Journal of Aquatic Biology & Fisheries | 2021 | **9** | pp. 55-59

ISSN 2321–340X

Morphometric and Meristic Analysis of Half-Smooth Golden Pufferfish *Lagocephalus spadiceus* (Richardson, 1845) (Actinopterygii, Tetraodontiformes) from Kerala Coast

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Abstract

The morphometric and meristic characters of the half-smooth golden pufferfish *Lagocephalus spadiceus* has been investigated for a period of six months. Morphometric analyses were performed using traditional methods. In order to compare the morphometric differences, if any, between the male and female of *L. spadiceus* 't' test was employed and PCA was applied to investigate the morphological variations shown by the sexes. Mann Whitney U test was also applied to check whether the meristic variables differ among the two sexes. For the 13 morphometric parameters considered, there was a significant difference between males and females in which the values obtained for the females outliers the male. The principal component analysis (PCA) showed that PC 1 coefficients were all positive, indicating no shape variation between males and females. Moreover, all the morphometric characters in PCA analyses showed a significant difference between males and females, but the three most important variables included total length, caudal peduncle width and eye diameter.

Keywords: Morphometric, Meristic, *Lagocephalus spadiceous*, PCA, Negative allometry

1. Introduction

Since the beginning of the past century, traditional morphometrics is considered as a tool used in the multidisciplinary approaches for stock identification (Teugals, 1982; Pepin and Carr, 1993; Tudela, 1999; Murta, 2000; Kai and Nakabo, 2002; O'Reilly and Hornt, 2004; Turan, 2004; Turan et al., 2005; Suneetha, 2005) and also been widely used for separating various species, population and races; it also helps in determining sexual dimorphism (Analaura *et al*., 2005). Morphological characters such as morphometrics and meristics have also been used to establish the evolutionary linkages between ancient and modern fish fauna (Deesri *et al*., 2009). Studies on morphometric measurements and statistical relationships of fishes are imperative for both fishery biology (Sparre *et al.*, 1989; Mustafa and Brooks 2008) and taxonomic studies. They also disclose the differences in body shape between separate individuals to distinguish populations of the same species (Hirsch et al., 2013).

Tetraodontids are circumglobal in tropical and temperate shallow waters, mostly marine, but several enter estuaries, and some live only in freshwater and are entirely absent from cold waters (Matsuura, 1997). Globally puffers of the genus *Lagocephalus* Swainson, 1839 belongs to the Family Tetraodontidae comprising of eleven species out of which five species viz., *L. guentheri*, *L. inermis*, *L. lunaris*, *L. lagocephalus*, and *L. scleratus* has been reported from India (Padmavathi, 2011). The present study was conducted in the demersal species *Lagocephalus spadiceus* (Richardson, 1845), which occurs in tropical waters and obtained as bycatch during trawling. *L. spadiceus* has a widespread distribution throughout the tropical Indian and Pacific Oceans (Froese and Pauly, 2016).

In recent decades, several workers have surveyed the morphology of Tetraodontiformes and have used their massive data sets to assess the familial relationship and try to determine the sister group of the order (Santini and Tyler, 2003; Holocraft, 2004, 2005, Matsuura, 2015). Corsini *et al*. (2010) studied morphometrics of tetraodontid *Tylerius spinosissimus* in the Aegean Sea. Morphometrics of *Lagocephalus scleratus* from the Mediterranean Sea was studied by Akyol *et al.* (2005), Aydin (2011) and Bineesh et al. (2014) from the Southwest coast of India. Morphological variations in porcupine fish and pufferfish were attempted by Kaleshkumar *et al*. (2018) from Tamil Nadu. Ragonese *et al.* (1997) studied the morphometric relationship of *Sphoeroides pachygaster* from the strait of Sicily. Biometry of *Arothron stellatus* from Shatt Al- Basrah Canal was studied by Abed e*t al.* (2013).

The reports on the increase in the landings of *Lagocephalus* spp. in the south-west and south-east coasts of India notwithstanding, there has been no specific study thus far on the meristic and morphometric studies of Half-smooth golden pufferfish *Lagocephalus spadiceus*. We, therefore, present thorough morphological and meristic features of the species to address the knowledge gap.

2. Materials and Methods

Fishes for the present study were collected from the commercial trawlers of Neendakara (8°56'19'N 76°32'25E), and Sakthikulangara (8°55'30'N 76°33'22'E), landing centres of Kollam district. The specimens were collected for a period of six months (November 2015 to April 2016) from fishermen, where *Lagocephalus spadiceus* were obtained as trawl bycatch. A total of seventy fishes (males; N= 32) and females;

Received on: 02-01-2021; Revised on:16-04-2021; Accepted on: 03-05-2021

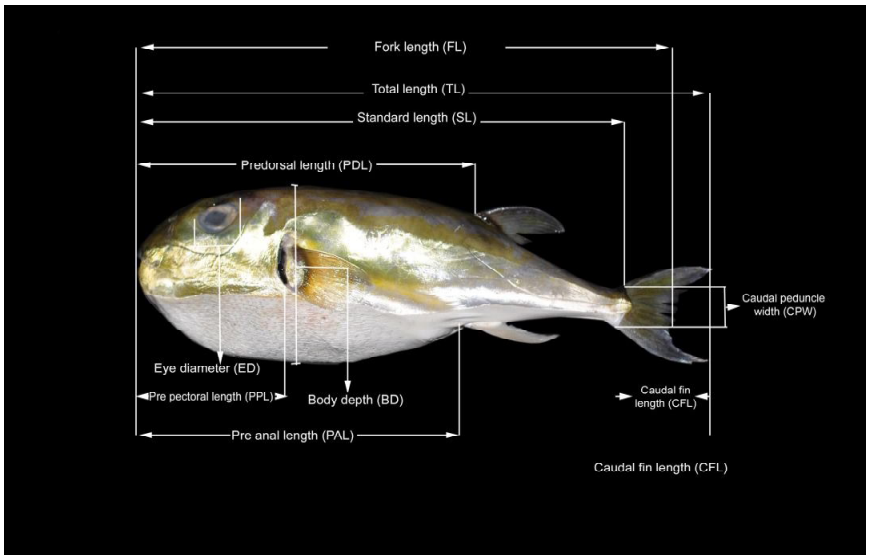

Fig. 1. Morphometric measurements of *Lagocephalus spadiecus*

N=38) were randomly, without any size bias, collected and analysed for the present study.

2.1. Collection and Preservation

Immediately after collection, samples were kept in an icebox and are taken to the laboratory for further studies. Soon after that, photo documentation of fish was done using a digital camera. The fish was then identified using FAO species identification sheets (Fischer and Bianchi, 1984) for fisheries purposes, and FishBase Worldwide Web Electronic Publication (www.fishbase.com, Froese and Pauly, 2016) as *Lagocephalus spadiceus* belonging to the family Tetraodontidae due to the characteristic four teeth, and lack of pelvic fin and a rhomboidal patch of spinules on the back. Weight of the fish is calculated using a Metler analytical balance up to the nearest gram and then preserved with 10% formalin for morphometric analysis.

2.2. Morphometry

The morphometric parameters taken up for the present investigation is provided in Fig. 1. Meristic analyses are done with characters such as dorsal fin rays, anal fin rays, pectoral fin rays, and caudal fin rays.

In the present study of morphometry, the method of "t" test proposed by Snedecor and Cochran (1975) was employed to check whether there is any difference in growth rate/pattern between males and females. A multivariate technique, principal component analysis (PCA), was used to determine which morphometric measurement most effectively differentiates between the sexes.

3. Results

A total of 13 morphometric characters (Fig. 1) were recorded for seventy fishes, including length and weight, sex was also determined. The morphometric characters were scrutinized for both males and females separately (Table 1), and the data were pooled to elucidate the total population dimorphism in the species (Tables 2&3).

Of the 32 males and 38 females considered for the study, the average total length of the species was recorded as 16.59±7.4 cm and a highly significant ($P < 0.001$) difference was observed (Table 1) between male (12.61cm) and female (18.54) which shows females are lengthier than males. Standard length also followed the same pattern with more length in females (15.6 cm) than the males (10.59 cm) with significant ($P < 0.001$) difference between sexes. Weight showed considerable fluctuation from specimen to specimen as it was obtained during different seasons. Weight of female (124.98gm) registered significantly ($P < 0.001$) high value, which is almost double or more the weight of males (46.59 gm) with a mean weight of 99.22 gm for the entire population.

The female values of pre-dorsal and pre-anal length outliers the male values with a significant difference (Table 1). Similar is the case for Pre-pectoral length, which was also registered significantly high value in the female population. The interorbital length and eye diameter were also found to be unique for the species with 2.41cm and 1.17 cm, respectively, for the total population, and the female population showed significantly high values for both, interorbital length and eye diameter. Caudal fin length and caudal peduncle width also followed the same pattern of difference with a mean value of 2.66 cm and 1.14 cm, respectively for the total population. Fork and head length and body depth showed a highly significant difference between sexes of *L. spadiceus.*

3.1. Meristic Characters

Dorsal, anal, pectoral and caudal fin rays were counted and recorded (Table 4), of which only pectoral and anal fin rays showed some degree of fluctuation among specimens and all other meristic characters remain constant for both the sexes as well as for the species. Hence statistical analysis resulted in a zero standard deviation and insignificant Mann Whitney U value.

3.2. Principal Component Analysis (PCA)

The results of the analyses highlight the incongruity between males and females. Factor analysis using principal components to delineate sexual difference resulted in significantly high loading values for all the 13 morphometric parameters under consideration (Table 5; Fig. 2). The analyses showed all morphometric characters

Table 1. Mean, median and standard deviation of different body characters of females and males of *L. spadiceus* with t value

Gender		Female			Male		
Morphometric Characters	Mean	Median	± SD	Mean	Median	± SD	t- value
Weight (gm)	124.98	143	97.6	46.59	20.4	71.82	3.420**
Total Length (TL) (cm)	18.54	21.2	7.54	12.61	11	5.31	3.377**
Standard Length (SL)	15.6	17.3	6.3	10.59	9.2	4.43	3.418**
Pre-Dorsal Length (PDL)	10.5	11.9	4.07	7.17	6.1	2.78	3.535**
Pre-Anal Length (PAL)	10.72	12.5	3.93	7.39	6.5	2.83	3.617**
Pre-Pectoral Length (PPL)	5.01	5.5	1.88	3.6	3.1	1.41	3.193**
Interorbital Length (IOL)	2.66	2.8	1.15	1.92	1.8	0.73	2.796**
Eye Diameter (ED)	1.31	1.5	0.6	0.87	0.8	0.39	3.208**
Caudal Fin Length (CFL)	2.94	3.2	1.36	2.09	1.9	1.08	2.615**
Caudal Peduncle Width (CPW)	1.3	1.4	0.55	0.83	0.8	0.34	3.720**
Fork Length (FL)	17.16	19.9	7.35	11.93	9.9	4.95	3.080**
Head Length (HL)	5.06	5.3	1.96	3.7	3.2	1.42	2.982**
Body Depth (BD)	4.4	5	1.71	3.11	2.8	1.12	3.275**

** P < 0.001

Table 2. Mean, median and Standard deviation of the total population of *L. spadiceus*

Morphometric characters	Mean	Median	± SD
Weight (gm)	99.22	29.1	96.8
Total Length (TL) (cm)	16.59	12.2	7.4
Standard Length (SL)	13.96	10.65	6.19
Pre-Dorsal Length (PDL)	9.4	7	4
Pre-Anal Length(PAL)	9.62	7.45	3.92
Pre-Pectoral Length (PPL)	4.55	3.8	1.85
Interorbital Length (IOL)	2.41	2	1.08
Eye Diameter (ED)	1.17	1	0.58
Caudal Fin Length (CFL)	2.66	2	1.33
Caudal Peduncle Width(CPW)	1.14	1	0.54
Fork Length(FL)	15.44	11.75	7.07
Head Length(HL)	4.61	3.75	1.9
Body Depth(BD)	3.97	3.15	1.65

** P < 0.001

Table 3. Mean, median and standard deviation of meristic characters of the total population of *L. spadiceus*

Meristic characters	Mean	Median	± SD
Dorsal fin rays	12	12	0
Anal fin rays	11.99	12	0.12
Pectoral fin rays	16.97	17	0.24
Caudal fin rays	15	15	0

considered for the present study played an important role in differentiating the males and females of *L. spadiceus*. The first principal component explained that the character total length (TL), which had a high factor loading value (0.998). The total length of the species formed the main character in sexual dimorphism of the species. The mean value of TL of females (18.54) in the population was much

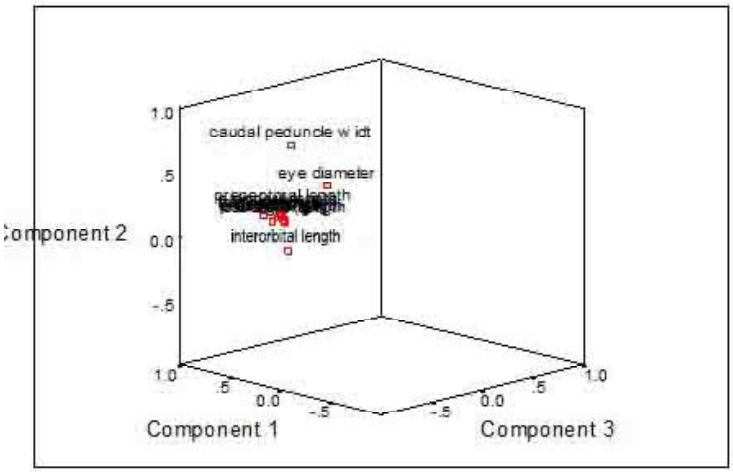

Fig. 2. Factor loading component plot on principal component analysis of meristic characters of male and female *L. spadiceus*

Table 4. Mean, median and standard deviation of meristic characters of the male and female population of *L. spadiceus* with Mann Whitney U-Value

Gender	Male			Female			
Meristic Characters	Mean	Median	± SD	Mean	Median	± SD	Mann Whitney U Value
Dorsal Fin Rays	12	12	0	12	12	0	540
Anal Fin Rays	12	12	0	11.98	12	0.15	529
Pectoral Fin Rays	16.91	17	0.42	17	17	0	517
Caudal Fin Rays	15	15	0	15	15	0	540

Table 5. PCA of transformed morphometric variables for *L. spadiceus*

Parameters	Component		
	1	2	3
Weight	0.960	-0.062	-0.004
Total Length	0.998	-0.026	-0.021
Standard Length	0.994	-0.010	-0.002
Pre-dorsal Length	0.992	-0.062	0.017
Pre-anal Length	0.974	-0.041	-0.107
Pre-pectoral Length	0.983	0.010	0.018
Interorbital Length	0.926	-0.281	-0.003
Eye Diameter	0.910	0.147	0.376
Caudal Fin Length	0.983	-0.081	0.024
Caudal Peduncle Width	0.808	0.576	-0.093
Fork Length	0.995	-0.039	0.008
Head Length	0.984	-0.053	0.007
Body Depth	0.962	0.021	-0.217

higher when compared to the TL of males (12.61) (Table 1). The second factor loading was for caudal peduncle width (0.576), which again showed a significant difference between males and females of the total population. Here also the mean value of caudal peduncle width of females (1.30) was significantly greater than that of males (0.83) (Table 1). The third PCA value (0.376) was recorded for eye diameter, which again showed a considerable difference between males and females of the species. The mean value of the eye diameter of the male is 0.87, and that of the female was 1.31 (Table 1).

4. Discussion

Our meristic counts and morphometric measurements match with those of Matsuura *et al*. (2011) and also a more recent record of Kiparissis *et al*. (2018) of *L. spadiceus* from Eastern Mediterranean. However, the meristic counts are slightly different from the reports of Golani *et al*. (2002) and Han *et al*. (2017) from Tamil Nadu. PC 1 coefficients were all positive, indicating no shape variation between sexes, but the characters such as total length, caudal peduncle width and eye diameter were found to be higher for females indicating significant difference in size between the sexes. Overall, it can be concluded that the growth of both the sexes in *Lagocephalus spadiceus* is negatively allometric.

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