Journal of Aquatic Biology & Fisheries | 2023 | 11(1) | pp. 124-129
ISSN 2321–340X
OPEN ACCESS
http://www.jabf.in/
University of Kerala, INDIA

Biometry and length-weight relationship of tomato hind grouper, *Cephalopholis sonnerati* (Valenciennes, 1828) (Serranidae) landed along the Vizhinjam coast of Kerala, India

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ABSTRACT

The study, investigates the Length-Weight Relationship (LWR) and morphology of *Cephalopholis sonnerati* landed along Vizhinjam during 2019-2020. Fish samples had a total length ranging from 120 to 545 mm with a coefficient of variation of 29.28%. Among the twenty-one morphometric characters expressed in the percentage of total length, there were four genetically controlled, five intermediate and twelve environmentally controlled characters. The fin formula of the fish can be written as D: IX, 14-16; PT:15-18; PL: I, 4-5; A. III + 9. The LWR indicates a significant (P< 0.05) positive allometric growth pattern for males and females, estimated as $W= 0.0000015L^{3.4250}$ and $W= 0.000015L^{3.0186}$ with r^2 (coefficient of determination) values of 0.922 and 0.896, respectively. The R square value of the relationship for the population is 0.9747, indicating a good fit. The LWR showed that the well-being of *C. sonnerati* is good. This study will help decide better conservation techniques and proper management methods for this reef-associated fish species. It will also provide relevant data for stock assessment and compare the same species' populations from different environments.

ARTICLE HISTORY

Received on: 30-03-2023
Revised on: 27-10-2023
Accepted on: 29-12-2023

KEYWORDS

Cephalopholis sonnerati,
Biometry,
Length-Weight Relationship,
Positive allometric growth,
Vizhinjam

1. Introduction

Groupers have contributed significantly to the growth of the Indian fishery sector. With the expansion of mechanized trawling all over India, they became one of the major candidates for targeted fishery in tropical and subtropical regions (Randall and Heemstra, 1991). They are predatory fishes primarily associated with coral reefs (Heemstra and Randall, 1993). Even though the coral reef ecosystem accommodates a large diversity of commercially important fishes like snappers, parrot fishes, groupers, emperor breams, unicorn fishes and surgeon fishes, groupers are the most expensive fish group. These are very popular for their high quality, tasty and tender meat, and their increasing demand has resulted in indiscriminate exploitation of the natural stock (Chiappone et al., 2000). Among them is the tomato hind grouper, *Cephalopholis sonnerati,* which is in high demand in the export and ornamental market (Saritha *et al*., 2014*)*. In and around Vizhinjam region, it is known as Thamban and is a highly preferred food fish in the domestic market. Their life history strategy of being protogynous hermaphrodites and forming spawning aggregations (Chan and Sadovy, 2002) makes them vulnerable to overfishing. So, for proper management, it is essential to find reliable information on this species' Length-Weight Relationship (LWR) and other biological data.

LWR calculations give insights chiefly into the fishery assessment measurements like stock composition, population dynamics and production (Bolger and Connoly, 1989; Erkoyuncu, 1995; King, 1996; Moutopoulos and Stergiou, 2000). Such studies can be used to devise methods of management and conservation of threatened and commercially important fishes. Morphometric characters describe various aspects of the body. Certain discrete, serially repeated, countable structures are fixed in an organism when it is still in the embryo or larval stage, which are accounted as meristic characters. These morphological and meristic features provide relevant data on different aspects like growth, death and reproduction, which ultimately helps in stock identification.

The main objective of this paper is to provide LWR and other biological parameters of *C. sonnerati* landed along the Vizhinjam coast of Kerala.

2. Methodology

The species, *C. sonnerati*, is a demersal fish resource commonly found in the coastal waters of Vizhinjam (80 22'45"N Latitude and 760 59'29"E Longitude). Fishery-related data on this species was collected from the Fishery Resources Assessment Division (FRAD) of Central Marine Fisheries Research Institute (CMFRI), India. For the morphological studies, fish specimens in fresh condition were collected from the artisanal fishers and middle men at the landing sites during 2019-2020. They were preserved in the icebox and then transported to the biology laboratory in Vizhinjam Regional Centre of CMFRI. After cleaning, each fish was weighed to get the total wet weight using a digital balance, and the total length, as the distance from the tip of the snout to the caudal fin, was recorded for each of them using a 30 cm ruler. The sex of the fish was confirmed by microscopic and histological methods. The following growth analyses were performed:

Twenty two morphometric measurements in percentage of total length i.e., the proportions to total length vs Standard length (SL), Head length (HL), Head depth (HD), Snout to prenostril distance (SPND), eye diameter (ED), Inter-orbital length (IOL), Pre dorsal length (PDL), Pre-pectoral length (PPL), Pre-pelvic length (PPEL), Pre-anal length (PAL), Body depth (BD), Dorsal fin base length (DFBL),

Pectoral fin base length (PFBL), Pelvic fin base length (PEFBL), Anal fin base length (AFBL), Pectoral fin length (PFL), Pelvic fin length (PEFL), Caudal peduncle length (CPL), Caudal peduncle depth (CPD), Pre-orbital length (POL) and Post orbital length (POOL), have been studied. Statistical analysis, especially mean, standard deviation, range, correlation and regression analysis, of these recorded calculations were done. All the morphometric characters were then categorized into genetically (<10%), intermediate (10-15%) and environmentally (>15%) controlled characters (Johal *et al*., 1994).

Linear regression is used to model the relation between length and weight (log-transformed) of the fish. Also, scatter diagrams of length and weight were plotted using Excel 2013. It is then defined by the cube law recommended by Le Cren (1951). $\mathbf{W = aL^b}$

Where, W is the weight of the fish (g), L is the total length (mm), 'a' is the regression intercept, and 'b' is the regression slope.

The logarithmic transformation of the above- mentioned equation is- **Log W = log a + b log L**

3. Results

The estimated landing of *C. sonnerati* along the Vizhinjam coast during 2019 is 37.81 tonnes, about 0.43 % of the total landing in Vizhinjam. The landing of *C. sonnerati* for the last few years is shown in Fig.1. The fishing of this species along the Vizhinjam coast is mainly carried out by traditional motorised or non-motorised outboard fibre boats of about 28- 32 feet in length. Hook and line is the main gear used to catch these species. During 2013-2019, along the Kerala coast, outboard hook and line contributed 28.7% of the catch of *C. sonnerati* followed by motorised drift net cum hook and line (27.95%), outboard gill net (24.63%), motorised hook and line (7.53%), motorised gill net (5.78%), outboard boat seine (3.41%), motorised drift net (1.22%), motorised other gears(0.62%), non-motorised gears(0.15%) and negligible amounts are provided by outboard drift net cum hook and line (0.004%) and non-motorised hook and line (0.001%) (Fig. 2). Number 13 hook with *Odonous niger* as bait, is popularly used in the capture of *C. sonnerati*. The length frequency distribution of the collected specimens is given in Fig. 3.

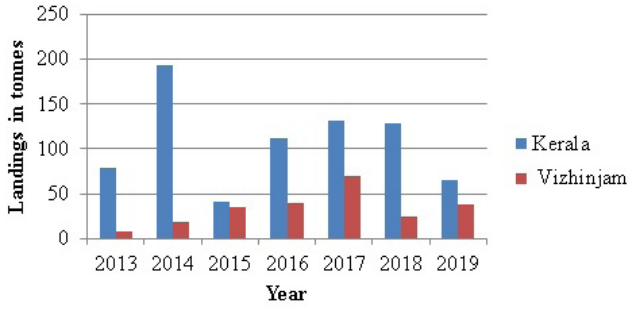

Fig. 1. Graph showing the landing of *Cephalopholis sonnerati* in Kerala and Vizinjam from 2013 to 2019.

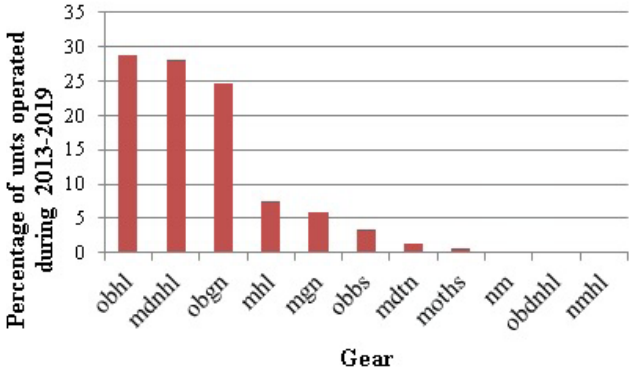

Fig. 2. Percentage of units operated during 2013-2019 in Kerala in catching *Cephalopholis sonnerati*

3.1 Morphometrics and meristic studies:

A total of 457 specimens of *C. sonnerati* ranging from 120 to 545 mm in total length formed the material for the present study. The descriptive statistics of *C. sonnerati* are given in Table 1, and the detailed statistical analysis of morphometric characters in relation to the percentage of total length is given in Table 2. From the study, it was evident that a maximum coefficient of variation of 49.23 % is shown in the case of pelvic fin base length followed by pectoral fin base length (39.4%) and pre-orbital length (37.92%) while the minimum coefficient of variation is found in pelvic fin length (10.35%). When a comparison is made between morphometric characters and total length (Table 2), pelvic fin base length showed the highest 'b'

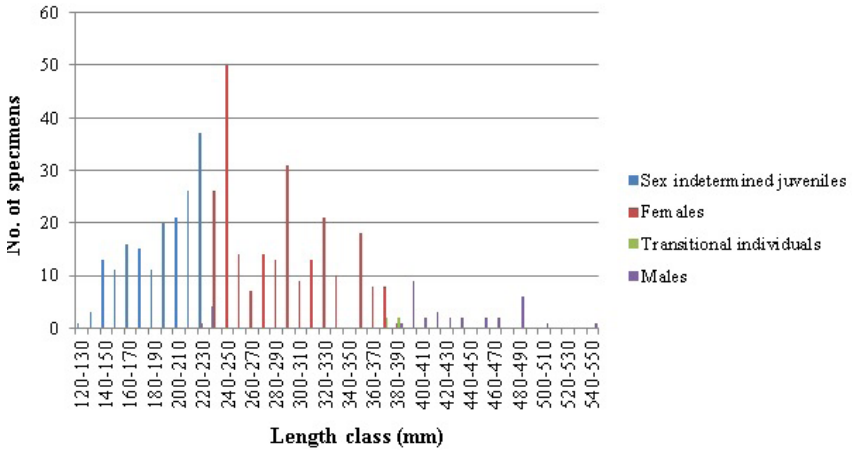

Fig. 3. Size frequency distribution of sex indetermined juveniles, Females, Transitional individuals and Males during the study period

Table 1. Descriptive statistics of Morphometrics of *Cephalopholis sonnerat*i

	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard Deviation	Standard Error	Coefficient of variation (%)
Total length	120	545	261.31	76.51	3.58	29.28
Standard length (SL)	84	418	216.85	66.54	3.11	30.69
Head length (HL)	26	138	79.99	24.75	1.16	30.95
Head depth (HD)	19	159	75.92	24.22	1.13	31.9
Snout to prenostril distance (SPND)	8	50	20.16	6.81	0.32	33.8
Eye diameter (ED)	5	17	10.81	1.84	0.09	17.02
Inter-orbital length (IOL)	6	32	14.96	4.51	0.21	30.17
Pre dorsal length (PDL)	38	166	86.24	24.63	1.15	28.56
Pre-pectoral length (PPL)	40	40	86.05	27.64	1.29	32.12
Pre-pelvic length (PPEL)	44	191	96.04	27.55	1.29	28.68
Pre-anal length (PAL)	72	289	153.34	44.58	2.09	29.07
Body depth (BD)	35	165	86.54	26.56	1.24	30.69
Dorsal fin base length (DFBL)	45	221	110.78	33.11	1.55	29.89
Pectoral fin base length (PFBL)	6	90	17.06	6.72	0.31	39.4
Pelvic fin base length (PEFBL)	4	28	11.98	5.9	0.28	49.23
Anal fin base length (AFBL)	20	86	44.05	12.63	0.59	28.68
Pectoral fin length (PFL)	23	92	52.2	13.54	0.63	25.93
Pelvic fin length (PEFL)	20	48	34.32	3.55	0.17	10.35
Caudal peduncle length (CPL)	10	57	29.85	9.09	0.43	30.46
Caudal peduncle depth (CPD)	12	62	29.02	9.62	0.45	33.16
Pre orbital length (POL)	10	71	23.64	8.97	0.42	37.92
Post orbital length (POOL)	20	82	44.96	14.41	0.67	32.05

Table 2. Mean, S.D., Correlation coefficient (r), Regression equation (Y=a+bX), Range and r^2 values between different morphometric characters of *Cephalopholis sonnerati*

	In percentage Total length					
	Mean (%)	Standard deviation	Correlation coefficient	Range, Range difference	Regression equation	r^2
Standard length(SL)	82.77	5.08	0.97	29.40-97.90 (68.5)	SL=0.69+1.03TL	0.93
Head length(HL)	30.5	2.56	0.96	21.67-37.90 (16.23)	HL=0.22+1.06TL	0.93
Head depth(HD)	28.94	3.08	0.95	14.6-39.90 (25.3)	HD=0.2+1.07TL	0.89
Snout to prenostril distance (SPND)	7.66	1.06	0.92	15.23-3.80 (11.43)	SPND=0.05+1.08TL	0.85
Eye diameter(ED)	4.32	0.77	0.78	6.21-2.75(3.46)	ED=0.78+0.47TL	0.63
Inter-orbital length(IOL)	5.77	0.88	0.87	9.45-3.36(6.09)	IOL=0.09+0.92TL	0.75
Pre dorsal length (PDL)	33.02	2.77	0.97	42.12-25.27(16.85)	PDL=0.36+0.99TL	0.94
Pre-pectoral length(PPL)	32.93	2.93	0.95	41.43-25.92(15.51)	PPL=0.37+0.98TL	0.91
Pre-pelvic length(PPEL)	36.94	3.31	0.95	44.19-27.27(16.92)	PPEL=0.51+0.94TL	0.9
Pre-anal length(PAL)	58.6	4.18	0.98	72.40-41.44(30.96)	PAL=0.58+1TL	0.96
Body depth(BD)	32.26	5.61	0.96	40.72-24.52(16.2)	BD=0.2+1.09TL	0.91
Dorsal fin base length(DFBL)	42.37	3.55	0.97	59.92-30.51(29.41)	DFBL=0.46+0.99TL	0.94
Pectoral fin base length(PFBL)	6.55	2.77	0.75	62.5-3.73(58.77)	PFBL=0.05+1.03TL	0.74
Pelvic fin base length(PEFBL)	4.43	1.38	0.84	8.47-1.78(6.69)	PEFBL=0.004+1.4TL	0.61
Anal fin base length(AFBL)	16.97	1.78	0.94	23.20-11.86(11.34)	AFBL=0.26+0.92TL	0.88
Pectoral fin length(PFL)	20.19	1.94	0.96	26.47-14.29(12.18)	PFL=0.44+0.86TL	0.91
Pelvic fin length(PEFL)	14.13	3.75	0.11	22.67-6.24(16.43)	PEFL=20.25+0.09TL	0.06
Caudal peduncle length(CPL)	11.42	1.72	0.9	18.42-6.99(11.43)	CPL=0.13+0.97TL	0.8
Caudal peduncle depth(CPD)	11.02	0.97	0.97	15.19-7.10(8.09)	CPD=0.06+1.1TL	0.94
Pre orbital length (POL)	8.93	1.46	0.88	17.71-6.19(11.52)	POL=0.04+1.17TL	0.85
Post orbital length (POOL)	17.18	3.13	0.87	35.43-11.22(24.21)	POOL=0.15+1.03TL	0.79

value of (1.4), indicating the highest growth rate followed by pre-orbital length (1.17) and caudal peduncle depth (1.1) and the lowest value is for pelvic fin length (0.09). The correlation coefficient of the various characters in the above- mentioned context ranges from 0.11 to 0.98 in which pre-anal length shows a high positive correlation (r=0.98) with a coefficient of determination (r^2) of 0.96 . The feature like pelvic fin length shows a comparatively low correlation coefficient (0.11) with a lower coefficient of determination (0.06) with a negative allometric growth. Between the twenty one morphometric characters in the percentage of total length, there were four genetically controlled, five intermediate and twelve environmentally controlled characters.

The examination of meristic characters revealed the fin formula of the fish as D: IX, 14-16; PT:15-18; PL: I, 4-5; A. III + 9. The number of opercular spines and branchiostegal rays are 3 and 7 respectively. The number of gill rakers on the upper limb varied between 7-9 and the lower limb between 13-16. The details of the meristic characters of *C. sonnerati* are given in Table 3.

3.2 Length Weight Relationship (LWR):

LWR of C. sonnerati for the female, male and pooled (Sex indetermined juveniles+ Females+ Transitional individuals + Males) data are established as:

Female: $W= 0.000015L^{3.02}$, Male: $0.0000015L^{3.43}$ and Pooled: $W= 0.0000075L^{3.14}$ respectively. The linearised expressions for the LWR *of* females, males and pooled are: Female: LnW= -11.11+3.02 LnL (r^2= 0.9), Male: LnW= -13.39+3.43 LnL (r^2= 0.92), and Pooled: LnW= -11.79+ 3.14 LnL (r^2= 0.98) respectively. Analysis revealed that there is significant (P<0.05) positive relationship between the length and weight of males and females. The value of b in the pooled data of *C. sonnerati* is greater than 3, indicating positive allometric growth, i.e., weight increases with length. Males exhibited a higher b value of 3.43 than females (3.02). The regression slope of males and females did not show any significant difference. The power relationship of length and weight for pooled (Fig. 4), females (Fig. 5) and males (Fig. 6) is being presented in scatter plots.

4. Discussion

Groupers are a highly diverse, fascinating group of reef-associated fishes which are commercially important. Even though they make a sizeable contribution to the global fishery, very little is known about the biology and length-weight relationship of most of the species. Fluctuations are observed in the fishery of *C. sonnerati* from the Kerala coast. During 2013-2019, Kerala coast alone has contributed more than 50 tonnes of this species each year. Various coastal ecosystems of India (Kerala, Tamil Nadu, Vishakhapatnam, Karnataka, Lakshadweep and Andaman and Nicobar Islands) have reported a wide diversity of *Cephalopholis* species (Jones and Kumaran, 1980; Talwar, 1990; Marine Biological Station, Chennai, 2003). The species of *C. sonnerati* is widely spread within the Indo-Pacific region (Behera *et al*., 2016). LWR in *C. sonnerati* studied by different workers from different parts of the world have been given in table 4. *C. sonnerati* form commercial fishery all year-round from Vizhinjam coast. Here, the species did not form a major fishery during earlier days. But due to their increasing demand as a delicacy in the local market, the species began to enjoy considerable economic importance in the traditional fishery. Thoothukudi coast has also seen year-round landing of this species (Kumar *et al*., 2006).

Table 3. Meristic characters of *C. sonnerati*

Meristic characters	Range
Gill rakers	7-9 upper limb 13-16 lower limb
Dorsal fin spines/rays	IX + 14 -16
Pectoral fins	15-18
Pelvic spines/ rays	I + 4-5
Anal fin spines/rays	III + 9
Caudal spines/rays	15-18
Branchiostegal rays	7
Opercular spines	3

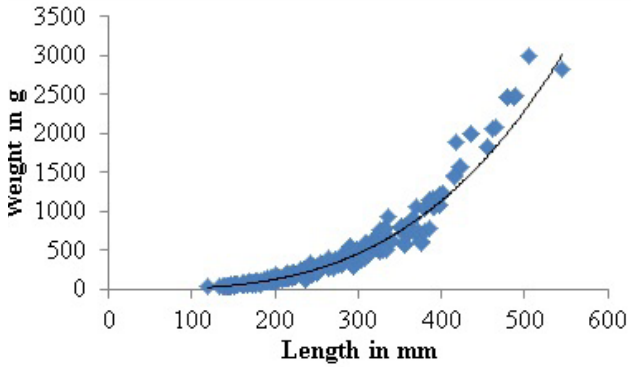

Fig. 4. LWR of pooled data (including sex indetermined juveniles and transitional individuals)

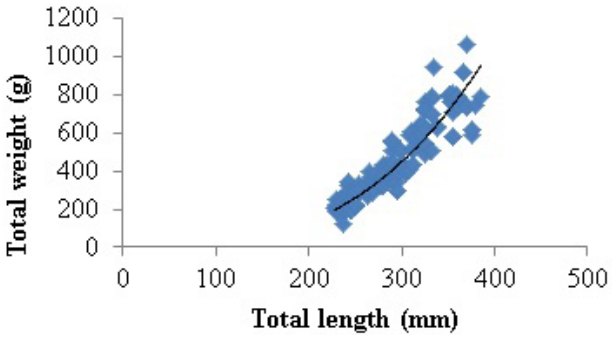

Fig. 5. LWR in females

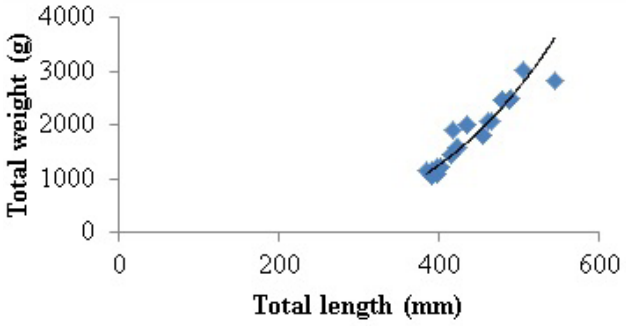

Fig. 6. LWR in males

Most of the morphometric characters of *C. sonnerati* examined indicate high degree of positive correlation with total length. A strong positive correlation reveals the linear association between compared characters which means growth in total length results direct growth in various body parts at different rates as observed in the present study. Craig (2007) reported high degree of correlation between total length and standard length for *Epinephelus ongus* from Okinawa, Japan. Positive allometric growths between head length, body head, eye diameter and wide mouth opening with total length of *E. polyphekadion* have been discussed by Jayadi *et al*., 2017. Dobriyal *et al*., (2006) reported that all body parts grow according to total length. Similar findings were also reported by Rawat and Agrawal (2003) as dimensions of all the body parts increases simultaneously with total length of fish. Several factors like seasonality, food availability, sex, sample size can influence the length-weight relation or the growth in fishes (Haimovici and Velasco, 2000). Generally, in groupers males are larger than the females, and they occur in few numbers in deep water (Mathew *et al*., 2002). *C. sonnerati* is a diandric protogynous hermaphrodite grouper (Chan and Sadovy, 2002) which would indicate that the larger ones in this species would most likely be males. In the present study, the growth pattern of *C. sonnerati* landing at Vizhinjam follows a positive allometry that coincides with the results given by Gonzales *et al*., 2000, Kulbicki *et al*., 2005, Sujatha *et al*., 2015 and Gumanao *et al*., 2016. The R square value for the relationship is 0.9747 indicating a good fit. Collar and Wainwright (2009) have indicated that body dimensions like gape, body depth and body length are directly related to the locomotary, foraging, feeding patterns and reproductive biology. Since groupers have lower levels of lateral compression, they depend more on the body and caudal fin movements. The bigger sized groupers are characterized by large gapes. Morphometric and meristic characters of *C. sonnerati* are being recorded by different authors like Heemstra and Randall, 1999, Allen and Erdmann, 2012 and Behera *et al*., 2016, which are almost identical to that of the specimens collected during this study.

5. Conclusion

The present study provides the growth pattern of Tomato hind grouper, *C. sonnerati* from the Vizhinjam coast in Kerala. The majority of morphological characters, considered in proportion to total length, were environmentally controlled. Positive allometry shown in the LW relationships of both the sexes and pooled one revealed that the rate of increase in body length is proportional to the rate of increase in body weight. All the morphometric characters except for the pelvic fin length show strong correlation with respect to the total length. The slight variations in the meristic features and values of 'a' and 'b' of various morphometric characters from earlier reports may be due to the change in stock characteristics. Standard length, Head length, Pre-dorsal length, Pre- pectoral length, Pre- pelvic length, Pre-anal length, Body depth, Dorsal fin base length, Pectoral fin length and Caudal peduncle depth have a high degree of homogeneity within the population as evident from the r2 values. This study will help decide better conservation techniques and management methods of *C. sonnerati*.

Acknowledgement

This research work was carried out at Vizhinjam Regional Centre of Central Marine Fisheries Research Institute (CMFRI) with the funding from University Grants Commission, India. The authors are thankful to Dr. A. Gopalakrishnan, Director, CMFRI and all the staffs of Vizhinjam Regional Centre for the coordination and support.

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