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LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR ESTIMATION OF THE COMMON SMOOTH-HOUND SHARK, *Mustelus mustelus* OFF THE SOUTHWESTERN COAST OF NIGERIA

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Abstract
Information on the length-weight relationship (LWR) and condition factor (K) of the common smooth-hound shark, Mustelus mustelus collected from fish landing sites located in the coastal areas of Lagos and Ondo States, Nigeria were provided in this study. The sharks were collected from March 2018 to September 2021. In total, 1,018 sharks were measured to the nearest centimeter with a tape measure for their total length while total weight was measured to the nearest gram on a digital balance. The linear regression equation for males, females and combined sexes using log-transformed length-weight relationship revealed a positive allometric growth (b>3) for the females and combined sexes while the males showed negative allometric growth reflecting a comparatively slower growth rate in total weight than in total length throughout the species ontogeny. The analysis of variance indicated a significant difference (P< 0.05) in the length and weight of the female M. mustelus sharks in both sampling locations. The newborn (TL < 50cm), medium (90cm≤TL<110cm) and large (TL≥110) size classes recorded a mean condition factor value of 0.4 while the young (50cm≤TL<70cm) and small (70cm≤TL<90cm) size classes had mean condition factor value of 0.3. The lowest K was recorded in October 2018; (0.33) while the highest K value was in January 2019; (0.43). The information obtained from this study would contribute greatly to the efforts to enrich the database on shark fisheries in Nigeria to achieve a better management of this critical species.

Key Words: *Mustelus mustelus, Length-Weight Relationship, Condition factor, Ecology, Nigeria*

Introduction

Elasmobranchs (sharks and rays) are one of world's most threatened vertebrate groups (Bräutigam *et al*., 2015 and Dulvy *et al.,* 2021a, b). They are amongst the marine megafauna that are highly susceptible to fishing pressures Dulvy *et al.* (2014) with capture fisheries largely contributing to their non-natural mortalities (Bonfil, 2000 and Dulvy *et al*., 2000, 2014) and late attainment of sexual maturity, slow growth rates, long

generation times and low reproductive attributing for their natural mortality (Dulvy *et al.,* 2017).

The common smooth-hound, *Mustelus mustelus* Linnaeus (1758) (Carcharhiniformes: Triakidae), is generally a small-sized shark with total length varying between 100cm to about 200cm (Reiner, 1996 and Sanches, 1991). It is a demersal shark with depth preference of about 350 m, although, captures and observations between 5 and 100m depth has been reported (Capapé *et al*., 2006). *M. mustelus* is distributed from western Africa to southern Africa, and down to the southwestern coasts of the Indian Ocean; it has also been observed in the Mediterranean Sea and across several oceanic eastern-Atlantic archipelagos: São Tomé and Príncipe, , Cape Verde, Canary Islands and Madeira (Compagno *et al.,* 2005).

To attain sustainable fisheries, it is important to monitor the status and population structure of the stock. In fisheries studies, Length–weight relationships (LWRs) are usually done to compare growth differences between the same species or different species in different habitats or regions (Gonçalves *et al.*, 1997; Calik and Saglam, 2017). The length–weight relationship (LWR) is a mathematic model that converts length into weight, and weight into length, as well as the estimation of biomass from the length frequency distribution. It is employed to develop stock assessment models (Dieb-Magalhães *et al.,* 2015; Baitha *et al*., 2018; Oliveira *et al*., 2020). LWR can be modified to produce life history data and population dynamics of a stock (Erzini, 1994; Petrakis and Stergiou, 1995; Kohler *et al.,* 1995; Haimovici and Velasco, 2000; Morato *et al.,* 2001; Borges *et al.,* 2003; Mendes *et al.,* 2004; Yeşilçiçek *et al.,* 2015).

LWRs differ among fish species, and it depends largely on its inherited body shape and other physiological factors such as spawning and maturity Schneider *et al*., (2000), changes could be seen over seasons and days (De Giosa *et al*., 2014). Furthermore, the growth process can differ among same species dwelling in various habitats and geographical areas, predisposed to several biotic and abiotic factors.

The condition factor is another biometric tool derived from the LWRs (Bannister, 1976). The condition factor is a measure of the relative robustness, or degree of well-being, of a fish. It primarily reflects the state of sexual maturity and degree of nourishment in a specific environment (Yilmaz *et al*., 2012; Mensah, 2015). Certain factors such as sex, gonad development, season, degree of fitness, suitability of the environment and availability of feeds can affect the condition factor of a fish (Khallaf *et al.,* 2003).

This study serves as a baseline study on *M. mustelus* off the Southwest Coast of Nigeria to 1) estimate its LWR 2) assess its condition factor by sex and size. The findings of this study will give fisheries managers a better understanding of this species to keep track of their growth and provide data on their stock status and populational structure.

Materials and Methods

The Study Area

One thousand and eighteen samples of *Mustelus mustelus* were collected randomly at six landing sites in the coastal regions of Lagos and Ondo including two fish markets in Lagos state (Liverpool and

Ijora Olopa Markets) between March 2018 and September 2021. The landing sites were located between 5°57′N–6°27′N and 3°23′E–4°54′E. The Guinea, Equatorial, Benguella and the Equatorial counter currents are the ocean currents that are dominant in this study sites (Akanmu and Onyema, 2020). These currents, which are associated with intense coastal upwelling and tropical sea surface temperatures, feed the westward North and South Equatorial Currents, respectively (Longhurst *et al.,* 2005).

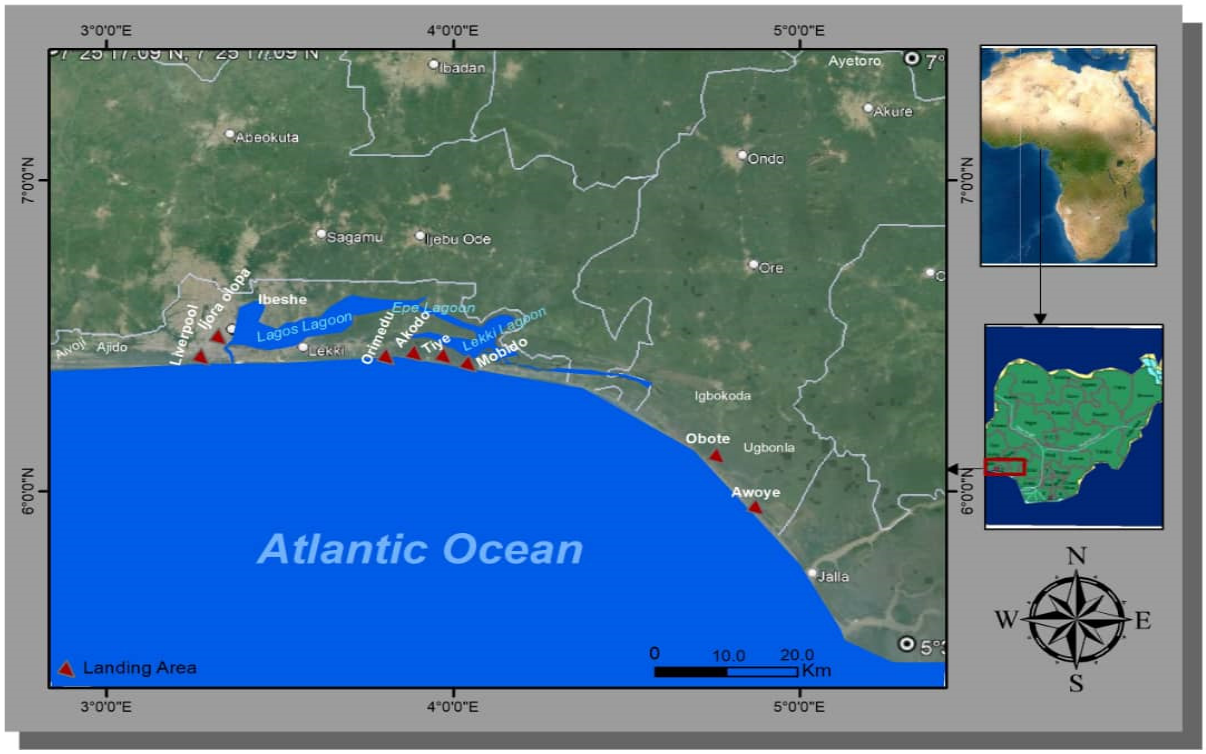

Fig. 1: Map of the study area showing the location of fish landing sites off the Southwestern Coast of Nigeria

Sampling Collection

Measurements of some large sharks were taken *in-situ* due to the challenge of transporting to the Laboratory while the smaller sized sharks were preserved in ice until returned to the laboratory. Length and weight measurements were taken after each specimen was properly thawed. Total Length (TL) was measured to the nearest centimeter with a tape measure; TL-distance from the tip of the snout to the end of the upper caudal lobe while the Total Weight (TW) was measured to the nearest gram on a digital balance.

Length-Weight Relationships

The length-weight relationship for this study was determined for females, males and the combination of both sexes, using a modified linear regression formula Tıraşın (1993) to determine the relationship between characters.

(TW) = a (TL)b

and a natural logarithm-transformed into a straight-line (Parsons, 1978) to determine

the cubic relationship between length (L) and weight (W).

$\log W = \log a + b \log L$

where, TW is total weight (g), TL is total length (cm), W is the body weight (measured in grams), L is the Total Length (measured in centimetres), log is the natural (Euler's) logarithm and a, and b are the regression constant (intercept) and the regression coefficient (slope) respectively. To establish LWRs with respect to periodic variations that can affect b Zargar *et al.,* (2012), fish were grouped according to the period when they were caught (Dry Season: November to May, Wet season: April to November).

Condition Factor

Length and weight data were used to determine the condition factor, K according to Bannister (1976):

$K = 100W/ L3$

where W is the body weight (measured in grams), L is the Total Length (measured in centimetres). Sizes were grouped based on length; newborn $TL < 50$, young $50 \leq TL < 70$, small $70 \leq TL < 90$, medium $90 \leq TL < 110$ and large $TL \geq 110$ cm Saidi *et al.,* (2009) to determine the condition factor based on size and sex.

Data Analysis

Relationship between length and weight of the fish was examined by simple linear regression analysis. The nonparametric Kruskal-Wallis's test (One-way Analysis of Variance) was conducted to perform comparisons of the length and weight of the fish across location. The minimum significant level for the relevant test was set at $p < 0.05$.

Results

Length-Weight Relationship

LWRs are very useful to provide a baseline for conservation strategies, particularly in species susceptible to overexploitation as elasmobranchs. The longest, smallest length (142cm, 39cm) and the highest, lowest weight (11600g, 350g) data obtained from this study indicated a diverse range of sizes obtained across the landing sites. The length data are in the same range when compared with sharks from Saros Bay (North Aegean Sea) Ismen *et al.* (2009); longest, smallest length (152.2cm, 46.8cm).

Table 1: Sizes, parameters of length-weight relationship (a and b) and the coefficient of determination (r^2) of *Mustelus mustelus* sharks off the Southwestern Coast of Nigeria

						Total length(cm)			Total weight (g)		
Sex	A	95% CI of a	B	95% CI of b	r²	Min.	Max.	Mean	Min.	Max.	Mean
Combined sexes	0.0022	(-2.710,2.610)	3.11	(3.084,3.137)	0.98	39	142	85.09	350	11600	3178
Females	0.0013	(-2.953,2.816)	3.23	(3.194,3.263)	0.99	47	142	98.69	400	11600	4904
Males	0.0048	(-2.386,2.212)	2.92	(2.866,2.960)	0.97	39	133	74.31	350	9700	1810

The logarithmic transformation of combined sex, males, and females *M. mustelus* length-weight relationships are illustrated in Fig 2(A, B, and C) respectively and are represented by the following regression equations:
Combined sex: log W = 2.7 + 3.11 Log l (r^2 = 0.98, n = 1,018); Fig. 16A
Female: log W = 2.89 + 3.23 log L (r^2 = 0.99, n=450); Fig 16C
Male: log W = 2. 3 + 2.92 log L (r^2 = 0.97, n = 568); Fig. 16B
Monthly logarithmic transformations of a, b, and r^2 values were also calculated. (Table 2).

Table 2: Monthly logarithmic transformation of LWR of *Mustelus mustelus* sharks off the Southwestern Coast of Nigeria

Months	r^2	A	B
2018 March	0.99	0.0019	3.1297
April	0.98	0.0100	3.2760
May	0.97	0.0019	3.1189
June	0.98	0.0021	3.1220
July	0.98	0.0012	3.2540
August	0.99	0.0038	2.9667
September	0.99	0.0014	3.2073
October	0.97	0.0128	2.6707
November	0.96	0.0014	3.2193
December	0.99	0.0017	3.1941
2019 January	0.93	0.2969	2.5660
February	0.98	0.0007	3.3696
March	0.98	0.0093	2.7938
April	0.99	0.0018	3.1688
May	0.98	0.0020	3.1277
June	0.98	0.0031	3.0375
July	0.98	0.0032	3.0219
August	0.98	0.0021	3.1130
September	0.98	0.0026	3.0814
October	0.99	0.0013	3.2377
November	0.99	0.0024	3.0822
December	0.96	0.0073	2.8392
2020 January	0.97	0.0012	3.2491
February	1.00	0.0010	3.2795
July	0.99	0.0023	3.1018
August	0.98	0.0022	3.1136
September	0.97	0.0041	2.9694
October	0.98	0.0029	3.0371
November	0.97	0.0026	3.0651
December	0.97	0.0041	2.9831
2021 January	0.99	0.0016	3.1660
February	0.97	0.0021	3.1208
March	0.99	0.0007	3.3481
April	0.99	0.0017	3.1587
May	0.99	0.0029	3.2385
June	0.98	0.0031	3.0332
July	0.99	0.0017	3.1659
August	0.99	0.0031	3.0333
September	0.99	0.0019	3.1355

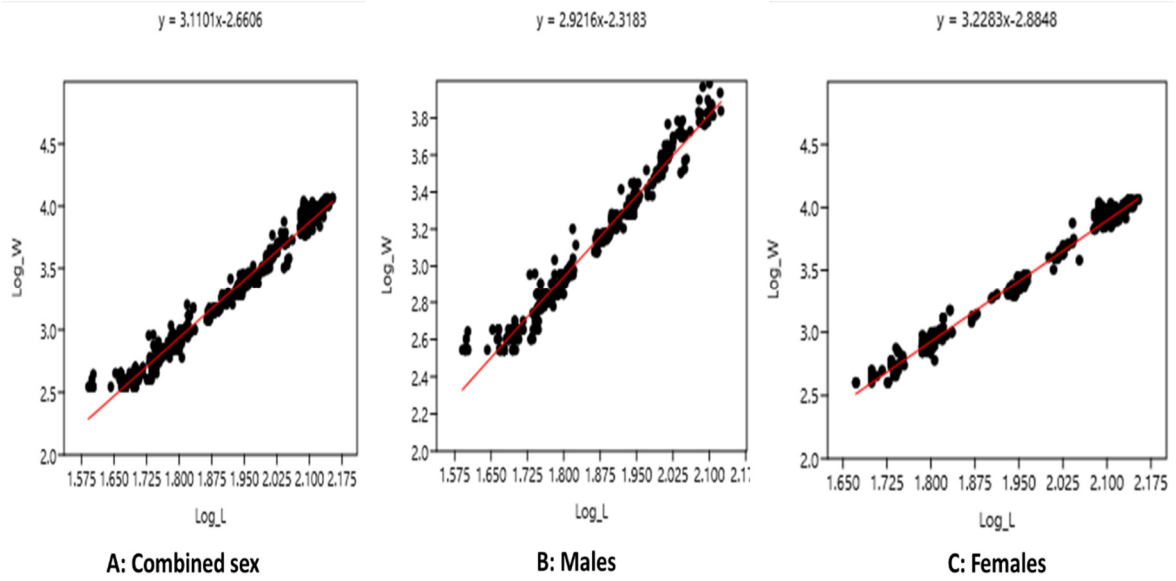

Fig. 2: Length-weight relationship of *Mustelus mustelus* sharks off the Southwestern Coast of Nigeria
: (A) combined sexes; (B) males; (C) females where log is the natural (Euler's) logarithm, W = Total weight and L = Total length

Table 3: The mean weight and length of the *Mustelus mustelus* sharks off. the Southwestern Coast of Nigeria.

		Sex	Mean ± S. E	Minimum	Maximum
WEIGHT	Ondo	Female	4620.26 ± 273.06[b]	400	11600
		Male	1810.83 ± 109.22[a]	350	10600
	Lagos	Male	1646.61 ± 106.64[a]	46.5	9300
		Female	4336.02 ± 261.31[b]	53.3	11600
LENGTH	Ondo	Female	96.92 ± 2.23[b]	47	142.4
		Male	74.10 ± 1.38[a]	39	134.2
	Lagos	Male	73.64 ± 1.31[a]	37.6	133
		Female	98.66 ± 1.98[b]	44	142.4

Alphabets with similar letter "a" indicates no significant differences (P>0.05)

The analysis of variance showed that there were significant differences (P<0.05) in the length and weight of the female *M. mustelus* sharks across both locations off the Southwestern Coast of Nigeria.

Condition Factor

The condition factor (K) ranged from 0.2-0.7, 0.3-0.7, and 0.2-0.6 for combined sexes, males, and females respectively. The mean condition factors of *M. mustelus* recorded was 0.4 across all the sex variation. Condition factor also varied with time though it was not seasonal. Monthly mean K was less than one throughout the study period (Fig 3).

The variations in condition factor (K) by size and sex of *M. mustelus* sharks off

the Southwest Coast, Nigeria are illustrated in Table 3. For each size class, the mean condition factor has the same value for both the combined sex, males, and females. The newborn, medium and large size classes recorded mean condition factor value of 0.4 while the young and small size classes had mean condition factor value of 0.3 across all sex.

Table 4: Condition factor (K) by sex and size of *Mustelus mustelus* sharks. off the Southwestern Coast of Nigeria

Sex	Females				Males				Combined Sex			
Size Classes (cm)	N	Mean TL (cm)	Mean TW(g)	Mean K	N	Mean TL (cm)	Mean TW (g)	Mean K	N	Mean TL (cm)	Mean TW (g)	Mean K
Newborn (TL < 50)	4	47	400	0.4	70	46.3	388.43	0.4	74	46.37	389.05	0.4
Young (50≤TL<70)	135	59.4	730.6	0.3	212	59.12	712.93	0.3	347	59.22	719.8	0.3
Small (70≤TL<90)	64	86	2104	0.3	163	81.2	1796	0.3	227	82.52	1883	0.3
Medium (90≤TL<110)	42	99.4	3597	0.4	77	100	3583	0.4	119	99.8	3587	0.4
Large (TL≥110)	205	129.4	8883	0.4	46	119.7	6114	0.4	251	127.6	8375	0.4
Total	450				568				1018			

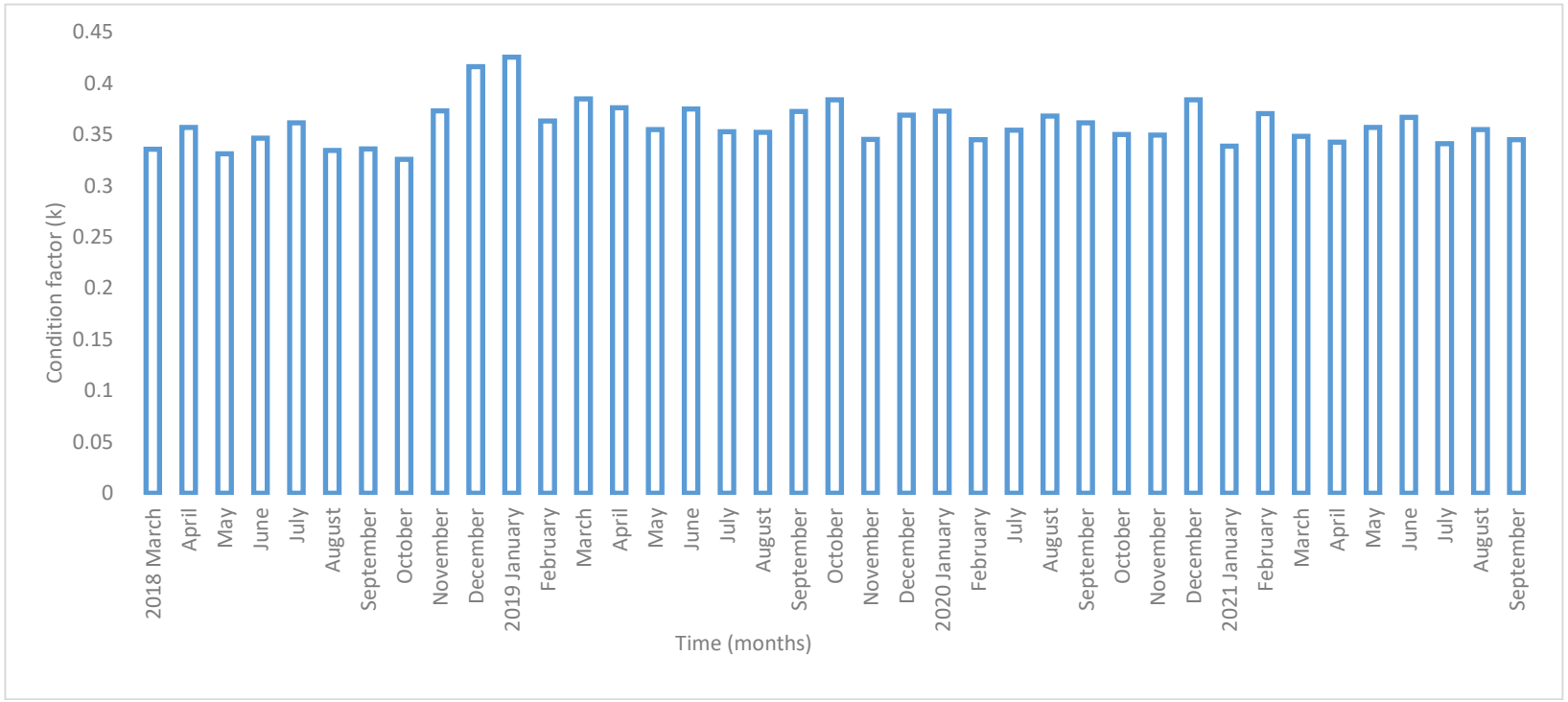

Fig. 3: Monthly changes in mean condition factor of *Mustelus mustelus* sharks off. the Southwestern Coast of Nigeria

Discussion

LWRs are useful tools in providing baseline data for conservation strategies, more importantly in species susceptible to overexploitation as elasmobranchs. The longest, smallest length (142cm, 39cm) and the highest, lowest weight (11600g, 350g) data obtained from this study indicated a diverse range of sizes obtained at the landing sites. The length data are in the same range when compared with sharks from Saros Bay (North Aegean Sea) Ismen *et al.* (2009); longest, smallest length (152.2cm, 46.8cm). The functional regression b values for this study ranged from 2.9131 – 3.2284 with females and the combined data having b values greater than 3, hence, exhibiting a positive allometric growth. Only the males of *Mustelus mustelus* was slightly lower than the ideal, indicating a tendency towards slightly negative allometric growth (b <3) which implies that it gained length faster than weight Ajibare *et al*. (2020) while the females did better in terms of fatness and robustness. This has been reported by Pasquino *et al*. (2016), Ismen *et al.* (2009), Filiz and Mater (2002) where it was observed that elasmobranch females commonly exhibit higher weights than males with these differences translated to the LWR parameters such as the higher values of b. The expected range of 2.5 < b > 3.5 by Froese, (2006) is confirmed in this study indicating normal growth dimensions and/or healthy populations. As can be seen in Table 4, b values identified by other authors of the same species in various locations ranged from 2.758 – 3.392 which is in close range to the values obtained in this study. The differences in b values could be due to factors such as differences in water temperature, differences in the numbers of specimen examined, food availability (Froese, 2006 and Kabasakal, 2022), suitability of habitat Nieto-Navarro *et al.,* (2010) as well as length ranges of the specimens captured, sex and gonad maturity (Kuriakose, 2017).

Table 5: Length–weight relationship parameters of *Mustelus mustelus* species identified by other authors in different regions

Sex	N	Min.(L)	Max.(L)	Min.(W)	Max.(W)	LWR	Area	Author
Male	46	46.8	148.3	390	10270	$W=0.0036L^{2.964}$	Saros Bay, Agean Sea	Ismen *et al.*, 2009
Female	24	49	152.2	382	14431	$W=0.0025L^{3.058}$	Saros Bay, Agean Sea	Ismen *et al.*, 2009
Combined	70	46.8	152.2	382	14431	$W=0.0034L^{2.979}$	Saros Bay, Agean Sea	Ismen *et al.,* 2009
Unsexed	16	38	75	-	-	$W=0.0062L^{2.758}$	Eastern Adriatic, Croatia	Dulac and Kraljeric, 1996
Combined	35	38.3	97.5	-	-	$W=0.0011L^{3.250}$	North Aegean Sea, Turkey	Filiz and Bilge, 2004
Male	14	38.3	97.5	116.37	1988	$W=0.0006L^{3.392}$	North Aegean Sea, Turkey	Filiz and Mater, 2002
Female	10	44	97.5	200	3170	$W=0.0008L^{3.307}$	North Aegean Sea, Turkey	Filiz and Mater, 2002
Combined	24	38.3	97.5	116.37	3170	$W=0.0062L^{2.758}$	North Aegean Sea, Turkey	Filiz and Mater, 2002
Male	2	82.4	89.8	1670.2	2337.9	-	Gökçeada Island, North Agean Sea	Yigin and Cabbar, 2021
Combined	3	66.9	89.8	808.8	2337.9	-	Gökçeada Island, North agean sea.	Yigin and Cabbar, 2021.

For many species, a higher r^2 value (> 0.95) reflects that a broad range of sizes and high population of samples were well represented in the research. In studies r^2 is < 0.95 a small number, a narrow size range of samples or an intrapopulation variation is indicated (Silva-Junior *et al.,* 2011). The present results were comparable to the respective r^2 values of 0.987, 0.991 and 0.988 for male, females, and combined sexes for *Mustelus mustelus* from Saros Bay, North Aegean Sea (Ismen *et al.,* 2009).

Lowest K value was in October 2018; 0.33 (rainy season) while the highest value was in January 2019; 0.43 (dry season). Sharks may have a better condition factor in the dry season due to reduction in their metabolic rate. The K values from this study was slightly higher than that described by Raouf *et al*., (2020) study of *M. mustelus* species from the Northern Tunisian Coasts, Mediterranean Sea (Females (0.3±0.02), combined sex (0.29±0.03)); Ozcan and Basusta (2018) at Gulf of Iskendurun, Northeastern Mediterranean Sea (highest K, 0.35 and lowest K, 0.25). Condition factor value < 1 for *mustelus mustelus* sharks might indicate an energetically efficient nature that allows them to maximize their oxygen consumption while minimizing their metabolic output. This study would provide a more comprehensive report on the length-weight relationship and conditions of this species. The estimated parameters should be applied to the species within the specific length ranges analysed.

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