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MORPHOMETRIC STUDY AND SEXUAL MATURITY IN *LOLIGO DUVAUCELI* D' ORBIGNY

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ABSTRACT

Morphometric measurements have been carried out in the present study on 103 male squids to recognise the degree of reproductive maturation of the animal along with the size at which maturity occurs first, to know the differentiation of hectocotylised arm as an indicator of sexual maturity and to establisn a correlation between the external morphological traits and the testis, various parts of the male reproductive tract and hectocotylised arm.

INTRODUCTION

GIESE (1959) reported that the gonad's development and its correlation to any linear development of the animal had not had much application. However, Haley (1969, 1973) used morphometric measurements on carapace, eye stalk and chelae to determine the reproductive maturity of the crabs *Ocypoda quadrata* and *O. ceratophthalmus*. Morphometric investigations on animal speceis also help to understand the inter-relation between the various features like total length, total weight, fecundity, etc. Further, morphometric study is a reliable technique for recognizing the degree of reproductive maturation without sacrificing the animals (Paulraj, 1980 ; Saravanan, 1981 ; Rajasekaran, 1981 ; Anandan, 1982).

The present study is restricted to the following major endeavours :

1. To recognise the degree of reproductive maturation of the animal along with the size at which maturity occurs first.
2. The differentiation of hectocotylised arm as an indicator of sexual maturity.
3. The growth pattern of body parts including reproductive organs such as testis, spermatophoric gland, Needham's sac, posterior vasdeferens and hectocotylised arm.
4. To establish a correlation between the external morphological traits and the testis, various parts of the male reproductive tract and hectocotylised arm.

MATERIAL AND METHODS

The squid *Loligo duvauceli* were collected at North Madras, southeast coast of India. The various morphological characters such as dorsal mantle length, mantle circumference at head end, largest breadth including fins and the length of the different parts of the reproductive system such as the testis, spermatophoric gland, Needham's sac and posterior vasdeferens. Further, the length and breadth of normal and hectocotylised arms have been done for different size groups.

Male squids were considered to be ' maturing ' whenever spermatids could be detected in the testis, ' mature ' when spermatophores occur in Needham's sac and posterior vasdeferens

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and 'fully mature' when spermatophores occur in plenty in these organs.

RESULTS

The values of weight of different size groups of squids showed inconsistency which is statistically verified and hence the dorsal mantle length has been taken as a standard measure. Rao (1954) has also used the dorsal mantle length as a standard measure in the squid *Sepioteuthis arctipinnis*. To determine and express the size at which the males attained reproductive maturity, squids were grouped in size classes based upon 1.5 cm interval of dorsal mantle length (Table 1). Immature squids which have attained beyond 4.5 cm dorsal mantle length are represented in Table 2.

TABLE 1. *The relation between dorsal mantle length and maturity of the testis in* Loligo duvauceli *as observed upon dissection*

Dorsal mantle length (Average for 1.5 cm intervals)	Number of males with			
	Immature Testis	Maturing Testis	Mature Testis	Fully matured Testis
3.0 ..	4			
4.5 ..	3	1		
6.0 ..	8	8	1	
7.5 ..	2	2	4	8
9.0 ..	—	5	4	18
10.5 ..	—	—	—	12
12.0 ..	—	—	—	10
13.5 ..	—	—	—	5
15.0 ..	—	—	—	5
16.5 ..	—	—	—	1
18.0 ..	—	—	—	1
19.5 ..	—	—	—	1
	17	16	9	61

Total 103 male ; Range of dorsal mantle length 2.0—18.5 cm.

Immature testis Meiosis not started

Maturing testis Meiosis just started

Mature testis with few spermatophores in spermatophoric sac and PVD

Fully mature testis with moderate number to plenty of spermatophores in spermatophoric sac and PVD

TABLE 2. *Morphometry (cm) of immature males beyond 4.5 cm dorsal mantle length*

Length of		
Dorsal mantle	Testis	Spermatophoric gland
4.6	0.5	0.3
4.8	0.2	0.3
5.0	0.5	0.3
5.5	0.5	0.3
5.7	0.7	0.4
5.7	0.3	0.3
5.8	0.5	0.3
6.0	0.3	0.3
7.0	0.4	0.4
7.5	0.3	0.4

Differentiation of hectocotylised arm : Not distinct
Stage of maturity : Immature
Spermatiphore : Nil

Table 3 reveals the smallest maturing male, largest immature male, smallest mature male with few spermatophores and the smallest fully mature males with moderate number of spermatophores and plenty of spermatophores.

The growth of different body parts relative to dorsal mantle length was analysed to determine whether certain dimensions are reliable indicators of reproductive maturity. The scatter diagrams (Fig. 1 to 4) are coded to indicate gonadal maturity. The mean value and standard deviation for all the 15 variables are given in Table 4. Correlation coefficient between dorsal mantle length and other variables are provided in Table 5.

DISCUSSION

Morphometric study on *L. duvauceli* (Table 1) reveals that the smallest squid of 4.5 cm dorsal mantle length possesses maturing testis. Out

TABLE 3. *The smallest maturing male and largest immature male, smallest mature male with few spermatophores and smallest fully mature males with moderate number of spermatophores and plenty of spermatophores*

Length (cm) of			Differentiation of hectocotylised arm	Stage of maturity	spermatophore
Dorsal mantle	Testis	Spermato-phoric gland			
4.5	0.8	0.6	Distinct	Maturing	Nil
7.5	0.3	0.4	Not distinct	Immature	Nil
5.5	1.5	0.7	Distinct	Mature	Few
6.5	2.0	0.9	,,	Fully mature	moderate
7.0	2.6	1.9	,,	,,	Plenty

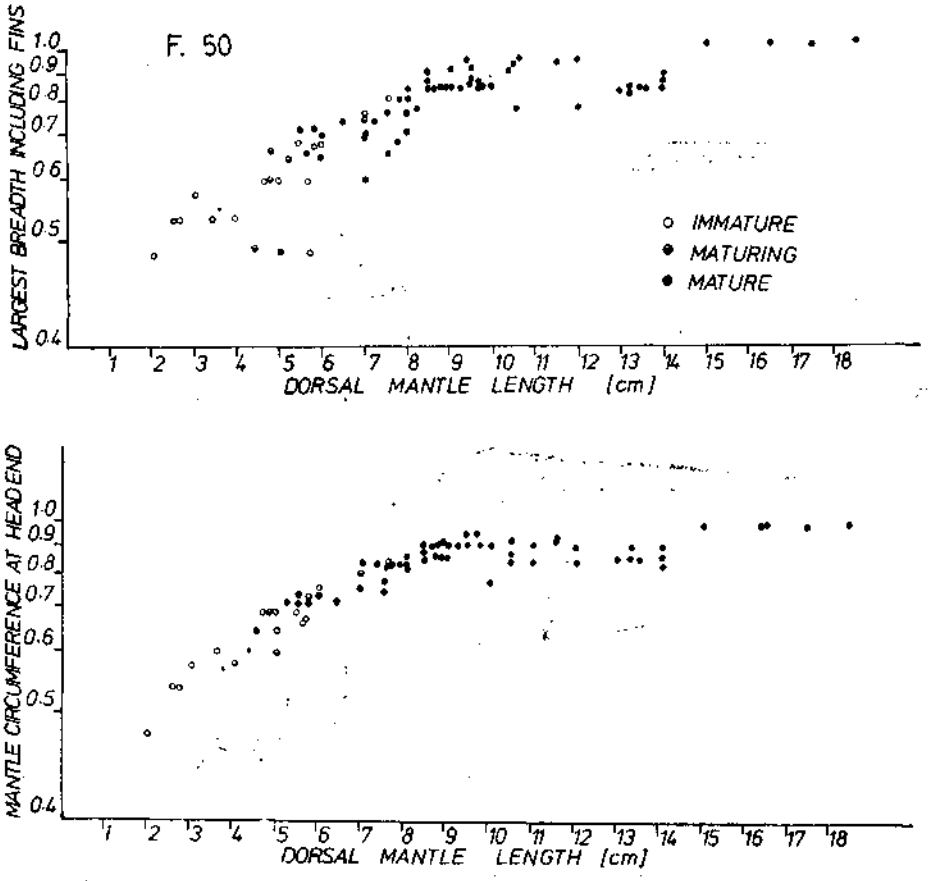

FIG. 1. Isometric growth pattern of the largest breadth including fins and the mantle circumference at head end to the dorsal mantle length till the onset of maturity and negative allometry beyond.

of four male squids collected in the range of 3.1 to 4.5 cm dorsal mantle length, only one with 4.5 cm dorsal mantle length showed maturing testis. Seventeen male squids were collected in the range of 4.6 to 6.0 cm dorsal mantle length and among these nine showed maturing testis and one mature testis. Hence maturing condition might be attained between 4.5 to 6.0 cm dorsal mantle length though the size of the immature male extends to a dorsal mantle length of 7.5 cm (Table 2). But out of sixteen males collected in the range of 6.1 to 7.5 cm dorsal mantle length, only two squids were immature. These two squids might either be spent males or pathological

TABLE 4. *Means and Standard Deviations for* 15 *variables of* L. duvauceli

Parameters	Mean	Standard deviation
Weight (gm)	29.83	20.40
Dorsal mantle length	8.54	3.22
Mantle circumference at head end	6.75	1.52
Largest breadth including fins	6.30	1.91
Testis length	2.02	0.99
Needham's sac length	0.75	0.38
Spermatophoric gland length	1.00	0.47
Posterior vasdeferens length	1.95	1.03
Hectocotylised arm length	4.28	1.24
,, ,, breadth	0.35	0.08
,, ,, distal region without suckers	1.67	0.83
,, ,, total suckers	23.94	8.21
Normal arm length	3.86	1.10
,, breadth	0.23	0.08
,, suckers	36.66	9.09

TABLE 5. *Correlation coefficient between dorsal mantle length and other* 13 *variables of* L. duvauceli

Correlation coefficient between the dorsal mantle length and parameters	Correlation coefficient
Mantle circumference at head end ..	0.807
Largest breadth including fins ..	0.860
Testis length ..	0.674
Spermatophoric gland-length ..	0.714
Needham's sac length ..	0.777
Posterior vasdeferenes-length ..	0.758
Hectocotylised arm length ..	0.660
,, breadth ..	0.687
,, distal region without suckers ..	0.484
,, total scukers ..	0.327
Normal arm length ..	0.637
,, breadth ..	0.415
,, total suckers ..	0.598

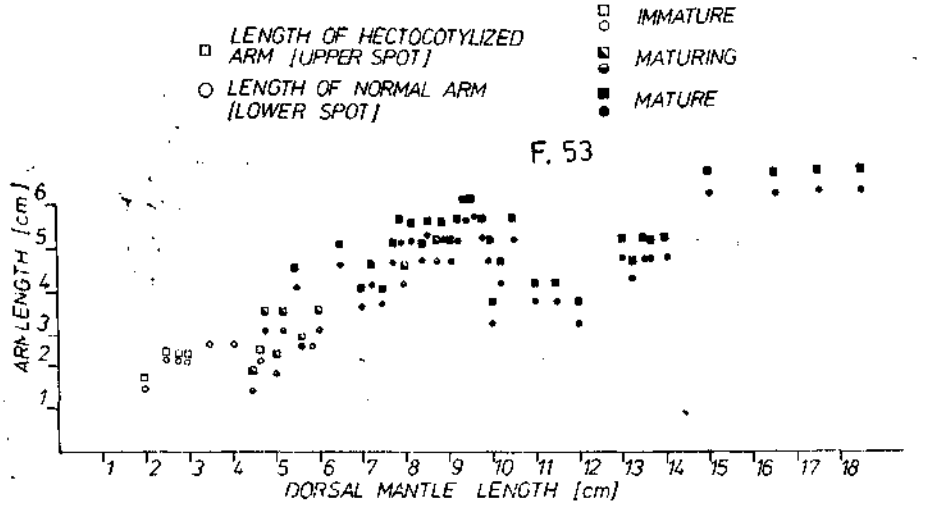

FIG. 2. Growth pattern of the fourth right and left arms to the dorsal mantle length — Isometric growth is present till the mature stage and there is negative allometry beyond.

condition might be the reason for their immaturity. Examination of the hectocotylised arm of these two squids revealed that there was no differentiation or modification in this arm. Callan (1939) working on *Octopus vulgaris* found that castration and subsequent removal of hectocotylus did not cause the regenerated arm to revert back to the normal arm. Hence the absence of differentiation or modification in this arm of these two squids might not be due to regeneration, but on the other hand be due to pathological condition leading to the retention of immaturity.

Table 3 also shows the smallest mature male with few spermatophores of 5.5 cm dorsal mantle length, the smallest fully mature male with moderate number of spermatophores of 6.5 cm dorsal mantle length and the smallest fully mature male with plenty of spermatophores of 7.0 cm dorsal mantle length.

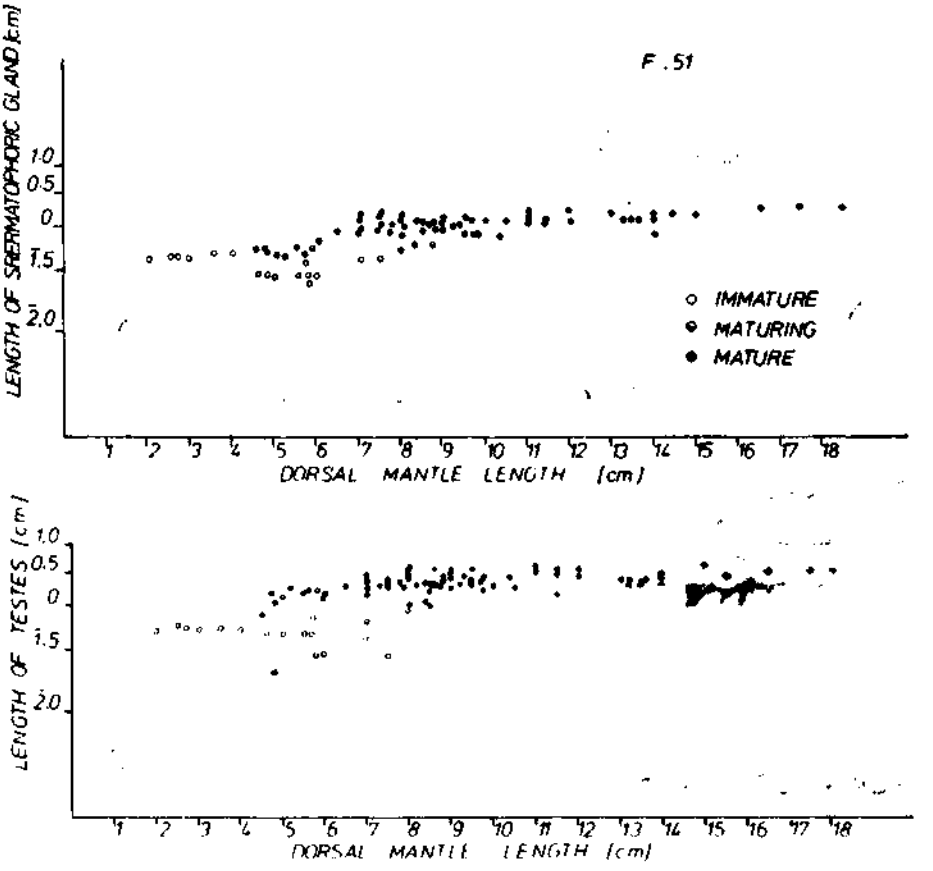

FIG. 3. Negative allometric growth pattern of the testes and the spermatophoric gland to the dorsal mantle length.

An analysis of morphometric data indicates that at the dorsal mantle length of 4.5—6.0 cm, mantle circumference of head end of 4.5—5.8 cm, largest breadth including fins of 3-5 cm normal length of arm length of 1.4-3.0 cm, and hectocotylised arm length of 1.9-3.5 cm, male *L. duvauceli* attains sexual maturity first.

It is obvious from Table 6 that maturing squids show the onset of hectocotylisation by way of (*a*) lengthening of the 4th left arm by

TABLE 6. *A comparison of morphometric measurements of normal and hectocotylised arms of immature, maturing, mature and fully mature* L. duvauceli

Stage of maturity	Dorsal mantle length (cm)		Length (cm)		Breadth (cm)		Number of Suckers		Length of distal portion devoid of suckers	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Normal IVth Right arm										
Immature	4.6	2.0—7.5	2.4	1.5—3.9	0.16	0.1—0.2	28	20—52		
Maturing	6.4	4.5—8.6	3.2	1.4—4.5	0.2	0.1—0.3	35	22—50		
Mature	7.4	5.5—8.6	4.0	2.5—5.0	0.2	0.1—0.3	38	28—50		
Fully Mature	10.3	6.5—18.5	4.4	3.0—6.0	0.25	0.1—0.5	36	30—56		
Hectocotylised IVth Left arm										
Immature	4.6	2.0—7.5	2.5	1.7—4.0	0.2	0.1—0.4	24	12—42	0.0	0.0
Maturing	6.4	4.5—8.6	3.5	1.9—5.0	0.3	0.2—0.4	25	15—50	1.2	0.5—1.5
Mature	7.4	5.5—8.6	4.5	3.0—5.0	0.3	0.2—0.4	26	12—40	2.0	1.5—3.0
Fully Mature	10.3	6.5—18.5	5.0	4.0—6.5	0.4	0.3—0.7	24	15—32	2.0	1.5—3.0

atleast 0.5 cm (*b*) broadening by at least 0.1 cm and (*c*) modification leading to the development of a plain terminal portion with a length of atleast 0.5 cm and reduction in the suckers by atleast 4 when compared to the normal arm, the 4th right arm. The immature squids on the other hand do not show such differences between these two arms. However very young male squids in the size range of 2-3 cm dorsal mantle length show the ill development of suckers on the 4th left arm. It appears that there is delay in the development of suckers in 4th left arm. However, prior to the reaching of maturing condition, the 4th right and left arms appear to be identical. Thus differentiation of 4th left arm into the hectocotylised arm commences with the onset of sexual maturity, hence the hectocotylised arm may be used as an indicator for recognising sexual maturity without sacrificing the animal.

In *S. officinalis*, when the males have reached a length of about 6 cm, meiosis begins and spermatozoans are formed in the classical fashion (Thesing, 1904). Concurrent with the onset of meiosis the hectocotylus condition appears as a modification of one arm (Arnold and Arnold, 1977). Callan (1939) working on *O. vulgaris* found that castration and subsequent removal of hectylus did not cause the regenerated arm to revert back to the normal arm. He concluded that there was no evidence that the gonad produced a sex hormone which controls development of secondary sexual characters. However, the fact that hectocotylisation commences only with the onset of sexual maturity suggests a possible hormonal role which needs to be investigated.

Studies on relative growth of various parts indicate a change in growth pattern at the time of maturity. Three growth patterns are recognized in morphometric measurements of crustaceans by various investigators (Haley, 1969 ; Paulraj, 1980). They are (1) isometric growth pattern, (2) positive allometry and (3) negative allometry. In isometric growth pattern the growth rate of parts is identical with that of the standard or whole animal while positive and negative allometry denote respectively growth rate of parts above or below the standard

(Huxley and Tiessier, 1936). Dorsal mantle length has been taken as a reference dimension or standard in the present study. The study has revealed that mantle circumference at head end the largest breadth including fins show isometric growth pattern to that of dorsal length more than the corresponding normal arm from the maturing stage. As far as the internal reproductive organs such as testis, spermatophoric gland, Needham's sac and PVD are concerned, they exhibit negative allometry (Fig. 3 and 4) throughout. Further

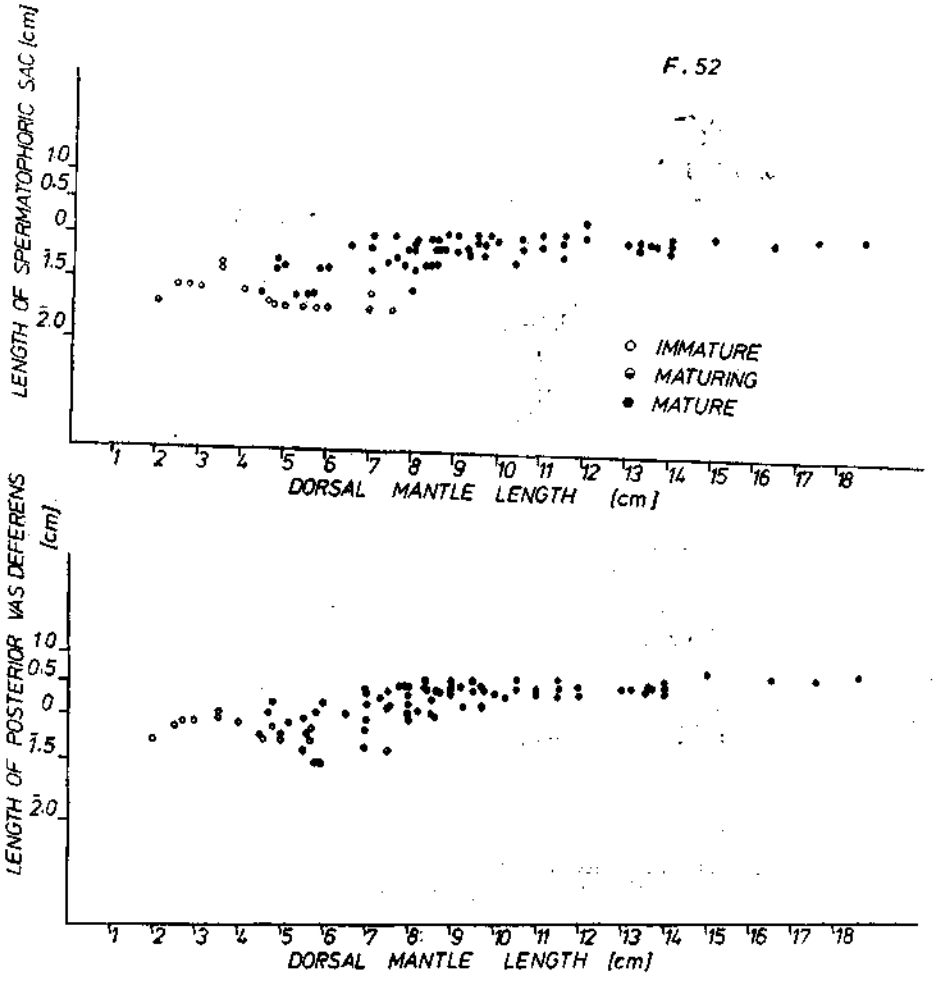

FIG. 4. Negative allometric growth pattern of posterior vas-deferens and spermatophoric gland to the dorsal mantle length.

mantle length till the onset of maturity and negative allometry beyond (Fig. 1). Similarly the fourth right and left arms show isometry to the dorsal mantle length till the mature stage and negative allometry beyond (Fig. 2). However, the hectocotylised arm increase in once maturity is attained, lengthwise increase of these organs practically ceases.

Table 5 provides correlation coefficient between dorsal mantle length and other 13 variables of which mantle circumference at head

end, largest breadth including fins, testis length, spermatophoric gland length, Needham's sac length, hectocotylised arm length hectocotylised arm breadth and normal arm length show high significant correlation, while the distal region length of hectocotylised arm, total suckers of hectocotylised arm show low, but significant correlation. Morphometric data on other species of cephalopods are not available for comparison.

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