Morphometric characteristics of the Indian ringed skate, *Orbiraja powelli* (Alcock, 1898), from the Southwest coast of India

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Original Article

Abstract

Specimens of *Orbiraja powelli* were collected during May and October'2008 from the southwest coast of India. Males have a total length (TL) of 24.9 cm to 41 cm with a mean value of 35.7 cm, whereas, females TL varied from 27.6 cm to 51.5 cm with a mean value of 44.1 cm. Similarly, males were found to grow in weight at a rate less than cubical (b< 3), whereas, females grew in weight at a rate more than cubical concerning TL and DL (b> 3), resulting in two types of growth, negative allometric for males and positive allometric for females. However, males and females grew in near uniformity until it reaches around 35 cm TL. Since then the growth rate diverges resulting in females becoming relatively heavier than males. This reversal in the growth pattern from juvenile to adult was noticed in other parameters also. Sexually dimorphic relationships were observed between seven morphometric variables, wherein, the variables, disc width, tail length and pre-orbital length were well discriminated between the sexes.

Keywords: Sexual dimorphism, morphometrics, Orbiraja powelli. Arabian Sea, skate

Introduction

Skates of the family Rajidae, comprising about 228 valid species (Last and Stevens, 1994) are distributed throughout the world's oceans, from shallow inshore waters to the abyssal plains and even in the estuarine environment. However, they exhibit the greatest diversity in the cold deep water of the continental slopes and the continental shelves of the temperate inshore and offshore waters. Some skates have even penetrated from inshore areas to the deep water of tropical environments (Last and Compagno, 1999). One such skate is the Indian ringed skate, *Orbiraja powelli* (Alcock, 1898) with wider distribution in the Indian waters. It is demersal in nature and generally inhabits the deeper part of the continental shelf and upper slope in tropical waters (McEachran and Dunn 1998) off the coasts of India, Myanmar and Pakistan at depths of 122–244 m (Cronin, 2009). In Indian waters, its occurrence has been reported along the southwest coast of India (Akhilesh *et al*., 2010).

Skates, in general, exhibit significant differences in their morphology and growth between the sexes and the populations. The study on the related species *Raja miraletus* of the South African waters (Ebert *et al.,* 2008) and *R. clavata* of the Solway Firth of the Irish sea (Nottage and Perkins, 1983) indicate that significant differences exist between the sexes, in its morphology and growth. Similarly, the skate *Amblyraja radiata* (Templeman, 1987) has also been reported to exhibit a dimorphic relationship in its length and weight. However, no study on the relationship between various morphological variables is available for the species *Orbiraja powelli* on the southwest coast of India. As this information is required to understand the population structure of the species, the present study analysed the data on the length–weight and other morphological parameters to understand the morphological variation, if any, for the existence of sexual dimorphism and growth reversal in the *O. powelli.*

Material and methods

A total of 81 stations were sampled all along the southwest coast of India including the Wadge Bank, during the survey

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cruises of Matsya Varshini, a fisheries resources survey vessel of the Fishery Survey of India. (Table 1, Fig. 1). Out of which, 41 stations were sampled during the month of May and the remaining 40 stations were sampled during October 08. Samples were collected in 100-200 and 200-
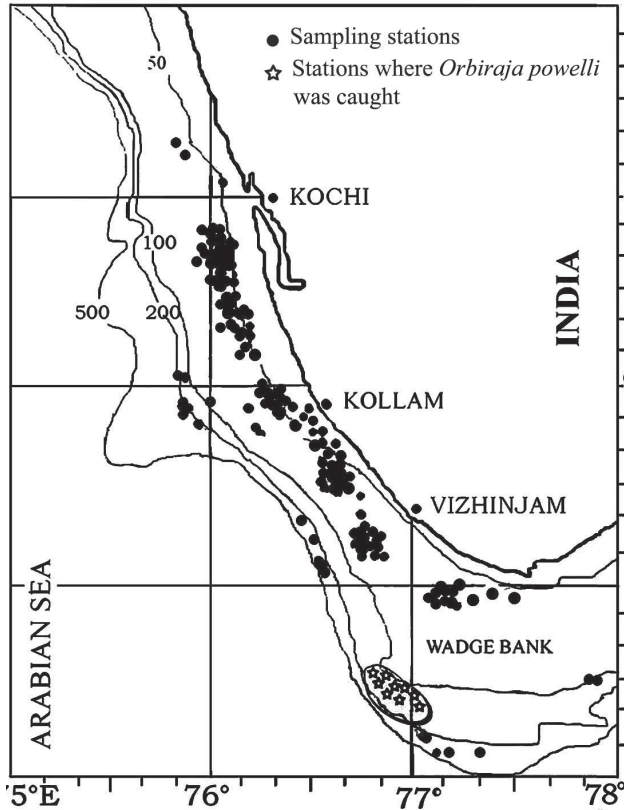

Fig. 1. Map of the Southwest coast of India showing the sampling area and stations, where *Orbiraja powelli* was collected

500 m depth strata by using 45.6 m head rope length expo model fish trawl by adopting a stratified random sampling method. A survey was carried out during the daytime. The net was dragged for 90 minutes at a station with 3.0 knot speed, sampling 4.5 nautical miles of track in each station. During the survey operation, a total of 34 specimens of skates were caught along with other species. All 34 specimens were identified as *Orbiraja powelli* (Fig. 2), following the photograph and keys provided in the Froese and Pauly (2013), McEachran and Fechhelm (1982) and McEachran and Dunn (1998).

Specimens of *O. powelli* were invariably available and collected only from 7° N Latitude at 112 – 209 m depth zone of the Wadge Bank (Fig. 1 and Table 1), though sampling was done all along the southwest coast of India. The collected samples were preserved onboard the vessel by freezing the same at -20 $^\circ$C and brought to the shore laboratory. At the shore, specimens were subjected to further studies after thawing to room temperature. Specimens were measured to the nearest millimetre (mm) and weighed to the nearest gram (g) by sex. Morphometric parameters such as total length (TL), tail length (Tail L), disc length (DL), disc width (DW), pre-oral (P Oral), pre-orbital (P Orbital) and Inter dorsal (ID) were recorded. In addition, the Clasper length (CL) of male specimens was measured from the cloacal opening to the tip of the claspers. Measurements were *taken following* the FAO species identification guide for fishery purposes edited by Carpenter and Niem (1999)

As the length-weight relationship in fish has been demonstrated as an exponential relation (Tıraşin, 1993), the L and W data were log-transformed, and regression

Table 1. Details of the sampling stations for the month of May, and October'08 where *Orbiraja powelli* juveniles and adults were found along the Southwest coast of India

| Date | Station Nos. | Area | | | | Depth (m) | Bottom Nature | Numbers collected |
		Shooting		Hauling				
		Lat	Long	Lat	Long			
May								
	09	07°26′	76°58′	07°22′	77°05′	126	Stone/Mud	2
	10	07°21′	77°04′	07°25′	77°01′	123	Stone	1
22.05.08	11	07°24′	77°57′	07°26′	77°02′	112	Stone/Mud	2
	12	07°29′	76°58′	07°27′	77°02′	112	Stone/Mud	1
October								
18.10.08	12	07°33′	76°51′	07°29′	76°52′	123	Mud/ Stone	7
	13	07°26′	76°55′	07°29′	76°52′	120	Mud/ Stone	9
19.10.08	14	07°28′	76°59′	07°25′	77°01′	120	Mud/ Stone	6
20.10.08	19	07°12′	77°03′	07°10′	77°06′	209	Mud/ Stone	4
	20	07°28′	76°52′	07°25′	76°56′	123	Mud/ Stone	2
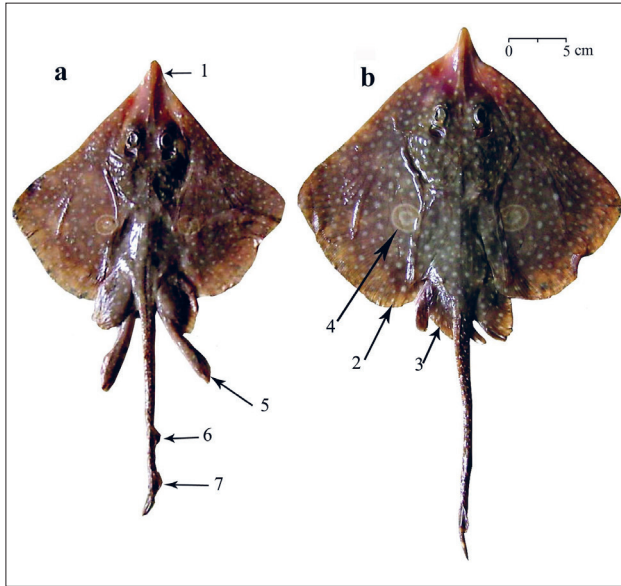
Fig. 2. Dorsal view of *Orbiraja powelli*. (a) Male and (b) Female.
1-Snout, 2-Pectoral fin, 3-Pelvic fin, 4-Ocelli, 5-Clasper, 6-First dorsal fin,
7- Second dorsal fin.

curves were fitted to pairs of observations by sex using the equation, $W = a\ L^b$. Where, L is the total length (cm), and 'a' and 'b' are constants. The constants 'a' and 'b' in both functions were computed employing the least squares regression with a 95% confidence interval. The nature and degree of relationship between various morphological parameters were studied using simple linear regression equation $Y = a + bX$ as recommended by Ricker (1973) and correlation coefficient models. Where Y is the dependent variable and X is the independent variable. The regression coefficients a and b represent the intercept and slope of the line respectively. The slope of the fitted L and W regression curves and the calculated linear regression lines of males and females were compared by ANCOVA with a 95 % confidence interval to determine if there were any significant variations between the length–weight and morphometric relationships of males and females. Wherever the slopes were equal and the regression lines were parallel, then the intercept was compared to study the significance. Statistical significance

has been tested for both the zero slope parameter and slope parameter equal to 3 and 1 respectively using the *p*-value approach.

Results and discussion

Length-weight relationship

The regression equation for the cubical relationship of the parameters set TL-TWt, DL-TWt and DW-TWt were calculated for both males and females and presented in Table 2, Fig. 3. There has been a high degree of correlation between the parameters in each set. Male, in the earlier stage, though had a higher growth rate than the female concerning the TL and DL, the growth rate got reversed at a particular length and the female became heavier than the male in the adult stage. The divergence in the growth rate between the sexes begins once the species reaches around 35 cm of TL resulting in females becoming relatively heavier than males. A substantial difference in a similar relationship between the sexes of *R. miraletus*, has been reported by Ebert *et al.* (2008) in the South African waters and for *R. clavata* by Nottage and Perkins (1983) in the Solway Firth of Irish sea as well. Besides, male growth was nearly cubical concerning TL than in relation to DL, wherein it was less than cubical. However, concerning DW, the male had a constant higher growth in weight than the female counterpart. The difference in the growth, between male and female were significant in the slope values of the curve TL-TWt (F-5.791342, P-0.021362) and DW-TWt (F-34.7937, P-0.0000). On the other hand, the difference was not significant between the sexes in the curve DL-TWt (F-3.7699, P-0.06162). As a result, it is revealed that significant differences exist in the growth between the sexes of *Orbiraja powelli*. Males grow in weight, less proportionate (b< 3) to their growth in TL and DL, whereas females grow more than proportionate (b> 3), resulting in two different types of growth curves. This type of growth has also been reported for males and females of *R. miraletus* in temperate waters (Jardas, 1973) and in other elasmobranch species concerning TL (Froese and Pauly, 2003). However,

Table 2. Sex-wise length weight equation for different morphological parameters with a total weight of *Orbiraja powelli*

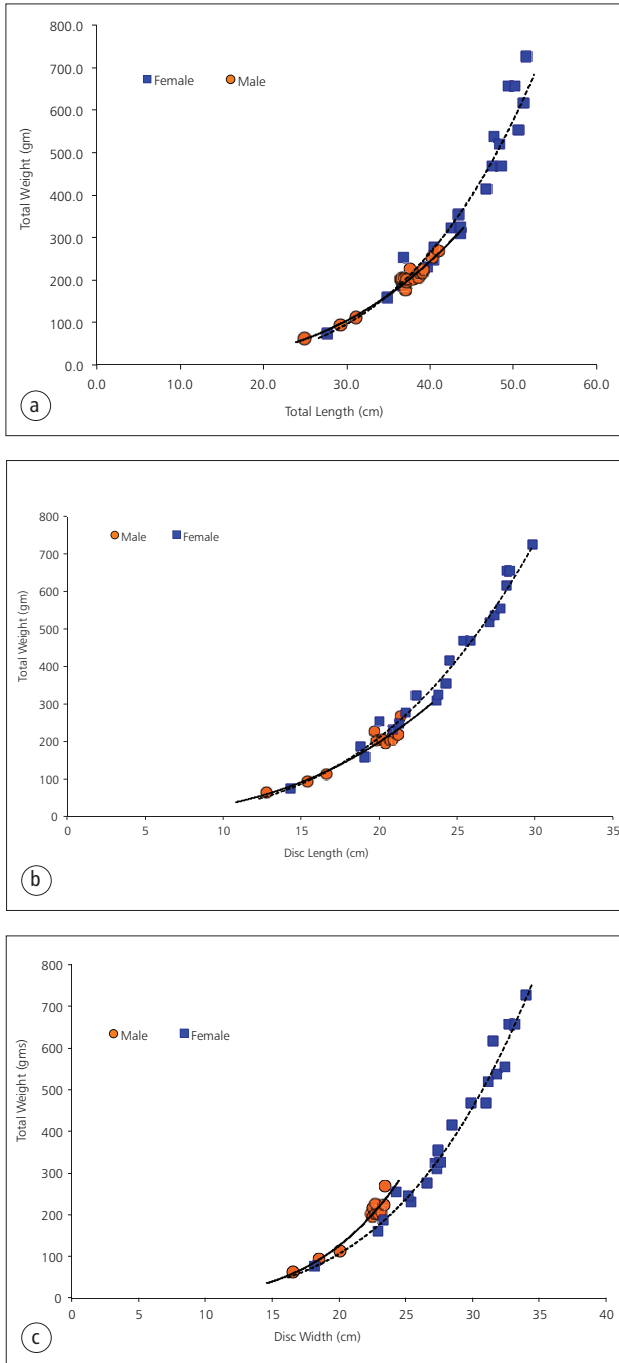| Curve	sex	N	Equation	R^2	P
TL–TWt	M	18	$0.0046\ TL^{2.9504}$	0.9766	0.00
	F	21	$0.0006\ TL^{3.5034}$	0.9652	0.00
DL–TWt	M	12	$0.0616\ DL^{2.6955}$	0.9642	0.00
	F	21	$0.0207\ DL^{3.0798}$	0.9799	0.00
DW–TWt	M	12	$0.0008\ DW^{3.9958}$	0.9737	0.00
	F	21	$0.0022\ DW^{3.6051}$	0.9835	0.00

Fig. 3 . Length-weight relationship in *Orbiraja powelli*. (a) Total length and weight,(b) Disc length and weight, (c) Disc width and weight

in difference to TL and DL the growth in weight concerning DW is uniformly more than proportionate (b > 3) in both the sexes of *O. powelli* and significantly different from each sex.

Morphometric relationship

The morphometric relationships were studied for nine sets of parameters in each sex. Sample size, length range and mean

(± SD) values are presented in Table 3. Male TL was found to vary from 24.9 cm to 41 cm with a mean value of 35.7 cm, whereas female TL varied from 27.6 cm to 51.5 cm with a mean value of 44.1 cm. The equation of linear regression and its correlation coefficient for each set of parameters are presented in Table 4. The linear regression line fitted between TL and Tail L (Fig. 4a) has been significantly different between the sexes (F-5.8930, P-0.02120). Juvenile males of < 34.5 cm TL have relatively smaller tails than juvenile females of the same length, whereas adult males of > 34.5 cm TL were found to have longer tails than females. Similarly, males have a smaller DL than females in < 20 cm TL (Fig. 4b) and have longer DL than females, in the specimen > 20 cm TL. However, the relationship of TL- DL between males and females is not statistically significant (F-1.4245, P-0.2417). Besides, in contrast to Tail L and DL, males have a broader DW than females in < 30 cm TL and have a relatively smaller DW than females when it grows larger than 30 cm TL (Fig. 4c) and significantly differs between the sex (F-9.6498, P-0.0040). The difference in the relationship between DL and DW has also been more pronounced and significant (F-9.8297, P-0.0037) from juvenile to adult (Fig. 4d). The juvenile female has a smaller DW than DL compared to the male of similar length until it reaches 12 cm of DL, after that the DW of the female grows wider than the male.

The relationship between Pre Orbital Length and Pre Oral length with TL is perfectly linear and parallel with each other (Fig. 4 e, f) and differs significantly between the sexes (F-9.0740, P-0.0051; F-8.5822, P-0.0063). Males have comparatively longer P Orbital and P Oral lengths than females from the juvenile stage onwards. The same trend continues throughout life. Similarly, juvenile females of < 6.3 cm of P Oral length have shorter P Orbital length than the male of the same P Oral length until it grows longer than 6.3 cm of P Oral length (Fig. 5a). However, this difference is not significant between the sexes (F-1.0712, P-0.3086). The growth of DW concerning DL and Pre Orbital length concerning Pre Oral length have also been slow in the juvenile stage of females and subsequently increases than males in the adult stage. It has been observed that males have longer DL, Tail L, Pre Orbital and Pre Oral lengths than females concerning TL, after attaining sexual maturity. The longer Pre Orbital and Pre Oral lengths of the male specimen than the female counterpart of the same TL have been corroborated by McEachran and Fechhelm (1982) from the *O. powelli* specimen collected from the Gulf of Aden. It is also observed that the relationship between ID and Tail length is highly scattered with a correlation coefficient of 0.44 and 0.13 for the male and female respectively (Fig.5b). The intensity and nature of the relationship between CL and TL have also been studied in males and found to be positively correlated with a direct linear relationship (Fig. 5c).

Table 3. Sex-wise length range, mean and SD of different morphometric parameters of *Orbiraja powelli*

Parameters	Males				Females			
	n	Range	Mean	SD	n	Range	Mean	SD
Total Length	12	24.9–41	35.7	4.74	22	27.6 – 51.5	44.1	6.2
Tail Length	12	11.4 – 19.8	16.2	2.29	22	12.5 – 22.1	19.1	2.4
Disc Length	12	12.8 – 21.4	19.1	2.69	22	14.3 – 29.8	24.1	3.9
Disc Width	12	16.6 – 23.5	21.7	2.18	22	18.2–34	28.3	4.0
Pre Orbital Length	12	3.8 – 6.6	5.8	0.89	22	3.9 – 8.7	6.9	1.2
Pre Oral Length	12	4.4 – 7.8	6.6	1.00	22	4.7 – 9.6	7.8	1.2
Inter-Dorsal Length	12	1.1 – 2.7	2.0	0.57	22	1.1 – 3.0	2.1	0.5
Clasper Length	12	2.4 – 10.4	8.3	2.84	22	—	—	—

Table 4. Sex-wise linear regression equation for the morphometric relationship of *Orbiraja powelli*

Curve	Sex	n	Equation	R^2	P
TL – Tail length	M	12	Tail L =−0.72 + 0.4743 *TL*	0.9654	0.00
	F	22	Tail L = 2.9785 + 0.3647 *TL*	0.9336	0.00
TL – Disc Length	M	12	DL =−0.8258 + 0.5583 *TL*	0.9703	0.00
	F	22	DL = -3.2636 + 0.6207 *TL*	0.9702	0.00
TL – Disc Width	M	12	DW = 5.7312 + 0.449 *TL*	0.9579	0.00
	F	22	DW = 0.4881 + 0.631 *TL*	0.9652	0.00
TL – Pre Orbital	M	12	P Orb =−0.703 + 0.1812 *TL*	0.9225	0.00
	F	22	P Orb =−1.318 + 0.1864 *TL*	0.9217	0.00
TL – Pre Oral	M	12	P Oral =−0.6827 + 0.2042 *TL*	0.9472	0.00
	F	22	P Oral =−0.4063 + 0.1853 *TL*	0.9067	0.00
Tail L– Inter Dorsal	M	12	ID =−0.6938 + 0.1638 *TL*	0.4384	0.03
	F	22	ID = 0.7131 + 0.0721 *TL*	0.1325	0.12
TL – Claspers L	M	12	CL =−12.456 + 0.5828 *TL*	0.9443	0.00
DL–DW	M	12	DW= 6.5626 + 0.7954 *DL*	0.9658	0.00
	F	22	DW = 3.944 + 1.011 *DL*	0.9836	0.00
Pre Oral–Pre Orb	M	12	P Orb = 0.1393 + 0.8514 *P Oral*	0.8969	0.00
	F	22	P Orb =−0.5911 + 0.9649 *P Oral*	0.9353	0.00

In general, there has been a reversal in the growth pattern of many parameters from juvenile to adult. For instance, in males, the growth rate of tail and disc length has been slow when compared to females at the juvenile stage. Subsequently, there has been a reversal in the growth rate, resulting in a longer tail and disc than the female. The growth rate of the DW concerning TL has been slow in the juvenile females and subsequently get reversed in the adult female resulting in broader Disc than the male. This broader DW in the female of *O. powelli* than its male counterpart of the same length has also been reported by McEachran and Fechhelm (1982) from the Gulf of Aden. A similar trend has also been reported in *Atlantoraja cyclophora* (Oddone and

Vooren, 2004), where a significant difference in the disc shapes has been observed between the sexes with females exhibiting a broader disc than males from 35 cm TL onwards. A growth pattern in which males have a wider disc width than females in the juvenile stage and get reversed in the adult stage has also been reported for *Rioraja agassizi*. This trend may probably be due to the relatively fast growth of DW than the TL in females. Ebert *et al.* (2008) have reported that species exhibiting the appreciably different relationship between TL and DW in male and female shows sexual dimorphism in a disc shape. In addition, it is reported that male skates in general are sexually dimorphic, with the disc becoming bell-shaped as they mature. However, whether it
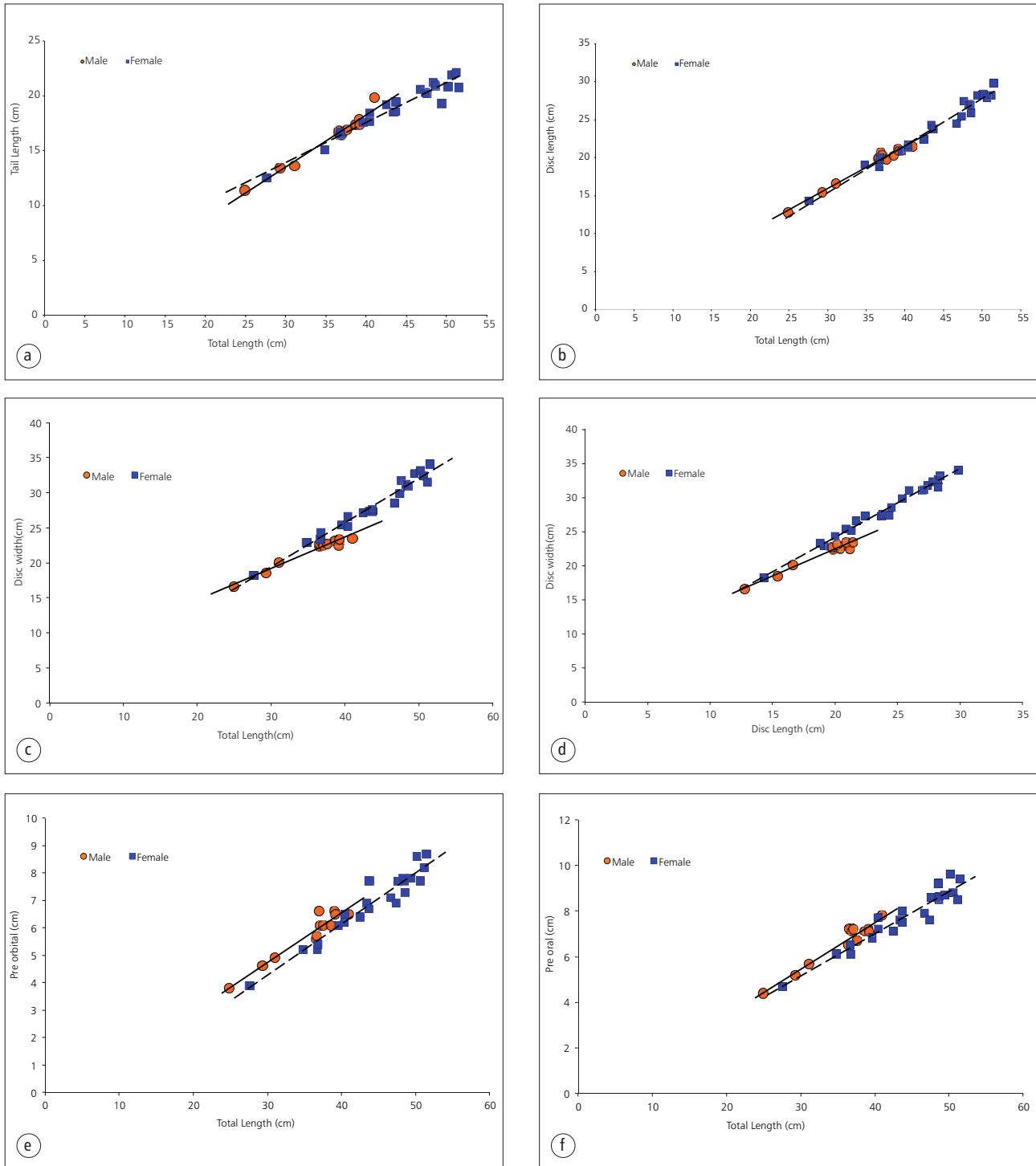
Fig. 4. Linear relationship between different sets of morphological parameters in *Orbiraja powelli*. (a) Tail – Total length, (b) Disc length – Total length, (c) Disc width – Total length (d) Disc width – Disc length, (e) Pre orbital – Total length, (f) Pre oral – Total length.

has any behavioural or adaptational relevance is unknown and worth further investigation. In contrast to the above observations, the relationship between TL and DW is not significant for *R. miraletus* in the Adriatic Sea (Ungaro, 2004) and *A. platana* in the Southeastern Brazilian Waters

of the SW Atlantic Ocean (Oddone and Amorim, 2007). This variation might have occurred due to the geographic and hydrographic characteristics of the areas (Capapé, 1977). It may be concluded that *Orbiraja powelli* exhibits growth reversal and sexual dimorphism in its growth in weight
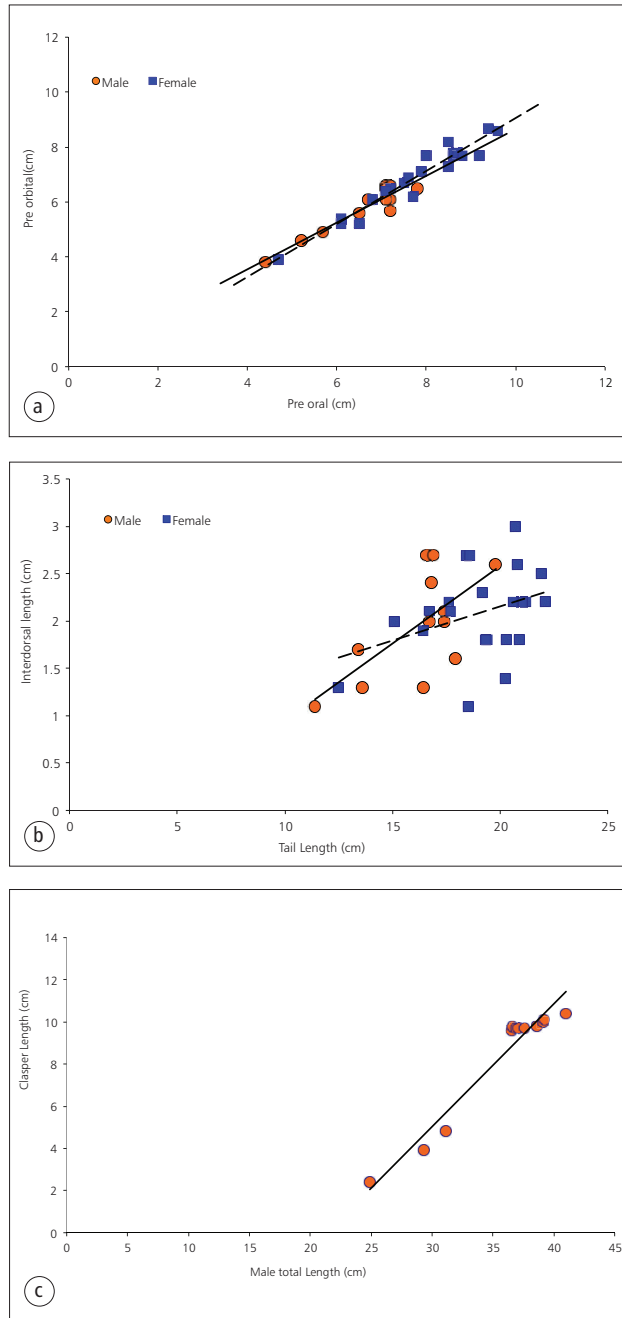
Fig. 5. Linear relationship between different sets of morphological parameters in *Orbiraja powelli* (a) Pre orbital – Pre oral, (b) Inter dorsal – Total length, (c) Clasper length – Male total length.

per unit gain in total length and the growth of the linear variables such as Disc width, Pre Orbital and Pre Oral lengths as prevalent in other skate species.

Acknowledgements

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