COMPARATIVE STUDY ON CERTAIN ASPECTS OF THE BIOLOGY OF *MACROBRACHIUM EQUIDENS EQUIDENS* (DANA,1852) AND *M. EQUIDENS PILLAII* JAYACHANDRAN, 1989

By

ANITTA SEBASTIAN

THESIS

Submitted in partial fulfilment of the requirement for the degree

MASTER OF FISHERIES SCIENCE

Faculty of Fisheries

Kerala Agricultural University

DEPARTMENT OF FISHERY BIOLOGY

COLLEGE OF FISHERIES

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1993

DEDICATED

TO

MY PARENTS

DECLARATION

I hereby declare that this thesis entitled "COMPARATIVE STUDY ON CERTAIN ASPECTS OF THE BIOLOGY OF MACROBRACHIUM EQUIDENS EQUIDENS (DANA, 1852) AND M. EQUIDENS PILLAII JAYACHANDRAN, 1989" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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ANITTA SEBASTIAN

CERTIFICATE

Certified that this thesis entitled "COMPARATIVE STUDY ON CERTAIN ASPECTS OF THE BIOLOGY OF MACROBRACHIUM EQUIDENS EQUIDENS (DANA, 1852) AND M. EQUIDENS PILLAII JAYACHANDRAN, 1989" is a record of research work done independently by Smt. ANITTA SEBASTIAN under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

I. INTRODUCTION

Freshwater prawns have been a neglected resource in India till recently. With the development of an export market and increased domestic demand a considerable price rise has been observed for this which aroused growing interest among fishermen, farmers and entrepreneurs to augment production through capture and culture.

The ever increasing demand for prawns has put an increasing pressure on the capture of the wild stock. Because of this pressure for harvesting more and more, this resource at present is in a phase of decline. Only fragmentary data is available on freshwater prawn landings. It is estimated that the freshwater prawns contributed to about 20,000 tonnes in India annually during the early sixties (Tripathi, 1992).

In Kerala the maximum production of Macrobrachium rosenbergii was noticed during 1960 (429 t) by Raman (1967). It has now declined to less than 50 t (Jayachandran and Joseph, 1992). According to Kurkup et al. (1992) the Palaemonid prawns contribute to 1.63% of the total exploited fishery resources of Vembanad lake. On an average, from Hooghly Matlah estuarine system a production of about 5.05 t and 2.27 t for M. malcolmsonii and M. rosenbergii respectively was recorded during the period 1962-1966 (Rao, 1969). The production of M. malcolmsonii in the lake Kolleru, Andhra

Pradesh was of the tune of 85.58 t in 1978-79 and 46.84 t in 1979-80. The contribution of M. rude from the above lake is substantial (7.43 t in 1978-79 and 12.66 t in 1979-80) (Rao, 1982). M. choprai landings in the river Ganga ranged from 5 Kg to 1600 Kg per month during the year 1986 (Shree Prakash, 1989).

According to the assessment made by New (1990) the global production of M. rosenbergii through culture was of the order of 27,065 mt during 1987-88. India's contribution to the same was about 150 mt and 198 mt during 1989 and 1990 respectively.

In India 15 species of Macrobrachium are reported to be important from the fisheries point of view (Jayachandran and Joseph, 1992), of which M. rosenbergii, M. malcolmsonii, and M. choprai are the large sized ones. Others are small sized which are abundantly available and contribute substantially to the capture fisheries (M. villosimanus, M. lamarrei lamarrei, M. idella, M. rude, M. equidens equidens, M. equidens pillaii, M. scabriculum and M. mirabile). In Vembanad lake the Palaemonid prawn fisheries is constituted by 4 species viz., M. rosenbergii, M. idella, M. scabriculum and M. equidens with a landing of about 39.29, 68.3, 6.78 and 3.34 (tonnes) respectively. (Kurup et al, 1992).

Two distinct populations of M. equidens co-exist in the Cochin backwaters as well as in other brackish water areas along the south west coast of India. These populations have been given a subspecies status, M. equidens equidens and M. equidens pillaii (Jayachandran, 1989; Jayachandran and Joseph, 1989; 1992). According to Holthuis (1950) this species shows great intraspecific variations and in the light of this, various independently proposed names have been synonomised.

M. equidens equidens was originally described by Dana (1852) as Palaemon equidens from Singapore waters. De Man in 1892 described a species from West Flores and Celebes under the name Palaemon (Eupalaemon) sundaicus. De Man (1888) described a species from Mergui Archipelago for which he gave the name Palaemon equidens. A comparison of De Man's above two descriptions reveals that both refer to one and the same species. The name Palaemon sundaicus proposed by De Man has been followed by many later taxonomists (Weber, 1897, Hildendorf, 1898; Coutiére, 1901; Lanchester, 1901; 1906; Nobili, 1903; Cowles, 1914; Stebbing, 1915; Kemp, 1918; J. Roux, 1919; 1923; 1932; Barnard, 1920; 1947; Yu, 1931; Estampador 1937; Suvatti, 1937) reported this species from different parts of the world. Simultaneous with the description of Palaemon sundaicus, De Man (1892) described yet another species under the name Palaemon Eupalaemon equidens which at a later date was elevated to a new species by himself namely, Palaemon neglectus, which is actually M. javanicum De Man 1897 expressed doubts regarding the identification of Palaemon sundaicus by himself and opined that this species is more related to Palaemon dispar. According to Holthuis (1950) Palaemon dispar is M. australe. The opinion of Kemp (1918) also lends support to this view.

Moreover many varieties of Palaemon sundaicus have been described, namely, var. bataviana De Man, 1897, var. brachydactyla Nobili, 1899; var. De Mani Nobili, 1899 and var. baramensis De Man, 1902. The descriptions of the above varieties are based not essentially on males alone but on females, immature and adult specimens also. It is noteworthy to mention here that most of the diagnostic characters for each variety are also applicable to the two populations found in the Cochin Backwaters.

In literature, this species has been described as new by many: Palaemon (Eupalaemon) acanthosoma Nobili (1899); Palaemon nasutus Nobiili (1903); Palaemon sulcatus Henderson and Matthai (1910), Palaemon delagoae Stebbing (1915), Urocaridella barradailei Stebbing (1923), Macrobrachium striatus Pillai (1990).

It can be seen that there exist a lot of confusion regarding the identity of the species. The present investigation has been undertaken to re-examine thoroughly the status of the two populations for which the following studies have been carried out:

1. Morphological,
2. Morophometric and meristic,
3. Length-weight relationship,
4. Electrophoresis,
5. Oogenesis.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

2.1. Systematics

Henderson (1893) studied the prawns of Pondichery which seems to be the pioneer study on Indian palaemonids. Serious taxonomic studies on South Indian palaemonids are the following. Henderson and Matthai (1910) carried out elaborate taxonomic studies of the South Indian fresh water prawns of the genus Palaemon. They have described a few new species. Nataraj (1942) catalogued the prawns of Travancore. George (1969) brought out an elaborate compendium on the systematics of Indian prawns. Jalihal et al (1988) described 10 species under the genus Macrobrachium. They have also given a key for their identification. Detailed systematic studies and resource potential of Palaemonid prawns of the south west coast of India have been carried out by Jayachandran (1984, 1989, 1992) and Jayachandran and Joseph (1988, 1989, 1992).

The taxonomic studies of North Indian prawns have been carried out by many (Kemp, 1917; 1924;1925; Tiwari, 1947a; 1952; Chopra and Tiwari, 1948). A number of new species have been reported of which one species, M. cavernicola is a cavernicolous form with degenerated eyes. Systematics and key for the identification of economically important species of the genus Macrobrachium has been published recently by Jayachandran and Joseph (1992).

M. equidens was originally described by Dana (1852a) under the name *Palaemon equidens*. The same nomenclature was found to be used by various other taxonomists for referring this species (Dana, 1852a, 1855; Weitenweber, 1854; Von Martens, 1868; De Man, 1888a; Ortmann, 1891). However De Man in 1892 described yet another species from Flores and Celebes under the name *Palaemon* (*Eupalaemon*) *sundaicus* which was based on a female specimen. In literature it can be seen that many taxonomists followed De Man in naming their specimens either as *Palaemon* (*Eupalaemon*) *sundaicus* (Weber, 1897; Hilgendorf, 1898; Coutiére, 1901; Nobili, 1903; J. Roux, 1917; 1919; 1932), *Palaemon sundaicus* (Lanchester, 1966; Cowles, 1915; Stebbing, 1915; Kemp, 1918; Yu, 1931; Estampador, 1937; Barnard, 1947) or *Eupalaemon sundaicus* (Stebbing, 1910; Barnard, 1920). Because of this reason this species had been best known under the specific name *Sundaicus* under the genus *Palaemon*.

There are a series of good descriptions and illustrations of this species but under various other names, such as *Palaemon* (*Eupalaemon*) *acanthosoma* Nobili, 1897; *Palaemon nasutus* Nobili, 1903a; *Palaemon sulcatus* Henderson & Matthai, 1910; *Palaemon delagoae* Stebbing, 1915; *Urocaridella borradailei* Stebbing, 1923; *Palaemon sundaicus* var. *bataviana* De Man, 1897; *Palaemon sundaicus* var. *brachydactyla* Nobili, 1899; *Palaemon sundaicus* var. *De Mani* Nobili, 1899; *Palaemon sundaicus* var. *baramensis* De Man, 1902. Holthuis (1950) in his classic work on the subfamily Palaemoninae made an elaborate comparative study of the specimens and descriptions of this species from world over and arrived at the conclusion that the above names are mere synonyms of M. equidens.

In India, the first description of this species had been made by Henderson and Matthai (1910) under the name Palaemon sulcatus. The description of this species was based on 5 male and 1 female specimens collected from Cochin backwaters. Out of the 5 male specimens, 3 had short, straight rostrum and 2 had long, curved rostrum. Jayachandran (1989) described two subspecies of M. equidens under the name M. equidens equidens and M.equidens pillaii from Kerala waters. This study was based on comparing the morphological characters. However Pillai (1990) described a new species from Cochin backwaters under the name M. striatus. This species is closely related to M. equidens. He observed striking differences in the life history of these two species. The colouration and morphological characters of M. striatus reveals its similarity with M. equidens pillaii and the 3 male specimens with short straight rostrum of Henderson and Matthai (1910). The above review clearly indicates the great confusion that exist in the status of these two species. The present study has been undertaken to establish the status of these two populations.

2.2. Morphometric Studies

Eventhough studies on the growth pattern is one of the important methods for confirming the species identity morphometric made an elaborate comparative study of the specimens and descriptions of this species from world over and arrived at the conclusion that the above names are mere synonyms of M. equidens.

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2.2. Morphometric Studies

Eventhough studies on the growth pattern is one of the important methods for confirming the species identity morphometric studies on decapods seem to be rare. Tazelar (1930) studied the relative growth of different parts in M. rosenbergii. Huxley (1932) threw some light on the problems of relative growth in certain crustaceans. Rao (1967) related the total length with carapace length in M. rosebergii of the Hooghly esturine system. Raman (1967) also observed a linear relationship of carapace length to total length in males and females of M. rosenbergii. Allometric studies of M. scabriculum and M. idella have been carried out by Jayachandran and Joseph (1985; 1988). Jayachandran and Balasubramanian (1987) made a comparative study on rostrum length-total length relationships in Macrobrachium idella and M.scabriculum. Koshy (1969) statistically established sexual dimorphism in M.lamarrei lamarrei. Sexually dimorphic growth patterns have been well established in some species of Macrobrachium such as M. rosenbergii (Rajyalakshmi, 1962; 1966; Smith et al., 1978; Ling, 1969); M. malcolmsonii (Ibrahim, 1962; Rajyalakshmi, 1962; 1974; 1980) and M. choprai (Sree Prakash et al 1982; 1989). In the case of the two varieties of Macrobrachium equidens, Jagadisha (1977) reported morphological differences such as rostral length with reference to antennal scale, number and position of dorsal and ventral rostral teeth, relative lengths of carpus and chela of second peraeopod between adult males of the two varieties.

2.3. Meristic Studies

Though many taxonomic characters of decapod crustaceans are based on meristic counts, references dealing with statistical studies on decapods seem to be rare. Tazelar (1930) studied the relative growth of different parts in M. rosenbergii. Huxley (1932) threw some light on the problems of relative growth in certain crustaceans. Rao (1967) related the total length with carapace length in M. rosebergii of the Hooghly esturine system. Raman (1967) also observed a linear relationship of carapace length to total length in males and females of M. rosenbergii. Allometric studies of M. scabriculum and M. idella have been carried out by Jayachandran and Joseph (1985; 1988). Jayachandran and Balasubramanian (1987) made a comparative study on rostrum length-total length relationships in Macrobrachium idella and M.scabriculum. Koshy (1969) statistically established sexual dimorphism in M.lamarrei lamarrei. Sexually dimorphic growth patterns have been well established in some species of Macrobrachium such as M. rosenbergii (Rajyalakshmi, 1962; 1966; Smith et al., 1978; Ling, 1969); M. malcolmsonii (Ibrahim, 1962; Rajyalakshmi, 1962; 1974; 1980) and M. choprai (Sree Prakash et al 1982; 1989). In the case of the two varieties of Macrobrachium equidens, Jagadisha (1977) reported morphological differences such as rostral length with reference to antennal scale, number and position of dorsal and ventral rostral teeth, relative lengths of carpus and chela of second peraeopod between adult males of the two varieties.

2.3. Meristic Studies

Though many taxonomic characters of decapod crustaceans are based on meristic counts, references dealing with statistical treatment of such attributes are not many. Tiwari, (1962; 1963) tried to distinguish populations of *Macrobrachium altifrons* and *M. latimanus* from different geographical regions on the basis of meristic characters. Koshy (1969) observed that in *M. lamarrei* the position, number and pattern of arrangement of teeth are important diagnostic characters for the species. Jagadisha (1977) recorded differences in number and position of dorsal and ventral, rostral teeth between the two varieties of *Macrobrachium equidens* (Dana, 1852).

2.4. Length-weight Relationships

Growth is essentially a change in mass and as such is measured by weight. Weight in organism may be considered as a function of length and the relationship is species specific. Such studies in palaemonids are limited. Rajyalakshmi (1962) and Rao (1967) worked out the length-weight relationships of *M. rosenbergii*. The length-weight relationship of *Macrobrachium malcolmsonii* of river Godavari has been carried out (Ibrahim, 1962). In the case of *M. rosenbergii* of northern Balgoda lake in Sri Lanka, Jinadasa (1985) reported that male, in general, weigh more than females. Jayachandran and Joseph (1988) made a comparative study on the length-weight relationships of *M. idella* and *M. scabriculum*. Length-weight relationship of *M. dayanum* has been worked out by Rajesh *et al* (1990). Length-weight relationships of *M. malcolmsonii* under experimental conditions (after providing artificial feed) have been studied by Venkatesvaran (1990). Kurup *et al.* (1992) worked out the length-weight relationships of *M. rosenbergii* and *M. idella* in the Vembanad lake. The length-weight relationship of *M. rosenbergii* reared in Pokkali field has been done by Mathew and Mohan (1992).

2.5. Electrophoresis

Electrophoretic analysis has been used by many in Ichthyotaxonomy (Tsuyuki and Eve Roberts, 1963; Tsuyuki *et al.*, 1965; 1968; Cowie, 1968; Fischen and Tsuyuki, 1970; Devadasan and Rajendranathan, 1971; Meneses, 1976; Kurian, 1977; Maria and Meneses, 1979; Chakraborty, 1990 and Smith, 1990). Similar studies in crustaceans are very limited. Barlow and Ridgeway (1969) and Bourguet (1977) have studied the changes in serum proteins during moulting and reproductive cycles of American lobster, *Homarus americanus* and *Penaeus japonicus* respectively. Durliat and Vranckx (1967) observed the changes in the water soluble proteins in the integument of *Astacus leptodactylus*. Lavery and Staples (1990) used allozyme electrophoresis for the identification of two species of penaeid prawn post-larvae. Polyacrylamide gel electrophoresis has been used in the study of muscle proteins in the palaemonids of Western Australia (Boulton and Knott, 1984). Paul Pandian (1975) analysed the serum and muscle proteins of crabs of Porto Novo waters. An experimental study on the effects of age and imposed fasting on the serum proteins of an isopod, Porcellio laevis has been carried out by Alikhan and Lysenkos (1973).

Serum protein patterns of some penaeid prawns have been elucidated by Lee and Lim (1973). Classical studies on the population genetics of Penaeus aztecus, Penaeus duorarum and Penaeus setiferus of the Gulf of Mexico have been carried out by Lester (1979). In India basic data on the electrophoretic band patterns of Metapenaeus dobsoni, Penaeus indicus and Penaeus monodon, Metapenaeus affinis, Metapenaeus monoceros, Parapenaeopsis hardwickii, Parapenaeopsis stylifera have been collected by Devadasan and Nair (1971); Kulkarni et al. (1980); Thomas (1981) and Prathibha (1984). Philip (1987) analysed the band pattern of different species belonging to the genera Penaeus, Parapenaeopsis and Metapenaeus. It can be seen that electrophoretic separation of proteins is a reliable approach to population studies as has already been opined by Lester (1980).

2.6. Oogenesis

Gametogenesis is the most important phase of reproduction in every organism. Among economically important prawns, information on gametogenesis has been very much scanty.

Histological changes associated with maturity stages in females have been enunciated in some marine prawns. Subramanyam (1965) and Rao (1968) categorised the maturity stages and simultaneous intra-ovarian changes in P. indicus. Similar studies have also been made in M. affinis, M. dobsoni and P. stylifera by Rao (1968) and in Parapenaeopsis hardwickii by Kulkarni and Nagabhushanam (1982). Nadarajalingam and subramoniam (1982) have given a histological classification of developmental stages of crustacean oogenesis.

Detailed studies on oogenesis have been carried out in a number of freshwater prawns. Aiyer (1953) has given a detailed description on the female reproductive system of Palaemon idae (= M.idella idella). Rajyalakshmi (1961, 1980) studied the maturation and breeding in estuarine prawns, M. rosenbergii, M. mirabile and M. malcolmsonii in the Hooghly estuary. Kamiguchi (1971) studied the effects of eyestalk removal in relation to ovarian growth in Palaemon paucidens. Charles and Subramoniam (1982) made a comparative study on the external morphology of the ovary and oogenesis in two edible freshwater prawns viz., M. malcolmsonii and M. lamarrei. Rao et al. (1981) and Singh et al. (1988) have broughtout histological changes of ovarian maturation in M. lanchesteri and M. birmanicum respectively. Papathanassiou and King (1984) carried out electron microscopic studies on the oogenesis in Palaemon serratus. A detailed account on oogenesis of Macrobrachium idella has been given by Jayachandran and Joseph (1986b) and Joshi and Diwan (1992) and that of M. malcolmsonii by Philip and Subramoniam (1992).

MATERIALS AND METHODS

III. MATERIALS AND METHODS

A total number of 353 specimens (173 specimens of M. equidens equidens - 88 males and 85 females; 180 specimens of M.equidens pillaii - 109 males and 71 females) were collected from the Vembanad lake at Panangad and were subjected to various analyses during the course of the present investigation. Live specimens (60 numbers) were utilized for the electrophoretic and oogenetic studies and the rest were preserved in 8-10 percent formalin and subsequently utilized for the systematic, morphometric, length-weight relationship and meristic studies.

3.1. Systematics

A total of 293 specimens (143 specimens of M. equidens equidens and 150 specimens of M.equidens pillaii were collected from Cochin backwaters during the period 1990-1992. The specimens were identified with the help of relevant literature (Dana, 1852a; De Man, 1892; Henderson and Matthai, 1910; Kemp, 1918; Holthuis, 1950; Jayachandran, 1989; 1991; Pillai, 1990). Structural details of rostrum, carapace, abdomen, telson and all appendages were accurately noted and drawn to scale. Live specimens were also utilised for observing the colouration.

3.2. Morphometric Studies

A total number of 143 specimens of M. equidens equidens (73 males, ranging in total length (TL) from 51 to 97 mm and 70 females ranging in TL from 49 to 81 mm) and 150 specimens of *M. equidens pillaii* (94 males, ranging in TL from 48 to 91 mm and 56 females, ranging in total length from 39 to 77 mm) were collected from Cochin backwaters at Panangad. For the present study, the following parameters were accurately measured with the help of dividers and scale.

1. Total length: Length from the tip of the rostrum to the tip of the telson.

2. Carapace length: Length from the tip of the rostrum to the posterior limit of carapace. Here rostrum is part of carapace.

3. Cephalothoracic length: Length from the orbit to the posterior limit of the carapce, where all the cephalothoracic somites are seen and rostrum excluded.

4. Rostrum length: Length between the tip of the rostrum and orbital angle.

5. Carapace width: Maximum horizontal width of carapace.

6. Telson length: Length between the posterior limit of abdomen and tip of telson.

7. Body length: Length between the orbital angle and posterior limit of abdomen.

8. Abdominal length: Length between anterior and posterior limits of abdomen.

9. Total length of 2nd chelate leg: Length from the base of the ischium to the tip of the dactylus (includes lengths of ischium, merus, carpus, palm and fingers).

10. Ischium length: Length between the proximal and distal aspects of ischium.

11. Merus length: Length between the proximal and distal limits of merus.

12. Carpus length: Length between the proximal and distal ends of carpus.

13. Propodus length (Chela length): Length between the proximal and distal aspects of propodus (includes palm and fingers).

14. Palm length: Length from the proximal limit of propodus to the proximal limit of fingers (excluding fingers).

15. Dactylus length: Length of movable finger.

In the present study the characters namely carapace length, body length, abdominal length, telson length, total length of 2nd chelate leg and length of various podomeres are related to total length. The chephalothoracic length, width of carapace and length of rostrum (Head characters) are related with carapace length. Similarly, the lengths of ischium, merus, carpus, propodus, palm and fingers are related to the total length of 2nd chelate leg. The method of analysis of covariance was applied to confirm whether any significant differences in the growth rates exist between sexes and also between the subspecies with regard to various morphometric characters (Snedecor and Cochran, 1975).

3.3. Meristic Studies

One hundred and forty specimens of M. equidens equidens (70 males & 70 females) and 95 specimens of M. equidens pillaii (64 males & 31 females) were collected from Cochin Backwaters at Panangad. The total number of teeth on the dorsal margin including the post-orbital teeth is taken as the dorsal teeth. Similarly the total number of teeth on the ventral margin is considered as the ventral teeth. A few teeth seen behind the orbital angle is included as the post-orbital teeth. The tooth which is seen immediately above the orbit is never counted as post-orbital tooth. From this data, the range of teeth and percentage frequency distribution of teeth have been calculated. Chi-square test has applied to find out whether any significant difference exists between the sexes and also between the two subspecies with respect to the above characters.

3.4. Length-weight Relationships

One hundred and twenty two specimens of *M. equidens pillaii* (66 males and 56 females) and 130 specimens of *M. equidens equidens* (65 males and 65 females) have been collected from the Cochin Backwaters at Panangad, Kerala, for the present study. Total length (mm) and weight (mg) for each specimen were accurately measured. The method of analysis of covariance (Snedecor and Cochran, 1975) has been applied to find the regression coefficient). For the linear representation of the relationships, all length and weight measurements have been transformed into their logarithmic values and expressed as Log W = Loga + n LogL.

3.5. Electrophoresis

3.5.1. Collection of specimens.

Live specimens of *M.equidens equidens* and *M. equidens pillaii* were collected from Cochin backwaters at Panangad, Cochin, during night by using a hand net (specially designed) and a torch, They were immediately transported to the laboratory and kept alive in cement cisterns containing brackish water and were utilised for the study.

3.5.2. Extraction of water soluble proteins.

Specimens of the *M. equidens equidens* used for the analysis ranged from 60 to 80 mm in length and 5.5 to 5.7 gm in weight and those of M. equidens pillaii ranged from 65 to 75 mm and 3.5 to 3.75 gm, respectively.

The prawns were beheaded, peeled, deveined and the muscle tissue was then blotted off to remove the moisture. The tissue was immediately weighed and homogenised with an equal volume of distilled water under ice cold conditions. The homogenate was then centrifuged at 2000 r.p.m. at 4°C for 1 hour. The clear supernatent was used for the electrophoretic study.

Disc SDS polyacrylamide gel electrophoresis (SDS-PAGE) was conducted using the method of Laemeli (1970).

3.5.3. Reagents.

1. Acrylamide: Bis Acrylamide solution

30 gm of acrylamide and 0.8 gm of bisacrylamide were dissolved in distilled water and made up to 100 ml and stored in dark bottles at 4°C.

2. Sodiumdodecyl Sulphate (SDS).

10% (W/V) of SDS was prepared in every 2-3 weeks and stored at room temperature.

3. Electrode Buffer (Tris-glycine buffer pH8.3, 0.1% W/V SDS).

6 gm of Tris, 28.8 gm of glycine and 1 gm SDS were dissolved

in 1 litre of distilled water.

4. Spacer Buffer (Tris buffer pH 6.7)

5.98 gm of Tris was dissolved in minimum volume of 1 N HCl and the pH was then adjusted to 6.7 and the final volume made up to 100 ml.

5. Discontinuous gel buffer (Tris buffer pH 6.9)

36.3 gm of Tris was dissolved in 1 N HCl and then the pH adjusted to 6.9. The volume was then made upto 100 ml using distilled water.

6. Ammonium per sulphate solution 10% (W/V)

7. Coomassie brilliant blue R-250 (0.2%)

The staining solution was prepared by dissolving 2 gm of Coomassie blue in a solvent mixture consisting of 465 ml of methanol, 70 ml of glacial acetic acid and 465 ml of distilled water.

8. Destaining solvent.

Destaining solvent was prepared by mixing 100 ml of methanol, 150 ml of glacial acetic acid and 1750 ml of distilled water.

9. Composition of resolving gel (7.5%).

Acrylamide Bis Acrylamide - 5 ml.

Tris buffer pH 8.9 - 5 ml.

Water - 9.5 ml.

10% SDS - 0.2 ml.

TEMED - 0.03 ml.

Ammonium per sulphate (10% W/V) - 0.3 ml.

10. Composition of 3.6% spacer gel.

Acrylamide : Bis acrylamide - 0.61 ml.

Tris buffer pH (6.7) - 0.63 ml.

Water - 3.64 ml.

10% SDS - 0.05 ml.

TEMED - 0.01 ml.

Ammonium per sulphate - 0.08 ml.

11. Sample buffer

Sample buffer was prepared by mixing 2.5 ml of Tris buffer pH 6.7, 4 ml of SDS 10%, 2 ml of glycerol and 11.5 ml of distilled water.

12. TEMED (N, N, N', N' - Tetramethyl ethylene diamine)

3.5.4. Casting of the gel.

Gels were moulded in the form of gel rods. Glass tubes, both end open and having a uniform diameter of 0.5 cm and length of 7.5 cm were selected. They were placed in a suitable stand in vertical position and the lower end of each tube was sealed with cellophane paper.

Resolving gel solution was prepared and 1.1 ml of this was poured into each gel tube along the side of the tube using a pipette. Care was taken to avoid bubble formations while pouring the solution. After this, one drop of butanol: water mixture (1:1 V/V) was placed on the top of the gel solution to avoid meniscus formation. The gel was allowed to polymerise for 1 hour and then the upper layer of butanol-water mixture was removed carefully with a blotting paper. Spacer gel solution was prepared as mentioned earlier and 0.2 ml of this was poured. A drop of butanol-water mixture (1:1) was then added to avoid meniscus formation and the gel was allowed to polymerise for 1 hour. The butanol-water layer was removed after polymerization. Now the gel tubes are ready for elctrophoresis.

3.5.5. Sample application and electrophoresis.

The gel tubes were inserted into the grommets of the upper buffer tank. This was then placed over the lower buffer tank containing the electrode buffer. Electrode buffer was also added to the upper buffer tank. The protein sample was mixed with an equal volume of sample buffer and 5 ul of 0.025% aqueous bromophenol blue solution was added and 50 ul of this mixture was applied to the top of the gel tube using a Hamilton syringe. The upper buffer tank was closed with the lid and electrical connections were given. The power pack was adjusted in such a way as to pass a current of 4 mA per gel tube. When the bromophenol blue reached the lower end of the gel tubes the supply of current was terminated. Buffer was poured out and gel tubes were removed from the grommet. The gels in the tubes were removed by injecting electrode buffer in between the gel and tube with the help of a syringe.

3.5.6. Staining.

Coomassie brilliant blue 0.2% (W/V) was used as the stain. The gels were stained for 20 minutes in a test tube.

3.5.7. Destaining.

Excess dye was removed by repeated washing with the destaining solvent, till the bands appeared as dark blue disc against a clear background. The developed gels were kept in the destaining solvent itself and photographed.

3.6. Oogenesis

Live female specimens of *M. equidens equidens* and *M. equidens pillaii* in different stages of maturity were collected from the Cochin backwaters. For histological studies ovaries were dissected out and fixed in alcoholic Bouins fluid for 6 to 8 hour period. They were washed and dehydrated in the ascending alcohol series, cleared in Xylene and embedded in Paraffin wax (58-60°C). Serial sections were cut at 5-6 u and stained with Harris haematoxylin and counterstained with alcoholic Eosin and mounted in DPX.

The histological changes associated with ovarian maturation were observed under a compound microscope.

RESULTS

IV. RESULTS

4.1. Systematics

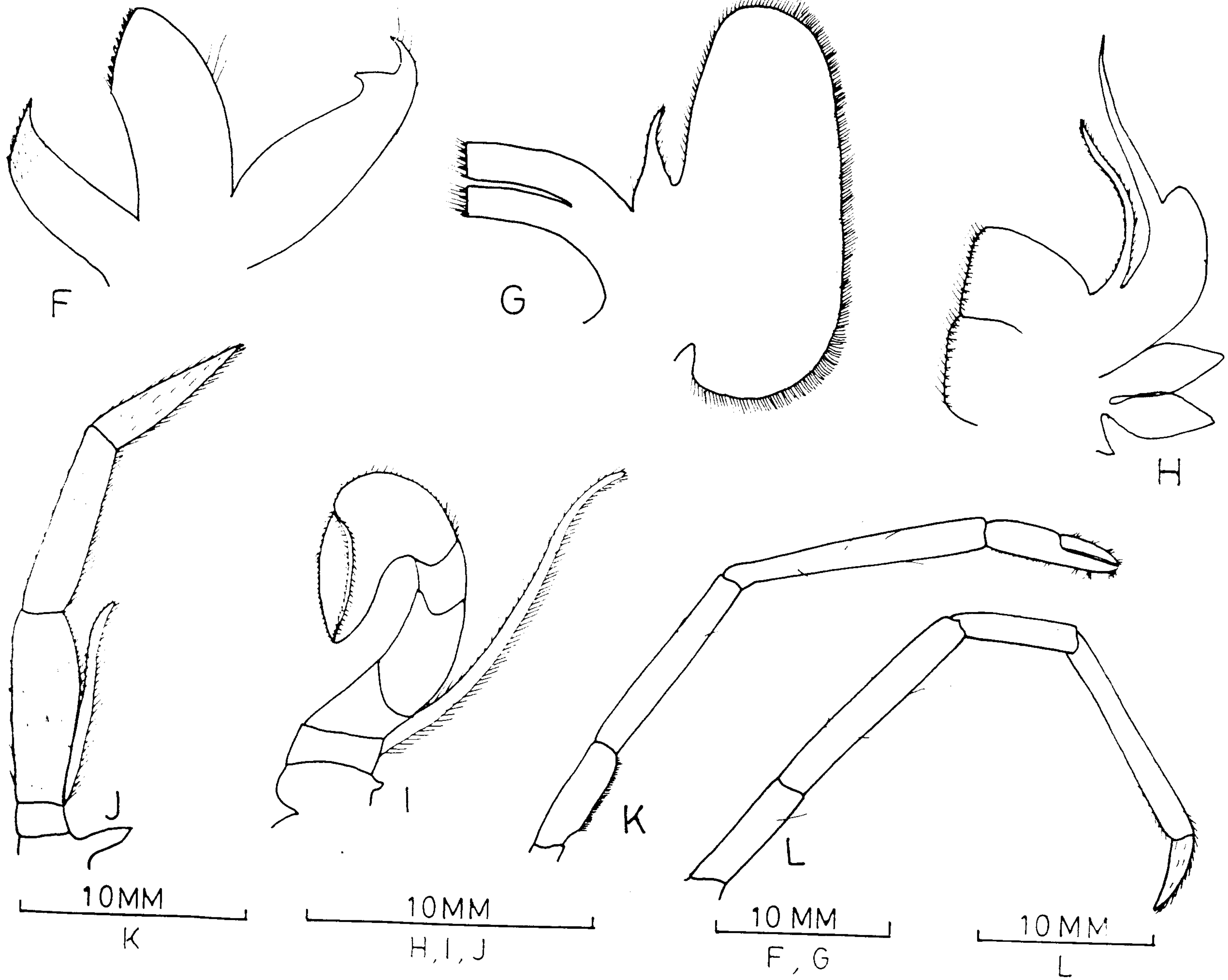
4.1.1. Macrobrachium equidens equidens (Dana, 1852).

Palaemon equidens Dana, 1852, Proc. Acad. nat. Sci. Philad., 6:26

4.1.1.1. Synonymy: Palaemon equidens Dana, 1852; 1852a; 1855 Weitenweber, 1854; De Man, 1888a; Ortmann, 1891; Palaemon equidens (aequidens) Von Martens, 1868; Palaemon (Eupalaemon) sundaicus De Man, 1892; 1897; 1898; Weber, 1897; Hilgendorf, 1898; Coutiere, 1900; Nobili, 1903; J. Roux, 1917; 1919; 1923; 1932; Palaemon sundaicus Coutiére, 1901; Lanchester, 1901; 1906; Cowles, 1914; Stebbing, 1915; Yu, 1931; Estampador, 1937; Barnard, 1947; Eupalaemon sundaicus Stebbing, 1910; Barnard, 1926; Bithynis (Eupalaemon) sundaicus Rathbun, 1910; Palaemon sundaicus bataviana De Man, 1897; Palaemon (Eupalaemon) sundaicus brachydactyla Nobili, 1899; Palaemon sundaicus De Mani Nobili, 1899; Palaemon (Eupalaemon) acanthosama Nobili, 1899; De Man, 1908; 1915; J. Roux, 1912; Palaemon (Eupalaemon) sundaicus baramensis De Man, 1902, Palaemon (Eupalaemon) nasutus Nobili, 1903a; Palaemon sulcatus Henderson & Matthai, 1910 (Part of the collection); Panikkar, 1937; Nataraj, 1942; Palaemon delagoae Stebbing, 1915; Rathbun, 1935; Palaemon nasutus Nouvel, 1932; Urocaridella borradailei Stebbing, 1923; Macrobrachium sundaicus Suvatti, 1937; Macrobrachium equidens Holthuis, 1950 (with complete synonymy); 1980; Macrobrachium equidens equidens Jayachandran, 1989; Jayachandran & Joseph, 1989;

Fig. 1. Colour photograph of Macrobrachium equidens equidens (Dana, 1852), collected from Cochin Backwaters at Panangad.

FIG. 3



1990; Cryphiops (Macrobrachium) equidens Johnson, 1966.

4.1.1.2. Redescription (Male).

Body laterally compressed. Rostrum long, entending beyond the antennal scale, basal crest not elevated, distal end distinctly curved upwards; upper margin bears 9 to 12 teeth of which 3 teeth distinctly post-orbital in position, first tooth situated at bout anterior 1/3rd of the carapace, the interval between the first three teeth and that between 6th and 7th are more than that between the teeth of 3rd to 5th, 9th tooth very widely separated from 8th, 10th tooth subdistal and smaller in size. Ventral margin bears 4 to 6 teeth, 1st ventral tooth situated beyond the level of the 6th dorsal tooth, 2nd beyond the level of 7th, 3rd ventral tooth almost at the level of 8th, 4th ventral tooth behind the level of 9th, 5th ventral tooth just beyond the level of 9th. Small setae present in between the teeth of both dorsal and ventral margins (Fig. 2A).

Carapace generally smooth except for a few minute tubercles on the immediate lateral sides of the post-orbital teeth, antennal and hepatic spines characteristic of the genus present, the latter is situated close to the former almost in a line. A faint groove present ventral to the hepatic spine (Fig. 2A).

Abdomen smooth; the pleurae of 1st to 3rd segments broadly rounded at their postero-ventral margins, those of 4th and 5th directed backwards, that of 6th ending in a sharp point.

Telson robust, dorsally scabrous, distal end extends beyond the level of outer lateral spine of exopod of uropod; dorsal surface bears 2 pairs of spines, anterior pair almost midway, posterior pair halfway between the anterior pair and tip of telson; distal end also bears 2 pairs of spines, outer pair smaller and immovable which doesnot reach the tip of telson, inner pair longer, slender and movable which overreaches the tip of telson; in between the inner pair of movable spines a large number of plumose setae present. A tuft of setae also present at the proximal dorsal surface (Fig. 2B).

Three segments of the antennular peduncle in the ratio 6:2.25:5; the proximal segment broad in which lodges the eye, stylocerite reaches more than 1/3rd length of basal segment, a row of setae are seen along the ventral outer lateral margin; the antero-lateral margin ends in a sharp spine which reaches as far as the anterior lobe which is fringed with a row of setae; the distal segment longer than the middle one and bears two flagellae of which the upper one is bifid (Fig. 2C).

Antennal peduncle (protopod) short, bisegmented; basis bears a sharp spine; scale long and broad, outer margin concave and ends in a sharp spine which does not reach the tip of lamella; the lamella beyond spine broadly rounded; the flagellar peduncle 3 segmented, flagellum long (Fig. 2D).

Mandible highly chitinised, apophysis much longer than the incisor process in the ratio 7.5:4.5; incisor process tridentate, palp 3- segmented, the basal segment shortest and distal segment longest (Fig. 2E).

Maxillula flat, 3-lobed; proximal two lobes project inwards and their tips bear still spines and setae (gnathobases); palp distally bifid which hooks around the outer edge of the labium and affords a leverage to the whole appendage (Fig. 3F).

Maxilla also flat; protopod slender, bilobed, curved inwards and end in stiff spines and setae; endopod slender, small; exopod very broad and its outer margin fringed with setae (Fig. 3G).

Coxa and basis of first maxilliped foliaceous, project inwards, free end bear two rows of stiff setae (gnathobases); endopod slender, unjointed; exopod too slender and bears a thin plate-like expansion along the proximal half of its length, epipod bilobed (Fig. 3H).

Second maxilliped more pediform; coxa bears an epipod and a gill; exopod slender, flagellar; endopod five segmented (ischium, merus, carpus, propodus and dactylus), the propodus and dectylus are strongly bent inwards and backwards so as to be parallel to the main axis of enopod formed by the proximal three podomeres. Owing to the backward growth and extension of the propodus, the dactylus comes to be along the median side of the propodus and forms a firm cutting plate bearing pointed spines along its inner edge (Fig. 3I).

Third maxilliped pediform; coxa and basis short, coxa bears a prominent epipod; endopod three segmented in the ratio 6.5:6.5:5.5; exopod slender, reaches slightly beyond the tip of proximal segment of endopod (Fig. 3J).

First chelate legs slender, the podomeres possess the following average percentage length: Ischium - 17.86, Merus - 29.28, Carpus - 35, Propods - 17.9, Palm - 11.43, Dactylus - 6.43; ischium bears a row of short stiff setae ventrally; fingers slender almost equal to palm and bear tufts of setae; proximal ventral palm also provided with very short stiff setae (Fig. 3K).

The second chelate legs well developed, strong, about 1.4 to 1.65 times (average 1.44 times) as long as the total length of the body; ischium flat, shorter than merus, carpus and palm, but as long as the fingers; merus cylindrical in shape, much shorter than carpus and palm; carpus too cylindrical, distal part broader than proximal, shorter than chela but longer than palm; palm about 1.5 times longer than fingers, proximal part cylindrical and a little broader than the distal palm, fingers more than half as long as palm, tips curved inwards, both fingers entirely velvetty pubescent; movable finger bears two large proximal denticles and immovable finger with one proximal denticle. The flattened nature of the distal palm, curved fingers and velvetty pubescence are quite characteristic of the subspecies (Fig. 4 M,N). The podomeres possess the following average percentage length; Ischium - 13.68, Merus - 18.88, Carpus - 31.69, Propodus - 35.74, Dactylus - 13.29, Palm - 23.89.

The non chelate legs increase in total length from first to third, in which ischium longer than dactylus but as long as or shorter than carpus; merus longer than palm or as long as propodus; dactylus simple.

Protopod of pleopods bisegmented of which coxa very short and basis long. Endopod of first pleopod shorter than exopod, both rami broad and fringed with long plumose setae. Second pleopod in which exopod slightly longer than endopod; endopod bears appendix interna and appedix musculina. The inner part of appendix musculina bears very long stiff spinous setae; appendix interna more than half the length of appendix musculina; 3rd, 4th and 5th pleopods similar to 2nd pleopod except for the absence of appendix musculina (Fig. 4O,P,Q).

Uropod with single segmented protopod which bears two rami, outer margin of exopod ends in a very strong spine; distal part of both exopod and endopod broadly rounded and no accessory spine on the uropodal exopod (Fig. 4R).

4.1.1.3. Redescription (Female).

Rostrum moderately long, extending as far as the antennal scale, tip slightly curved upwards, the upper margin with 9-11 teeth of which 3 teeth post-orbital. The body generally glabrous. The cornea almost reduced. The second cheliped equal sized, less than the total length of the body, fingers slender and without any

FIG. 2

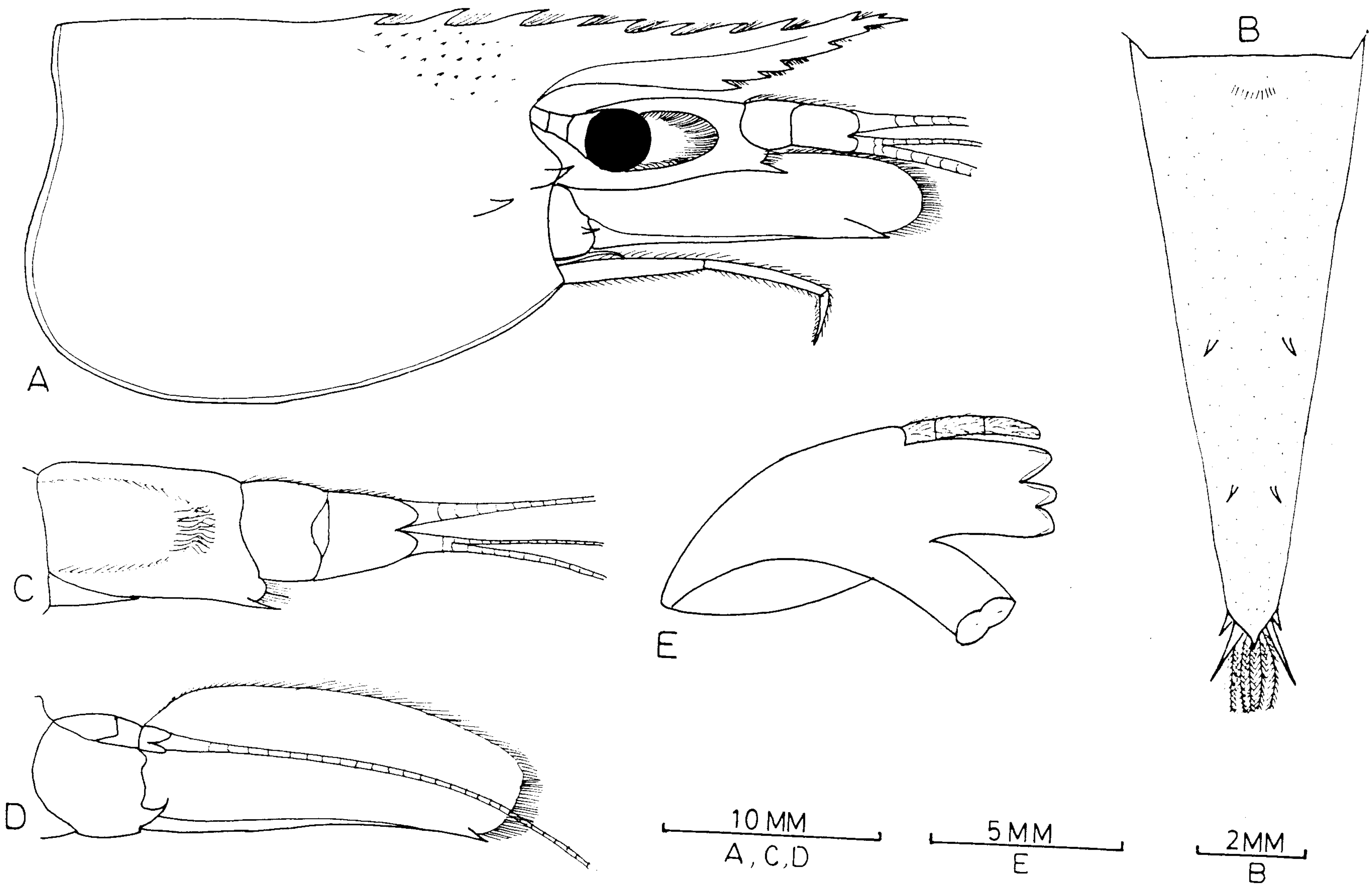


FIG. 3

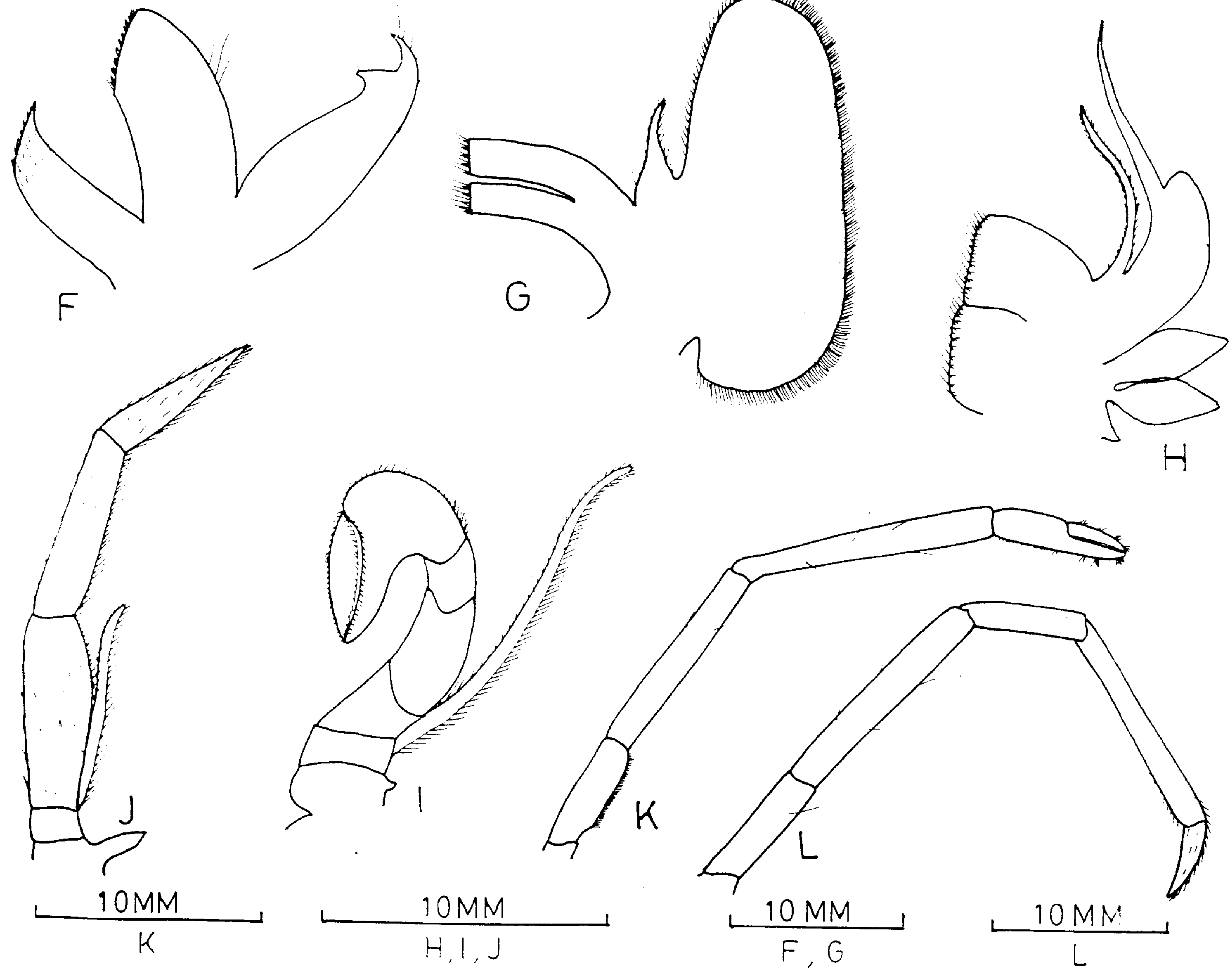
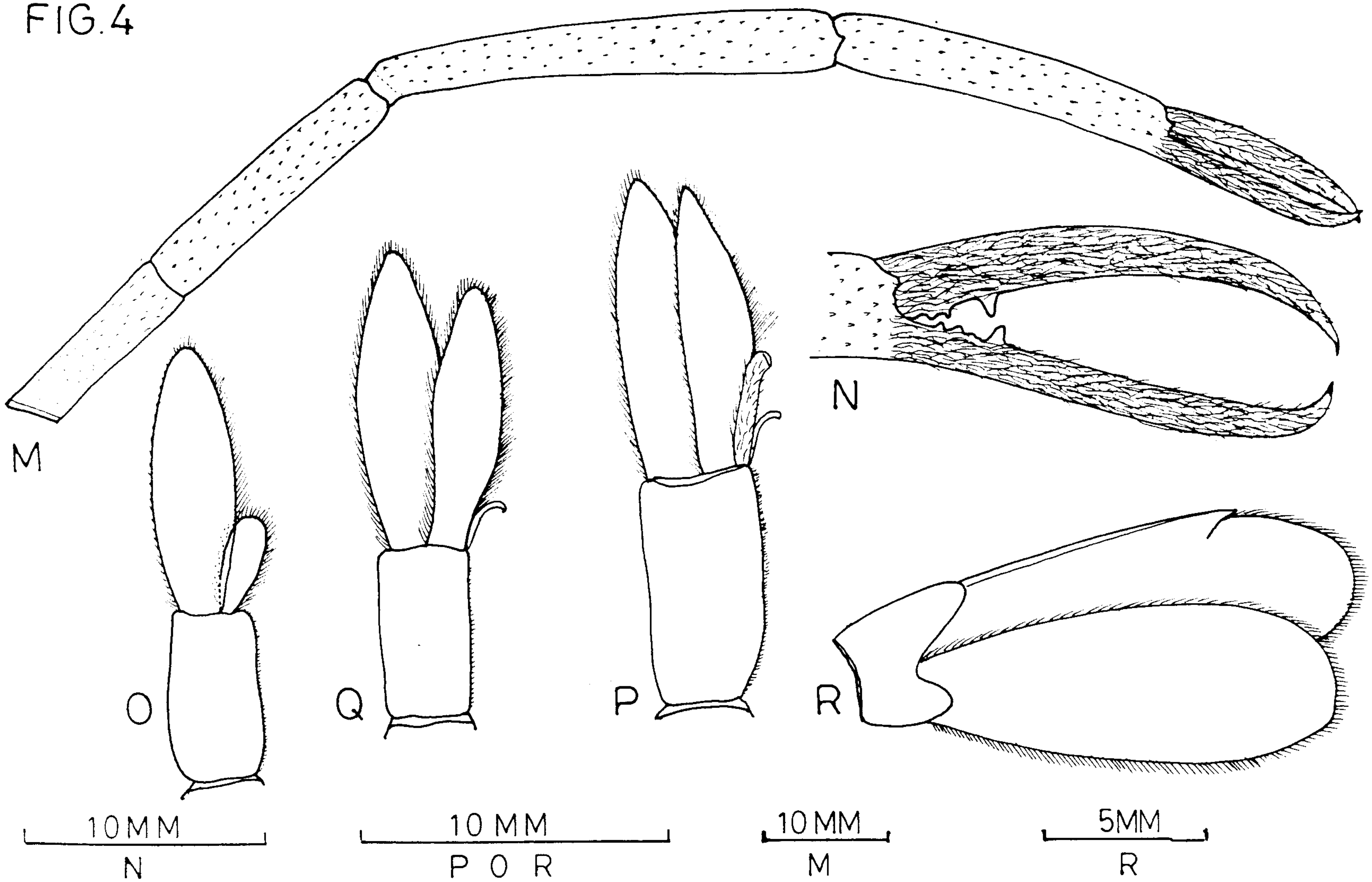


FIG. 4



hairs; proximal cutting edges of the fingers with one or two denticles; palm longer than fingers, width of palm and distal carpus almost same. Uropodal exopod without accessory spine.

4.1.1.4. Colouration.

The body is pale yellowish with brown spotted pigments, which are more on the lateral sides. The second peraeopods are generally brownish with dark patches. Both the fingers of second paraeopod of males are entirely pubescent. The non-chelate legs are with widely separated alternating dark and brown bands. The uropods are with dark patches and is more so along the lateral border. Cornea of the eyes is almost pale without much pigmentation.

4.1.2. Macrobrachium equidens pillaii Jayachandran, 1989.

Jayachandran, K.V., 1989, Symp. Coastal zone management, Cochin, Feb. 20-23, 1989 (in Press); Jayachandran, K.V. and Joseph, N.I., 1989, Proc. 1st Kerala Science Congress, 26-28 February, 1989, Cochin: 108.

4.1.2.1. Synonyms: Palaemon sulcatus Henderson & Matthai, 1910 (Part of the collection) Macrobrachium striatus Pillai, 1990.

4.1.2.2. Redescription (Male).

Body laterally compressed. Rostrum short, extending as

far as or just beyond the antennular peduncle, but does not reach as far as the apex of the antennal scale, distal end acute; upper margin nearly straight, and bears 9-12 teeth of which 4 teeth post orbital, 5th above the orbit, proximalmost tooth situated at about anterior 1/3rd of carapace length, the intervals between the proximal 3 teeth are more than those between the next 3 teeth, which are again followed by widely spaced teeth, ultimate tooth subdistal and penultimate closer to ultimate. Lower margin curved, bears 3-5 teeth, situated in the distal half (usually between the levels of 7th and 11th teeth). Small setae present in between the teeth of both upper and lower margins (Fig. 6A).

Carapace scabrous due to the presence of minute prickles. Antennal and hepatic spines prominent, arranged almost in a line (Fig. 6A).

Abdomen glabrous except the 6th somite, the pleurae of first 3 somites broadly rounded at the postero-ventral margins; those of 4th and 5th directed backwards, while that of 6th ending in a sharp spine. The sixth somite nearly 2 times as long as the 5th.

Telson robust, conical, scabrous dorsally, distal end reaches beyond the level of outer spine of uropodal exopod. The dorsal surface bears two pairs of spines, the anterior pair midway whereas the posterior pair slightly proximal to the middle between the anterior pair and tip of telson. The distal end also bears

2 pairs of spines, the outer pair shorter and immovable, the inner pair longer and movable which overreaches the tip of telson. A few plumose setae (5-6 pairs) present in between the inner pair of spines (Fig. 6B).

Three segments of the antennular peduncle in the ratio 6.5:2.5:3. The anterolateral spine of the basal segment very sharp, directed outwards and extends as far as the middle of second segment; upper antennular flagellum bifid, the shorter flagellum only 1/5th of the longer flagellum (Fig. 7F).

Antennal scale 2.5 times as long as its maximum width, outer lateral spine subdistal in position and directed forwards, the distal lamella oblique (Fig. 7G).

Mandible highly chitinised; apophysis much longer than the incisor process, in the ratio 7.5:4.5; incisor process tridendate; palp 3 segmented, the basal segment shortest while the distal segment longest (Fig. 6C).

Maxillula flat, 3-lobed; proximal two lobes project inwards and their tips bear stiff spines and setae (gnathobases); palp distally bifid which hooks round the outer edge of the labium and affords a leverage to the whole appendage (Fig. 7H).

Maxilla also flat; protopodite slender, bi-lobed, curved inwards, tips bear stiff spines and setae; endopod small exopod very broad and its outer margin fringed with setae (Fig. 7I).

Coxa and basis of first maxilliped foliaceous, project inwards, free ends bear two rows of stiff setae (gnathobases) endopod slender and unjointed; exopod too slender and bears a thin plate like expansion along the proximal half of its length; epipod bilobed (Fig. 7J).

Second maxilliped more pediform; coxa bears an epipod and a gill; exopod slender, flagellar, endopod five segmented (ischium, merus, carpus, propodus and dactylus), the propodus and dactylus are strongly bent inwards and backwards so as to be parallel to the main aixs of endopod formed by the proximal three podomeres. Owing to the backward growth and extension of the propodus the dactylus comes to be along the median side of the propodus and forms a firm cutting plate bearing pointed spines along its inner edge (Fig. 7K).

Third maxilliped pediform; coxa and basis short, coxa bears a prominent epipod; endopod three segmented in the ratio 6.5:6.5:5.5, slender, reaches slightly beyond the tip of proximal segment of endopod (Fig. 7L).

The first chelate legs slender, not reaching the tip of merus of second peraeopod when extended; the average percentage length of podomeres are - Ischium - 17.32; Merus - 29.13; Carpus - 34.65; Propodus - 18.89; Dactylus - 7.09 (Fig. 6D).

Second peraeopods very strong and elongated, about 1.25 times as long as the total length of the body; ischium flat, shortest, about 1/3rd of carpus; merus about half the size of carpus, about 6 times that of maximum width; carpus cylindrical, longer than palm but shorter than chela; palm about twice the length of fingers and subcylindrical proximal palm much wider than the distal palm; fingers equal sized and curved at an angle of 45° from the long axis of palm; fixed finger bears one prominent denticle and 2-3 very small denticles proximally and bears hairs only on the cutting edge; movable finger entirely pubescent and bears two large proximal denticles. All podomeres are entirely tuberculated (Fig. 8N,O).

The average percentage lengths of various podomeres are: ischium - 13.25; Merus - 18.57, carpus - 30.05; propodus - 38.18; palm - 24.44, dactylus - 13.70.

The non-chelate legs equal sized, in which ischium equals carpus; merus equals propodus; dactylus simple (Fig. 6E).

Protopod of pleopods bisegmented of which coxa very short and basis long; endopod of first pleopod shorter than exopod, both rami broad and fringed with long plumose setae. Second pleopod in which exopod slightly longer than endopod; endopod bears appendix interna and appendix musculina, inner part of appendix musculina bears very long stiff spinous setae, appendix interna more than half the length of appendix musculina. Third to fifth pleopods similar to second except for the absence of appendix musculina (Fig. 8P,O,R).

Uropod with single segmented protopod which bears two rami, outer margin of exopod ends in a very strong spine. The distal part of both exopod and endopod broadly rounded and bears an accessory spine on the uropodal exopod (Fig. 7M).

4.1.2.3. Description (Female).

The rostrum short, extending beyond antennular peduncle and rarely reaches upto the antennal scale; upper margin generally straight and bears 11-13 teeth of which 3 or 4 teeth post-orbital. The body generally glabrous. The cornea slightly pigmented. The second chelipeds equal sized and less than the total length of the body; movable finger feebly pubescent on its entire surface; fingers with one or two small denticles on the proximal cutting edges; palm much longer than fingers, width of palm more than the distal end of carpus. Uropodal exopod with accessory spine.

4.1.2.4. Colouration.

Olive green with very distinct yellow longitudinal stripes. The colour of the second cheliped is brown and with yellow patches. The fingers are with yellow motlings. The non-chelate legs are closely striped with alternating yellow and brown bands. The uropods bear deep yellow patches which are more along the lateral border.

FIG. 6

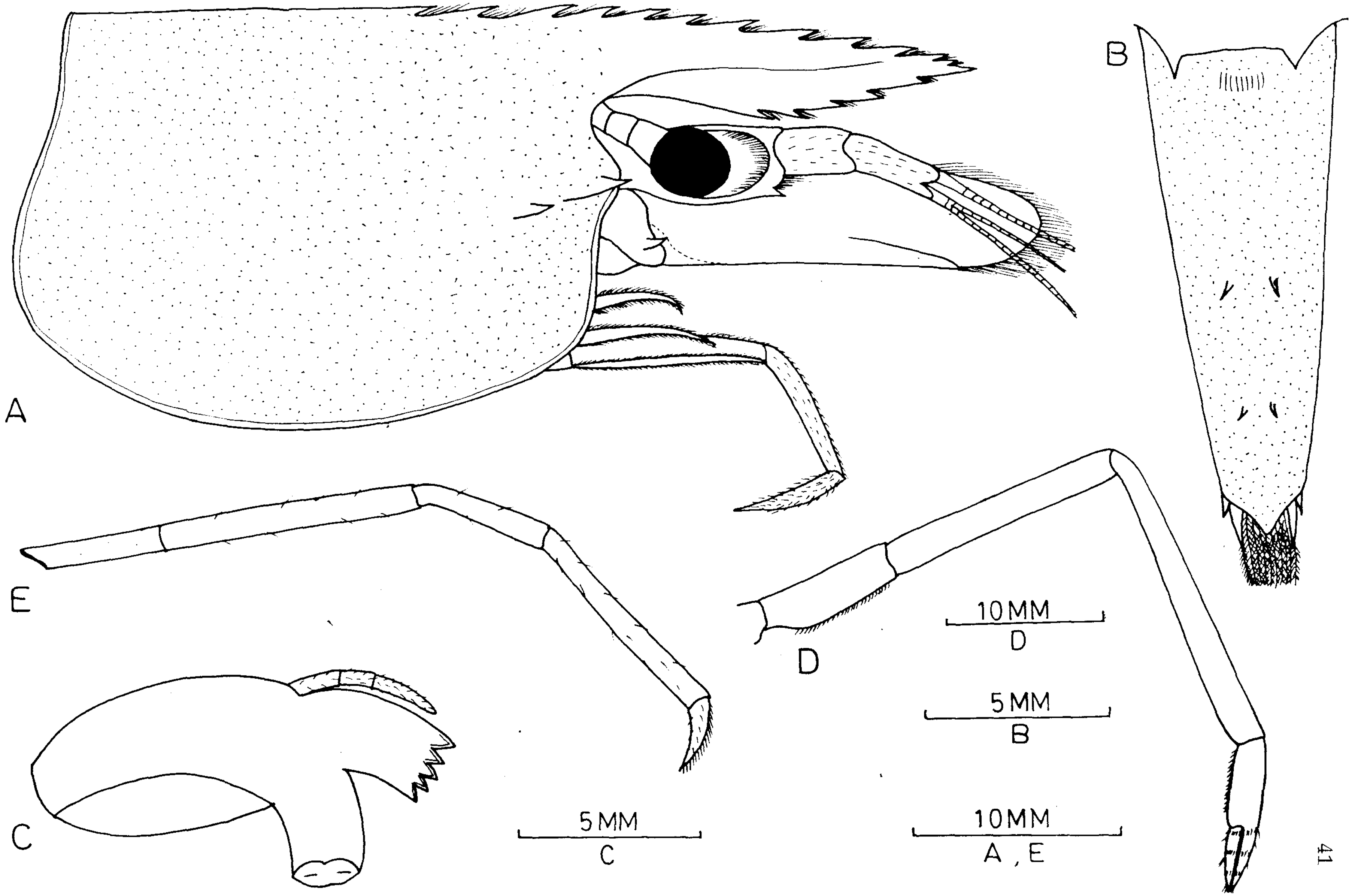


FIG.7

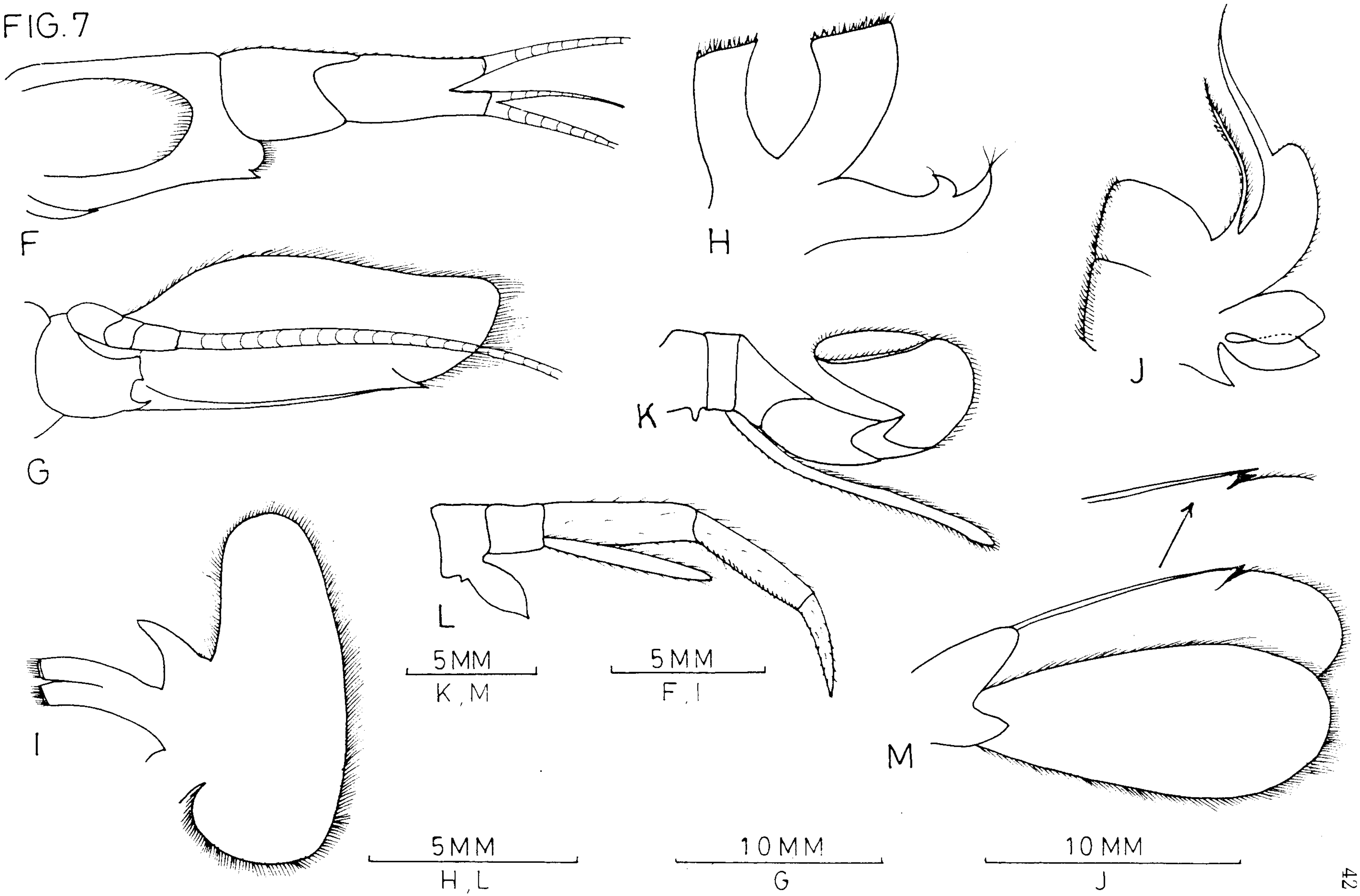


FIG.8

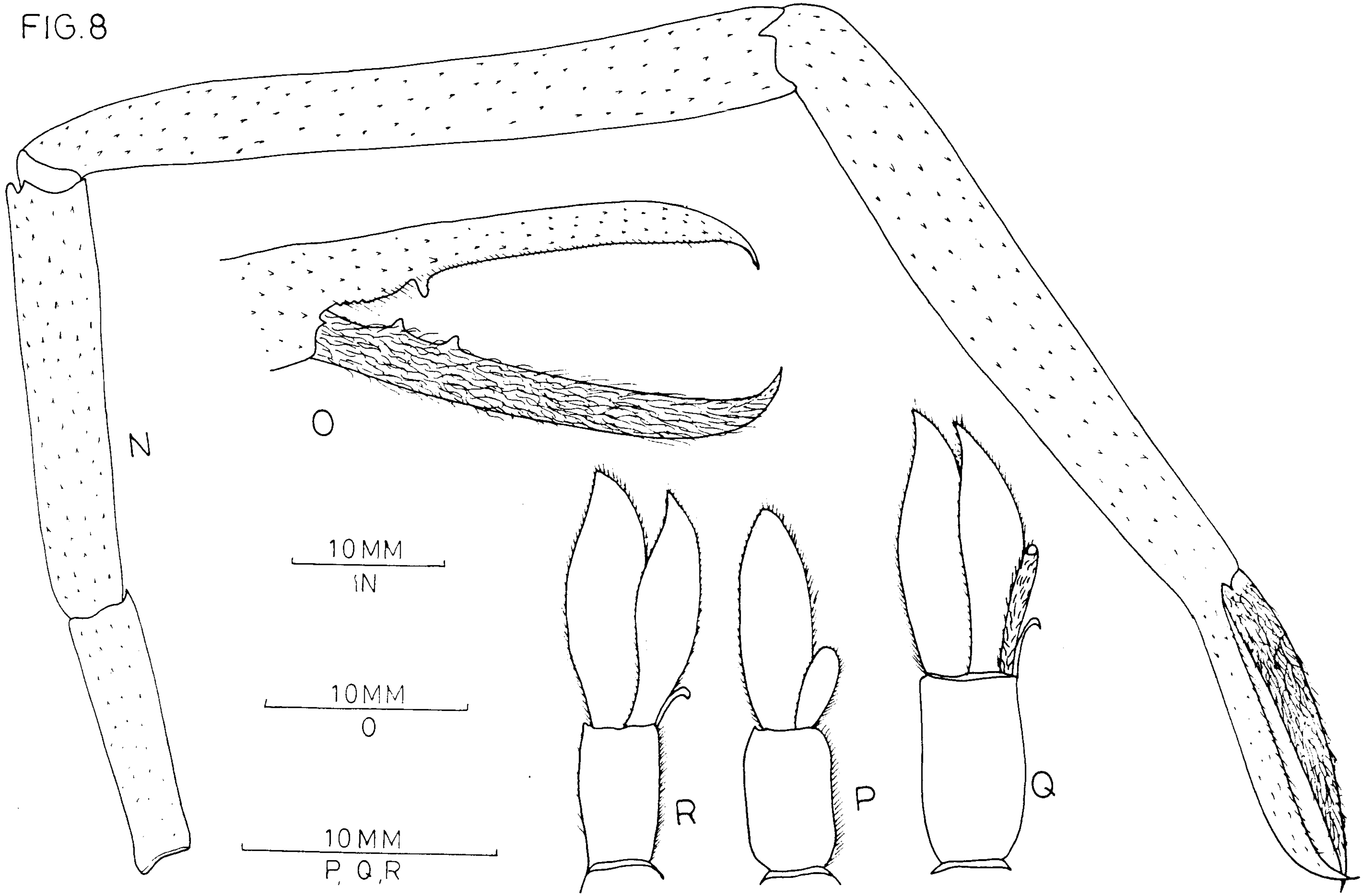


Table 1

Comparison of characters of *M. equidens equidens* and *M. equidens pillaii*.

Sl. No.	Character	*M.equidens equidens*	*M.equidens pillaii*
1.	Rostrum	Extends beyond the antennal scale; upper margin concave; distal end curved upwards	Extends only up to the tip of antennular pedencle; never reaches up to the antennal scale; upper margin straight.
2.	Range of dorsal teeth	Male 9-12, Female 8-12	Male 9-12, Female 10-11
3.	Number of post orbital teeth	Male 3-5, Female 3-4	Male 2-6, Female 3-4
4.	Ventral teeth	Male 4-6, Female 4-6	Male 3-5, Female 4-5
5.	Nature of Carapace	Smooth except on either side of post-orbital teeth	Scabrous
6.	Abdomen	Glabrous	Glabrous
7.	Telson	Scabrous	Scabrous
8.	Position of dorsal spines	Anterior pair - Almost midway Posterior pair - Halfway between anterior pair and tip of telson	Anterior pair - Midway Posterior pair - Slightly proximal to the middle between the anterior pair and tip of telson.
9.	Ratio of the 3 segments of antennular peduncle	6:2.5:4	6.5:2.5:3
10.	Basal segment of antennule	Anterolateral spine very sharp amd extends beyond the anterolateral margin	Anterolateral spine not very sharp which does not extend beyond anterolateral margin.

(Contd...)

11.	Antennal Scale	Distal lamella broadly rounded outer lateral margin concave	distal lamella oblique outer lateral margin concave
12.	Ratio of 3 segments of endopod of 3rd maxilliped	6.5:6.5:5.5	6.5:6.5:5.5
13.	<u>Ist chelate leg</u> Ratio of podomers	5:8.2:9.8:5:1.8	5.5:9.25:11:6:2.25
	Ratio of palm to fingers	3.2:1.8	3.75:2.25
14.	<u>IInd chelate leg</u>	Comparatively slender, entirely tuberculated about 1.44 times long as the total length of body	Comparatively stronger and much longer about 1.23 time long as the total length of body.
	Average percentage length of podomers	I-13.68, M-18.88, c-31.69, P-35.74, D-13.29, Palm-23.89	I-13.20, M-18.57, C-30.05, P-38.18, D-13.74, Palm-24.44
15.	Width of palm	Width of basal palm same as the width of distal carpus	Width of basal palm more than the width of distal carpus.
16.	Ratio of carpus to chela	30:13.7	31.6:13.2
17.	Ratio of palm to fingers	23.8:13.2	24.4:10.9
18.	Nature of fingers	Both the fingers are entirely pubescent	Movable finger entirely pubescent, fixed finger with hairs restricted on the cutting edges.
19.	Uropod	Exopod doesnot possess an accessory spine	Exopod possess an accessory spine.
20.	Colouration	Translucent, marbled or spotted	Greyish, Greenish or Reddish

of Cephalothoracic length is higher in males whereas rostrum length and width of carapace are higher in females (Table 8). Regression equations have been derived and presented in Table 9 and Figures,20-22.

4.2.1.3. Characters related to total length of 2nd cheliped.

Here, only the ischium and merus showed significant differences at slopes (1% and 5% levels respectively) whereas dactylus showed significance at elevation (5% level) (Table 10). The carpus, produs, and palm did not show any significant difference either at slope or elevation. The regression coefficients and average sizes are given in Table 11. The growth rate was more in males in the case of propodus length and dactylus length, whereas it was higher in females in the case of ischium, merus, carpus and palm. The average sizes of these body parts were greater in males than in females. The regression equations for the above characters have been derived and given in Table 12 and Figures, 23-28.

4.2..2. *Macrobrachium equidens pillaii*.

4.2.2.1. Characters related to total length.

The results are given in Table 13,14 & 15. The results showed that the growth pattern of carapace length, abdominal length, propodus length and dactylus length were significantly different between the sexes at slopes itself (at 1% level). Growth patterns of merus, palm and total length of 2nd chelate leg were significant at elevations (5%, 1% and 1% respectively). However the growth patterns of telson, ischium and carpus were not significantly different. Regression coefficients and average sizes of body measurements are presented in Table 16. It can be seen that the growth rates of carapace length, abdominal length, ischium length, propodus length, palm length and total length of 2nd chelate leg were higher in males, whereas the average sizes of all these characters were greater in males than in females. Regression equations have been derived for the characters (Table 6; Figures, 9-19.).

4.2.2.2. Characters related to carapace length.

Among the characters of the carapace, only the Cephalothoracic length showed significant difference between sexes, at 5% level (slope values) (Table 17). The growth rate of cephalothorax of males was greater, whereas the growth rate was greater in females with regard to rostrum length and carapace width. The average sizes of all these characters were higher in males (Table 18). Regression equations for these characters are given in Table 9 and Figures, 20-22).

4.2.2.3. Character related to the total length of 2nd cheliped.

From the table 19 it is clear that only the growth of ischium showed significant difference at slopes. The other characters namely merus length, carpus length, propodus length, dactylus length and palm length were not significantly different either at slopes or elevations. The regression equations and average sizes of body measurements are presented in Table 20, which showed that males have a slightly greater growth rate only in the case of propodus length and dactylus length. Regarding the other characters it was greater in females. As in the other species, here also mean values were higher in males. Regression equations have been derived separately for males and females and are presented in Table 12 and Figures 23-28.

4.2.3. Comparison between males of the two subspecies.

4.2.3.1. Characters related to total length.

The results of the analysis of covariance are given in Tables 21, 22 & 23 which indicate that all characters except telson length and body length, are significantly different at slopes (5% level). Abdominal length, ischium length, merus length and propodus length showed significant difference at 1% level. The carapace length is significant at elevations only (1% level). Regression coefficients and mean values are given in Table 24. Male *M. equidens equidens* has a higher growth rate only in the case of abdominal length. In all other characters analysed, males of *M. equidens pillaii* showed higher growth rate. In the case of telson, the growth rate is same for both the subsepceis.

However the mean values of these body parts are higher in the case of *M. equidens equidens*.

4.2.3.2. Characters related to carapace length.

The result of analysis of covariance (Table 25) show that all the three characters exhibit significant differences at slopes (1% and 5% level). The growth rates and average sizes of these characters are given in Table 26. The growth rate is higher in *m. equidens pillaii* in the case of Cephalothoracic length , rostrum length and carapace width. But the mean values of these characters are higher in the case of *M. equidens equidens*.

4.2.3.3. Characters related to total length of 2nd Cheliped.

The results are given in Table 27. It shows that growth pattern of ischium, propodus and palm are significantly different at slope (1%, 5% and 5% level respectively). The other characters, merus, carpus, and dactylus showed similar growth patterns. The growth rates of all podomeres of *M. equidens pillaii* are higher than *M. equidens equidens* except the ischium length (Table 28).

4.2.4. Comparison between females of the two subspecies.

4.2.4.1. Characters related to total length.

The results are given in Tables 20, 30 & 31. All body

4.2.4.3. Characters related to total length of 2nd cheliped.

The results of the analysis of covariance is given in Table 35. The growth pattern of ischium, propodus, and palm are significant between the two subspecies (slopes). Prododus of the two subspecies exhibits significant difference at elevations (1%) level. The remaining characters showed similar growth patterns. The growth rates of carpus and palm are higher in M.equidens equidens. Propodus shows same growth rate in the two subspecies whereas it is higher in M.equidens pillaii with regard to the remaining characters (Table 36).

4.3. Meristic Studies

4.3.1. Range of rostral teeth.

The range of dorsal teeth in the males of the two subspecies namely, M. equidens equidens and M. equidens pillaii is from 9 to 12. In females of the former species the range is between 8-12 whereas it is only 10-11 in the latter.

Of the dorsal teeth, the post-orbital teeth ranged between 3-5 and 3-4 in males and females respectively of M. equidens equidens. However, the males of M. equidens pillaii possessed a wider range (2-6) and females of this subspecies exhibited the same range as observed in the other subspecies (3-4).

With regard to ventral teeth, both sexes of M. equidens equidens have shown homogeneity in the range of teeth (4-6). The males and females of *M. equidens pillaii* possessed 3-5 and 4-5 teeth respectively (Table 37).

4.3.2. Percentage frequency distribution of teeth.

Table 38 provides the percentage frequency of the distribution of dorsal teeth. In males of both the subspecies, most frequent number of dorsal teeth is 10 which is followed by 11 and 9. In the case of female *M. equidens equidens* the order being 10, 9 and 11. However, the range of dorsal teeth in the female *M. equidens pillii* is very narrow and the maximum frequency observed is 10.

Regarding the post-orbital teeth, a characteristic pattern of the distribution of teeth is discernible. Maximum percentage occurrence of teeth is 3 in both the sexes of *M. equidens equidens* whereas it is 4 in both the sexes of *M. equidens pillaii*.

The two subspecies possess distinct number of ventral teeth. In both the sexes of *M. equidens equidens*, the maximum frequency of teeth is 5 which is followed by 6. In *M. equidens pillaii*, the maximum frequency is 4 which is followed by 5.

4.3.3. Chi-square test.

The results are presented in Table 39. It is interesting to note that the pattern of distribution of teeth (dorsal, post-orbital and ventral teeth) in M. equidens equidens shows clear sexual dimorphism (significant at 5% level) whereas M. equidens pillaii exhibits sexual dimorphism only with regard to the ventral teeth. In the other two characters viz., dorsal teeth and post-orbital teeth, the sexes are homogenous.

Between the two subspecies, there is no significant difference in the number of dorsal teeth in the two sexes of the two subspecies. However in all other characters, significant differences between the subspecies have been observed (significant at 5% level).

4.4. Length-weight Relationship

The results of analysis of covariance, regression coefficients and mean value are given in Tables 40 to 43.

4.4.1. M. equidens equidens.

There is a significant difference in the length-weight relationship (1% level) between the sexes (Table 40). The rate of growth as well as average size are higher in males than in females (Table 42). Regression equations have been calculated separately for the sexes and presented in Table 43 and Figures 29,30.

4.4.2. M. equidens pillaii.

In variance with M. equidens equidens, this subspecies does not show significant difference in the length-weight relationship between sexes (Table 40). Here, the growth rate is faster in females whereas the average size is greater in males (Table 42). Regression equations for males and females are given in Table 43 and Figures 31,32.

4.4.3. Comparison between males of the two subspecies.

The table 41 shows that the two sub-species differ significantly in their growth patterns at 5% level. On a comparison of the regression coefficients and average weight of the males of the two subspecies, *M. equidens equidens* showed higher values (Table 42).

4.4.4. Comparison between females of the two subspecies.

The results are given in table 41. The females of the two subspecies also differ significantly in their growth patterns as in the case of males (significant at 5% level). Here the growth rate is faster in *M. equidens pillaii* whereas the average size is greater in *M. equidens equidens*.

The regression coefficients of the length-weight relationship of the females of *M. equidens equidens* and males of both the subspecies are less than 3. The males of *M. equidens pillaii* has a growth coefficient higher than 3 (3.29). It means that increase in weight of both the sexes of M. equidens equidens is found to be at a rate slightly lower than the cube of its length. In the case of M. equidens pillaii the increase in weight of females is found to be at a rate higher than the cube of its length and in males it is lower than the cube of its length.

According to Allen (1938) for an ideal fish which maintains a constant shape, the value of 'n' will be 3. Though the above formula holds good for the length-weight relationship of males and females of both the subspecies, it appears advisable to test the regression coefficients against the isometric growth value of 3 to find whether there is any significant departure from the value of 3 during the different stages and conditions of growth. For this purpose a test was conducted for the species as a whole by using the formula:

$$t = \frac{3-n}{Sb}$$

where Sb is the standard error of the corresponding regression coefficient 'n'. The result of this analysis is given in table 44.

The growth departs significantly from the isometric growth in the case of both sexes of the two subspecies. Hence the cubic formula $W = KL^3$ may not be appropriate for representing the length-weight relationship in these cases.

Table - 2

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of M. *equidens equidens* with respect to total length.

Source	df	Deviation from regression							
		Carapace length		Abdominal length		Telson length		Body length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within									
Male	71	108.23	1.52	205.49	2.89	45.95	0.65	3790.30	53.38
Female	68	418.79	6.16	283.78	4.17	196.59	2.89	3146.16	46.27
Pooled within	139	527.02	3.79	489.27	3.52	242.54	1.74	6936.46	49.90
	140	563.83	4.03	499.27	3.57	274.99	1.96	6940.68	49.58
Difference between slopes	1	36.81	36.81	9.99	9.99	32.45	32.45	4.22	4.22
Between & within	141	576.64	-	513.61	-	275.57	-	7258.70	-
Between adjusted means	1	12.81	12.81	14.34	14.34	0.58	0.58	318.11	318.11
Comparison of slopes		9.709*		2.839NS		18.597*		0.085NS	
Comparison of elevations		3.181**		4.021**		0.293NS		0.417NS	

* - Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 3

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of M. equidens equidens with respect to total length.

Source	df	Deviation from regression							
		Ischium length		Merus length		Carpus length		Propodus length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within									
Male	71	1221.61	17.21	1817.27	25.60	6399.99	90.14	8153.51	114.84
Female	68	700.69	10.30	123.73	1.82	728.15	10.71	512.62	7.54
Pooled within	139	1922.30	13.83	1941.00	13.96	7128.14	51.28	8666.12	62.35
	140	2158.64	15.42	1965.72	14.04	7164.73	51.28	8733.27	62.38
Difference between slopes	1	236.34	236.34	24.72	24.72	36.59	36.59	67.15	67.15
Between & within	141	2216.10	-	2878.05	-	10449.35	-	12240.92	-
Between adjusted means	1	57.45	57.45	912.33	912.33	3284.62	3284.62	3507.62	3507.62
Comparison of slopes		17.089*		1.770NS		0.713NS		1.077NS	
Comparison of elevations		3.726**		64.977*		64.182*		56.230*	

* - Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 4

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of *M. equidens equidens* with respect to total length.

Source	df	Deviation from degression					
		Dactylus length		Palm length		Total length of IInd chelate leg	
		SS	MSS	SS	MSS	SS	MSS
Within							
Male	71	829.64	11.69	4309.51	60.70	67869.96	955.91
Female	68	76.98	1.13	241.37	3.55	6227.20	91.58
Pooled within	139	906.63	6.52	4550.88	32.74	74097.15	533.07
	140	956.52	6.83	4572.58	32.66	74396.10	531.40
Difference between slopes	1	49.90	49.90	21.69	21.69	298.95	298.95
Between & within	141	1362.72	-	6094.09	-	104844.5	-
Between adjusted means	1	406.20	406.20	1521.52	1521.52	30448.35	30448.35
Comparison of slopes		7.650*		0.663NS		0.561NS	
Comparison of elevations		59.453*		46.585*		57.298*	

* - Significant at 1% level NS - Not significant

Table - 6

Regression equations of various morphometric characters related to total length in *M.equidens equidens* and *M. equidens pillaii*.

Sl.No.	Characters	Male	Female
	M. equidens equidens		
1.	Carapace length	y = 0.47064x-0.36058	y = 0.4592x-1.05879
2.	Abdominal length	y = 0.3847x-0.61735	y = 0.40607x+0.4344
3.	Telson length	y = 0.11393x+1.88127	y = 0.1248x+0.7078
4.	Body length	y = 0.23299x+30.92514	y = 0.60704x+4.61256
5.	Ischium length	y = 0.20554x-3.48989	y = 0.14474x-0.62848
6.	Merus length	y = 0.37492x-11.52142	y = 0.19132x-2.41261
7.	Carpus length	y = 0.69299x-24.99904	y = 0.31063x-5.79103
8.	Propodus length	y = 0.78705x-27.56461	y = 0.38575x-6.86951
9.	Dactylus length	y = 0.23506x-5.27724	y = 0.14188x-1.70728
10.	Palm length	y = 0.55718x-22.01385	y = 0.24554x-4.93048
11.	Length of 2nd chelate leg	y = 1.96463x-57.79955	y = 0.14474x-0.62848

(Contd...)

M. equidens pillaii

1.	Carapace length	y = 0.44721x+0.67602	y = 0.43612x+0.72008
2.	Abdominal length	y = 0.40548x-0.55719	y = 0.39193x+0.98618
3.	Telson length	y = 0.13492x+0.73463	y = 0.14422x-0.27732
4.	Body length	y = 0.69707x-1.64714	y = 0.68213x-0.20974
5.	Ischium length	y = 0.22972x-4.7115	y = 0.15666x-1.69742
6.	Merus length	y = 0.41471x-12.70080	y = 0.2166x-2.89258
7.	Carpus length	y = 0.82747x-30.91612	y = 0.34467x-6.42242
8.	Propodus length	y = 1.01971x-36.67916	y = 0.41502x-5.08579
9.	Dactylus length	y = 0.28577x-7.99378	y = 0.14388x-0.98926
10.	Palm length	y = 0.77060x-29.79214	y = 0.29502x-5.05405
11.	Length of 2nd chelate leg	y = 2.56463x-88.78573	y = 113296x-16.09821

Table - 7

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of *M. equidens equidens* with respect to carapace length.

Source	df	Deviation from regression					
		Cephalothoracic length		Rostrum length		carapace width	
		SS	MSS	SS	MSS	SS	MSS
Within							
Male	73	270.09	3.70	942.44	12.91	481.91	6.60
Female	68	679.91	10.00	99.15	1.46	246.88	3.63
Pooled within	141	950.00	6.74	1041.59	7.39	728.78	5.17
	142	1119.32	7.88	1185.07	8.35	728.87	5.13
Difference between slopes	1	169.32	169.32	143.48	143.48	0.08	0.08
Between & within	143	1262.71		1209.87	-	763.03	
Between adjusted means	1	143.39	143.39	24.80	24.80	34.16	
Comparison of slopes		25.13*		19.423*		0.016NS	
Comparison of elevations		18.190*		2.972NS		6.655*	

* - Significant at 1% level NS - Not significant

Table - 8

Regression coefficients (growth rates) and average size of body measurements for males and females of *M. equidens equidens* (compared to carapace length)

Sl.No.	Morphometric characters	Regression coefficients		Mean values	
		Male	Female	Male	Female
1.	Cephalothoracic length	0.28	0.13	18.8933	16.2714
2.	Rostrum length	0.09	0.46	15.7467	12.0571
3.	Carapace width	0.12	0.11	13.0200	11.1214

Table - 9

Regression equations of various "head" characters related to carapace length in *M. equidens equidens* and *M. equidens pillaii*

Sl.No.	Characters	Male	Female
	M. equidens equidens		
1.	Rostrum length	y = 0.27969x+6.27831	y = 0.38897x+1.32725
2.	Cephalothoracic length	y = 0.57739x-0.65331	y = 0.56718x+0.62543
3.	Carapace width	y = 0.4180x-1.13076	y = 0.37895x+0.66795
	M. equidens pillaii		
1.	Rostrum length	y = 0.35499x+2.22796	y = 0.36349x+1.92104
2.	Cephalothoracic length	y = 0.55829x+1.29325	y = 0.61834x-0.65930
3.	Carapace width	y = 0.38903x+0.59888	y = 0.40391x-0.08647

Table - 10

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of <u>M. equidens equidens</u> with respect to total length of 2nd chelate leg.

Source	df	Deviation from regression											
		Ischium length		Merus length		Carpus length		Propodus length		Dactylus length		Palm length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within													
Male	71	133.63	1.88	384.06	5.41	338.70	13.32	1192.42	16.79	346.06	4.87	634.62	8.94
Female	68	28.46	0.42	16.20	0.24	225.04	3.84	31.89	0.47	34.21	0.50	37.28	0.55
Pooled within	139	162.09	1.17	400.26	2.88	1163.74	8.37	1224.31	8.81	380.28	2.74	671.89	4.83
	140	174.04	1.24	403.05	2.88	1171.84	8.37	1229.11	8.78	388.92	2.78	672.92	4.81
Difference between slopes	1	11.95	11.95	2.79	2.79	8.10	8.10	4.80	4.80	8.65	8.65	1.02	1.02
Between & within	141	175.57	-	414.60		1198.40		1232.71		427.27		678.53	
Between adjusted means	1	1.53	1.53	11.55	11.55	26.56	26.56	3.61	3.61	38.35	38.35	5.61	5.61
Comparison of slopes		10.246*		0.968NS		0.967NS		0.544NS		3.161NS		0.211NS	
Comparison of elevations		1.233NS		4.012**		3.193NS		0.411NS		13.804*		1.167NS	

- Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 12

Regression equations of various podomeres related to total length of 2nd cheliped in *M. equidens equidens* and *M. equidens pillaii*

Sl.No.	Characters	Male	Female
	M. equidens equidens		
1.	Ischium length	y = 0.09x + 3.96	y = 0.13x + 1.90
2.	Merus length	y = 0.15x + 2.95	y = 0.17x + 1.07
3.	Carpus length	y = 0.29x + 0.46	y = 0.33x - 2.61
4.	Propodus length	y = 0.33x + 1.36	y = 0.36 - 0.54
5.	Dactylus length	y = 0.09x + 4.30	y = 0.13x + 0.94
6.	Palm length	y = 0.24x - 2.07	y = 0.23x - 0.86
	M. equidens pillaii		
1.	Ischium length	y = 0.08x + 3.97	y = 0.14x + 0.62
2.	Merus length	y = 0.15x + 2.56	y = 0.19x + 0.28
3.	Carpus length	y = 0.3x - 0.62	y = 0.31x - 1.84
4.	Propodus length	y = 0.38x + 0.09	y = 0.36 + 0.94
5.	Dactylus length	y = 0.10x + 2.73	y = 0.12x + 1.31
6.	Palm length	y = 0.28x - 1.33	y = 0.26x - 1.08

Table - 13

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of *M. equidens pillaii* with respect to total length.

Source	df	Deviations from regression							
		Carapace length		Abdominal length		Telson length		Body length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within									
Male	92	251.13	2.73	2950.13	32.07	579.40	6.30	7081.78	76.98
Female	54	814.44	15.08	204.62	3.79	155.82	2.89	1310.26	24.26
Pooled within	146	1065.57	7.30	3154.75	21.61	735.22	5.04	8392.05	57.48
	147	1146.00	7.80	3307.90	22.50	746.40	5.08	9008.94	61.29
Difference between slopes	1	80.43	80.43	153.14	153.14	11.18	11.18	616.89	616.89
Between & within	148	1153.17	-	3308.07	-	760.24	-	9089.85	-
Between adjusted means	1	7.17	7.17	0.17	0.17	13.84	13.84	80.91	80.91
Comparison of slopes		11.020*		7.087*		2.221NS		10.732*	
Comparison of elevations		0.920NS		0.008NS		2.725NS		1.320NS	

* - Significant at 1% level NS - Not significant

Table - 14

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of M.equidens pillaii with respect to total length.

Source	df	Deviations from regression							
		Ischium length		Merus length		Carpus length		Propodus length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within									
Male	92	2043.01	22.21	2373.07	25.79	9980.92	108.49	14181.10	154.14
Female	54	645.18	11.95	231.78	4.29	266.57	4.94	93.27	1.73
Pooled within	146	2688.19	18.41	2604.85	17.84	10247.48	70.19	14274.38	97.77
	147	2688.19	18.29	2676.08	18.20	10248.51	69.72	14996.17	102.01
Difference between slopes	1	0.18	0.18	71.24	71.24	1.02	1.02	721.79	721.79
Between & within	148	2793.02	-	2703.42	-	10341.67	-	28316.50	-
Between adjusted means	1	104.65	104.65	27.34	27.34	93.17	93.17	13320.33	13320.33
Comparison of slopes		0.010NS		3.993**		0.015NS		7.383*	
Comparison of elevations		5.722**		1.502NS		1.336NS		130.573*	

* - Significant at 1% level   ** - Significant at 5% level   NS - Not significant

Table - 15

Analysis of covariance (comparison oof regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of M. equidens pillaii with respect to total length.

Source	df	Deviation from regression					
		Dactylus length		Palm length		Total length of IInd chelate leg	
		SS	MSS	SS	MSS	SS	MSS
Within							
Male	92	1376.40	14.96	8561.62	93.06	93406.85	1015.29
Female	54	191.03	3.54	160.91	2.98	2890.15	53.52
Pooled within	146	1567.43	10.74	8722.52	59.74	96297.00	659.57
	147	1644.68	11.19	8743.10	59.48	96542.21	656.75
Difference between slopes	1	77.25	77.25	20.58	20.58	245.20	245.20
Between & within	148	1872.51	-	10100.31		111367.5	
Between adjusted means	1	227.82	227.82	1357.21	1357.21	14825.32	14825.32
Comparison of slopes		7.196*		0.344NS		0.372NS	
Comparison of elevations		20.363*		22.819*		22.574*	

* - Significant at 1% level NS - Not significant

Table - 16

Regression coefficient (growth rates) and average sizes of body measurements for males and females of M. equidens pillaii (compared to total length).

Sl.No.	Morphometric characters	Regression coefficients		Mean value	
		Male	Female	Male	Female
1.	Carapace length	0.45	0.31	30.3298	26.6964
2.	Abdominal length	0.17	0.36	26.3298	24.3304
3.	Telson length	0.09	0.15	9.6809	8.3125
4.	Body length	0.29	0.70	44.5745	40.4196
5.	Ischium length	0.17	0.16	10.5213	7.6339
6.	Merus length	0.22	0.35	14.7979	10.0089
7.	Carpus length	0.41	0.43	23.9521	14.1071
8.	Propodus length	0.58	0.15	30.9362	19.6339
9.	Dactylus length	0.16	0.30	10.9553	7.5804
10.	Palm length	0.38	0.30	21.3053	12.5179
11.	Total length of IInd chelate leg	1.41	1.16	81.2713	51.3839

Table - 17

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of M. equidens pillaii with respect to carapace length.

Source	df	Deviation from regression					
		Cephalothoracic length		Rostrum length		Carapace width	
		SS	MSS	SS	MSS	SS	MSS
Within							
Male	93	119.47	1.28	756.04	8.13	905.50	9.74
Female	54	192.06	3.56	119.34	2.21	190.02	3.52
Pooled within	147	311.52	2.12	875.37	5.95	1095.52	7.45
	148	321.39	2.17	887.07	5.99	1119.51	7.56
Difference between slopes	1	9.86	9.86	11.69	11.69	23.99	23.99
Between & within	149	321.39	-	893.98	-	1142.38	-
Between adjusted means	1	0.00	0.00	6.91	6.91	22.88	22.88
Comparison of slopes		4.655**		1.963NS		3.220NS	
Comparison of elevations		0.001NS		1.153NS		3.024NS	

** - Significant at 5% level NS - Not significant

Table - 18

Regression coefficient (growth rates) and average size of body measurement for males and females of *M. equidens pillaii* (compared to carapace length).

Sl.No.	Morphometric characters	Regression coefficients		Mean value	
		Male	Female	Male	Female
1.	Cephalothoracic length	0.35	0.25	18.1684	15.8482
2.	Rostrum length	0.45	0.57	12.9579	11.6250
3.	Carapace width	0.29	0.45	12.3579	10.6964

Table - 19

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between sexes of <u>M.equidens pillaii</u> with respect to total length of 2nd chelate leg.

Source	df	Deviation from regression											
		Ischium length		Merus length		Carpus length		Propodus length		Dactylus length		Palm length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS
Males	54	47.84	0.89	18.85	0.35	31.70	0.59	43.77	0.81	32.82	0.61	54.89	1.02
Females	92	211.65	2.30	327.38	0.56	1506.09	16.37	1914.37	20.81	416.06	4.52	1321.87	14.37
Pooled within	146	259.48	1.78	346.24	2.37	1537.79	10.53	1958.14	13.41	448.88	3.07	1376.77	9.43
	147	284.31	1.93	358.11	2.44	1538.29	10.46	1960.12	13.33	452.31	3.08	1378.30	9.38
Difference between slopes	1	24.83	24.83	11.87	11.87	0.51	0.51	1.97	1.97	3.44	3.44	1.53	1.53
Between & within	148	288.05		359.33		1555.84		1960.12		454.95		1385.07	
Between adjusted means	1	3.74	3.74	1.23	1.23	17.55	17.55	0.01	0.01	2.64	2.64	6.77	6.77
Comparison of slopes		13.968*		5.008**		0.0484NS		0.147NS		0.119NS		0.162NS	
Comparison of elevations		1.933NS		0.504NS		1.67782NS		0.000NS		0.858NS		0.722NS	

* - Significant at 1% level   ** - Significant at 5% level   NS - Not sifnificant

Table - 21

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between males of *M. equidens pillaii* and *M. equidens equidens* with respect to total length.

Source	df	Deviation from regression							
		Carapace length		Abdominal length		Telson length		Body length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within									
MPM	92	251.13	2.73	2950.13	32.07	579.40	6.30	7081.78	76.98
MEM	71	869.80	12.25	210.02	2.96	241.99	3.41	5046.00	71.07
Pooled within	163	1120.93	6.88	3160.16	19.39	821.40	5.04	12127.79	74.40
	164	1123.73	6.85	3401.82	20.74	821.42	5.01	12129.74	73.96
Difference between slopes	1	2.79	2.79	241.67	241.67	0.02	0.02	1.96	1.96
Between & within	165	1172.87	-	3451.93	-	821.59	-	12203.3	
Between adjusted means	1	49.15	49.15	50.11	50.11	0.17	0.17	73.56	73.56
Comparison of slopes		0.406NS		12.465**		0.004NS		0.026NS	
Comparison of elevations		7.173*		2.416NS		0.034NS		0.995NS	

* - Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 22

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between males of *M. equidens pillaii* and *M. equidens equidens* with respect to total length.

Source	df	Deviation from regression							
		Ischium length		Merus length		Carpus length		Propodus length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within MPM	92	2043.01	22.21	2373.07	25.79	9980.92	108.49	14181.10	154.14
	71	1743.61	24.56	1833.84	25.83	6540.49	92.12	8196.62	115.45
Pooled within	163	3786.62	23.23	4206.91	25.81	16521.41	101.36	22377.73	137.29
	164	3919.13	23.90	4351.92	26.54	16963.57	103.44	23419.80	142.80
Difference between slopes	1	132.51	132.51	145.01	145.01	442.16	442.16	1042.08	1042.08
Between & within	165	3937.06	-	4354.77	-	16963.58	-	23850.74	-
Between adjusted means	1	17.93	17.93	2.85	2.85	0.01	0.01	430.93	430.93
Comparison of slopes		5.704*		5.618*		4.362**		7.591*	
Comparison of elevations		0.750NS		0.107NS		0.000NS		3.018NS	

* - Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 23

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between males of M. equidens pillaii and M. equidens equidens with respect to total length.

Source	df	Deviation from regression					
		Dactylus length		Palm length		Total length of IInd chelate leg	
		SS	MSS	SS	MSS	SS	MSS
Within MPM	92	1376.40	14.96	8561.62	93.06	93406.85	1015.29
MEM	71	828.45	11.67	4334.74	61.05	71973.23	1013.71
Pooled within	163	2204.85	13.53	12896.36	79.12	165380.10	1014.60
Difference between slopes	1	77.02	77.02	417.65	417.65	5944.47	5944.47
Between & within	165	2286.85		13935.66	-	171566.60	-
Between adjusted means	1	4.98	4.98	621.65	621.65	242.06	242.06
Comparison of slopes		5.694**		5.279**		5.859**	
Comparison of slopes		0.358NS		7.657*		0.232NS	

* - Significant at 1% level   ** - Significant at 5% level   NS - Not significant

Table - 24

Regression coefficients (growth rates) and average sizes of body measurements of males of *M. equidens equidens* and *M. equidens pillaii* (compared to total length).

Sl.No.	Morphometric characters	Regression coefficient		Mean value	
		M.equidens equidens	*M.equidens pillaii*	*M.equidens equidens*	*M.equidens pillaii*
1.	Carapace length	0.42	0.45	34.4795	30.3298
2.	Abdominal length	0.38	0.17	29.0959	26.3298
3.	Telson length	0.09	0.09	10.3151	9.6809
4.	Body length	0.28	0.29	48.1725	44.5745
5.	Ischium length	0.01	0.17	11.726	10.5213
6.	Merus length	0.05	0.22	16.2329	14.7979
7.	Carpus length	0.12	0.41	26.3014	23.9521
8.	Propodus length	0.13	0.58	30.6986	30.9362
9.	Dactylus length	0.04	0.16	17.1233	10.9553
10.	Palm length	0.09	0.38	19.2329	21.3053
11.	Total length of IInd chelate leg	0.34	1.41	87.6370	81.2713

Table - 25

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between males of M. equidens pillaii with respect to carapace length.

Source	df	Deviation from regression					
		Cephalothoracic length		Rostrum length		Carapace length	
		SS	MSS	SS	MSS	SS	MSS
MEM	73	269.36	3.69	911.13	12.48	482.08	6.60
MPM	93	119.47	1.28	756.04	8.13	1185.05	12.74
Pooled within	167	399.32	2.39	1816.79	10.88	1708.07	10.23
	166	388.82	2.34	1667.17	10.04	1667.13	10.04
Difference between slopes	1	10.50	10.50	149.62	149.62	40.93	40.93
Between & within	168	505.01	-	1821.03	-	1709.53	-
Between adjusted means	1	105.69	105.69	4.24	4.24	-	-
Comparison of slopes		4.482**		14.898*		4.076**	
Comparison of elevations		44.201*		0.389NS		0.144NS	

* - Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 26

Regression coefficients (growth rates) and average size of body measurements of males of *M. equidens equidens* and *M. equidens pillaii* (compared to carapace length).

Sl.No.	Morphometric characters	Regression coefficients		Mean value	
		MEM	MPM	MEM	MPM
1.	Cephalothorocic length	0.27	0.35	18.8933	18.1684
2.	Rostrum length	0.12	0.45	15.7467	12.9579
3.	Carapace width	0.12	0.29	13.020	12.3579

Table - 27

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between males of M. equidens equidens and M. equidens pillaii with respect to total length of IInd chelate leg.

Source	df	Deviations from regression											
		Ischium length		Merus length		Carpus length		Propodus length		Dactylus length		Palm length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS
MEM	71	133.43	1.88	384.06	5.41	938.70	13.22	1192.42	16.69	346.06	4.87	634.62	8.94
MPM	92	211.65	2.30	327.38	3.56	1506.09	16.37	1914.37	20.81	416.06	4.52	1321.87	14.37
Pooled within	163	345.28	2.12	711.44	4.36	2444.79	15.00	3106.79	19.06	762.12	4.68	1956.49	12.00
	164	347.93	2.12	711.48	4.34	2447.09	14.92	3188.32	19.44	767.97	4.68	2007.58	12.24
Difference between slopes	1	2.64	2.64	0.04	0.04	2.29	2.29	81.53	81.53	5.85	5.85	51.09	51.09
Between & within	165	366.41		720.64		2455.01		3453.73		780.30		2585.02	
Between adjusted means	1	18.49	18.49	9.16	9.16	7.92	7.92	265.41	265.41	12.33	12.33	577.44	577.44
Comparison of slopes		1.248NS		0.008NS		0.153NS		4.278**		1.252NS		4.257**	
Comparison of elevations		8.715*		2.111NS		0.531NS		13.652*		2.633NS		47.171*	

* - Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 28

Regression coefficients (growth rates) of body measurements of males of two species, *M. equidens equidens* and *M. equidens pillaii* (compared to total length of IInd chelate leg).

Sl.No.	Morphometric characters	Regression coefficients	
		M. equidens equidens	*M. equidens pillaii*
1.	Ischium length	0.09	0.08
2.	Merus length	0.15	0.15
3.	Carpus length	0.29	0.30
4.	Propodus length	0.33	0.38
5.	Palm length	0.09	0.10
6.	Dactylus length	0.24	0.28

Table - 29

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between females of M. equidens pillaii and M. equidens equidens with respect to total length.

Source	df	Deviation from regression							
		Carapace length		Abdominal length		Telson length		Body length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within									
MPF	54	168.22	3.12	142.58	2.64	44.96	0.83	151.11	2.80
MEF	68	137.73	2.03	165.56	2.43	36.86	0.54	791.63	11.64
Pooled within	122	305.95	2.51	308.14	2.53	81.82	0.67	942.74	7.73
	123	307.25	2.50	308.63	2.51	82.74	0.67	956.51	7.78
Difference between slopes	1	1.30	1.30	0.49	0.49	0.92	0.92	13.77	13.77
Between & within	124	311.32	-	311.60	-	83.98	-	958.11	-
Between adjusted means	1	4.07	4.07	2.97	2.97	1.24	1.24	1.60	1.60
Comparison of slopes		0.519NS		0.193NS		1.372NS		1.782NS	
Comparison of elevations		1.631NS		1.184NS		1.848NS		0.206NS	

NS - Not significant

Table - 30

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between females of M. equidens pillaii and M. equidens equidens with respect to total length.

Source	df	Deviation from regression							
		Ischium length		Merus length		Carpus length		Propodus length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS
Within MPF	54	66.03	1.22	171.15	3.17	183.22	3.39	41.13	0.76
MEF	68	58.01	0.85	61.21	0.90	551.71	8.11	282.43	4.15
Pooled within	122	124.04	1.02	232.37	1.90	734.93	6.02	323.56	2.65
	123	124.39	1.01	289.77	2.36	761.53	6.19	466.36	3.79
Difference between slopes	1	0.35	0.35	57.41	57.41	26.60	26.60	142.80	142.80
Between & within	124	127.88	-	1165.86	-	2288.26	-	2880.01	-
Between adjusted means	1	3.49	3.49	876.09	876.09	1526.73	1526.73	2413.65	2413.65
Comparison of slopes		0.342NS		30.142*		4.418**		53.846*	
Comparison of elevations		3.455NS		371.225*		246.644*		636.846*	

* - Significant at 1% level   ** - Significant at 5% level   NS - Not significant

Table - 31

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between females of M. equidens pillaii and M. equidens equidens with respect to total length.

Source	df	Deviation from regression					
		Dactylus length		Palm length		Total length of IInd chelate leg	
		SS	MSS	SS	MSS	SS	MSS
Within							
MPF	54	152.25	2.82	152.25	2.82	1159.22	21.47
MEF	68	56.78	0.83	136.13	2.00	2065.10	30.37
Pooled within	122	209.03	1.71	288.38	2.36	3224.31	26.43
	123	266.27	2.16	294.35	2.39	3243.21	26.37
Difference between slopes	1	57.25	57.25	5.98	5.98	18.90	18.90
Between & within	124	1367.10	-	550.28	-	4194.35	-
Between adjusted means	1	1100.82	1100.82	255.93	255.93	951.14	951.14
Comparison of slopes		33.479*		2.533NS		0.715NS	
Comparison of elevations		509.639*		107.083*		36.069*	

* - Significant at 1% level NS - Not significant

Table - 32

Regression coefficients (growth rates) and average sizes of body measurements of females of *M. equidens equidens* and *M. equidens pillaii* (compared to total length).

Sl.No.	Morphometric characters	Regression coefficients		Mean value	
		MEF	MPF	MEF	MPF
1.	Carapace length	0.46	0.44	27.58	26.6964
2.	Abdominal length	0.41	0.39	25.76	24.33
3.	Telson length	0.12	0.14	8.492	8.312
4.	Body length	0.61	0.68	42.47	40.419
5.	Ischium length	0.14	0.16	8.400	7.633
6.	Merus length	0.19	0.34	9.5214	10.008
7.	Carpus length	0.31	0.42	13.585	14.107
8.	Propodus length	0.39	0.14	17.1929	19.633
9.	Dactylus length	0.14	0.30	7.1429	7.5804
10.	Palm length	0.25	0.30	10.3857	12.517
11.	Total length of IInd chelate leg	1.04	1.13	48.8714	51.38

Table - 33

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between females of M. equidens equidens and M. equidens pillaii with respect to carapace length.

Source	df	Deviation from regression					
		Cephalothoracic length		Rostrum length		Carapace width	
		SS	MSS	SS	MSS	SS	MSS
MEF	68	50.96	0.75	70.42	1.04	71.38	1.05
MPF	54	52.33	0.97	83.18	1.54	159.62	2.96
Pooled within	122	103.28	0.85	153.59	1.26	231.00	1.89
	123	103.65	0.84	155.08	1.26	231.36	1.88
Difference between slopes	1	0.37	0.37	1.49	1.49	0.35	0.35
Between & within	124	103.95	-	155.42	-	231.53	-
Between adjusted means	1	0.30	0.30	0.35	0.35	0.18	0.18
Comparison of slopes		0.435NS		1.180NS		0.187NS	
Comparison of elevations		0.356NS		0.274NS		0.095NS	

NS - Not significant

Table - 34

Regression coefficients (growth rates) and average size of body measurements of females of *M. equidens equidens* and *M. equidens pillaii* (compared to carapace length).

Sl.No.	Morphometric characters	Regression coefficients		Mean value	
		MEF	MPF	MEF	MPF
1.	Cephalothoracic length	0.39	0.36	16.2714	15.8482
2.	Roostrum length	0.57	0.62	12.0571	11.6250
3.	Carapace width	0.38	0.40	11.1214	10.6964

Table - 35

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between females of M. equidens equidens and M. equidens pillaii with respect to total length.

Source	df	Deviation from regression											
		Ischium length		Merus length		Carpus length		Propodus length		Dactylus length		Palm length	
		SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS	SS	MSS
MEF	68	28.46	0.42	16.20	0.24	225.04	3.31	31.89	0.47	34.21	0.50	37.28	0.55
MPF	54	47.84	0.89	18.85	0.35	31.70	0.59	43.77	0.81	32.82	0.61	54.89	1.02
Pooled within	122	76.30	0.63	35.06	0.29	256.74	2.10	75.66	0.62	67.03	0.55	92.17	0.76
	123	76.34	0.62	36.06	0.29	258.40	2.10	75.66	0.62	67.12	0.55	96.63	0.79
Difference between slopes	1	0.05	0.05	1.00	1.00	1.66	1.66	0.00	0.00	0.09	0.09	4.46	4.46
Between & within	124	113.86		36.09		260.83		147.39		67.60		166.26	
Between adjusted means	1	37.52	37.52	0.03	0.03	2.43	2.43	71.73	71.73	0.48	0.48	69.62	69.62
Comparison of slopes		0.077NS		3.494NS		0.787NS		0.005NS		0.165NS		5.905**	
Comparison of elevations		60.450*		0.096NS		1.158NS		116.602*		0.881NS		88.623*	

* - Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 36

Regression coefficients (growth rates) of body measurements of females of *M. equidens equidens* and *M. equidens pillaii* (Compared to total length of IInd chelate leg).

Sl.No.	Morphometric characters	Regression coefficients	
		MEF	MPF
1.	Ischium length	0.13	0.14
2.	Merus length	0.17	0.19
3.	Carpus length	0.33	0.31
4.	Propodus length	0.36	0.36
5.	Palm length	0.13	0.12
6.	Dactylus length	0.23	0.26

Table - 37

Range of teeth on the dorsal, post-orbital and ventral regions of rostrum of *M. equidens equidens* and *M. equidens pillaii*.

Subspecies/Sex	Total No.of specimens	Range of teeth		
		Dorsal	Post-dorsal	Ventral
M.equidens equidens				
Male	70	9-12	3-5	4-6
Female	70	8-12	3-4	4-6
M.equidens pillaii				
Male	65	9-12	2-6	3-5
Female	31	10-11	3-4	4-5

Table - 38

Percentage frequency distribution of dorsal, post-orbital and ventral rostral teeth of *M. equidens equidens* and *M. equidens pillaii*.

Sub-species/Sex	Dorsal teeth				Post orbital teeth				Ventral teeth			
	9	10	11	12	2	3	4	5	3	4	5	6
M.equidens equidens												
Male	9.7	51.4	34.7	4.2	..	80	20	..	..	20	63.4	16.9
Female	17.4	68.1	11.6	2.9	..	95.7	4.3	..	..	5.7	77.1	17.1
M.equidens pillaii												
Male	6.3	57.8	32.8	3.1	3.1	34.4	57.8	4.7	6.2	73.8	20	..
Female	..	74.2	25.8	..	..	48.4	54.8	..	..	46.7	53.3	..

Table - 39

Chi-square test applied to the frequencies of dorsal, post-orbital and ventral rostral teeth of *M. equidens equidens* and *M. equidens pillaii*.

Sub-species/sex	Character	Observed Chi-square	df	Table value	Level of significance (P)
A. Within the subspecies:-					
M.equidens equidens	Dorsal	11.409	3	7.82	0.05
	Post-orbital	8.104	1	3.80	0.05
	Ventral	6.268	2	5.99	0.05
M.equidens pillaii	Dorsal	0.994	1	3.84	N.S
	Post-orbital	0.791	1	3.84	N.S
	Ventral	9.500	1	3.84	0.05
B. Between the subspecies:-					
Male	Dorsal teeth	0.903	3	7.81	N.S
	Post-orbital	25.312	1	3.84	0.05
	Ventral	36.261	1	3.84	0.05
Female	Dorsal teeth	1.653	1	3.84	N.S
	Post-orbital	33.260	1	3.84	0.05
	Ventral teeth	19.210	1	3.84	0.05

N.S - Not significant

Table - 41

Analysis of covariance (comparison of regression lines)

To compare the growth rates (slopes) or elevations of morphometric characters between males of M. equidens equidens and M. equidens pillaii and also between females of the two subspecies with respect to total length of prawns.

Source	Deviation from regression					
	Males			Females		
	df	SS	MSS	df	SS	MSS
Within						
MEM	63	1.29	0.02	63	10.14	0.16
MPM	64	1.95	0.03	54	0.61	0.01
Pooled within	128	3.34	0.03	118	11.18	0.09
	127	3.34	0.03	117	10.75	0.09
Difference between slopes	1	0.11	0.11	1	0.43	0.43
Between & within	129	3.39	..	119	11.81	..
Between adjusted means	1	0.05	0.05	1	0.63	0.63
Comparison of slopes		4.256**		4.667**		
Comparison of elevations		1.820NS		6.615*		

* - Significant at 1% level ** - Significant at 5% level NS - Not significant

Table - 42

Regression coefficient (growth rates) and average weight for males and females of *M.equidens equidens* and *M. equidens pillaii*.

(Rate of growth and average weight compared to total length of prawns)

Species/sex	Regression coefficients	Mean value
M. equidens equidens		
Male	2.60	4.161
Female	1.34	2.861
M. equidens pillaii		
Male	1.73	3.654
Female	3.23	2.318

Table - 43

Regression equations relating the weight to total length.

Species	Male	Female
M. equidens equidens	log W = 2.60087 log TL - 4.274	log W = 3.14804 log TL - 5.2317
M. equidens pillaii	log W = 1.72933 log TL - 2.63013	log W = 3.23153 log TL - 5.42074

Table - 44

Estimated 't' values for males and females of *M. equidens equidens* and *M. equidens pillaii*.

Species/sex	df	Regression coefficient	Standard error	't' value
M. equidens equidens				
Male	64	2.60	0.17448	2.2925**
Female	54	1.34	0.10625	15.6235*
M. equidens pillaii				
Male	63	1.73	0.14298	8.8824*
Female	63	3.23	0.07930	2.9003*

* - Significant at 1% level ** - Significant at 5% level.

FIG.9 - Relationship between Total length and Carapace length (mm)

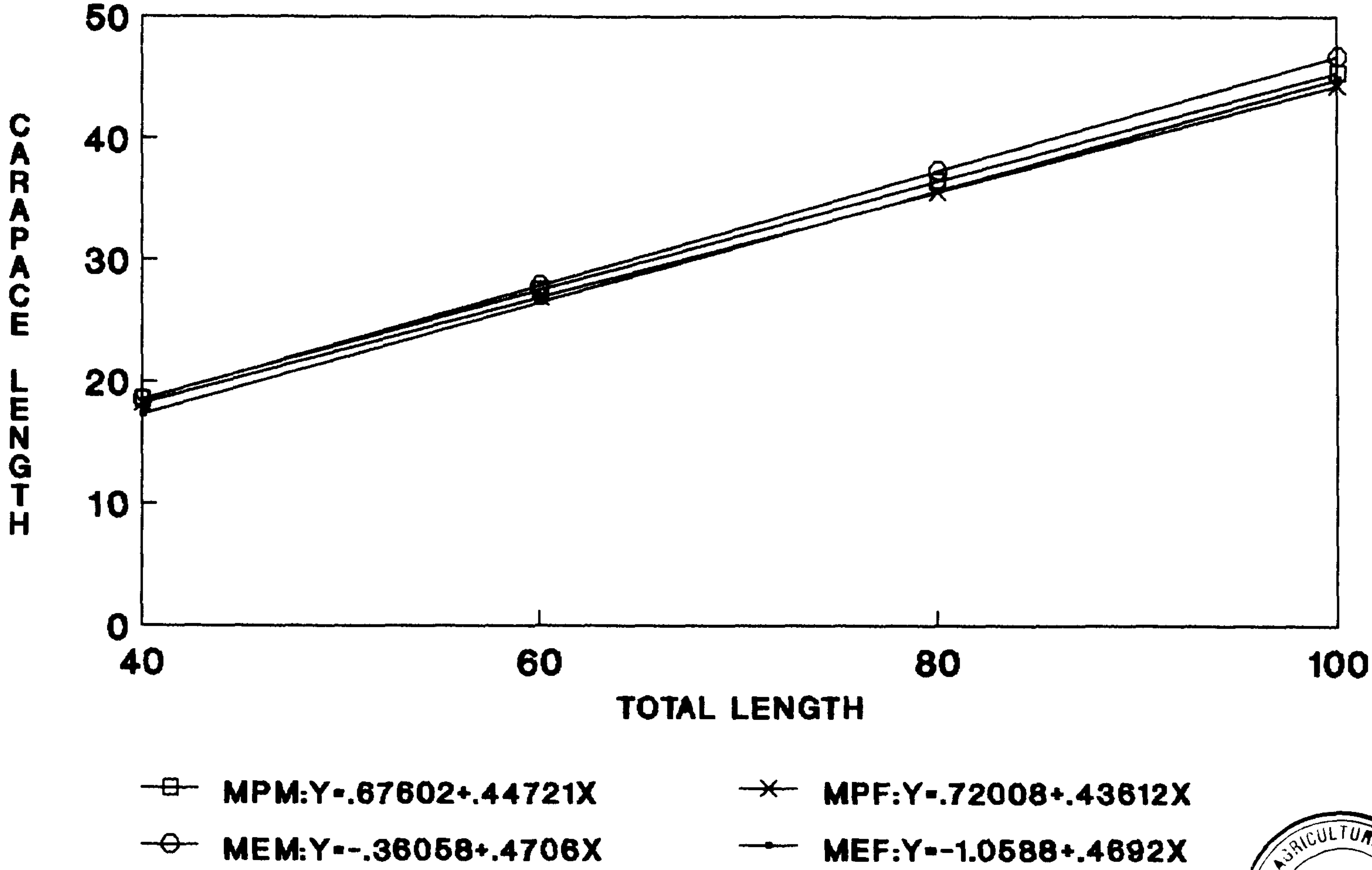


FIG.10 - Relationship between Total length and Abdominal length (mm)

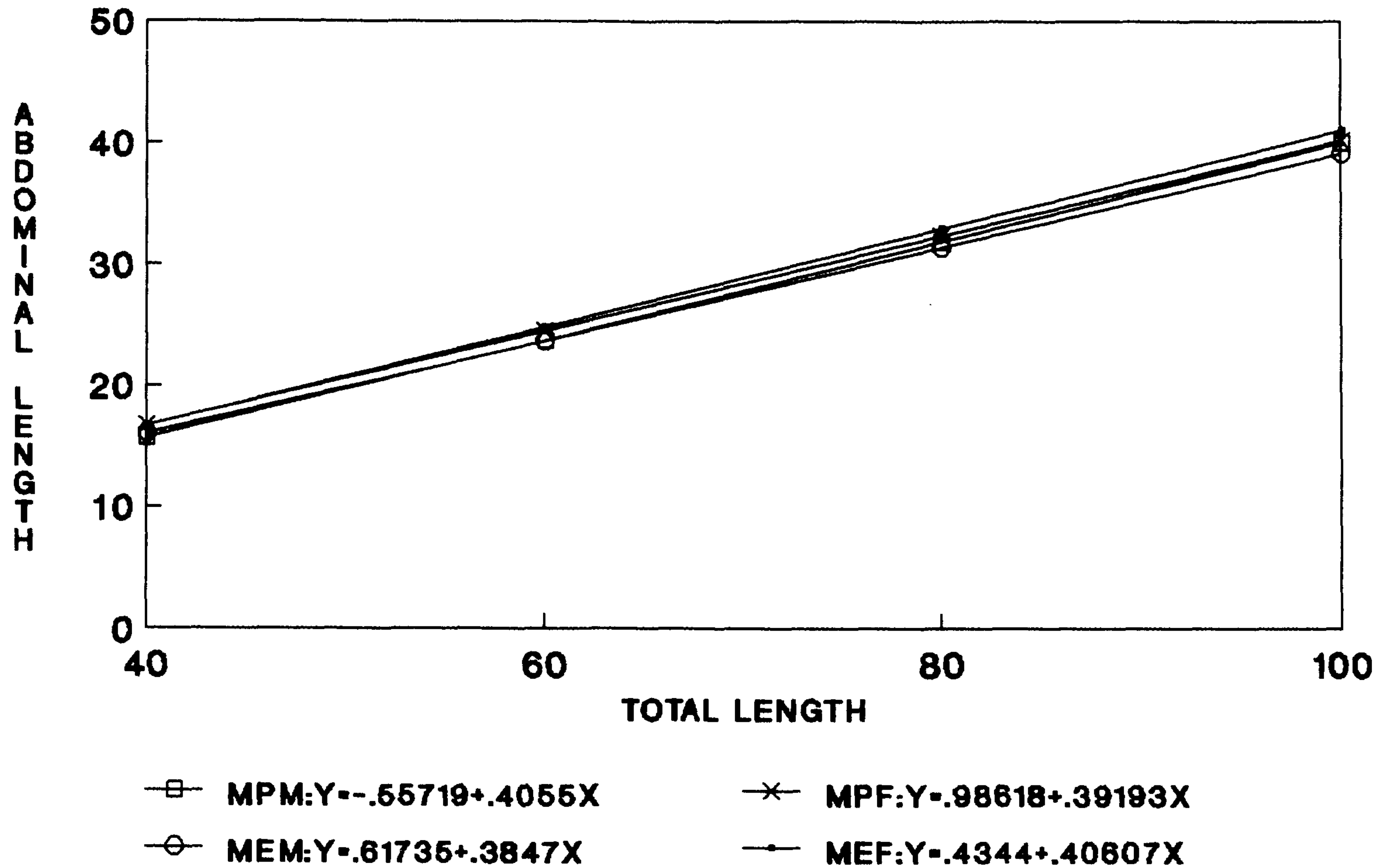


FIG.11 - Relationship between Total length and Body length (mm)

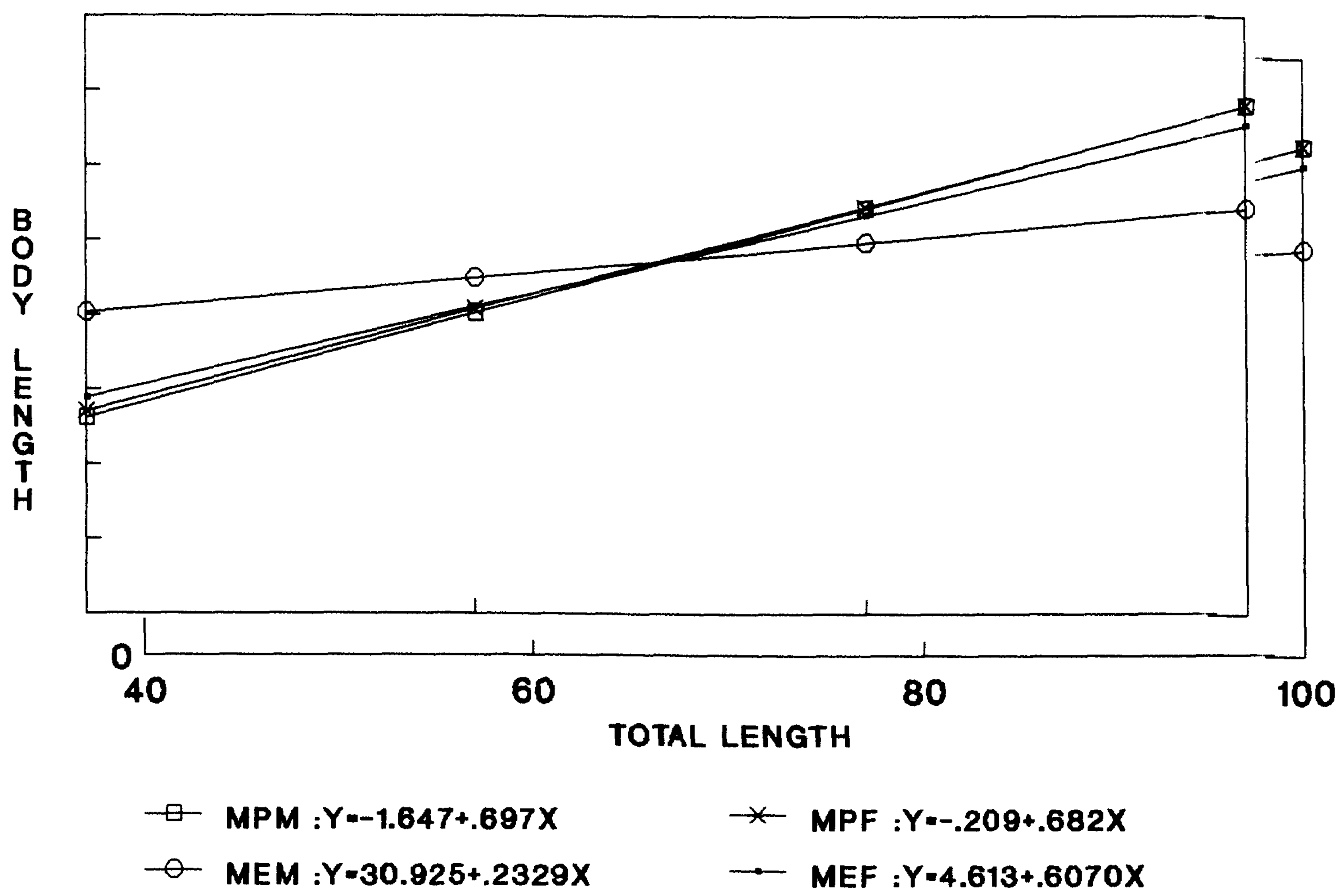


FIG.12 - Relationship between Total length and Telson length (mm)

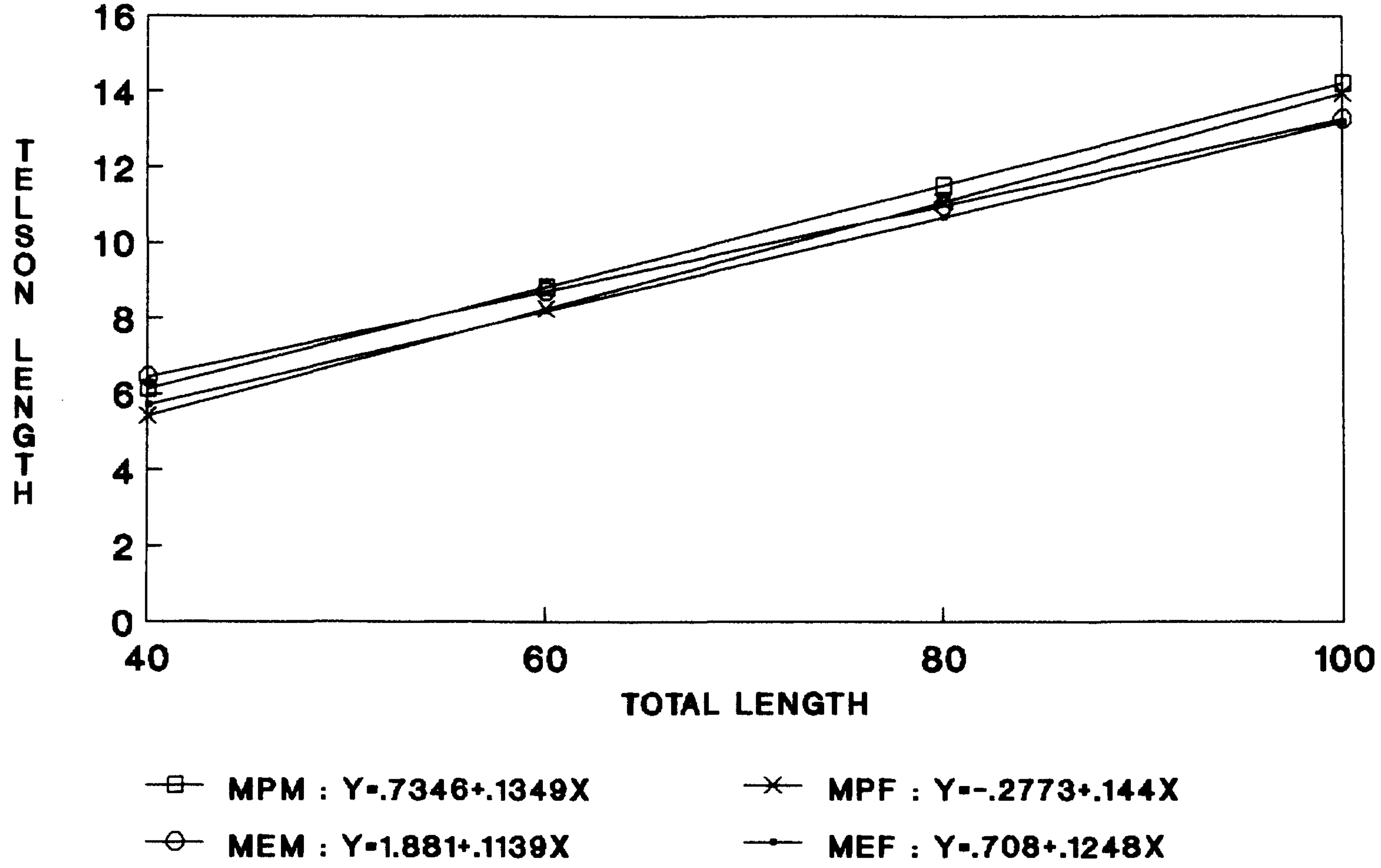


FIG.13 - Relationship between Total length and Ischium length (mm)

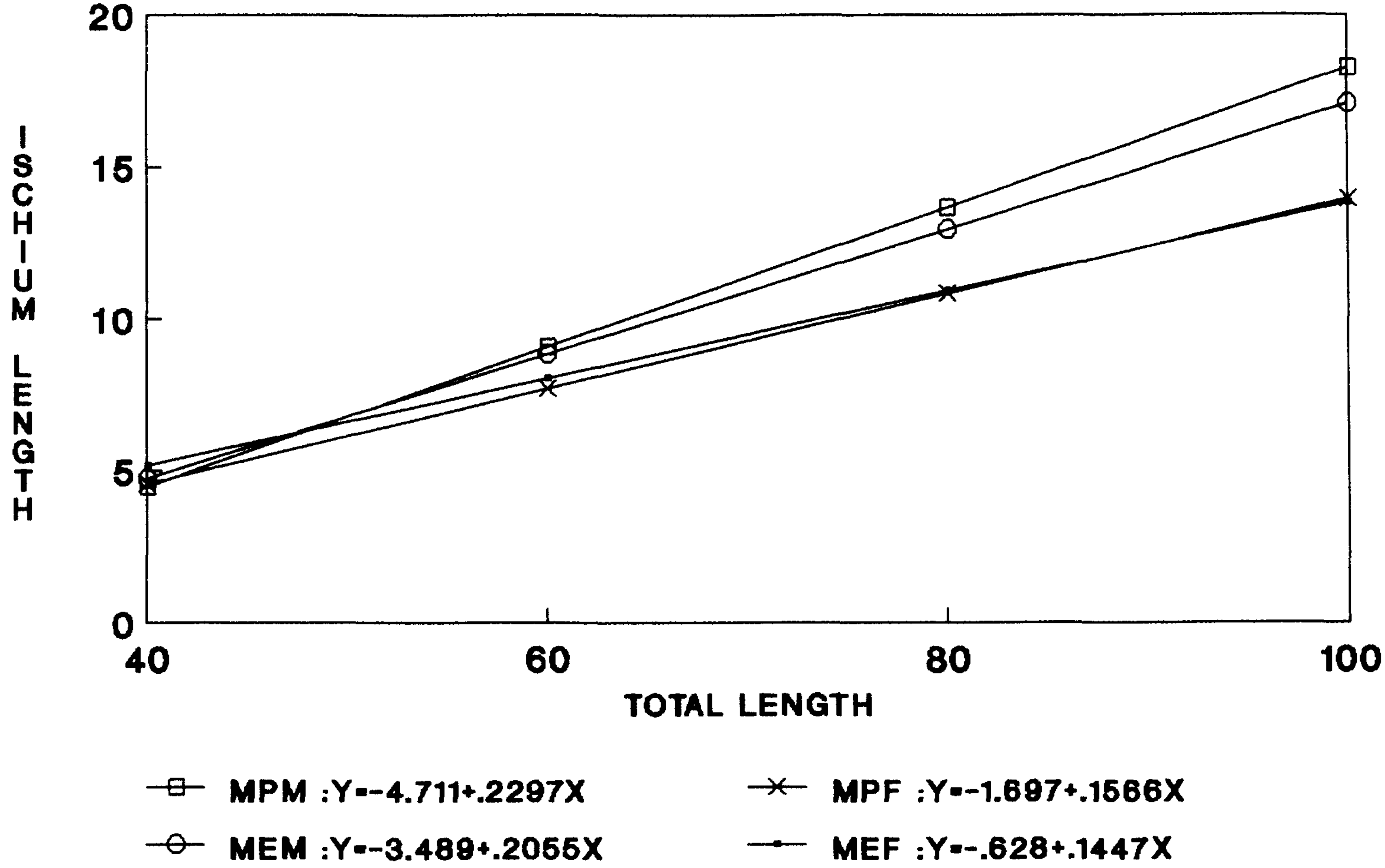


FIG.14 - Relationship between Total length and Merus length (mm)

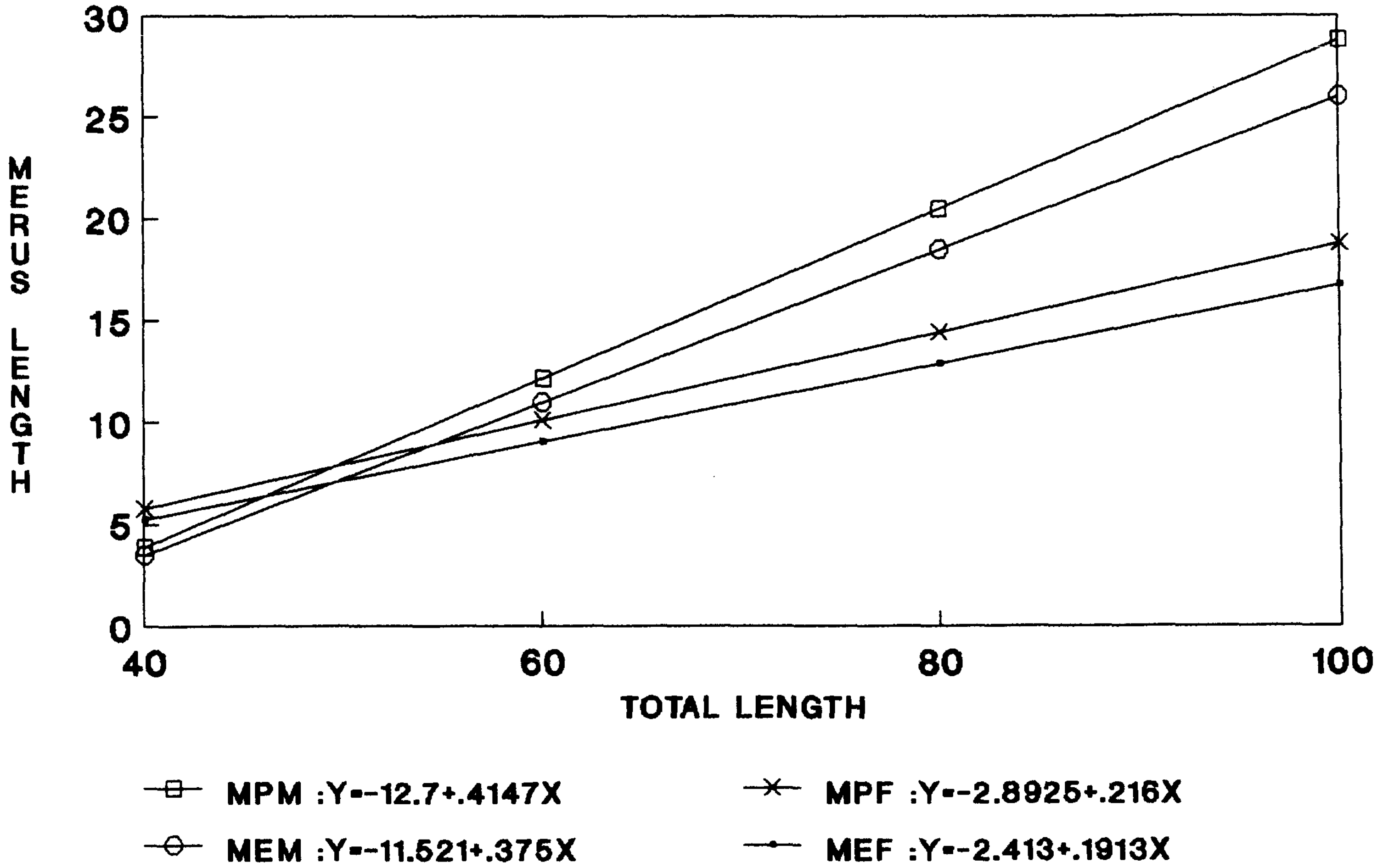


FIG.15 - Relationship between Total length and Carpus length (mm)

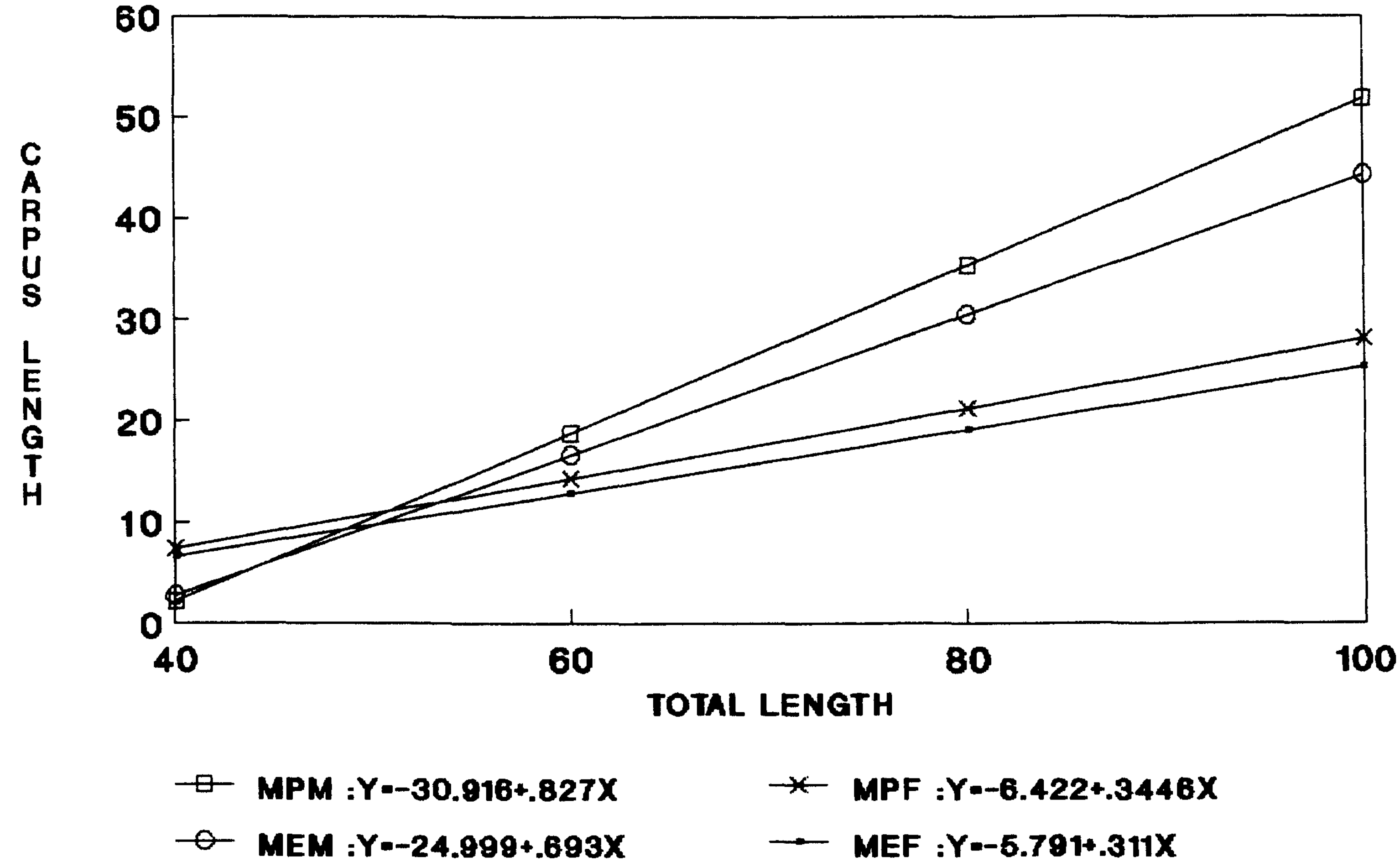


FIG.16 - Relationship between Total length and Propodus length (mm)

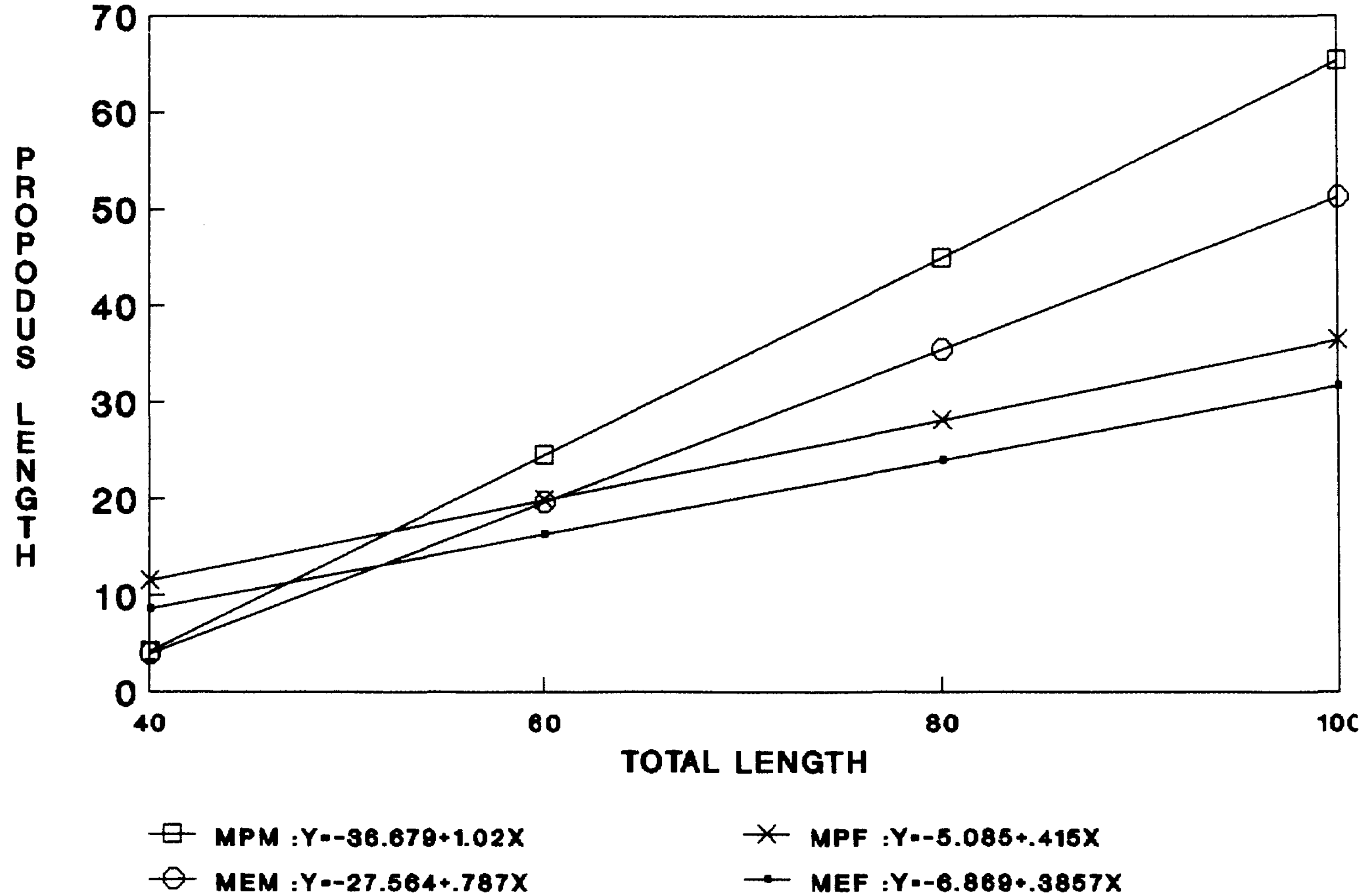


FIG.17 - Relationship between Total length and Palm length (mm)

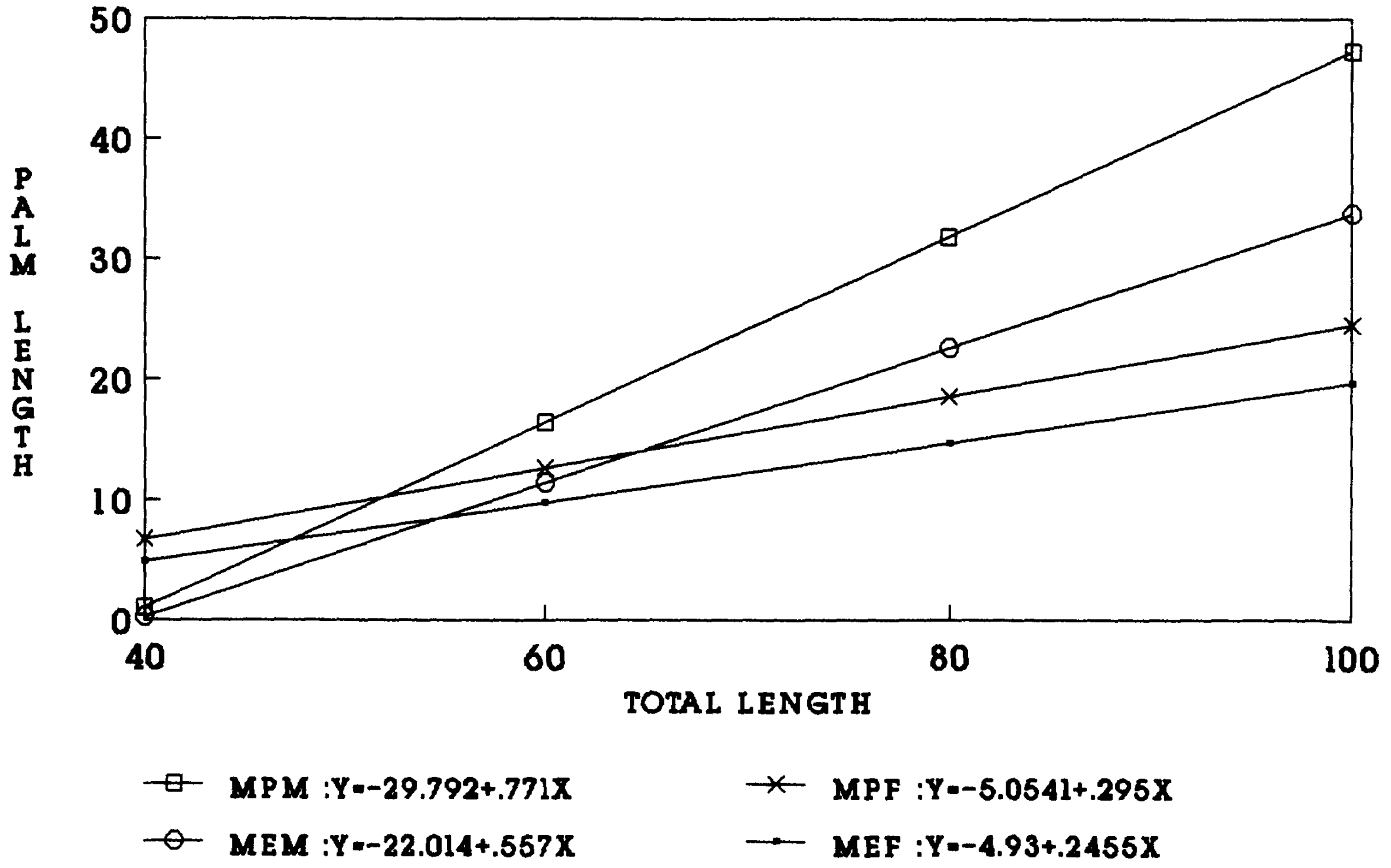


FIG.18 - Relationship between Total length and Dactylus length (mm)

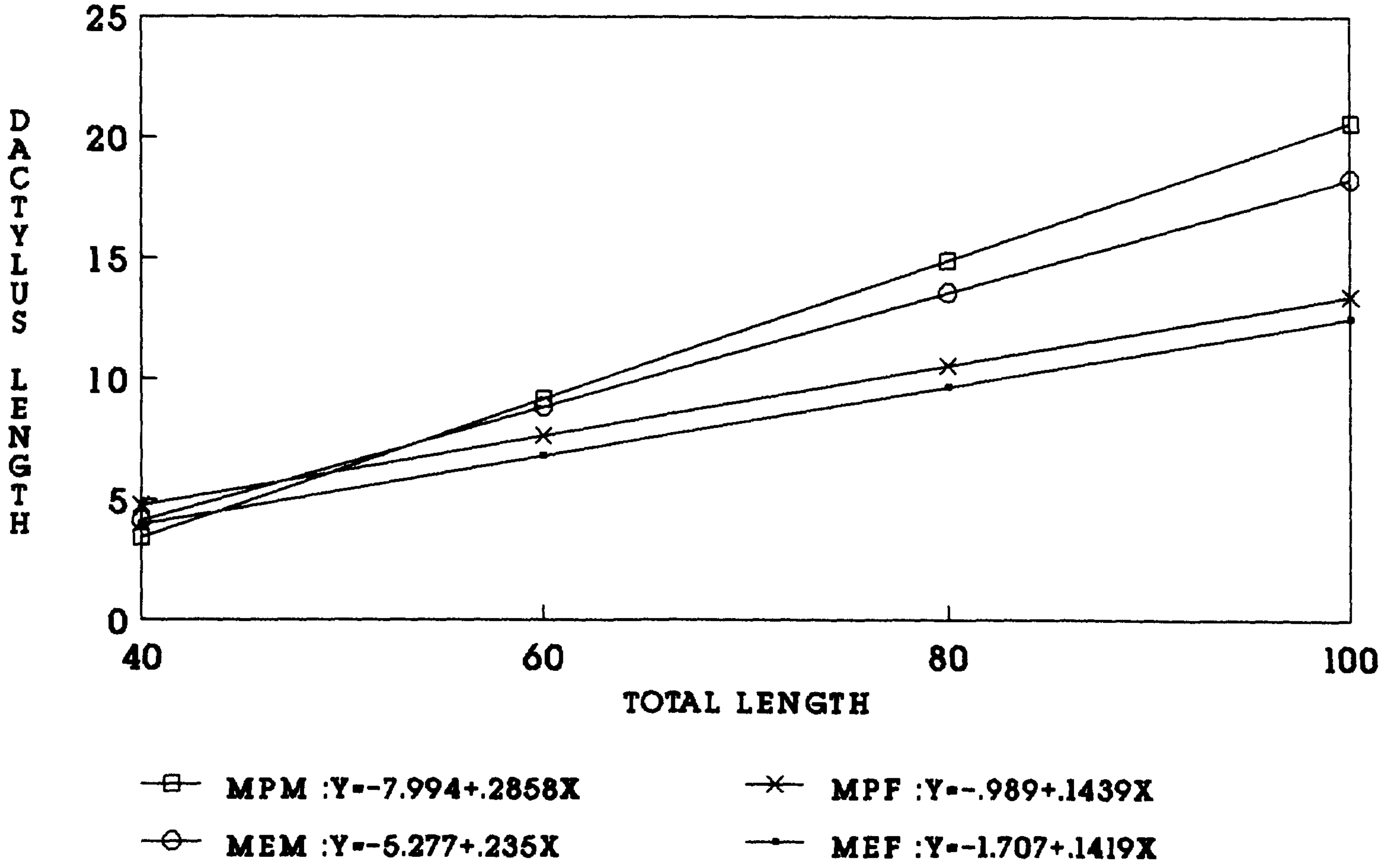


FIG.19 - Relationship between Total length and second Chelate leg (mm)

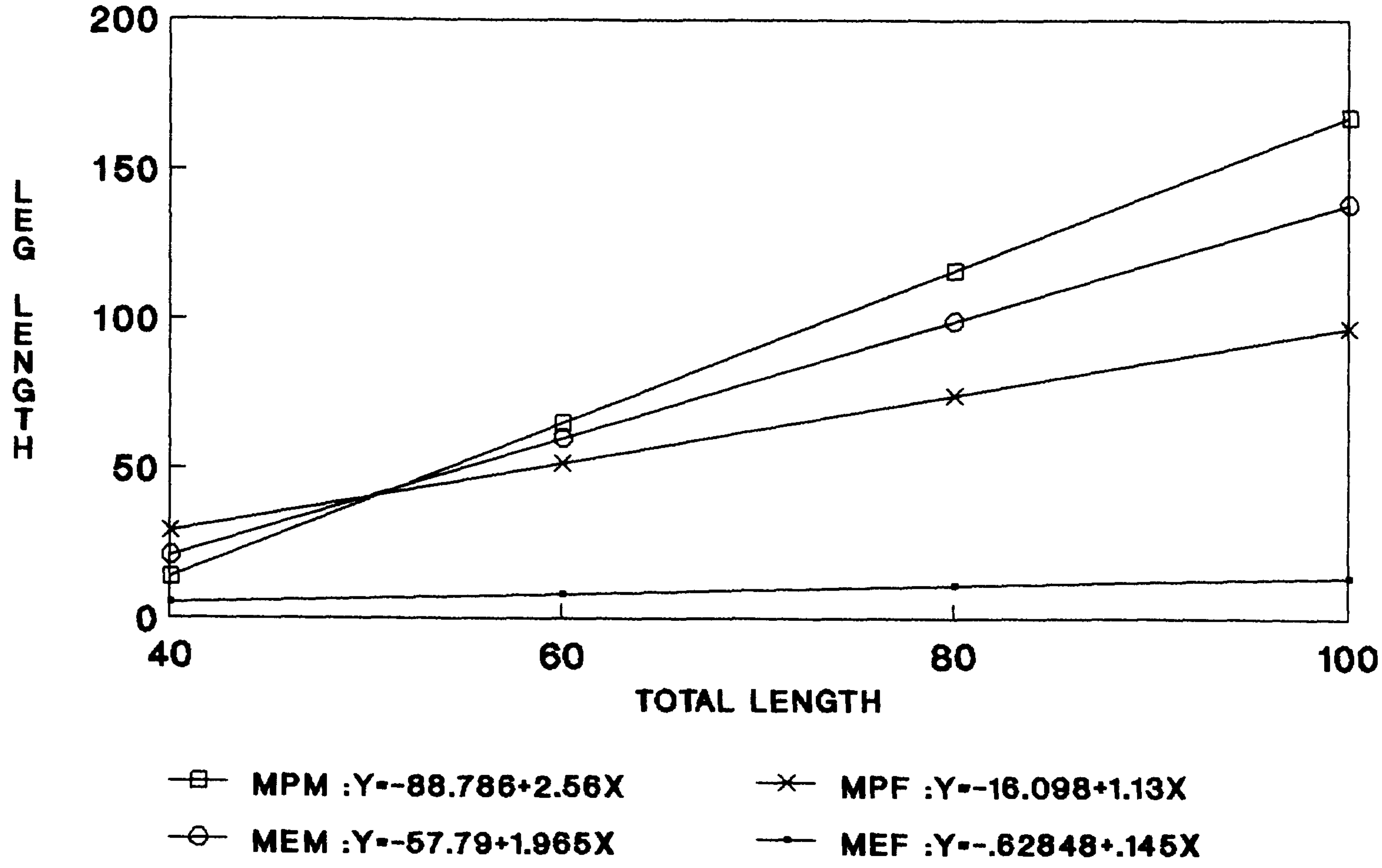


FIG.20 - Relationship between Carapace length and Rostrum length (mm)

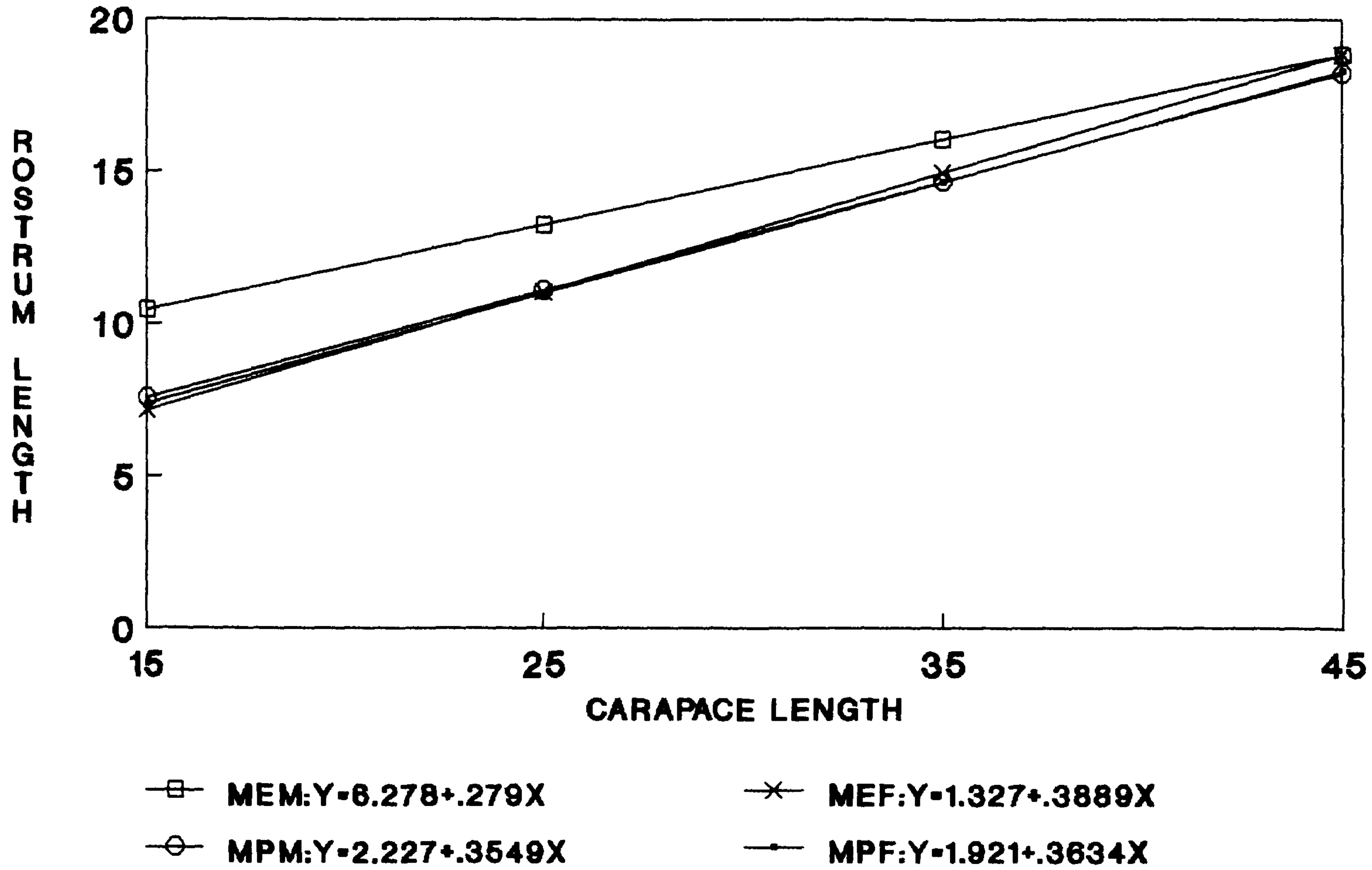
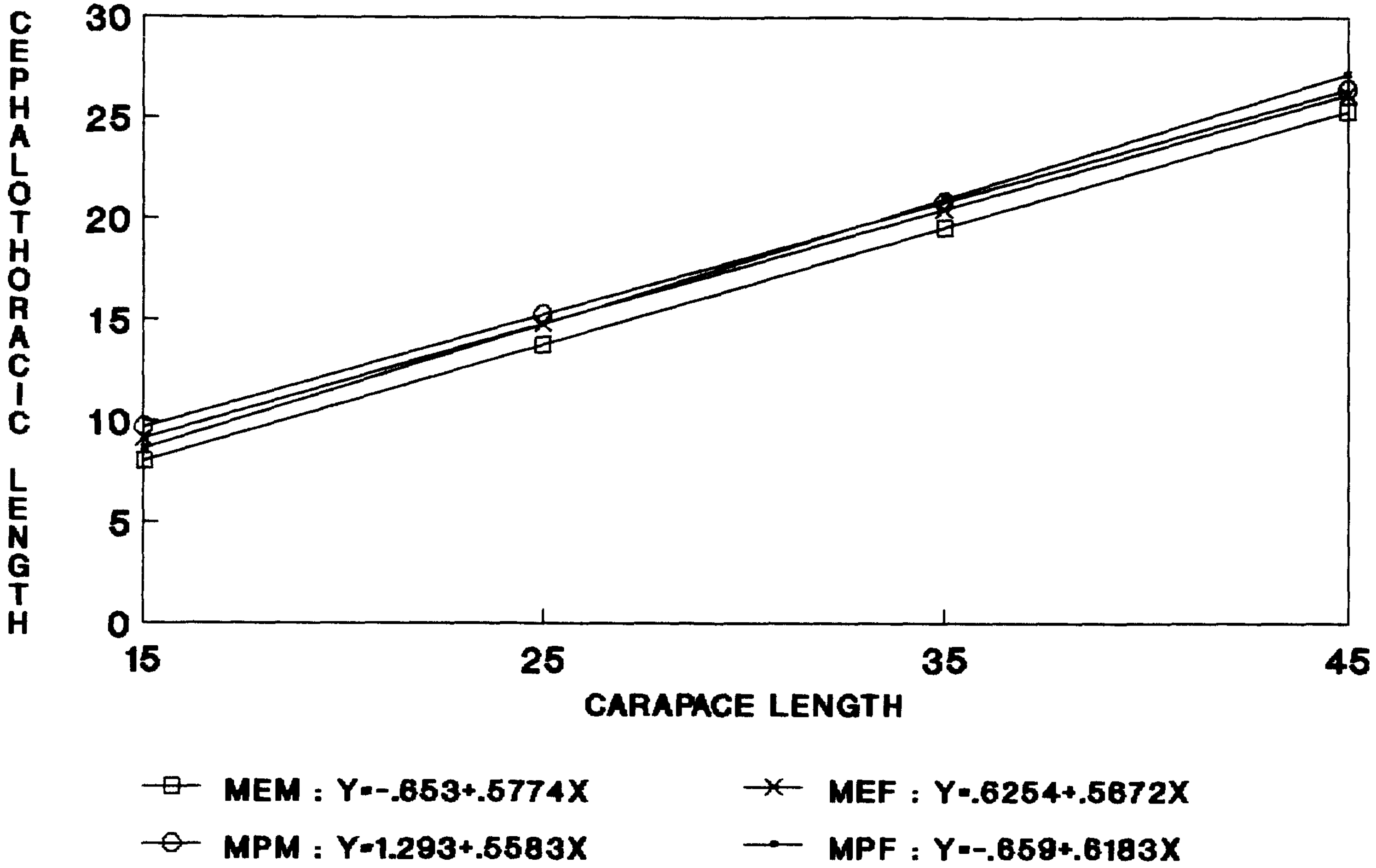


FIG.21 - Relationship between Carapace length and Cephalothoracic length (mm)



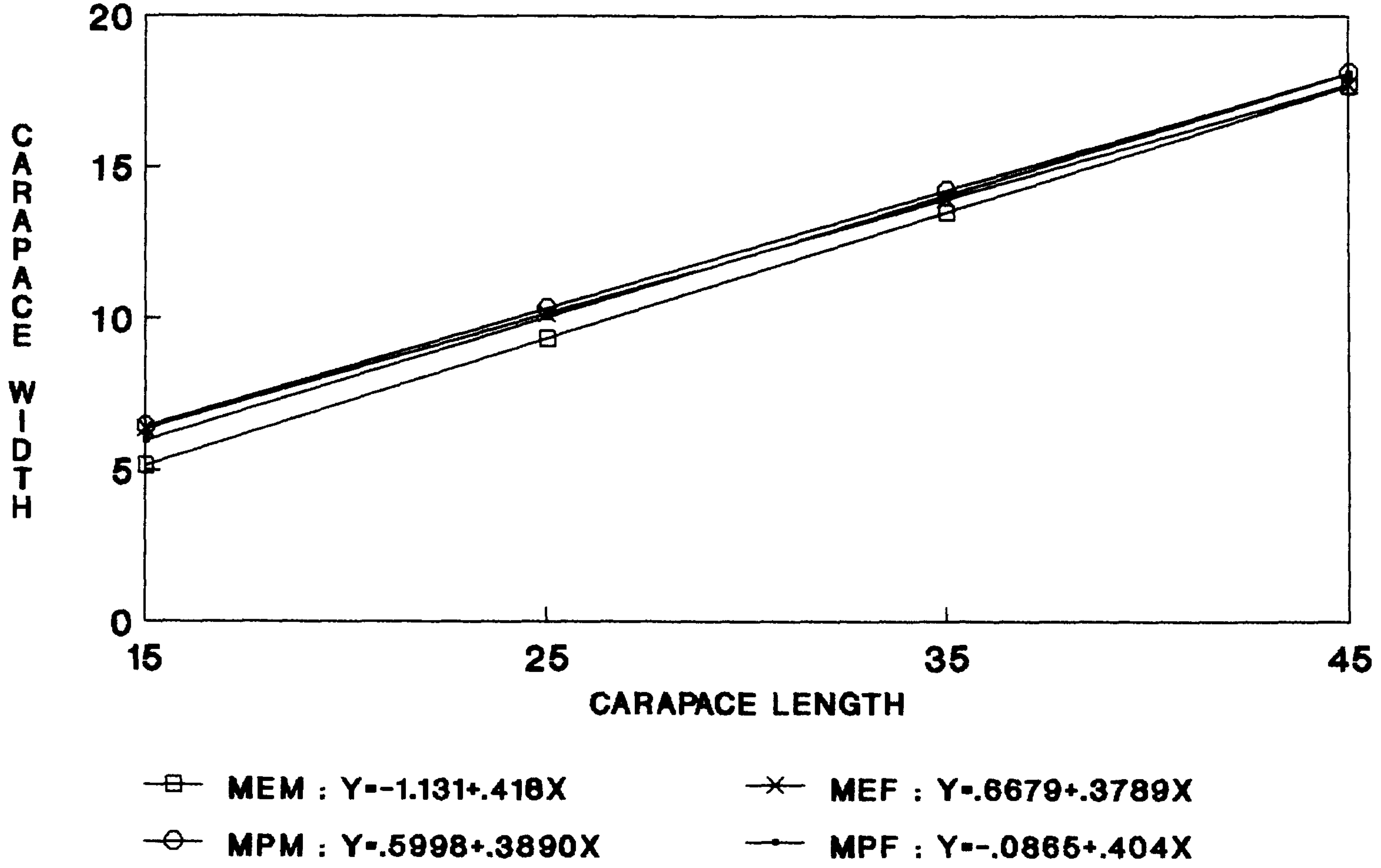


FIG.22 - Relationship between Carapace length and Carapace width (mm)

FIG.23 - Relationship between length of leg and ischium length (mm)

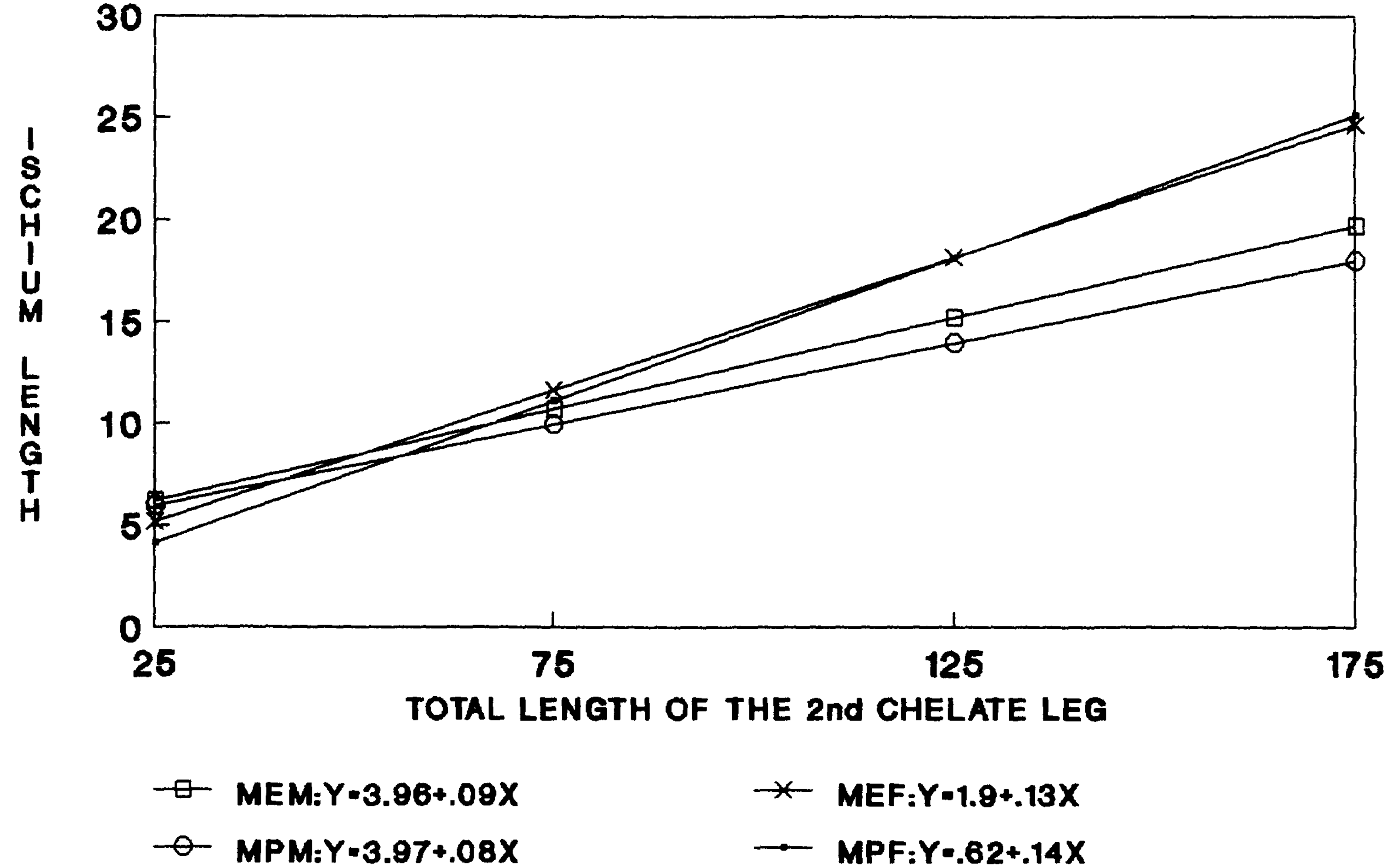


FIG.24 - Relationship between length of leg and Merus length (mm)

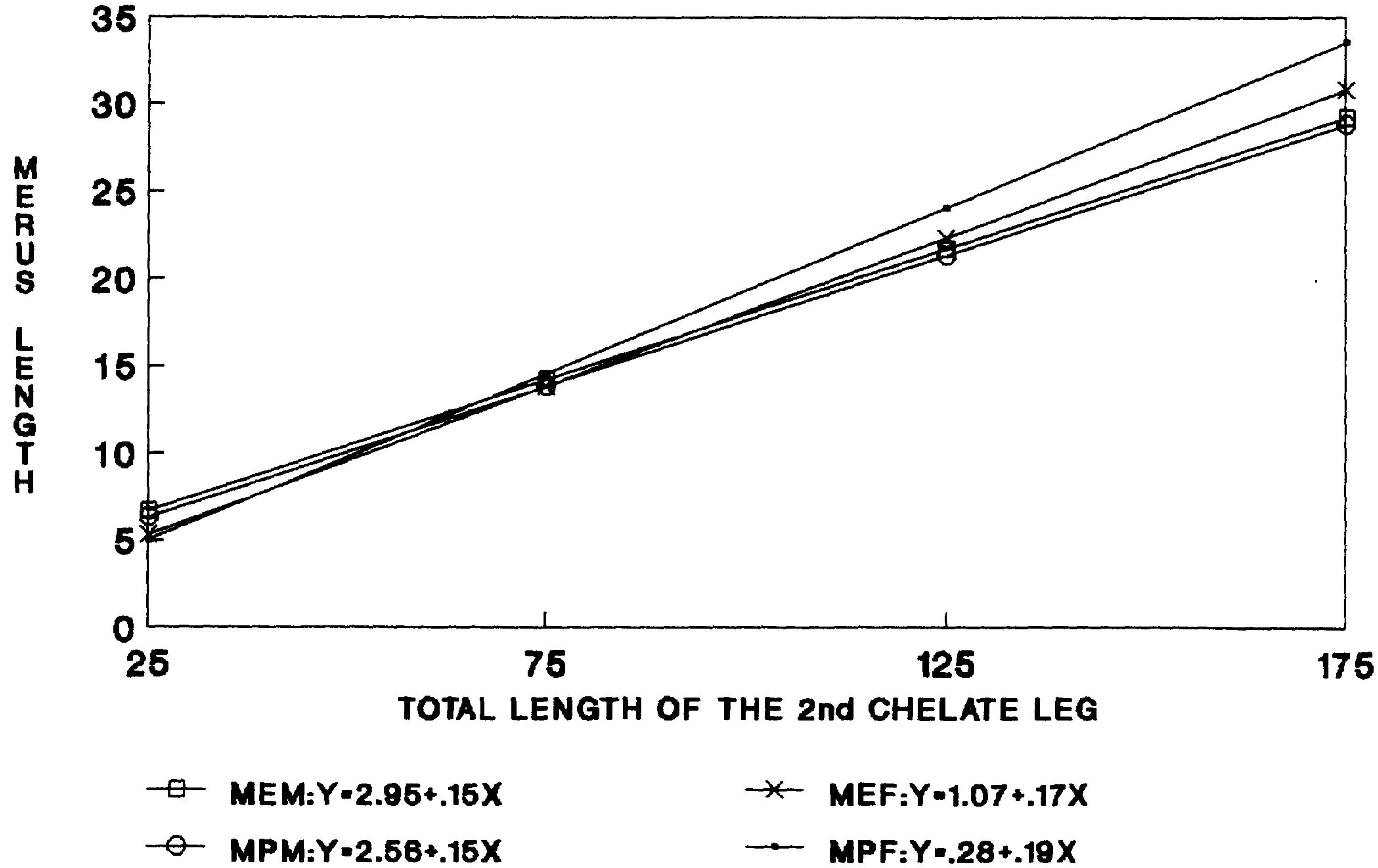


FIG.25 - Relationship between length of leg and Carpus length (mm)

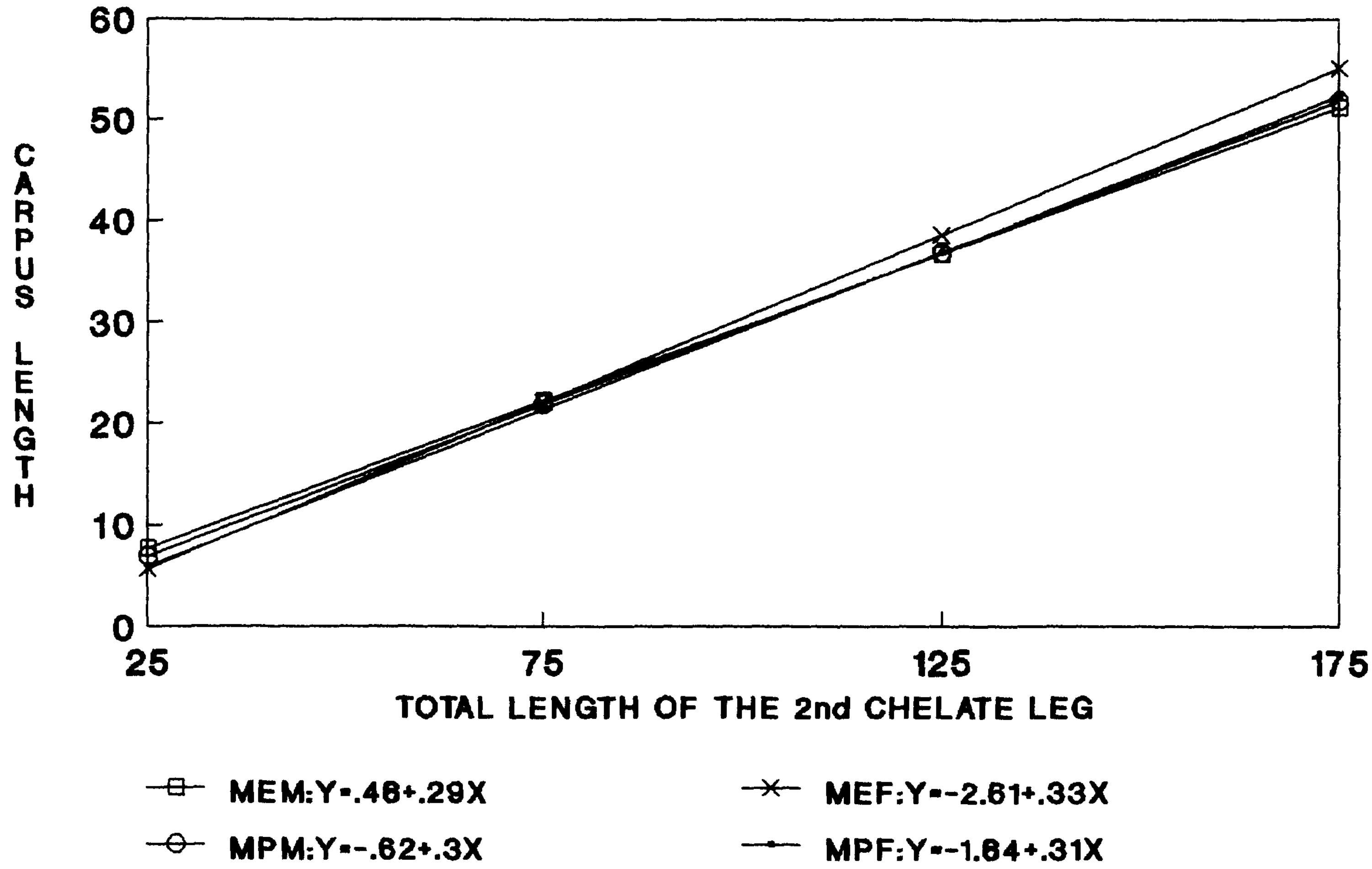


FIG.26 - Relationship between length of leg and Propodus length (mm)

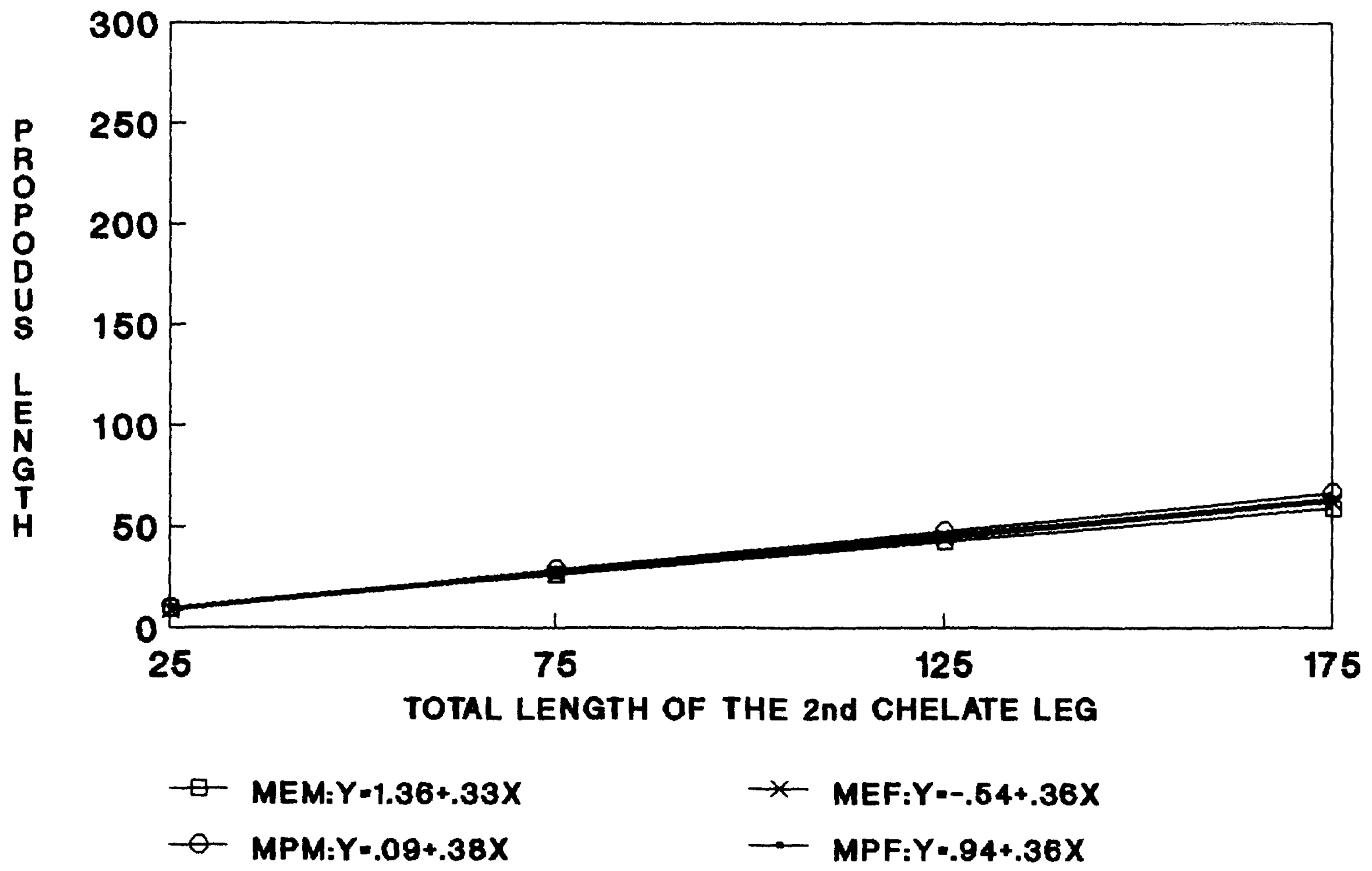


FIG.28 - Relationship between length of leg and Dactylus length (mm)

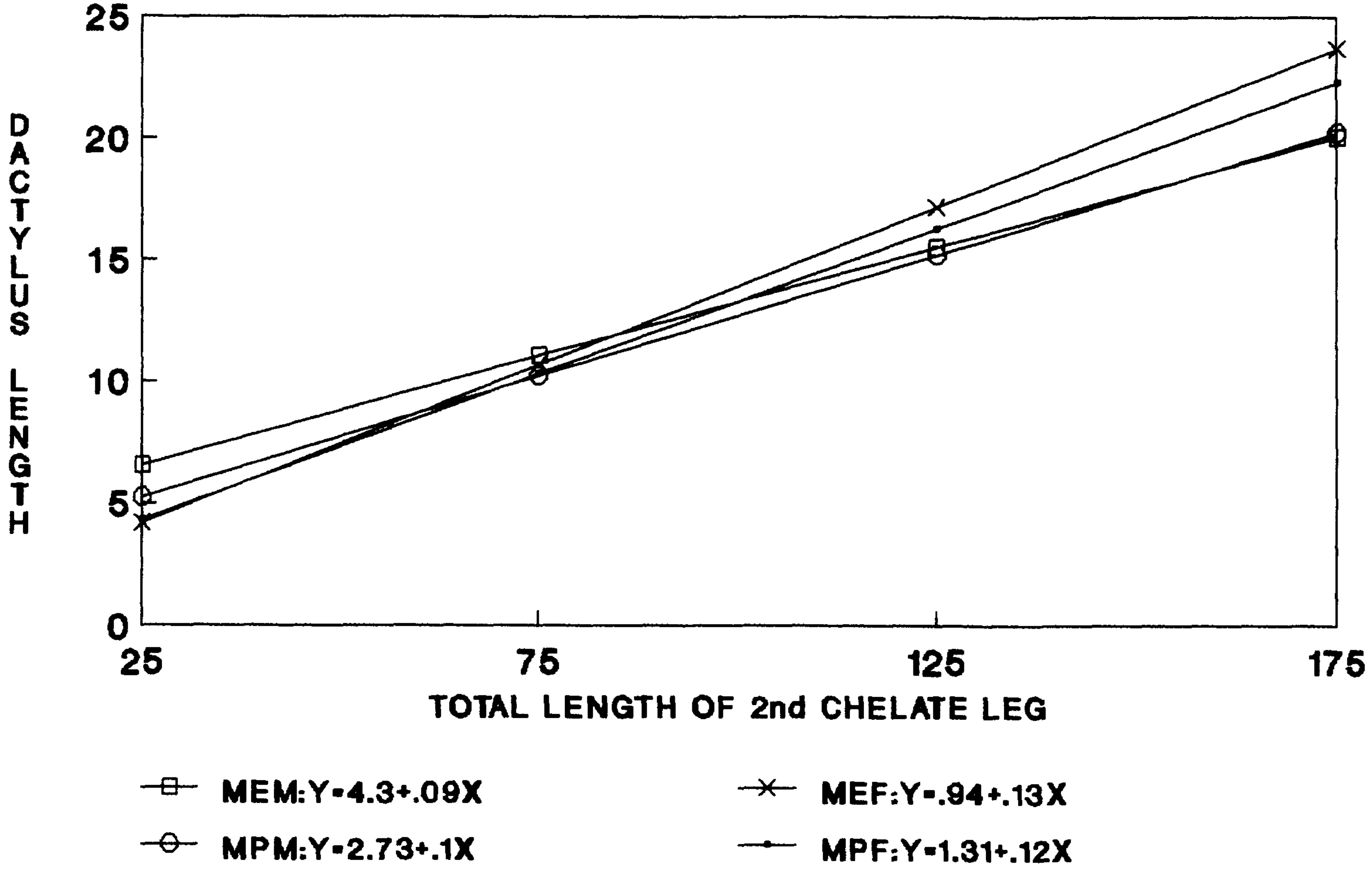


FIG.29 Relationship between log length & logweight of M.equidens equidens (Male)

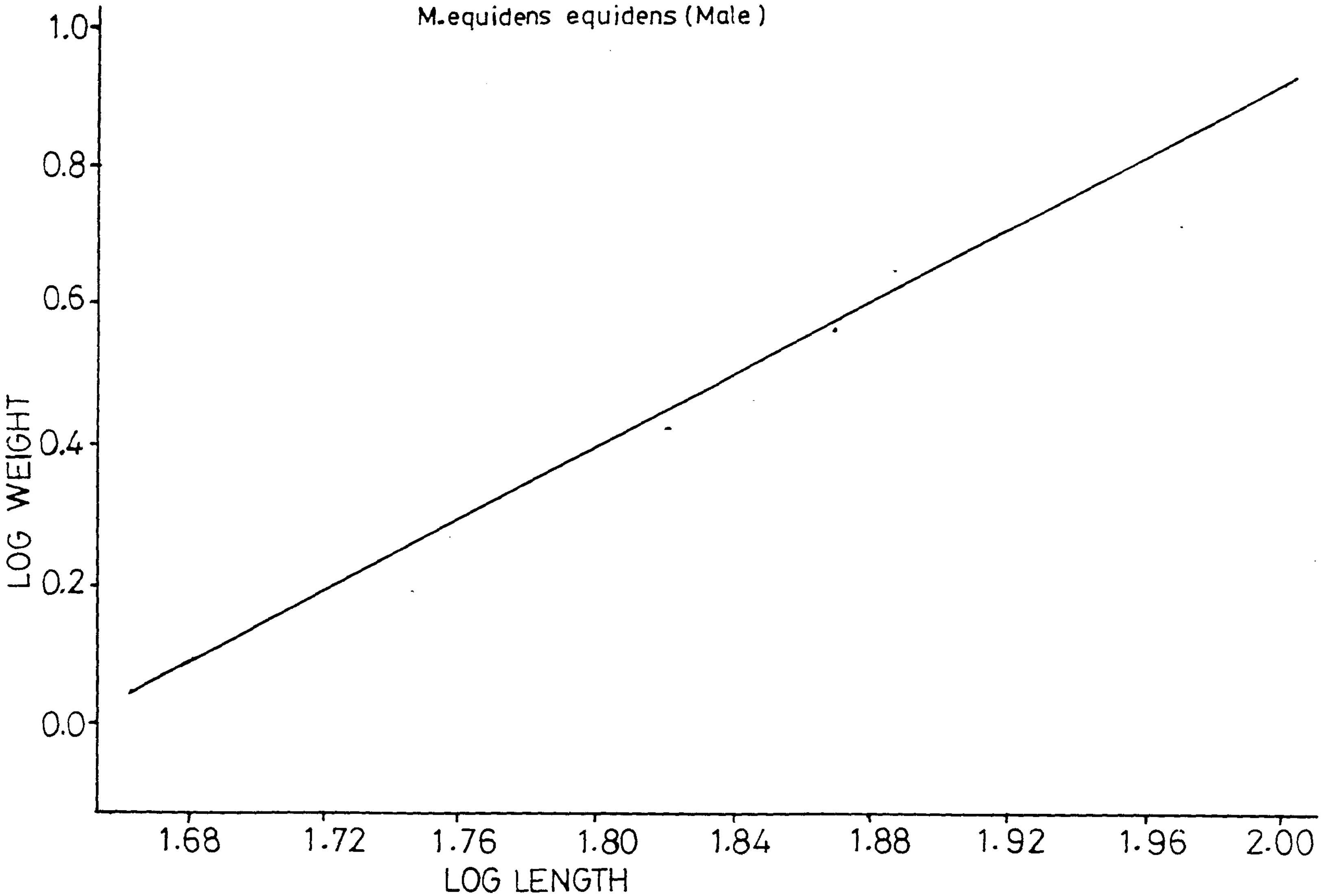


FIG. 30 Relationship between loglength & logweight of M.equidens equidens (Female)

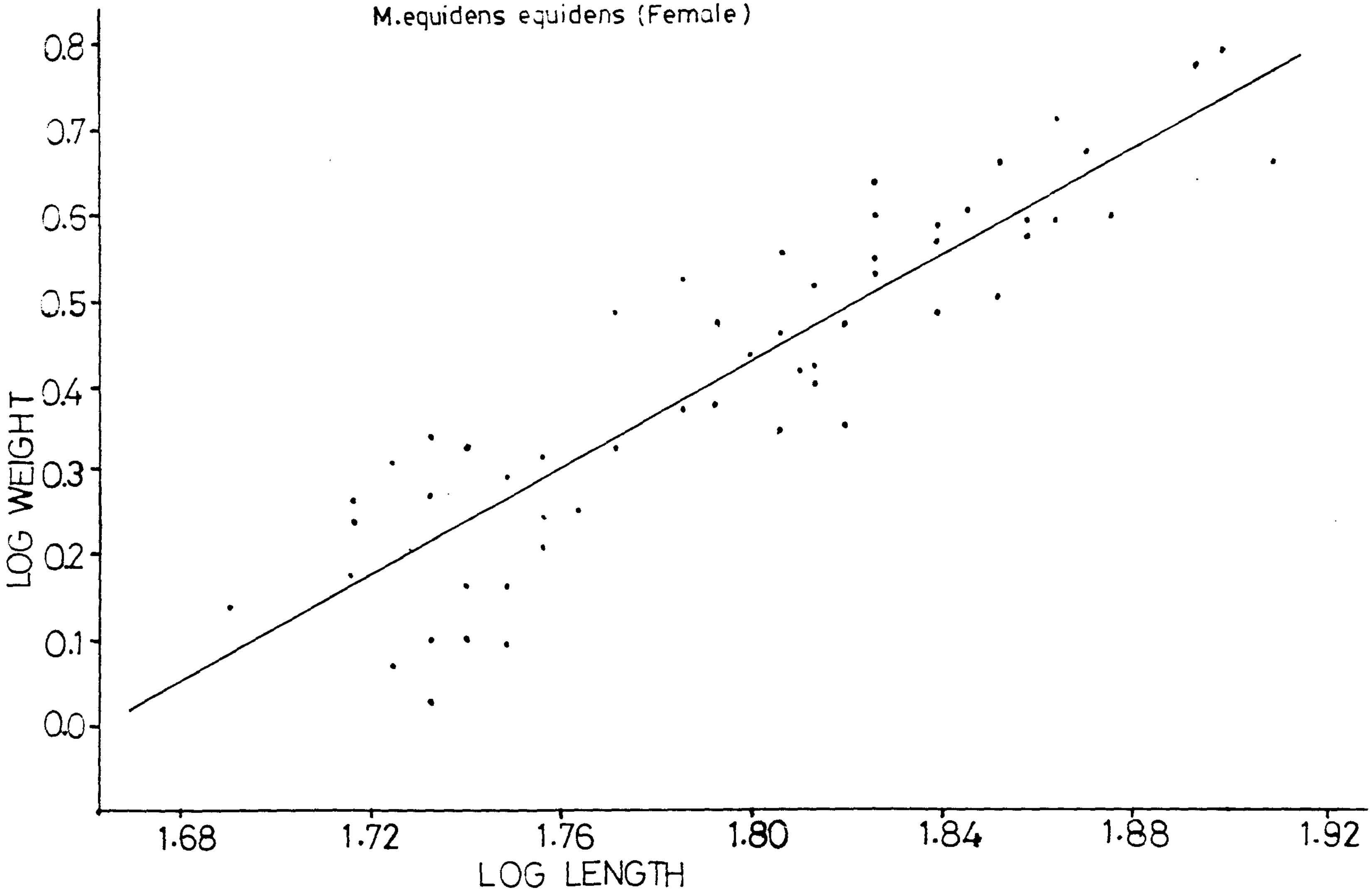


FIG 31 Relationship between loglength & logweight of M.equidens pillaii (Male)

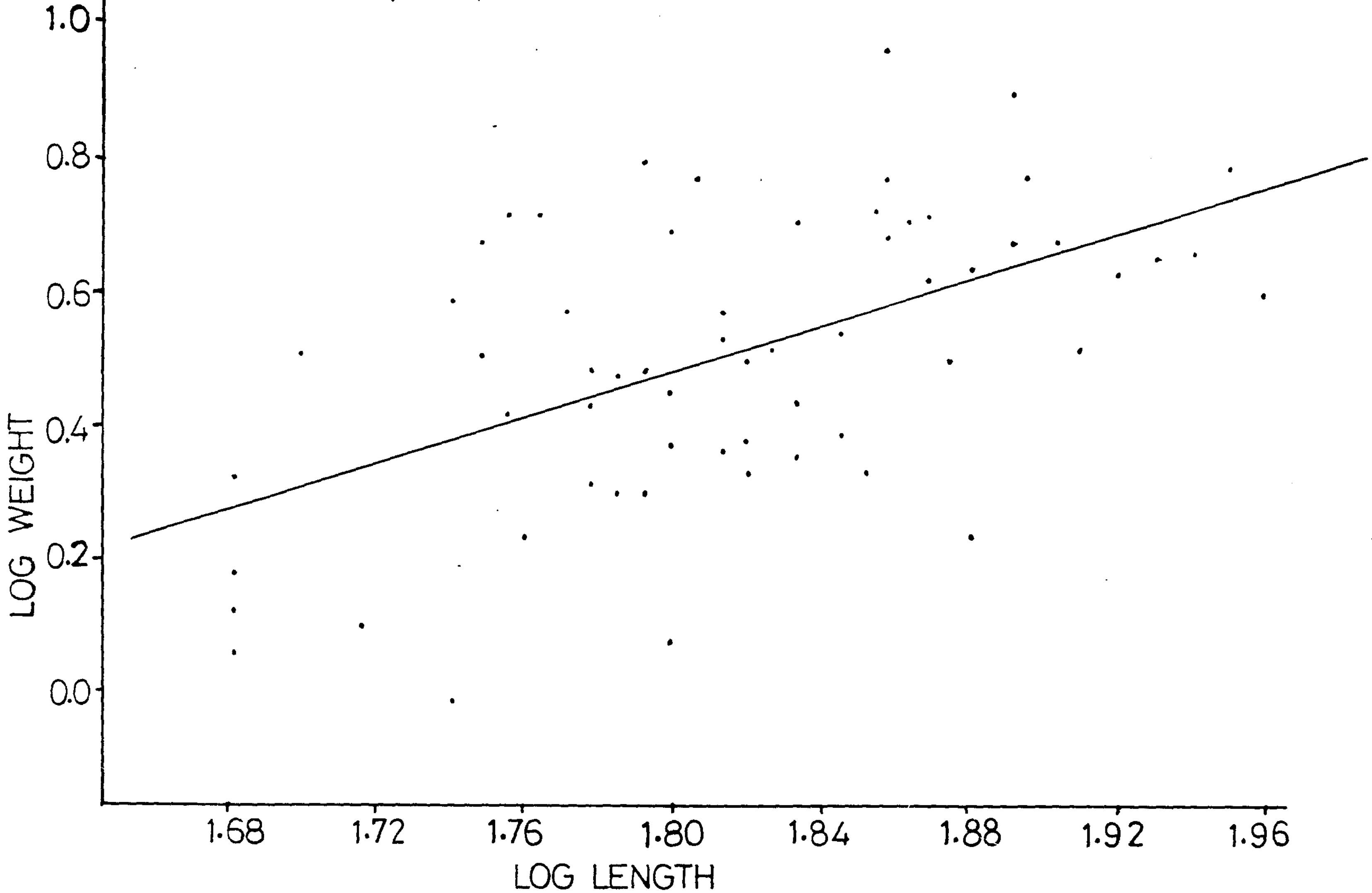
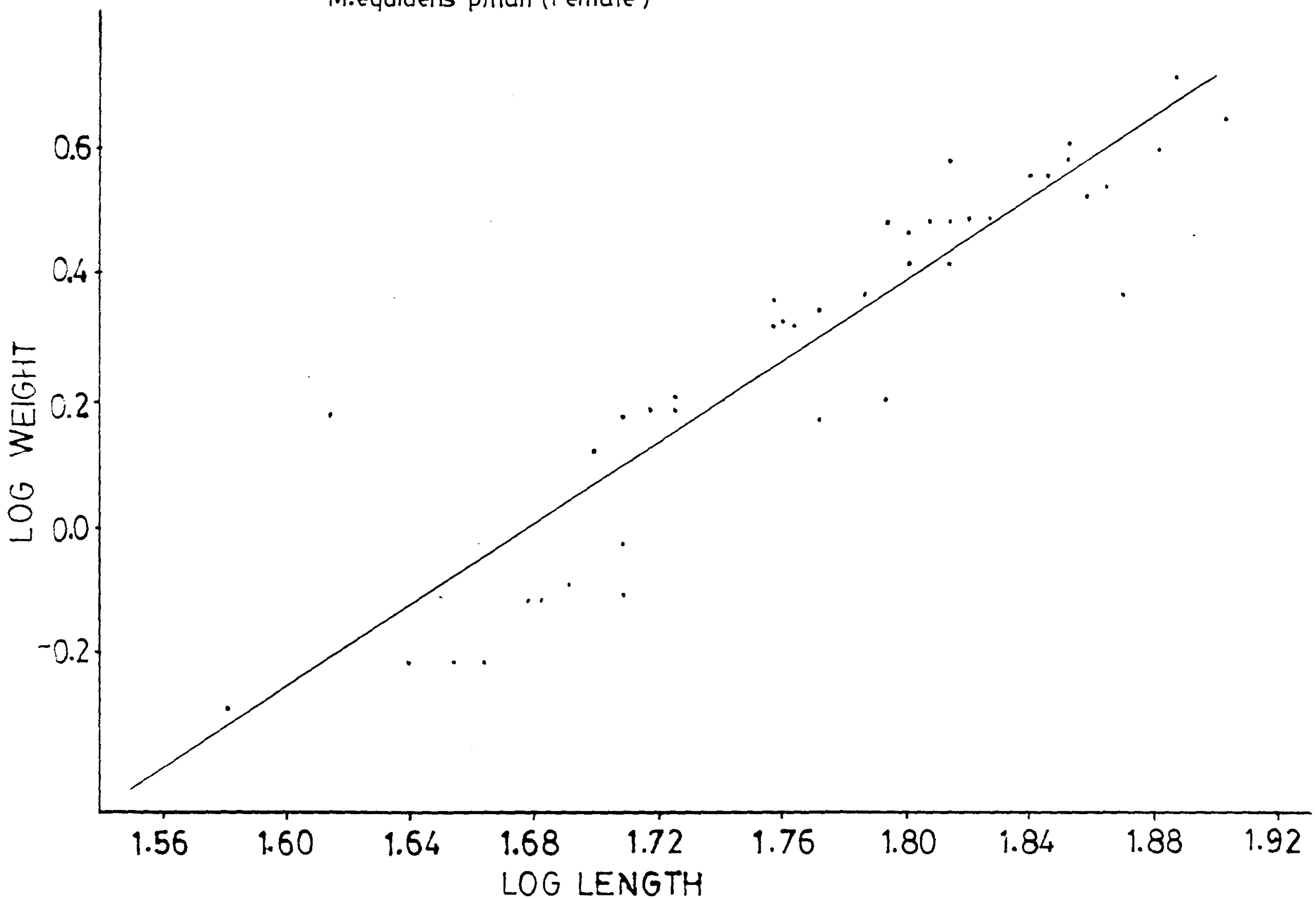


FIG 32 Relationship between log length & log weight of M. equidens pillaii (Female)



4.5. Electrophoresis

The electrophoretic patterns of the water soluble muscle proteins of *M. equidens equidens* and *M. equidens pillaii* are given in Figure (33A & B). The results show that there is an apparent difference in the total number of protein bands in the two subspecies (Table 45). There are 6 bands in *M. equidens equidens*, but there are only 4 protein bands in the other subspecies. Band No.1 and Band No.4 are absent in *M.equidens pillaii*. Band nos. 2,3,5 and 6 are common in both the sub species and they show similar electrophoretic mobility. Though the electrophoretic mobility of band No.6 is same for both subspecies, the intensity of band no.6 for *M. equidens pillaii* is more, showing a higher content of that particular protein. Band No.5 of *M. equidens equidens* is more prominent than the corresponding band for *M. equidens pillaii*.

Table 45

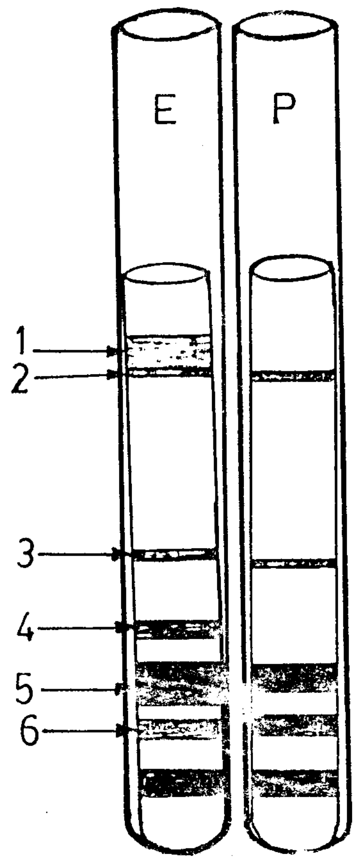
A comparison of protein bands in the two subspecies.

Subspecies	Bands						Total number of bands.
	1	2	3	4	5	6	
M. equidens equidens.	+	+	+	+	+	+	6
M. equidens pillaii.	–	+	+	–	+	+	4

\+ indicate presence of band   – indicate absence of band.


E
9

Fig.33B. A diagramatic representation of the electrophorograms of water soluble muscle proteins of M.equidens equidens and M.equidens pillaii



E - M equidens equidens P-M equidens pillaii

4.6. Oogenesis

4.6.1. Structure of ovary.

The female reproductive systems of both *M. equidens equidens* and *M. equidens pillaii* consist each of a pair of ovaries, oviducts, gonopores and external sperm receptacle area. The ovaries are seen resting above the hepatophancreas, below the heart. Each ovary is an elongated flattened mass or lobe. The two ovaries are apposed side by side so as to appear like a single structure with two posteriorly directed lobes. The lobes are so closely approximated so that the space between them appears like a median slit which widens out slightly at its anterior end forming a passage for the cardio-pyloric strand.

As maturation advances, the ova are deposited with yolk so that the ovary enlarges anteriorly, posteriorly and laterally. Accordingly the size and colour of ovaries change depending on the degree of ripeness. In the fully ripe stage the ovary extends anteriorly as far as the renal sac and posteriorly into the first abdominal segment. Immature ovary is generally transluscent, gradually truns to greenish and finally greenish brown when fully ripe.

4.6.2. Classification of maturity stages.

The maturity stages of female *M. equidens equidens* and *M. equidens pillaii* are classified following Philip and Subramanian

Table - 46

Maturity stages of *M. equidens equidens* and *M. equidens pillaii*.

Stage	Description
Stage I (Immature virgin)	Ovary occupies 1/6th of the size of carapace cavity, transluscent.
Stage II (Maturing I)	Ovary occupies 2/6th of the carapace cavity, colourless. Black spots can be seen here and there. Ova still not visible to the naked eye.
Stage III (Maturing II)	Ovary occupies nearly 1/4th of the carapace cavity, yellowish in colour. The ova clearly visible to the naked eye.
Stage IV (Maturing III)	Ovary occupies 1/2 the size of carapace cavity, yellowish in colour. Ova more distinct. It starts to bulge out laterally.
Stage V (Mature I)	Ovary occupies 3/4th the size of carapace cavity. Ovary greenish brown in colour. The lateral expansion of the ovary is of considerable magnitude.
Stage VI (Mature II or Ripe)	Ovary completely fills the carapace cavity and extends up to abdominal segment. The anterior part of the ovary is comparatively narrow while the middle region is broadened due to the lateral expansion and from the broadened middle region, the ovary narrows posteriorly.

(1990) and are given in table 46.

4.6.3. Histology of Ovary.

The immature ovaries of *M. equidens equidens* and *M. equidens pillaii* are surrounded by a thin ovarian wall, which is composed of two distinct layers (E). The outer layer of pavement epithelium is thin and moderately basophilic with haematoxylin-eosin staining. The inner layer is thick, basophilic and is identified as germinal epithelium. These two layers of cells are connected together by a thin layer of connective tissue. The inner epithelium of the ovarian wall together with the structureless lamina form a close investing layer around the developing oocytes, thus forming the follicles. The follicles are in the form of small compartments enclosing the developing ova (Fig. 34A).

4.6.4. Germogen.

Germogen (G) is the region of inner epithelium from where new oogonial cells are budded off. In cross section, each ovary contains a ridge of tissue which appears in the form of a finger shaped invagination, arising from the region where the two ovarian lobes meet ventrally. This region is also known as the germinal zone or formative region. The germinal zone of *M. equidens pillaii* is invaginated more centrally than *M. equidens equidens*. The zone of proliferation persists in all maturity stages (Fig. 34A & B).

4.6.5. Histological changes associated with growth of ova.

The histological changes associated with the growth of ova in both the subspecies follow almost similar patterns. The following description relates to the oogenesis of *M. equidens equidens*. Considerable variations have been observed in the deposition of yolk platelets in the two subspecies and these have been dealt in detail at appropriate places.

The growth of ova in the ovary is a dynamic process comprising of a generative phase or proliferative phase and a vegetative phase or growth phase. Depending on the histomorphology of ovary the process of oogenesis has been classified into five stages based on the classification of Kulkarni and Nagabushanam (1982), Nadarajalingam and Subramoniam (1982) and Jayachandran and Joseph (1988).

4.6.5.1. Oogonial stage.

The oogonia are the newly budded off cells from the germogen. They are seen in clusters in the immediate vicinity of the germogen. These cells are characterized by small rounded or oval cells, with a large central nucleus, which is basophilic (Oo). Both the nucleus and cytoplasm stain dark with haematoxylin. The prominent nucleus is surrounded by a thin rim of homogenous cytoplasm which is free of granules. The boundary between the Oocytes is inconspicuous.

The follicle cells (F) are obviously absent in this stage (A). The oogonial cells are present throughout the maturation cycle and are transformed into previtellogenic phase. The nucleolus is not distinguishable (Fig. 34A & B).

4.6.5.2. Previtellogenesis I.

After a period of division and growth, the oogonial cells are transformed into the primary oocyte stage. The primary oocytes (Po) assume varying shapes due to pressure exerted by the surrounding cells. These are seen crowded immediately around the germinal zone peripheral to the oogonial cells. The characteristic feature of oocytes at this stage is the possession of large dense active nucleus and strongly basophilic granular cytoplasm in greater volume. The chromatin matter inside the nucleus stains deep with haematoxylin (Fig. 34A & B, 35A & B).

At a later stage the nucleus of the primary oocyte becomes enlarged and less dense called the germinal vesicle (N). The germinal vesicle occupies a major part of the oocyte with only a thin film of cytoplasm around it. The germinal vesicle is round in outline. The germinal vesicle contains deeply stained nucleolus. The nucleolus is seen either in the centre of the germinal vesicle or to one side. The end of this stage is marked by the appearance of two nucleolii (n) inside the nucleoplasm. The previtellogenic oocytes are seen in the ovary of all stages of maturation except stage VI. However they are abundant in stages I, II, III and rare in IV and V (Fig. 36A; 34B).

4.6.5.3. Previtellogenesis-II.

In this stage also the oocytes are either rounded, oval or polygonal in outline. The germinal vesicle is large which occupies a major part of the oocyte. At this stage two nucleolii (n) are seen which is a characteristic feature of this stage. In some oocytes the nucleolii may be smaller. Very often the two nucleolii may be seen free in the nucleoplasm. The nucleoplasm is finely granular with a few larger granules of scattered chromatin. The follicle cells (F) are prominent at this stage (Fig. 36A; 34B).

During this phase the volume of the cytoplasm has increased considerably. The cytoplasm appears clear and non-granular. Oocytes of this stage are observed in stages II, III & IV.

4.6.5.4. Vitellogenesis-I.

This stage is characterised by the appearance of yolk vesicles (V) in the ooplasm which are spherical in shape. The germinal vesicle is very conspicuous. The nucleus, as well as the ooplasm are basophilic. The nucleoplasm is non-granular. The germinal vesicle may contain a nucleolus. During this stage the volume of cytoplasm increase to a greater extent and the cytoplasm becomes granular. In the cytoplasm small, oval or spherical or oblong lipid vesicles start appearing. At first stage these vesicles are peripheral in one or two concentric layers (Fig. 36B; 35B).

At a later stage the entire ooplasm is filled with these vesicles. From this stage onwards two groups of oocytes could be noticed - the oocytes concentrated around the germogen without lipid vesicles and the outer zone of oocytes with lipid vesicles. The oocytes seen crowded around the germogen are small and are in the previtellogenesis-I and II. The oocytes seen in the outer zone are in the advanced stage of development. The oocytes of the outer zone continue its growth and finally attain maturity and are ovulated into the brood chamber. During this time the immature ova remain dormant. After ovulation of the first batch a second batch of ova from the immature stock enter into the vitellogenic stage.

At this stage, each oocyte is covered with follicles. The follicle cells are oval in shape and highly basophilic. These oocytes are observed in maturity stages III, IV and V, their number being highest in stage IV.

4.6.5.5. Vitellogenesis-II.

The oocytes of this stage are marked by the increase in size and accumulation of yolk platelets (y) amidst lipid vesicles. The nucleus are not visible. The yolk platelets start its appearance only after the cytoplasm gets filled with lipid vesicles. The yolk platelets are highly acidophilic (Fig. 37A).

A characteristic difference of yolk platelet deposition has been noticed in M. equidens pillaii. Here the yolk platelet (y) deposition starts much earlier, i.e., soon after the formation of two layers of concentric lipid vesicles (Fig. 37B). This is in contrast to what is observed in M. equidens equidens where the yolk platelet deposition commences only after filling the entire cytoplasm with lipid vesicles.

The folliculogenesis is observed to be complete at this stage. The follicle layer at this stage is membraneous with scattered nuclei here and there.

The disappearance of the nuclear membrane does not mark the end of the growth period of oocyte. It increases in size by further yolk, platelet accumulation. The follicle cells surrounding the oocytes are completely flattened. These oocytes (O) are observed in maturity stages V and VI (Fig. 38A & B).

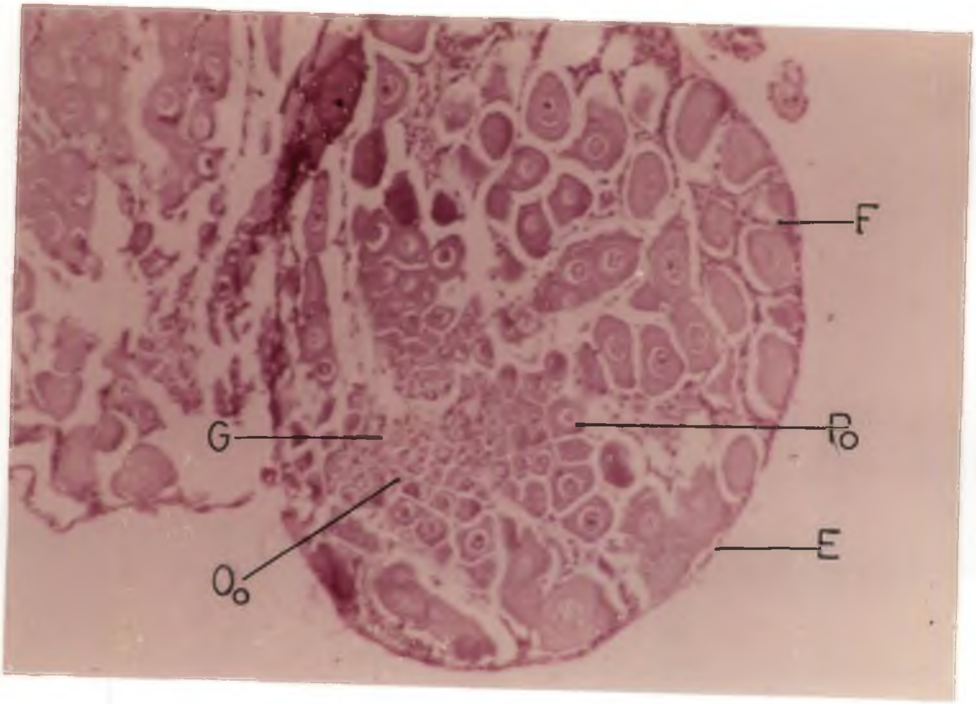
4.6.5.6. Degenerating or Resorbing Oocytes.

Fully mature ova are shed into the brood chamber. Sometimes one or two mature ova may remain unovulated. Such eggs undergo degeneration (D). In the ovarian tissue, these oocytes are marked by disintegrated nucleus, irregular shape enlarged connective tissue (ct) and unclear cellular details (Fig. 39A & B).

Fig. 33A. Electrophorograms of water soluble muscle proteins of _M. equidens equidens_ and _M. equidens pillaii_ (Photograph).

Fig. 34A. Photomicrograph of immature ovary of *M. equidens equidens* showing germogen (G), Oogonia (Oo), follicle cells (F) Germinal epithelium (E) and previtellogenic oocytes, Haematoxylin and Eosin staining 5 u sections x 5.

Fig. 34B. Photomicrograph of immature ovary of *M. equidens pillaii* showing the Germogen (G), Oogonial cells (Oo), Follicle cells (F), Previtellogenic oocytes (PO), with two nucleoli (n) and prominent nucleus (N), Haematoxylin and Eosin staining 5 u section x 10.


F
G
Po
E
Oo

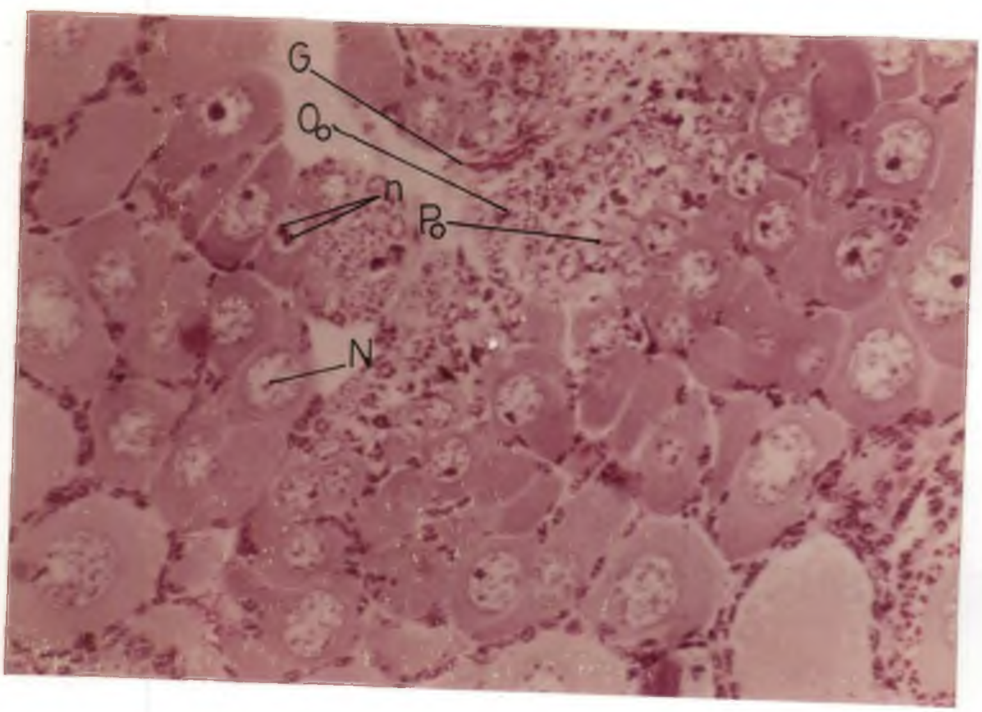
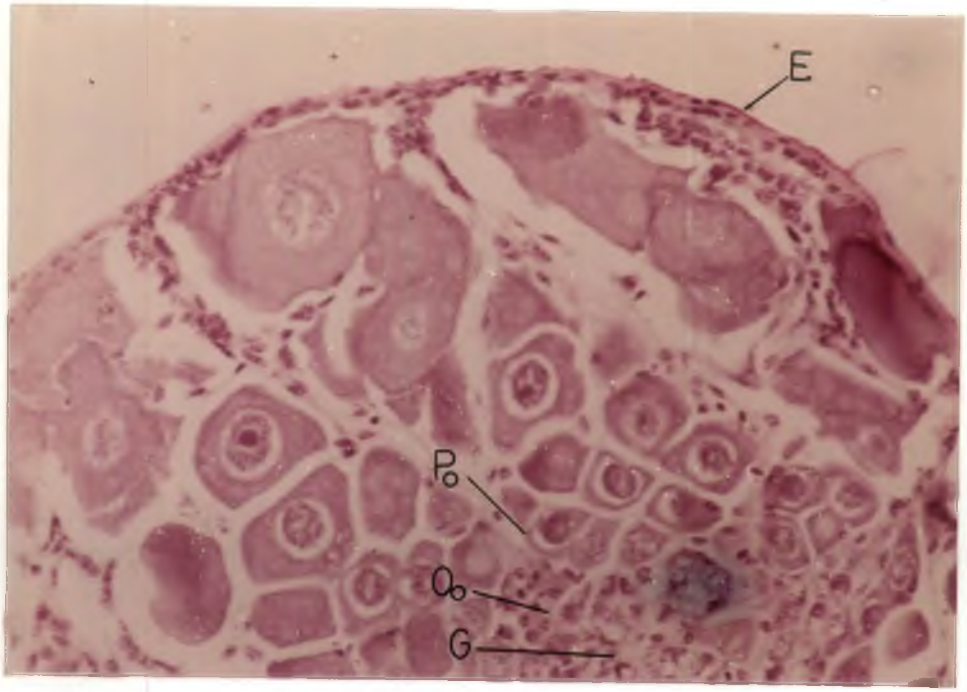

G
Oo
n
Po
N

Fig. 35A. Photomicrograph of part of immaure ovary of M. equidens equidens showing Oogonial cells (Oo), Germogen (G), Germinal epithelium (E), and Previtellogenic Oocytes (PO), Haematoxylin and Eosin staining 5 u sections x 10.

Fig. 35B. Photomicrograph of part of immature ovary of M. equidens pillaii showing the Follicle cells (F), Germogen (G), Oogonial cells (Oo), Previtellogenic oocytes (PO), with prominent nucleus (N).


E
Po
Oo
G

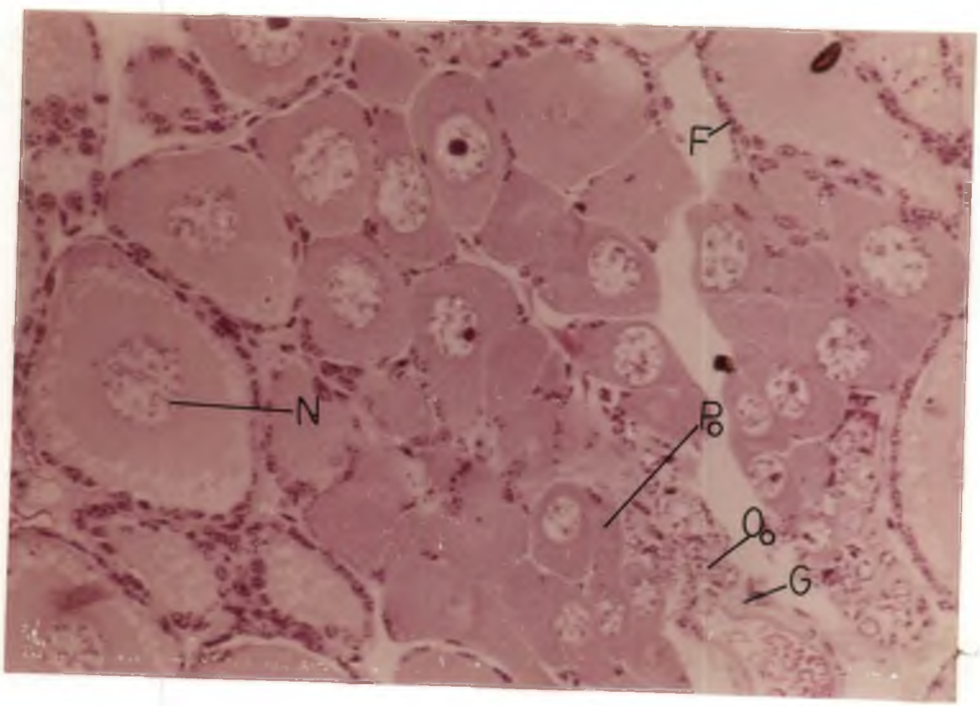
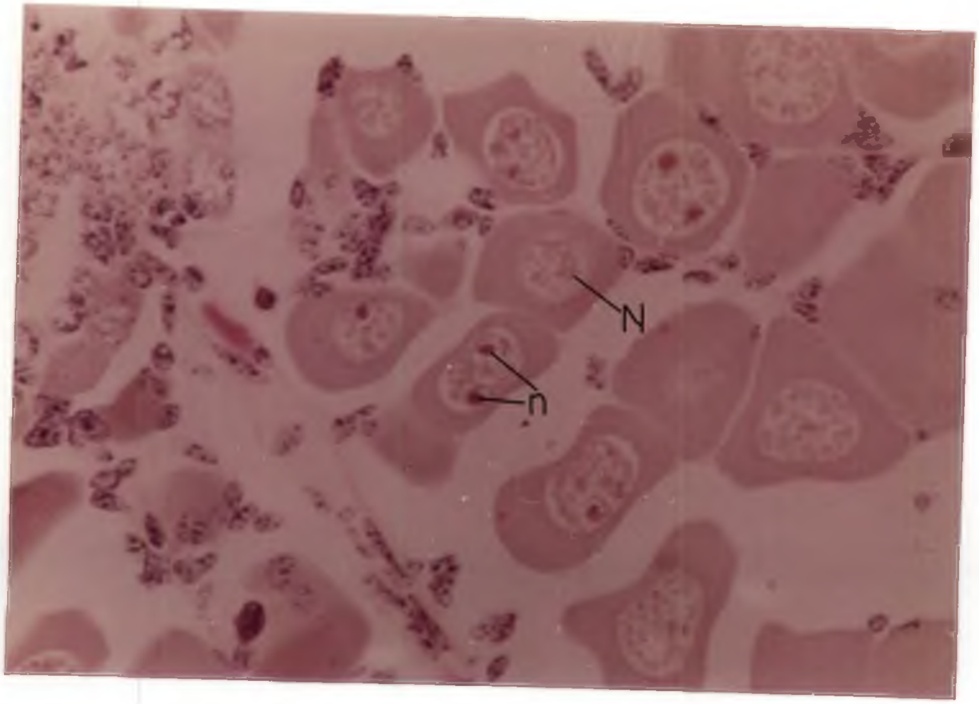

F
N
Po
Oo
G

Fig. 36A. Photomicrograph of Previtellogenic II oocyte of *M. equidens equidens* showing prominent nucleus (N) and two nucleoli (N).

Fig. 36B. Photomicrograph of Vitellogenic stage I oocyte of *M. equidens equidens* showing lipid vesicles (V), along the periphery of ooplasm and nucleus (N). Follicle cells are seen surrounding the oocyte. Haematoxylin and eosin staining 5 u sections x 20.


N
n

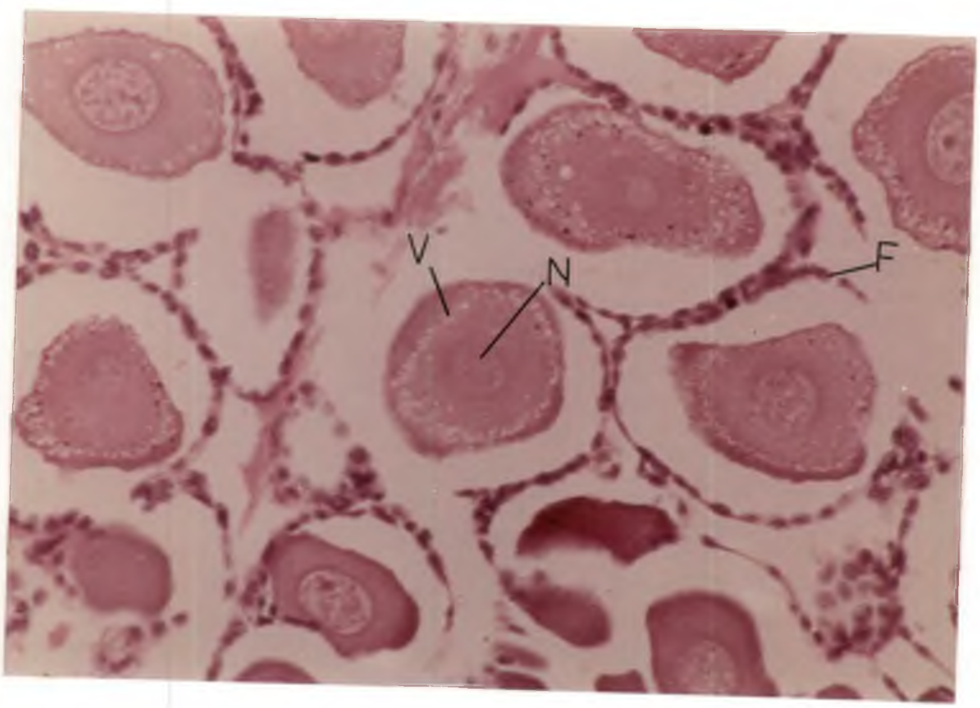
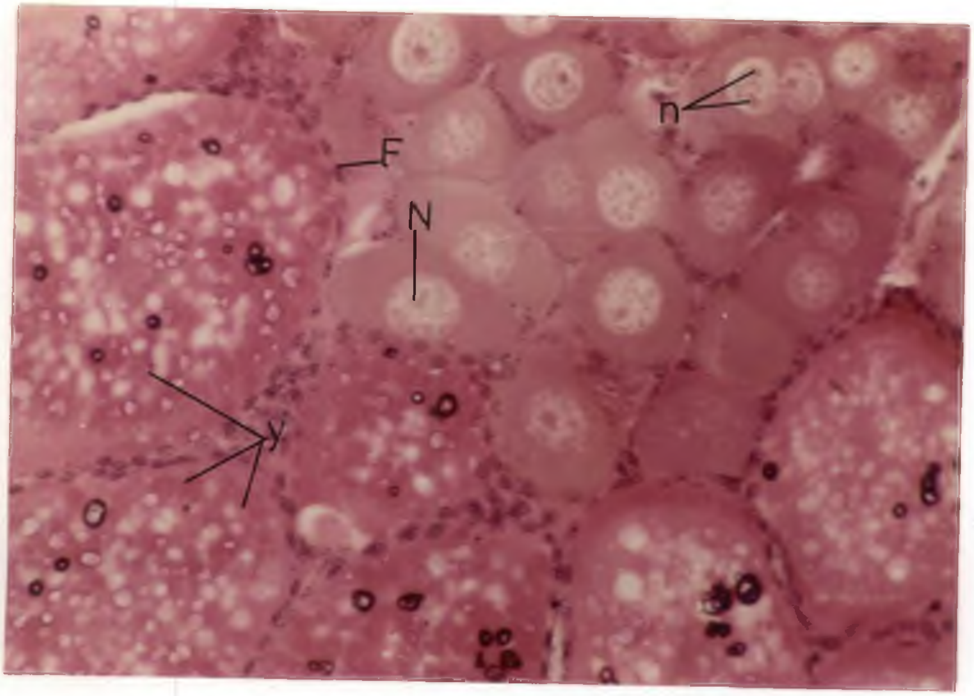

V
N
F

Fig. 37A. Photomicrograph of part of mature ovary of M. equidens equidens showing sequential arrangement of oocytes-Oogonial cells (Oo) more centrally, followed by previtellogenic oocytes (P I/P II) and Vitellogenic oocytes (VI and VII). The previtellogenic oocytes with two nucleoli (n), nucleus (N), and vitellogenic oocytes with yolk platelets (Y) can be seen Haematoxylin and Eosin staining 5 u sections x 10.

Fig. 37B. Photomicrograph of oocytes of M. equidens pillaii in the vitellogenic stage I in which yolk platelets (Y) start depositing immediately after the deposition of two layers of lipid vesicles. Follicle cells completely surrounding the oocyte, nucleus (N) and nucleolus (N) can be seen Haematoxylin and Eosin staining 5 u sections x 10.


n
F
N
y

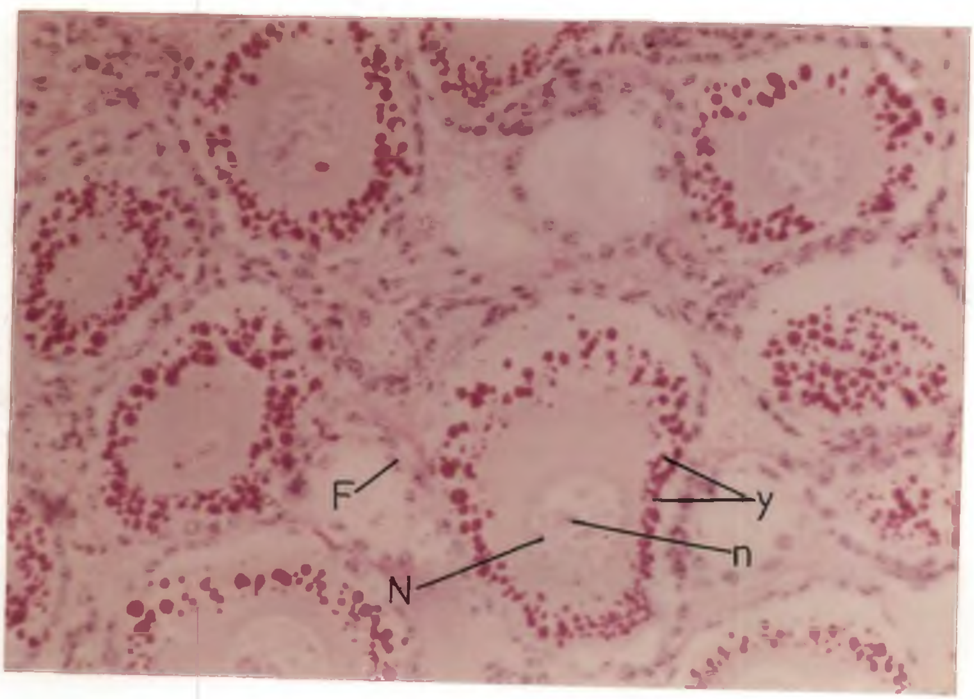

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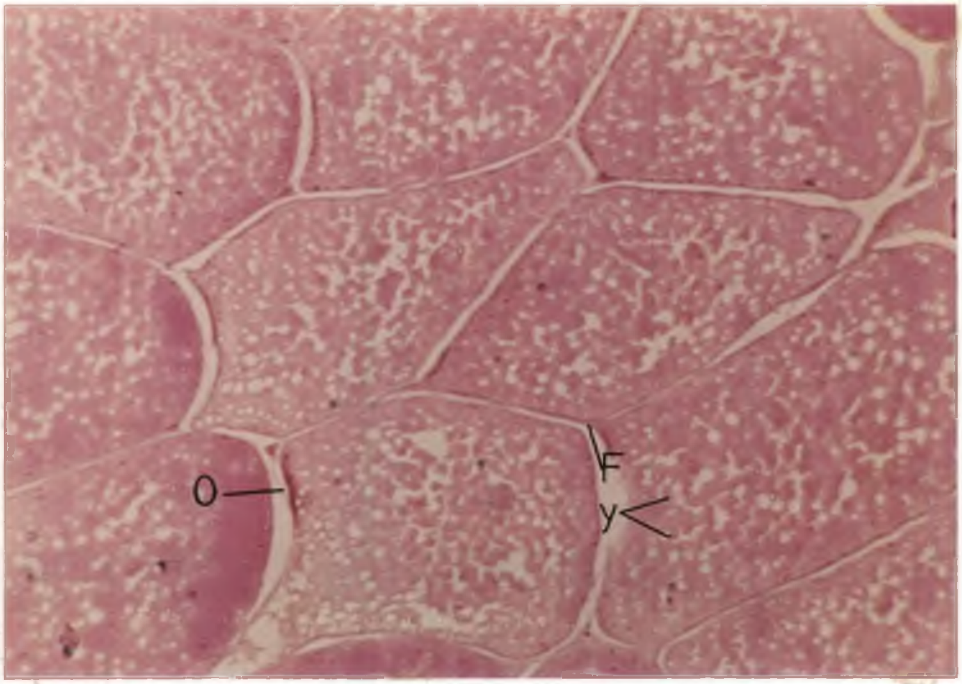
Fig. 38A. Photomicrograph of mature ovum (O) of *M. equidens equidens* showing the yolk platelets (Y) of Follicle cells (F), Haematoxylin and Eosin staining 5 u sections x 10.

Fig. 38B. Photomicrograph of mature ovum (O) of *M. equidens pillaii* showing the yolk platelets (Y) Follicle cells (F), Haematoxylin and Eosin staining 5 u sections x 10.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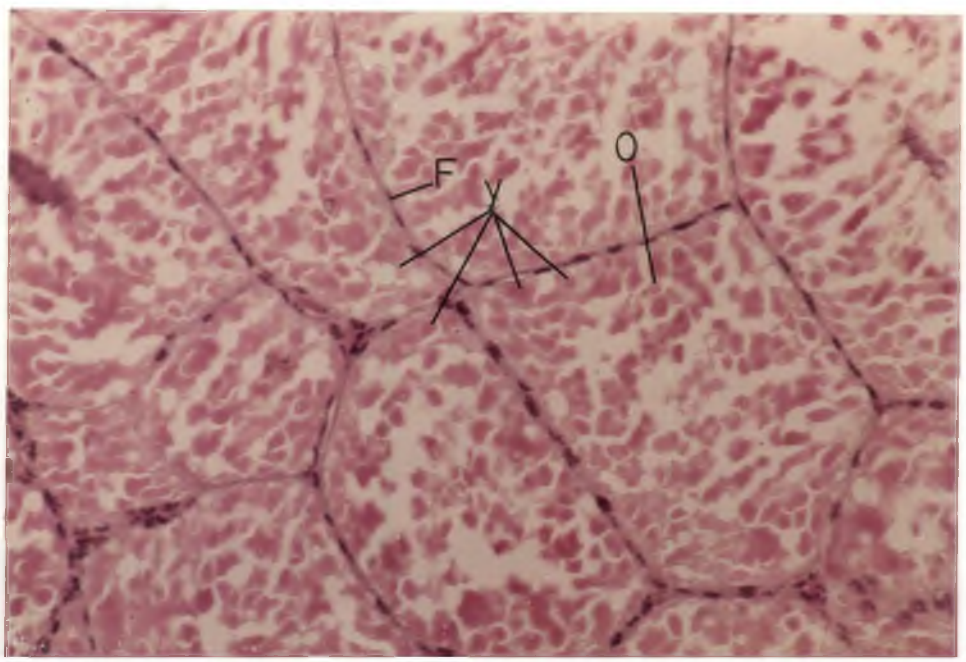
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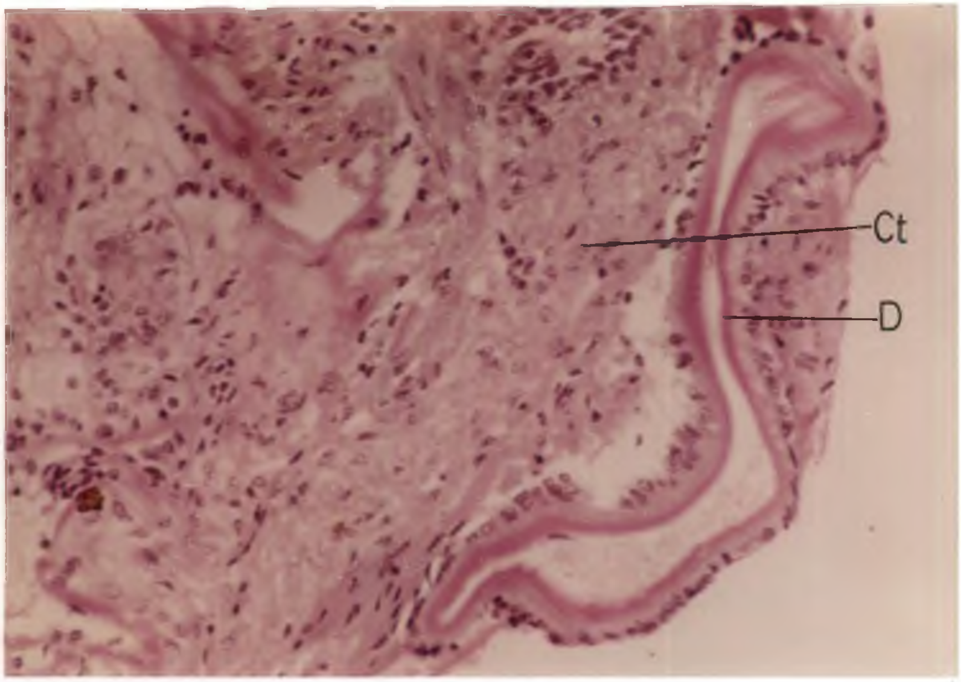
Fig. 39A. Photomicrograph of an atretic oocyte of *M. equidens equidens* showing degenerating ova ($\bar{D}$) and connective tissue (Ct).

Fig. 39B. Photomicrograph of an atretic oocyte of *M. equidens pillaii* showing degenerating ova ($\bar{D}$) and connective tissue (Ct).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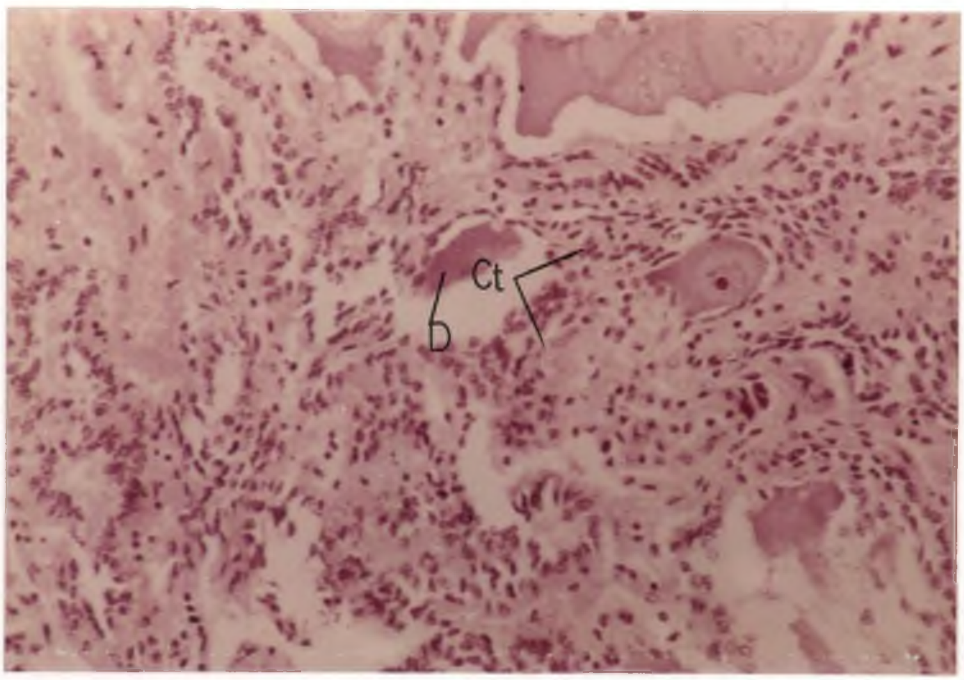
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DISCUSSION

V. DISCUSSION

5.1. Systematics

Dana (1852a) described a new species from Singapore waters under the name Palaemon equidens. According to him this species is characterized by:

1. A long, upwardly curved rostrum which extends beyond the antennal scale.

2. Smooth carapace
3. Upper margin with 10-11 teeth and lower margin with 6 teeth
4. Long second cheliped with both the fingers entirely pubescent.

Subsequently, this species has also been described by some taxonomists under the very same name (Dana, 1852a; 1855; Weitenweber, 1854; Von Martens, 1868; De Man, 1888a; Ortmann, 1891) and the characters mentioned in all these descriptions are comparable, and found to belong to P. equidens Dana.

De Man (1852) described a species from Flores and Celebes under the name Palaemon (Eupalaemon) sundaicus. This description was based on female specimens. The good illustration of the specimens reveals the following details.

1. Rosrum is long, slender, and distal end curved upwards.
2. Upper margin of rostrum bears 11 teeth of which two teeth are post-orbital.
3. Lower margin bears 4 teeth.
4. Carapace is smooth.
5. Both antennal and hepatic spines are situated in a line.

The characteristic shape, arrangement of teeth both on the upper and lower margins of the rostrum, comparatively smooth carapace and position of antennal and heptic spines undoubtedly establishes its identity with Palaemon equidens Dana and therefore Palaemon (Eupalaemon) sundaicus De Man is a synonym of P. equidens Dana (Holthuis, 1950). But De Man in the same publication (1892, page 453, Pl. 26, Fig.36) described yet another species under the name Palaemon (Eupalaemon) equidens. The fingers of second chelate leg of this species possessed 3 to 4 denticles on the proximal part of the cutting edges. The characters of the rostrum, smooth carapace and denticles of the fingers of the 2nd chelate leg confirm that this species doesnot belong to P. equidens Dana but, as already expressed by De Man (1897), Kemp (1918) and Holthuis (1950), belong to M. australe (Guerin-Meneville). Many scientists have followed De Man in naming their specimens as: Palaemon (Eupalaemon) sundaicus (Weber, 1897; Hilgendorf, 1898; Coutière, 1901; Nobili, 1903; J. Roux, 1917; 1919; 1932), Palaemon sundaicus (Lanchester, 1966; Cowles, 1915; Stebbing, 1915; Kemp, 1918; Yu, 1931; Estampador, 1937; Barnard, 1947) or Eupalaemon sundaicus (Stebbing, 1910; Barnard, 1920).

Holthuis (1950) reported that "comparison of Stebbing's description and figures with the present species makes it clear that Urocaridella borradailei is nothing other than Macrobrachium equidens as is shown by the shape of the rostrum and the situation of the hepatic spine". Barnard (1947) already pointed out that Stebbing's Urocaridella borradailei belongs to P. equidens.

In literature many varieties of Palaemon sundaicus have been reported viz. var bataviana De Man, var. brachydatyla Nobili (1899), var. De Mani Nobili (1899) and var. baramensis De Man 1902). The var. bataviana is characterized by the presence of:

a) Slightly longer rostrum.
b) Carpus of 2nd leg 1 1/3 times as long as merus.
c) Palm of second chela slightly shorter than the merus.
d) The fingers of the longer second leg are provided with closely packed woolly hairs.
e) The less slender legs.

The var. brachydactyla Nobili is characterised by

a) The fingers of the 2nd legs are very much shorter than the palm, the relation being $\frac{1}{2.2} - \frac{1}{2.3}$
b) Hairs are present on the fingers on 2nd legs.

The var. De mani Nobili possesses the following diagnostic characters.

1. The specimens are smaller (Ovigerous females of 45-52 mm) than in the typical form (70-82 mm).

2. Only two (seldom three) teeth of rostrum placed behind the orbit.

3. The carpus of second leg is less slender, because it is more thickened anteriorly.

4. The palm is somewhat longer than merus.

The Var. baramensis according to De Man are -

a. The rostrum is only slightly curved upwards distally.
b. The hepatic spine lies slightly lower than in the typical form.
c. The carpus of the second leg is almost twice as long as the merus.

Holthuis (1950) has made elaborate studies on the specimens of these varieties from various localities of the world and also the literature concerning M. equidens and came to the conclusion that all the above varieties are one and same.

Johnson (1966) while listing the edible crustaceans of Malaysia, has mentioned the prawn, Cryphiops (Macrobrachium) equidens which refers to M. equidens only.

Henderson and Matthai (1910) described a new species from Cochin backwaters (Palaemon sulcatus). Their description was based on 6 specimens of which 5 were males and rest a female. In their collection two types of specimens could be recognised and the striking characters of each category is given below:

Type - 1 (3 male specimens)

1. Rostrum is short which extends nearly as far as the distal margin of the antennal scale.

2. Upper margin of rostrum stright (distal end not curved upwards, or if at all only very slightly curved upwards).

3. Upper margin bears from 11 to 12 teeth of which 3 teeth post orbital.

4. Lower margin possess 4-6 teeth.
5. Palm of 2nd chela subcylindrical.
6. Tip of fingers incurred.
7. Presence of a lateral groove free of spinules which runs along the outerside of merus, carpus, and palm, being most distinct on the carpus.

8. Dark brown mottlings occur on fingers.

9. Only the movable finger is entirely pubescent while the immovable finger is with hairs restricted on the cutting edges.

Type II (2 Male specimens)

1. Upper margin is concave (distal end curved upwards).

2. Rostrum is long which extends beyond the distal end of antennal scale.

3. Upper margin bears 11-12 teeth of which 3 teeth post-orbital.

4. Lower margin bears from 4-5 teeth.

Jayachandran (1989) and Jayachandran and Joseph (1989; 1992) observed two subspecies from Cochin backwaters and also from other backwaters and estuaries of the south-west coast of India (M. equidens equidens and M. equidens pillaii). These are the only descriptions as subspecies. The characters for these two subspecies are as described for Type I and II by Henderson and Matthai (1910). Detailed investigations have been undertaken in order to establish the status of the two subspecies. The results indicate that these subspecies have the credibility to be elevated to the species level. M. equidens equidens is nothing but P. equidens Dana (= M. equidens) and type II of Henderson and Matthai and M. equidens pillaii is actually the type I of Henderson and Matthai.

The description of P. sulcatus is based on the largest specimen having a total length of 93 mm. It possessed in addition to the straight rostrum all other characters mentioned for type I. The particular nature of pubescence, i.e., pubescence similar to P. idae (=M. idella) is quite characteristic to M. equidens pillaii which is in contrast to M.equidens equidens where both the fingers are entirely pubescent. Unfortunately, Henderson and Matthai did not mention this character for their specimens measuring 82 mm in total length. Similarly mottling on the fingers could be observed only if pubescence is absent. Taking all these into consideration it can be confirmed that the type I is essentially M.equidens pillaii and type II is M.equidens equidens. Both these studies are based on specimens from Cochin backwaters. Henderson and Matthai (1910) did not mention the colouration of their specimens probably because they did analyse preserved specimens.

After taking up the present investigation, Pillai (1990) has described a new species under the name Macrobrachium striatus. He has created this new species mainly because of the difference in the larval characters. He has also reported that these two species do not interbreed. A comparison of the important characters of P. sulcatus, M. equidens pillaii and M. striatus (See Henderson and Matthai, 1910; Jayachandran, 1989; Jayachandran and Joseph, 1989; Pillai, 1990), will help to prove conclusively that they all belong to the same taxon.

5.2. Morphometric Studies

Two kinds of analysis have been carried out, namely, growth patterns between sexes of each subspecies and growth patterns between males and between females of the two subspecies. It is found that the growth patterns of carapace length, cephalothoracic length, rostral length, telson length, ischium length, merus length ischium length, propodus length, palm length, total length and 2nd cheliped are higher in males than in females in *M. equidens pillaii*. The rate of growth of cephalothorax in relation to carapace length is higher in males than in females in both the subspecies. A comparison of rates of growth of the podomeres in relation to 2nd cheliped of males and females of the two subspecies showed that males of both the subspecies exhibited higher growth rates with regard to ischium, merus, carpus and palm lengths. The length of propodus alone showed significant difference between males of the two subspecies. In *M.equidens equidens* growth rate of propodus is in favour of females whereas in the other subspecies it is in favour of males. The growth rate of dactylus in both subspecies is in favour of males.

In *M. lamarrei* the growth rate is higher in females than in males (Koshy, 1969). In *M. idella* the growth rates of carapace length and telson length in relation to total length are faster in males whereas that of carapace width in relation to carapace length is faster in females (Jayachandran and Joseph, 1988a). In *M. scabriculum* the growth rate is higher in males in all the characters studied (Jayachandran and Joseph, 1985).

In both the subspecies the average sizes of all the characters are greater in males than in females. In many species of *Macrobrachium*, the males grow larger than females. Thus *M. rosenbergii*, *M. malcolmsonii*, *M. idella* and *M. scabriculum* generally come under this category. In variance with this, Jayachandran and Joseph (1985, 1988a) found the average length and width of carapace length of rostrum and length of telson of M. idella are higher in females than in males.

In some other species of the genus Macrobrachium, the females are larger than the males. This has been reflected in the growth studies in M. lamarrei lamarrei (Koshy, 1969).

Comparitive analysis of growth patterns, growth rates and average sizes between the males and between the females of the two subspecies revealed interesting results. It can be seen that out of the 11 characters of males related to total length of the two subspecies 8 characters (abdominal length, ischium length, merus, length, carpus length, propodus length, dactylus length, palm length and total length of IInd cheliped) showed significant difference between them. All the 3 characters which are related to carapace length exhibited significant difference in growth patterns. Similarly 3 (ischium, propodus and palm) out of 6 segments of the second cheliped when related to its total length showed significant difference in growth patterns.

The growth rates of various body parts in relation to total length, carapace length and total length of 2nd peraeopod when compared between males of the two subspecies, M. equidens pillaii showed faster growth rate for most of the characters than

M. equidens equidens except the case of abdominal length and ischium length. Telson length in relation to total length and merus length in relation to the total length of 2nd cheliped, showed similar growth rate. However the average size is found to be in favour of *M. equidens equidens* except palm length in which it is in favour of *M. equidens pillaii*.

A similar analysis of growth patterns, growth rates and average sizes between females the two subspecies, significant differences in the growth patterns have been observed with regard to merus, carpus, propodus, palm and dactylus. It can be seen that the growth rates of *M. equidens pillaii* is slightly faster in majority of the characters. However, the average sizes of carapace length, abdominal length, telson length, body length, ischium length, cephalothoracic length, rostral length and width of carapace are greater in *M. equidens equidens*. The average sizes of the remaining characters are in favour of *M. equidens pillaii*.

The present detailed morphometric analysis conclusively proves that the two subspecies differ very much in a number of characters, such as abdominal length, cephalothoracic length, rostral length, width of carapace, abdominal length, ischium length, merus length, carpus length, propodus length, dactylus length, palm length and total length of 2nd chelipeds. These characters are to be considered taxonomically most valid ones for establishing the status of the

Joseph (1988) for M. idella and M. scabriculum. Males of M. equidens equidens have a higher growth rate which is in variance with M. equidens pillaii, where females have a higher growth rate. Higher growth rate of females have been reported for M. idella and M. scabriculum alsoo (Jayachandran and Joseph, Op. cit). In both the subspecies the average weight is in favour of males. In the case of M. idella females have a higher average weight than males whereas males have higher average weight in M. scabriculum. The males of M. rosenbergii in general weigh more than females in the North, Balgoda lake in Sri Lanka (Jinadasa, 1985).

The analysis showed that the two subspecies exhibit allometric growth.

The unit increase in weight with unit increase in length of females of M. equidens pillaii is found to be higher than the isometric growth value 3. In a number of palaemonid as well as penaeid prawns, similar situations have been reported, viz., M. malcomsonii from Hooghly estuary (3.38788 - male; 3.82041 - female). (Ibrahim, 1962), M. rosenbergii from Hooghly estuarine system (3.1935 and 3.2276 for the species) (Rajyalakshmi, 1961 and Rao, 1867) and from Vembanad lake (3.1803 for males). Kurup et al., 1992); M. idella from Vellayani lake, (3.4773 - male and 3.5142 - female) (Jayachandran and Joseph, 1988) and from Vembanad lake (3.31 - male and 3.243 - female) (Kurup et al., 1992); P. monodon

(3.1032 - males) (Rao, 1971); P. indicus (3.4554 - male and 3.0776 - female) (Rao, 1971). However, the males of M. equidens pillaii and both the sexes of M. equidens equidens showed a growth rate lower than the cube of its length. In the case of Leander styliferus (2.8754) (Kunju, 1955); M. monoceros (2.7603) (George, 1959); Parapenaeopsis sculptilis (2.944) (Hall, 1962), Metapenaeus affinis (2.7867) (Subrahmanyan, 1967); females of P. monodon (2.9022) (Rao, 1971) and in females of M. rosenbergii (2.5208) (Kurup et al., 1992) the growth values are lower than 3 as obtained in the case of the males of M. equidens pillaii.

The 't' test indicates that in the two subspecies, the growth departs significantly from the isometric growth value-3. Therefore, the formula $W = aL^n$ may be taken ideal for representing the length-weight relationship.

When the growth pattern and growth rate of males of the two subspecies are compared, it is found that the males of the two subspecies differ significantly. Similarly, the growth pattern and growth rate of the females of the two subspecies also differ significantly.

These results conclusively prove that the two populations are distinct species.

5.5. Electrophoresis

Electrophoresis of water soluble proteins has been used for confirming the identity of a species and also for establishing the status of two or more closely related species (Tusuyuki et al, 1965; Mackie, 1969). It is generally found that the difference between the band patterns of very closely related species is of high magnitude.

A comparison of the elctrophoretic pattern of the water soluble muscle proteins of the two subspecies shows that there is marked difference in the number of bands. Certain zones are common to both the subspecies, and some others are absent in any one. These clearly show that the two subspecies are quite different which is in variance to the observation by Holthuis (1950). There are 6 bands in M.equidens equidens and only 4 in M.equidens pillaii.

Apart from the elaborate studies on fishes (Tusuyuki and Roberts 1965); Tsuyuki et al 1968; Ficher and Tsuyuki, 1970; Kurian, 1971, Dhulked and Rao, 1976; Menezes, 1979, Theophilus and Rao, 1988; Chakraborty, 1990) there are similar studies in crustaceans as well (Fielder, 1971; Pandian, 1975; Lester, 1979; Kulkarni, 1980; Thomas, 1981; Mulley and Latters, 1981; Philip, 1989; Lavery and Staples, 1990).

In the genus Metapenaeus, the band pattern of three species differ very much. The number of bands in M. monoceros, Josy and Diwan (1992) could recognise only 6 maturity stages in M. idella. Philip and Subramoniam (1992) have also observed 6 maturity stages in M. malcolmsonii.

In both M. equidens equidens and M. equidens pillaii, there is a well developed germogen, which is seen as a finger like invagination arising from the region where the two ovaries meet ventrally. Adiyodi and Subramoniam (1983) while reviewing the germarium in crustaceans had grouped them into 5 broad categories such as 1) peripheral, 2) peripheral but confined to lateral or ventral regions as a thin band, 3) central as a germinal cord, 4) germ nests and 5) peripheral with germinal nests. The germarium of the prawns presently studied, in all probability belongs to the second category mentioned above, eventhough at mature stages, it is more centrally placed. In lower crustaceans there is no well defined area in the inner layer of ovary which acts as the germogen where the ova are budded off from the general inner layer of the ovary (Calman, 1909). On the contrary in higher crustaceans the germogen area is restricted to certain regions of the ovary. In Parapenaeopsis hardwickii the germogen is ventrolateral in position (Kulkarni and Nagabhushanam, 1982). In M.malcolmsonii the inner lateral sides of the ovary invaginates from the germogen (Charles and Subramoniam, 1982). In M.idella a similar condition has been observed in which the germogen is located on the mesial wall of the ovary in the from of finger like projections. (Jayachandran and Joseph, 1988b;Joshi and Diwan, 1992). However in M.lamarrei, the entire inner wall of the ovary acts as the germarium. Therefore, the two subspecies under study resemble other palaemonids mentioned above except M.lamarrei.

Information concerning the suquential changes of oocyte growth within the ovary in palaemonids is meagre. In agreeing with the observations of Nadarajalingam and Subramoniam (1982) and Jayachandran and Joseph (1988b, 6 well marked histological stages have been identified in M.equidens equidens and M.equidens pillaii namely, Oogonial stage, Previtellogenesis I and Previtellogenesis II, Vitellogenesis I and Vitellogenesis II and degenerating stage. Charles and Subramoniam (1982) identified only 5 histological stages for M.malcolmsonii and M.lamarrei. The present investigation revealed that sequential changes of oogenesis of M.equidens equidens follows the same pattern as observed in other palaemonids like M. idella, and P. serratus. However the early stages of (Oogonial and previtellogenesis) M. equidens pillaii resembles those of M. equidens equidens as well as M. idella and P. serratus whereas the latter stages of vitellogenesis, show considerable variation between the two subspecies. Here the yolk platelets deposition commences immediately after the formation of two layers of lipid vesicles. This feature has not so far been reported in any other palaemonid under normal conditions. However Kamiguchi (1971) reported that yolk granules deposition starts immediately after the formation of two layers of lipid vesicles in Palaemon paucidens under bilateral eyestalk extirpation.

investigation also this groove has been observed in *M. sulcatus*. Such a groove is not clearly seen in *M. equidens*. In the light of these, the valid names proposed for these species are -

1) *Macrobrachium equidens* (Dana, 1852), the spotted prawn and
2) *Macrobrachium sulcatus* (Henderson and Matthai, 1910), the striped prawn.

SUMMARY

VI. SUMMARY

Two distinct populations of Macrobrachium equidens namely, the spotted and the striped varieties co-exist in Cochin backwaters and other estuaries and backwaters of the west coast of India. In Cochin area they support a minor fishery. A review of literature reveals that a lot of confusion exists in the taxonomic status of these two populations. In this context a thorough study became absolutely essential, in order to establish the status of the two populations.

Detailed investigations on the following aspects have been carried out.

1) Morphological
2) Morphometric
3) Meristic
4) Length-weight relationship
5) Electrophoresis
6) Oogenesis

1) Detailed descriptions of the two subspecies have been given in the text.

2) There are characters which are constant for each subspecies and no intermediary forms have been noticed. This may be because of the fact that these two populations do not interbreed.

3) The two subspecies differ markedly in their colouration. *M. equidens equidens* is spotted in colouration whereas *M. equidens pillaii* is striped.

4) Detailed morphometric studies have been carried out. The results revealed that the growth patterns between the males of the two subspecies showed significant difference (either at 1% or 5% level) in the case of the characters such as abdominal length, carapace length, ischium length, merus length, propodus length (characters related to total length) cephalothoracic length, rostrum length and carapace width (characters related to carapace length) and lengths of ischium, propodus and palm (characters related to 2nd cheliped). The growth rates of all the characters studied are higher in the case of *M. equidens pillaii* except for the abdominal length and ischium length. However, the mean values of all characters are higher in the case of *M. equidens equidens*.

5) The females of the two subspecies also showed significant difference in the growth patterns of the following characters - Lengths of merus, carpus, propodus, dactylus in relation to total length and ischium, propodus and palm in relation to length of 2nd cheliped. The growth rate of carpus, palm, cephalothoracic, carapace and abdominal is higher in *M. equidens equidens*. The average size of all characters is higher in *M. equidens equidens* except for merus, carpus, propodus, dactylus and palm.

6) The meristic counts of dorsal, post-orbital and ventral teeth have been taken and subjected to chi-square analysis. In the males of both the subspecies the range of dorsal teeth has been from 9-12 whereas in the females the range has been between 8-12 (M. equidens equidens) and 10-11 (M. equidens pillaii).

7) The number of post orbital teeth ranged between 3-5 and 3-4 for males and females respectively of M. equidens equidens and 2-6 and 3-4 for males and females of M. equidens pillaii respectively.

8) In the case of ventral teeth, both the sexes of M. equidens equidens have shown homogeneity (4-6). The males and females of M. equidens pillaii possessed 3-5 and 4-5 teeth respectively.

9) The percentage frequency distribution of dorsal, post-orbital and ventral teeth have been statistically worked out. In males of both the subspecies the most frequent number of dorsal teeth is 10 (51.4% - M. equidens equidens and 57.8% - M. equidens pillaii) which is followed by 11 (34.7% - M. equidens equidens and 32.8% - M. equidens pillaii). In the females of both the subspecies the most frequent occurrence of dorsal teeth is 10 (68.1% - M. equidens equidens and 74.2% - M. equidens pillaii) which is followed by 11 (11.6% - M. equidens equidens and 25.8% - M. equidens pillaii).

10) In both the sexes of M. equidens equidens the maximum percentage occurrence of post orbital teeth is 3 (80% - male; 95.1% - female) which is followed by 4 (20% male; 43% female) whereas in M. equidens pillaii, it is 4 (57.8% - male; 54.8%- female) which is followed by 3 (34.4% - male; 48.4% - female).

11) The maximum percentage frequency of ventral teeth of M. equidens equidens is 5 (63.4% - male; 77.1% - female) and it is 4 (73.8%) in the case of male M. equidens pillaii and 5 (53.3%) (733.8%) in the case of female.

12) Chi-square analysis revealed that clear sexual dimorphism exists (significant at 5% level) with regard to dorsal, post-orbital and ventral teeth in the case of M. equidens equidens whereas M. equidens pillaii, exhibits sexual dimorphism only with regard to the ventral teeth (significant at 5% level).

13) The above analysis also revealed that there is significant difference (5% level) between males of the two subspecies regarding the possession of post-orbital and ventral teeth. A similar result has been observed between females of the two subspecies regarding the same characters. However, there is no significant difference observed between males and also between females of the two subspecies regarding the possession of dorsal teeth.

14) Length-weight relationship studies showed that the relationship is significantly different (1% level) between the sexes of

M. equidens equidens whereas it remains same in the two sexes of M. equidens pillaii. The rate of growth and average size of the both sexes of the two subspecies are also worked out.

15) Significant differences in the length-weight relationships (5% level) have been observed between males and also between females of the two subspecies.

16) The growth rate of male M. equidens equidens (2.6) has been found to be greater than that of male M. equidens pillaii (1.73) whereas the growth rate of female M. equidens pillaii (3.23) has been found to be higher than that of the female of M. equidens equidens (1.34).

17) The mean values of weight of both male (4.161) and female (2.861) of M. equidens equidens have been found to be higher than that of male (3.654) and female (2.318) of M. equidens pillaii respectively.

18) The 't' test analysis revealed that the growth departs significantly from the isometric growth value-3, in the case of both sexes of the two subspecies.

19) SDS polyacrylamide gel electrophoresis of the water soluble muscle proteins of the two subspecies has been carried out. A comparison of electrophorogram of the two subspecies

revealed significant difference in the no. of bands and also in the intensity of staining of band. M. equidens equidens exhibited 6 clear bands whereas M. equidens pillaii showed only 4.

20) Six maturity stages have been identified in both the subspecies. The stages have been classified based on the growth of ovary in relation to carapace cavity.

21) Histological studies of the growth of ova in the ovary showed 6 stages, namely, Oogonial, previtellogenesis I, previtellogenesis II, Vitellogenesis I, Vitellogenesis II and degenerating ova. Similar patterns have been observed in the two subspecies except Vitellogenesis I. In M.equidens equidens the yolk platelet deposition starts, only after the entire ooplasm got filled with the lipid vesicles. But in M. equidens pillaii the yolk platelet formation begins immediately after the formation of two layers of lipid vesicles. Therefore the oogenesis of the two subspecies differ significantly. The oogenetic pattern observed in M. equidens pillaii seems to be rare in palaemonid prawns.

22) The present investigation revealed that the two subspecies showed significant differences in all the biological characters studied. It provides conclusive proof for elevating them to the level of species. Pillai (1990) has already established

that the two populations differ in their larval life history and also that they do not interbreed.

22) The striped variety had been described as new species twice before as Palaemon sulcatus by Henderson and Matthai (1910) and Macrobrachium striatus by Pillai (1990). Since Henderson and Matthai's description is preoccupied by any other name, the present study proposes the correct name of the two populations as M. equidens (Dana, 1852) spotted prawn and M. sulcatus (Henderson and Matthai, 1910) striped prawn.

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COMPARATIVE STUDY ON CERTAIN ASPECTS OF THE BIOLOGY OF *MACROBRACHIUM EQUIDENS EQUIDENS* (DANA, 1852) AND *M. EQUIDENS PILLAII* JAYACHANDRAN, 1989

By

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ABSTRACT OF A THESIS

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VIII. ABSTRACT

The aim of the present study has been to establish the taxonomic status of *Macrobrachium equidens equidens* (Dana, 1852) (spotted variety) and *M. equidens pillaii* Jayachandran, 1989 (striped variety) which co-exist in Cochin backwaters, by undertaking investigations on certain aspects of their biology.

The two populations differ in colouration, length and arrangement of teeth in the rostrum, nature of carapace, telson, proportions of different podomeres and nature of pubescence of fingers of 2nd cheliped. Considerable differences in the growth patterns of the two populations also have been noticed in the characters, such as, rostrum, cephalothorax, carapace, width of carapace and ischium, merus, carpus, propodus, palm and fingers of 2nd cheliped. The meristic studies revealed that the arrangement of rostral teeth is specific for each population. Similarly these two populations differ in the length-weight relationships also.

The SDS polyacrylamide gel electrophorogram showed clear difference in the number and position of bands in the two populations. Though the early part of oogenesis of the two populations showed similarity, considerable differences have been observed in the yolk deposition.