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Stock structure based on truss network analysis, length weight relationship and condition factor of *Decapterus macrosoma* (Bleeker, 1851) from two fishing areas, Red Sea, Egypt

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ABSTRACT

The round scad, *Decapterus macrosoma* is an important pelagic carangid species distributed in the Indo-Pacific and the Southeast Atlantic including the Red Sea. Using the truss network based on images (TNA), the stock structure of *D. macrosoma* from two fishing grounds, Suez and Hurghada, was evaluated. Information on the length-weight relationship and condition factor of this species were provided. The b-values of LWR were 2.86 in Suez and 2.87 in Hurghada, with an R^2 estimate greater than 0.92, indicating a negative allometric growth type for both studied areas. A narrow distribution range of relative condition factor (Kn) was observed in the two fishing areas, recording a value of 0.95-1.075 with a mean of 1.013±0.038 for Hurghada and 0.911- 1.098 with an average of 1.017±0.039 for Suez. No differences were detected in LWR and Kn values between the two stocks. The form factors of this species were calculated between 0.006 and 0.14, with 0.01 as a mean and median value. The truss network analysis based on 15 measurements between eight landmarks revealed that the stock of *D. macrosoma* in the two areas was identical. This may be due to the similarity of the ecological and physical conditions of the Suez Gulf and Hurghada, Red Sea. Within stock, distinctions were reported in the present study. Thus, the study would aid in the development and conservation arrangements of this species, as well as in properly taking the right decision for the management of both studied areas.

INTRODUCTION

The Red Sea is a narrow, long and semi-closed water body that etxents to 2,000 km long. It has a surface area of about 458,620km^2, and a maximum width of 355km. The Egyptian Red Sea sector extends about 1080km from Mersa Halayab in the south to the Suez city in the north with a mean anuual apporoximate catch of 30 thousand ton **(Mehanna & El-Gammal, 2007)**. In 2020, the fish production from this long coast was 50 thousand ton **(GAFRD, 2020)**. There are several fishing grounds along the Egyptian Red Sea, of which the Gulf of Suez and Hurghada are the most productive.

Purse-seine fishery has a great economical significance and is considered as the most productive fishing gear in the Gulf of Suez, representing about 77% of the total annual fish landing from the gulf. Nevertheless, there are few studies that focus on evaluating the status of the exploited stocks in this type of fisheries **(Shaheen *et al.*, 1983; Sanders *et al.*, 1984a, b; El- Gammal & Breikaa, 1994; Mehanna, 1999, 2022; Farrag *et al.*, 2018)**. Information about fish stocks is essential for any management strategy since any fish stock must be singly assessed and regulated to ensure its productivity. Identifying the fish stock is the base for its assessment and consequently proposing the regulatory measures for its rational exploitation. Many methods were initiated for stock identification, from which the morphometric and meristic characters were considered **(WWF, 2018; Ramya *et al.*, 2021)**.

The truss network analysis is a landmark-based morphological method that shows no restrictions on the path of discrepancy or the positioning of shape modifications **(Mahfuj *et al.*, 2022)**. It is a very efficient tool in capturing appropriate data about the profile of a certain individual **(Cavalcanti *et al.*, 1999)**. The measured values of this network are a group of measurements among landmarks that constitute a reliable pattern of interlinked quadrilaterals all over the body **(Strauss & Bookstein, 2017)**. Storage of fish images is useful to select more distinguish points feature and detailed verification of extraordinary variants **(Cadrin & Friedland, 1999)**. The landmarks are fearuers with connection of varants organs, such as anal pores, fin insertion and head, and therefore, the network must look like the profile of the sample from which it is inferred **(Rawat *et al.*, 2017)**.

Round scad, *Decapterus macrosoma*, is a pelagic schooling species that is widely distributed in the Indo-Pacific and the Southeast Atlantic (including the Red Sea), and in the Central Pacific Islands of Peru (including Galapagos Islands) to the Gulf of California and South Korea **(Smith-Vaniz, 1995; Kuiter & Tononzuka, 2001, Mundy, 2005; Fishbase, 2022)**.

Regarding interdisciplinary stock identification, the analysis of morphometric characters delivers information on phenotypic populations and stocks, which have similar growth rates, mortality, and reproductive rates **(Booke, 1981)**. The truss network system is the best alternative to the traditional morphometric dimensions and characters. It covers the fish in an identical network and increases the probability of extracting the differences among morphometric dimensions within and among species **(Turan, 1999)**. Whereas, the traditional morphometric dimensions and characters have biased coverage over the body **(Strauss & Bookstein, 1982)**.

For proposing management strategies to conserve the fish species, an appropriate information about the stock structure in its areas of distribution is essential. The present study was undertaken to describe changes in shape features in order to stock identification of the round scad from the Egyptian Red Sea. In addition, this study described the differences in stock of *D. macrosoma* from two fishing grounds along the Red Sea, Egypt by using truss network analysis for the first time.

MATERIALS AND METHODS

1. Sample collection

Fish samples were obtained from two fishing areas along the Red Sea, Suez (29.9737° N 32.5263° E) and Hurghada (27.2579° N, 33.8116° E). A total of 89 round scads from Hurghada and 103 from Suez were used in this study. The samples were obtained from the commercial landings of purse-seiners operating in both areas during the period from October 2021 to April 2022.

2. Measurements and methods

The measurements of the standard length (SL) to the nearest 0.1 cm and weight (W) to the nearest 0.01 g were used to calculate the LWRs by the method of least squares as follows **(LeCren, 1951)**: $W = aSL^b$, with the logarithmic transformation **(Froese, 2006)** form: $\text{Log } W = \log a + b \log L$

The relative condition factor (Kn) was calculated using the following equation of **Froese (2006)**: $Kn = W / (aL^b)$

For imaging the samples and measuring the truss network data, the collected samples were washed under running water at first, then each individual fish was positioned flat on a bench surface, and the left side was snapped from a perpendicular angle using a tripod mounted Nikon D50 digital camera. Eight inter-landmark dimensions were documented on the digital pictures for TRU analysis, and 15 truss dimensions were recorded (Fig. 1) using tpsDig2 V2.1 software **(Rohlf, 2006)**.

Afterward, the truss measurements were tested using SPSS 21 software version and Microsoft Excel Spreadsheets through the application of the UNIVARIATE analysis of variance (ANOVA).

To eliminate any effect of size variations in the traditional morphometric measurements and TRU sets of data, the formula of **Elliott *et al.* (1995)** was applied as: $M_{adj} = M (L_o / L_s)\ b$, where M_{adj} is the size adjusted measurement; L_s is the overall mean standard length (SL) for all fish in each analysis; L_o is the standard length of the fish; M is the original measurement, and b is the slope of the regression between log M and log L_o.

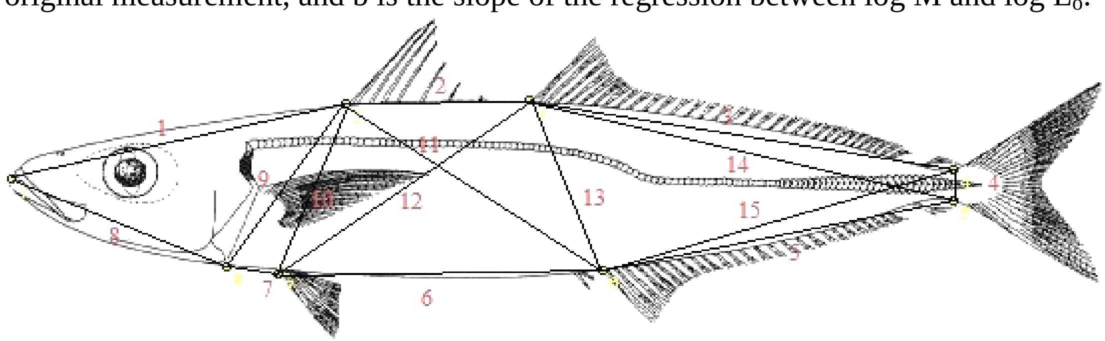

Fig. 1. Fish with eight landmarks and fifteen distances used for truss-network (TRU analysis, indicated by Red letters and black lines) .

RESULTS

1. Description of fishery

The fishing gears deployed by the Egyptian fishers in the Red Sea are divided into semi and industrial fishery (bottom trawl and purse seine), and the artisanal fishery (hand and long lines, trammel and gillnets, crab nets). Round scad is a pelagic species mainly exploited by purse-seiners in Hurghada and Suez fishing areas. Purse-seine fishery (Table 1) is mainly concentrated in the Gulf of Suez. The number of fishing boats operated inside the Gulf varied between 56 and 83 vessels. The vessels are 12.5 and 30m long, powered by engines of 200 to more than 800hp with the majority (63 vessel) of 400-600hp. The purse-seine fisheries are operated during night utlizing lighted dinghies, hence creating illumination that result in concentrating the fish before setting the net itself **(Mehanna, 2022)**. All fishing come to a halt in around ten days each month when the moon is full. The length of the net ranges between 200 and 300m, whereas its depth ranges from 50 to 80 m. The nets are manually pulled, and the crew number usually ranges between 25 and 30 persons (Fig. 2) .

The fishing season for purse-seine fishery was a short time (from October through May in general). The fishing trip takes two to five days duration at the beginning of each season as most fishing activities are relatively performed close to the landing site of Ataka in the city of Suez. However, fishing trip takes more days later during season. This kind of fisheries contributed to apporximately 77.9% of the total fish catch from the Gulf of Suez, constituting about 32% of gulf's gross revenue **(Mehanna, 2022)**.

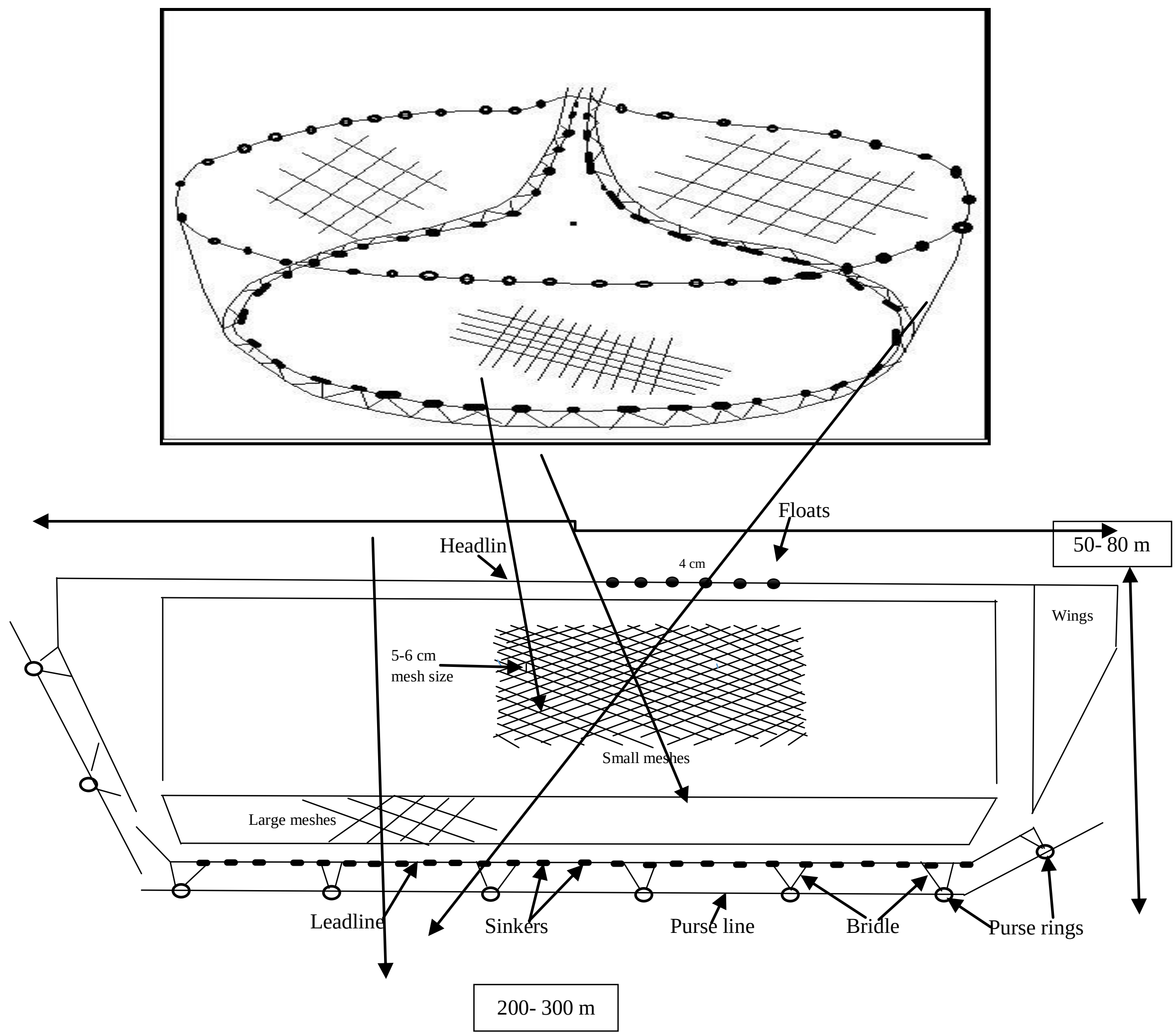

Fig. 2. The design and dimensions of the net used in this study during fishing season of 2021-2022

Table 1. Purse seine fishery in Hurghada and Suez, Red Sea, Egypt

Purse seine fishery	Suez	Hurghada
No. of fishing boats	84	21
Fishing trip	10 days/month	11 days/month
No. of crew	20 to30 persons	20 to30 persons
vessel length 2	20- 25 m	20- 25 m
HP	60- 400 hp	60- 400 hp
Fishing time	in fall moon	in fall moon
No. of shots/day	4 to 6	2 to 3
Time of each shots	1- 2 h	1- 2 h
Net length	300- 500 m	100- 300 m
Net depth	up to 100 m	up to 100 m
Vessels equipped	nets are hauld by winches manually	nets are hauld by winches manually

2. Length–Weight Relationship

The length-weight relationship of 192 specimens of *D. macrosoma*, 89 specimens from Hurghada and 103 from Suez, were calculated. *D. macrosoma* varied in standard length from 15.55 to 193.51cm and in weight from 53.19 and 102.77 g in Hurghada, while for Suez, it ranged between 14.4 and 18.95cm in total length and between 42.41 and 95.63 g in weight. Length- weight equations for the investigated species are represented in Fig. (3, 4). The b value was 2.86 for Suez and 2.87 for Hurghada; the growth type is negative allometric as the b-value was significantly different from three (less than 3).

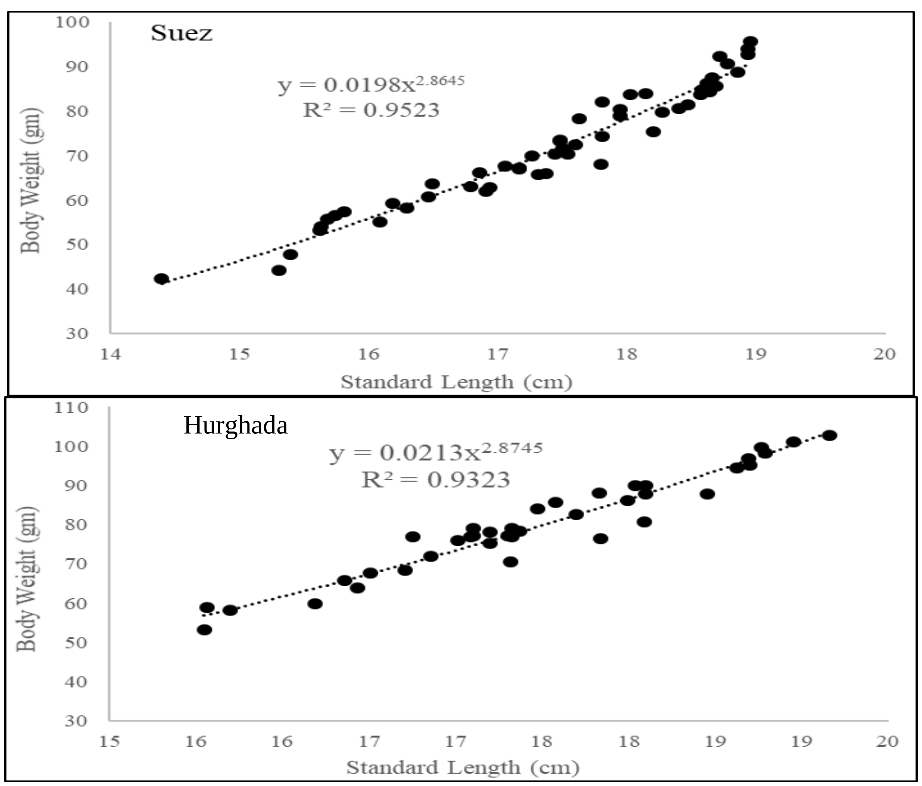

Fig. 3. Length- weight relationship of *Decapterus macrosoma* from Suez and Hurghada

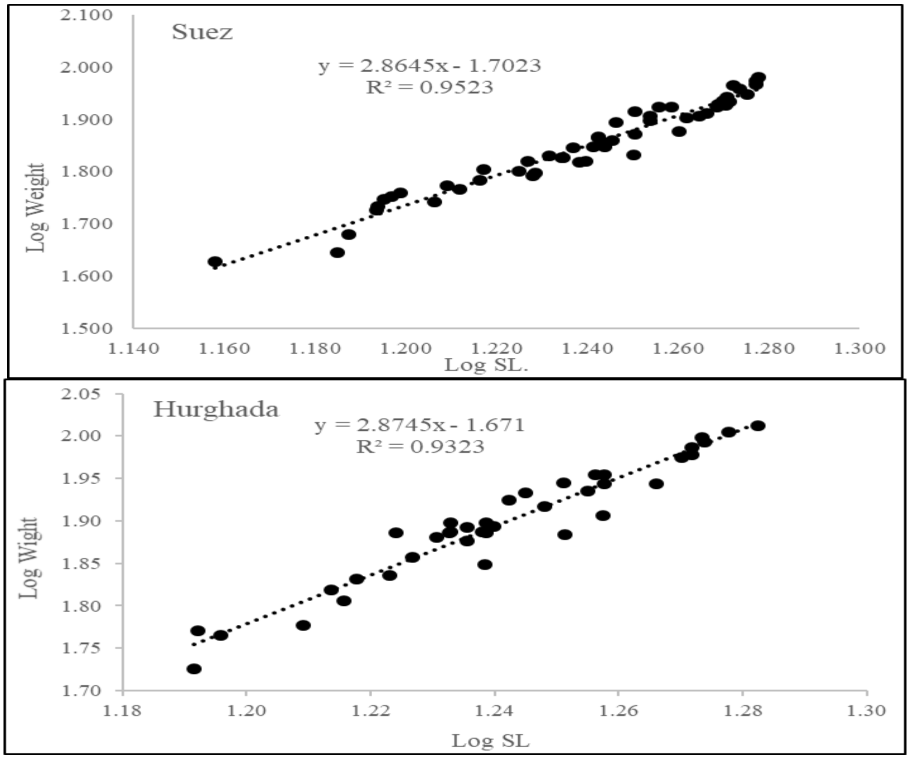

Fig. 4. Logarithmic form of length- weight relationship of *Decapterus macrosoma* from Suez and Hurghada

3. *Relative condition factor (K_n)*

According to length, the relative condition factors fluctuated from length to length (Table 2 & Fig. 5), The highest relative condition of Hurghada was observed at 17cm, with a mean value of 1.024±0.043, while the lowest mean value (1.003±0.050) was at length group of 15 cm. For the Gulf of Suez, the highest mean value of the condition factor was 1.024±0.046 at fish length of 17cm, and the lowest mean value was 1.003±0.000 at length of 14cm.

Table 2. Variations of relative condition factor (Kn) with length for *D. macrosoma* from Hurghada and Suez

Length cm	Hurghada		Suez	
	Min.- Max.	Average± SD	Min.- Max.	Average± SD
14	---	---	1.043-1.043	1.003±0.000
15	0.949-1.049	1.003±0.050	0.912-1.080	1.016±0.060
16	0.952-1.108	1.011±0.049	0.912-1.019	1.019±0.048
17	0.920-1.075	1.024±0.043	0.911-1.098	1.024±0.046
18	0.931-1.060	1.011±0.037	0.911-1.018	1.013±0.043
19	1.007-1.021	1.014±0.010	1.071-1.071	1.013±0.000
Average	0.949- 1.075	1.013±0.038	0.911- 1.098	1.017±0.039

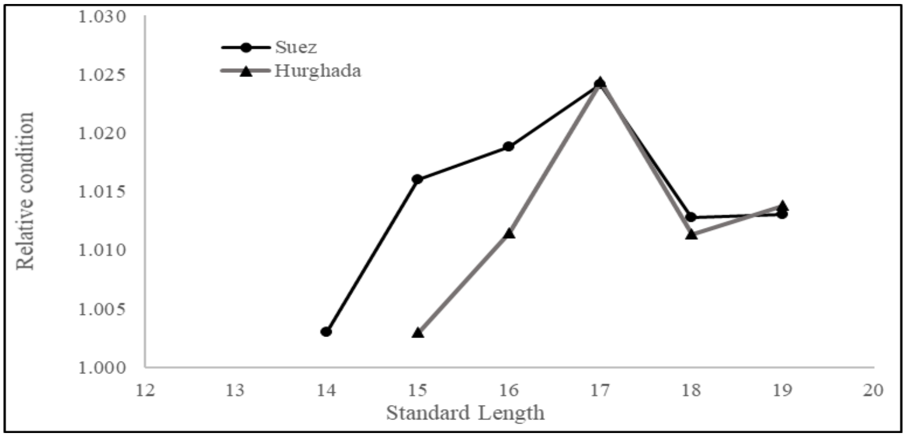

Fig. 5. Variation of relative condition factor (Kn) with length for Hurghada and Gulf of Suez

4. Morphometric measures

A total of 192 samples were collected from Suez (103 specimens) and Hurghada (89 specimens). The standard length (SL) varied between 155.47 and 193.51mm (177.71±8.93) for Hurghada and 144.0- 189.52mm (176.81± 8.57) for Suez samples, while the total length (TL) range was 177.46- 220.50mm (201.79±10.48) and 176.67-217.67 mm (198.99±9.57) for Hurghada and Suez, respectively. The measurements of 3-4 and 3-11 length (table 3) for both regions were investigated. The boxplot for minimum, maximum and median measurements for truss network is represented in Fig. (6). The high values were observed for measures 3-4 and 3-5. For comparing the difference between the two stocks, ANOVA test (Table 4) was applied and confirmed the correlation between the two areas. In addition, no significant difference (P > 0.05) was recorded for nearly all measurements (deductig the measurement 2- 8).

Table 3. Statistical descriptions of fish standard length and body trees network measurements of two regions in the Red Sea, Egypt

No.	Measurement	Hurghada				Suez			
		Min	Max	Average	SD	Min	Max	Average	SD
	SL	155.47	193.51	177.71	8.93	144	189.52	176.81	8.57
1	**1-2**	55.20	72.51	65.37	3.42	55.80	69.27	63.26	3.41
2	**2-3**	29.39	39.73	34.27	2.56	29.34	41.33	35.24	2.61
3	**3-4**	70.42	90.69	81.42	4.94	69.71	90.95	81.60	4.83
4	**4-5**	4.04	6.67	5.29	0.59	4.09	6.67	5.22	0.61
5	**5-6**	59.75	72.64	65.52	3.14	56.34	73.90	65.14	3.70
6	**6-7**	51.76	70.41	62.71	4.77	52.46	82.95	62.86	5.52
7	**7-8**	7.64	13.56	11.41	7.06	8.76	13.26	10.90	1.09
8	**8-9**	35.81	48.83	43.60	2.50	38.42	47.21	43.74	2.14
9	**9-10**	33.82	42.64	38.26	2.26	30.10	42.72	36.83	2.85
10	**10-11**	30.42	40.37	36.79	4.41	27.95	39.78	34.04	2.58
11	**11-1**	50.30	68.28	59.77	4.50	52.04	65.39	75.64	4.77
12	**2-11**	40.07	66.65	57.70	4.52	47.63	63.64	55.89	4.21
13	**2-10**	31.97	84.73	38.96	7.97	31.10	44.03	37.98	3.23
14	**3-11**	70.18	89.28	82.03	4.82	70.15	89.36	83.08	4.88
15	**3-10**	61.31	75.94	67.70	3.56	58.22	73.33	66.29	3.35

Table 4. Anova test results for two stock areas of *D. macrosoma* from the Red Sea, Egypt

Truss network distances	Sum of Squares	df	Mean Square	F	Sig.
1-2	11.070	1	11.070	0.714	0.401
2-3	13.231	1	13.231	2.680	0.106
3-4	9.560	1	9.560	0.413	0.522
4-5	0.000	1	0.000	0.000	0.991
5-6	0.694	1	0.694	0.043	0.837
6-7	7.300	1	7.300	0.430	0.514
7-8	1.193	1	1.193	0.132	0.717
8-1	2.839	1	2.839	0.374	0.543
2-8	8.012	1	8.012	1.658	**0.000**
2-7	34.671	1	34.671	3.807	0.055
2.6	20.769	1	20.769	1.243	0.268
3-7	6.593	1	6.593	0.424	0.517
3-6	1.775	1	1.775	0.104	0.747
3-5	27.717	1	27.717	1.160	0.285
6-3	2.653	1	2.653	0.163	0.688

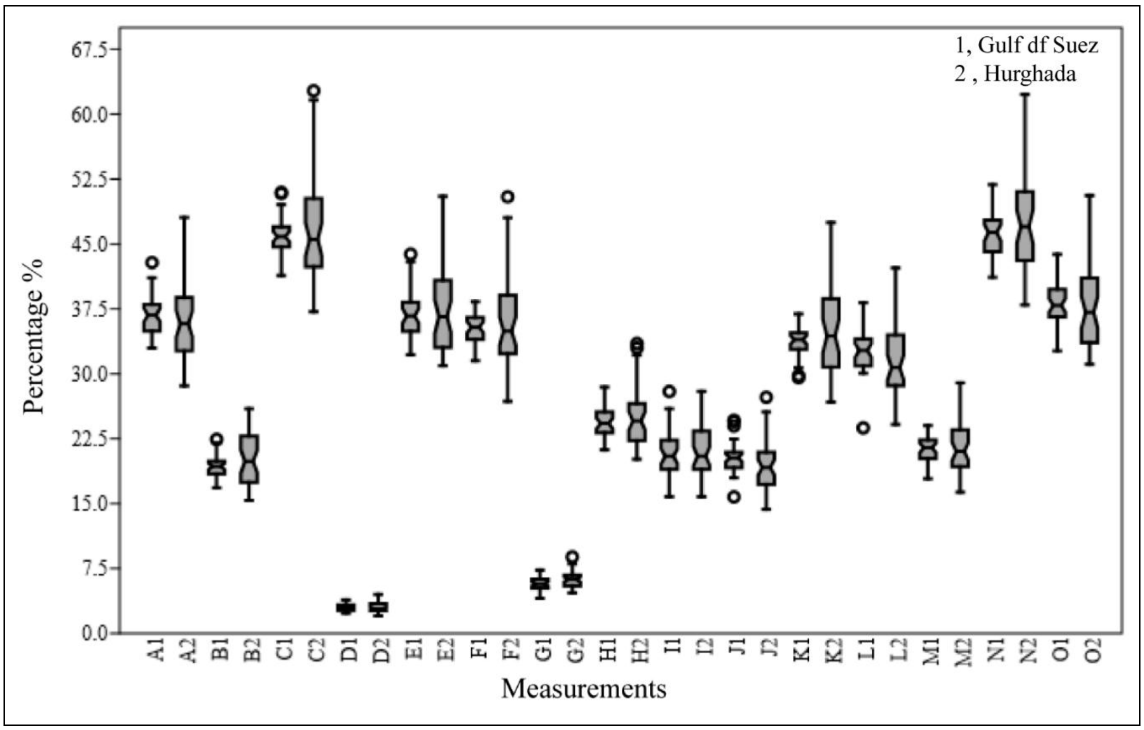

Fig. 6. The relation among measurements and percentage to standard length; A1-A2,1-2; B1-B2, 2-3; C1-C2, 3-4; D1- D2,4-5; E1-E2,5-6; F1-F2,6-7; G1-G2,7-8; H1-H2,8-1; I- I2, 2-8; J1-J2, 2-7; K1-K2, 2-6; L1-L2, 3-7; 3-6; 3-5; 6-3.

DISCUSSION

Morphometric variance among stocks of a species is considered a significant marker for delineating the population dynamics and evaluating the stocks for the management and sustainable harvest purposes **(Randall & Pyle, 2008; Vishalakshi &**

Singh, 2008; Khan *et al*. 2013). The present study was done on the samples collected from the commercial catches of purse seine in two different fishing areas (Hurghada and the Gulf of Suez fishing area).

The study used the truss network analysis for the first time along with some biological aspects such as length- weight relationship and condition factor to differentiate the round scad stock between the two studied areas. The length-weight relationship, (b) value, is usually used to display the fish's robustness according to **Le Cren (1951)** who stated that, the value of exponent (b) gives the isometric growth mode if it is equal to three or not significantly different from three, while the mode is considered allometric if it is considerably different from three (Table 5).

The exponent b-value for the round scad species was 2.86 and 2.87 for Suez Gulf and Hurghada, respectively. These values reflect the negative allometric model of growth. The values of (b) for Hurghada are less than those recorded in previous studies **(Ronquillo, 1975; Sousa & Gj_saeter, 1987; Atmadja, 1988; Padilla, 1991; Pauly *et al*., 1996; Palla *et al*., 2018)**. Their results reflected different modes of growth, which may be due to fish samples' size, length range, varied habitats and condition.

The relative condition factors (Kn) based on the length for the round scad was determined, and the highest relative condition in Hurghada was observed at 17 cm with mean value (1.024±0.043), while the lowest value (1.003±0.050) was observed at length group of 15cm. Regarding the Gulf of Suez, the highest value of condition was 1.024±0.046 at length 17cm, and the lowest value was 1.003±0.000 at length 14cm.

There are few studies dealing with the estimation of the condition factors (absolute and relative) for the scad species; therefore, the comparison of the present condition factor estimates with another studies was very difficult. The present results showed a fluctuation trend in Kn values with fish length.

Generally, the degree of variation between or within fish populations may be higher than other vertebrates. Morphological variation is widely used to isolate of proportion of a stock within local habitat factors. The basic separation between population may be notable in phenotypic and genetic variation, leading to degree of a sufficient information **(Wimberger, 1992; Turan, 2004)**. This variation may be found through varied processes, such as spawning area, distribution, hydrographic features, migration between regions and areas **(Iles & Sinclair, 1982; Begg *et al*., 1999)**.

The results obtained from the truss-based morphometric analysis indicate that the *D. macrosoma* stock from the Suez Gulf is morphologically not different from that collected from the proper Red Sea. This similarity in the morphological measurements between the two areas is attributed to the closeness of the two habitat areas and the nearly similar environmental and ecological parameters **(Morcos, 1970)**. However, this requires more verification through the molecular genetic investigations to confirm these results.

The truss network system may be a good way to separate between populations within fishes, and there are many studies in brackish, fresh and marine water environments that verified this. In the current study, the truss protocol revealed a close similarity between the *D. macrosoma* stock inhabiting the Gulf of Suez and Hurghada fishing ground of Red Sea suggesting the necessity for more studies.

The results in this study may be assigned by further biochemical, molecular, the microsatellite and DNA applications **(Graves, 1998; Turan *et al*., 1998; Shaw *et al*., 1999; Swatipriyanka *et al*., 2011)** together with morphometric studies. In the light of this morphometric study, the development of proper guidelines for the implementation of appropriate mesh size in both the coasts may help sustain this resource for the future use.

Table 5. Length- weight relationship parameters of *Decapterus macrsosoma* from different localities

Country	Locality	a	b	Length (cm)	Length type	r^2	n	References
Philippines	Palawan / 1998-2014	0.01	2.95	14.4 - 22.2	TL	0.772	132	Palla *et al*. 2018
Indonesia	Western region	0.0076	3.005	7.5 - 31.5	TL	0.867	---	Pauly *et al*. 1996
Indonesia	Java Sea	0.009	3.01	---	---	---	---	Atmadja 1988
Philippines	Guimaras Strait, 1988-89	0.01	3.1	---	---	---	---	Padilla 1991
Philippines	1966-69	0.0056	3.17	8.0 - 30.0	TL	---	5899	Ronquillo 1975
Mozambique	Sofala Bank, 1979-82	0.0038	3.258	15.3 - 22.5	FL	0.889	2000	Sousa and Gj_saeter 1987
Egypt	Gulf of Suez	0.0198	2.86	15.5- 19.35	SL	0.9523	103	Present study
Egypt	Hurghada	0.0213	2.87	14.4- 18.95	SL	0.9323	89	Present study

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