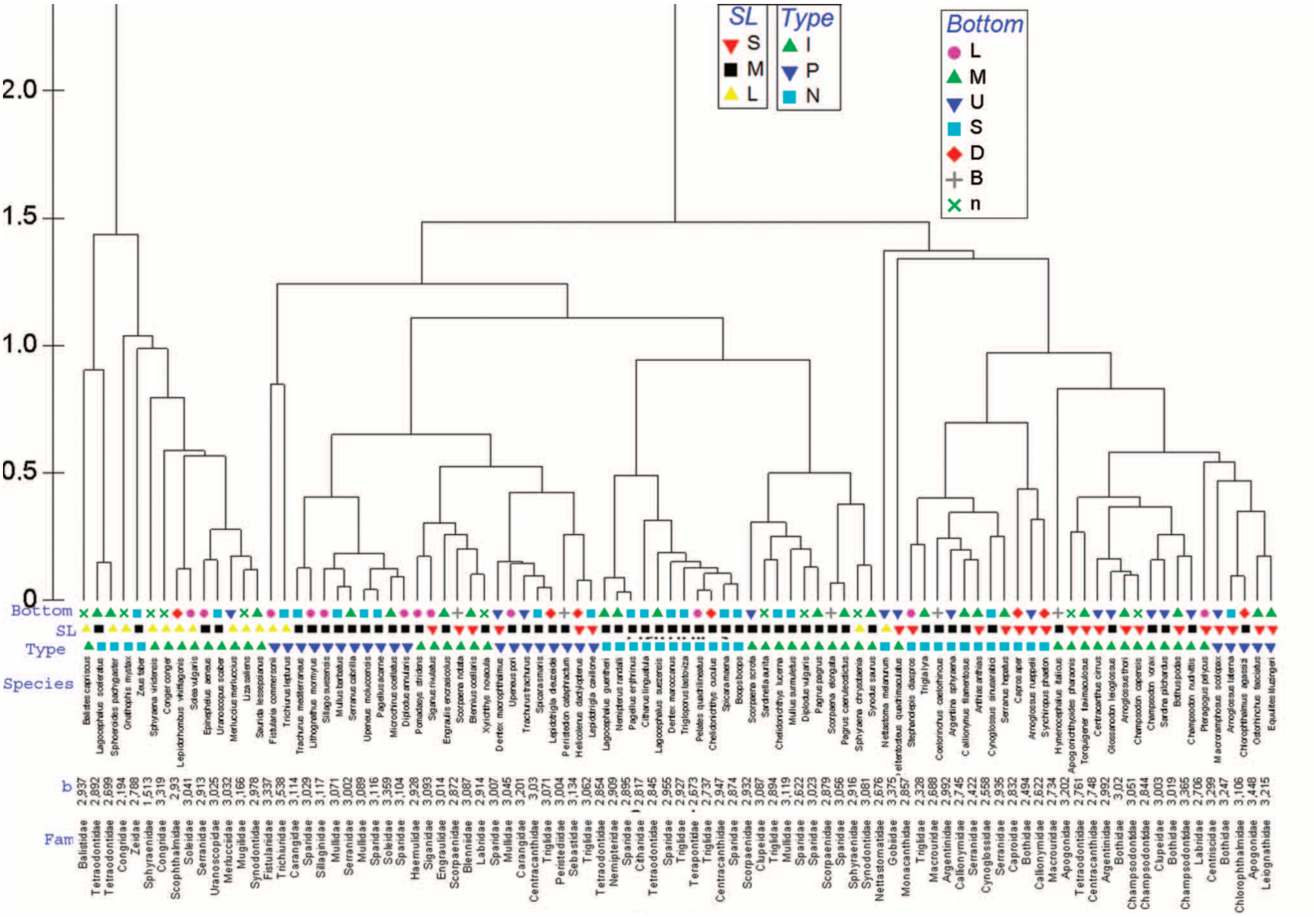

Figure 2. Dendrogram clustering the osseous fish species characterized with morphometry (mean length and mean weight), regression constants (a and b) and growth type of weight with the length, $\log_{10}$-tranformed data to the Euclidean distance (SL: mean length of fish, S: <10 cm, M:10-15 cm and L: >15 cm, Type: growth type, I: Isometric, N: negative allometric, and P: positive allometric growth, and Bottom depth L; lower shelf 10-25 m, M; middle shelf 75-125 m, U; upper shelf 125-200 m, S: shelf 10-200 m, D: deep 200-300 m, and B: shelf break 300 m).

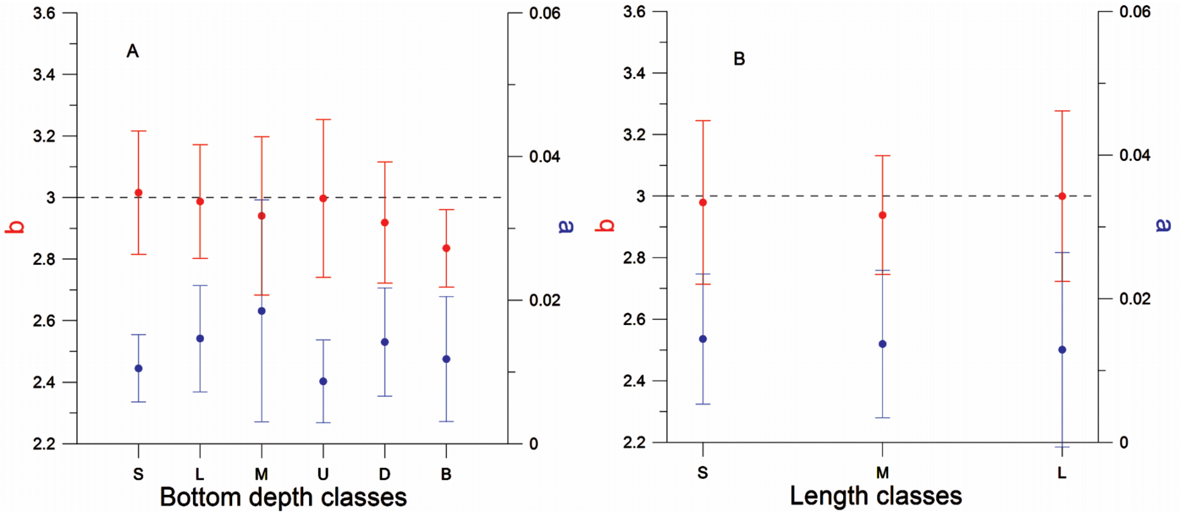

Figure 3. Bottom depth (**A**) and fish size gradient (**B**) of L-W regression constants (*a* and *b* in *X* ± *SD*) of the osseous fish (L: lower shelf 10-25 m, M: middle shelf 75-125 m, U: upper shelf 125-200 m; S: shelf 10-200 m, D: deep bottom 200-300 m, and B: shelf break 300 m) (SL: mean length of fish, S: <10 cm, M:10-15 cm and L: >15 cm).

Using the density (abundance and biomass) data of the present study, de Meo et al. (2018) found however similar ecological depth gradient of fish, three assemblages: shallow waters (10-25 m), intermediate waters (75-125 m) and deep waters (125-200 m) depending on the bottom types which could induce classification of growth type of the fish. With exception of the flatted species, some species shaped in torpedo such as mullid species occurred on the entire shelf since they had different substrate utilization during the various life stages and seasons (Lombarte et al., 2000). Therefore, the ubiquitous species had isometric or positive allometric growth. Zooplankton biomass values were found to be higher especially close to the coast. In these oligotrophic waters the planktonic web is also tightly controlled by the heterotrophic component, based on the transfer of dissolved organic matter (Siokou-Frangou, et al., 2010), which derived the better body condition of such fish. The L and W varied seasonally depending on diet, stomach fullness, and food availability (Weatherley & Gill, 1987; Wootton, 1990).

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