Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(3): 767 – 782 (2023)
www.ejabf.journals.ekb.eg

Species Diversity, Abundance, Distribution and Length Weight Relationship of Groupers (Family: Serranidae) in the Red Sea, Egypt

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ARTICLE INFO

Article History:
Received: April 27, 2023
Accepted: June 6, 2023
Online: June 29, 2023

Keywords:
Groupers,
Species composition,
Distribution,
Abundance,
Red Sea

ABSTRACT

Groupers are valuable targets for artisanal and recreational fisheries in the Red Sea. The present study aimed to create for the first time a grouper database, including information on species composition, abundance distribution, and length- weight relationships of grouper species from the Red Sea. Twenty grouper species were collected from three investigated sites; namely, Hurghada (site II) where landings showed the most diversity with 18 species, Shalateen (site III) that yielded 16 species, and El Tur (site I), the site with the least number of species (only 4 grouper species). The highest abundance of grouper individuals was recorded in Shalateen (49%), followed by Hurghada (35%) and El Tur (16%). The collected grouper species belonged to six genera: *Epinephelus*, *Cephalopholis*, *Anyperodon*, *Plectropomus*, *Aethaloperca* and *Variola*. The genus *Epinephelus* was the most specious in the samples, with 10 species, while the genera *Cephalopholis* and *Plectropomus* were represented by 5 and 2 species, respectively, while *Anyperodon*, *Aethaloperca* and *Variola* were detected with one species. According to IUCN, three species in the Red Sea have been declared vulnerable. In this study, data on the length-weight relationship (LWR) was presented for the most abundant species (15 grouper species). For 10 of the 15 species, it is the first estimate of LWR parameters in the Red Sea.

INTRODUCTION

The Red Sea is characterized by its marvelous marine life and astounding biological diversity, such as coral reefs, mangrove forests and sea grass beds, which act as nurseries and shelters for many commercially important fish species (**Sheppard, 2003**). Approximately, 260 species of hard coral (**DeVantier *et al.*, 2000**) and over 1,200 species of fish have been recorded from the Red Sea. Over the last decades, anthropogenic impacts on the Red Sea environment have resulted in habitat loss and degradation, and as a result, several fish species, notably groupers (Family: Serranidae) have become critically endangered. Serranid comprises about 449 species in 69 genera all over the world (**Nelson, 1994**). Four subfamilies of the serranid fishes occur in the Red Sea: Serraninae, Liopropominae, Anthiinae and Epinephelinae (**Harmelin-Vivien & Bouchon, 1976**; **Hassan, 1983, 1988**; **Ghorab, *et al.*, 1986**; **Heemstra & Randall,**

1993). Epinephelinae is the most common and widespread subfamily; 22 species of this family have been recorded from the Red Sea (**Randall & Ben Tuvia, 1983**).

Groupers form an important part of reef fisheries landings in the Gulf of Suez and Red Sea, where they are mainly caught by hooks and lines, trammel and gill nets. Catches of groupers from the Egyptian Red Sea are recorded at the species level as the most economically species (*Cephalopholis miniata, C. argus, Epinephelus areolatus, E. tauvina*, and *Plectropomus truncatus*), while the other grouper species are included in a mixed category called groupers. Recorded landings of all grouper species reached 2370 ton in 2017, constituting about 4.7 % of all fish landings from the Egyptian Red Sea (**GAFRD, 2018**).

The majority of grouper species inhabiting the Red Sea live in or on coral reefs, but few species inhabit deeper water. They are active carnivorous fish, most of them bottom-dwellers and feed mainly on crustaceans and small fish. They are mostly benthic and exceptionally bathypelagic; they are chiefly solitary at least when adults. They are oviparous fishes, and their eggs are pelagic, and many fishes of this family are valued as game and commercially important fishes (**UNESCO, 1985**).

Biological studies on grouper species from the Red Sea are very scarce.Thus, **Randall and Ben-Tuvia (1983)**, **Ghorab, *et al.* (1986)**, **Hassan (1988)**, **Mahmoud *et al.* (2009)**, **Abd-Allah (2015)**, **Osman *et al.* (2018)**, **El Ganainy (2017)**, **Abd-Allah (2019)**, **Galal-Khallaf *et al*. (2019)** and **Saleh *et al.* (2019)** have addressed the identification and biological aspects of some grouper species in the Red Sea.

Data on species composition, distribution and abundance are crucial in evaluating the spatial effects of fishing effort (**Jennings & Polunin, 1995**), determining recruitment variability (**Caley *et al.*, 1996**) and trend analysis. The biological life history of groupers is the main factor in their susceptibility to overexploitation, biological information is essential for management purposes. Hence, our knowledge of the biological parameters of a stock, including the length-weight relationship (LWR) is of great importance in fishery biology studies. Thus, the objective of this study was to build for the first time a grouper database by providing information on species composition, abundance, distribution and length- weight relationships of grouper species from the Egyptian waters of the Red Sea.

MATERIALS AND METHODS

1. Study area

The Red Sea is about 2250km long, and at its widest point, it extends for 355km wide. It has a maximum depth of 2211m in the central median trench, and an average depth of 490m. However, there are also extensive shallow shelves, noted for their marine life and corals. Three fisheries landing sites were selected along the Egyptian Red Sea (Fig. 1). Site I: El Tur region, which is situated in the southern part of the Gulf of Suez (28°12′ 29.40″ N and 33° 36′ 35.00″ E). Site II: Hurghada, situated in the northern part of the Red Sea (27° 15′ 51.99″ N and 33° 49′ 29.75″ E), and Site III: Shalateen, in the most southern part of the Egyptian Red Sea, located at 520km south of Hurghada (23° 09′ 0″ N and 35° 36′ 51″ E). The location of sampling sites was documented using the global positioning system.

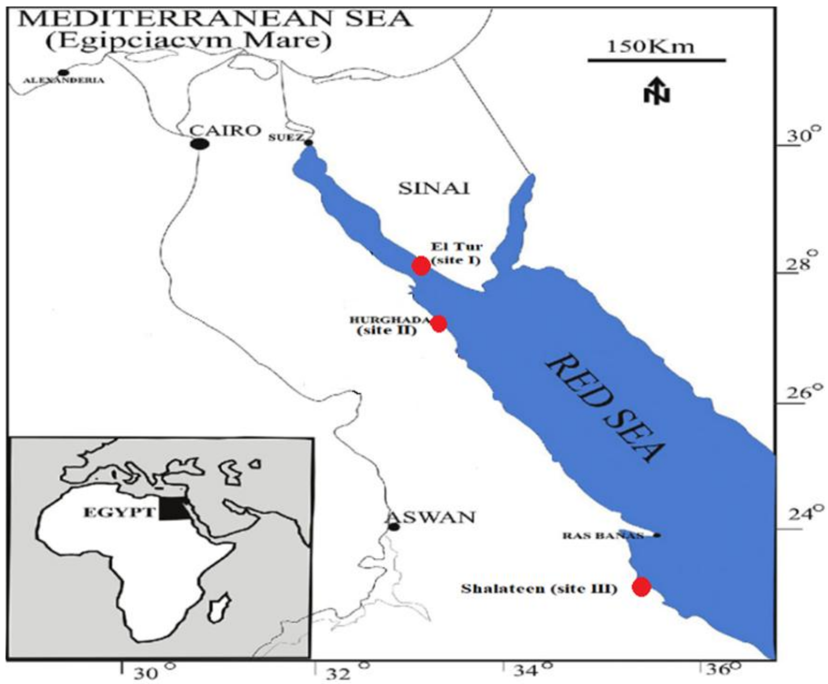

Fig. 1. A map of the Red Sea showing the study sites (fishing harbors El Tor, Hurghada and Shalateen) for sample collection

2. Sampling and data analysis

Random fish samples were seasonally collected (2020-2022) from the artisanal fishery at the three investigated sites. The artisanal fishery in the Egyptian waters of the Red Sea depends mainly on hooks and lines, trammels and gill nets. The grouper fish samples were identified with the help of standard reference books (**Randall, 1983; Randall & Ben-Tuvia, 1983; Heemstra & Randall, 1993; Myers, 1999; Craig *et al.*, 2011; Allen & Erdmann, 2012**). Each specimen was measured to the nearest cm and weighed to the nearest gram.

The present status of the collected grouper species was assessed in four categories on the basis of the availability of fish in the catches of the Red Sea: common (C) species found throughout the year; seasonal (S) species found seasonally; rare (R) species found sporadically, and very rare (VR) species found accidently.

Percentage abundance was used to determine the numerical dominance of species at each site. Tukey simultaneous 95% confidence level test was used to test the difference in numerical abundance of species among sites.

The species-site relationship was determined by the distribution area occurrence of different species (**Negi & Mamgain, 2013**) as follows:

Number of sites for each species x 100/total number of individuals of all species

The fish diversity index (H') was calculated as per the standard method (**Shannon-Wiever, 1949**).

The mathematical relationship between length and weight was described by the common equation $W = a L^b$ (**Ricker, 1975**), where W is the total weight in g; L is the total length in cm, and a and b are the constant parameters to be estimated.

RESULTS

1. Species diversity, abundance and distribution

Twenty grouper species were collected from the three investigated sites. Hurghada landings (site II) were the most diverse with 18 species, while Shalateen yielded 16 species, and El Tur was the least diverse landing site, with only 4 grouper species (Fig 2). On the other hand, the highest abundance of grouper individuals was recorded in Shalateen (49%), followed by Hurghada (35%), and the least number was collected from El Tur (16%).

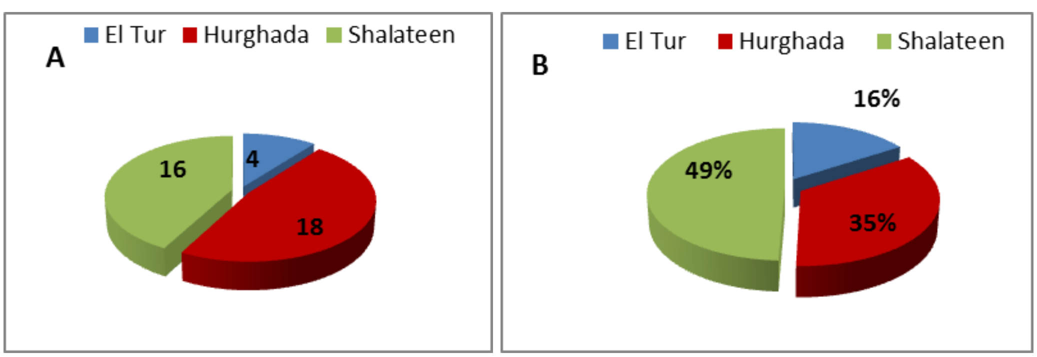

Fig. 2. Species richness (A) and percentage of individuals (B) at the different investigated sites

The collected grouper species belonged to six genera: *Epinephelus*, *Cephalopholis*, *Anyperodon*, *Plectropomus*, *Aethaloperca* and *Variola* (Table 1). The genus *Epinephelus* was the most represented in the samples, with 10 species, while the genera *Cephalopholis* and *Plectropomus* were represented by 5 and 2 species, respectively, and *Anyperodon*, *Aethaloperca* and *Variola* by only one species (Fig. 3). *Epinephelus* is the most abundant genus, comprising about 61.8% of the samples, followed by *Cephalopholis* (24.3) and *Plectropomus* (6%) (Fig. 4). The number of individuals per genus at different sites (Fig. 5) showed that *Epinephelus* is the most abundant genus at all studied sites, and it is the only represented genus in El Tur, southern Gulf of Suez. The genus *Cephalopholis* is more represented in Hurghada than Shalateen. The occurrence of the other four genera is higher in Shalateen than Hurghada (Fig. 5).

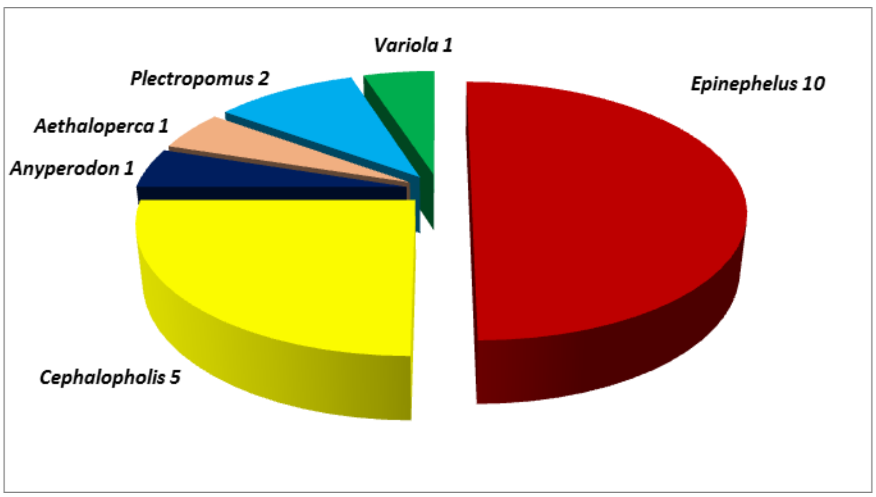

Fig. 3. Number of species in different Epinephelines genera in the Red Sea

Table 1. Relative abundance, distribution area of occurrence, availability status, and IUCN status of grouper species at different sites in the Red Sea

		Percentage occurrence					
		Site I Tur	Site II Hurghada	Site III Shalateen	Distribution area of % occurrence	availability status	IUCN status
Epinephelus	*tauvina*	11.97	13.08	12.70	0.336	C	DD
	polyphekadion		12.11	16.78	0.224	C	VU
	chlorostigma	26.06	9.00	7.03	0.336	C	LC
	summana	19.72	9.76	18.27	0.336	C	LC
	areolatus	42.25	3.76	0.91	0.336	C	LC
	fasciatus	0	3.22	0.68	0.224	R	LC
	morrhua			1.13	0.112	R	LC
	fuscoguttatus	0	0.32		0.112	VR	VU
	malabaricus	0	0.32		0.112	VR	LC
	coioides	0	0.32		0.112	VR	LC
Cephalopholis	*miniata*	0	20.23	13.93	0.224	C	LC
	argus	0	10.23	5.22	0.224	C	LC
	sexmaculata	0	0.96	0.23	0.224	R	LC
	oligostikta	0	6.72		0.112	S	LC
	hemistiktos	0		1.81	0.112	R	LC
Aethaloperca	*rogaa*	0	5.14	4.54	0.224	S	LC
Anyperodon	*leucogrammicus*	0	2.89	3.17	0.224	S	LC
Plectropomus	*maculatus*	0	0.32	4.31	0.112	S	LC
	areolatus	0	0.96	7.26	0.224	S	VU
Variola	*louti*	0	0.64	2.04	0.224	S	LC

Vulnerable (VU), Least Concern (LC) and Data Deficient (DD)

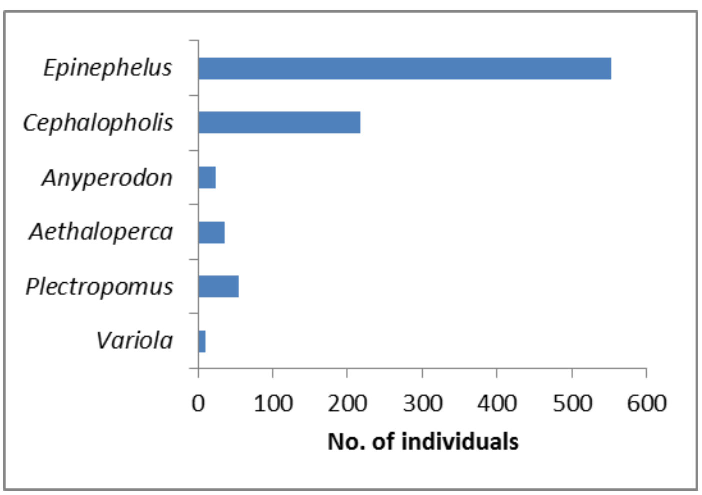

Fig. 4. Total number of collected grouper individuals in different genera

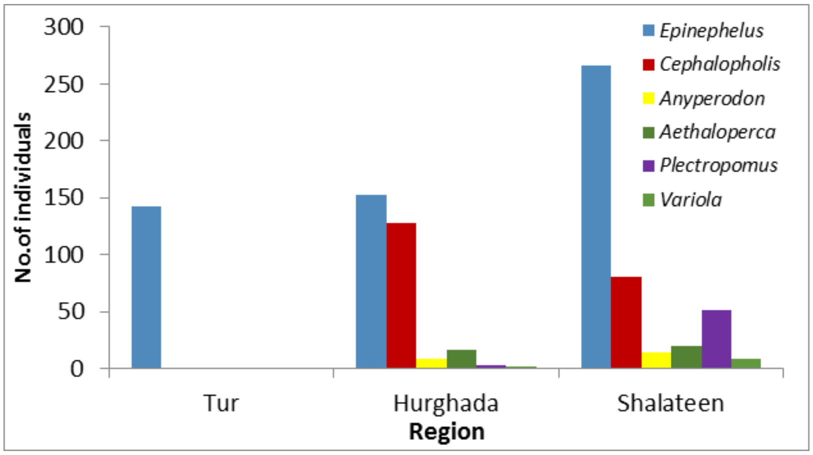

Fig. 5. Occurrence of different Epinephelines genera in the three investigated regions

The numerical abundance of species collected from the different sites varied slightly (*P*= 0.105). At El Tur, the ereolate grouper *E. areolatus* was numerically the most abundant (42.3%) in the catch, followed by the brownspotted grouper *E. chlorostigma* (26.1%) and the summana grouper *E. summana* (19.7), then the least abundant was *E. tauvina* (12.0%) (Table 1) (Fig. 6).

In Hurghada, the most commonly landed species was *C. miniata* (21.2%), followed by *E. polyphekadion* (15.1), *E. tauvina* (13.1) and C. *argus* (11.2). The other species collected from Hurghada were represented by <10% of the samples, with six species having a very low relative abundance (< 1%) (Table 1) (Fig. 6). *E. summana* was the most abundant species in Shalateen, comprising about 19.3%. *E. areolatus*, *E. fasciatus*, and *C. sexmaculata* were the least abundant by a percentage <1 (Table 1) (Fig. 6).

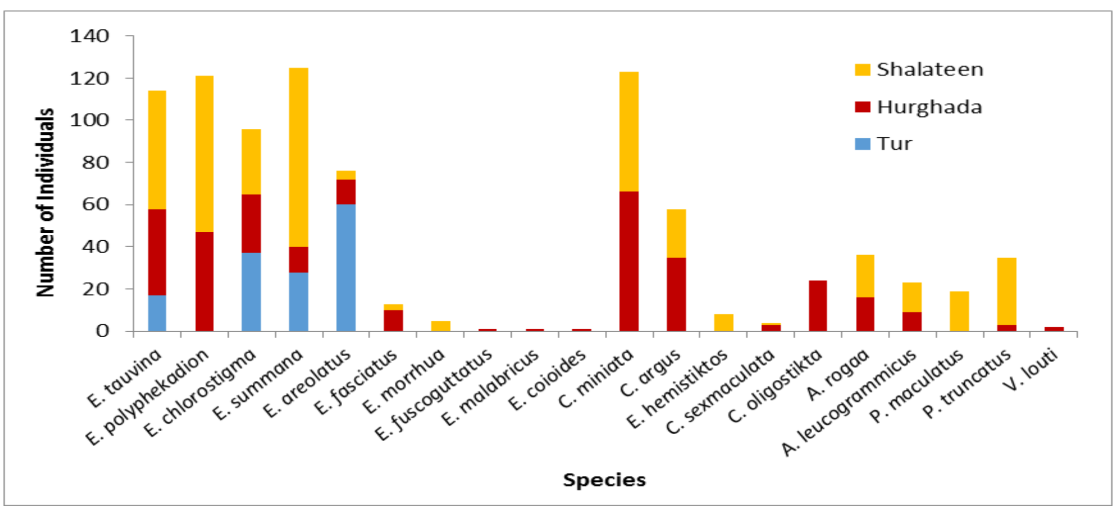

Fig. 6. The numerical abundance of grouper species collected from the three different sites

The Shannon-Wiener diversity index of the three different sampling sites indicated a strong relationship with overall species richness, ranging from 0.56 to 1.02. The highest grouper fish diversity was recorded at site II (1.022), followed by site III (1.015) and site I (0.560).

2. Availability and status of the grouper species

In the present study, the twenty grouper species were categorized into four status levels according to their availability. It was found that seven species (35%) were common; six were seasonal (30%); four were rare (20%), and three species were very rare (15%) (Table. 1).

According to IUCN (2018), three of the recorded grouper species in the Red Sea (*E. polyphekadion*, *E. fuscoguttatus* and *Plectropomus areolatus*) have been declared vulnerable (VU), 16 species are least concern (LC), and one species (*E. tauvina*) is data deficient (DD) (Table 1).

3. Length weight relationship

For estimating the weight- length relationship, 845 grouper individuals representing the most abundant 15 species were used; the rest of the species (5 species) were represented by very low numbers. For 10 species (66.7% of the total), this is the first estimate of length weight constants in the Egyptian Red Sea (marked by a star in Table (2).

The results of the regression analysis, together with the descriptive statistics are shown in Table (2). All regressions are significant ($P < 0.05$), with a coefficient of determination (r^2) higher than 0.90 for all species. Eight species exhibited isometric growth: six were positive allometric, and only one species (*Aethaloperca rogaa*) was characterized by negative allometric growth. The values of the exponent (b) varied from 2.865 (*A. rogaa*) to 3.455 (*V. lotti*), with the mean b equal to 3.097. The frequency distribution of the b values ranged from 1 to 4, as shown in Fig. (7).

Table 2. Length-weight relationship for 15 grouper species from the Red Sea

Species	No.	Length(cm) Min - Max	Weight(gm) Min - Max	A	95% CI of a	b	95% CI of b	Residual standard error	r^2
E. Tauvina	114	23.6-62.0	189.5-3137.0	0.012	0.006-0.024	3.021	2.383-3.204	0.664	0.907
*E. polyphekadion**	121	20.2-47.8	120.0-2109.0	0.013	0.008-0.019	3.075	2.958-3.193	0.248	0.958
E. chlorostigma	96	13.9-64.8	175.8-4480.0	0.018	0.011-0.029	2.967	2.827-3.107	0.467	0.949
*E. summana**	125	19.7-65.5	118.0-4365.0	0.011	0.079-0.014	3.113	3.033-3.192	0.208	0.980
E. areolatus	76	11.2-50.5	21.2-1944.0	0.014	0.011-0.019	2.995	2.958-3.026	0.432	0.981
E. fasciatus	13	21.1-29.8	136.9-422.4	0.010	0.025-0.042	3.124	2.688-3.560	0.007	0.958
C. miniata	88	17.4-42.1	75.6-1367.0	0.014	0.071-0.027	3.047	2.843-3.251	0.499	0.911
*C. argus**	58	21.0-41.0	146.5-1471.6	0.078	0.044-0.014	3.223	3.051-3.395	0.090	0.960
*C. oligostikta**	23	23.2-35.1	178.7-681.7	0.016	0.046-0.057	2.989	2.605-3.373	0.021	0.930
*C. hemistiktos**	8	16.2-21.5	66.2-153.7	0.018	0.070-0.048	2.938	2.599-3.277	0.001	0.987
*A. rogaa**	36	17.5-42.4	102.9-1513.0	0.027	0.014-0.051	2.865	2.672-3.059	0.092	0.964
*A.leucogrammicus**	22	32.8-54.5	459.3-2511.0	0.011	0.025-0.050	3.036	2.634-3.438	0.035	0.922
*P. maculatus**	19	23.9-53.4	186.0-2238.6	0.084	0.045-0.014	3.156	2.992-3.320	0.024	0.990
*P. areolatus**	35	23.1-54.0	131.2-2649.2	0.029	0.015-0.053	3.445	3.275-3.616	0.059	0.981
*V. louti**	11	22.5-44.0	95.1-843.6	0.019	0.009-0.039	3.455	3.248-3.664	0.014	0.990

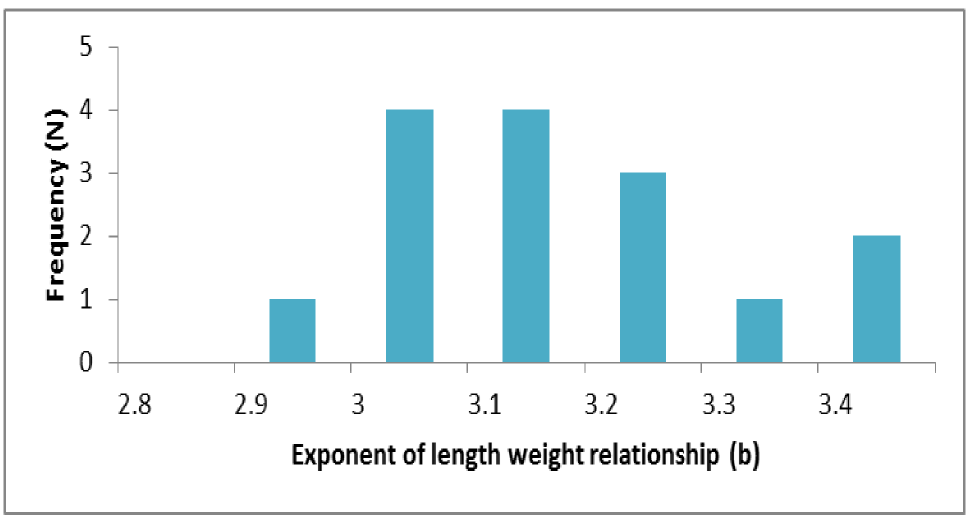

Fig. 7. The frequency distribution of the exponent (b) of the length- weight relationship of grouper species from the Red Sea

DISCUSSION

Despite the commercial and ecological importance of groupers in the Red Sea, very little is known about their diversity and biology in the area. Groupers form a sizable portion of the small- scale artisanal reef fishery recorded landings of all grouper species with 2370 ton in 2017, constituting about 4.7% of all fish landings from the Egyptian sector of the Red Sea (**GAFRD, 2018**). The morphological identification based on **Randall and Heemstra (1991)**, **Heemstra and Randall (1993)**, **Myers (1999)**, **Craig *et al.* (2011)** and **Allen and Erdmann (2012)** revealed the presence of 20 epinephelines species belonging to seven genera in the Red Sea of Egypt. **Randall (1983)** and **Randall and Ben-Tuvia (1983)** recorded 22 serranid species in the Red Sea. **Saleh *et al.* (2019)** recorded 16 grouper species in the Gulf of Aqaba, the northernmost eastern extension of the Red Sea. Our morphological identification was confirmed by **Galal-Khallaf *et al.* (2019)**, who used mitochondrial DNA variations, applied cytochrome oxidase subunit I (COI), and 12srRNA genes sequencing. GenBank comparisons, phylogenetic analyses and comparisons of pairwise distances studied species authentication and identified their relations at the international scale. Their results exhibited > 98% identity with *E. fasciatus*, *A. rogaa*, *C. oligosticta*, *E. areolatus*, *V. louti*, *P. areolatus*, *E. malabaricus*, *C. sexmaculata*, *E. summana*, *E. chlorostigma*, *E. polyphekadion*, *C.miniata*, *A. leucogrammicus*, *E. tauvina*, *C. argus* and *C. hemistiktos*.

For the total 20 grouper species collected from the Egyptian Red Sea, Hurghada in the north of the Red Sea had the highest diversity of groupers (18species), followed by Shalateen in the South (16 species), and then the least diversity was recorded in the El Tur, the northernmost site, with only 4 grouper species. The lower diversity rate in El Tur may be explained by the fact that the fringing reefs at the El Tur are vulnerable to breakage caused by destructive fishing practices and boat anchoring (**El Ganainy *et al.*, 2008)**. There is evidence that reefs can support abundant and diverse fish assemblages as long as reef structure is maintained (**Lindahl *et al.*, 2000**).

Higher percentage occurrences of *Epinephelus polyphekadion*, *E. summana*, and *Plectropomus areolatus* were recorded at Shalateen, while at Hurghada, *E. tauvina*, *C. miniata* and *C. argus* were the most abundant. *E. areolatus* and *E. chlorostigma* were the dominant grouper species in El Tur region. The spatial variation in grouper diversity may be due to differences in fishing pressure, habitat characteristics or variability in recruitment (**Agembe *et al.*, 2010**). Fishing in the Red Sea is dominated by small-scale artisanal activities, hand lines, long lines, and to a lesser extent, gill- and trammel- nets employed in addition to some beach seines and cast nets. 155 boats are licensed to land their catch at El-Tur, 744 in Hurghada, and 200 in Shalateen (**El Ganainy, 2017**). This variation in the number of vessels (as an index of fishing effort) may play an important role in the spatial grouper diversity in the Red Sea. Groupers are high –site- fidelity sedentary fish, often around coral heads (**Kaunda-Arara and Rose 2004**), a feature that makes their distribution dependent on the complexity of their environment. In addition, site fidelity and spawning of certain species in aggregations render them susceptible to fishing mortality owing to their abundance and distribution being predictable (**Domeier & Colin, 1997**). Most Red Sea groupers spawn in aggregations locally called "farshat". The sites of these aggregations are well identified for the most economically commercial species (*E. tauvina*, *C. miniata* and *C. argus),* and most of the aggregation sites are recorded around the small islands near Hurghada and Shalateen (**El Ganainy, 2017**); this behavior could influence the spatial variations observed in species diversity and sample sizes between the three sites. The highest grouper abundance recorded in Shalateen may be attributed to the fact that Shalateen is the least exploited area in the Egyptian Red Sea (**Abdallah, 2019**).

E. tauvina and *E. summana* are common and abundant in the waters of the three studied sites; this may be attributed to the fact that these two species are resident in the Red Sea, and the geographical distribution of *E. summana* is restricted to the Red Sea and Gulf of Aden (**Rhodes & Tupper, 2008**). It can also be due to the overall similarity in the geospatial distribution of the fringing reef along the Red Sea (**Sanders & Morgan, 1989**). Although El Tur (site I) shares a similar reef structure with the other two sites, the low diversity in El Tur may be due to the excessive fishing pressure exerted on the associated reef fisheries at this site (**Sanders & Morgan, 1989; Ahmed & El Ganainy, 2000; El Ganainy & Ahmed, 2002**).

According to the International Union for Nature Conservation (**IUCN, 2018**), one of the recorded species (*C. hemistiktos*) is declared as least concern (LC). This species has a disjoint distribution, including the northern Red Sea, the southern Gulf of Adden and the Arabian Gulf. It is found in relation to patchily distributed coral reefs, and it is subject to overfishing and habitat destruction (**Choat *et al*., 2008a, b**). The species is a slow growing species, with a long life span of 20 (**Grandcourt *et al.* 2013**) to 26 years (**Matthews & Samuel 1987**), and late sexual maturation (13 years) (**Grandcourt *et al.*, 2013**). Three of the recorded species in the Red Sea have been categorized as "vulnerable" and in critical need of conservation. These are *P. areolatus, E. polyphekadion* and *E. fuscoguttatus.* Based on the **IUCN (2018)** database, the major threats to these species are overfishing by commercial and recreational fisheries, spawning aggregation sites and timing are often widely known by fishers and easily accessed in outer reef passages, which increase their susceptibility to exploitation (**Sadov *et al.*, 2012**).

Other grouper species are identified by the IUCN as "least concern" or ¨data deficient¨, mainly due to their wide geographical distribution, cryptic nature, and/or lack of adequate regional fisheries data (**Galal Khallaf *et al.*, 2019**). Overfishing and habitat loss, mainly due to coral bleaching events, are the major threats for *E. fasciatus, E. chlorostigma, E. areolatus, E. tauvina, E. summana, E. epistictus, E. malabaricus, A. rogaa, C. sexmaculata, C. oligosticta, C. miniata, P. maculatus, C. argus, A.*

leucogrammicus and *V. louti* (**Sheppard, 2003; Cabanban *et al.*, 2008a, b; Choat *et al.*, 2008a, b; Fennessy *et al*., 2008; Heemstra *et al*., 2008a, b; Kawabe & Kohno, 2009; Liu & Choat, 2008; Rhodes *et al.*, 2008)**.

Length-weight relationships (LWR) of fish serve as building blocks in ichthyology and fishery science (**Edelist, 2012**). Length-weight relationships have important implications for fisheries science and population dynamics (**Erzini, 1994**). This information is necessary in stock assessment models (**Morato *et al.*, 2001**). It is commonly used in the ecosystem modeling approach (**Christensen & Pauly, 1992; Christensen & Walters, 2004)**. For more precise weight estimates, it is advisable to make use of local values (**Moutopoulos & Stergiou, 2002; Morey *et al.*, 2003**). Most of the length- weight relationships reported in this study agree with those obtained previously for *E. fasciatus*, *E. chlorostigma*, *E. areolatus*, *E. tauvina* and *C. argus* in different localities (**Mathews, 1987; Currey *et al.*, 2010; Kandula *et al.*, 2014; Kanikawa *et al.*, 2015**). However, some species, such as *E. fasciatus*, *C. miniata*, *A. leucogrammicus*, *P. maculatus*, and *V. louti* showed different b values than those obtained by **Letourneur *et al.* (1998)**, **Mapleston *et al.* (2009)** and **Palla *et al*. (2018**) in other Indo-Pacific regions. These variations may be due to differences in the number of sampled specimens, narrower or wider size ranges, and/or different sampling environments.

The present study showed high grouper diversity in the Red Sea. The results would contribute to build a biological database of grouper populations in the Red Sea, and the estimated length - weight parameters for 15 species are useful for modeling the grouper stocks, which would help in the proper management of these valuable resources.

Declaration of competing interest

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

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