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Length weight relationships of demersal reef fishes from south west coast of India

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Original Article

Abstract

Length weight relationship of thirteen demersal reef fish species in three genera in two families Serranidae and Lutjanidae from northern Arabian Sea was estimated. A total of 7344 specimens from the thirteen species were used for the study. Sample sizes ranged from 25 to 4428 mm with the smallest sample size being that of *Cephalopholis sonnerati*. New maximum length was estimated for *Epinephelus areolatus, Pristipomoides typus* and *Pinjalo lewisi*. Significant differences in the slopes of length weight relationships between males and females for *Epinephelus diacanthus,* was observed. Fishes studied are in the Least Concern (LC) category in the IUCN list.

Keywords*: Length weight, groupers, LWR, maximum length, snapper, conservation, IUCN status*

Introduction

Global capture fisheries production reached 96.4 million t in 2018, an increase of 5.4% compared to the last three years average. This rise was mostly from marine capture fisheries, which contributed to an increase of 3.2 t during 2017-18, an increase from 81.2 million t in 2017 to 84.4 million t in 2018 (FAO, 2020). Among the threats to marine resources, overfishing has often been highlighted as a major contributor to population decline and yet fishing effort increased globally over the past decade (Sadovy *et al*., 2020). Groupers are one of the most popular commercial marine fish species worldwide which are susceptible to fishing pressure due to their biological characteristics (Sadovy *et al*., 2012, 2020; Lee and Sadovy, 1998; Rhodes and Tupper, 2000). Intense harvesting of wild caught groupers and snappers have resulted in decreased production over the last decade (Rhodes *et al*., 2008). Snapper and groupers are caught by a variety of gears including hooks and line, bottom longline, traps, gillnets, and trawl. In certain areas, excessive use of traps for collecting species for Capture Based Aquaculture (CBA) has caused severe negative impacts on juveniles, as well as on habitats and fish stocks. International status of these commercially exploited groups is known due to the recently concluded work by IUCN the Barometer of Life (Sadovy *et al*., 2020). However, the country status of many snapper and grouper stocks is unknown, particularly in the multispecies small-scale fisheries in developing countries where national species wise reporting systems are absent or insufficient, and often categorised as miscellaneous catch. There is lack of effective management in many nations where snapper and grouper are harvested from wild. The life history characteristics of many snapper and grouper species (*eg.* slow growing, late maturing, seasonal spawning aggregations) make them particularly susceptible to overexploitation. National-level policies, no take zones, spawning area protection and management is needed to ensure sustainability of widespread stocks of snapper and grouper. In general, the possible effects of the snapper and grouper fisheries on coral reefs and interactions with the ecosystem are not well understood. Studies on the biology and ecology of different grouper species can assist precautionary management decisions since we know that larger, longer-lived, species may be those most vulnerable to fishing and that aggregation-spawning species are particularly susceptible to overfishing (Sadovy *et al.*, 2020).

India's marine fish production showed signs of revival in 2017 with the annual marine fish landings registering a 5.6% increase compared to the previous year. The total fish landing in the country stood at 3.69 million t in 2019. Total landings of groupers in India were relatively stable from 2007 to 2013, but increased from 2013. The increase was especially due to increased landings in Gujarat, Karnataka and Kerala on the west coast and Tamil Nadu and Andhra Pradesh on south east coast (Nair, 2018 a, b). The increase in landings is partially due to the high market value commanded in export sector. In the fiscal year 2019, the export value of fish and fishery products from India amounted to over 476 billion Indian rupees (MPEDA, 2019). An estimated 26508 t of rock cods and 10246 t of snappers was landed in the country in various harbours during the year (CMFRI, 2020). Kerala which lies between northern latitude of 8°.17'.30"N and 12°.47'.40" N and east longitudes 74°.27'.47" E and 77°.37'.12" E. has the prominent harbours of Cochin and Munambam along with Neendakara on the South Kerala for groupers and snappers. It has supported a variety of fishing activities for a long time with the reef fishery being high during the post monsoon and extending into the early part of the year up to March.

Around 42 species of groupers (Nair and Kuriakose, 2014) and 62 species of snappers (Nair *et al.*, 2014) have been reported from Indian waters. Length weight data are primary information generated from fish sampling methodologies and the length weight relationship (LWR) is predominantly useful to estimate the average weight for a given length group, where length measurement is converted into weight particularly in the case of the large-sized fishes in the field or on-board vessels where technical difficulty exists in weighing, (Froese, 2006; Froese and Pauly, 2011). Length-weight relationship (LWR) can also be used for deriving comparisons between different stages in life history, to compare fish populations from different regions, different habitat groups (Petrakis and Stergiou, 1995; Gonçalves *et al.*, 1997) tracking seasonal variations in fish growth (Richter *et al.*, 2000) as an important character for differentiation of taxonomic units; in setting up of yield equations (Beverton and Holt, 1957) and assessing the data that contains only length frequency measurements and thus serves as an important fishery management tool in fisheries biology and stock assessments in all water bodies. LWR also enables the determination of fish age, structure and health by providing various facts about its seasonal cycles and influential aspects of the biotic and abiotic factors (Ayoade and Ikulala, 2007). This is because an average fish weight of a given length group can easily be estimated by establishing a mathematical relation between length and weight parameters (Beyer, 1987; Erzini 1994; Garcia *et al.*, 1998; Haimovici and Velasco, 2000) and are therefore a pre-requisite for assessing the population characteristics of fishes (Le Cren, 1951).

Although over 276 species are reported in the commercial fishery of Kerala, very few papers deal with length weight relationship of these species from the waters of the south west coast of India. Literature survey revealed only few studies addressing biometrics of fish in Kerala waters (Roul *et al.*, 2017 a, b; 2018); however still very few on groupers of India (Premalatha, 1989; Ameer Hamsa and Mohamad Kasim, 1992; Chakraborty, 1994; Rangaswamy *et al.*, 1999; Govindraju *et al.*, 2004; Manojkumar, 2005; Sivakami and Seetha, 2006; Sujatha *et al.*, 2015; Nair *et al.*, 2017) and snappers (Mathew, 2003; Velamala *et al.*, 2019). The present investigation forms part of the biological studies on commercial reef fish species being exported from Kochi. The length weight parameters are reported for these commercial fish species caught in the commercial trawls. Hence, the aim of this study was 1) to estimate LWRs for 13 fish species (including, three genera of Serranidae and three genera of Lutjanidiae namely *Pristipomoides, Pinjalo* and *Lutjanus* species) and 2) will enhance management and conservation, and allow future comparisons between populations of the same species.

Material and methods

Fishes were collected on weekly basis from Cochin Fisheries Harbour (Lat. 09°56'327"N, Long. 76°15'764"E), Munambam Fisheries Harbour (Lat. 10°10'965"N, Long. 76°10'258"E) and Kalamukku (Lat. 09°59'924"N, Long. 76°14'564"E) Fisheries Harbour (Fig. 1).

A total of thirteen species in three genera in two families Serranidae and Lutjanidae were collected during the period of April 2012 to March 2017. Length weight data were collected both from the field as well as from fishes brought to the laboratory from the fishes landed from the three harbours in Kerala. All morphometric measurements were conducted

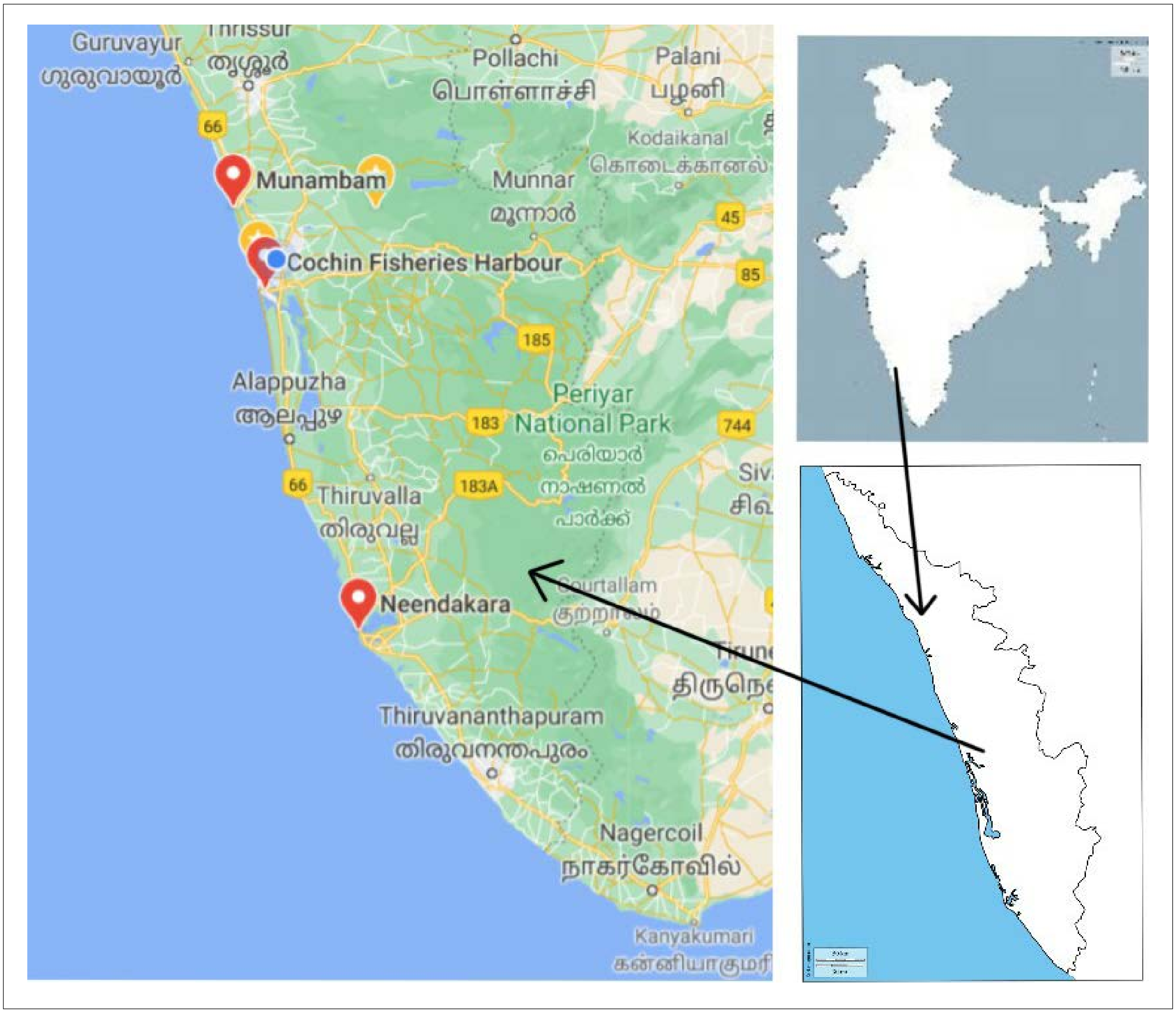

Fig. 1. Location of sample collection along Central Kerala

according to Froese and Pauly (2011). The total samples comprised of the fishes *Epinephelus longispinis, Epinephelus areolatus, Epinephelus diacanthus, Variola louti, Epinephelus chlorostigma, Cephalopholis sonnerati* in the Family Serranidae and *Lutjanus lutjanus, Lutjanus kasmira, Pristipomoides filamentosus, Pristipomoides typus, Pinjalo lewisi, Lutjanus gibbus, Lutjanus bohar* in the Family Lutjanidae. These fishes are caught mainly with gillnets, hooks and line and the juveniles in trawl nets. Each specimen was identified to species level in the field as well as in laboratory by using standard text books. (Allen, 1985; Heemstra and Randall, 1993; Craig *et al.*, 2011; Nair and Kuriakose, 2014).

Biometric measurements of each fish was taken. The length measurement such as total length (TL) was taken using a digital Vernier caliper with 0.1 cm accuracy and measurements over 300 mm were taken using measuring tape. The total body weight (TW) was taken by an electronic weighing balance with 0.1 g accuracy.

Data analysis

Calculations for combined sexes, female and male fish specimens were done after Le Cren (1951). The sexes were noted and data tabulated sex wise. Where only few numbers of the species were collected, data for both sexes were pooled to ascertain the length weight relationship. Length weight relationship is expressed as

$W = a\,L^{b}$ ……. (Equation 1) (Froese, 2006; Froese *et al.*, 2014)

in the usual notations

In order to linear the data, log transformed equation was used

Log W = Log a + b log L……………………….. (Equation 2)

in the usual notations

Statistical analysis

The parameters a & b were estimated by linear regression on the Log-transformed (Log10) equation log (W) = log (a) + b log (L). To evaluate the statistical significance of the regression in the LWRs data, ANOVA was used for $P < 0.05$ and the b-value for each species was tested by t-test to verify that it was significantly different from the predictions for isometric growth (b = 3). The power of the relationship was calculated r^2 (coefficient of determination). The coefficient of determination (r^2) is a measure of the quality of a linear regression's prediction (a value close to 1 means a better model). All the calculated values were converted in to the logarithmic form for excluding the outlier values. All statistical analysis was carried out using Windows Excel. The length and weight were log transformed and the resulting linear relationship was fitted by the least square regression using the independent variable. Analysis of variance (ANOVA) was used to test the significance of the regression.

IUCN Red List status

Fishes were also evaluated for their Red List categories as per International Union for Conservation of Nature (IUCN) status and criteria followed. The Red List Index (RLI) shows trends in overall extinction risk for species, and is used by governments to track their progress towards targets for reducing biodiversity loss (IUCN, 2020) (Table 2).

Results and discussion

A total of 7344 specimens from thirteen species in six genera belonging to two families Serranidae and Lutjanidae were used for the study. Sample sizes ranged from 25 to 4428 mm with the smallest sample size being that of *C. sonnerati* a rare reef associated fish seen occasionally in the landings and the largest being that of *E. diacanthus* the Spinycheek grouper. (Table 1). Size range also showed variations since *E. diacanthus* was available both in the trawler landings as well in hooks and line and gill nets. Fishes like *L. lutjanus* and *L. kasmira* are small in size, while fishes like *P. filamentosus* and *P. typus*, *L. gibbus* and *L. bohar* were extremely larger to sample for detailed biology and hence lesser proportion in sexes were observed. Juveniles of groupers like *E. diacanthus* are also exploited by trawlers, while bigger fishes *E. diacanthus*, *P. typus, L. gibbus, L. kasmira, L. argentimaculatus* are exploited by hooks and line. The smallest fish sampled was *L. lutjanus* of weight 6 g and length 79 mm and the biggest fish was *L. bohar* weighing 8.3 Kg with a length of 890 mm. This was close to the maximum length (90 cm) recorded for this species (Frimodt, 1995). Nair and To (2018) reported the maximum total length for *E. areolatus* as 47 cm and maximum weight as 1.4 kg. The earlier reported size in the fishery for *E. areolatus* was 19-32 cm from the commercial fishery from India (Sujatha *et al.*, 2015). In the present study new maximum lengths and weight has been reported for *E. areolatus* (49.5 cm; 1.5 kg) and *P. typus* (730 mm; 2.2 kg) and the maximum reported length (90 cm) for *P. lewisi.* Groupers, which are protogynous hermaphrodites, begin life as females and subsequently become males in most populations (Huntsman and Schaaf, 1994) and therefore in most sampled populations, males are fewer in number (Shapiro, 1987). Sex changing species may be more susceptible to heavy fishing pressure than gonochoristic fishes (Levin and Grimes, 2002). Fisheries targeting large individuals of grouper stocks or generally heavy fishing pressure that potentially leads to overfishing differentially reduce the number of male fish in protogynous groupers (Alonzo and Mangel, 2004).

The theoretical value of 'b' (regression coefficient) in a length-weight relationship is said to be 3 and the growth is said to be isometric *ie.*, when the shape of the fish remains constant at different lengths. In the present study, the length-weight relationships (LWRs) was calculated by using cubic law as suggested by Le Cren (1951) for the analysis of values of b. If $b<3$ then fish growth is negatively allometric and if $b>3$ then growth is positively allometric. In the present study the b value for *E. longispinis* is 3.28. Gayanilo and Pauly (1997) mentions that due to ecological changes 'b' values of fish species deviate from normal range. In this study, the values of 'b' showed positive allometry in the growth of male, female and combined sexes of *E. diacanthus* (Table 2). In the present study, the estimated b values for the serranid species of *E. longipinis* ranged from 2.7 to 3.6, with male fishes showing a lower b value. The b value of *E. areolatus* ranged from 2.95 to 3.2 and *E. diacanthus* were all in 3.1 range. In *V. louti* and *C. sonnerati* the b values were within the 3.1-3.2 range; however, it was less for *E. chlorostigma*. In snappers, for *P. typus*, b values were lesser than 2.5. For all the other species studied, the values were between 2.5-3.5. The b for all the 13 species fluctuated between 2.8 to 3.2 as can be seen in the Box whisker plot (Fig. 2). The mean value was 2.96 (+/-0.96) with a minimum value of 2.3 for *P. filamentosus* and maximum value of 3.6 for *V. louti*. Sujatha *et al.* (2010) examined length-weight relationship in *E. epistictus, E. magniscuttis, E. latifasciatus* and *E. radiatus* collected from east coast of India. In this case b-value for *E. epistictus* showed negative allometric growth, b-values for *E. magniscuttis* and *E. radiatus* showed positive allometric growth and isometric growth in case of *E. latifasciatus.* When *b* is greater than 3.0, fish becomes heavier showing a positive allometric growth and this reflects optimum conditions for growth.

Table 1. Number, length, weight and sex of species sampled at the study sites

Species		Number (n)	Length range (mm) Min (mm)	Max (mm)	Mean L (mm)	Max Length (TL cm)*	Wt (g) range Min (g)	Max (g)	Mean Wt (g)
Epinephelus longispinis	Pooled	210	270	455	361	55	260	1525	766
	Female	192	270	455	360		260	1515	757
	Male	16	280	440	363		323	1525	779
Epinephelus areolatus	Pooled	375	193	495	342	47	75	1497	514
	Female	269	193	475	335		75	1326	484
	Male	101	205	495	362		102	1497	601
Epinephelus diacanthus	Pooled	2214	135	500	274	55	41	1976	350
	Female	1927	135	485	271		58	1925	336
	Male	286	165	500	297		60	1976	442
Variola louti	Pooled	138	215	640	435	83	100	3380	1033
	Female	74	215	565	411		100	1856	829
	Male	21	310	495	404		315	1497	784
Epinephelus chlorostigma	Pooled	63	233	427	342	63	204	370	543
Cephalopholis sonnerati	Pooled	25	189	275	233	57	100	370	211.8
Lutjanus lutjanus	Pooled	147	79	295	177	35	**6**	362	113
	Female	33	165	292	226		71	351	170
	Male	53	164	295	235		65	362	191
Lutjanus kasmira	Pooled	146	153	270	223	40	50	309	164
	Female	43	153	270	213		50	309	142
	Male	102	172	265	228		70	265	174
Pristipomoides filamentosus	Pooled	123	280	725	411	100	245	4855	855
	Female	72	280	563	406		245	1954	801
	Male	49	306	725	417		320	4855	938
Pristipomoides typus	Pooled	100	280	730	471	70	305	3578	1187
	Female	53	280	720	461		305	3578	1143
	Male	47	285	730	484		330	2580	1237
Pinjalo lewisi	Pooled	85	299	498	371	50	400	1700	782
	Female	36	299	475	363		405	1490	716
	Male	49	300	498	376		400	1700	830
Lutjanus gibbus	Pooled	205	210	440	330	50	175	1035	523
Lutjanus bohar	Pooled	90	255	890	553	90	271	8300	3235

*Froese, R. and D. Pauly. Editors. 2019. FishBase.

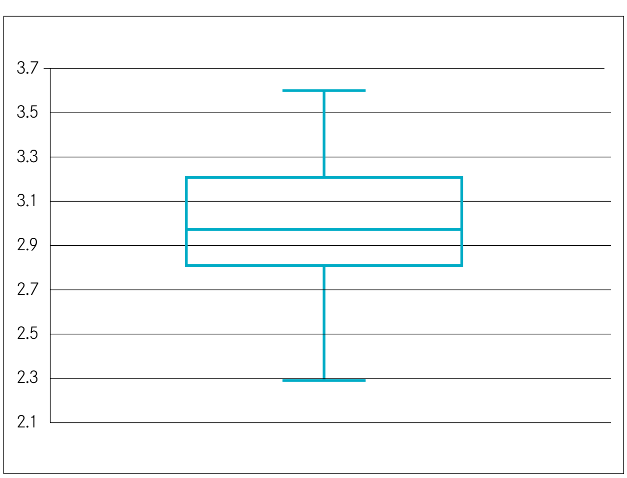

Fig. 2. Box-Whiskers plots of the exponent b of length-weight relationships for 13 fish species studied

The exponent value of 3 for any particular species indicates that the fish is growing isometrically and the environmental conditions are conducive for optimum growth. Apart from this, some fishes like *P. typus* and *L. gibbus* did not attain the coefficient 3 showing disproportional growth between length and weight, and this can be attributed to environmental factors which inhibit growth (Swain, 1993), frequency of more immature individuals in the population and to food availability (Andrian and Barbeiri, 1992). Beverton and Holt (1957) opined that since 'a' and 'b' of allometric formula might vary within a wide range for very similar data and are very sensitive to even slight variations in various factors, allometric formula worked better than cubic formula. A survey of literature reveals that the regression coefficient exhibits inter and intra-specific variations. Mathew (2003) had worked on the length-weight relation of *P. typus* (pooled) ranging in length from 21.5-34.9

Table 2. Descriptive statistics and the estimated length weight relationship parameters of groupers and snappers sampled in the Northern Arabian Sea

Species		Parameters								Growth rate
		a	a (95% CI)		b	b (95% CI)				
			Lower	Upper		Lower	Upper	r^2	IUCN status	
Epinephelus longispinis	Pooled	2.9E-06	1.59E-06	5.27E-06	3.28	2.73	3.05	0.951	LC	positive allometry
	Female	3.36E-06	1.81E-06	6.25E-06	3.26	3.15	3.36	0.951		positive allometry
	Male	2.85E-06	3.47E-07	2.35E-05	3.28	2.93	3.64	0.965		positive allometry
Epinephelus areolatus	Pooled	7.12E-06	4.96E-06	1.02E-05	3.2	3.03	3.15	0.963	LC	positive allometry
	Female	7.68E-06	5.2E-06	1.13E-05	3.1	3.01	3.15	0.968		positive allometry
	Male	7.55E-06	3.37E-06	1.7E-05	3.1	2.95	3.22	0.952		positive allometry
Epinephelus diacanthus	Pooled	8.93E-06	7.96E-06	1E-05	3.1	3.06	3.1	0.975	LC	positive allometry
	Female	9.08E-06	7.99E-06	1.03E-05	3.1	3.05	3.1	0.972		positive allometry
	Male	9.88E-06	7.84E-06	1.25E-05	3.1	3.02	3.1	0.987		positive allometry
Variola louti	Pooled	2.31E-06	1.23E-06	4.34E-06	3.3	3.15	3.36	0.965	LC	positive allometry
	Female	3.39E-06	1.58E-06	7.24E-06	3.2	3.1	3.3	0.972		positive allometry
	Male	3.04E-07	4.02E-08	2.3E-06	3.6	3.3	3.9	0.963		positive allometry
Epinephelus chlorostigma	Pooled	0.000885	8.39E-05	0.009338	2.3	1.9	2.7	0.820	LC	negative allometry
Cephalopholis sonnerati	Pooled	1.63E-06	9.48E-06	2.79E-07	3.4	3.1	3.7	0.954	LC	positive allometry
Lutjanus lutjanus	Pooled	9.81E-06	8.32E-06	1.16E-05	3.1	3.0	3.1	0.995	LC	positive allometry
	Female	5.03E-05	2.14E-05	0.000118	2.8	2.6	2.9	0.976		negative allometry
	Male	7.8E-05	4.2E-05	0.000145	2.7	2.6	2.8	0.977		negative allometry
Lutjanus kasmira	Pooled	1.85E-05	1.04E-05	3.29E-05	3.0	2.9	3.1	0.954	LC	negative allometry
	Female	8.76E-06	3.02E-06	2.54E-05	3.1	2.9	3.3	0.960		positive allometry
	Male	5.13E-05	2.37E-05	0.000111	2.8	2.6	2.9	0.937		negative allometry
Pristipomoides filamentosus	Pooled	1.33E-05	7.74E-06	2.29E-05	3.0	2.9	3.1	0.972	LC	negative allometry
	Female	1.37E-05	6.97E-06	2.68E-05	3.0	2.9	3.1	0.975		negative allometry
	Male	1.32E-05	5.19E-06	3.36E-05	3.0	2.8	3.1	0.969		negative allometry
Pristipomoides typus	Pooled	0.000597	0.000261	0.001365	2.3	2.2	2.5	0.923	LC	negative allometry
	Female	0.000444	0.000142	0.00139	2.4	2.2	2.6	0.927		negative allometry
	Male	0.00095	0.000267	0.003382	2.3	2.1	2.5	0.915		negative allometry
Pinjalo lewisi	Pooled	2.52E-05	1.15E-05	5.52E-05	2.9	2.8	3.0	0.958	LC	negative allometry
	Female	4.69E-05	1.11E-05	0.000198	2.8	2.6	3.1	0.941		negative allometry
	Male	1.000025	8.05E-06	5.6E-05	2.9	2.8	3.1	0.965		negative allometry
Lutjanus gibbus	Pooled	0.000216	9.81E-05	0.000476	2.5	2.4	2.7	0.930	LC	negative allometry
Lutjanus bohar	Pooled	1.85E-05	1.32E-05	2.58E-05	3.0	2.9	3.0	0.996	LC	negative allometry

a: intercept; b: slope of relationship; CI: confidence interval; r^2: coefficient of determination. LC: Least Concern

cm and results point to be log W= -5.1002+3.0303 log L and females in the length range 35- 60 cm as

log W= -1.4959+2.7063 log L. In the present study, the length range of the fishes for *P. typus* was 28 -73 cm and the LWR is

LogW=Log-3.2240256+2.3 Log L in the case of pooled, Log W= Log -3.35261703 +2.4 Log L

in the case of females and Log W = Log -3.0222763 +2.3 Log L in the case of males

The LWR for *E. areolatus* estimated by Mathew (2003) was

LogW =-1.2521+2.55772 log L for females and

log W= -0.8994+2.3287 log L for males.

Mathew (2002) estimated the length -weight relationship of *E. chlorostigma* sexwise as,

log W= -2.7115+3.0425 log L in the case of females and log W= -1.7501+2.8497 log L in males, using fishes of the length range 32-65 cm. Premalatha (1989) estimated length-weight relationship for the females of *E. diacanthus* along Kerala coast as log W= -l.3056+2.6117 log L, based on specimens ranging from 20 to 55 cm and for *E. areolatus* as

log W=-l.2521+2.55772 log L for females and log W= -0.8994+2.3287 log L for males derived, based on specimens ranging from 29 to 55 cm. The results of the present study point to a positive value for the exponent for *E. diacanthus* and *E. areolatus* as can be seen from the Table 2. Published reports related to the length weight relationship show that the values of exponent for certain fishes are low when compared to the hypothetical value. The difference in the exponent value of *E. chlorostigma* and *E. areolatus* recorded in the present study shows that environmental conditions are more suitable to *E. diacanthus* and *E. areolatus* compared to *E. chlorostigma* and the latter species may be facing more competition for food, space and other factors necessary for an isometric growth. The

Table 3. Length weight equation of the different species sexwise

Species		Length Weight equation
Epinephelus longispinis	Pooled	Log W= Log -5.53771733+3.28 Log L
	Female	Log W= Log -5.473681146+3.26Log L
	Male	Log W= Log -5.44715416+3.28Log L
Epinephelus areolatus	Pooled	Log W= Log -5.147750514+3.2 Log L
	Female	Log W= Log --5.114842456+3.1Log L
	Male	Log W= Log -5.1218450+3.1Log L
Epinephelus diacanthus	Pooled	Log W= Log -5.04908305 +3.1 Log L
	Female	Log W= Log-5.041839512 +3.1 Log L
	Male	Log W= Log -5.0052792563 +3.1 Log L
Variola louti	Pooled	Log W= Log-5.6367351777+3.3Log L
	Female	Log W= Log -5.4699826835 +3.2 Log L
	Male	Log W= Log-6.5171860 +3.6 Log L
Epinephelus chlorostigma	Pooled	Log W= Log -3.0530567 +2.3 Log L
Cephalopholis sonnerati	Pooled	Log W= Log-5.78781239559 +3.5 Log L
Lutjanus lutjanus	Pooled	Log W= Log-5.008334116 +3.1 Log L
	Female	Log W= Log -4.2986974 +2.8 Log L
	Male	Log W= Log -4.10787694 +2.7 Log L
Lutjanus kasmira	Pooled	Log W= Log -4.73181908 +2.95 Log L
	Female	Log W= Log -5.057440562 +3.1 Log L
	Male	Log W= Log -4.29002617288 +2.8 Log L
Pristipomoides filamentosus	Pooled	Log W= Log -4.875361577 +2.97 Log L
	Female	Log W= Log -4.8644624 +2.96 Log L
	Male	Log W= Log -4.8793166 +2.96 Log L
Pristipomoides typus	Pooled	Log W= Log -3.2240256 +2.3 Log L
	Female	Log W= Log -3.35261703 +2.4 Log L
	Male	Log W= Log -3.0222763 +2.3 Log L
Pinjalo lewisi	Pooled	Log W= Log -4.599131764 +2.9 Log L
	Female	Log W= Log -4.328900318 +2.8 Log L
	Male	Log W= Log 0.00001093081 +2.9 Log L
Lutjanus gibbus	Pooled	Log W= Log -3.6655462488 +2.53 Log L
Lutjanus bohar	Pooled	Log W= Log -4.733750898 +2.9627 Log L

value of exponent (b) for *E. chlorostigma* reported by Mees (1992) from a different locality was high when compared to the value registered in the present study. This variation may be because of the difference in the ecological conditions of the habitats. This discrepancy in the values of regression coefficient may be related to factors such as physical and chemical conditions of the environments, food availability, competition with indigenous species, immature individuals in the samples, etc. Cone (1989) and Laurence (1979) opined that the variation from the isometric relationship may however be minor for some early life history aspects but may become more important in the calculation of metabolic processes. As a result, fish condition studies assume that heavier fishes are often of better conditions and condition indices have been frequently used by fish culturists as indicators of the general population 'well-being or fitness'.

In Indian waters, the exploitation of groupers occurs in the range 13-64 cm; the minimum legal size (MLS) recommended for exploitation is 18 cm for *E. diacanthus* (Mohamed *et al.*, 2014). However, smaller sized fishes are often caught in trawlers, causing the mean size in fishery to come down to 27 cm. Shakeel and Ahmad (1996) stated that in commercial fishery, the removal of groupers less than the average maturity length of 30.5 cm from the medium-size group and 40.5 cm from the large-size group should be prohibited. These two size restrictions are expected to result in about 80% of commercial and potentially commercial grouper species being caught after having spawned once. Mathew *et al.* (2002) reports that in groupers, males are larger, fewer in number and occur in deeper waters which could probably be the reason in the difference in the numbers of males over females.

Conservation status

A notable result in the study is the IUCN status of all the species studied. The fishes were referred to the IUCN Red List status to get the comprehensive information source on the global extinction risk status of the species. (IUCN, 2020). Each species studied was checked in the Red List for its individual status and updated. *E. diacanthus* which was in the Vulnerable Status (Nair *et al.*, 2017) till recently has been placed in the Least Concern (LC) category with a management advisory that, given its susceptibility to unsustainable exploitation, especially due to the trawl fishery, further research is needed on its population, life history and management practices (Nair, 2018a). Suggested area closures that protect critical habitat as well as installing satellite tracking devices in individual trawlers to monitor fishing activity are other advisories mentioned. Hence constant monitoring of the resource is a necessity. *E. areolatus* has been assessed as Least Concern (Nair and To., 2018) with heavy fishing pressure on a localised level as a potential threat to this species. *E. longipinnis* (Nair, 2018b) and *V. louti* (Nair *et al.*, 2018) had a stable population without much threats and was classified as Least Concern. *L. lutjanus* and *L. kasmira* are two species which had entered the commercial fishery recently. The population structure and trend is unknown, with not much information on threats, hence the fish is assessed as Least Concern. (Russell *et al.*, 2016 a, b, c).

The length-weight relationship in fishes is influenced by a number of factors including season, habitat, gonad maturity, sex, diet, stomach fullness, health and differences in the length ranges, sampling amounts of the specimen caught (Tesch, 1968), which were not accounted for in the present study. These may also have contributed to differences in results. It must be noted, however, that LWRs differ among fish species depending on the inherited body shape and the physiological factors such as maturity and spawning (Schneider *et al.*, 2000). This relationship might change over seasons or even days (De Giosa *et al.*, 2014). It is argued that "b" may change during different time periods illustrating the fullness of stomach, general condition of appetite and gonads stages (Zaher *et al.*, 2015). In addition, the growth process can differ in the same species dwelling in diverse locations, influenced by numerous biotic and abiotic factors.

Length-weight relationships and condition factors are two of the most important biological aspects to assess the growth rate and condition of fish (Muchlisin *et al.*, 2010). Therefore, the information on length-weight relationship and condition factor are important to plan a better conservation strategy of the fishery resources (Muchlisin *et al.*, 2015). The negative allometry shown by the smaller sized species is in tally with their sizes as they grow they are slender. The length weight relationship along with the minimum maximum length recorded in the fishery will serve as inputs for further fishery management modelling and hence play an important role in management and protection program of their natural stocks. Knowledge on life history characteristics is of great importance for effective implementation of sound conservation strategies since the effects of fishing on protogynous populations are extremely difficult to measure without complete information on the reproductive patterns, sex ratios, and other biological aspects of fish stocks (Tupper, 1999).

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