



Length-weight relationship and condition factor of the glasshead grenadier *Hymenocephalus italicus* (Gadiformes: Macrouridae) from Gökçeada Island (Northern Aegean Sea, Türkiye)

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Abstract

This study investigated the length-weight relationship (LWR) and condition factors of the glasshead grenadier *Hymenocephalus italicus* (Giglioli, 1884) from the deep waters surrounding Gökçeada Island in the northern Aegean Sea (Türkiye). Fish specimens were collected between March 2015 and April 2017 during commercial bottom trawl operations at depths ranging from 109.7 to 332.8 m. A total of 245 individuals were analyzed. Total length (TL) ranged from 4.10 to 14.10 cm (mean: 11.20 ± 0.10 cm), while total weight (W) ranged from 0.41 to 5.45 g (mean: 2.62 ± 0.05 g). The LWR was described by the equation $W = 0.0577 \cdot TL^{1.5667}$, corresponding to the logarithmic form $\log(W) = -1.2388 + 1.5667 \cdot \log(TL)$. The regression model was statistically significant ($p < 0.001$) and explained a moderate proportion of the variance ($R^2 = 0.545$). The estimated growth coefficient ($b = 1.5667$; 95% CI: 1.386-1.748) was significantly lower than the theoretical isometric value of 3, indicating negative allometric growth. Mean Fulton's condition factor (K) and relative condition factor (K_n) were 0.194 ± 0.005 and 0.171 ± 0.005 , respectively. This investigation provides foundational biological data for *H. italicus* in the northern Aegean Sea. It underscores the importance of standardized morphometric protocols, particularly the use of pre-anal length (PAL), in future studies of deep demersal ichthyofauna.

Keywords: LWR, Trawl, Discard, Condition factor, Macrourid species, Deep-sea fish

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1. Introduction

Deep-sea demersal fishes constitute a key structural and functional element of continental slope ecosystems, making significant contributions to biomass, trophic connectivity, and benthopelagic energy flow (D'Onghia et al., 2000). Within this group, macrourid (grenadiers or rattails) fishes are particularly notable due to their broad bathymetric distribution, high abundance in slope assemblages, and ecological role as intermediate and upper-level consumers in deep-sea food webs (Cohen et

al., 1990; D'Onghia et al., 2000). Although most macrourids have little direct commercial value, they are frequently represented in trawl catches and are considered informative components of deep demersal ecosystem structure and functioning (Massutí et al., 1995; D'Onghia et al., 2000).

The glasshead grenadier (*Hymenocephalus italicus* Giglioli, 1884) is a small benthopelagic macrourid widely distributed in the Mediterranean Sea and adjacent Atlantic-influenced regions. The species is



generally associated with the upper and middle continental slope, where it is a recurrent component of deep demersal fish communities (Cohen et al., 1990; Massutí et al., 1995). Previous studies have shown that *H. italicus* is typically most abundant between 400 and 600 m depth, while its abundance progressively declines below this range and may become very low or disappear near 900 m in some Mediterranean sectors (Massutí et al., 1995). Comparable bathymetric patterns have been reported from the Catalan Sea (Massutí et al., 1995), the western Ionian Sea (D'Onghia et al., 2000), and the Iberian Mediterranean margin (Moranta et al., 2007; Cartes et al., 2021), indicating a relatively consistent depth-related ecological distribution across the Mediterranean (Schwarzhan, 2014).

In addition to its bathymetric distribution, *H. italicus* is ecologically relevant because of its trophic role in deep-sea food webs. General faunistic and taxonomic syntheses indicate that the species occurs predominantly at depths shallower than approximately 500 m and feeds mainly on pelagic copepods, followed by euphausiids, amphipods, shrimps, ostracods, cumaceans, and other small crustaceans, with occasional ingestion of small fishes (Cohen et al., 1990). Although *H. italicus* has negligible direct commercial value due to its small body size and commonly discarded in demersal fisheries, its recurrent occurrence and numerical abundance indicate a potentially important role in energy transfer between pelagic and benthic compartments in slope environments. This ecological relevance is further reflected in its conservation status, as the species is currently classified as Least Concern on the IUCN Red List (Iwamoto, 2015).

Despite its ecological relevance (D'Onghia et al., 2000; García-Ruiz et al., 2019; D'Iglio et al., 2025), *H. italicus* remains comparatively underrepresented in the fisheries and fish biology literature of the northern Aegean Sea, especially with respect to species-specific morphometric and condition-based analyses (Filiz & Taskavak, 2008). In the broader Mediterranean, previous studies have mainly focused on distribution (Massutí et al., 1995; García-Ruiz et al., 2019), assemblage structure (Labropoulou et al., 2000; Politou et al., 2008), population biology, and growth-related characteristics of macrourids (D'Onghia et al., 2000; Sion et al., 2012) rather than on local-scale biometric assessment of this species. In the northern Aegean, *H. italicus* has been recorded in demersal trawl surveys and fish assemblage studies, confirming its presence as a regular component of deeper fish communities (Karakulak & Keskin, 2007). However, to the best of our knowledge, no previous study has specifically described the length-weight relationship (LWR) and condition factors of *H. italicus* from the waters

surrounding Gökçeada Island. This gap is important because LWRs are among the most widely used descriptors in fisheries biology. They provide essential information for estimating biomass from length-frequency data, comparing growth patterns among populations, converting length-based observations into weight-based models, and evaluating deviations from isometric growth (Ricker, 1975; Froese, 2006). Deviations from isometry may reflect ontogenetic changes, body shape, reproductive condition, food availability, habitat-specific environmental conditions, and sampling structure (Ricker, 1975; Froese, 2006). Therefore, region-specific LWR estimates are essential for robust biological interpretation and meaningful comparison among populations.

In deep-water macrourids, however, the interpretation of LWRs may be further complicated by morphological constraints related to body form. Many species in this family possess a strongly elongated, tapering, and fragile posterior body region, which can reduce the precision and repeatability of total length (*TL*) measurements. This issue is particularly relevant for *H. italicus*, whose delicate caudal extremity is highly susceptible to bending, breakage, or distortion during capture and handling. In fact, previous morphometric studies on macrourids have often preferred pre-anal length (*PAL*) rather than *TL* because *PAL* provides a more stable and biologically meaningful measure of body size in elongate slope fishes (Massutí et al., 1995). Consequently, local LWR studies on *H. italicus* are important not only for documenting biological variation, but also for evaluating the methodological implications of morphometric choice in deep-sea fishes.

The length-weight relationships of various fish species in the northern Aegean Sea have been thoroughly examined by numerous researchers (Lamprakakis et al., 2003; Filiz & Bilge, 2004; Karakulak et al., 2006; Cengiz, 2012, 2013a, 2013b, 2019, 2021a, 2021b, 2022a, 2022b, 2022c, 2022d; Altın et al., 2015; Gonulal, 2017; Ayyildiz & Altın, 2018; Ayyildiz et al., 2019; Cengiz et al., 2019a, 2019b, 2019c; Adamidou et al., 2020; Cengiz & Paruğ, 2021, 2022). In contrast, studies focusing on bycatch and discarded species within commercial trawl fisheries in the same region remain relatively scarce (Soykan et al., 2016, 2019). Furthermore, Soykan and Kınacıgil (2021) investigated the length-weight relationships of certain discarded fish species in the central Aegean Sea.

The northern Aegean coast of Türkiye is commonly divided into several sub-regions, including the Edremit and Saros Bays, the Bozcaada and Gökçeada Islands, and the Gallipoli Peninsula (Cengiz & Paruğ, 2020). Gökçeada Island, the westernmost and largest island of

Türkiye, is located at the entrance of Saros Bay (Cengiz, 2023) and offers a particularly valuable setting for such an assessment. The island lies within a hydrographically dynamic sector influenced by the Çanakkale Strait, Black Sea-derived nutrient-rich waters, and regional circulation patterns. These oceanographic characteristics contribute to relatively high productivity and habitat heterogeneity compared with the more oligotrophic sectors of the eastern Mediterranean. In addition, fisheries constitute an important economic activity in the region (Cengiz, 2020). Previous studies conducted around Gökçeada have highlighted the ecological importance of the area for fish diversity, coastal habitats, and trawl-associated assemblages (Kale et al., 2014a, 2014b, 2015a, 2015b, 2021; Altın et al., 2015, 2020; Acarli et al., 2018, 2022a, 2022b). However, most existing work from the area has focused on coastal biodiversity, shallow-water fish communities, or multi-species bycatch/discard assemblages, while species-specific biological information for deep demersal fishes remains scarce.

The present study addresses a clear local and taxon-specific knowledge gap by providing the first detailed assessment of the length-weight relationship, growth type, and condition factors of *H. italicus* from the deep waters surrounding Gökçeada Island. Based on the species' deep-water ecology, elongated macrourid morphology, and the known sensitivity of length-based

morphometrics in such fishes, we hypothesized that the Gökçeada population of *H. italicus* would exhibit non-isometric growth, potentially differing from the more conventional scaling patterns commonly reported for many shelf-associated teleosts. By addressing this hypothesis, the present study was designed with three main objectives: (i) to estimate the LWR parameters of the species, (ii) to determine whether growth deviates significantly from isometry, and (iii) to assess the general physiological status of the sampled population using Fulton's condition factor (K) and Le Cren's relative condition factor (K_n).

2. Material and Method

2.1. Study area and sampling

Fish specimens were obtained from the coastal waters of Gökçeada Island in the northern Aegean Sea between March 2015 and April 2017 (Figure 1). Sampling was conducted during the commercial trawl fishing season using a standard commercial trawl net fitted with a codend having a 44 mm opening mesh size as defined by the Turkish fisheries regulation (Communiqué No. 6/1). Bottom trawl surveys covered a bathymetric range from 109.7 m to 332.8 m. Following the MEDITS program guidelines (Bertrand et al., 1997), all hauls were conducted during daytime hours to ensure consistency.

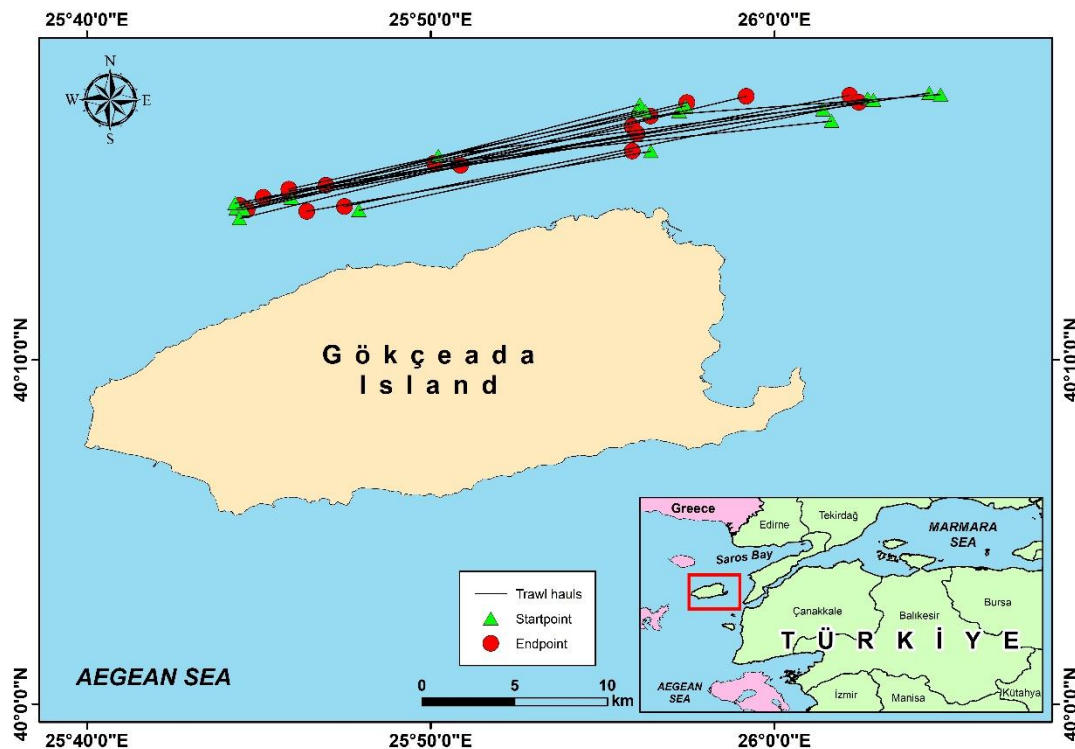


Figure 1. Study area and samplings

2.2. Statistical analyses

The total length (TL) of each individual was measured to the nearest 0.1 cm, and the total weight (W) was recorded to the nearest 0.01 g. The length-weight relationship (LWR) was determined using the power function (Eq. 1) (Ricker, 1975).

$$W = aL^b \quad (1)$$

where a is the intercept and b is the allometric growth coefficient. To facilitate linear regression, the equation was log-transformed (Eq. 2):

$$\log(W) = \log(a) + b \log(L) \quad (2)$$

The physiological status of the population was assessed using Fulton's (1904) condition factor (K) (Eq. 3) and Le Cren's (1951) relative condition factor (K_n) (Eq. 4):

$$K = 100 \frac{W}{L^3} \quad (3)$$

In this equation, K is the condition factor, L is the total length (cm) and W is the total weight (g).

$$K_n = \frac{W}{aL^b} \quad (4)$$

In this equation, K_n is the relative condition factor, L is the length (cm) and W is the total weight (g) of individuals, a is the intercept and b is the slope obtained from the LWR estimation.

To determine whether growth significantly deviated from isometry ($b=3$), a Student's t -test (Zar, 1984) was performed using the formula given below (Eq. 5):

$$t = \frac{b - 3}{SE(b)} \quad (5)$$

Growth was classified as isometric ($b=3$), positive allometric ($b>3$), or negative allometric ($b<3$) based on the calculated slope (Froese, 2006). Descriptive statistics, including mean, standard error, skewness, and kurtosis, were calculated for all parameters.

3. Results

A total of 245 individuals of *H. italicus* were analyzed. The frequency distributions of total length and total weight for *H. italicus* are presented in Figure 2. The sampled individuals exhibited a relatively concentrated size structure, with most specimens clustering around the intermediate size classes. Total length of the sampled individuals ranged from 4.10 to 14.10 cm with a mean of 11.20 ± 0.10 cm, while total weight ranged from 0.41 to 5.45 g with a mean of 2.62 ± 0.05 g. In both distributions, the majority of individuals were concentrated around the central classes, while relatively few specimens were represented at the smallest and largest size intervals. The fitted normal curves indicate that both length and weight distributions generally followed a unimodal pattern, although slight asymmetry was evident, particularly in the lower size and weight classes due to the presence of a limited number of small individuals. Descriptive statistics for the total length, weight, and condition factors are provided in Table 1.

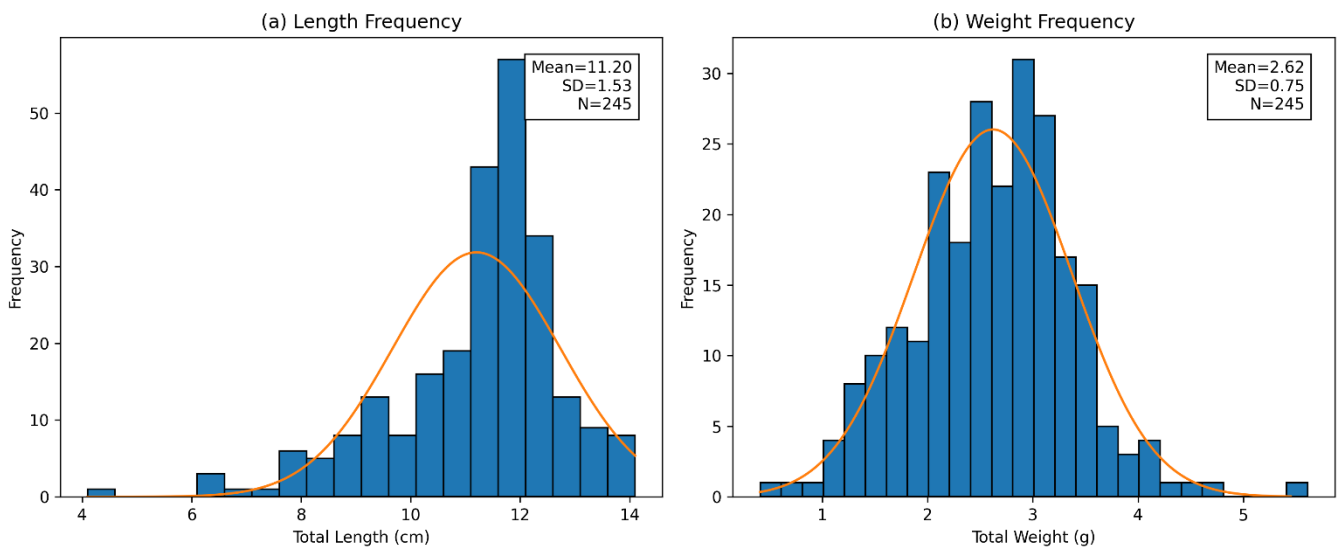


Figure 2. Frequency distributions of total length (a) and total weight (b) of *Hymenocephalus italicus* collected from Gökçeada Island (northern Aegean Sea). Solid lines represent fitted normal distribution curves. Mean, standard deviation (SD), and sample size (N) are shown within each panel

Table 1. Descriptive statistics of the total length, weight, Fulton's condition factor (K) and Le Cren's relative condition factor (K_n) for the glasshead grenadier (*Hymenocephalus italicus*) from Gökçeada Island, northern Aegean Sea (sample size: 245)

Values	Total Length	Weight	K (Fulton)	K_n (Le Cren)
Mean	11.20	2.62	0.19	0.17
Standard Error	0.10	0.05	0.005	0.005
Skewness	-1.19	0.04	2.19	2.69
Kurtosis	2.25	0.60	6.02	9.95
Minimum	4.10	0.41	0.10	0.08
Maximum	14.10	5.45	0.59	0.67

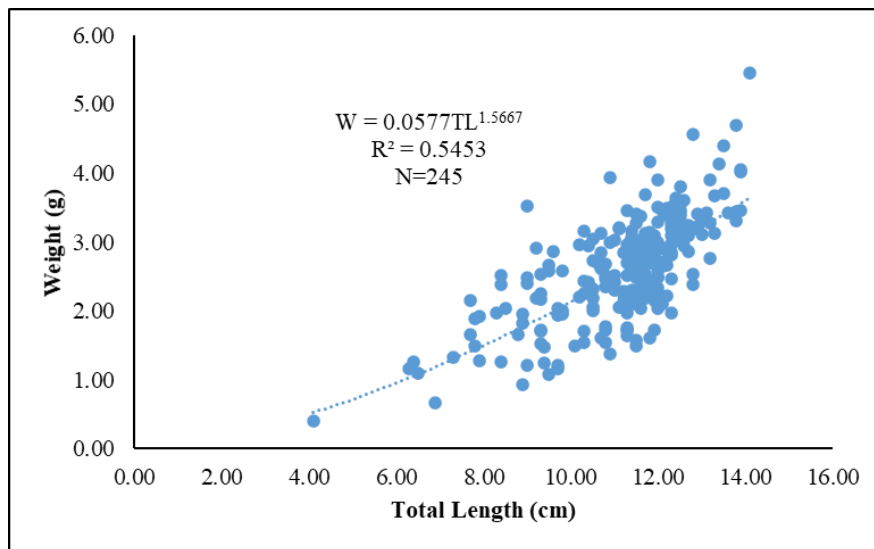


Figure 3. Length-weight relationship of *Hymenocephalus italicus* from Gökçeada Island (northern Aegean Sea)

The length-weight relationship was estimated using the power equation $W = aL^b$. The derived regression equation for the Gökçeada population was $W = 0.0577 \cdot TL^{1.5667}$ or in logarithmic form $\log(W) = -1.2388 + 1.5667 \log(TL)$. The model was statistically significant ($p < 0.001$) and explained a moderate proportion of the variance ($R^2 = 0.545$). The length-weight relationship of *H. italicus* is presented in Figure 3.

The estimated growth coefficient was $b = 1.5667$ with a 95% confidence interval of 1.386-1.748. This was significantly lower than the theoretical isometric value of 3 (t -test, $p < 0.001$), indicating negative allometric growth in the studied population.

The mean condition factor values were 0.194 ± 0.005 for Fulton's condition factor (K) and 0.171 ± 0.005 for the relative condition factor (K_n). Fulton's K ranged between 0.098 and 0.595, while K_n ranged between 0.083 and 0.667.

4. Discussion

The present study contributes new information on the length-weight relationship (LWR) and condition status of *H. italicus* inhabiting the deep continental shelf and

upper slope waters around Gökçeada Island in the northern Aegean Sea. Macrourid fishes are recognized as one of the most important components of deep demersal assemblages in the Mediterranean, contributing significantly to biomass and trophic functioning despite their low commercial value (Sion et al., 2012). In this context, the present results contribute valuable biological data for a species that is both ecologically relevant and still relatively underrepresented in regional fisheries studies.

The estimated LWR revealed a growth coefficient of $b = 1.5667$, indicating negative allometric growth. Although deviations from isometry are common in fishes, the observed value is clearly lower than the range generally reported for Mediterranean teleosts. Previous studies on macrourids from the eastern Aegean Sea reported b values ranging between 2.51 and 3.49, including negative, isometric, and positive allometric growth depending on species (Filiz & Taskavak, 2008). Therefore, the markedly low b value observed in the present study suggests that either species-specific traits or environmental and methodological factors play a significant role in shaping the growth pattern of *H. italicus* in the Gökçeada region.

Table 2. Published length-weight relationship (LWR) parameters for *Hymenocephalus italicus* reported from different geographic regions using total length (*TL*) and pre-anal length (*PAL*) measurements

<i>N</i>	<i>a</i>	<i>b</i>	<i>R</i> ²	<i>G</i>	<i>L</i>	Location	References
245	0.0577	1.5667	0.545	-A	TL (4.10-14.10 cm)	Gökçeada Island, northern Aegean Sea, Türkiye	Present study
98	0.0069	2.510	0.880	-A	TL (6.70-16.80 cm)	Sığacık Bay, eastern Aegean Sea, Türkiye	Filiz and Taskavak (2008)
76	0.0077	2.450	0.771	NA	TL (8.2-15.5 cm)	Antalya Bay, Mediterranean, Türkiye	Deval et al. (2014)
91	0.0034	2.891	0.860	-A	TL (7.4-14.9 cm)	Southeast Aegean Sea, Türkiye	Yapici et al. (2015)
117	0.0027	2.504	0.958	+A	TL (7.1-16.0 cm)	Northeastern Mediterranean	Başusta et al. (2025)
60 (♀)	0.0024	2.632	0.958	+A	TL (8.30-16.0 cm)	Northeastern Mediterranean	Başusta et al. (2025)
57 (♂)	0.0033	2.575	0.959	+A	TL (7.10-14.50 cm)	Northeastern Mediterranean	Başusta et al. (2025)
69	0.1277	2.7964	0.965	-A	PAL (2.2-5.1 cm)*	Western Mediterranean	Morey et al. (2003)

Note: Only studies explicitly reporting LWR parameters in the form $W = aL^b$ were included in the main comparison. *N*: sample size; NA: Not applicable; ♀: female individuals; ♂: male individuals; *a* and *b*: parameters derived from the LWR; *R*²: coefficient of determination; *G*: growth type (-A: negative allometric; +A: positive allometric); *L*: length type (*TL*: total length; *PAL*: pre-anal length).

*Although one study used pre-anal length (*PAL*) instead of total length (*TL*), it was included due to the limited number of published length-weight relationship studies available for *H. italicus*. However, direct comparison between *PAL*-based and *TL*-based LWR parameters should be interpreted with caution because the two morphometric measurements are not directly equivalent.

Comparison of LWR results with previously published papers was presented in Table 2. The currently available literature indicates that published LWR data for *H. italicus* are still limited, but the few available studies provide important comparative context for the present findings. In particular, Başusta et al. (2025) reported the first large-scale LWR estimates for *H. italicus* from the northeastern Mediterranean, with the relationship for all individuals expressed as $W = 0.0027 \cdot TL^{2.504}$ (*R*²=0.958, SE(*b*)=0.051), while sex-specific analyses yielded $W = 0.0024 \cdot TL^{2.632}$ for females (*R*²=0.958, SE(*b*)=0.072) and $W = 0.0033 \cdot TL^{2.575}$ for males (*R*²=0.959, SE(*b*)=0.072). Likewise, Filiz and Taskavak (2008) reported *b*=2.51 for the eastern Aegean Sea, while Morey et al. (2003) reported *b*=2.7964 for the western Mediterranean. In contrast, the present study yielded *b*=1.5667, indicating a much stronger departure from isometric growth. These estimates are substantially higher than the *b*=1.5667 obtained in the present study, indicating a much stronger weight increase with length in the northeastern Mediterranean population. Taken together, these results suggest that the *b* value obtained in the present study is the lowest so far reported for the species, clearly deviating from the more moderate allometric scaling documented elsewhere in the Mediterranean.

Several explanations may account for this discrepancy. First, regional ecological variability may play a role, as slope fish populations are known to respond to local differences in food availability, hydrography, and bathymetric habitat structure. Second, sample composition, including sex ratio, maturity stage, and seasonal pooling, may strongly influence the estimated allometric coefficient. This is particularly relevant

because Başusta et al. (2025) showed that even within the same regional population, females and males produced slightly different LWR parameters. Third, and perhaps most importantly in the case of *H. italicus*, morphometric methodology may significantly affect the outcome. Macrourid fishes possess an extremely elongated, tapering, and fragile caudal region, making total length (*TL*) measurements particularly sensitive to handling-related distortion and measurement error. Some studies were not included in the main LWR comparison (Table 2) because they do not provide directly comparable $W = aL^b$ parameters. In this respect, Massutí et al. (1995) demonstrated a strong morphometric relationship based on pre-anal length (*PAL*) ($HL = 0.0674 + 0.5872 \cdot PAL$; *n*=154; *R*²=0.92), supporting the use of *PAL* as a more stable size descriptor in this species. Likewise, D'Onghia et al. (2000) reported significant population-level morphometric relationships for large Mediterranean samples (*n*=6353), supporting the view that body-size estimation in this species is strongly influenced by the choice of morphometric variable. Therefore, the unusually low *b* value estimated here should be interpreted not only as a biological pattern, but also as a likely consequence of using *TL* in a species for which *PAL* may provide a more reliable morphometric basis. Future studies should prioritize *PAL*-based LWR estimation to improve comparability and reduce measurement-related uncertainty.

From a biological perspective, the observed negative allometry may be partly explained by the ontogenetic structure of the sampled population. Previous studies on macrourid fishes have demonstrated that size-frequency distributions often exhibit multimodal patterns and that

population structure is influenced by depth-related variation, seasonal dynamics, and recruitment processes (D'Onghia et al., 2000). In particular, *H. italicus* exhibits prolonged recruitment and slow growth, with individuals of different life stages co-occurring within the same depth range (D'Onghia et al., 2000). When such heterogeneous size groups are analyzed together, deviations from isometric growth are expected, as body proportions and tissue allocation change throughout ontogeny.

Another important factor is the bathymetric and ecological context of the study area. Macrourids are dominant components of slope ecosystems, typically inhabiting depths between 200 and 2000 m and playing key roles in benthopelagic food webs (Massutí et al., 1995). In the Mediterranean, deep-sea environments are characterized by relatively stable physical conditions but limited and variable food supply, which strongly influences fish growth and energy allocation (Sarda et al., 2004). *H. italicus* in particular is known to feed mainly on suprabenthic and benthopelagic prey, with feeding intensity and diet composition varying temporally (Madurell & Cartes, 2006). Such trophic flexibility, combined with patchy prey availability, can lead to substantial variability in body mass relative to length and may contribute to reduced weight gain with increasing size.

At the assemblage level, deep demersal fish communities in the Mediterranean are strongly influenced by food availability, seasonal dynamics, and trophic interactions (Madurell et al., 2004). Long-term studies have shown that shifts in benthopelagic food webs can alter species composition, biomass, and trophic structure (Cartes et al., 2009). Since *H. italicus* is a benthopelagic feeder linking pelagic and benthic trophic pathways, its growth pattern is likely sensitive to such ecosystem-level variability. Therefore, the low b value observed here may reflect not only individual growth dynamics but also broader ecological processes operating in the Gökçeada slope ecosystem.

The bathymetric distribution of macrourids further supports this interpretation. Previous studies have shown that *H. italicus* abundance and biomass generally decrease below certain depths, while mean body size tends to increase with depth (Massutí et al., 1995). Similarly, large-scale analyses across the Mediterranean have revealed spatial and depth-related variability in abundance and size structure of macrourid populations (García-Ruiz et al., 2019). Such patterns indicate that growth and body form are closely linked to habitat use and environmental gradients, reinforcing the idea that the observed allometry is ecologically driven.

Condition factors (K and K_n) are widely used bio-indicators for assessing the nutritional and physiological status of fish populations within their habitats (Morey et al., 2003; Kale et al., 2021). The condition factor results obtained in the present study are consistent with the observed growth pattern of *H. italicus*. The moderate mean values of Fulton's condition factor (K) and relative condition factor (K_n), together with their relatively wide ranges, indicate inter-individual variability in physiological condition. Such variability is expected in deep-sea species, where feeding opportunities are irregular and energy intake is closely associated with the episodic availability of prey resources. In general, higher condition factor values are associated with favorable environmental and nutritional conditions, whereas lower values may reflect poorer physiological status or growth limitations. For the relative condition factor, values close to 1 indicate that individuals conform to the expected weight predicted from the population length-weight relationship, while deviations from 1 may suggest differences in individual condition relative to the population average (Kale et al., 2021; Acarli et al., 2022a). However, in elongated and slender-bodied species such as macrourids, relatively low Fulton's K values may naturally occur due to species-specific body morphology. Moreover, since Fulton's K assumes isometric growth, its applicability may be limited in species exhibiting strong allometry. In contrast, K_n is considered more appropriate under such conditions because it is directly derived from the empirical LWR.

A further methodological issue that should be considered when interpreting the present LWR results is the morphological peculiarity of the species, particularly the structure of the caudal region. *H. italicus* exhibits a highly elongated, fragile, and tapering tail, which is characteristic of many macrourid fishes and is associated with their benthopelagic lifestyle and locomotion. Such morphology can introduce significant uncertainty in total length (TL) measurements, especially if the caudal extremity is damaged, curved, or inconsistently positioned. In fact, morphometric studies on macrourids frequently rely on pre-anal length (PAL) as a more stable and biologically meaningful metric, particularly in growth and maturity analyses (Massutí et al., 1995). Since TL was used in the present study, part of the deviation observed in the LWR, especially the low b value, may reflect measurement-related bias associated with tail morphology. Therefore, future studies on *H. italicus* are strongly recommended to incorporate PAL -based analyses alongside TL measurements in order to reduce measurement error and obtain more reliable growth estimates.

The Gökçeada region itself provides an ecologically meaningful framework for interpreting these findings. The northern Aegean Sea is characterized by heterogeneous hydrographic conditions, complex circulation patterns, and variable productivity, all of which can influence deep benthic and demersal communities (Puerta et al., 2025). Such environmental variability may affect prey availability, habitat use, and energy allocation in slope-dwelling fishes, thereby influencing growth patterns and condition indices. Consequently, the observed growth characteristics of *H. italicus* may represent a combined effect of species-specific biology and local environmental conditions rather than a universal trait.

Despite these insights, the present study has some limitations that should be acknowledged. The LWR parameters were derived from pooled samples covering different seasons and depth ranges, and therefore represent population-level averages rather than fixed biological constants. Given the known influence of sex, maturity stage, season, and depth on growth patterns in macrourids, future studies should aim to stratify samples accordingly to better resolve intra-population variability.

In conclusion, the low b value observed in the present study should be interpreted as the result of multiple interacting factors, including ontogenetic variability, trophic ecology, deep-sea environmental conditions, and measurement sensitivity related to body morphology. Rather than representing a statistical anomaly, it likely reflects the adaptive growth strategy of *H. italicus* within the deep demersal ecosystem of the northern Aegean Sea. From a broader perspective, improving the understanding of growth patterns and condition in deep-sea fishes is essential for interpreting energy flow, trophic connectivity, and ecosystem functioning in slope environments. Such knowledge is also increasingly relevant in the context of expanding deep-sea exploitation and environmental change. Therefore, future research integrating standardized morphometric approaches (e.g., *PAL*), seasonal sampling, and bathymetric stratification will be critical for enhancing the ecological interpretation and management of deep demersal fish communities in the Mediterranean.

5. Conclusion

The present study provides the first detailed assessment of the length-weight relationship and condition factors of *H. italicus* from the deep waters surrounding Gökçeada Island in the northern Aegean Sea. The species exhibited a negative allometric growth pattern, with an estimated growth coefficient significantly lower than the theoretical isometric value. The condition

indices obtained in this study suggest moderate but variable body condition among individuals, which is consistent with the ecological variability expected in deep demersal environments. The relatively low b value observed here likely reflects the combined influence of population structure, deep-water ecological conditions, and morphological measurement sensitivity, particularly due to the elongated and fragile caudal region of the species. In this respect, the use of pre-anal length (*PAL*) instead of total length (*TL*) may provide more robust morphometric estimates in future studies. The results presented here contribute valuable baseline biological information for *H. italicus* in the northern Aegean Sea. Such information is crucial for advancing knowledge of the species' growth dynamics, ecological role, and population-level variability within Mediterranean deep demersal ecosystems. Future research incorporating seasonal sampling, depth-stratified approaches, and *PAL*-based morphometric analyses will be valuable for refining biological assessments and strengthening ecosystem-based evaluations of deep-sea fish assemblages in the region.

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Conflict of interest

The authors declare that there is not any conflict of interest regarding the publication of this manuscript.

Ethical Approval

This article does not require ethics committee approval.

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