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Length-Weight Relationships and Condition Factors of Bony Fishes Inhabiting the Southern East Mediterranean Sea, Bardawil Lagoon, Egypt

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ABSTRACT

The present study was designed to list the species of bony fish in Bardawil Lagoon and document their length-weight relationships (LWRs) and the condition factor (K) during the heavy using small trawling period (Kalsa net). The catch in the present work, identified to species level, consisted of 20 species, 14 of which were bony fish belonging to eight families. In total, 2072 specimens (weighing 250 Kg) of bony fish were collected and investigated. The determination coefficient (R^2) of LWRs ranged from 0.929 to 0.984, indicating strong relationships. In general, the ***b***-value of LWRs for the investigated species ranged from 2.84 to 3.42. Based on the results of the t-test, b-values in the present study revealed that nine species showed isometric growth and the remaining were allometric. The average values of K were 0.92, 0.88, and 1.033 for autumn, spring, and summer, respectively. Moreover, the values of the relative condition factors ranged from 0.97 to 1.03. Results showed that Bardawil Lagoon has a good environmental condition for better fish growth. The data from the present study can be valuable as a reference for the management and sustainability of these species in Bardawil Lagoon and the Mediterranean basin.

INTRODUCTION

The lagoons are among the most productive aquatic ecosystems which for thousands of years have been exploited by humans **(Lasserre, 1979)**. This is true for the Bardawil Lagoon in the eastern Mediterranean. It is considered one of the most important fish-producing lagoons along the northern coast of Egypt. According to **GAFRD (2022)**, Bardawil Lagoon has produced an average annual catch of about 3500 MT in the last 10 years.

Before the period of study (2010th), domination of crustacean species was remarkable due to the dredging of inlets led to the appearance of the small trawling (*kalsa* net) **(Khalil & Mehanna, 2006)**. Many changes had occurred to the lagoon fauna and enhanced the availability of food items for fish **(Anonyms, 2012)**.

The optimal exploitation of fish stocks requires estimating the population size of this stock, and this can only be done by knowing the length-weight relationship (LWR) for each individual body in the population. Data from LWRs help in predicting the required weight and estimating the yield from the length. In addition, it is useful for monitoring the state of a population's health **(Cone, 1989; Dulčić & Kraljević, 1996; Garcia *et al*., 1998; Ecoutin *et al*., 2005)**.

The condition factor (K) is an indicator of the general condition of the fish as it reflects the physical and biological conditions and fluctuations through the interaction between feeding conditions, parasitic infections and physiological factors **(Le Cren, 1951)**. The condition factor (K) was used for understanding the changes in weight for length assuming that the length-weight relationship obeys the cube law (**Kurup & Samuel, 1987)**

The relative condition factor (K_n) is of great importance in fishery assessment studies since it provides information about the growth of the fish, its general well-being, fitness in a marine habitat, or the state of development of the gonad. The study on the relative condition factor (K_n) can be used to compare the plumpness of fish and hence permitting a fish culturist to compare the weight of fish to a standard calculated weight to determine if the fish are in better or poorer condition than the standard. The relative condition factor can also be used to compare general well-being and fitness. In general fitness for fish species is assumed when (K_n) values are equal to or close to 1 **(Thomas, 1969; Kurup & Samuel, 1987; Jisr *et al*., 2018)**.

Studies have been conducted on the species under study in Bardawil Lagoon and worldwide, e.g. **El-Ganainy *et al*. (2002)**, **Bariche (2006)**, **Mehanna (2006a, b)**, **El-Far (2008)**, **Salem *et al*. (2010)**, **Mehanna and Salem (2012)**, **Sümer (2012)**, **Mehanna and Hegazi (2013)**, **Acarli *et al*. (2014)**, **Castaldelli *et al*. (2014)**, **Boulenger *et al*. (2015)**, **Gabr (2015)**, **Hagras (2015)**, **Desouky (2016)**, **Mohamed (2016)**, **Mohammed *et al*. (2016)**, **Belhassan *et al*. (2017)**, **El-Drawany (2017a, b), Kassem (2017)**, **Abdalhamid *et al*. (2018), El-Aiatt and Shalloof (2018), Al-Zahaby *et al*. (2018), Mehanna *et al*. (2018)**, **Ontomwa *et al*. (2018)**, **El-Aiatt and Shalloof (2019)**, **El-Aiatt *et al*. (2019)**, **Mehanna *et al*. (2019a, b)**, **Philips (2019)**, **Reis and Ateş (2019)**, **Abdelhak *et al*. (2020)**, **İhsanoğlu *et al*. (2020)**, **El-Bokhty and Amin (2020)**, **El-Mor *et al*. (2020)**, **Reis (2020)**, **Innal (2021)**, **Mehanna and Farouk (2021)**, **Mrizek *et al*. (2021)**, **El-Aiatt *et al*. (2022)**, **El-Drawany *et al*. (2022)** and **Çiloğlu (2023)**.

The present study aimed to document the data on length-weight relationships, condition factors, and relative condition factors of some bony fishes to evaluate the biological status and fitness of these species. These data may act as a valuable reference for the management and sustainability of these species in the Mediterranean area.

MATERIALS AND METHODS

Area of study

Bardawil Lagoon extends along the northern coast of Sinai from 32º 40˴ to 33 º 30˴ E and from 31 º 03˴ to 31º 14˴ N. The lagoon covers an area of 650km², with a maximum length of 90km and a maximum width of 22km. It is characterized with its shallow water, reaching up to 3m in depth. Three inlets connect the lagoon with the Mediterranean Sea, namely Boughaze I, II and Zaranik (Fig. 1).

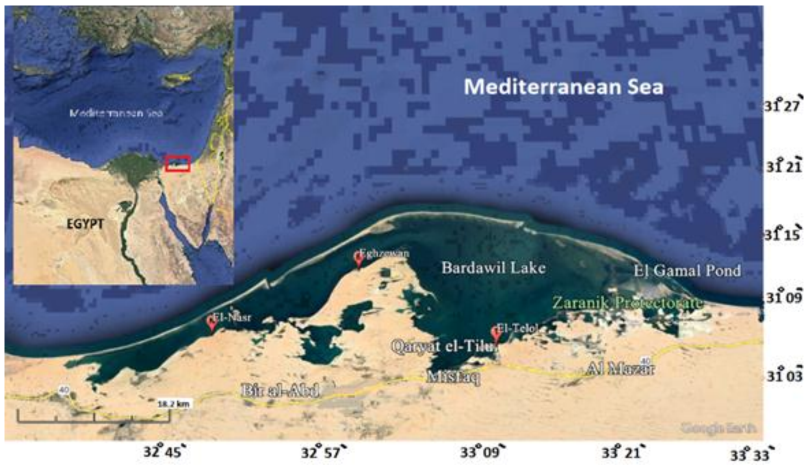


Fig. 1. Map of Bardawil Lagoon (area of study) and its location in Egypt

Data and samples collection

Sixteen field surveys were conducted at four landing sites (El-Nasr, El-Negila, Eghzewan and El-Telol) in Bardawil Lagoon in the early morning during the 2012 fishing season. Fish samples were collected from the commercial catch and then identified to species level. For each specimen, the total length (L) in cm and total weight (W) in g were recorded.

Data analysis

The length-weight relationship (LWR) of fish is usually expressed according to the equation assessed in the study of **Le-Cren (1951)**: $W= a\ L^b$, where (W) is the body weight of the fish in g and (L) is the total length in cm, while (a) and (b) are constants. The parameters (a) and (b) were estimated by following the linear regression of the transformed equation**:** Log (W) = Log (a) + b Log (L).

The values of the exponent (b) provide information on fish growth. Ideal value of b = 3, which represents isometric growth. When $b< 3$, then fish is slimmer with increasing length, and growth will be negative allometric. When $b > 3$, fish becomes heavier, showing positive allometric growth and reflecting optimum conditions for growth. The null hypothesis of the isometric growth (H_0: b =3) was tested by *t*–test, using the statistic: $t_s= (b-3)/S_b$**,** where t_s is the student's *t*-test; b is the slope, and S_b is the standard error of the slope for $\alpha=0.05$ for testing significant differences among slopes (b) between two regressions for the same species (**Zar, 1984; Sokal & Rohlf, 1987; Morey *et al*., 2003**).

The condition factor (K) was calculated by **Fulton (1902)**. $K=100W/L^3$, where (W) is fish body weight in g, and (L) is the stotal fish length in cm. On the other hand, the relative condition factor (K_n) was calculated according to **Le Cren (1951)** using the following equation: $K_n = W_0/W_c$, where (W_0) is the observed weight, and (W_c) is the calculated weight. The good growth condition of the fish is deduced when $K_n \geq 1$, while the organism is in poor growth condition compared to an average individual with the same length when $K_n < 1$ **(Jisr *et al*., 2018)**.

RESULTS

In the present study, the fishing activity in Bardawil Lagoon extended for three seasons: autumn, spring and summer, while winter was the closed season. From the lagoon commercial catch, a total of 2072 bony fish from 14 species belonging to eight families were investigated. Their families were family Mugilidae (*Chelon auratus*, *Chelon labrosus*, *Chelon ramada*, *Mugil cephalus* and *Planiliza carinata*), family Soleaidae (*Solea aegyptiaca* and *Solea solea*), family Anguillidae (*Anguilla anguilla*), family Moronidae (*Dicentrarchus labrax* and *D. punctatus*), family Hemiramphidae (*Hemiramphus far*), family Sparidae (*Sparus aurata*), family Siganidae (*Siganus rivulatus*) and family Terapontidae (*Terapon puta*). Seven species were recorded during the fishing season throughout the whole study period. They were *C. auratus*, *C. ramada*, *M. cephalus*, *S. aegyptiaca*, *S. solea*, *D. labrax* and *S. aurata*. On the other hand, *H. far*, *S. rivulatus* and *T. puta* were registered during autumn and spring. Moreover, *C. labrosus* and *A. anguilla* appeared in catch during spring, while *P. carinata* was recorded during autumn. It was noticed that only one specimen of *D. punctatus* was found during spring.

Length-weight relationships

The total number of each species ranged from 16 (*C. labrosus*) to 485 (*M. cephalus*) specimens. Moreover, in all samples, the average total length ranged from 12.8 (*T. puta*) to 39.9 cm (*A. anguilla*), and the average total body weight ranged from 27.7 to 226.6g for *T. puta* and *M. cephalus*, respectively. The estimated length-weight equation had strong relationships; the determination coefficient (R^2) ranged from 0.929 (for *P. carinata*) to 0.984 (for *S. aurata*). Moreover, the obtained values of growth exponent *b* for the 13 species were close to three; they ranged from 2.84 (for *C. ramada*) to 3.42 (for *H. far*).

Based on the results of the *t*-test of *b*-values, it was revealed that four species showed an allometric growth ($P < 0.05$), two of which had positive allometric growth (*H. far* and *S. aegyptiaca*), while the other two species showed a negative allometric growth (*C. ramada* and *T. puta*). Whereas, the nine remaining species recorded an isometric growth ($P > 0.05$).

Table (1) shows the descriptive statistics of each investigated species: number of specimens, total length (mean with standard deviation, range), total weight (mean with standard deviation, range), parameters of the length-weight relationship, *b*-value *t*-test (standard error, t-calculated, p-value, confidence limit) and type of growth.

Table 1. Length- weight relationships of 13 fish species from Bardawil Lagoon

Species	N	L, mean±SD. (Lmin- Lmax)	W, mean±SD. (Wmin- Wmax)	a	*b*	R^2	S.E. of *b* (95% C.I.)	*t* - Test 0.05 (2) t_s	*P*-Value	G.T.
C. auratus	167	18.0±2.5 (12.2-30.6)	51.2±23.2 (13.4-219.3)	0.0102	2.93	0.974	0.05 (2.82-3.03)	-1.38	0.171	Isometric
C. labrosus	16	24.2±1.9 (20.3-27.7)	135.4±36.2 (72.5-209.1)	0.0029	3.37	0.956	0.19 (2.96-3.79)	1.93	0.074	Isometric
C. ramada	110	20.6±4.5 (13-41.7)	76.5±68 (18.3-548.4)	0.0123	2.84	0.956	0.06 (2.73-2.96)	-2.68	8×10^{-3}	Allometric (-)
M. cephalus	485	26.7±8.2 (12.5-49.6)	226.6±185.9 (18-1089.7)	0.0095	2.99	0.980	0.02 (2.95-3.03)	-0.58	0.56	Isometric
P. carinata	39	17.1±2.06 (12.9-21.9)	44.0±16.03 (17.8-85.6)	0.0085	2.999	0.929	0.19 (2.61-3.39)	- 0.005	0.996	Isometric
S. aegyptiaca	243	18.8±3.7 (9.8-34)	67.7±52.9 (5.6-343)	0.0054	3.17	0.960	0.04 (3.09-3.25)	4	8×10^{-5}	Allometric (+)
S. solea	281	19±3 (10.5-30)	67.2±33.6 (9.7-264.2)	0.008	3.04	0.956	0.04 (2.97-3.12)	1.08	0.28	Isometric
A. anguilla	19	39.9±8.5 (24.7-55.4)	112.6±75.3 (21.1-281.3)	0.0008	3.17	0.976	0.12 (2.92-3.42)	1.4	0.18	Isometric
D. labrax	216	26.4±5.4 (18.1-63.3)	203.8±211 (52-2554)	0.0109	2.96	0.974	0.03 (2.9-3.03)	-1.15	0.25	Isometric
H. far	94	27.6±3 (22.2-38.2)	62.6±26.9 (24.5-174.8)	0.0007	3.42	0.935	0.10 (3.20-3.58)	4.06	2×10^{-5}	Allometric (+)
S. aurata	222	18.8±3.6 (10.7-30)	106.8±63.7 (15.1-417)	0.0142	3.01	0.984	0.03 (2.95-3.06)	0.24	0.81	Isometric
S. rivulatus	50	13±2 (8.2-17.8)	29.9±14.2 (6.3-77.5)	0.0125	3.00	0.980	0.06 (2.88-3.13)	0.03	0.98	Isometric
T. puta	130	12.8±2.2 (7.8-19.2)	27.7±13.6 (78.6-27.7)	0.0167	2.88	0.950	0.06 (2.76-3.00)	-2.04	0.04	Allometric (-)

N: Sample size, L: Length, W: Weight, SD: Standard deviation, Min: Minimum, Max: Maximum, a: Intercept, b: Slope, R^2: Determination coefficient, SE: Stander error of b, 95% CL: Confidence limit level, tc: T-test, and G.T.: Growth type.

Condition factor

The values of condition factors (K) and relative condition factors (K_n) according to the length variation of species under search are estimated in Table (2). From the results, it turned out that the average of K varied from 0.15±0.02 (*A. anguilla*) to 1.45±0.11 (*S. aurata*), while the average of K_n values ranged from 0.97± 0.06 (*T. puta*) to 1.03±0.12 (*A. anguilla*).

With respect to season, the values of condition factors (K and K_n) for the evaluated species in the current study are shown in Table (3). In autumn, a lower estimated value of K was recorded for *H. far* (0.28±0.03), while a higher value was recorded for *S. aurata* (1.43±0.11). On the other hand, the lower value of K_n was 0.92±0.11 for *T. puta*, and the higher value was 1.02±0.10 for *C. ramada*. In spring, the lower K value (0.15±0.02) was found for *A. anguilla*, and the higher value (1.40±0.13) was found for *S. aurata*. The lower value of K_n (0.97±0.09) was recorded for *S. aurata*, and the higher value (1.05±0.09) was that of *H. far*. In summer, *S. aegyptiaca* recorded a lower k- value (0.9±0.08), while *S. aurata* recorded a higher value (1.48±0.10). The lower value of K_n (0.98±0.08) and the higher value (1.22±0.03) were recorded for *S. aegyptiaca* and *C. ramada*, respectively.

Table 2. Average condition factor (K) and relative condition factor (K_n) of 13 fish species in Bardawil Lagoon during the period of study

Species	Condition factor (K)				Relative condition factor (K_n)			
	Min.	**Max.**	**Avr.**	**±SD**	**Min.**	**Max.**	**Avr.**	**±SD**
C. auratus	0.71	0.88	0.81	0.05	0.84	1.08	0.98	0.02
C. labrosus	0.87	0.97	0.93	0.04	0.95	1.01	0.98	0.02
C. ramada	0.59	0.88	0.77	0.06	0.82	1.13	1.02	0.08
M. cephalus	0.39	2.95	0.93	0.16	0.43	3.22	1.01	0.17
P. carinata	0.73	1.08	0.85	0.09	0.87	1.27	1.00	0.11
S. aegyptiaca	0.36	1.14	0.89	0.10	0.41	1.33	1.00	0.11
S. solea	0.68	1.24	0.91	0.10	0.75	1.36	1.01	0.11
A. anguilla	0.13	0.21	0.15	0.02	0.86	1.37	1.03	0.12
D. labrax	0.53	1.20	0.97	0.08	0.55	1.25	1.01	0.08
H. far	0.23	0.34	0.29	0.03	0.78	1.11	0.99	0.08
S. aurata	1.12	1.81	1.45	0.11	0.77	1.25	1.00	0.08
S. rivulatus	1.14	1.31	1.24	0.05	0.91	1.04	0.99	0.04
T. puta	1.10	1.30	1.19	0.08	0.84	1.04	0.97	0.06

Table 3. Condition factor (K) and relative condition factor (K_n) according to the season of 13 fish species in Bardawil Lagoon during the study period

Species	Season	No	Length range				Condition factor			
			Min.	**Max.**	**Aver.**	**SD±**	**K**	**SD±**	**K_n**	**SD±**
C. auratus	**Aut**	74	14.8	23.1	18.7	2.2	0.81	0.07	0.99	0.09
	Spr	65	12.2	30.6	17.4	3	0.81	0.06	0.98	0.08
	Sum	28	15.6	19.7	17.6	1.1	0.92	0.08	1.11	0.1
C. labrosus	**Spr**	16	20.3	27.7	24.2	1.9	0.94	0.06	0.99	0.06
C. ramada	**Aut**	42	14.7	41.7	21.5	6.23	0.78	0.08	1.02	0.1
	Spr	63	13	29.5	20.2	2.86	0.75	0.09	0.98	0.11

	Sum	5	15.8	19.4	17.4	1.49	0.95	0.03	1.22	0.03
M. cephalus	**Aut**	261	8.3	48.1	26.8	8.5	0.92	0.13	1.00	0.15
	Spr	182	12.5	49.6	25.6	8.1	0.92	0.18	1.01	0.19
	Sum	42	15.8	43.2	30.0	6.6	1.04	0.16	1.14	0.18
P. carinata	**Aut**	39	12.90	21.90	17.07	2.06	0.85	0.09	1.00	0.11
S. aegyptiaca	**Aut**	174	13.9	32	18.0	2.7	0.88	0.10	1.00	0.11
	Spr	52	9.8	34	20.1	5.5	0.91	0.10	1.01	0.10
	Sum	17	17.9	30.6	22.4	3.5	0.90	0.08	0.98	0.08
S. solea	**Aut**	113	14.4	27.3	18.6	2.3	0.91	0.10	1.01	0.11
	Spr	106	10.5	30	19.7	3.3	0.91	0.09	1.00	0.10
	Sum	62	14	26	18.3	3.2	0.93	0.09	1.03	0.11
A. Anguilla	**Spr**	19	24.7	55.4	39.9	8.48	0.15	0.02	1.032	0.12
D. labrax	**Aut**	79	18.1	46.5	26.0	6.6	0.97	0.08	1.01	0.08
	Spr	102	19	45.2	25.8	3.4	0.95	0.08	0.99	0.08
	Sum	35	23.8	63.3	29.2	6.6	1.01	0.08	1.05	0.08
H. far	**Aut**	83	22.2	38.2	27.6	3.04	0.28	0.03	1.01	0.1
	Spr	11	22.5	31.7	26.9	2.74	0.29	0.03	1.05	0.09
S. aurata	**Aut**	81	16.3	27.4	19.4	1.6	1.43	0.11	0.99	0.07
	Spr	32	16.1	30	21.8	2.5	1.4	0.13	0.97	0.09
	Sum	109	10.7	26.8	17.4	4.3	1.48	0.10	1.02	0.07
S. rivulatus	**Aut**	9	14.2	17.8	16.3	1.25	1.21	0.09	0.96	0.07
	Spr	41	8.2	15.1	12.3	1.37	1.27	0.08	1.01	0.06
T. puta	**Aut**	27	11.2	19.2	15.2	1.97	1.1	0.13	0.92	0.11
	Spr	103	7.8	17.2	12.1	1.78	1.28	0.12	1.03	0.1

DISCUSSION

The determination of the length weight relationship (LWR) in fish is an important tool in fisheries studies. It is a morphological character that provides information on the growth pattern, fish fitness, condition, general health and habitat conditions (**Schneider *et al*., 2000; Froese, 2006**). Moreover, LWR helps in predicting the weight from length required in yield assessment **(Garcia *et al*., 1998**), and it can be apply to study maturity condition and feeding rate **(Beyer, 1987)**. Results in the present study revealed that the determination coefficient (R^2) for the investigated species ranged from 0.929 to 0.984. This indicates that the length-weight equations had strong relations. LWRs differ among fish species depending on the inherited body shape and physiological factors, such as maturity and spawning (**Schneider *et al*., 2000**).

Obtained values of growth exponent (*b*-value) for the 13 species investigated ranged from 2.84 to 3.42. **Tesch (1971**) elucidated that, these values are reasonable since they lie between 2.0 and 4.0 in most fish. In *C. auratus*, the *b*-value (2.93) tends to be closer to that recorded by **Mehanna (2006a)** and **Mehanna and Farouk (2021)**, and smaller than that recorded in the study of **Mrizek *et al*. (2021)**. *C. labrosus* recorded a higher value of the parameter b (3.37) compared to others studies (**Acarli *et al*., 2014; El-Mor *et al*., 2020; Mehanna & Farouk, 2021**). In addition, the *b*-value of *H. far* (3.42) is higher than that of other studies (**Ontomwa *et al*., 2018; Mehanna *et al*. 2019a; Mehanna & Farouk 2021**). On the other hand, the *b*-values of the other ten species varied within the range for *S. aurata* (**Tharwat *et al*., 1998; Ahmed, 2011; Al-Zahaby *et al*., 2018; Abdalla, 2019; Mehanna & Farouk, 2021**); *M. cephalus* (**El-Ganainy *et al*., 2002; Mehanna & Heagazy, 2013; Mehanna & Farouk, 2021; El-Aiatt *et al*., 2022; Çiloğlu, 2023**); *S. rivulatus* (**Bariche, 2006; El-Far, 2008; Sumir, 2012; Hagras, 2015; Belhassan *et al.*, 2017; Abdelhak *et al*., 2020; Mehanna & Farouk, 2021**); *C. ramada* (**Mehanna, 2006b; Salem *et al.* , 2010; Sümer, 2012; Mohamed, 2016; Mohammed *et al*., 2016; El-Aiatt & Shalloof, 2018; Mehanna *et al*., 2018; El-Bokhty & Amin, 2020)**; *D. labrax* **(Abdel-Hakim *et al*., 2010; Acarli *et al*., 2014; Abdalla, 2019; Shalloof *et al*., 2019; Mehanna & Farouk, 2021; El-Aiatt *et al*., 2022; El-Drawany *et al*., 2022)**; *S. solea* **(Mehanna & Salem, 2012; El-Far, 2014; El-Aiatt *et al*., 2019; İhsanoğlu *et al*., 2020; Mehanna & Farouk, 2021)**; *A. anguilla* **(Castaldelli *et al*., 2014; Boulenger *et al*., 2015; Abdalhamid *et al*., 2018)**; *S. aegyptiaca* **(El-Far, 2014; Gabr, 2015; Mehanna & Farouk, 2021)**; *P. carinata* **(Belhassan *et al*., 2017; Mehanna *et al*., 2019b; Innal, 2021)** and *T. puta* **(Kassem, 2017; El-Drawany, 2017a, b; El-Aiatt & Shalloof, 2019; Philips, 2019**). The differences in *b*-values, as shown in Table (4), can be attributed to the combination of one or more factor(s), such as differences in specimen number, area, season and length ranges **(Moutopoulos & Stergiou, 2002)**.

In the present work, four species had allometric growth and nine species had isometric growth. Two of the allometric growth species (*H. far* and *S. aegyptiaca*) had positive allometry and the other two species (*C. ramada* and *T. puta*) had negative allometry. Positive allometric growth implies that the fish becomes relatively stouter or deeper-bodied as it increases in length, while negative allometric growth implies that the fish becomes slenderer as it increases in weight. On the other hand, isometric growth is associated with no change in body shape as an organism grows **(Riedel *et al.*, 2007; Nehemia *et al.*, 2012)**. The results showed that Bardawil Lagoon has good environmental conditions for better fish growth.

Table 4. Comparison of length-weight relationships and regression parameters (a, b and r) of the 13 species from Bardawil Lagoon and different locations

Species	Location	a	*b*	r	Author
C. auratus	Bardawil Lagoon, Egypt	0.010	2.93	0.95	Present study
		0.007	3.05	0.98	Mrizek *et al*. (2021)
		0.009	2.93	0.96	Mehanna (2006a)

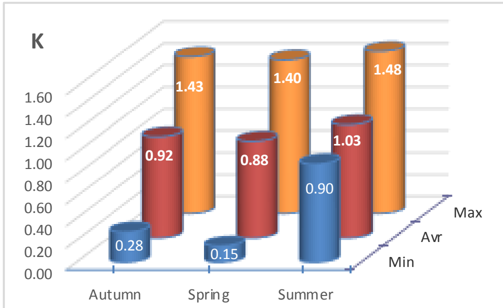
	Mediterranean Sea, Egypt	0.009	2.94	0.96	Mehanna and Farouk (2021)
	Köyceğiz Lagoon, Turkey	0.009	2.96	0.99	Reis and Ateş (2019)
C. labrosus	Bardawil Lagoon, Egypt	0.003	3.37	0.96	Present study
	Mediterranean Sea, Egypt	0.014	2.90	0.97	Mehanna and Farouk (2021)
	Um-Hufayan Lagoon, Libya	0.007	3.06		El-Mor *et al*. (2020)
	Homa Lagoon, Turkey	0.008	3.06	0.83	Acarli *et al.* (2014)
C. ramada	Bardawil Lagoon, Egypt	0.012	2.84	0.96	Present study
		0.01	2.95	0.95	El-Aiatt and Shalloof (2018)
		0.018	2.75	0.94	Mehanna *et al*. (2018)
		0.017	2.76		Mohamed (2016)
		0.018	2.76		Salem *et al*. (2010)
		0.005	3.13	0.98	Mehanna (2006b)
	Manzala Lake, Egypt	0.010	2.94	0.99	El-Bokhty and Amin (2020)
	Beymelek Lagoon, Turkey	0.051	2.47	0.76	Sümer (2012)
	Ain El-Ghzala Lagoon, Libya	0.016	2.85	0.75	Mohammed *et al*. (2016)
M. cephalus	Bardawil Lagoon, Egypt	0.010	2.99	0.98	Present study
		0.027	2.69	0.96	El-Aiatt *et al*. (2022)
		0.014	2.89	0.92	Mehanna and Heagazy (2013)
		0.015	2.89		El-Ganainy *et al*. (2002)
	Mediterranean Sea, Egypt	0.001	2.98	0.98	Mehanna and Farouk (2021)
	Köyceğiz Lagoon, Turkey	0.004	3.20	0.97	Çiloğlu (2023)
P. carinata	Bardawil Lagoon, Egypt	0.009	2.999	0.93	Present study
	Bitter Lakes, Egypt	0.018	2.81	0.93	Mehanna *et al*. (2019b)
	Mediterranean Sea, Libya	0.005	2.87		Belhassan *et al*. (2017)
	River Estuaries, Turkey	0.008	3.17	0.93	Innal (2021)
S. aegyptiaca	Bardawil Lagoon, Egypt	0.005	3.17	0.96	Present study
		0.005	3.18	0.96	Gabr (2015)
	Qarun Lake, Egypt	0.013	2.84	0.89	El-Far (2014)
	Mediterranean Sea, Egypt	0.006	3.15	0.88	Mehanna and Farouk (2021)
S. solea	Bardawil Lagoon, Egypt	0.008	3.04	0.96	Present study
		0.005	3.22	0.95	El-Aiatt *et al*. (2019)
		0.006	3.11	0.91	Mehanna and Salem (2012)

	Qarun Lake, Egypt	0.021	2.67	0.89	El-Far (2014)
	Mediterranean Sea, Egypt	0.007	3.09	0.91	Mehanna and Farouk (2021)
	Marmara Sea, Turkey	0.014	2.83	0.97	İhsanoğlu *et al*. (2020)
A. anguilla	Bardawil Lagoon, Egypt	0.001	3.17	0.98	Present study
	Um-Hufayan Lagoon, Libya	0.016	3.23	0.97	Abdalhamid *et al*. (2018)
	Comacchio Lagoon, Italy	0.001	3.22	0.96	Castaldelli *et al*. (2014)
	Esva, Spain	0.001	3.32	0.98	Boulenger *et al*. (2015)
	Stour, Britain	0.001	3.20	0.97	
	Scheldt, Belgium	0.007	2.26	0.89	
	Burrishoole, Ireland	0.003	2.86	0.93	
D. labrax	Bardawil Lagoon, Egypt	0.011	2.96	0.97	Present study
			2.95		El-Aiatt *et al*. (2022)
		0.008	3.04	1.00	Abdalla (2019)
		0.009	3.01		Shalloof *et al*. (2019)
		0.019	2.82		Abdel-Hakim *et al* (2010)
		0.007	3.08	0.98	El-Drawany *et al*. (2022)
	Mediterranean Sea, Egypt	0.008	3.06	0.98	Mehanna and Farouk (2021)
	Homa Lagoon, Turkey	0.015	2.95	0.99	Acarli *et al*. (2014)
H. far	Bardawil Lagoon, Egypt	0.001	3.42	0.93	Present study
		0.005	3.08	0.93	Mehanna *et al.* (2019a)
	Mediterranean Sea, Egypt	0.004	3.08	0.92	Mehanna and Farouk (2021)
	South coast, Kenya	4×10^{-6}	3	0.95	Ontomwa *et al.* (2018)
		9×10^{-6}	2.7	0.89	
S. aurata	Bardawil Lagoon, Egypt	0.014	3.01	0.98	Present study
		0.015	3.01	0.98	Al-Zahaby *et al.* (2018)
		0.019	2.93	0.99	Abdalla (2019)
		0.025	2.81		Ahmed (2011)
		0.13	3.04		Tharwat *et al.* (1998)
	Mediterranean Sea, Egypt	0.011	3.09	0.98	Mehanna and Farouk (2021)
	Köyceğiz Lagoon, Turkey	0.014	3.01	0.94	Reis (2020)
S. rivulatus	Bardawil Lagoon, Egypt	0.013	3.00	0.98	Present study
		0.016	2.90		Hagras (2015)

	Mediterranean Sea, Egypt	0.015	2.91	0.93	Abdelhak *et al.* (2020)
		0.011	2.98	0.97	Mehanna and Farouk (2021)
		0.023	2.78	0.93	El-Far (2008)
	Mediterranean Sea, Lebanon	0.01	3.04	0.99	Bariche (2006)
	Mediterranean Sea, Turkey	0.016	2.94	0.97	Sumir (2012)
	Mediterranean Sea, Libya	0.006	3.25		Belhassan *et al.* (2017)
T. puta	Bardawil Lagoon, Egypt	0.017	2.88	0.95	Present study
		0.008	3.02	0.96	El-Aiatt and Shalloof (2019)
			2.78		Kassem (2017)
	Mediterranean Sea, Egypt	0.008	3.06	0.997	Philips (2019)
	Lake Timsah, Egypt	0.023	2.88	0.98	El-Drawany (2017a)
	Bitter lakes, Egypt	♂0.022	2.9		El-Drawany (2017b)
		♀0.020	2.9		

Fulton's coefficient of condition factor which demonstrates the mathematical relationship between a fish's length and weight displays the degree of fish robustness or welfare, and its value might vary depending on factors including age, size, weight, sex and/or maturity level. The highest condition factors (K) were recorded in *S. aurata* (1.45), *S. rivulatus* (1.24) and *T. puta* (1.19). Moreover, the lowest values were recorded in *A. anguilla* (0.15), *H. far* (0.29) and *C. ramada* (0.77). In all fish species, the relative condition factors (K_n) were around 1.0 and ranged from 0.97 (for *T. puta*) to 1.03 (for *A. anguilla*). The deviation of the relative condition factor from 1.0 can refer to the availability of food and the life cycle of fish species **(Le Cren, 1951)**.

Regarding the different seasons (Fig. 2), the average values of K were 0.92 (from 0.28 to 1.43), 0.88 (from 0.15 to 1.40) and 1.033 (from 0.90 to 1.48) for autumn, spring and summer, respectively. Fish growth status including the fish condition is influenced by a variety of parameters, including reproductive cycles, food availability, environmental and habitat factors **(Morato *et al.*, 2001)**. In autumn, K_n values ranged from 0.92 to 1.02, with an average of 0.99. While in spring, the K_n values were 0.97, 1.05 and 1.0 for minimum, maximum and average, respectively. Moreover, the minimum value of K_n in summer was 0.98, and the maximum was 1.22 (average value= 1.08). The values of K and K_n varying according to seasons are influenced by environmental conditions, food availability and the gonadal maturity, as suggested by many authors **(Jhingran, 1952; Bashirullah, 1975; Braga, 1986; Morato *et al*., 2001)**.



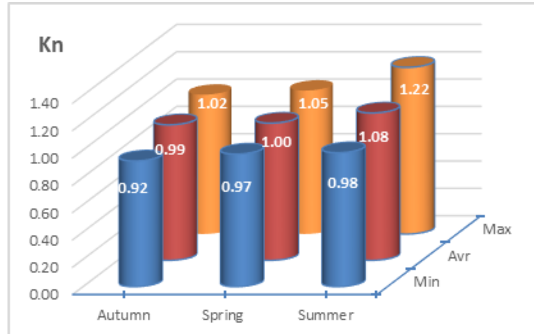


Fig. 2. Seasonal variation in condition factor (minimum, average and maximum) of Bardawil Lagoon fishes; K, condition factor and K_n, relative condition factor

CONCLUSION

The present study provides information about the length-weight relationships of 13 bony fish species inhabiting the Bardawil Lagoon to document the growth conditions during the study period. Results showed that Bardawil Lagoon has a good environmental condition for better fish growth, as nine of the investigated species had growth isometry. The condition factor revealed that all species had good fitness. The data from the present study could be valuable as a reference for the management and sustainability of these species in Bardawil Lagoon and the Mediterranean basin.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could influence the work reported in this paper.

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