A review of Malaysian freshwater Copepoda with notes on new records and little known species

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Abstract

Twenty species of freeliving Cyclopoida occurring in freshwaters of Peninsula Malaysia were recorded. Twelve species are new records. Illustrated descriptions of these species are given. A list of Malaysian Calanoida is given. Cosmopolitanism is discussed with reference to *Mesocyclops, Macrocyclops*, and *Thermocyclops*.

Introduction

Until very recently the systematics of freshwater Copepoda of Malaysia was practically unknown, unlike that of neighbouring Indonesia, India and Sri Lanka. Recent studies, however, have given us a fairly comprehensive listing of Malaysian Copepoda, descriptions of new species, new records and redescriptions. The Cyclopoida have been dealt with comprehensively by Fernando & Ponyi (1981). They also reviewed all the previous literature on Malaysian forms. In all, 15 species were recorded based on extensive and intensive collecting. The Calanoida have also been studied in detail in a series of papers by Dussart *et al.* (1984), Kiefer (1974a, b) and Lai & Fernando (1978a, b, 1979, 1980, 1981).

Coincident with these recent studies on Malaysian Copepoda there has been a significant increase in our knowledge of their morphology and distribution and a much improved evaluation of the specific status especially in some genera. This is embodied in such papers as Dussart (1982), Dussart & Fernando (in press b), Kiefer (1981), Tai & Chen (1979) and Van de Velde (1984). Earlier workers like Gurney (1933) and Rylov (1963) accepted a much wider cosmopolitanism in the Cyclopoida. In the intervening period between these studies and the early 1970's many species had been described but not generally accepted. Some European species were recorded extensively in the tropical and subtropical zones globally. Now it appears that many Cyclopoida are more restricted in their distribution e.g. *Mesocyclops leuckarti* and *Macrocyclops distinctus*. The Calanoida from tropical regions were very poorly described until the early 1970's and species diagnosis was at best unreliable. The work of many systematists in Africa, Asia and South America including the extensive papers of Dussart (1982), Kiefer (1982) and the worldwide catalogue of Dussart & Defaye (1983) have better defined this group throughout the world including the tropics. Many nomenclatural changes are necessary to bring tropical Copepoda taxonomy in line with recent findings.

In the present study we have examined a large number of recently collected Malaysian samples (1981–83; 248 samples) and re-examined some relevant material studied earlier by Fernando & Ponyi (1981) and Lai & Fernando (1978a, b; 1979, 1980, 1981). We have found that the list of Fernando & Ponyi (1981) needs updating. We have recorded a total of 20 species of which 12 are new records for Malaysia. We have given short notes on some of

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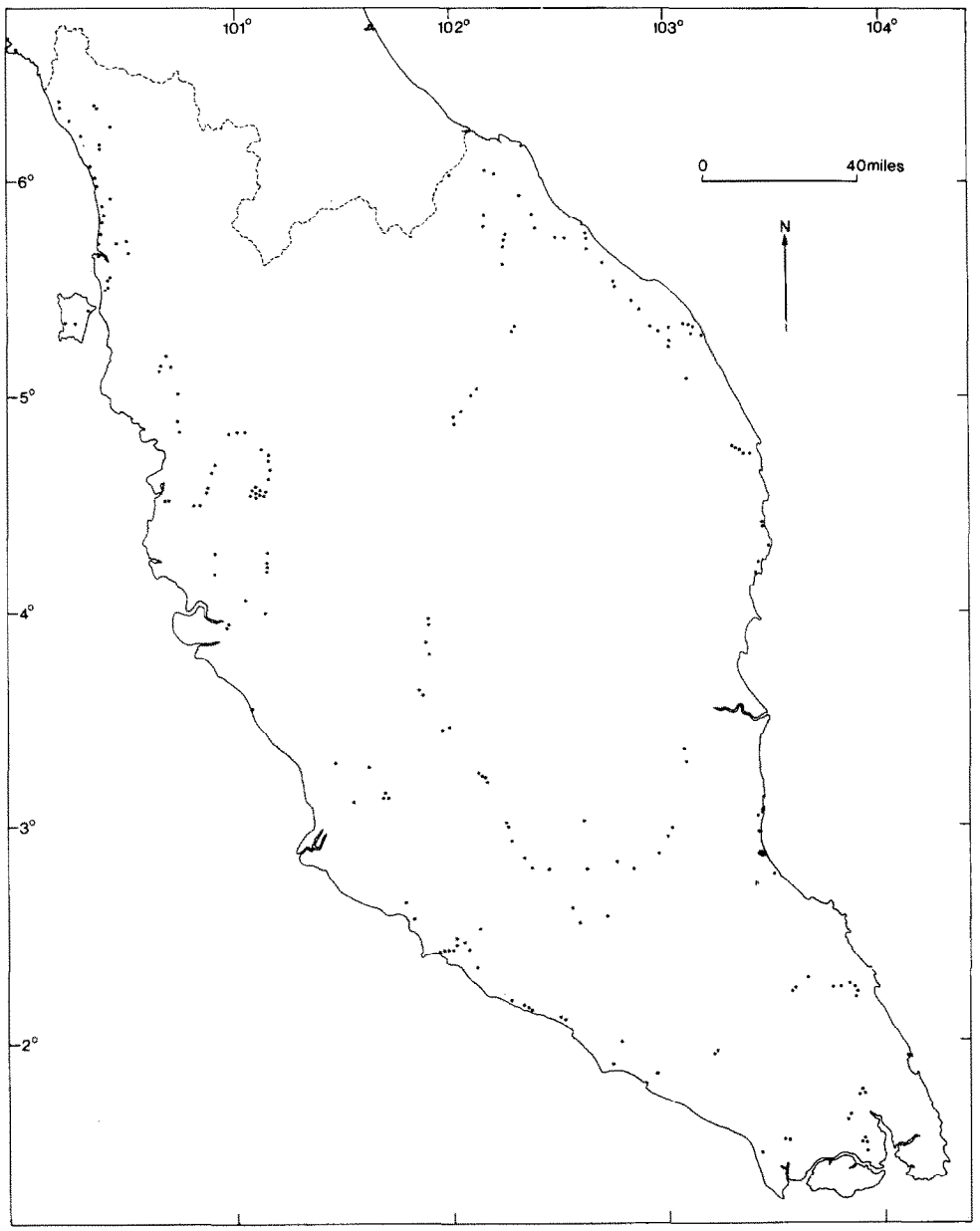


Fig. 1. Map of Peninsular Malaysia showing the distribution of zooplankton samples studied. • sampling locality (some dots represent a number of samples collected from adjacent water bodies in a single locality).

these new records and reviewed the status of some other Malaysian species. We have illustrated these species based on Malaysian material.

Materials and methods

Samples were collected from a wide range of habitats and extensively throughout Peninsular Malaysia (Fig. 1). Plankton nets of mouth sizes 20 and 25 cm and mesh size 10 and 25 (157 μm and 64 μm respectively) were used to collect qualitative

samples. The material collected was immediately preserved in 5–10% formaldehyde. In the laboratory, specimens were sorted and treated with either a solution consisting of 10 ml glycerine, 90 ml 70% alcohol and 1 g Rose Bengal or with glycerine only. Specimens were dissected under a binocular microscope in glycerine and drawings were made using a camera lucida. All measurements are in μm.

Results

Cyclopoida

A comparative listing of species recorded in earlier studies and our own records is given in Table 1. Fernando & Ponyi (1981) have listed 15 species occurring in the 8 main habitat types while in the present study we have listed 20 species. Of these 12 species were recorded by both Fernando & Ponyi (1981) and us. However, some of the species common to both studies have had their nomenclature revised viz. *Ectocyclops phaleratus* = *E. rubescens; Macrocyclops distinctus* = *M. neuter; Mesocyclops leuckarti* = *M. aspericornis, M. pehpeiensis, M. thermocyclopoides* and *M. cf. thermocyclopoides; Metacyclops minutus* = *M. pectiniatus;* and *Microcyclops dengizicus* = *Apocyclops borneoensis.*

Table 1. List of freeliving Cyclopoida recorded in Malaysia.

Species	Fernando & Ponyi (1981)	Present study
Cryptocyclops bicolor (Sars)	+	+
+ *C. intermedius* Shen and Tai		+
+ *C. linjanticus* Kiefer		+
Ectocyclops phaleratus (Koch)	+	
+ *E. rubescens* Brady		+
'Eucyclops serrulatus' Fischer	+	+
Macrocyclops albidus (Jurine)	+	
* *M. distinctus* (Richard)	+	
M. fuscus (Jurine)	+	
+ *M. neuter* Kiefer		+
Mesocyclops aspericornis (Daday)		+
* *M. leuckarti* (Claus)	+	
+ *M. pehpeiensis* Hu		+
+ *M. thermocyclopoides* Harada		+
+ *M.* cf. *thermocyclopoides* Harada		+
* *Metacyclops minutus* Kiefer	+	
+ *M. pectiniatus* Shen & Tai		+
+ *Apocyclops borneoensis* Lindberg		+
* *Apocyclops dengizicus* (Lepeschkin)	+	
'Microcyclops varicans' (Sars)	+	+
Paracyclops affinis (Sars)	+	+
'P. fimbriatus' (Fischer)	+	+
'Thermocyclops crassus' (Fischer)	+	+
+ *T.* cf. *decipiens* (Kiefer)		+
* *T.* cf. *schmeili* Brehm	+	
+ *T. orientalis* Dussart & Fernando		+
+ *T. rylovi* (?) Smirnov		+
'Tropocyclops prasinus' Fischer	+	+

* misidentifications

\+ new records

We have retained the names *'E. serrulatus', 'M. varicans', 'P. fimbriatus'* and *'T. prasinus'* realizing that they may well be species complexes as we have stated for *M. varicans* with tropical representatives of species closely related to the well known species described mainly from Europe.

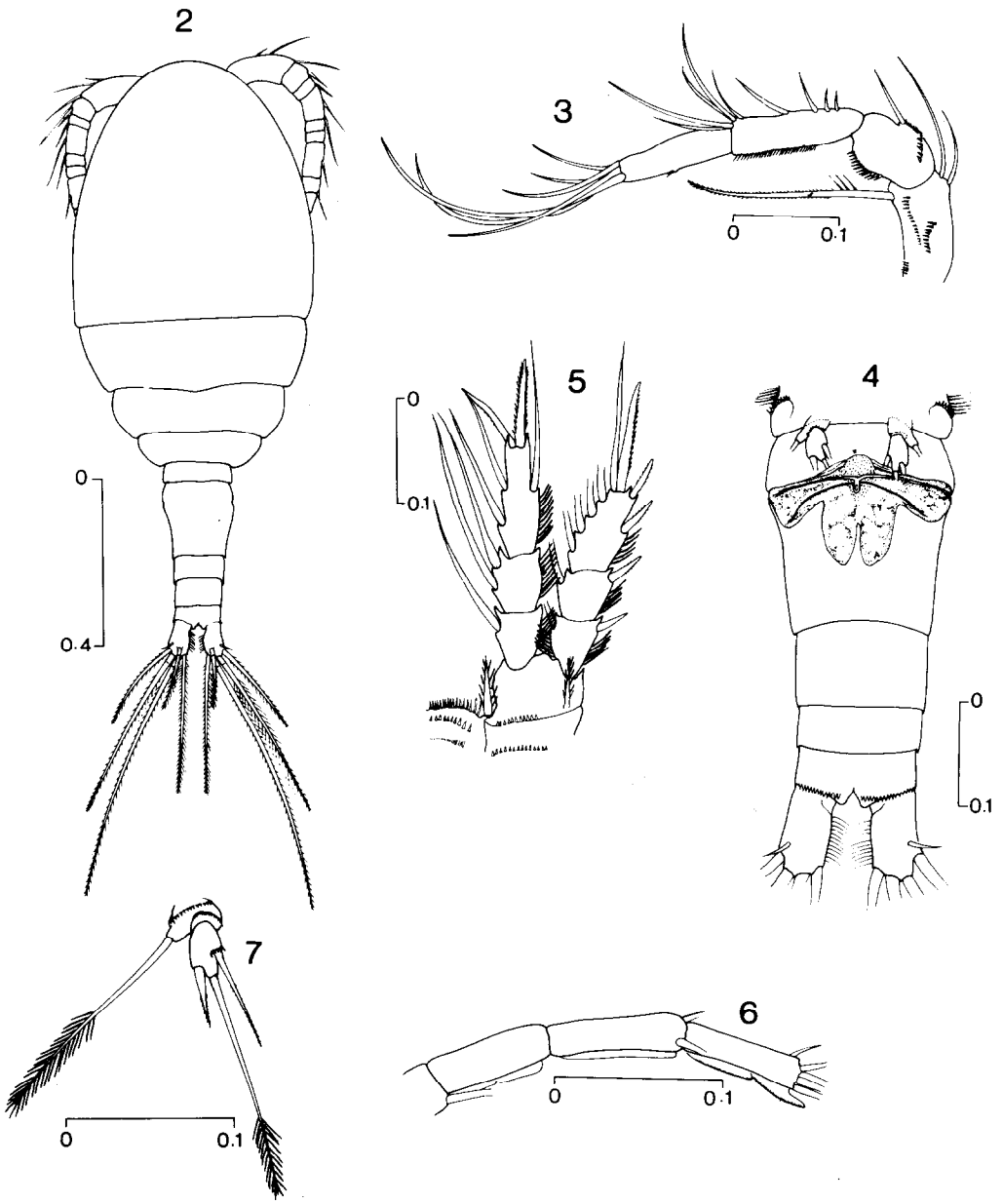
Notes on some species

Macrocyclops neuter Kiefer, 1931

Gurney (1933) mentions this species under his discussion on the synonomy of *Macrocyclops distinctus* Richard. He was uncertain whether *M. neuter* should be considered a separate species and remained noncommittal on its status as he had not seen any specimens. *M. distinctus*, originally recorded from Europe, has been considered widely distributed. Yeatman (1963) lists this species from North America although admitting that no authentic record existed, since he considered the species cosmopolitan. Recently Dussart & Fernando (in press) found *M. neuter* in Sri Lanka. It appears very likely that all Asian (and probably extra-European) records of *M. distinctus* are other species.

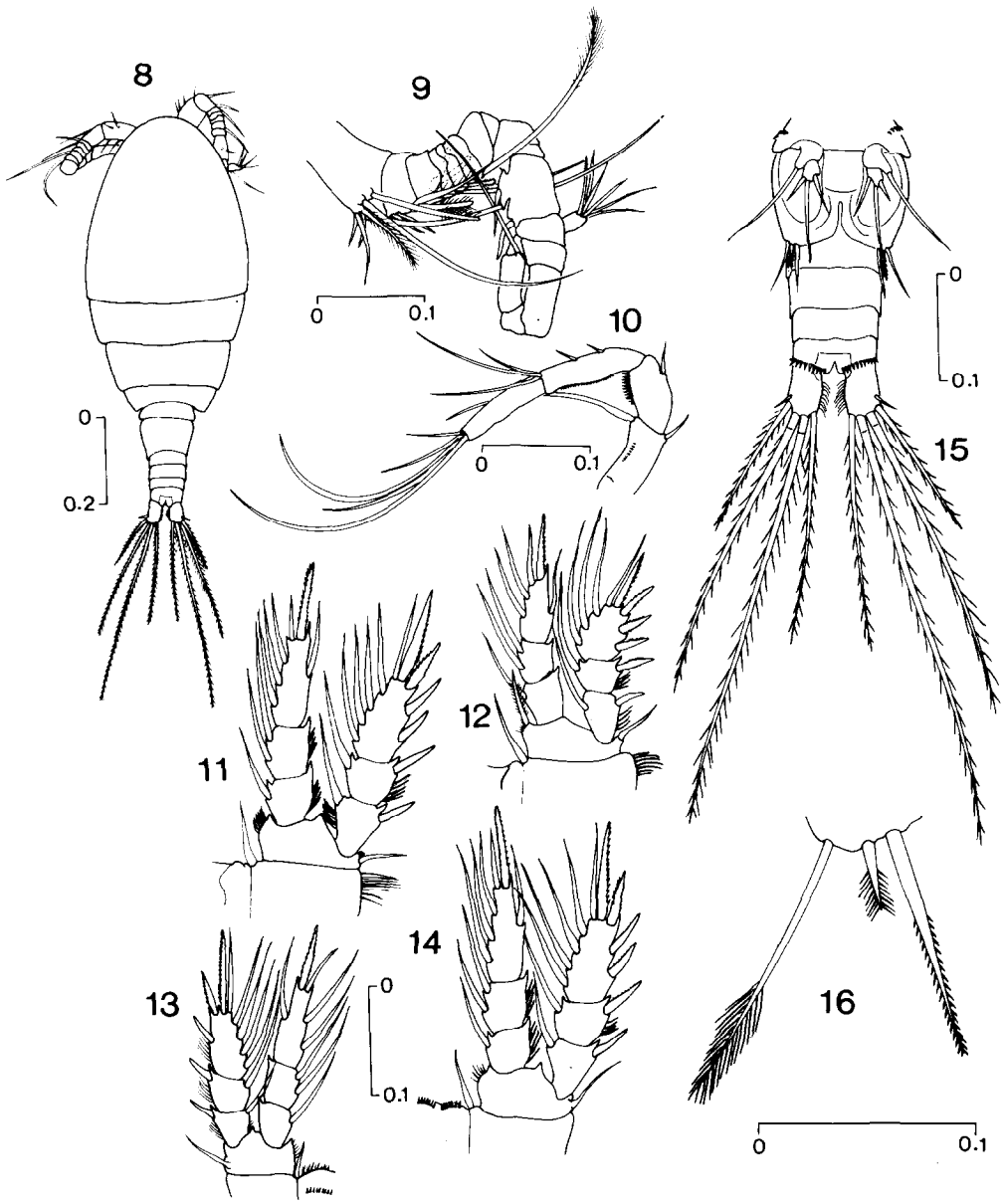
Since the descriptions of *M. neuter* (Kiefer, 1931, 1933) are very brief and incomplete, we have given comprehensive illustrations and some comments on diagnostic characteristics. Also among material collected and examined by one of us (C.H.F.), a male of *M. neuter*, hitherto undescribed, was found in a sample from Rangoon, Burma. We have illustrated and described this specimen.

Female: Length 1430–1520 μm. Thorax robust and rounded. Th_1 1.35 times longer than wide (Fig. 2). Spine patterns on A_2 well developed (Fig. 3). This species is similar morphologically to *Macrocyclops distinctus* in the presence of sparse hairs on the inner edges of the furcal rami (Fig. 4); seminal receptacle, except in that the proximal portion is relatively larger than the bifid distal section (Fig. 4) unlike that in *M. distinctus*; P_4 and its connecting lamella are similar (Fig. 5). Another difference is the finely serrated hyaline membrane on seg-



Figs 2–7. Macrocyclops neuter, 2 female, 3 antenna, 4 abdominal segments with seminal receptacle and furca, 5 fourth leg, 6 hyaline membrane on segments 15–17 of antennule, 7 fifth leg (scales in mm).

ment 17 of A_1 (Fig. 6) as compared with a smooth hyaline membrane in *M. distinctus*. Rylov (1963) however, mentions in his key to *M. distinctus* that the hyaline membrane can either be smooth or finely serrated. A diagnostic difference between the two species is P_5. In *M. neuter* the lateral apical spines are much shorter than the median apical seta (Fig. 7). The outer apical spine is about 0.3 the length of the median apical seta while the inner spine is 0.5 the length of the median apical seta. In *M. distinctus* the relative lengths of these spines and seta are very different (Gurney, 1933). The furcal rami are twice as long as wide unlike *M. distinctus* where it is 3 times as long as wide (Gurney,



Figs 8–16. Macrocyclops neuter, 8 male, 9 antennule, 10 antenna, 11–14 first–fourth legs, 15 abdominal segments with fifth and sixth legs, 16 sixth leg (scales in mm).

1933). The difference in evaluation of the status of *M. distinctus* and *M. neuter* by Gurney (1933) and Rylov (1963) and ours is very probable due to their considering more than one species under a single name at a period when cosmopolitanism was more generally accepted.

Description of the male from Zafar Shah Road pond, Rangoon, Burma, 20.XI.73

Male: Length 1100 μm. Body similar in shape to that of the female (Fig. 8). Antennule has five aesthetes, on each on segments 1, 2 and 5 and two on segment 3 (Fig. 9). Antenna 2 similar to that of the female except that it has a simpler spine ornamentation on the basipodite and fewer setae on the

third segment (Fig. 10). The swimming legs are similar to those of the female except for numerous differences in spinule ornamentation (Figs. 11–14). P_5 is similar to that of the female although larger relative to its body size; P_6 consists of a ventro-lateral and a medial seta, and a dorso-lateral spine (Fig. 16). The ventro-lateral seta is 3.5 and 1.15 times as long as the median seta and the dorso-lateral spine respectively. The ventro-lateral seta of P_6 of *M. distinctus* is about 1.2 times as long as the median seta. It is only 0.5 as long as the dorso-lateral spine (Gurney, 1933). The differences between the males of *M. neuter* and *M. distinctus* further support our contention that the two species are indeed separate.

Localities; 4–40, 101; 1–115[1].

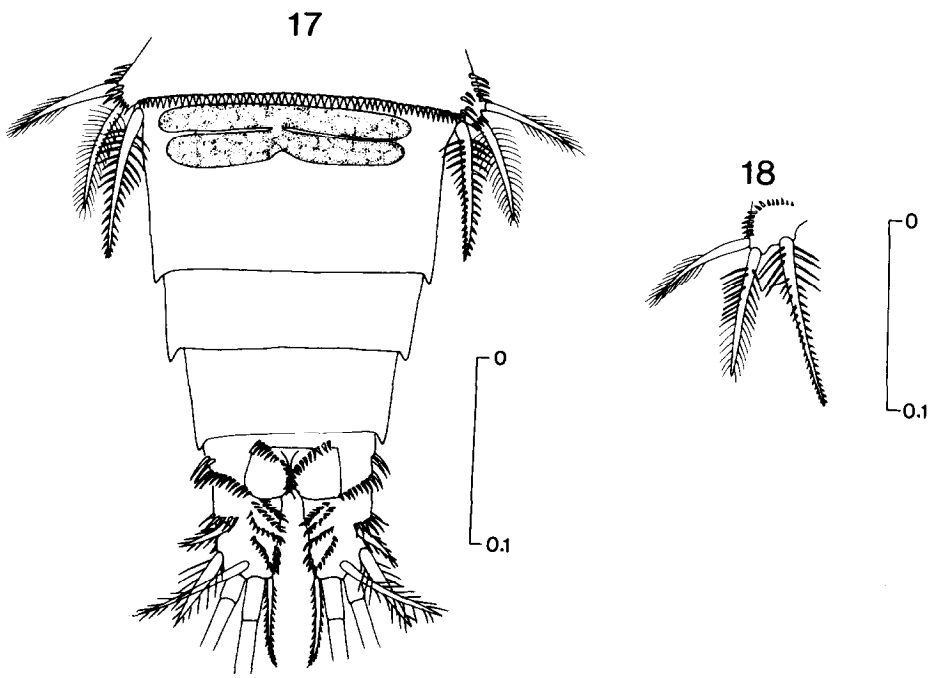
Ectocyclops rubescens Brady, 1904

Many records of this species in Southeast Asia are probably listed as *Ectocyclops phaleratus* (Koch). Fryer (1955) in his review of the genus *Ectocyclops* however, concurs with Gurney's (1933) opinion that the differences in morphological characters are too trivial to warrant separating *E. rubescens* as a distinct species. Dussart (1982), however, has pointed out significant morphological differences between the two species – in the spinule pattern of the furcal rami and the shapes and relative lengths of the appendages of P_5.

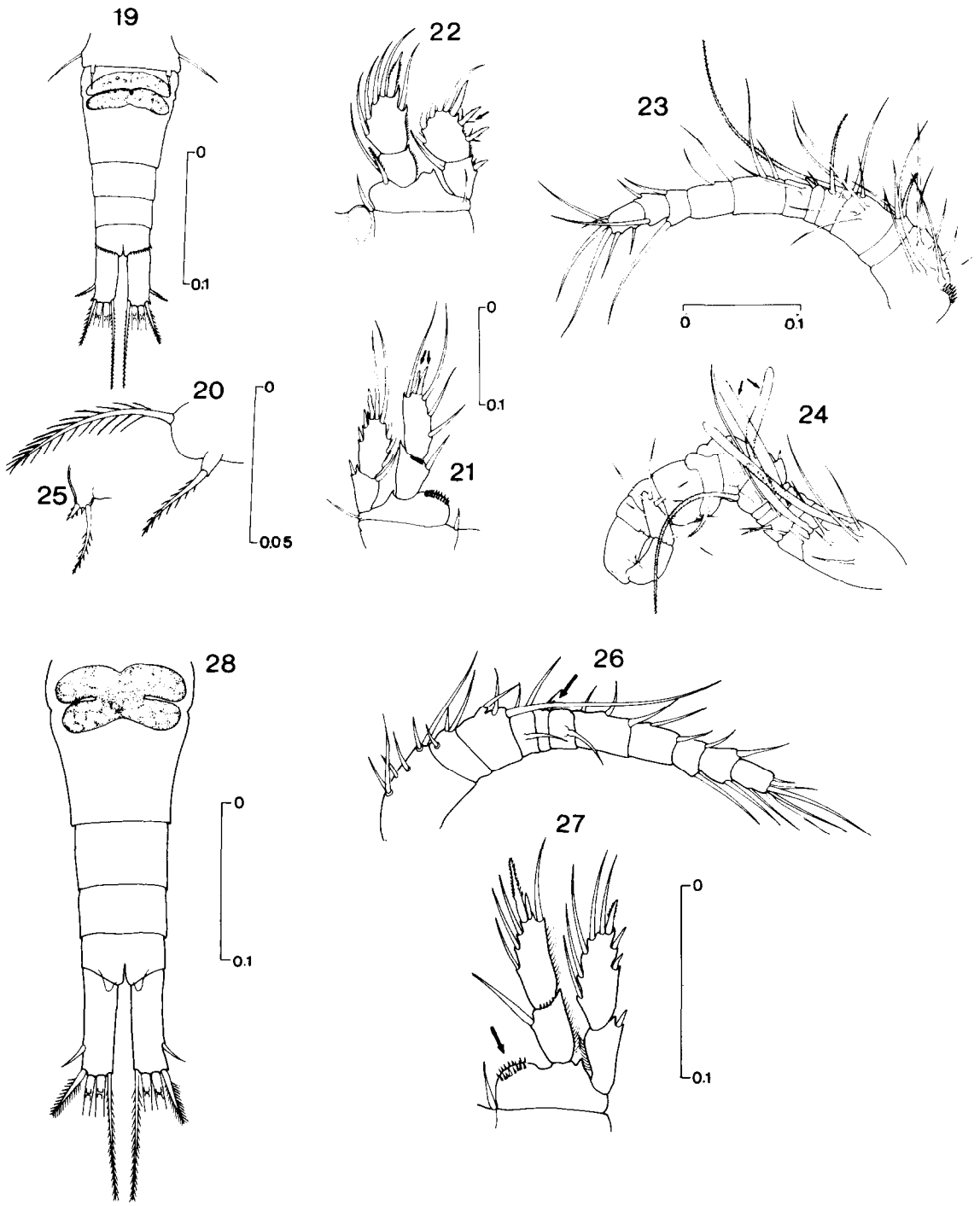
Female: Length 739–757 μm. The specimens we examined are similar to that of *E. rubescens* according to Dussart (1982) and differ from *E. phaleratus*. The furcal rami have four rows of spinules (Fig. 17) while those of *E. phaleratus* has only three rows (Dussart, 1982). The spine of P_5 is longer than the setae (Fig. 18). We agree with Dussart (1982) that *E. rubescens* should be considered a separate species. At the present time we cannot say whether both these species occur in Malaysia. Dussart (1982) recorded both species in Madagascar.

Localities: 4–40, 55, 49, 8, 113, 1, 2, 7, 52, 62.

[1] Locality data given in appendix 1. We have given numbers and latitude and longitude for a few localities but they cover all the species we have listed. A more detailed study will include this data for all localities.



Figs 17–18. Ectocyclops rubescens, 17 abdominal segments with seminal receptacle and furca, 18 fifth leg (scales are in mm).



Figs 19–28. 19–24 *Cryptocyclops intermedius*, 19 abdominal segments with seminal receptacle, 20 fifth leg, 21 fourth leg, 22 first leg, 23 antennule of female, 24 antennule of male, 25 sixth leg, 26–28 *Cryptocyclops linjanticus*, 26 antennule, 27 fourth leg, 28 abdominal segments with seminal receptacle (scales are in mm).

Cryptocyclops species

In addition to *Cryptocyclops bicolor* Sars, 1963 recorded by Fernando & Ponyi (1981) we found two more species of the genus, *C. intermedius* and *C. linjanticus.*

Cryptocyclops intermedius Shen & Tai, 1964

Cryptocyclops intermedius was first recorded from China by Shen & Tai (1964). This is the first record outside China.

Female: Length 555–580 μm. The animal is small and slender. It resembles the species described by Shen & Tai (1964) in features such as the seminal receptacle and P_5 (Figs. 19–20) except for the apical spines of enp_2 P_4. In the Malaysian specimens the ratio of the internal apical spine to the external apical spine is 1.33:1 (Fig. 21) while that of the Chinese specimens is 2.1:1 (Shen & Tai, 1964). A diagnostic feature of *C. intermedius* is the presence of a pair of setae on the proximal ends of the spines of exp_2 P_1 (Fig. 22). This is illustrated by Shen & Tai (1964). A small blunt aesthete is present on segment 5 of the antennule (Fig. 23) as in most *Microcyclops* species we have examined.

Male: Length: 470 μm. Smaller and more slender than the female. Its antennule is characterised by four ribbon like sensory structures (Fig. 24). Two of them are inserted on segment 1 and one each on segments 4 and 7. The illustrations by Shen & Tai (1964) show three such structures one each originating from segments 1, 6 and 8. P_6 consists of a short stout inner lateral spine, a weakly developed median spine and a long lateral seta (Fig. 24) which corresponds to Shen & Tai's (1964) description.

Locality: 8–861.

Cryptocyclops linjanticus Kiefer, 1928

This species was originally recorded from South Africa (Kiefer, 1928). Subsequently it has been recorded in other parts of Africa, Southeast Asia, Australia (Dussart, 1982) and China (Tai & Chen, 1979).

A single specimen was found in a sample obtained from a pond overgrown with macrophytes. This species was also described by Lindberg (1937) as *Cyclops (Microcyclops) tricolor.*

Female: Length N.A. This is a very small slender species. The specimen examined resembles that of the description of Dussart (1982). Unfortunately Kiefer (1928) provides illustrations of only the furca, basipodite, connecting lamella and enp_2 P_4, and P_5. However, all these structures conform morphologically to those of the specimens from Malaysia. Antennule with 11 segments and a small blunt aesthete on segment 5 (Fig. 26). *C. linjanticus* differs from the other *Cryptocyclops* species in the relative lengths of the external and internal apical spines of enp_2 P_4 the latter being 2.4 times longer than the former. The distal edge of the basipodite of P_4 has a circular row of short spinules (Fig. 27). The seminal receptacle is similar to that illustrated by Dussart (1982) except that the posterior median identation is not as deep (Fig. 28).

Locality: 179.

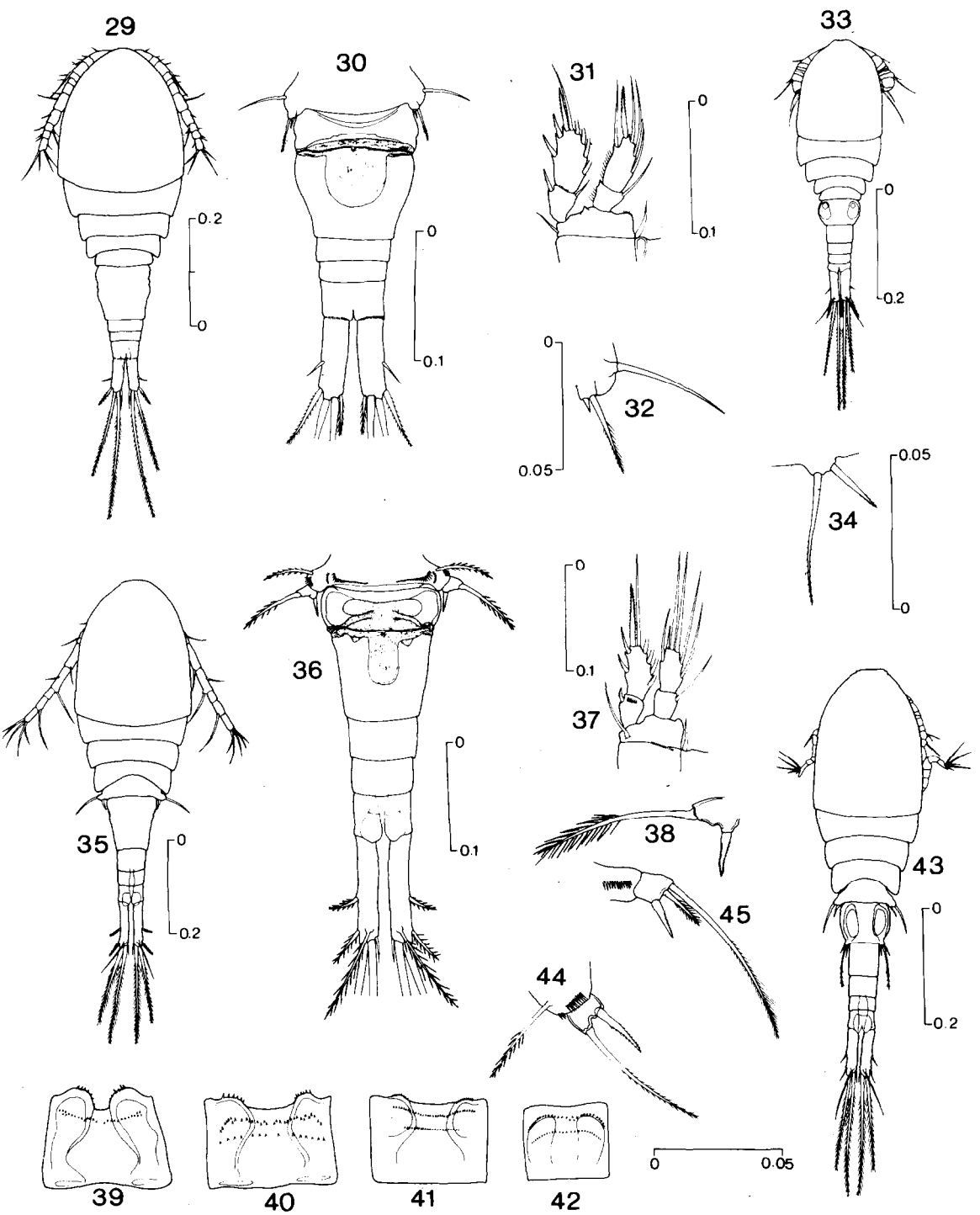
Metacyclops pectiniatus Shen & Tai, 1964

Fernando & Ponyi (1981) listed *Metacyclops minutus* from Malaysia. We reexamined this material and have concluded that it is actually *M. pectiniatus* originally described from China by Shen & Tai (1964).

Female: Length 685–735 μm. The animal has a rounded thorax which blends gradually with the abdominal segments (Fig. 29). The first abdominal segment is relatively long (110 μm) and is slightly longer than the combined lengths of the three succeeding abdominal segments (95 μm) (Fig. 30). The antennules are short and do not reach the caudal edge of Th_1. The specimens we examined are similar in several morphological characters to the illustrations of Shen & Tai (1964). However, a few differences were noted: The apical spine of enp_2 P_4 is as long as segment enp_1 P_4 (Fig. 31); it is relatively shorter in the species illustrated by Shen & Tai (1964). The outer seta of end P_5 is relatively longer than the seta in the Malaysian specimen (5.2 times as long as the inner spine) (Fig. 32) while it is only 2.7 times as long in the specimen described by Shen & Tai (1964). The seminal receptacle has a rounded caudal portion with a rather flat frontal portion (Fig. 30).

Male: Length 520 μm. The male is considerably smaller and more slender than the female (Fig. 33). It resembles closely the description given by Shen & Tai (1964) except for P_6 where two setae are present in the Malaysian specimen (Fig. 34) while only one seta is illustrated in Tai & Chen (1979). This is the first record of the species outside China.

Locality: 8–861.



Figs 29–45. 29–34 *Metacyclops pectiniatus*, 29 female, 30 abdominal segments with seminal receptacle, 31 fourth leg, 32 fifth leg, 33 male, 34 sixth leg, 35–45 *Apocyclops borneoensis*, 35 female, 36 abdominal segments with seminal receptacle and furca, 37 fourth leg, 38 fifth leg of female, 39–42 connecting lamella of first to fourth legs, 43 male, 44 fifth leg of male, 45 sixth leg (scales are in mm).

Apocyclops borneoensis Lindberg, 1954

Microcyclops dengizicus was recorded by Fernando & Ponyi (1981) in Malaysia. We reexamined this material and found that it is really *Apocyclops borneoensis* recorded in Borneo (Lindberg, 1954) and China (Tai & Chen, 1979). It can be differentiated from *M. dengizicus* by its longer antennules which reach the third thoracic segment and the very poorly developed inner apical furcal setae (Figs. 35 & 36).

Female: Length 825–870 μm. Body slender, resembles that described by Lindberg (1954) and Tai & Chen (1979). However, slight differences exist. Apical seta is 4.2 times longer than the outer spine of enp_2 P_4 (Fig. 37). The furcal rami index (length to width) is 9.5 in contrast to 6.5–8.5 in the specimens described by Lindberg (1954). The seta of Th_5 is shorter than the apical seta of P_5 (Fig. 36) unlike the equal lengths of these two structures described by Lindberg (1954). The spine of P_5 is articulated at its base (Fig. 38) in contrast to the lack of articulation in the specimens described by Lindberg (1954). The seminal receptacle is as illustrated in (Fig. 36). It has well developed anterior and posterior portions. Th_5 has a pair of two rows of spinules near its caudal edge (Fig. 36). All the connecting lamellae of the swimming legs have either one or two rows of spinules (Figs. 39–42). The free edge of these lamellae of P_1-P_3 also have a row of spinules while it is smooth in P_4.

Male: Length 705 μm. The male is smaller and more slender than the female (Fig. 43). It, however, resembles the female generally in morphological characters except for P_5 where the difference in relative lengths of the outer and inner spine is less (2.44:1) in the male (Fig. 44) in comparison with that of the female (3.5:1) (Fig. 38). The relative length ratios of the internal spine, median and external setae of P_6 are 15:19:68 μm (Fig. 45) which differs from that of Lindberg's (1954) ratio of 12:36:83 μm.

Locality: 1–137.

Microcyclops varicans and its relatives

This species has been recorded from Malaysia by Fernando & Ponyi (1981). It is supposed to be cosmopolitan. Some Malaysian material we examined can be placed in this species. However, the definition of this species is not precise enough to enable us to say with certainty that the Malaysian material belongs to this species.

Other species of *Microcyclops* occur in Malaysia. However, we have not studied sufficient material in detail to delimit these at the present time. The morphological differences we noted suggest at least two additional species.

The status of *Microcyclops varicans* may show a similar situation to that of the so called cosmopolitan *Mesocyclops leuckarti.*

Localities: 4–40, 40, 49, 55, 56, 157, 179, 180, 197.

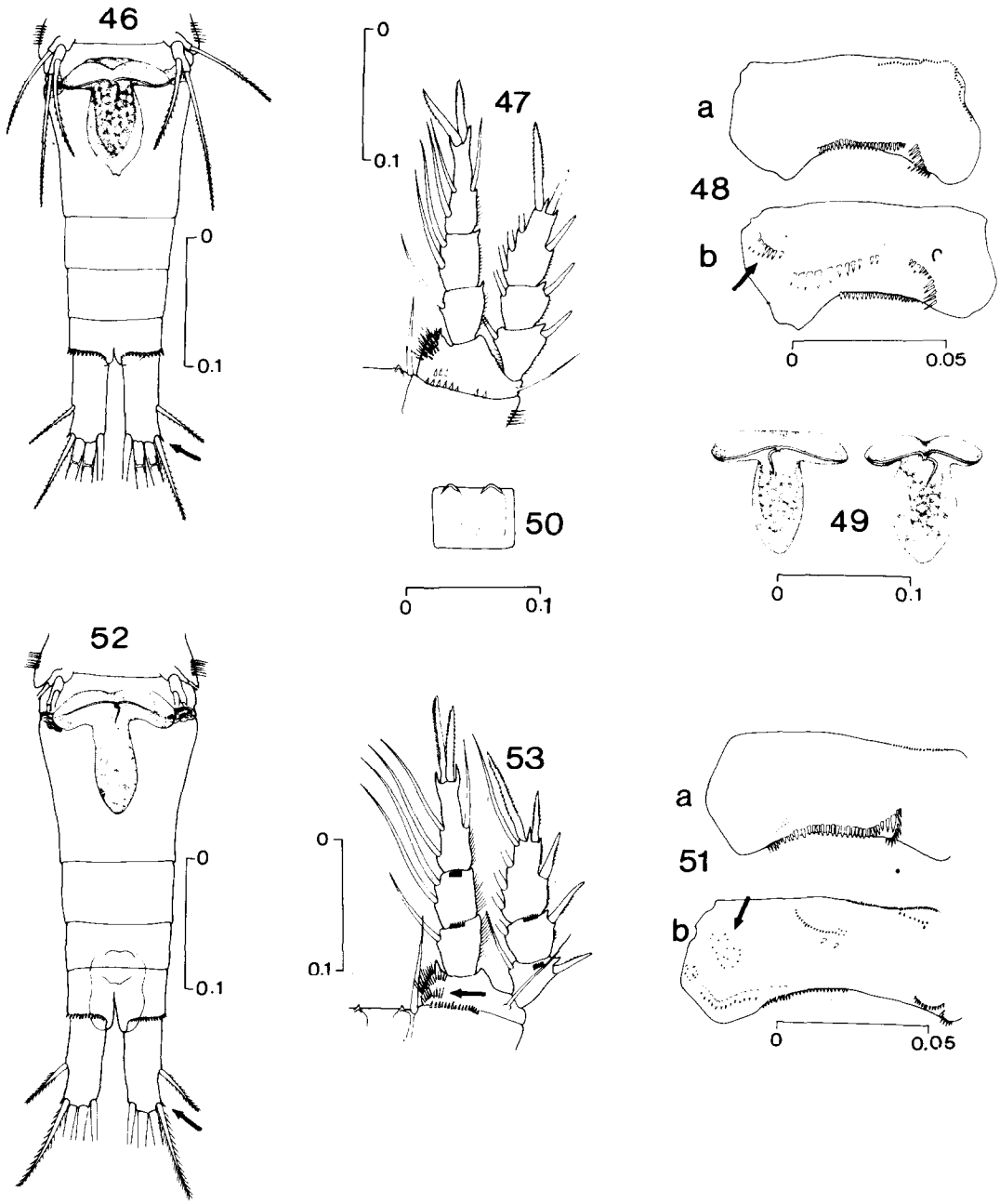
Mesocyclops species

Until very recently most records of tropical *Mesocyclops* were considered *M. leuckarti* (Gurney, 1933; Rylov, 1963). Kiefer (1981) has shown the presence of 12 species of the genus in the Old World. More recently Van de Velde (1984) has given detailed descriptions of many African species. In light of this knowledge we have revised the Malaysian members of the genus. At least four species occur in Malaysia. These are *M. thermocyclopoides M.* cf. *thermocyclopoides, M. aspericonris* and *M. pehpeiensis.* We shall give brief descriptions of all these species.

It appears from the data we have so far that *M.* cf. *thermocyclopoides* is most common. However, we feel that the definition of this widespread species is not precise enough (see later). Further studies based on material from a wide geographic area is necessary to clarify the situation.

Mesocyclops thermocyclopoides complex

M. thermocyclopoides was first described by Harada (1931) from Formosa. However, his description and illustrations are inadequate to differentiate it from the other species of *Mesocyclops* especially *M. dussarti* Van de Velde, 1984. Based on Kiefer's (1981) and Van de Velde's (1984) descriptions and illustrations we can only tentatively define two species under *M. thermocyclopoides* Harada (*M.* cf. *thermocyclopoides* and *M. thermocyclopoides* s. str.).



Figs 46–53. 46–50 *Mesocyclops* c.f. *thermocyclopiodes* 46 abdominal segments with seminal receptacle and furca, 47 fourth leg, 48 basipodite of antenna (a.: frontal view, b.: caudal view), 49 variations in seminal receptacles, 50 connecting lamella of fourth leg, 51–53 *Mesocyclops thermocyclopoides* (s. str.), 51 basipodite of antenna (a.: frontal view, b.: caudal view), 52 abdominal segments with seminal receptacle and furca, 53 fourth leg. (scales are in mm).

Mesocyclops cf. *thermocyclopoides*

Female: Length 880–1 030 μm. This species has a seminal receptacle and enp$_3$ P$_4$ apical spines of *M. thermocyclopoides* as described by Kiefer (1981) and Van de Velde (1984) (Figs. 46 & 47). However, the spine pattern on the basipodite of A$_2$ differs from that of the description and illustration given by Van de Velde (1984) (Fig. 48). Although she examined a specimen from the type locality she unfortunately illustrated a specimen collected from Calcutta, India. In the Malaysian specimens there is a prominent row of 6–7 spines on the distal portion of the caudal surface of the basipodite of A$_2$ (Fig. 48b). Van de Velde's (1984) description of the basipodite differs from this where in place of this distal row of spines there is a cluster of tiny spinules. Spinules are also present at the insertion of external lateral apical furcal setae in the Malaysian specimens (Fig. 46). No such spinules are present in *M. thermocyclopoides* (from Calcutta) described by Van de Velde (1982). The characteristics described above for the Malaysian species agree more with *M. dussarti* reportedly found only in Africa. Measurements of total length, enp$_3$ P$_4$ index, and its apical spine index do not conform with Harada's (1931) description (Table 2). The Malaysian species, however, is smaller than *M. dussarti* although there is an overlap in the enp$_3$ P$_4$ and furcal indices (Table 2).

Localities: 54, 62, 75, 77, 101, 155, 156, 176, 179, 180, 204, 4–40.

Mesocyclops thermocyclopoides s. str

Female: Length 1 025–1 045 μm. In a sample collected from a marsh we found a *M. thermocyclopoides* species that has the spinule patterns on the basipodite of A$_2$ similar to that described by Van de Velde (1984) (Fig. 51b). However, spinules are present at the point of insertion of the lateral apical setae of the furcal rami (Fig. 52), whereas Van de Velde (1984) states that the absence of these spinules characterises *M. thermocyclopoides*. Further, there is an additional row of setae on the inner margin of the basipodite of P$_4$ (Fig. 53); this is absent in *M.* cf. *thermocyclopoides* (Fig. 47). In comparing the morphometric measurements between *M. thermocyclopoides* and *M. cf. thermocyclopoides* it was found that most of them overlap with the exception of Th$_1$ index and the furcal index (Table 3). However, if more specimens were measured there is good possibility of overlap in these indices occurring due to variability within the species. Diagnostic morphological characters such as the hyaline membrane of segment 17 of A$_1$ and the appendages of P$_5$ are similar in both species.

Morphological characters such as the shape of the posterior margin and pore canal of the seminal receptacle and the spines in the connecting lamella of P$_4$ are too variable for characterisation of the species (Figs. 46, 47, 49, 50). It would be necessary to study material from a wide geographic range before any valid conclusions can be reached on the status of *M. thermocyclopoides*-like species. Kiefer (1981) illustrated many variations in the details of the posterior margin of the seminal receptacle and the pore canal in material he considered to be *M. thermocyclopoides*. We have found similar variability in the chaetotaxy of the A$_2$ basipodite in what is apparently *M. thermocyclopoides*. Since her (1984) publication, Van de Velde (pers. commun.) considers the species she described from Calcutta as not the same as Harada's (1931) species.

Locality: 104.

Table 2. Morphometric measurements of *M. thermocyclopoides* Harada, *M. dussarti* Van de Velde, and *M. thermocyclopoides* found in Malaysia. L = Length, W = Width.

Species	Morphometric Parameters		
	Total length (μm)	Enp$_3$ P$_4$ index (L:W)	Furcal index (L:W)
M. thermocyclopoides Harada	780– 870	3.6 :1	3.4 –3.6 :1
M. dussarti Van de Velde	1 169–1 416	2.53–2.97:1	2.90–3.56:1
M. thermocyclopoides (present study)	1 025–1 045	2.8 :1	2.59 :1
M. cf. *thermocyclopoides* (present study)	880–1 030	2.41–3.26:1	2.29–3.13:1

Table 3. Morphometric measurements of the *Mesocyclops* species occurring in Malaysia. L = Length, W = Width, ES = external spine, I.S. = internal spine, L.S. = lateral seta of furcal ramus, D.S. = dorsal seta of furcal ramus.

Species	Th L:W	Enp. P. L:W	E.S.:I.S. Exp. P.	Abd L:W	Furcal rami L:W	LS:DS
Mesocyclops thermocyclopoides (s.str.)	1.10 – 1.12:1	2.8 :1	0.84 :1	1.26 :1	2.59 :1	1 :1
M. cf. *thermocyclopoides*	1.10 – 1.19:1	2.41 – 3.26:1	0.76 – 1.29:1	1.11 – 1.61:1	2.29 – 3.13:1	0.71 – 1.13:1
M. aspericornis	1.13 – 1.26:1	2.14 – 2.83:1	0.70 – 0.93:1	1.08 – 1.38:1	2.43 – 3.47:1	0.91 – 1.18:1
M. pehpeiensis	1.29 :1	2.73 :1	0.82 :1	1.09 :1	3.03 :1	0.95 :1

Mesocyclops aspericornis Daday, 1906

Mesocyclops aspericornis was originally described from Sumatra and recorded in Singapore and Hawaii by Daday (1906). It was considered a subspecies of *M. leuckarti* or a synonym of the species (Gurney, 1933). Kiefer (1981) revived and redescribed *M. aspericornis* and Van de Velde (1984) provides a comprehensive description of this species. It is found in Africa and Asia and also probably in South America (Dussart, 1984).

Mesocyclops aspericornis occurs less frequently and abundantly than *M. cf. thermocyclopoides* in Malaysian waters. However, they do co-occur in some water bodies. Van de Velde (1984) has also reported that it is not common in Africa.

Female: Length 1 110 – 1 210 μm. This species is larger than *M. cf. thermocyclopoides* and is readily recognised by a row of setae along the inner margins of the furcal rami (Fig. 54a) and the characteristic shape and structure of the seminal receptacle and its associated canals (Fig. 54b). Some of the morphometric characters concur with the descriptions of Kiefer (1981) and Van de Velde (1984) (Figs. 54, 55, 56 and Table 4). However, the inner apical spine of enp$_3$ P$_4$ is consistently longer than the outer apical spine which contrasts with Van de Velde's (1984) findings where the reverse in size differences were recorded.

Localities: 32, 49, 51, 56, 59, 87, 88, 117, 156, 157, 195, 197, 210, 215, 220.

Mesocyclops pehpeiensis Hu, 1943

Mesocyclops pehpeiensis was first recorded by Hu (1943) in China. In differentiating the many *Mesocyclops* species in tropical Asia, Kiefer (1981) described a new species *M. ruttneri* from a greenhouse in Austria but he presumed it came as a contamination from Java. We found that Kiefer's (1981) description of *M. ruttneri* fits that of *M. pehpeiensis*. This species is known to occur in Australia, Java, Burma, Sri Lanka (Dussart & Fernando in press b) and now in Malaysia.

M. pehpeiensis is the rarest of the three *Mesocyclops* species occurring in Malaysia. It is found only in samples collected from marshes.

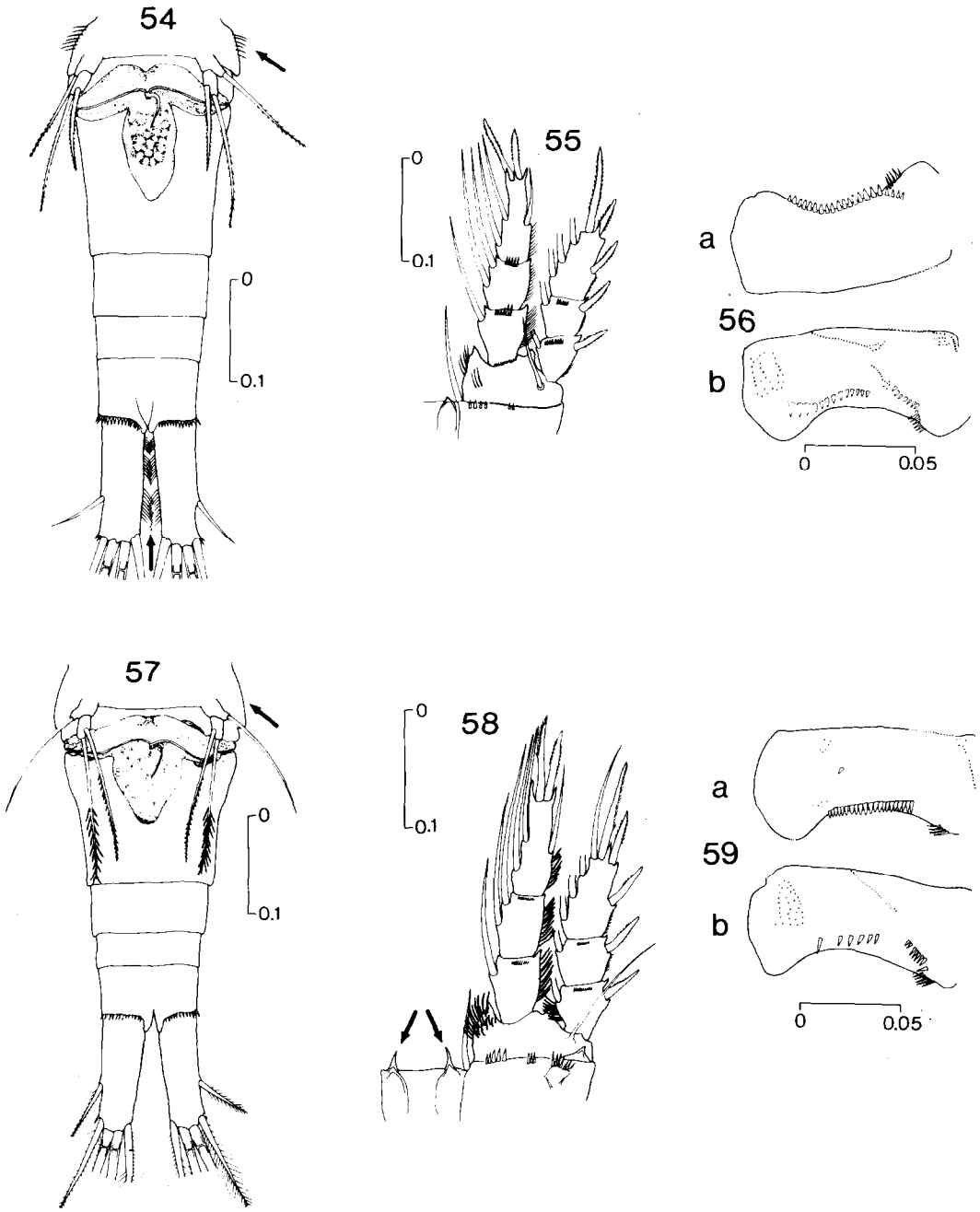
Female: Length 1 625 μm.

The specimens collected in Malaysia closely resemble the description of Hu (1943) (Table 5). It is differentiated from the other *Mesocyclops* species by its large size (1 625 μm to 1 045 μm for *M. thermocyclopoides* and 1 210 μm for *M. aspericornis*; absence of hairs on the lateral margin of Th$_5$ (Fig. 57); absence of hairs or spinules on the lateral appendage of P$_5$; the presence of a pair of large curved spines on the caudal edge of the connecting lamella of P$_4$ (Fig. 58); and the characteristic spinule patterns on the basipodite of A$_2$ (Fig. 59).

Localities: 12, 34, 104.

Table 4. Morphometric measurements of *M. aspericornis* given by Kiefer (1981), Van de Velde (1984) and from the present study.

Source	Total lenth (μm)	Abd L:W	Enp. P L:W	E.S.:I.S. Exp. P	Furcal rami L:W
Kiefer (1981)	1 200 – 1 500	1.1 – 1.2:1	–	–	3.0 – 5 :1
Van de Velde (1984)	1 183 – 1 313	–	2.50 :1	–	3.37 – 3.45:1
Present study	1 110 – 1 210	1.08 – 1.38:1	2.14 – 2.83:1	0.70 – 0.93:1	2.43 – 3.47:1



Figs 54–59. 54–56 *Mesocyclops aspericornis*, 54 abdominal segments with seminal receptacle and furca, 55 fourth leg, 56 basipodite of antenna (a.: caudal view, b.: frontal view), 57–59 *Mesocyclops pehpeiensis*, 57 abdominal segment with seminal receptacle and furca, 58 fourth leg, 59 basipodite of antenna (a.: frontal view, b.: caudal view) (scales are in mm).

Table 5. Morphometric measurements of *M. pehpeiensis* given by Hu (1943) and from the present study.

	Morphometric parameters		
	Total	Enp. P.	Furcal rami
Source	length (μm)	L:W	L:W
Hu 1943	1450 – 1700	3.00:1	3.80:1
Present study	1625	2.73:1	3.03:1

Table 6. Species list of Calanoida in Malaysia.

Species
Neodiaptomus handeli Brehm
Neodiaptomus blachei (Brehm)
Neodiaptomus botulifer Kiefer
Neodiaptomus malaindosinensis Lai & Fernando
Neodiaptomus mephistopheles Brehm
Neodiaptomus meggitti Kiefer
Pseudodiaptomus (Schmackeria) dauglishi Sewell
Pseudodiaptomus (Schmackeria) tollingerae Sewell
Tropodiaptomus ruttneri Brehm
Tropodiaptomus hebereri Kiefer
Tropodiaptomus vicinus Kiefer

Thermocyclops species

It has been generally accepted that *Thermocyclops crassus* (Fischer) is a cosmopolitan species and that it is very common in tropical regions especially in open waters. A closely related species *T. decipiens* has been found recently to be quite common in tropical regions (Dussart, 1982, unpubl. data). It is likely that may earlier records of *T. crassus* are really *T. decipiens*. The inability to separate these two species was due in the past to the lack of recognised diagnostic features. However, it is clear that the shape of the seminal receptacle can be used to separate them.

Four species of *Thermocyclops* are present in Malaysian freshwaters viz. *T. decipiens, T. crassus* and *T. orientalis* and *T. rylovi* cf. in order of their commoness in occurrence. Fernando & Ponyi (1981) recorded only two species. However, *T. orientalis* was listed as *T. cf. schmeili*. They did not differentiate the closely similar *T. cf. decipiens* and *T. crassus* which they certainly encountered.

Thermocyclops cf. *decipiens* Kiefer, 1929

Female: Length 910–940 μm. Body slender with very divergent furcal rami and apical setae characteristic of most species of the genus. It has an elongated seminal receptacle with the transverse portion recurved posteriorly (Fig. 60). The furcal, enp_3 P_4, and external to internal spine of enp_3 P_4 indices are 3.04–3.26, 2.50–3.00, and 0.50–0.52 respectively. The connecting lamella of P_4 has a pair of prominences with spines (Fig. 61). These characteristics concur with Dussart's (1982) description. Since Dussart & Fernando (in press b) list this as *T.* cf. *decipiens* we have retained this name.

Localities: 25, 28, 42, 100, 117, 155, 195, 197, 204, 210.

Thermocyclops crassus Fischer, 1853

Female: Length 878–925 μm. *T. crassus* is similar in shape to that of *T. decipiens*. Other similarities are the spined prominences on the connecting lamella of P_4, the divergent furcal rami and apical setae (Figs. 62, 63), the relative lengths of the external to internal spines of enp_3 P_4. The differences include the shape of the seminal receptacle (Fig. 62); the furcal rami, they are more robust with a furcal index of 2.08–2.38 and the relative lengths of the internal apical and internal median apical setae of the furcal rami (0.65–0.73).

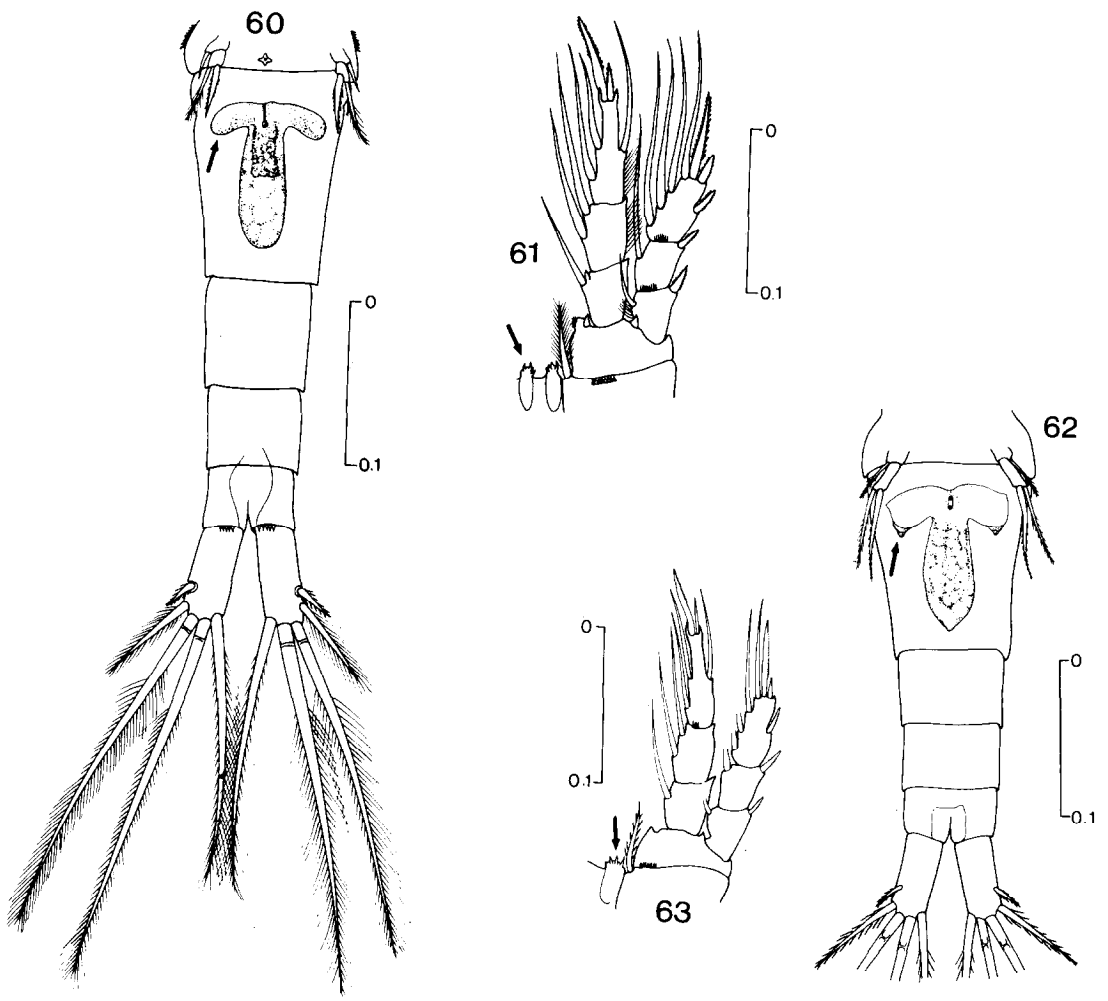
Localities: 7, 49, 68, 70, 72, 168.

Calanoida

The Malaysian Calanoida have been intensively studied recently. Eleven species have been recorded and described (Table 6).

Most Malaysian calanoids belong to the genus *Neodiaptomus* (6 of the 11). There is some confusion regarding the status and naming of *N. schmackeri* and *N. handeli* in the region but both Lai & Fernando (1978), and Rajendran (1971) conclude that the Malaysian species is *N. handeli*.

Kiefer (1981) has revised the species of *Tropodiaptomus*. The Malaysian species belonging to the genus have been revised by Lai & Fernando (1979). However, the nomenclature of some species needs updating.



Figs 60–63. 60–61 *Thermocyclops* cf. *decipiens* 60 abdominal segments with seminal receptacle and furca, 61 fourth leg, 62–63 *Thermocyclops crassus*, 62 abdominal segments with seminal receptacle and furca, 63 fourth leg (scales are in mm).

Discussion

The present study of the freshwater Cyclopoida and Calanoida of Malaysia has shown that the records of these organisms in tropical regions need updating, in light of recent studies on the systematics carried out elsewhere, especially in the tropics.

Until very recently it has been generally assumed that many Cyclopoida, Cladocera and Rotifera were cosmopolitan. Since the earliest systematics work on these animals was done mainly in Europe, European species names have been used extensively for many species worldwide. This approach is especially evident in the work of Gurney (1933) on the freshwater Copepoda. His work is comparable in morphological sophistication to recent work but his nomenclature was influenced by the acceptance of cosmopolitanism (Dussart & Fernando in press a).

Frey (1982) and Dumont (1983) have pointed out that cosmopolitanism in Cladocera and Rotifera respectively is not as widespread as generally accepted. Kiefer (1981) in revising *Mesocyclops* of the Old World showed that where only *Mesocyclops leuckarti*, the European species, was supposed to occur, at least 12 good species were found. More re-

cently Van de Velde (1984) has found that the African *Mesocyclops* are equally diverse and mostly different from Oriental and European species. The updating of our knowledge of other genera of Copepoda will certainly lead to major revisions in nomenclature. We have found that two European 'cosmopolitan' species *Ectocyclops phaleratus* and *Macrocyclops distinctus* formerly believed to occur in Malaysia are really other species. It is likely that *Eucyclops serrulatus, Microcyclops varicans* and *Thermocyclops crassus* will also be redefined both morphologically and geographically as more data becomes available.

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Appendix I

Selected localities where species were recorded in this study. The total number of localities studied was 248 (see Fig. 1). The numbers where each species was recorded is referred to in the text under locality.

Number in text	Locality Name	Habitat	Geographic position
4 – 40	Alor Star	marsh	6°07′N 100°22′E
117	Alor Star	ricefield	6°07′N 100°22′E
134	Alor Star	ricefield	6°07′N 100°22′E
7	Ayer Kuning	fish pond	4°11′N 101°09′E
113	Ayer Tawar	irrigation canal	5°29′N 100°23′E
55	Bahau	pond	2°49′N 102°25′E
56	Bahau	ricefield	2°49′N 102°25′E
25	Batu Pahat	ricefield	1°51′N 102°56′E
87	Beruas	ricefield	4°30′N 100°47′E
88	Beruas	ricefield	4°30′N 100°47′E
1 – 137	Butterworth	buffalo hole	5°25′N 100°25′E
72	Chemor	fish pond	4°43′N 101°07′E
75	Chemor	fish pond	4°43′N 101°07′E
77	Chemor	fish pond	4°43′N 101°07′E
210	Gua Musang	pond	4°53′N 101°58′E
8	Kampar	mining pool	3°52′N 103°22′E
104	Kampong Changkat Lobak	marh	5°08′N 100°38′E
59	Karak	pond	1°41′N 103°12′E
1	Kepong	stream	4°13′N 102°32′E
49	Kluang	marshy pond	5°25′N 100°39′E
51	Kluang	irrigation canal	5°25′N 100°39′E
176	Kota Bahru	pond	6°00′N 102°15′E
40	Kota Tinggi	mining pool	3°45′N 102°19′E
215	Kuala Muda	irrigation canal	5°35′N 100°23′E
179	Kuala Trengganu	marshy pond	5°20′N 103°08′E
180	Kuala Trengganu	pond	5°20′N 103°08′E
215	Ipoh	mining pool	4°35′N 101°05′E
204	Machang	pond	5°46′N 102°13′E
32	Masai	fish pond	6°41′N 100°15′E
195	Pasir Mas	ricefield	6°02′N 102°08′E
197	Pasir Mas	ricefield	6°02′N 102°08′E
12	Port Dickson	ricefield	2°30′N 101°54′E
220	Port Dickson	ricefield	2°30′N 101°54′E
155	Raub	fish pond	3°48′N 101°52′E
156	Raub	ricefield	3°48′N 101°52′E
157	Raub	ricefield	3°48′N 101°52′E
54	Segamat	swamp	2°25′N 102°24′E
2	Sekinchang	irrigation canal	4°34′N 101°04′E
100	Taiping	mining pool	4°51′N 100°44′E
101	Taiping	marsh	4°51′N 100°44′E
68	Tanjong Rambutan	mining pool	4°40′N 101°10′E
28	Ulu Choh	reservoir	1°32′N 103°33′E
8 – 811	Weng, Kedah		5°50′N 100°53′E

| Number in text | Locality Name | Habitat | Geographic position |