

VOL.66 NO.01 JANUARY-JUNE 2024 • PRINT ISSN 0025-3146 • ONLINE ISSN 2321-7898

JMBAI

**JOURNAL OF THE MARINE
BIOLOGICAL ASSOCIATION OF INDIA**



MBAI
Marine Biological Association of India





Length-weight relation of three species of goatfish from the south-east Arabian Sea

K. M. Vishnupriya^{1,2}, Rekha J. Nair^{1*} and A. T. Sangeetha^{1,2}

¹ICAR-Central Marine Fisheries Research Institute, Kochi-682 018, Kerala, India.

²Cochin University of Science and Technology, Kochi-682 022, Kerala, India.

*Correspondence e-mail: rekhacmfri@gmail.com

Received: 15 May 2023

Revised: 23 Nov 2023

Accepted: 19 Jan 2024

Published: 11 Apr 2024

Short communication

Abstract

Length-weight relationship (LWR) of *Upeneus guttatus* (Day 1868), *Upeneus sulphureus* (Cuvier, 1829) and *Parupeneus heptacanthus* (Lacepède, 1802) was assessed from the Southwest coast of India for a study period November 2020 to August 2021. The total length of *U. guttatus* varied from 86 to 197 mm, and wet weight ranged from 5 to 78.5 g. Regression coefficient *b* for male, female, and pooled *U. guttatus* was found to be 3.100, 3.144, and 3.376 respectively and coefficient of determination (r^2) was estimated to be 0.954 (male); 0.967 (female); 0.953 (pooled). The *b* value of *U. sulphureus* was found to be 3.14 and $r^2 = 0.943$ (pooled) and the total length varied from 112-181mm; wet weight: 18.2 to 87.5g. The *b* value of *P. heptacanthus* was found to be 3.135 and $r^2 = 0.976$ (pooled) and body length varied from 133-227 mm; wet weight: 29 to 179 g. A positive allometric growth factor was observed for all species. Mathematical models such as length-weight relationships help describe the growth parameters of fish at various time intervals. This study throws light on the LWRs of three species of goatfish available in Indian waters.

Keywords: Length-weight relationship, *Upeneus guttatus*, *Upeneus sulphureus*, *Parupeneus heptacanthus*, positive allometric

Introduction

Members of the family Mullidae popularly known as Red mullets or Goatfishes comprise about 102 species in six genera (Fricke *et al.*, 2023) worldwide and are one of the commercially important demersal fish in India. These fishes are widely distributed through tropical, subtropical, Indo-Pacific, and Western Atlantic regions. During 2020, 22434 t of goatfish were landed in India (CMFRI, 2021). However, goatfishes do not form a commercial fishery on the Kerala coast but occur along with the nemipterid fishes. Thomas (1969) studied 19

species from the Indian seas; 16 species have been reported to occur along the Indian coast (Vivekanandan *et al.*, 2003); 11 species have been reported to be commercially important along Tuticorin and Gulf of Mannar coasts (Mohanraj, 1999; Lakshmikanth *et al.*, 2021); Vishnupriya and Nair (2023) recorded the presence of 14 species under three genera from the different coasts of India. *U. guttatus* (two-tone goatfish) is characterized by a reddish body colour with red blotches on the upper side, the caudal fin with reddish bars, yellow coloured barbels. However, the body is devoid of a lateral side stripe. *U. sulphureus* (Sulphur goatfish) can be easily distinguished by having two yellow lateral body stripes; the caudal fin without bars; the tip of the first dorsal fin is pigmented black; the barbels white. *P. heptacanthus* is characterized by the presence of a single row of well-spaced stout conical teeth in jaws, the absence of teeth on the roof of the mouth, and a pale reddish spot just below the seventh and eighth lateral line scales (Ketabi *et al.*, 2017). *U. guttatus* was dominant among the goatfishes landed by the trawl fishery. Most species are shallow inhabitant and are usually seen between 40-60 m in depth (Vivekanandan *et al.*, 2003).

Length-weight relationship (LWR) are primary data generated from fishery biology studies which are used as basic parameters for fish stock assessment, fisheries management, and conservation (Thomas *et al.*, 2003; Froese, 2006; Siddique *et al.*, 2016; Das *et al.*, 2017; Satish Kumar *et al.*, 2019; Nair *et al.*, 2021). LWR can be used to assess the well-being of fish and to determine possible differences between separate unit stocks of the same species (King, 2007). Moreover, it is essential for stabilizing the taxonomic characteristics of species. (Pervin and Mortuza, 2008). Length-weight measurements in fish are commonly related to the life cycle, reproductive stages, food availability, climatic conditions, *etc.* Globally, the length-

weight relationships of *U. guttatus* have been studied (Kulbicki *et al.*, 2005; Habib, 2021). The length-weight relationships of *U. sulphureus* have been studied from different regions of India (Ali, 1978; Reuben *et al.*, 1994; Adarsh and James, 2016) and the World (Prayitno *et al.*, 2020; Vahabnezhad *et al.*, 2020; Clarito and Suerte, 2021). The length-weight relationships of *P. heptacanthus* have been studied from Tuticorin by Karuppasamy *et al.* (2019). Such information on these species is lacking from the southeast Arabian Sea and this study aims to provide information on the length-weight relationship (LWR) of *U. guttatus*, *U. sulphureus* and *P. heptacanthus* from these waters.

Material and methods

Samples were collected randomly every week from the Kalamukku Fisheries Harbour (Lat. 09°59'924" N, Long. 76°14'564" E) and Munambam Fisheries Harbour (Lat. 10°10'965" N, Long. 76°10'258" E) (Fig. 1) representing various length groups. The fish were mostly collected from fish trawls with a mesh size of 20-25mm and beach seines. A total of 355 specimens of *U. guttatus*, 87 specimens of *U. sulphureus* and 50 specimens of *P. heptacanthus* were collected from November 2020 to August 2021 for the present study. Species identification was made based on Uiblein *et al.* (2020) for *Upeneus* sp. and Randall (2004) and Uiblein *et al.* (2017) for *Parupeneus* sp. Biometric measurements of each specimen were taken. The length measurement total length (TL) and Standard length (SL) were taken using a graduated measuring scale (30 cm) to the nearest mm (millimetre). Body weight was measured in grams with the help of an electronic balance (Saffron Electronic Scale SES3T). Logarithmic values of the total length and weight of all samples were calculated before the length-weight analysis. Data calculations for combined sexes, female and male fish specimens were done after Le Cren (1951). The sexes were noted and data tabulated sex-wise for *U. guttatus* and combined for *U. sulphureus* and *P. heptacanthus*.

Length-weight relationship

The length-weight relationship was established by using the formula $W = aL^b$ (Le Cren, 1951) and the logarithmic form of the

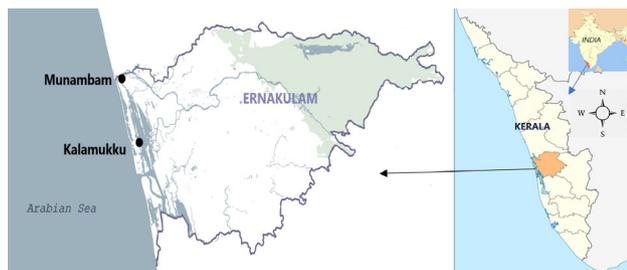


Fig. 1. Sampling locations

equation: $\text{Log } W = \text{log } a + b \text{ log } L$ where W =weight, L =length, a is the intercept and b is the slope of the log-transformed relation. By using the regression analysis the intercept and slope of the log-transformed relation were estimated. The 95% confidence interval for a , b , and r^2 values was also estimated. Data was analyzed by using Microsoft Office Excel 2013.

Statistical analysis

The parameters a and b were estimated by linear regression on the Log- transformed equation $\text{log } (W) = \text{log } (a) + b \text{ log } (L)$. 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 into the logarithmic form to exclude the outlier values. All statistical analysis was carried out using Windows Excel. The length and weight data were 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.

Results

Analysis of the samples of goatfishes from different fishing gears showed that bottom trawlers contributed to the major landings of goatfishes and gill nets contributed a small percentage. The species were reportedly collected from a depth of 50-70 m. The LWR of *U. guttatus* collected from landing centres were analyzed and found to be in the total length range 86 to 197 mm; of these 51 individuals were males, the total length and weight ranged from 101 to 165 mm and 11 to 57 g with mean value of 123.3 ± 17.03 mm and respectively; 127 were females in the total length and weight ranged from 95 to 197 mm and weight 9 to 78.5 g with mean value 139.5 ± 22.97 mm and 33.8 ± 17.26 respectively. Whereas the total length and weight of pooled samples ranged from 86 to 197 mm and weight 5 to 78.5 g with mean values of 121.2 ± 21.21 mm and 20.8 ± 13.84 g respectively. Specimens of *U. sulphureus* were measured; the total length and weight ranged from 112 to 18 mm and 18.2 to 87.5 g with mean values of 151.9 ± 14.64 mm and 49 ± 14.59 g respectively. Individuals of *P. heptacanthus* were measured in the total length and weight ranged from 133 to 227 mm and 29 to 179 g with mean values of 182.6 ± 25.46 mm and 92.6 ± 40.73 g respectively. (Table 1). The equation obtained for *U. guttatus*, *U. sulphureus* and *P. heptacanthus* are given in Table 2.

Parameters such as a and b and their range in 95% confidence interval and coefficient of determination (r^2) were found. The total length of *U. guttatus* was plotted against the weight (Fig. 2, 3 and 4) and a scatter diagram for female, male and pooled was obtained. A combined scatter diagram for *U. sulphureus* (Fig. 5) and *P. heptacanthus* (Fig. 6) were plotted. The length-weight relationship for males and females was found to be not significantly different at the 5% level. Both show a positive allometric growth pattern ($b > 3$). Therefore, a pooled equation for *U. guttatus* was arrived at as $\log W = \log 1.691 + 3.376 \log L$ ($r^2 = 0.95$) (95% C. I.). The b value of *U. sulphureus* was 3.1 also shows positive allometric growth.

Discussion

Length-weight relationships of fishes are useful for the management and conservation of fish populations. According to Tesch (1971), the length-weight relationship in fishes can be affected by habitat and area besides other factors such as seasonal effect, degree of stomach fullness, gonad maturity, sex, health, preservation techniques and differences in the observed length ranges of the specimens. Other factors such as fish behaviour also may affect the b value, (Muchlisin *et al.*, 2010).

The values of the b of LWRs usually ranged from 2.5–3.5 (Froese, 2006) or 2–4 as of Tesch (1971). Under ideal conditions, b value should be 3; the b value of 3 indicates that the fish grows symmetrically or isometrically; values other than 3 indicate allometric growth (Tesch, 1971). In the case of *U. sulphureus* and *U. guttatus* the b value was 3.1–3.4 showing a positive allometric growth. Generally, the b value at 3 states that the weight of a fish increases with a cube of its length.

Upeneus guttatus (Day, 1868)

The total length and weight range of *U. guttatus* (pooled) during the present study was 86–197 mm and 5–78.5 g respectively (Table 1). This records the maximum length of *U. guttatus* from the southeast Arabian Sea. Uiblein *et al.* (2020) recorded the maximum standard length (SL) for *U. guttatus*

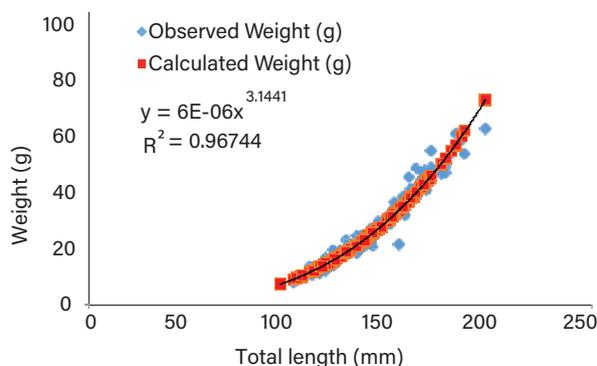


Fig. 2. Length-weight relationship for females of *U. guttatus*

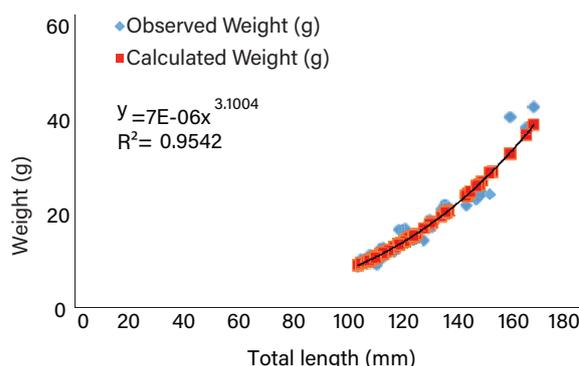


Fig. 3. Length-weight relationship for males of *U. guttatus*

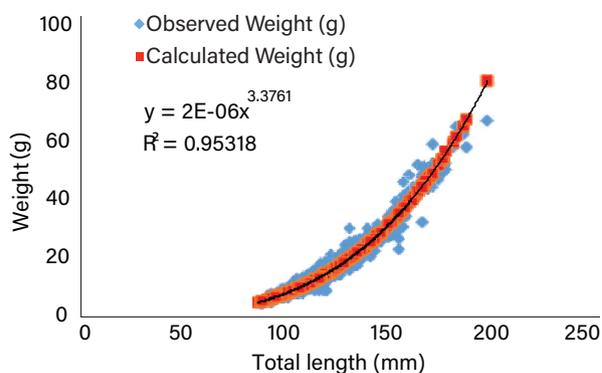


Fig. 4. Length-weight relationship of *U. guttatus* (Pooled)

Table 1. Parameters of the logarithmic regression equation for *U. guttatus*, *U. sulphureus* and *P. heptacanthus*

Species	Sex	n	Total length (mm)			Weight (g)			a	b	r^2	Growth type
			Min.	Max.	Mean±SD	Min.	Max.	Mean±SD				
<i>U. guttatus</i>	Male	51	101	165	123.3±17.03	11	57	22.3±10.72	6.869	3.100	0.954	Positive Allometric
	Female	127	95	197	139.5±22.97	9	78.5	33.8±17.26	5.571	3.144	0.967	Positive Allometric
	Pooled	355	86	197	121.2±21.21	5	78.5	20.8±13.84	1.691	3.376	0.953	Positive Allometric
<i>U. sulphureus</i>	Pooled	87	112	181	151.9±14.64	18.2	87.5	49±14.59	6.685	3.140	0.943	Positive Allometric
<i>P. heptacanthus</i>	Pooled	50	133	227	182.6±25.46	29	179	92.6±40.73	6.894	3.135	0.976	Positive Allometric

Table 2. Growth parameters of *U. guttatus*, *U. sulphureus* and *P. heptacanthus* from different locations

Species	Location	Sample size	Length(cm)		Weight (g)		a	b	r ²	Source
			Min	Max	Min	Max				
	World									
<i>U. guttatus</i>	New Caledonia	21	8.0 (FL)	13.5 (FL)	-	-	0.0218	2.883	0.990	Kulbicki <i>et al.</i> , 2005
	Malaysia	51	12.0 (TL)	19.5 (TL)	21.0	95.0	0.0084	3.132	0.973	Habib <i>et al.</i> , 2021
	World									
	Safaga Bay, Red Sea	750	5 (SL)	12.5 (SL)	-	-	0.0412	2.89		Boraey and Soliman, 1987
	Iraq	7574	5.0 (TL)	17.0 (TL)	8.0	130.5	0.0621	3.0125	0.94	Mohamed and Resen, 2010
	Persian Gulf	520	8.5 (FL)	17.0 (FL)	-	-	-1.7076	3.007	0.92	Vahabnezhad <i>et al.</i> , 2020
	Bay of Bengal	-	-	-	-	-	0.0306	2.833	-	Mustafa, 1999
	Daya Bay, China	-	-	-	-	-	0.01959	3.118	0.91	Xu <i>et al.</i> , 1994
	Beibu Gulf, China	5369	1.0 (SL)	22.5 (SL)	3.1	111.0	0.0258	2.95	0.997	Wang <i>et al.</i> , 2011
	Malaysia	1952	-	-	-	-	0.010	3.10	-	Ahmad <i>et al.</i> , 2003
	Australia	245	8 (FL)	11(FL)	-	-	0.0346	2.9	0.984	Willing and Pender, 1989
	New Caledonia	38	11.0(FL)	17.0 (FL)	-	-	0.0081	3.322	0.948	Kulbicki <i>et al.</i> , 2005
	Western Indonesia	-	5.5 (TL)	24.5 (TL)	-	-	0.0081	3.213	0.978	Pauly <i>et al.</i> , 1996
	Java (north coast)	-	-	-	-	-	0.009	3.193	-	Budihardjo, 1988
<i>U. sulphureus</i>	Java Sea	-	-	-	-	-	0.0159	3.124	0.9211	Prayitno <i>et al.</i> , 2020
	Philippines	-	-	-	-	-	0.0193	3.00		Federizon, 1993
	Davao Gulf, Philippines	31	5.3(SL)	12.5 (SL)	-	-	0.0055	3.683	0.966	Gumanao <i>et al.</i> , 2016
	Philippines	1129	8.0 (TL)	18.5 (TL)	6.0	86.0	0.0104	3.072	0.9039	Clarito and Suerte, 2021
	India									
	Maharashtra	103 (Male)	-	-	-	-	0.00000037	3.657	0.9903	Ali, 1978
		125 (Female)	-	-	-	-	0.00000083	3.510	0.9912	
	Andhra-Odisha coast	240 (Male)	9.1 (TL)	17.7 (TL)	-	-	0.000011	3.033	0.9909	Reuben <i>et al.</i> , 1994
		239 (Female)	10.2 (TL)	20.0 (TL)	-	-	0.000009	3.087	0.9800	
	Mandapam	89 (Male)	-	-	-	-	-0.837	2.051	-	Adarsh <i>et al.</i> , 2016
		51 (Female)	-	-	-	-	-1.544	2.564	-	
	Andhra Pradesh	97	11.14 (TL)	19.23 (TL)	18.01	78.1	0.00326	2.935	0.89	Nama <i>et al.</i> , 2020
	World									
	Gulf of Aqaba, Red Sea	170	12.7 (TL)	36.9 (TL)	-	-	0.00737	3.175	0.93	
	New Caledonia	520	5.5 (FL)	23.5 (FL)	-	-	0.0221	2.977	0.947	Letourneur <i>et al.</i> , 1998
	New Caledonia	522	5.5 (FL)	23.5 (FL)	-	-	0.0169	3.078	0.989	Kulbicki <i>et al.</i> , 2005
<i>P. heptacanthus</i>	Malaysia	527	-	-	-	-	0.011	3.08	-	Ahmad <i>et al.</i> , 2003
	Davao Gulf, Philippines	41	10 (SL)	22 (SL)	-	-	0.0341	2.912	0.967	Gumanao <i>et al.</i> , 2016
	American Samoa	278	18.3 (FL)	35.8 (FL)	104.0	877.0	0.0156	3.07	0.96	Matthews <i>et al.</i> , 2019
	India									
	Tuticorin	203	9.0 (TL)	31.5 (TL)	11.0	428.0	0.017	2.923	0.955	Karuppasamy <i>et al.</i> , 2019

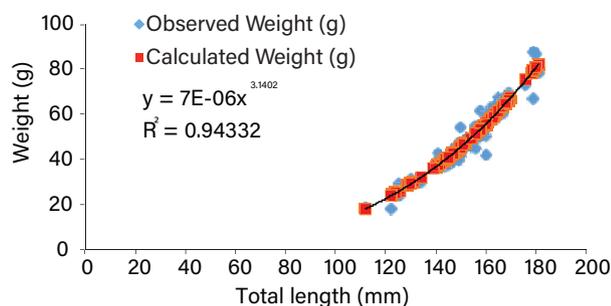
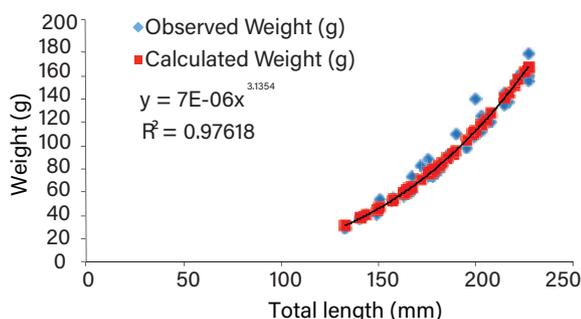
*(Different length types; Total length (TL), Standard length (SL) and Fork length (FL) were used for measuring length)

from the Western Indian Ocean as 142 mm and Habib *et al.* (2021) reported a length of 195 mm from the Eastern Indian Ocean both of which are lesser than the present study. The maximum SL recorded for the Red Sea was 160 mm (Uiblein and Heemstra, 2010). The *b* value of *U. guttatus* was 3.100, 3.144, and 3.376 for male, female, and the male-female pooled

data respectively. The LWR indicates a positive allometric growth pattern. Length-weight relationships were similar for both males and females, therefore a common relation was arrived at by pooling the data for males, females, and indeterminates. Habib *et al.* (2021) reported that the *b* value of *U. guttatus* for pooled data was 3.135 showing a positive

Table 3. The equation obtained for *U. guttatus*, *U. sulphureus* and *P. heptacanthus*

Species	Sex	Equation
<i>U. guttatus</i>	Males	Log W = 6.869 + 3.100 Log L ($r^2 = 0.954$)
	Females	Log W = 5.571 + 3.144 Log L ($r^2 = 0.967$)
	Pooled	Log W = 1.691 + 3.376 Log L ($r^2 = 0.953$)
<i>U. sulphureus</i>	Pooled	Log W = 6.685 + 3.140 Log L ($r^2 = 0.943$)
<i>P. heptacanthus</i>	Pooled	Log W = 6.894 + 3.135 Log L ($r^2 = 0.976$)

Fig. 5. Length-weight relationship of *U. sulphureus* (Pooled)Fig. 6. Length-Weight relationship of *P. heptacanthus* (Pooled)

allometric growth pattern from Chendering, Terengganu, Malaysia, while from New Caledonian Kulbicki *et al.* (2005) got a negative allometric growth pattern of b value 2.883 which may be attributed to the ecological factors such as variation in temperature, spawning conditions, food supply and habitat preferences. The other mullid species reportedly shows a positive allometric growth pattern.

Upeneus sulphureus (Cuvier, 1829)

The length and weight of *U. sulphureus* ranged from 112-181mm and 18.2-87.5 g respectively (Table 1). In this study *U. sulphureus* had a b value of 3.140 and $r^2 = 0.948$ showing a positive allometric growth pattern; Mohamed and Resen (2010) got an isometric growth pattern ($r^2 = 0.94$; $b = 3.012$)

from northwest Arabian Gulf for *U. sulphureus*. Similarly, Vahabnezhad *et al.* (2020) also got an isometric growth pattern from the same region with $r^2 = 0.92$ and $b = 3.0$.

Growth, mortality, and exploitation parameters of *U. sulphureus* were estimated from the east coast of Peninsular Malaysia by Ahmad *et al.* (2003) who obtained a positive allometric growth pattern with $b = 3.10$. Studies also showed positive allometry by Kulbicki *et al.* (2005) from New Caledonia, ($b = 3.322$; $r^2 = 0.948$), Prayitno *et al.* (2020) from Java Sea ($b = 3.124$; $r^2 = 0.921$). The regression coefficients of Ahmad *et al.* (2003) and Prayitno *et al.* (2020) were similar to the present study. Clarito and Suerte (2021) got an isometric growth pattern for *U. sulphureus* ($r^2 = 0.903$; $b = 3.072$) from the Visayan Sea, Philippines. However Wang *et al.* (2011) got a b value of 2.95 and $r^2 = 0.997$ showing a negative allometric growth pattern from the Beibu Gulf of China, which may be due to the ecological factors. Ali (1978) derived separate equations for male and female fish samples from Maharashtra. He observed a positive allometric growth pattern for *U. sulphureus* with b values of 3.51 and 3.65 for females and males respectively. Reuben *et al.* (1994) got an isometric growth pattern for *U. sulphureus* with a b value of 3.03 from the coast of Andhra Pradesh and Odisha. Adarsh and James (2016) from Mandapam studied the length-weight relationship of *U. sulphureus* and obtained a b value of 2.051 and 2.712 for males and females which shows a negative allometric growth pattern, the results are quite strange given the highly productive water of the GoMBR (Gulf of Mannar Biosphere Reserve). Likewise, Nama *et al.* (2020) got a negative allometric growth pattern with $r^2 = 0.89$ and $b = 2.93$ from the coast of Andhra Pradesh.

Parupeneus heptacanthus (Lacepède, 1802)

From this study, the total length range and weight range of *P. heptacanthus* is seen to range from 133-227 mm and 29-179 g respectively (Table 1). Study results show that *P. heptacanthus* has a b value of 3.135 from this study pointing to positive allometric growth. An isometric growth pattern for *P. heptacanthus* was observed by Kulbicki *et al.* (2005) from New Caledonia and Matthews *et al.* (2019) from American Samoa with $b = 3.07$, while Karuppasamy *et al.* (2019) observed

a negative allometric growth pattern for *P. heptacanthus* from Tuticorin; thereby showing more information on the west coast of India. Most of the LWR studies of the *U. guttatus*, *U. sulphureus* and *P. heptacanthus* were done in the eastern Indian Ocean, Red Sea and Persian Gulf regions (Table 3).

Length-weight relationships (LWRs) are mathematical expressions of the relationships between length and weight that allow one to be predicted when the other is known (Le Cren, 1951). Furthermore, life history and morphological comparisons within populations of the same species, as well as comparisons between species, can benefit from information on length and weight (Ecoutin *et al.*, 2005). The growth rate is normally faster at younger stages of life history and slows as the fish ages. During the reproductive phase, growth slows due to the increased food partitioning for reproductive growth. Food availability improves growth in length and weight, similarly, optimum climatic conditions initiate good growth. The difference between the two sexes of species can be explained by factors such as different length ranges, length distributions, and differences in the length at first maturity (Stergiou, 1991; Vassilopoulou and Papaconstantinou, 1994). The change in the *b* value occurs during various seasons and can be generally related to the fullness of the stomach, stages of the gonads and overall hunger state (Zaher *et al.*, 2015)

Acknowledgements

The authors thank the Director, Central Marine Fisheries Research Institute for the support and facilities provided, and the Council of Scientific and Industrial Research for financial support and also wish to thank fishermen for providing samples for the study.

References

- Adarsh, S. and R. A. James. 2016. Morphometric role on length-length and length weight relationship of sulphur goatfish (*Upeneus sulphureus*, Cuvier 1829) from Mandapam Coast, Southern India. *International Journal of Advanced Research*, 4 (1): 825-839.
- Ahmad, A. T., M. M. Isa, M. S. Ismail and S. Yusof. 2003 Status of demersal fishery resources of Malaysia. In Silvestre G, Garces L, Stobutzki I, Ahmed M, Valmonte-Santos RA, Luna C, Lachica-Aliño L, Munro P, Christensen V, Pauly D (eds.) Assessment, management and future directions for coastal fisheries in Asian countries. *World Fish Center Conference Proceedings*, 67: 83-136.
- Al-Absy, A. and A. Ajjad. 1988. The morphology, biometry, weight-length relationship and growth of the goatfish *Parupeneus cinnabarinus* (Cuvier & Valenciennes) in the Gulf of Aqaba, Red Sea. *Arab. Gulf. J. Sci. Res.*, 6 (2): 265-273.
- Ali, M. 1978. Length-weight relationship of *Upeneus sulphureus* (Cuvier, 1829) collected off Maharashtra coast. *Journal of the Indian Fisheries Association*, 8: 32-36.
- Boraey, F. A. and F. M. Soliman. 1987. Length-weight relationship, relative condition, and food and feeding habits of the goatfish *Upeneus sulphureus* Cuv. & Val. in Safaga Bay of the Red Sea. *J. Inland Fish. Soc., India*, 19 (2): 47-52.
- Budihardjo, S. 1988. Growth, mortality and biomass estimation of goat fish (*Upeneus sulphureus*) in the Java Sea, Indonesia. *FAO Fish. Rep.*, 389: 193-213.
- Budihardjo, S. 1988. Growth, mortality and biomass estimation of goat fish (*Upeneus sulphureus*) in the Java Sea, Indonesia. *FAO Fish. Rep.*, 389: 193-213.
- Clarito, Q. Y. and N. O. Suerte. 2021. Population Dynamics of Sulphur Goatfish, *Upeneus sulphureus* (Cuvier, 1829) in the Visayan Sea, Philippines. *J. Fish. Environ.*, 45 (2): 43-54.
- CMFRI. 2021. Annual Report 2020. Central Marine Fisheries Research Institute, Kochi. 284 pp. Retrieved from <http://www.cmfri.org.in>
- Das, S., M. A. Barbhuiya, R. I. Barbhuiya and D. Kar. 2017. A study on the length-weight relationship and relative condition factor in *Glossogobius giuris* found in River Singla in the Karimganj district of Assam, India. *J. Agric. Vet. Sci.*, 10 (4): 67-69.
- Ecoutin, J. M., J. J. Albaret and S. Trape. 2005. Length-weight relationships for fish populations of a relatively undisturbed tropical estuary: The Gambia. *Fish. Res.*, 72 (2-3): 347-351.
- Federizon, R. 1993. Using vital statistics and survey catch composition data for tropical multispecies fish stock assessment: application to the demersal resources of the central Philippines. Alfred-Wegener-Institut für Polar-und Meeresforschung. Bremerhaven. Ph.D. dissertation. 201 pp.
- Fricke, R., W. N. Eschmeyer and J. D. Fong. 2023. Species by Family/Subfamily. Retrieved from <http://researcharchive.calacademy.org/research/ichthyology/catalog/SpeciesByFamily.asp>. Electronic version accessed 10/11/ 2021
- Froese, R. 2006. Cube law, condition factor and weight-length relationships: history, meta analysis and recommendations. *J. Appl. Ichthyol.*, 22 (4): 241-253.
- Gumanao, G. S., M. M. Saceda-Cardoza, B. Mueller and A. R. Bos. 2016. Length-weight and length-length relationships of 139 Indo-Pacific fish species (Teleostei) from the Davao Gulf, Philippines. *J. Appl. Ichthyol.*, 33 (2): 377-385.
- Habib, A., M. I. A. Hanizar, M. S. Kamal, M. A. S. Azmi and Y. G. Seah. 2021. Length-Weight relationships of four demersal fish species from Chendering, Terengganu, Malaysia. *Thalassas: An International J. Mar. Sci.*, 37 (1): 205-207.
- Karuppasamy, K., A. M. Babu, P. Jawahar, V. Vidhya, S. Boda and G. V. S. Deva. 2019. Length-weight relationship of two goat fish species *Parupeneus heptacanthus* (Lacepède, 1802) and *Upeneus moluccensis* (Bleeker, 1855), (Family Mullidae) from Tuticorin coast of Tamil Nadu, India. *J. Aquacult. Trop.*, 34 (1/2): 129-134.
- Ketabi, R., H. R. Esmaeili, S. Echreshavi and S. Jamili. 2017. A note on the cinnabar goatfish, *Parupeneus heptacanthus* (Lacepède, 1802) from northern parts of the Persian Gulf and the Makran Sea (Teleostei: Mullidae). *Fish Taxa*, 2 (4):195-200.
- King, M. 2007. Fisheries biology, assessment and management. Second Edition. *Blackwell Scientific Publications*, Oxford, p. 1-381.
- Kulbicki, M., N. Guillemot and M. Amand. 2005. A general approach to length-weight relationships for New Caledonian lagoon fishes. *Cybiurn*, 29 (3): 235-252.
- Lakshmikanth, A. R., M. Anand and K. Ranges. 2021. Length-weight relationship of *Upeneus vittatus* (Forsskal, 1775) from the Gulf of Mannar coast (Mandapam, Tamil Nadu), India. *Indian J. Geomarine. Sci.*, 50 (05): 423-427.
- Le Cren, E. D. 1951. The Length-Weight Relationship and Seasonal Cycle in Gonad Weight and Condition in the Perch (*Perca fluviatilis*). *J. Anim. Ecol.*, 20 (2):201-219.
- Letourneur, Y., M. Kulbicki and P. Labrosse. 1998. Length-weight relationships of fish from coral reefs and lagoons of New Caledonia, southwestern Pacific Ocean: an update. *Naga ICLARM Q.* 21 (4): 39-46.
- Matthews, T., D. Ochavillo, S. Felise, T. Letalie, M. Letuane, E. Schuster, A. Soonaolo, S. Tofaono, A. Tua and F. Tuilagi. 2019. Length-weight Relationships for 71 Reef and Bottomfish Species from Tutuila and Aunu'u, American Samoa. *Pacific Islands. Fish. Sci. Cent. Admin. Rep. H.*, 19 (03): 1-9.
- Mohamed, A. R. M. and A. K. Resen. 2010. The population status of sulphur goatfish *Upeneus sulphureus* in the Iraqi marine waters, northwest Arabian Gulf. *Mesopotamian J. Mar. Sci.*, 25 (1): 31-40.
- Mohanraj, J. 1999. *Fishery, biology, exploitation and population dynamics of commercially important goat fishes in Tuticorin coast, Gulf of Mannar*, Ph D thesis, Madurai Kamaraj University, Tamil Nadu, India, 308 pp.
- Muchlisin, Z. A., M. Musman and M. N. Siti Azizah. 2010. Length-weight relationships and condition factors of two threatened fishes, *Rasbora tawarensis* and *Poropuntius tawarensis*, endemic to Lake Laut Tawar, Aceh Province, Indonesia. *J. Appl. Ichthyol.*, 26 (6): 949-953.
- Mustafa, M. G. 1999. Population dynamics of penaeid shrimps and demersal finfishes from trawl fishery in the Bay of Bengal and implication for the management. Ph D thesis. *University of Dhaka*. Bangladesh. 223 pp.
- Nair, R. J., P. K. Seetha, K. T. S. Sunil and M. Radhakrishnan. 2021. Length weight relationships of Demersal reef fishes from south west coast of India. *J. Mar. Bio. Ass. India*, 63 (1): 40-48.
- Nama, S., K. K. Ramteke, S. Bhushan, V. Pathak and A. K. Jaiswar. 2020. Length-weight relationship of four goatfish species along Kakinada coast, Andhra Pradesh, India. *J. Exp. Zool. India*, 23 (2): 1741-1743.
- Pauly, D., A. Cabanban and F. S. B. Torres Jr. 1996. Fishery biology of 40 trawl-caught teleosts of western Indonesia. In D. Pauly and P. Martosubroto (eds.) Baseline studies of biodiversity: the fish resource of western Indonesia. *ICLARM Studies and Reviews*, 23. p. 135-216.
- Pervin, M. R. and M. G. Mortuza. 2008. Notes on length-weight relationship and condition factor of fresh water fish, *Labeo boga* (Hamilton) (Cypriniformes: Cyprinidae). *Univ. J. Zool. Rajshahi Univ.*, 27: 97-98.
- Prayitno, M. A., H. Setiawan, I. Jatmiko, M. A. Rahman and D. G. R. Wiadnya. 2020. Spawning potential ratio (SPR) of Sulphur Goatfish (*Upeneus sulphureus*): biological basis for demersal fishery management in Java Sea. *IOP Publishing in IOP Conf. Ser.: Earth Environ. Sci.*, 441, 012141: 1-9.

- Randall, J. E. 2004. Revision of the goatfish genus *Parupeneus* (Perciformes: Mullidae), with descriptions of two new species. *Indo-Pacific Fishes*. Bishop Museum, Honolulu, Hawaii. 36: 1-64.
- Reuben, S., K. Vijayakumaran and K. Chittibabu. 1994. Growth, maturity and mortality of *Upeneus sulphureus* from Andhra-Orissa coast. *Indian J. Fish.*, 41 (2): 87-91.
- Satish Kumar, M., S. Ghosh, K. Sreeramulu, V. Uma Mahesh, M. V. Rao and P. Rohit. 2019. Length-weight relationship of *Thunnus albacares*, landed along north Andhra Pradesh. *J. Mar. Biol. Ass. India*, 61 (1): 66-70.
- Siddique, M. A. M., M. S. K. Khan, A. Habib, M. K. A. Bhuiyan and S. Aftabuddin. 2016. Size frequency and length-weight relationships of three semi-tropical cephalopods, Indian squid *Photololigo duvaucelii*, needle cuttlefish *Sepia aculeata*, and spineless cuttlefish *Sepiella inermis* from the coastal waters of Bangladesh, Bay of Bengal. *Zool. Ecol.*, 26 (3): 176-180.
- Stergiou, K. I. 1991. Biology, ecology and dynamics of *Cepola macrophthalma* (L. 1758) (Pisces Cepolidae) in the Euboikos and Pagassitikos Gulfs. Aristotle University of Thessaloniki, Greece. Ph. D. dissertation. 222 pp.
- Tesch, F. W. 1971. Age and growth. In Ricker, W. E. (Ed), *Methods for assessment of fish production in fresh waters*. Blackwell Scientific Publications, p. 99-130.
- Thomas, P. A. 1969. *The goat fishes (Family Mullidae) of the Indian Seas. Memoir III*. Marine Biological Association of India, Mandapam Camp. 174 pp.
- Thomas, J., S. Venu and B. M. Kurup. 2003. Length-weight relationship of some deep-sea fish inhabiting the continental slope beyond 250 m depth along the West Coast of India. *NAGA*, 26 (2): 17-21.
- Uiblein, F. and P. C. Heemstra. 2010. A taxonomic view of the western Indian Ocean goatfishes of the genus *Upeneus* (Family Mullidae), with descriptions of four new species. *Smithiana Bulletin*, 11: 35-71.
- Uiblein, F., T. A. Hoang and D. Gledhill. 2017. Redescription and new records of Jansen's goatfish, *Parupeneus janseni* (Mullidae), from the Western Pacific and Eastern Indian Ocean. *Zootaxa*, 4344 (3): 541-559.
- Uiblein, F., G. Gouws, M. Lisher and B. S. Malauene. 2020. *Upeneus flores*, a new goatfish from South Africa and Mozambique, with updated taxonomic accounts for *U. guttatus* and *U. pori* and a key to Western Indian Ocean *Upeneus* species (Mullidae). *Zootaxa*, 4834 (4): 523-555.
- Vahabnezhad, A., S. A. Taghvimotlagh and A. Salarpouri. 2020. Estimation of growth parameters and mortality rate of *Upeneus sulphureus* (Cuvier, 1829) in the Persian Gulf ecosystem. *J. Surv. Fish. Sci.*, 7 (1): 69-81.
- Vassilopoulou, V. and C. Papaconstantinou. 1994. Age, growth, and mortality of the spotted flounder (*Citharus linguatula* Linnaeus 1758) in the Aegean Sea. *Scientia Marina*, 58: 261-267.
- Vishnupriya, K. M. and J. Nair Rekha. 2023. Distribution and diversity of Goatfishes, (Mullidae, Teleostei, Syngnathiformes), along the Indian Coast. *J. Mar. Biol. Ass. India*, 65 (1): 114-120.
- Vivekanandan, E., U. Rajkumar, R. J. Nair and V. Gandhi. 2003. Goatfishes. In: M. Mohan Joseph and A. A. Jayaprakash (Eds.) Status of Exploited Marine Fishery Resources of India. *CMFRI*, p. 158-163.
- Wang, X. H., Y. S. Qiu, G. P. Zhu, F. Y. Du, D. R. Sun and S. L. Huang. 2011. Length-weight relationships of 69 fish species in the Beibu Gulf, northern South China Sea. *J. Appl. Ichthyol.*, 27 (3): 959-961.
- Willing, R. S. and P. J. Pender. 1989. Length-weight relationships for 45 species of fish and three invertebrates from Australia's northern prawn fishery. *Northern Territory Dept. Primary Industry and Fish. Australia. Tech. Bull.*, 142: 57 pp.
- Xu, G., W. Zheng and G. Huang. 1994. Atlas of the fishes and their biology in Daya Bay. *Anhui Scientific and Technical Publishers, P.R.O.C.* 311 pp.
- Zaher, F. M., B. M. S. Rahman, A. Rahman, M. A. Alam and M. H. Pramanik. 2015. Length-weight relationship and GSI of Hilsa, *Tenualosa ilisha* (Hamilton, 1822) fishes in Meghna River, Bangladesh. *Int. J. Nat. Soc. Sci.*, 2: 82-88.