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Morphometric Relationships and Sexual Dimorphism in *Pethia punctata,* An Endemic Barb of Western Ghats, India

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Abstract: Length-length relationships and morphometry-based sexual dimorphism in *Pethia punctata*, an endemic barb having food and ornamental importance have been determined using 33 morphometric parameters. The species exhibits persistent dichromatic characteristics with the possession of two to three rows of black spots on the dorsal fin in males vs lacking the same in females. Males' develop bright golden nuptial color with faintly red-tipped anal and pelvic fins while females do not exhibit any such color development. LLRs revealed that various lengths vs. standard length follow an allometric relationship (1<b>1). Total length and standard length are correlated positively as well as significantly correlated with a good fit (R^2>0.9). Six morphometric parameters showed significant differences ($p<0.05$) between males and females (HL, SPD, PoDL, CPL, ML and FPL). The first pectoral-fin ray length showed significant variation between males and females (p=0.003). This firsthand basal information on morphometrics and biometry based sexual dimorphism in *P. punctata* will be aiding life-history studies as well as conservation and sustainable use of the fish species.

Keywords: Allometry, Morphometric relationships, Sexual dimorphism, Nuptial coloration, Conservation

Morphometric relationships, particularly the length-length relationships are useful parameters for the prediction of the well-being of fish species, vital tool aiding in resolving taxonomic ambiguities as well as comparing life-history traits among populations of fish species (Nazir and Khan 2017, Parvin et al 2018). In fishes, length-length relationships are also relevant in the assessment of stock vis-a-vis population. The present study is aimed to analyse the morphometric relationships and sexual dimorphism (based on color pattern as well as biometric features) in the 'dotted sawfin barb', *Pethia punctata*, a small indigenous fish of Western Ghats. This Smiliogastrin barb is traded as an aquarium fish (Dahanukar 2015) as well as consumed by the tribal fishers in Kerala (Prajith et al 2016). As there is a great dearth of information on biological aspects of the species including biometric relationships and sexual dimorphism aiding in conservation and sustainable exploitation actions, the current study was undertaken to fill these gaps.

MATERIAL AND METHODS

Sample collection: Individuals of *Pethia punctata* were obtained from the tributary of Periyar River adjoining the Bhoothathankettu Dam (10˚07'56.77" N and 76˚39'48.40" E) in Ernakulam district, Kerala state, India for a year from August 2020 to July 2021. A total of 274 samples were used for analysis with 33 morphometric parameters measured from individual specimens following Armbruster (2012) using a Yamayo dial calliper (Table 1). For analyzing the sexual dichromatism and secondary sexual characters in the species, images of males and females were captured separately during the spawning season.

Statistical analysis: Length-length relationships of 33 morphometric measurements were estimated for 274 individuals (males =137; females =137) using linear regression after log transformation over standard length. Based on slope (b) values LLRs were divided into isometric and allometric categories (Oliviera and Almada 1995) i.e. if the upper limit of confidence level (CL) is lesser than one than its negative allometry and if lower limit of CL is greater than one than positive allometry. Significant ($p<0.05$) morphometric differences between males (n=137) and females (n=137), all the 33 measurements were analysed using the Mann-Whitney U test as well as regression analysis using PAST software.

RESULTS AND DISCUSSION

Morphometric data of *Pethia punctata* from Periyar river is presented in Table 1. The coefficient of determination (R^2) was >0.9 for SL vs. TL depicting that were highly significant and correlated, while for other parameters it was less than 0.9. The regression analysis showed that 13 parameters showed negative allometry, four morphometric parameters showed positive allometry while for the remaining parameters the 95% CL of 'b' does not exhibit much variation from isometry (b=1) (Table 2). TL vs SL relationship was reported as highly significant (R^2>0.9) and similar results have been obtained for congeneric species viz. *Pethia ticto, P. ornatus, Puntius chola* and *P. sophore* from wetlands of Lakhimpur district, Assam, India (Kaushik and Bordoloi 2015). The similar trend of allometry of SL with other morphometric parameters has been reported in other fish species viz. *Salmostoma bacaila* from Bangladesh (Parvin et al 2018) and *Oreochromis mossambicus* from Incomati River, Mozambique (Oliviera and Almada 1995).

Distinct sexual dichromatic characteristics of persistent and non- persistent types have been exhibited by the species. Possession of three rows of black spots on the dorsal fin of males and its absence in the female counterparts, is recognized as a persistent character (Katwate et al 2014). The males developed a golden yellow nuptial color with slight red coloration on the tips of the anal fin and pelvic fins while females retain the natural olive green color with silvery flanks in mature condition (Fig. 2 & 3). The smallest male that has developed rows of black spots on the dorsal fin had 22 mm TL

Table 1. Morphometric data of *Pethia punctata* (n=274) from Periyar river

Parameter	Code	Mean	S.D
Total length	TL (mm)	42.663	6.718
Standard length (SL)	SL (mm)	32.076	5.320
	%SL		
Predorsal length	PDL	53.412	4.458
Snout-supraoccipital distance	SnSuD	22.373	2.336
Head length	HL	28.621	2.530
Snout-pectoral distance	SnPD	29.173	2.603
Snout-gill distance	SnGD	24.352	2.334
Postorbital head length	PoHL	11.425	1.546
Gill-pelvic distance	GPvD	28.493	3.022
Supraoccipital-dorsal distance	SuDD	31.387	3.148
Supraoccipital-pelvic distance	SuPvD	33.126	3.665
Dorsal-pelvic distance	DFL	17.172	1.883
Dorsal-fin base length	DPvD	33.126	3.665
Postdorsal length	PoDL	2.766	3.532
Dorsal-anal distance	DAD	25.465	2.766
Anal-fin base length	AFL	9.808	1.713
Caudal-peduncle length	CPL	19.182	2.039
Caudal-peduncle depth	CPD	13.102	1.382
Inter-pectoral width	IPW	11.299	1.777
Inter-pelvic width	IPvW	6.509	1.100
Vent-anal distance	VAD	2.402	0.625
First dorsal ray length	FDL	28.104	3.147
First pectoral ray length	FPL	20.175	2.329
First pelvic ray length	FPvL	22.950	2.287
First anal ray length	FAL	16.915	2.058
	%HL		
Orbit length	OL	33.792	3.575
Internarial width	INW	18.201	3.106
Interorbital width	IOW	32.615	4.081
Head width	HW	45.812	4.303
Gape width	GW	18.129	3.222
Snout length	SnL	25.036	2.908
Upper-jaw length	UL	17.939	3.312
Mandible length	ML	11.385	2.600

confirming this as a unique persistent sexually dimorphic character of the species. But on contrary, two individuals (length class 50-55 cm) out of the 274 individuals examined, were found to possess rows of black spots on the dorsal fin with mature ovary and retained here as a serious subject of further investigation. Sexual dimorphism and dichromatism help in the estimation of the range of sexual selection in a species (Mieno and Karino 2017). Smiliogastrin cyprinids usually develop secondary sexual dimorphic characters of different types, viz tubercles in *Barbodes carnaticus* (Basavaraja et al 2019), *Dawkinsia tambraparniei* (Rajesh et al 2014), *Haludaria melanampyx* (Harikumar 1992); filamentous prolongation of anterior few rays of dorsal fin during the spawning season in *D. filamentosa* (Mahadevi et al 2020) and development of stripes or bands with intense coloration during breeding season in *Puntius chola* (Angami 2012), *P. parrah* (Vincent 2013). Though *P. punctata* belongs to the same subfamily, did not develop any such nuptial secondary sexual characters, but as an alternative, the males developed a bright golden color in par with the dull coloration of the female. Sexual dimorphism using morphometric characteristics revealed that six-length measurements of males differed significantly from females viz. HL, SPD, PoDL, CPL, ML, and FPL whereas, other morphometric parameters

Table 2. Length-length relationships of *Pethia punctata* (n=274) from Periyar river

Equation	Regression parameters		95% CL of a		95% CL of b		R^2
	a	b					
SL=a+bTL	1.681	0.932	1.545	1.828	0.908	0.956	0.954
SL=a+bPDL	0.613	0.960	0.511	0.736	0.907	1.031	0.824
SL=a+bSnSuD	0.618	0.710	0.289	1.322	0.490	0.930	0.129
SL=a+bSnL	0.088	0.938	0.062	0.123	0.839	1.036	0.563
SL=a+bUL	0.163	0.658	0.088	0.303	0.479	0.837	0.162
SL=a+bHL	0.522	0.826	0.444	0.612	0.780	0.872	0.819
SL=a+bSnPD	0.417	0.843	0.343	0.507	0.787	0.900	0.762
SL=a+bSnGD	0584	0.801	0.257	1.329	0.563	1.039	0.139
SL=a+bOL	0.497	0.524	0.391	0.630	0.455	0.593	0.453
SL=a+bPoHL	0.151	0.918	0.108	0.210	0.821	1.014	0.562
SL=a+bGPvD	0.233	1.057	0.185	0.294	0.990	1.124	0.780
SL=a+bSuPD	0.533	0.927	0.252	1.124	0.711	1.143	0.207
SL=a+bSuDD	0.200	1.129	0.164	0.245	1.071	1.187	0.843
SL=a+bDPvD	0.277	1.051	0.217	0.353	0.980	1.121	0.761
SL=a+bDFL	0.188	0.943	0.146	0.242	0.899	1.046	0.715
SL=a+bDAD	0.141	1.169	0.113	0.178	1.103	1.234	0.818
SL=a+bPoDL	0.328	1.007	0.248	0.433	0.927	1.088	0.691
SL=a+bAFL	0.063	1.121	0.039	0.102	0.984	1.259	0.485
SL=a+bCPL	0.215	0.966	0.167	0.277	0.892	1.039	0.711
SL=a+bCPD	0.112	1.043	0.086	0.147	0.966	1120	0.722
SL=a+bINW	0.141	0.705	0.080	0.250	0.540	0.869	0.207
SL=a+bIOW	0.089	1.008	0.063	0.126	0.909	1.108	0.592
SL=a+bHW	0.195	0.883	0.139	0.273	0.785	0.980	0.538
SL=a+bML	0.110	0.640	0.061	0.196	0.472	0.807	0.172
SL=a+bGW	0.098	0.812	0.035	0.274	0.517	1.107	0.097
SL=a+bIPW	0.062	1.167	0.0403	0.097	1.040	1.295	0.544
SL=a+bIPvW	0.023	1.293	0.013	0.039	1.140	1.447	0.502
SL=a+bVAD	0.018	1.066	0.009	0.036	0.870	1.263	0.295
SL=a+bFDL	0.609	0.775	0.480	0.774	0.706	0.844	0.641
SL=a+bFPL	0.276	0.907	0.210	0.362	0.829	0.986	0.656
SL=a+bFPvL	0.555	0.743	0.464	0.665	0.691	0.795	0.743
SL=a+bFAL	0.304	0.829	0.231	0.400	0.750	0.908	0.609

were not found differing (Table 3). The regression equations and coefficients of determination were estimated for all the six significantly different parameters (Fig. 4). The results differed when each length class was analysed separately. First pectoral ray length showed significant variation between sexes for lower length classes but differed in large length classes (Table 4), similarly post dorsal length also could be a predictor for different length classes. Length class-wise assessment of morphometric characteristics showed variation for different parameters for different size classes in *P. punctata*, but no prior data was available on size class morphometric sexual variation for any Indian *Pethia* spp. for comparison. In *Oreochromis mossambicus* size class was considered separately and reported that pelvic fins showed significant variation between sexes in small and medium-size class but not in large (Oliviera and Almada 1995). Biometry based sexual difference has been reported in *Pethia ticto* (Bahuguna et al 2010) while, in *Pethia conchonius* no

Table 3. Analysis of biometry based sexual dimorphism in *Pethia punctata* (n=274) using U test

Parameter	Male		Female		U test (p)
	Mean	±S. D	Mean	±S. D	
TL	42.8567	±5.97304	42.4643	±7.42493	0.137
SL	32.2685	±4.71379	31.8772	5.89069	0.0826
PDL	17.2229	±2.60154	17.1267	3.12647	0.1473
SnSuD	11.8946	±56.5746	7.08886	1.03893	0.0723
SnL	2.31069	0.38552	2.29157	0.49259	0.2572
UL	1.65708	0.27777	1.62943	0.36886	0.4458
HL	9.24618	1.21717	9.08429	1.48263	0.0443*
SnPD	9.40194	1.26487	15.6848	76.6563	0.0487*
SnGD	7.81507	1.06515	7.78379	1.34021	0.3236
OL	3.09521	0.32512	3.04629	0.41365	0.0854
PoHL	3.64938	0.6332	3.68564	0.77147	0.7691
GPvD	9.28056	1.6421	9.09853	1.92543	0.0625
SuDD	10.1621	1.91599	10.1624	2.25002	0.4405
SuPvD	13.2141	2.00605	20.3824	86.9154	0.2046
DPvD	10.5227	1.79186	10.8523	2.40938	0.879
DFL	5.51007	0.87981	5.55493	1.15767	0.6121
DAL	8.15493	1.54496	8.31721	1.99349	0.6217
PoDL	11.0028	1.80443	10.759	2.23295	0.0077*
AFL	3.15514	0.72897	3.18464	0.82688	0.6854
CPL	6.26306	1.04804	6.09493	1.21767	0.0449*
CPD	4.21931	0.709	4.23193	0.89645	0.3768
INW	1.67618	0.30162	1.65507	0.33827	0.4644
IOW	3.00625	0.53648	2.99571	0.62115	0.4321
HW	4.20715	0.6708	4.20179	0.76319	0.3834
ML	1.0666	0.24249	1.00264	0.2291	0.0104*
GW	1.66736	0.30062	2.95379	15.4162	0.379
IPW	3.62847	0.78925	3.69121	0.93812	0.6484
IPvW	2.12364	0.45798	2.10614	0.58273	0.1828
VAD	0.7961	0.24868	0.7675	0.2327	0.2471
FDL	8.96375	1.26623	8.9982	1.42414	0.6402
FPL	6.65319	1.03442	6.27164	1.21323	0.0003*
FPvL	7.38681	0.95678	7.26107	1.07082	0.0591
FAL	5.46035	0.81311	5.35471	0.94825	0.0869

Table 4. Length class wise morphometric sexual dimorphism using two sample t-test

Parameter	35-40	40-45	45-50	50-55	55-60
HL	0.0305	NS	NS	NS	NS
SnPD	NS	NS	NS	NS	NS
PoDL	NS	NS	0.040	NS	0.011
CPL	0.030	NS	0.002	NS	NS
CPD	NS	NS	NS	0.006	NS
ML	0.009	NS	NS	NS	NS
FPL	0.012	0.014	0.002	NS	NS
SuPvD	NS	NS	NS	NS	0.047

significant morphometric differences have been reported between sexes (Dobriyal et al 2007). In *Puntius singhala*, CPL (caudal peduncle length), PFL (pectoral fin length), and FBD (dorsal fin base) revealed signification variation between males and females (Gunawickrama 2009). No significant differences have been observed between male and female body sizes but the males possessed significantly longer pectoral fin than females in *P. punctata*; the exact function of this character in *P. punctata* needs to be investigated. No such character has been reported in any of the Indian Smiliogastrin cyprinid; similar results have been reported in *Pethia titteya* (a species endemic to Sri Lanka) from Japan under captive conditions, among sexes a difference in lengths of fins observed (Mieno and Karino 2017). Similarly, in Korean

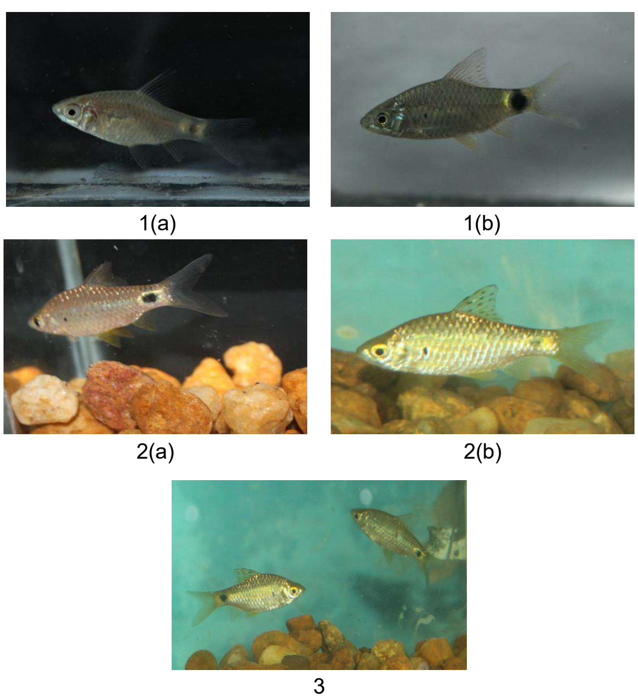

Fig. 1a) Juvenile female b) Juvenile male, 2a) Mature female b) Mature male, 3) Nuptial coloration developed by mature male and female of *P. punctata* during courtship

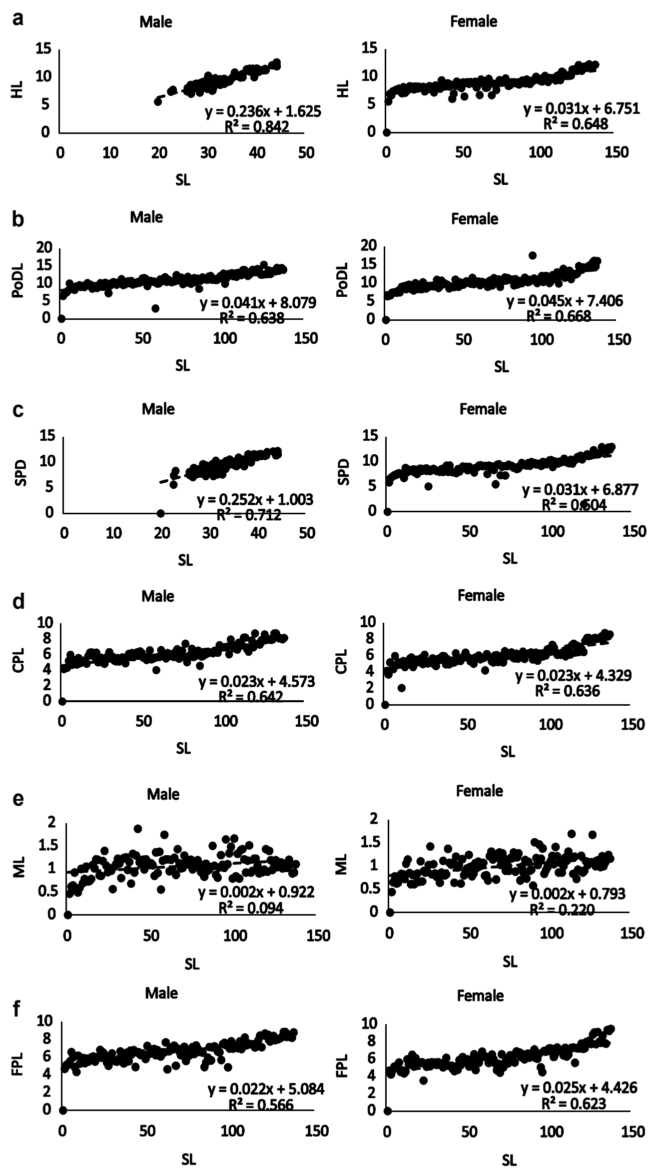

Fig. 4. Linear regression graph of standard length of males and females with a) head length b) post dorsal length c) snout pectoral distance d) caudal peduncle length e) mandible length f) first pectoral-fin ray length

chub *Zacco koreanus*, the significant differences in pectoral fin i.e. males possessing longer pectoral fin than females have been reported (Kim et al 2008). It is reported in several studies that females prefer males possessing longer fins for mating (Basolo 1990, Karino 2009, Karino et al 2011). Similarly, *Schsitura cf. aurantiaca,* males possess longer pectoral fins as compared to females (Plongsesthee et al 2012). In *Cobitis sp*. length of pectoral fins are longer in males as compared to females and differs significantly between sexes in five species studied (*C. bilineata, C. dalmatine, C. narentana, C. ilyrica, C. herzegoviniensis*) (Buj et al 2015).

CONCLUSION

The dichromatism of persistent and non-persistent modes can play a vital role in distinguishing sexes of *Pethia punctata*. This firsthand information on morphometric relationships, dichromatism and biometry based sexual dimorphism of this endemic fish species will be of great use in understanding the ecology, adaptations, and life history.

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