



Population structure of the purpleback squid *Sthenoteuthis oualaniensis* (Lesson, 1830) along the south-west coast of India

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ABSTRACT

To understand the population structure and distribution of the purpleback squid *Sthenoteuthis oualaniensis* off the south-west coast of India, a total of 1,015 specimens of the species were collected from the area between lat 07° to 11°N and long 74° to 77° E at a depth of 180 – 2601m during January 2007 to December 2008. Specimens were measured for dorsal mantle length (DML), tentacle length (TL), tentacular club length (TCL), fin width (FW), total weight (TWt) and mantle weight (MWt). Morphometric analyses of the variables indicate the existence of two forms, a medium and a dwarf form with significant difference in growth between them. Study suggests that males were dominant until about 15 cm DML for medium form and 11 cm DML for the dwarf form. However, the overall sex ratio of female to male was 6:4 for the medium and 8:2 for the dwarf form. Males were invariably smaller than the females in both the forms ranging from 9 to 19 cm DML in the medium form and 9 to 13 cm DML in dwarf form. The highest frequency of the mature medium form was in the DML range of 17-19 cm for males and 19-23 cm for females. Similarly, in mature dwarf forms the DML was in the range 10-11 cm for males and 12-14 cm for females. Dwarf forms were more prevalent in 7°N latitude (60%) than the 10°N latitude (28%), whereas medium forms were more prevalent in 10°N latitude (72%) than 7°N latitude (40%). Results clearly indicate the occurrence of medium and dwarf forms of *S. oualaniensis* along the south-west coast of India. The shape and size of the fins were identified to be important key features to differentiate dwarf population from the medium form of *S. oualaniensis* in the field.

Keywords: Morphological indicators, Population structure, Purple back squid, South-west coast of India, *Sthenoteuthis oualaniensis*

Introduction

The tropical Indo-Pacific pelagic squid *Sthenoteuthis oualaniensis* (Lesson, 1830) is one of the important and widely distributed oceanic fishery resources. It is the most abundant and large sized squid in the Indo-Pacific region with an estimated biomass of 8-11 million t throughout its distributional range (Nigmatullin, 1990). The estimated biomass of the species in the Indian Ocean is about 2 million t (Zuev *et al.*, 1985) with high concentration of 12 to 42 t km⁻² in the Arabian Sea during the month of November-January (Nesis, 1993). Nesis (1993) described a complex population structure for *S. oualaniensis*, incorporating three major and two minor forms *viz.*, a giant form, a medium form with double lateral axes of the rachi, a medium form with single lateral axes of the rachi, a dwarf form and a small early-maturing form. *S. oualaniensis* is sexually dimorphic, with females growing larger than males. Dimorphism in sucker ring

dentition and the difference in size suggest a difference in the feeding spectrum of males and females (Snyder, 1998). As no substantial study on the population structure of *S. oualaniensis* has been reported from the south-west coast of India till date, the present study was undertaken in order to understand the population structure and distribution of the species along the south-west coast of India. An attempt has also been made to identify the key morphological features that would be useful to distinguish dwarf forms from medium forms in the field.

Materials and methods

Specimens of *S. oualaniensis* were collected during January 2007 - December 2008 from the area between lat 07° N to 11° N and long 74° E to 77° E along the south-west coast of India at a depth range of 180 – 2601 m. (Fig.1). *Matsya Sugundhi* (31.5 m OAL, 245.8 GRT and 650 BHP), the long liner-cum-squid jigger of the Fishery Survey of India (FSI) and 44-60 footer gillnetters as well

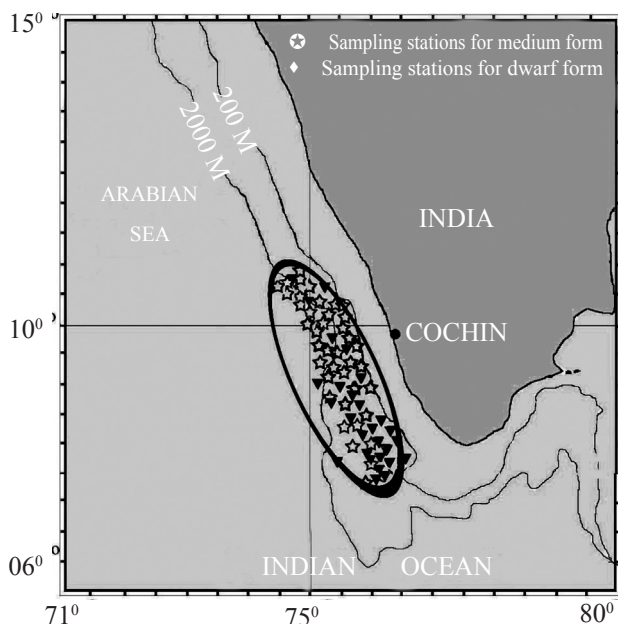


Fig. 1. Map of south-west coast of India showing the sampling areas

as tuna long-liners of the Cochin based Colachal fishing boats were the prime source for the samples. In addition, squids were also collected by hand jigging operation onboard the FSI trawler *Matsya Varshini* during its night drifting. *Matsya Sugundhi* employed automatic squid jigging machine to collect the samples, while the fishing boats and *Matsya Varshini* employed hand-line with jigs to collect the samples. No sample could be collected for a period of 45 days due to ban of mechanised fishing in the west coast of India, from June 15th to July 30th. Two forms of *S. oualaniensis* were identified, one medium and another dwarf form, on the basis of the description provided by Nesis (1993). However, the specimens were subjected to detailed study for confirmation of the plastic phenotype forms.

In total, 1015 specimens were collected during the period of study, out of which, 565 were identified as medium forms and 450 were dwarf forms. Measurements were taken (Fig. 2) following Cohen (1976). The sex-wise measurements for dorsal mantle length (DML), tentacle length (TL), tentacular club length (TCL), and fin width (FW) were taken in a straight line to the nearest millimeter (mm). Total weight (TWt) and mantle weight (MWt) were measured to the nearest gram (g). The details of the sample size and the parameters collected are furnished in Table 1.

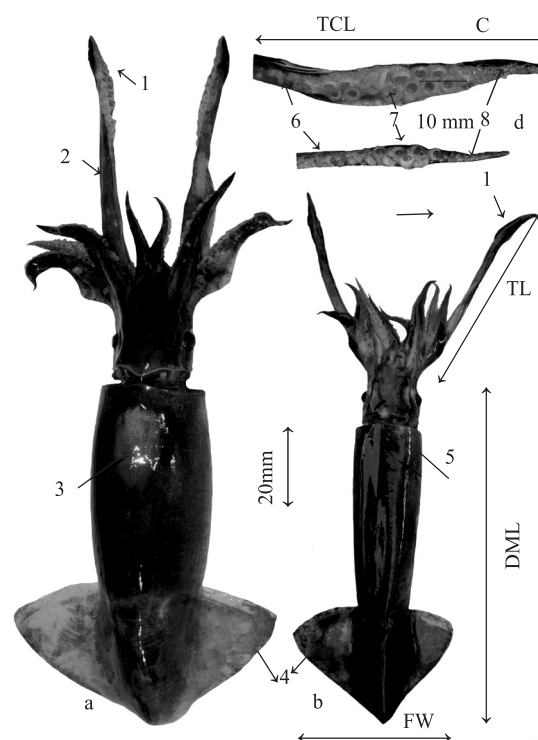


Fig. 2. Dorsal view of *S. oualaniensis* 1. Tentacular club, 2. Tentacle, 3. Photophore, 4. Fin, 5. Absence of photophore, 6. Carpus, 7. Manus, 8. Dactylus

Table 1. Morphometric parameters of males and females of *Sthenoteuthis oualaniensis*

Parameters	Males				Females				Total			
	n	Range	Mean	SD	n	Range	Mean	SD	n	Range	Mean	SD
Dwarf form												
Dorsal mantle length	77	9.2-13.4	11.05	1.11	373	9.1-16.5	12.92	1.26	450	9.1-16.5	12.6	1.42
Total weight	77	20-63	37.49	10.8	373	26-111	58.23	16.5	450	20-111	54.65	17.5
Mantle weight	40	12-33	17.7	4.8	105	17-46	29	6.20	145	12-46	25.8	7.7
Tentacle length	37	12.6-16.3	14.36	1.04	99	13.8-20.4	17.4	1.67	136	12.6-20.4	16.58	2.04
Tentacle club length	37	3.2-4.2	3.65	0.25	99	3.8-5.7	4.6	0.47	136	3.2-5.7	4.3	0.6
Fin width	29	5.9-9.0	7.09	0.72	47	7.7-11.6	9.5	0.98	76	5.9-11.6	8.6	1.48
Medium form												
Dorsal mantle length	237	9.8-19.5	13.97	2.06	328	10-27	16.61	3.81	565	9.8-27	15.50	3.5
Total weight	237	43-322	127.8	58.05	328	39-794	227.8	156.71	565	39-794	186	134.5
Mantle weight	94	39-179	92.3	34.7	102	38-420	153.7	91.43	196	38-420	124	76.5
Tentacle length	86	15.8-34.3	22.02	3.7	94	15.4-44.8	27.62	7.0	180	15.4-44.8	24.94	6.28
Tentacle club length	86	4.2-11.5	6.84	1.39	94	4.8-15.3	9.07	2.5	180	4.2-15.3	8.0	2.34
Fin width	39	10.9-18.6	12.63	1.38	63	10.9-20.5	15.03	2.6	102	10.9-20.5	14.11	2.5

Length-weight data collected were log-transformed (natural logarithms) and predictive regression equations were calculated correlating \ln DML to \ln TWt, and \ln DML to \ln MWt, for both medium and dwarf forms and compared by the equation $W = aL^b$, where 'W' is the weight in 'g', 'L' the DML in cm, 'a' intercept and 'b' slope. If $b > 3$ then the squid is considered to have grown in weight at a rate faster than the DML, *i.e.*, positive allometric growth. If $b = 3$ then the two dimensions are considered to have grown isometrically. If $b < 3$, then the squid is considered to gain weight is at a rate slower than the DML, indicating negative allometric growth (Zeidberg, 2004).

The relationship between other linear variables such as DML, TL, TCL and FW were studied applying simple linear regression equation, $Y = a + bX$ as recommended by Ricker (1973). Confidence interval was calculated at 95% level for the coefficient b. 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. The regression slope of medium and dwarf forms were compared by ANCOVA to determine whether any significant variation existed between them (Ricker, 1973). Wherever the regression lines were parallel and the slopes were equal, then elevations (y-intercept) were compared to study the significance. Sex ratio for both dwarf and medium forms were analysed and tested by Chi-square test. The distribution pattern was analysed from the percentage of occurrence of both the dwarf and medium form in each latitude.

Results and discussion

Length-weight relationship

The regression equation for DML–TWt curve indicates a lower slope value of less than the expected cubical value of '3' ($b=2.67$) for the dwarf form and a higher slope value of greater than '3' ($b=3.05$) for the medium

form (Table 2). The b value for medium form is similar to the value indicated by Suzuki *et al.* (1986) ($b=3.15$ for 158–205 mm DML) for *S. oualaniensis* in Hawaiian waters. This confirms the differential pattern of growth between the two forms, negative allometric growth for dwarf and positive allometric growth for medium form (Fig. 3a). Females of dwarf and medium forms as well as males of dwarf and medium forms also followed similar growth pattern with significant difference between the forms (Female $-F=56.54$, $p < 0.01$ and Male $-F=8.82$, $p < 0.01$). Similar difference in growth pattern also exists between the sexes of the medium form with females exhibiting positive allometric growth ($b=3.13$) and males exhibiting isometric growth ($b=2.98$) (Table 2; Fig. 3b & c), indicating the existence of sexual dimorphism within the forms. Chen *et al.* (2007), however, indicated negative allometric growth for both female ($b=2.9$) and male ($b=2.58$) *S. oualaniensis* in the north-west Indian Ocean. This possibly could have occurred, due to the analyses of sample in the DML range of 11 to 61 cm, containing different phenotypic forms of *S. oualaniensis*. Females ($b=2.61$) and males ($b=2.6$) of dwarf form did not exhibit differential pattern of growth, as both were found to grow with negative allometry.

The MWt in relation to DML indicated negative allometric growth in both medium ($b=2.8$) and dwarf forms ($b=2.4$) with significant variation between the forms ($F=31.32$, $p < 0.01$) (Table 2). Similar growth pattern was observed in females of dwarf and medium forms ($F=16.92$, $p < 0.01$), (Table 2). This may be due to the disproportionate growth of female reproductive organs in weight during that stage. Gabr *et al.* (1999) reported mantle muscle as an energy source during gonadal development in cuttlefish, *Sepia dollfusii*. In females of *Loligo forbesi*, gonad size and mantle weight were reported to be inversely proportional which indicate the mobilisation of mantle tissue to produce ovarian tissue

Table 2. Inter-population length-weight relationship of dwarf and medium forms of *S. oualaniensis* in the south-west coast of India

Curve	Form	n	R ²	a L ^b	CI (b)	p (b)	Growth
DML- TWt	D	450	0.88	0.0613 x ^{2.67**}	(2.6, 2.8)	0.00	- Allometric
	M	565	0.970	0.379 x ^{3.05**}	(3.0, 3.1)	0.04	+ Allometric
DML–TWt (Female)	D	373	0.84	0.0717 x ^{2.61**}	(2.5, 2.7)	0.00	- Allometric
	M	328	0.97	0.0296 x ^{3.13**}	(3.1, 3.2)	0.00	+ Allometric
DML–TWt (Male)	D	77	0.86	0.0699 x ^{2.60**}	(2.4, 2.8)	0.00	- Allometric
	M	237	0.95	0.0466 x ^{2.98**}	(2.9, 3.1)	0.59	Isometric
DML–MWt	D	145	0.94	0.0546 x ^{2.42**}	(2.3, 2.5)	0.00	- Allometric
	M	196	0.97	0.041 x ^{2.82**}	(2.7, 2.9)	0.00	- Allometric
DML–MWt (Female)	D	105	0.89	0.0618 x ^{2.37**}	(2.2, 2.5)	0.00	- Allometric
	M	102	0.97	0.0383 x ^{2.83**}	(2.7, 2.9)	0.00	- Allometric
DML–MWt (Male)	D	40	0.86	0.0342 x ^{2.62**}	(2.3, 3.0)	0.03	- Allometric
	M	94	0.94	0.0289 x ^{2.96**}	(2.8, 3.1)	0.52	Isometric

** b coefficient is highly significant at 0 level

D : Dwarf, M : Medium, R² : Correlation coefficient, a L^b : equation, CI (b) : Confidence interval of the coefficient b (95%), p(b) : Hypothesis testing for slope parameter equal to 3 using the p-value approach

(Smith *et al.*, 2005). Similarly, the mantle mass of female *Illex argentinus* decreases in relation to mantle length with maturity (Hatfield *et al.*, 1992; Rodhouse and Hatfield, 1992; Clarke *et al.*, 1994). *Loligo opalescens* apparently utilises mantle protein as a food reserve during spawning (Fields, 1950; 1965; Evans, 1976).

The slope values of male dwarf and medium form were distinctively higher than its female counterpart. However, the dwarf male has a negative allometric trend in growth while in medium males isometric growth pattern was observed (Fig. 3e and f). The difference between the DML–MWt curve of dwarf and medium male was not significant ($F=3.17$, $p = 0.07$). The rate of increase in MWt and total weight of the male dwarf and medium forms is similar, indicating possible proportionate growth

of the MWt and male reproductive organs. The scatter diagram plotted for the length weight data of the medium and dwarf forms clearly indicated the presence of two populations with different growth trends.

Morphological relationships

The linear regression equations derived for the set of parameters DML–TL, DML–TCL, DML–FW and TWt–MWt, its goodness of fit, slope confidence interval and p values for both the dwarf and medium forms indicated that the regression slope of all set of parameters were highly significant and showed a stronger influence of the DML on the corresponding dependent variable (Table 3). The p value equal to 1 also indicates high level of significance of the linear growth except for the relationship between DML – TL of males and females of dwarf forms. Medium

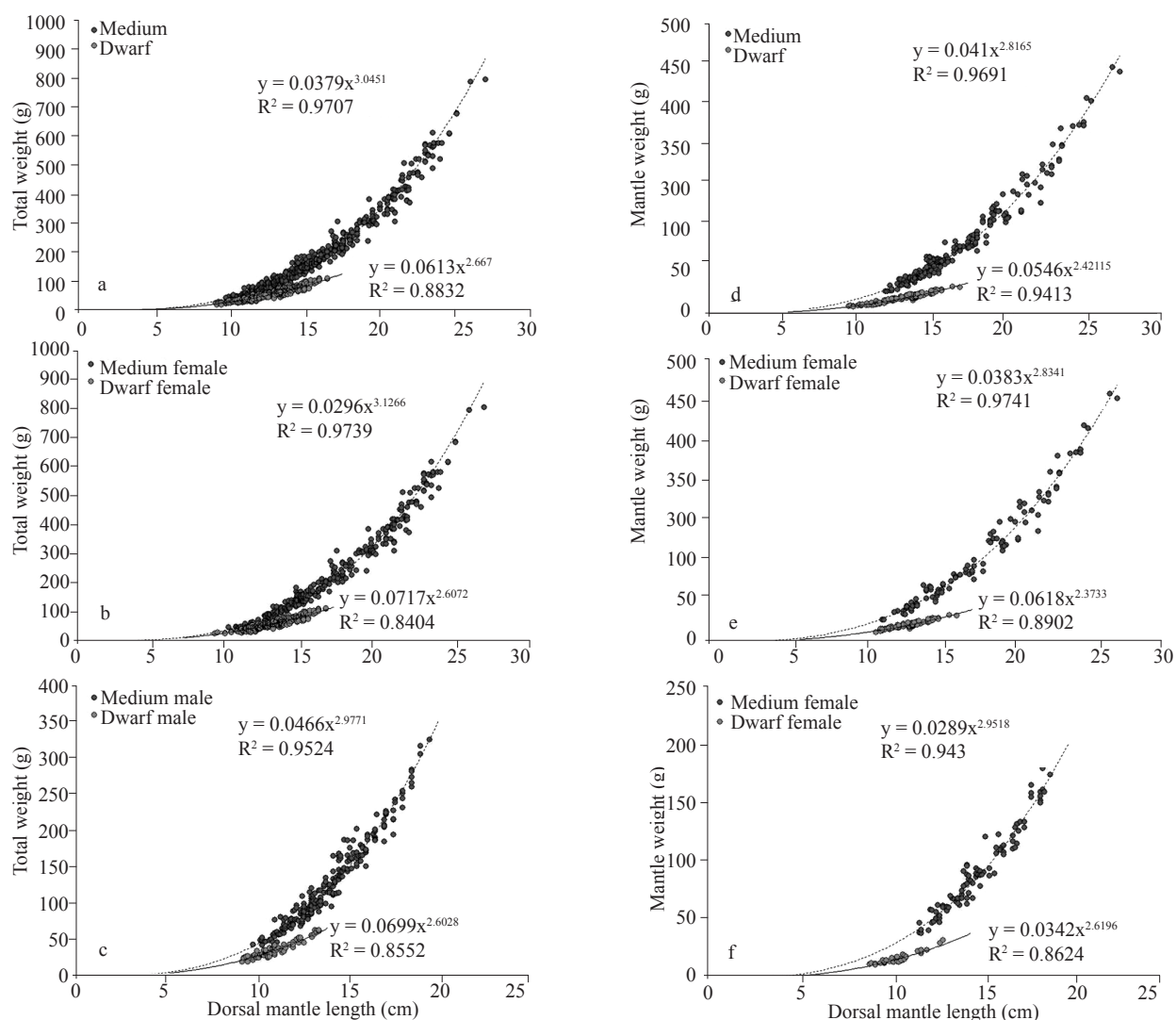


Fig. 3. Dorsal mantle length-total weight relationship in dwarf and medium forms of *S. oualaniensis* (a) Dwarf and medium forms, (b) Dwarf female and medium female, (c) Dwarf male and medium male, (d) Dorsal mantle length-mantle weight relationship between dwarf and medium forms, (e) Dwarf female and medium female, (f) Dwarf male and medium male

Table 3. Inter-population morphometric relationship of dwarf and medium forms of *S. oualaniensis* in the south-west coast of India

Curve	Form	n	R ²	a+ b x	CI (b)	p (b)
DML- TL	D	136	0.8	1.920 +1.159**x	(1.06, 1.26)	0.00
	M	180	0.93	- 4.949 +1.804**x	(1.73, 1.88)	0.00
DML-TL (Female)	D	99	0.65	2.437 +1.125**x	(0.96, 1.29)	0.14
	M	94	0.92	- 4.039 +1.769**x	(1.66, 1.88)	0.00
DML-TL (Male)	D	37	0.65	5.136 +0.848**x	(0.64, 1.06)	0.15
	M	86	0.90	- 3.944 +1.716**x	(1.60, 1.84)	0.00
DML- TCL	D	136	0.86	- 0.116 +0.352**x	(0.33, 0.38)	0.00
	M	180	0.89	- 2.889 +0.658**x	(0.62, 0.69)	0.00
DML-TCL (Female)	D	99	0.74	0.036 +0.342**x	(0.30, 0.38)	0.00
	M	94	0.87	- 2.135 +0.627**x	(0.58, 0.68)	0.00
DML-TCL(Male)	D	37	0.90	1.057 +0.239**x	(0.21, 0.27)	0.00
	M	86	0.87	- 2.651 +0.627**x	(0.57, 0.68)	0.00
DML- FW	D	76	0.94	- 0.944 +0.767**x	(0.72, 0.81)	0.00
	M	102	0.95	1.748 +0.760**x	(0.73, 0.79)	0.00
DML- FW (Female)	D	47	0.87	- 0.415 +0.731**x	(0.65, 0.81)	0.00
	M	63	0.95	2.346 +0.735**x	(0.69, 0.78)	0.00
DML- FW (Male)	D	29	0.74	- 0.108 +0.683**x	(0.52, 0.84)	0.00
	M	39	0.91	2.193 +0.713**x	(0.64, 0.78)	0.00
TWt-MWt	D	145	0.90	1.503 +0.468**x	(0.44, 0.49)	0.00
	M	196	0.98	4.959 +0.530**x	(0.52, 0.54)	0.00

** b coefficient is highly significant at 0 level

D :Dwarf, M : Medium, R² : Correlation coefficient, a+bx : equation, CI (b) : Confidence interval of the coefficient b (95%), p (b) : Hypothesis testing for slope parameter equal to 1 using the p-value approach

form showed a higher slope and a lower intercept for the TL and TCL when compared to the dwarf form. The DML- TL and DML-TCL curves differed significantly between the dwarf and medium forms (TL: F=52.32, p< 0.01; TCL: F=59.63, p<0.01). Similar trend exists between same sex of the dwarf and medium forms (Fig. 4). The difference in TCL between the dwarf and medium forms was highly significant (F=59.63; p< 0.01) and are clearly evident in the scatter diagram (Fig. 4d).

The TCL of dwarf forms were relatively smaller in size than that of medium forms.

The TCL: TL ratio of 1:4 for dwarf and 1:3 for medium form indicate smaller TCL in dwarf form. The TL and TCL of both medium and dwarf forms were near equal in smaller squids of DML <12 cm. TL and TCL of medium form was found to be longer than the dwarf form of same DML. The divergence happens during the course of growth of the squid. Kashiwada and Recksiek (1978)

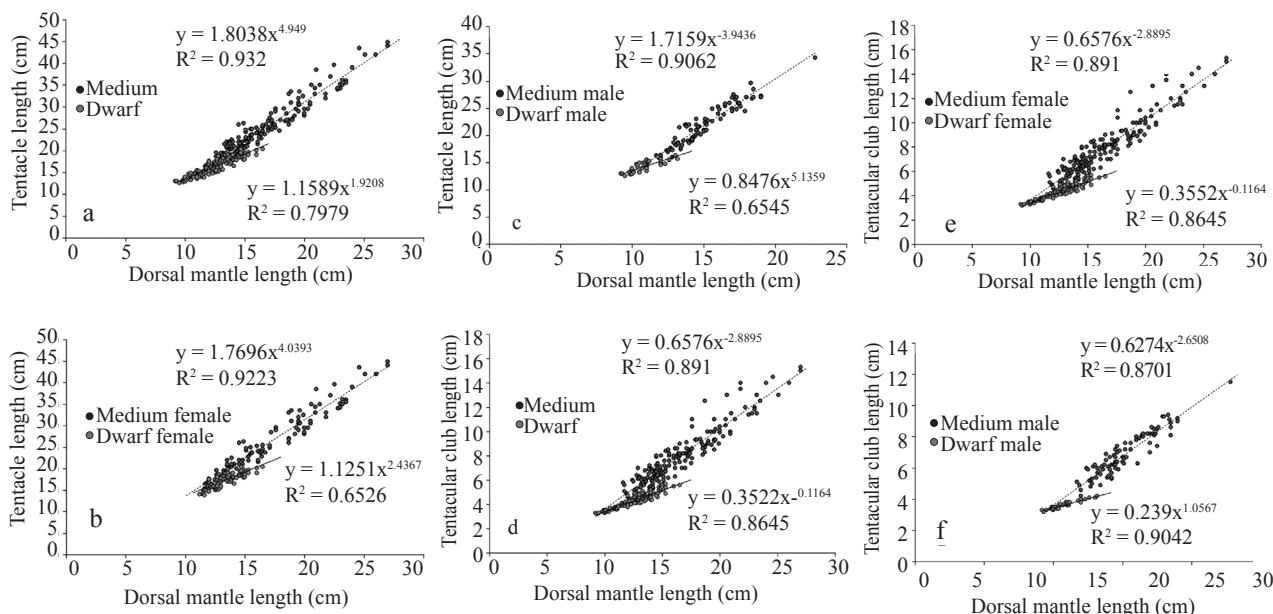


Fig. 4. Mantle length–tentacle length relationship in dwarf and medium forms of *S. oualaniensis* (a) Dwarf and medium forms, (b) Dwarf female and medium female, (c) Dwarf male and medium male. Comparison of mantle length–tentacular club length relationship between (d) Dwarf and medium forms, (e) Dwarf female and medium female, (f) Dwarf male and medium male

also used TL and TCL in differentiating sub-populations of *Loligo opalescens*.

The FW of medium form showed higher slope and intercept than the dwarf form in relation to the DML (Fig. 5 a-c) and varied significantly ($F=830.87$; $p < 0.01$) in intercept from the dwarf form. This showed a clear difference in the growth trends of fin of dwarf form from the medium form. Female and male of medium form also showed similar higher slopes and intercepts for growth trends in fins than that of similar sexes of the dwarf form. Dwarf forms have 12% lesser fin width than the medium one. The length width ratio of fins of dwarf forms (1: 1.6) differed from that of medium forms (1: 2) (Fig. 6). This characteristic shorter fin width and the relative concaveness of the posterior margin of the fin of the dwarf form could

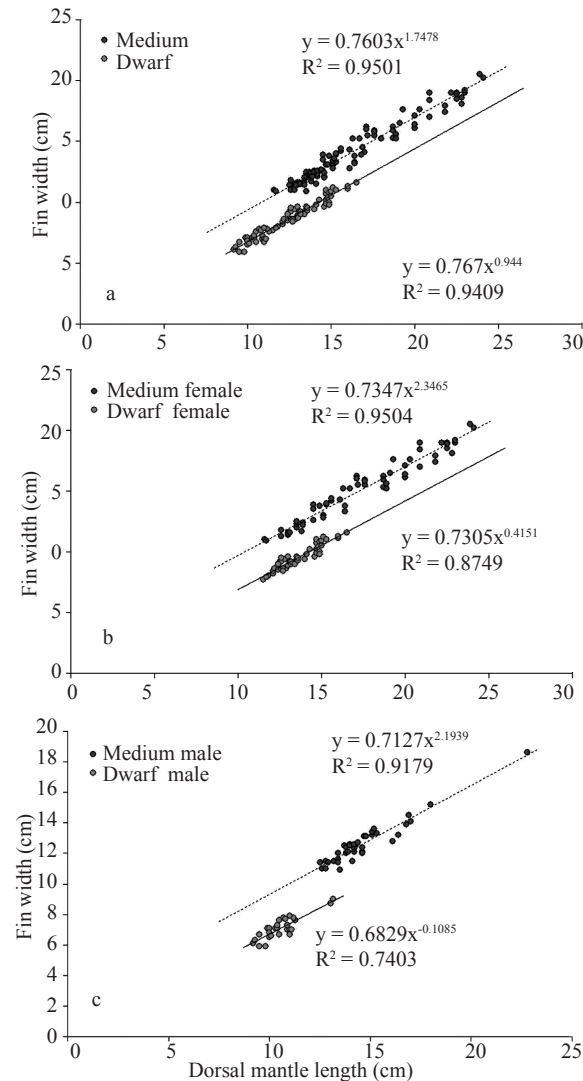


Fig. 5. Mantle length–fin width relationship between dwarf and medium forms of *S. oualaniensis* (a) Dwarf and medium forms, (b) Dwarf female and medium female, (c) Dwarf male and medium male.

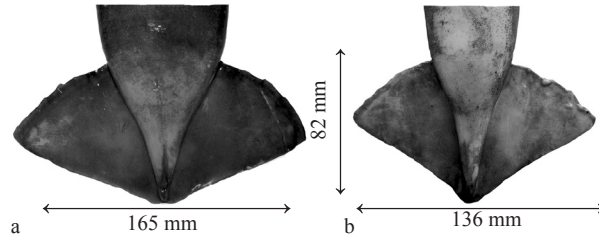


Fig. 6. Size and shape of fins in dwarf and medium forms of *S. oualaniensis*

be used as the distinct morphological trait to differentiate the dwarf form from the medium form. Regression line fitted between the TWt and MWt for both the dwarf and medium forms (Fig.7) showed that the medium form had a higher slope and elevation than the dwarf form with significant difference at the intercept level ($F=45.62$; $p < 0.01$). This indicate higher mantle weight for medium compared to that of the dwarf form.

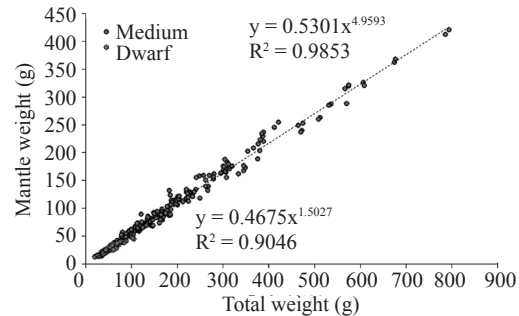


Fig. 7. Mantle weight-total weight relationship between dwarf and medium forms of *S. oualaniensis*

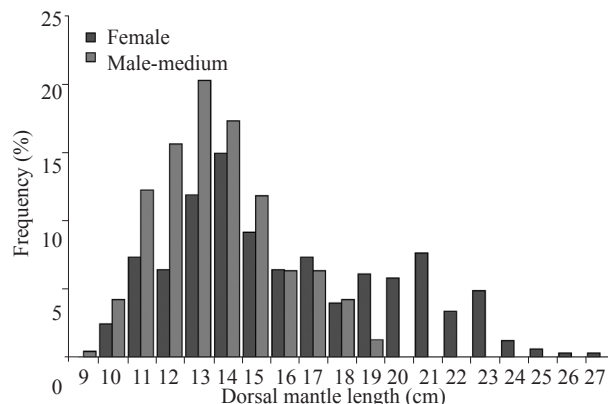
Sex ratio and sexual dimorphism

The overall ratio of female to male was 6: 4 for the medium and 8: 2 for the dwarf form. In dwarf form, females were caught in more numbers than males throughout the year except in the month of May. In medium form, females dominated only in the first and last quarters of the year and also in the month of May (Table 4). The shape of the size frequency curves of the squid (Fig. 8 and 9) caught during this study suggest that males were dominant until about 15 cm DML for medium forms and 11 cm DML for the dwarf form. Beyond this size frequency, females dominated. Occurrence of large number of females to males in both medium and dwarf forms might be due to the selectivity of the catching method. The size of the jigs may also play a direct role on the size of the squid attracted and caught as it emulates the prey. Siriraksophon et al. (2000) reported that in *S. oualaniensis*, the ratio of females to males caught by jigging machines was 4:1 in Philippines. However, according to Trotsenko and Pinchukov (1994) in the north-west Indian ocean, the sex ratio had a seasonal variation, and the ratio (F:M) was 1:0.24 in summer, but changed to 1:0.52 in winter. Nesis (1993) found that the sex ratio is nearly equal among young squids but strongly shifted to females among sub adults/adults.

Table 4. Sex ratio and Chi-square test of medium and dwarf forms

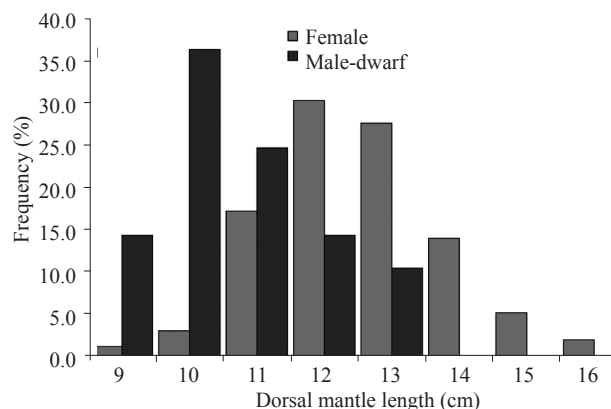
Months	Medium form				Chi square test	Dwarf form				Chi square test
	Female		Male			Female		Male		
	Nos.	%	Nos.	%		Nos.	%	Nos.	%	
Jan'07	26.0	96.0	1.0	4.0	0.00	15.0	83.0	3.0	17.0	0.00
Feb'07	15.0	83.0	3.0	17.0	0.00	11.0	100.0	0.0	0.0	0.00
Mar'07	15.0	45.0	18.0	55.0	0.60	5.0	100.0	0.0	0.0	0.03
Apr'07	3.0	33.0	6.0	67.0	0.32	10.0	100.0	0.0	0.0	0.00
May'07	3.0	75.0	1.0	25.0	0.32	5.0	50.0	5.0	50.0	1.00
Jun'07	4.0	40.0	6.0	60.0	0.53	12.0	100.0	0.0	0.0	0.00
Jul'07	--	--	--	--	--	--	--	--	--	--
Aug'07	10.0	42.0	14.0	58.0	0.41	15.0	83.0	3.0	17.0	0.00
Sep'07	10.0	27.0	27.0	73.0	0.01	13.0	100.0	0.0	0.0	0.00
Oct'07	91.0	55.0	73.0	45.0	0.16	197.0	89.0	25.0	11.0	0.00
Nov'07	14.0	78.0	4.0	22.0	0.02	0.0	00	0.0	00	0.00
Dec'07	25.0	100.0	0.0	0.0	0.00	0.0	00	0.0	00	0.00
Jan'08	15.0	94.0	1.0	6.0	0.00	7.0	70.0	3.0	30.0	0.21
Feb'08	13.0	81.0	3.0	19.0	0.01	14.0	100.0	0.0	0.0	0.00
Mar'08	8.0	44.0	10.0	56.0	0.64	0.0	0.0	0.0	0.0	0.00
Apr'08	2.0	29.0	5.0	71.0	0.26	10.0	83.0	2.0	17.0	0.02
May'08	3.0	75.0	1.0	25.0	0.32	2.0	29.0	5.0	71.0	0.26
Jun'08	3.0	33.0	6.0	67.0	0.32	7.0	78.0	2.0	22.0	0.10
Jul'08	--	--	--	--	--	--	--	--	--	--
Aug'08	5.0	36.0	9.0	64.0	0.29	14.0	61.0	9.0	39.0	0.30
Sep'08	4.0	17.0	19.0	83.0	0.00	5.0	56.0	4.0	44.0	0.74
Oct'08	34.0	62.0	21.0	38.0	0.08	28.0	67.0	14.0	33.0	0.03
Nov'08	11.0	73.0	4.0	27.0	0.07	0.0	00	0.0	00	0.00
Dec'08	14.0	74.0	5.0	26.0	0.04	3.0	60.0	2.0	40.0	0.65

Males of *S. oualaniensis* were invariably smaller than the females in both the forms ranging from 9 to 19 cm DML in the medium form and 9 to 13 cm DML in dwarf form. Female ranged between 10 cm and 27 cm DML (Fig. 8) in medium form and between 9 cm and 16 cm DML in dwarf form (Fig. 9). In Hawaiian waters, among all squid captured larger than 10 cm DML, females exceeded males in abundance with 3:1 ratio (Young and Hirota, 1998). The highest frequency of the mature medium form was in the DML range of 17-19 cm for males and 19-23 cm for females. Similarly, in mature dwarf forms, highest frequency was in the DML from 10-11 cm for males and 12-14 cm for females. Females of both the medium and

Fig. 8. The sex-wise length frequency diagram of medium form of *S. oualaniensis*

dwarf forms were larger in length and weighed more than the males of the respective forms. Besides, females of the dwarf form had a larger TL, TCL and FW than its male counterpart. In medium form, TL was not distinctively different between the sexes, although the TCL and FW were distinct and larger in females.

In dwarf form, though TL and TCL were similar in both male and female around 10 cm DML subsequently the trend changes with female growing faster and larger than the male. Changes in the growth trajectories over a small DML range has also been observed by Shea and Vecchione (2002) in three species of oegopsid squids. However, in the medium form, the difference in growth in terms of

Fig. 9. The sex-wise length frequency diagram of the dwarf form of *S. oualaniensis*

TL and TCL of female and male in relation to DML is parallel and persists more or less evenly throughout the growth with female being larger in length than the male. The growth in terms of TCL against TL is parallel between male and female of both dwarf and medium forms and significantly ($p < 0.01$) different between the sexes with female having a higher TCL for the same TL than the male, indicating a dimorphic trend in the growth. Bello and Piscitelli (2000) showed that females of *Sthenoteuthis orbignyana* have longer tentacular clubs than males and ingest larger quantities of food than males at any given size. Similarly, both the dwarf and medium females had wider fin width than the male of the same DML. However, the difference was significant ($p < 0.01$) only for medium form. The present results corroborate the findings of Mangold-Wirz's (1963) as well as Ragonese and Jereb's (1991), that the growth rate of females is higher than those of males of *S. oualaniensis*.

Distribution pattern

Analyses of the data collected confirmed the occurrence of two forms of *S. oualaniensis* i.e., dwarf and medium forms along the south-west coast of India. The percentage of occurrence of the dwarf form was observed to increase from 28% at 10°N lat. to 60% in the 7°N lat. In contrast, the percentage of occurrence of the medium form gradually decreased from 72% at 10°N lat. to 40% in 7°N lat. The increased frequency of occurrence of the dwarf form towards 7°N has been in conformity with its natural distribution within the 10°N of the equator (Nesis, 1993). There seems to be an equilibrium in the population level of these two forms at 8°N lat., as the percentage of occurrence of the dwarf and medium forms were 53% and 47% respectively in this latitude (Fig. 10). Medium forms were more frequent in occurrence during the period of January to March and August to December with peak in the month of October. The dwarf forms were more frequently caught during January to February and August to October with the peak in the month of October, similar to medium forms. Though the availability of the medium form has

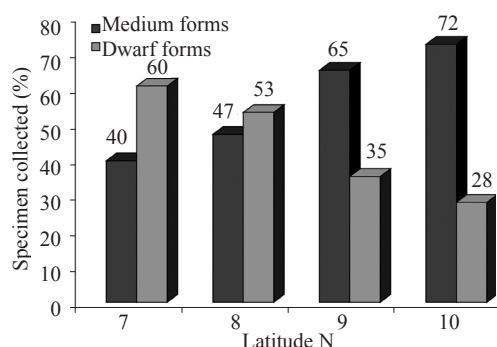


Fig.10. Latitude-wise distribution of dwarf and medium forms of *S. oualaniensis* in the south-west coast of India

been reported throughout the year, the occurrence of dwarf form in the study area has not been reported during the months of November'07, December'07, March'08 and November'08. The occurrence of more numbers in the month of October is in near conformity with the observation of Nesis (1993). The absence of dwarf form in the sample during certain months might be due to the non-effectiveness of the fishing gear to trap smaller sized dwarf forms. Size distribution of *S. oualaniensis* in the present study is consistent with the previous reports by Trotsenko and Pinchukov (1994) from Western Indian Ocean. The two plastic phenotypical forms of *S. oualaniensis* appeared to have a clear trend of distribution along the south-west coast of India.

Though the dwarf forms were distinguishable from the medium forms with respect to size, distribution and morphological traits, the shape and size of fins were found to be important key features to differentiate the dwarf population from the medium form of *S. oualaniensis* in the field.

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