http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 42(3), 241-247 (2025)

Su Ürünleri Dergisi (2025)
DOI: 10.12714/egejfas.42.3.06

RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

An investigation of the length-weight relationship for 13 fish species on the eastern coast of Libya in the Mediterranean Sea

Akdeniz'de Libya'nın doğu kıyısındaki 13 balık türü için boy-ağırlık ilişkisinin incelenmesi

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Received date: 18.05.2025 Accepted date: 24.07.2025

How to cite this paper:
Alfergani, E.S., & El-Mabrok, M. (2025). An investigation of the length-weight relationship for 13 fish species on the eastern coast of Libya in the Mediterranean Sea. *Ege Journal of Fisheries and Aquatic Sciences, 42*(3), 241-247. https://doi.org/10.12714/egejfas.42.3.06

Abstract: We estimated the length–weight relationships (LWRs) for 13 marine fish species from the eastern coast of Libya in the Mediterranean Sea. A total of 325 specimens were collected from four different locations. The LWR parameters (a and b) were determined using the power function model: $TW=aTL^b$. The regression coefficient b ranged from 2.182 (95% CI:1.607–2.689) in *Siganus rivulatus* to 3.328 (95% CI:2.700–3.955) in *Chelon saliens*. The coefficient of determination (r^2) varied between 0.52 and 0.99. Most species exhibited isometric growth patterns, except for *Siganus rivulatus*, *Sparisoma cretense*, and *Sardinella aurita*, which showed negative allometric growth. These findings contribute valuable baseline data to support fisheries management and conservation efforts in the region.

Keywords: Length-weight parameters, marine fishes, growth pattern, Libya coast

Öz: Akdeniz'deki Libya'nın doğu kıyısındaki 13 deniz balığı türü için boy-ağırlık ilişkilerini (LWR) hesapladık. Dört farklı lokasyondan toplam 325 örnek toplandı. LWR parametreleri (a ve b), güç fonksiyon modeli kullanılarak belirlendi: $TW=aTL^b$. Regresyon katsayısı b, *Siganus rivulatus* türünde 2,182 (95% CI:1,607-2,689) ile *Chelon saliens* türünde 3,328 (95% CI:2,700-3,955) arasında değişti. Belirleme katsayısı (r^2) 0,52 ile 0,99 arasında değişti. Negatif allometrik büyüme gösteren *Siganus rivulatus*, *Sparisoma cretense* ve *Sardinella aurita* hariç çoğu tür izometrik büyüme sergiledi. Bu bulgular, bölgedeki balıkçılık yönetimi ve koruma çabalarını desteklemek için değerli temel veriler sağlamaktadır.

Anahtar kelimeler: Boy-ağırlık parametreleri, deniz balıkları, büyüme modeli, Libya kıyıları

INTRODUCTION

Growth is one of the most extensively studied aspects of fish biology, as it is a good indicator of the health of both individuals and populations (Moyle and Cech, 2004). There are many key factors that affect fish growth, such as food availability, the number of fish competing for the same food supply, temperature, oxygen levels, and other water quality parameters, as well as the size, age, and sexual maturity of the fish (Kurikose, 2014). Fish growth is defined as the change in size over time (Dars et al., 2010). The length-weight relationship is an important tool for estimating fish weight relative to a given length (Bagenal and Tesch, 1978). It also helps determine fish growth patterns, assess fish stocks, and evaluate their general health and habitat conditions. It also allows us to compare the life cycles of different fish species in different regions and assess their health and other aspects of their populations (Schneider et al., 2000; Froese, 2006).

Many previous studies have been conducted in the Mediterranean to determine the length-weight relationship of native and invasive species, including Ragheb (2023) and Mehanna and Farouk (2021) in Egyptian water. Sen et al. (2024) and Özvarol (2014) conducted studies in Türkiye water, Jisr et al. (2018) in Lebanon water, Kondylatos et al. (2024) in Greece, Verdiell-Cubedo et al. (2006) in Spain water, Gonçalves et al. (1997) and Mendes et al. (2004) in Portugal water, Cherif et al. (2008) in Tunisia water, and Elbaraasi (2014) in Libya water. Although the Libyan coast is considered one of the largest marine areas in the Mediterranean, with a coastline length of about 2,000 km, and includes more than 304 recorded species (Elbaraasi et al., 2019), it is the least studied and suffers from a lack of recent data related to biometric relationships of fish species. The study aims to provide information on the length-weight relationships of thirteen fish species (*Synodus saurus*, *Scorpaena scrofa*, *Scorpaena notata*, *Sciaena umbra*, *Chelidonichthys lucerna*, *Boops boops*, *Siganus rivulatus*, *Chelon saliens*, *Pempheris rhomboidea*, *Sparisoma cretense*, *Scomber colias*, *Sardinella aurita*, and *Dicentrarchus labrax*), which were collected from four sites along the eastern coast of Libya. This study represents a scientific reference that can be built upon in future studies and contributes to establishing scientific foundations for the sustainable management of marine fisheries resources in the region.

MATERIALS AND METHODS

A total of thirteen fish species were collected during the period 2022–2023 with the assistance of local fishermen from four coastal locations along the eastern Mediterranean coast of Libya: Benghazi Port, Susa Harbor, Derna Harbour, and Ain

El-Ghazala Lagoon (Figure 1). The collected specimens were transferred to the laboratory, where species identification was performed using ichthyological taxonomic keys (Golani et al., 2006). A total of 325 specimens were collected and analyzed. In the laboratory, the total weight (TW) of each fish was measured to the nearest 0.01 g using a digital balance (Sartorius, BP2100S), and the total length (TL) was measured to the nearest 0.01 cm using a measuring board. The length-weight relationship was determined according to Ricker (1975): $TW=aTL^b$ this equation was converted to a logarithmic expression: $\ln TW=\ln a+b \ln TL$, where TW represents the total weight, TL represents the total length, a is the intercept, and b is the slope coefficient. We tested the value of b using the t-test and the 95% confidence interval. We calculated the confidence using the equation: $CI = b \pm (1.96 \times Sb)$, where b stands for the regression coefficient and Sb for the standard error of b's value. To determine if b is significantly different from 3, we used a student's t-test at a significance level of 0.05, $t_s = (b-3)/Sb$, where b is the regression coefficient and Sb is the standard error of the value of b (Sokal and Rohlf, 1987). All statistical analyses were conducted using SPSS (Version 21) and Excel (2013).

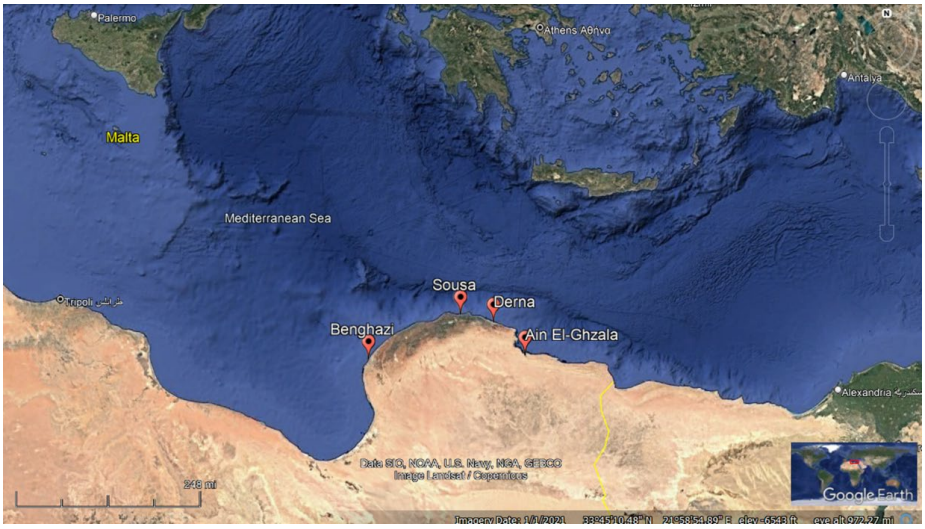

Figure 1. Map of study area along the eastern Libyan coast of the Mediterranean Sea

RESULTS

A total of 325 samples of thirteen species were collected from the eastern coast of Libya, with average lengths ranging from 13.75±0.270 in the *Boops boops* to 32.342±0.443 in the *Dicentrarchus labrax* and average weights ranging from 30.601±0.770 g to 371.884±17.486 g in the *Dicentrarchus labrax* and *Sardinella aurita*, respectively, as shown in Table 1. Two species of collected fish (*Siganus rivulatus* and *Pempheris rhomboidea*) are considered invasive, having entered the Mediterranean Sea through the Suez Canal. The length-weight relationship parameters were calculated as shown in Table 2. All relationships were statistically significant ($p<0.001$). The value of the coefficient of determination ranged from 0.52 in the *Scomber colias* to 0.99 in the *Chelidonichthys lucerne*, with the intercept (a) of the length-weight relationship ranging from 0.003 for the *Synodus saurus* to 0.135 for the *Siganus rivulatus*. Depending on the regression coefficient (t-test, CI95%), which ranged in the study fish from 2.182 (SE (b):0.259, CI95%:1.674-2.689) in the *Siganus rivulatus* to 3.328 (SE (b):0.320, CI95%:2.700-3.955) in *Chelon saliens.* The studied fish showed isometric growth (b=3), except for *Siganus rivulatus*, *Sparisoma cretense*, and *Sardinella aurita*, which showed negative allometric growth (b<3, $P<0.05$).

Table 1. Descriptive statistics for fish species collected from the eastern coast of Libya (N): Sample size, (TL): Total length, (TW): Total weight

Family	Species	N	TL (cm)	TW (g)	Region
Synodontidae	*Synodus saurus*	36	20.018±0.483	52.925±4.323	Benghazi Coast
Scorpaenidae	*Scorpaena scrofa*	9	23.800±0.987	229.575±24.980	Susa Coast
	Scorpaena notata	8	22.371±0.357	184.471±10.113	
Sciaenidae	*Sciaena umbra*	18	27.087±0.666	273.125±17.630	Derna Coast
Triglidae	*Chelidonichthys lucerna*	14	16.714±0.709	52.850±5.965	Ain El Ghazala Lagoon
Sparidae	*Boops boops*	35	13.75±0.270	32.500±1.583	Susa Coast
Siganidae	*Siganus rivulatus*	15	17.873±0.474	74.306±5.084	Ain El Ghazala Lagoon
Muglidae	*Chelon saliens*	20	22.445±0.402	114.525±7.193	Ain El Ghazala Lagoon
Pempheridae	*Pempheris rhomboidea*	25	15.010±0.271	51.471±2.417	Susa Coast
Scaridae	*Sparisoma cretense*	32	23.437±0.370	234.284±10.290	Susa Coast
Scombridae	*Scomber colias*	39	24.583±0.182	139.330±20.571	Benghazi Coast
Clupeidae	*Sardinella aurita*	53	16.290±0.134	30.601±0.770	Benghazi Coast
Moronidae	*Dicentrarchus labrax*	21	32.342±0.443	371.884±17.486	Benghazi Coast

Table 2. The length-weight relationships of 13 species of fish collected from the eastern coast of Libya (a: intercept, b: slope, SE: standard error of b, CI: confidence interval, r^2: determination coefficient)

Species	Regression parameters			CI95% of b	r^2	t-test	Growth type
	a	b	SE(b)			*p*-value	
Synodus saurus	0.003	3.298	0.175	2.955–3.641	0.91	0.107	Isometric
Scorpaena scrofa	0.039	2.721	0.197	2.334–3.107	0.95	0.199	Isometric
Scorpaena notate	0.012	3.086	0.200	2.694–3.478	0.97	0.680	Isometric
Sciaena umbra	0.054	2.578	0.260	2.068–3.087	0.87	0.124	Isometric
*Chelidonichthys lucerna**	0.006	3.150	0.121	2.912–3.387	0.99	0.238	Isometric
Boops boops	0.020	2.795	0.329	2.150–3.439	0.68	0.537	Isometric
Siganus rivulatus	0.135	2.182	0.259	1.6074–2.689	0.85	0.006	Allometry (-)
Chelon saliens	0.004	3.328	0.320	2.700–3.955	0.85	0.339	Isometric
Pempheris rhomboidea *	0.038	2.659	0.183	2.300–3.017	0.92	0.075	Isometric
*Sparisoma cretense**	0.096	2.468	0.227	2.023–2.912	0.80	0.025	Allometry (-)
Scomber colias	0.028	2.492	0.454	1.602–3.381	0.52	0.270	Isometric
Sardinella aurita	0.040	2.400	0.279	1.853–2.946	0.59	0.036	Allometry (-)
Dicentrarchus labrax	0.009	3.050	0.325	2.413–3.687	0.82	0.879	Isometric

*New data in Libyan waters.

DISCUSSION

The length–weight relationship offers important clues about fish growth patterns and overall condition (Ighwela et al., 2011). Variations in the b value reflect both biological characteristics and environmental influences on fish species, as this parameter indicates the general body shape. When b equals 3, it suggests that small and large individuals of a species exhibit similar body proportions and condition. However, a b value less than 3 indicates that larger individuals are either more elongated or that smaller ones were in better nutritional condition at the time of sampling (Froese, 2006). Differences in length-weight relationships among fish species can be attributed to various factors, including inherited body shape, physiological status, stages of reproductive development, stomach fullness, and seasonal variation (Schneider et al., 2000; De Giosa et al., 2014; Flura et al., 2015). In the present study, most species exhibited isometric growth patterns. Notable exceptions were *Siganus rivulatus* (Siganidae), *Sparisoma cretense* (Scaridae), and *Sardinella aurita* (Clupeidae), which showed negative allometric growth. In Greece, Kondylatos et al. (2024) recorded results that differed from our findings, with a positive allometric growth pattern in *Sparisoma cretense*, *Siganus rivulatus,* and *Synodus saurus* and a negative allometric growth in *Boops boops* and *Scorpaena scrofa,* in their study of 21 species from small-scale fisheries in Rhodes. In Egyptian waters off the coast of Alexandria, the growth patterns of *Sardinella aurita*, *Siganus rivulatus,* and *Boops boops* were isometric, while those of *Sparisoma cretense* were positive allometric growth (Ragheb, 2023).

In this study, *Chelidonichthys lucerna* was collected from Ain Ghazala Lagoon, a marine protected area designated in 2011. The species exhibits isometric growth (b=3.150, CI 95%: 2.912-3.387). Unlike previous studies from Italy (2.82), Portugal (2.668-2.93), Türkiye (3.01, CI95%:3.00-3.03), the Adriatic Sea (3.01, CI95%:3.00-3.03), and Spain (2.827, CI95%:2.707-2.948), where growth was negative allometric (Serena et al., 1998; Mendes et al., 2004; Olim and Borges, 2006; Vallisneri et al., 2010; Rodríguez-García et al., 2023), our findings align with Özdemir et al.'s (2019) b value of 2.987 (Table 3).

Pempheris rhomboidea, or Gassaetlla fish as we know it in Libya, is found in small groups in underwater caves. Locally, it has no economic value (Bazairi et al., 2013). The growth pattern in this study was isometric (b:2.659, CI95%:2.300-3.017). Kondylatos et al. (2024) reported that growth is negative in fish collected off Greece. On the other hand, the value of b ranged between 3.026 and 3.165 in Türkiye (Türker et al., 2020; Taskavak and Bilecenoglu, 2001); this value of b is higher than what we found.

Moutopoulos and Stergiou (2002) conducted a study on the length-weight relationship of 37 fish species in the Aegean Sea, four of which were included in our study. The b values for *S. aurita, S. scrofa*, *B. boops*, *S. cretense*, and *S. aurita* were 2.715, 2.999, 2.877, 3.311, and 2.804, respectively. It was closer in *B. boops* (b: 2.795). On the west coast of Portugal, the length-weight relationship of *B. boops* and *S. scrofa* was similar to our study with isometric growth, but *S. notata* had allometric growth (Mendes et al., 2004). The results of Mehanna and Farouk's (2021) study on the length-weight relationship indicated that the growth pattern is positive for *B. boops* (3.270). *S. aurita* (2.74) and *C. saliens* (2.929) exhibit negative allometric growth. The growth pattern for *D. labrax* (3.055), *S. saurus* (3.11), and *S. rivulatus* (2.984) is isometric, which differs from our results, except for *D. labrax*, *S. saurus*, and *S. aurita.* Previous research reports summarize the length-weight relationship in fish studied in various regions in Table 3. Many previous studies have reported that differences in locations, size of collected samples, sex, habitat, health status, diet, climate, temperature, salinity, and human activities, such as habitat change or degradation, pollution, and fishing pressure, cause differences in growth patterns for the same species (Moutopoulos and Stergiou 2002; Giacalone et al., 2010; Vieira et al., 2014; Kelly et al., 2017).

Table 3. Comparison of length-weight relationship parameters of the 13 species with previous studies. a: Intercept of the LWR; b: slope of the LWR; ES: standard error of b; CI95%: confidence interval; and r^2: determination coefficient.

Species	a	b	SEb	CI95%	r^2	Study area	Reference
	0.003	3.332	0.045	-	0.99	Azores/north-eastern Atlantic	Morato et al. (2001)
	0.020	2.715	0.136	-	0.95	Aegean Sea/Greece	Moutopoulos and Stergiou (2002)
S. saurus	0.005	3.117	-	2.890-3.344	0.95	Egypt (GFCM-GSA26)	Mehanna and Farouk (2021)
	0.007	3.013	-	-	0.95	Rhodes/Greece	Kondylatos et al. (2024)
	0.003	3.298	0.175	2.955-3.641	0.91	Benghazi coast/Libya	Current study
	0.012	3.124	-	2.858-3.389	0.96	Portuguese west coast	Mendes et al. (2004)
	0.016	2.999	0.075	-	0.98	Aegean Sea/Greece	Moutopoulos and Stergiou (2002)
S. scrofa	0.017	3.004	-	2.092-3.116	0.96	Izmir Bay/Aegean Sea of Türkiye	Bayhan et al. (2022)
	0.039	2.717	-	-	0.91	Rhodes/Greece	Kondylatos et al. (2024)
	0.015	3.071	-	-	0.95	Çanakkale region/Türkiye	Uğur and Oztekin (2024)
	0.039	2.721	0.197	2.334–3.107	0.95	Susa coast/Libya	Current study
	0.015	3.051	0.027	-	0.98	Azores/north-eastern Atlantic	Morato et al. (2001)
S. notata	0.013	3.147	-	3.025-3.269	0.97	Gulf of Cadiz/Spain	Rodríguez-García et al. (2023)
	0.005	3.447	-	3.185-3.710	0.85	Portuguese west coast	Mendes et al. (2004)
	0.012	3.086	0.200	2.694–3.478	0.97	Susa coast/Libya	Current study
	0.013	3.003	0.196	-	0.97	Southern Aegean Sea	Bilge et al. (2014)
S. umbra	0.005	3.25	0.032	-	0.97	Southeastern Black Sea /Ordu province, Türkiye	Aydın and Bengil (2020)
	0.007	3.203	-	3.157-3.248	0.98	Coast of Black Sea/Türkiye	Bodur et al. (2023)
	0.054	2.578	0.260	2.068–3.087	0.87	Derna Coast/Libya	Current study
	0.013	2.89	-	-	0.99	Italy, Tyrrhenian Sea	Serena et al. (1998)
	0.028	2.668	-	2.557-2.780	0.93	Portuguese west coast	Mendes et al. (2004)
	0.011	2.93	0.51	-	0.98	Portugal	Olim and Borges (2006)
C. lucerna	0.009	3.01	-	3.00-3.03	0.98	North-Middle Adriatic Sea	Vallisneri et al. (2010)
	0.010	2.987	0.043	2.891-3.072	0.98	Central Black Sea Coasts of Türkiye	Ozdemir et al. (2019)
	0.014	2.827	-	2.707-2.948	0.99	Gulf of Cadiz/Spain	Rodríguez-García et al. (2023)
	0.006	3.150	0.121	2.912-3.387	0.99	Ain El Ghazala Lagoon/Libya	Current study
	0.000	2.61	0.09	-	0.88	Central Aegean Sea, eastern Mediterranean	Kapiris and Klaoudatos (2011)
	0.014	2.877	0.081	-	0.91	Aegean Sea/Greece	Moutopoulos and Stergiou (2002)
	0.007	3.084	-	2.984-3.184	0.93	Portuguese west coast	Mendes et al. (2004)
B. boops	0.011	2.945	-	2.840-2.973	0.99	Alexandria/Egypt	Ragheb (2023)
	0.004	3.270	-	3.196-3.345	0.98	Egypt (GFCM-GSA26)	Mehanna and Farouk (2021)
	0.005	3.21	-	3.178-3.248	0.98	Gulf of Cadiz/Spain	Rodríguez-García et al. (2023)
	0.016	2.859	-	-	0.92	Rhodes/Greece	Kondylatos et al. (2024)
	0.020	2.795	0.329	2.150–3.439	0.68	Susa coast/Libya	Current study
	0.023	2.818	0.122	-	0.93	Libya	Shakman (2008)
	0.016	2.88	-	2.76-3.00	0.95	Antalya/Türkiye	Beğburs and Kebapçıoğlu (2013)
	0.009	3.079	-	2.894-3.294	0.98	Alexandria/Egypt	Ragheb (2023)
	0.015	2.90	-	-	0.93	Mediterranean Sea	Abdelhak et al. (2020)
S. rivulatus	0.011	3.034	-	-	0.94	Red Sea	
	0.009	3.097	0.255	2.550-3.644	0.91	Antalya Bay/Türkiye	Türker et al. (2020)
	0.011	2.984	-	2.915-3.054	0.97	Egypt (GFCM-GSA26)	Mehanna and Farouk (2021)
	0.009	3.105	-	-	0.90	Rhodes /Greece	Kondylatos et al. (2024)
	0.135	2.182	0.259	1.674–2.689	0.85	Ain El Ghazala Lagoon/Libya	Current study
	0.008	3.041	0.009	-	0.98	Mar Menor coastal lagoon (western Med. Sea)	Verdiell-Cubedo et al. (2006)
	0.006	3.043	0.057	2.99-3.09	0.99	Köyceğiz Lagoon in Türkiye	Reis and Ateş (2019)
C. saliens	0.012	2.929	-	2.901-2.957	0.89	Egypt (GFCM-GSA26)	Mehanna and Farouk (2021)
	0.012	2.856	-	2.634-3.077	0.78	Gorgan Bay/Southeast of the Caspian Sea	Kalteh (2023)
	0.007	2.989	0.003	-	0.97	Sea of Marmara/Türkiye	Şen et al. (2024)
	0.004	3.328	0.320	2.700–3.955	0.85	Ain El Ghazala Lagoon/Libya	Current study
	0.000	3.026	0.034	-	0.95	Eastern Mediterranean/Türkiye	Taskavak and Bilecenoglu (2001)
P. rhomboidea	0.011	3.165	0.301	2.509-3.80	0.90	Antalya Bay	Türker et al. (2020)
	0.020	2.877	-	-	0.94	Rhodes/Greece	Kondylatos et al. (2024)
	0.038	2.659	0.183	2.300–3.017	0.92	Susa coast/Libya	Current study
	0.010	3.129	0.010	-	0.99	Azores/north-eastern Atlantic	Morato et al. (2001)
S. cretense	0.005	3.311	0.102	-	0.98	Aegean Sea/Greece	Moutopoulos and Stergiou (2002)
	0.011	3.084	-	-	0.94	Rhodes/Greece	Kondylatos et al. (2024)
	0.096	2.468	0.227	2.023-2.912	0.80	Susa coast/Libya	Current study
	0.005	3.223	-	-	0.96	Adriatic Sea	Cikeš Keč and Zorica (2012)
	0.002	3.223	-	-	0.96	Mauritania (NW Africa)	Jurado-Ruzafa et al. (2017)
	0.009	2.948	-	2.604-3.292	0.85	Gulf of Cadiz/Spain	Rodríguez-García et al. (2023)
S. colias	0.002	3.368	-	-	0.98	Coast of Ghana	Kassah (2020)
	0.001	3.45	-	-	0.97	Morocco	Techetach et al. (2021)
	0.000	3.101	-	-	0.97	South of Sicily (Central Mediterranean Sea)	Falsone et al. (2022)
	0.028	2.492	0.454	1.602-3.381	0.52	Benghazi coast/ Libya	Current study
	0.015	2.804	0.280	-	0.86	Aegean Sea /Greece	Moutopoulos and Stergiou (2002)
	0.004	3.12	-	-	0.79	Adriatic Sea/ Croatia	Sinovcic et al. (2004)
	0.017	2.689	-	-	0.99	Alexandria/Egypt	Akel (2009)
S. aurita	0.005	3.09	-	-	0.98	Algerian eastern coasts	Dahel et al. (2016)
	0.014	2.745	-	2.724-2.767	0.94	Egypt (GFCM-GSA26)	Mehanna and Farouk (2021)
	0.01	3.07	-	-	0.96	Kakum Estuary/Ghana	Baidoo et al. (2022)
	0.040	2.40	0.279	1.853–2.946	0.59	Benghazi coast/Libya	Current study
	0.008	3.095	-	3.040-3.151	0.99	Gulf of Cádiz Beaches (Southwest Iber. Pen.)	Rodríguez-García et al. (2024)
D. labrax	0.007	3.055	-	2.971-3.139	0.98	Egypt (GFCM-GSA26)	Mehanna and Farouk (2021)
	0.021	2.815	-	2.745-2.885	0.95	Southern Coast of Black Sea	Karadurmuş and Aydın (2023)
	0.009	3.050	0.325	2.413–3.687	0.82	Benghazi coast/ Libya	Current study

CONCLUSION

This study presents the first length-weight relationship data for several marine fish species in Libyan waters, notably *Chelidonichthys lucerna, Pempheris rhomboidea,* and *Sparisoma cretense*. While most species exhibited isometric growth, a few demonstrated negative allometric patterns. These findings contribute valuable baseline information for fisheries assessment and ecological research in the region.

ACKNOWLEDGEMENTS

We would like to thank the faculty members of the department of marine biology for their valuable support in completing this research.

AUTHORSHIP CONTRIBUTIONS

All authors contributed to collecting samples performing statistical analysis, writing the manuscript, and contributing to the language review.

CONFLICT OF INTEREST

The authors declare that there are no known financial or personal conflicts that could influence their research.

ETHICS APPROVAL

No specific ethical approval was required for this study.

DECLARATION OF AI USE

The authors used QuillBot Premium solely for grammatical correction of the manuscript (grammar checker). All scientific content (research ideas, the introduction, results, and discussion presented in this manuscript) is the work of the authors.

DATA AVAILABILITY

For questions regarding the datasets, the corresponding author should be contacted.

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