THE FREELIVING FRESHWATER CYCLOPOID COPEPODA (CRUSTACEA) OF MALAYSIA AND SINGAPORE

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Abstract

A study of freeliving freshwater Cyclopoida of Malaysia and Singapore yielded 15 species. Some remarks are made on the morphology including a species belonging to the *schmeili group of Thermocyclops.* Shallow and vegetation-bearing habitats had the largest numbers of species. Most of the species are cosmopolitan. The three common species, *Mesocyclops leuckarti, Thermocyclops crassus* and *Microcyclops varicans* are eurytopic. *M. leuckarti* and *T. crassus* are the only species occurring commonly in limnetic situations in contrast to a much wider limnetic Cyclopoida species spectrum in temperate lakes. There appears to be a reduction in Cyclopoida from temperate to tropical latitudes, but the data on which this are based are at present fragmentary.

Introduction

The cyclopoid Copepoda are among the most ubiquitous microcrustaceans in lentic freshwaters, yet their occurrence in the tropics is poorly documented. The present study was undertaken in 1966 and completed in 1979. It documents the occurrence of freeliving cyclopoid Copepoda throughout the region based on intensive and extensive sampling over the study period. All types of freshwater habitats were sampled and 15 species were recorded. Systematic notes are given on a few species. Some comments are made on the species composition in different habitats, their commoness or rarity and their zoogeography. Tropical Cyclopoida in freshwaters are poor in species compared to sub-tropical and temperate regions. This conclusion is based on the very limited data available from the tropics and needs more thorough documentation.

Previous Literature

References to freshwater cyclopoid Copepoda of Malaysia and Singapore are very meagre indeed. There are some references to Cyclopoida in papers on the local fauna and limnology: Anon (1965), Fernando (1977), Johnson (1975), Lai & Chua (1976), Lim (in press), Lim & Furtado (1975), Mizuno & Mori (1970), Spandl (1925), and Sudzuki (1973). Lindberg (1954a) states that Spandl's records are erroneous and came from a mislabelled European sample from Hungary.

Some of the earlier works on freshwater Cyclopoida of humid tropical Asia, which includes Malaysia and Singapore, have been listed by Dussart (1974). This includes systematic studies from Burma; Lindberg (1949b), Cambodia (Kampuchea); Lindberg (1952), India; Lindberg, (1941, Kiefer, 1939 and other papers) and Indonesia (Kiefer, 1933 and other papers), Lindberg (1945a). More recent systematic works are Fernando (1974) on Sri Lanka and Mamaril & Fernando (1978) on Philippine material. Reference has been made to Thai freshwater Cyclopoida by Boonsom (1970) and Bricker *et al.* (1978).

A high proportion of freshwater Cyclopoida species are cosmopolitan or widely distributed (Rylov, 1963). Hence they can be diagnosed using the comprehensive European and North American monographs (Dussart, 1969; Gurney, 1933; Rylov, 1963 and Wilson & Yeatman, 1959). Simple, illustrated keys are also available for quick diagnosis in Harding & Smith (1960), Šrámek-Hušek (1953), Ueno (1973) and Wilson & Yeatman (1959). However, only two of these are in English. Species diagnosis is however seldom attempted by tropical hydrobiologists and misidentifications are not uncommon.

Probably most of the Oriental species of Cyclopoida have been described in the scattered literature (see Dussart 1974 and Fernando 1974), but the different authors have often dealt with very limited amounts of material. The diagnosis of species has also been complicated by differences in nomenclature. A more conservative approach to species naming has been followed by Gurney (1933), Rylov (1963), Wilson & Yeatman (1959) and Dussart (1969). A much larger number of species is accepted in the works of

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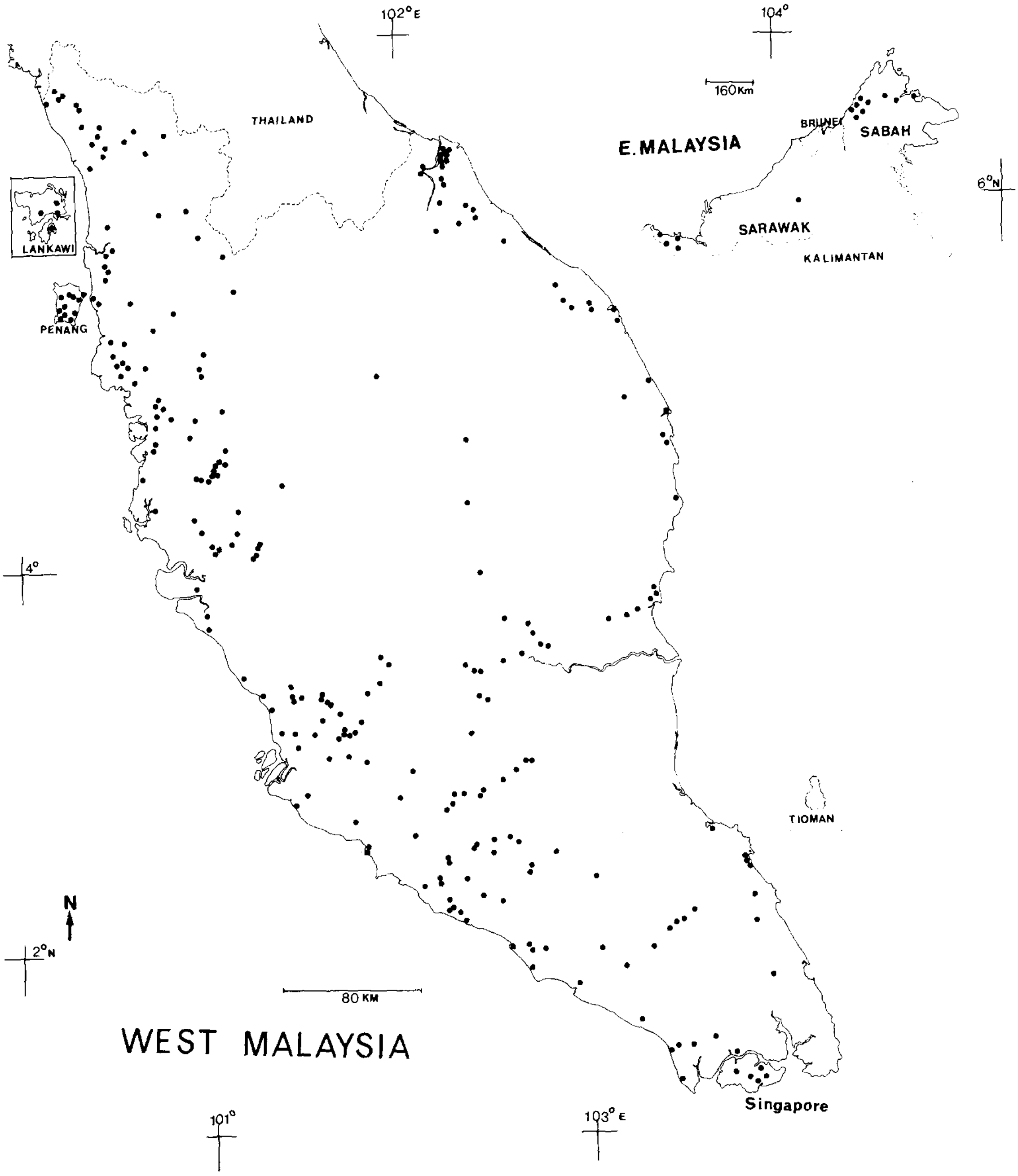


Fig. 1. Sampling localities in East and West Malaysia and Singapore. Each dot represents one more sites of collection. All types of freshwater habitats available were sampled. The latitude and longitude refer to West Malaysia and Singapore. Lankawi is placed closer than its normal position to West Malaysia. East Malaysia lies at the same latitude as West Malaysia but its longitude is approximately 110°E-120°C.

Lindberg (1954b), Kiefer (1933) and Lindberg (1941, 1949, 1952). All but the first of those papers refers to Oriental material. Hence the species number in the Oriental region is probably less than the number listed in these publications if we follow the conservative and more recent systematic literature on Cyclopoida.

Material and methods

The sampling localities are shown in Fig. 1. Samples were taken with plankton nets of mesh #10 (157 μm) and 25 (64 μm). Two sizes of plankton nets, with 15 cm and 20 cm mouth diameter were used. The smaller net was dragged

Table 1. Occurrence of freeliving Cyclopoida (percentage to nearest whole number) in different types of habitats sampled in East and West Malaysia. Singapore samples are not included in this analysis. Miscellaneous habitats refer mainly to small pools, drains etc. Mining pools are divided into two groups. The samples referred to in Jothy (1968) are treated separately from the other samples.

HABITAT TYPE / No. Samples / SPECIES	Ponds	Lakes	Marshes	Reservoirs	Mining pools (Jothy 1968)	Mining pools (Others)	Rice Fields	Rivers and Streams	Miscellaneous
	154	4	41	33	130	10	56	19	24
Cryptocyclops bicolor	1	-	-	-	-	-	4	5	-
Eutocyclops phaleratus	9	-	33	3	-	20	26	-	15
Eucyclops serrulatus	6	25	13	3	1	-	11	11	-
Macrocyclops albidus	-	-	-	-	-	-	-	5	-
Macrocyclops distinctus	-	-	4	-	-	-	-	-	-
Macrocyclops fuscus	1	-	-	-	-	-	-	-	-
Mesocyclops leuckarti	78	75	80	61	40	70	86	73	50
Metocyclops minutus	1	50	2	-	-	-	13	-	5
Microcyclops dengizicus	2	-	-	-	-	-	-	-	10
Microcyclops varicans	40	-	45	21	-	20	44	50	40
Paracyclops affinis	1	-	5	-	-	-	-	-	-
Paracyclops fimbriatus	1	-	4	-	-	10	-	-	5
Thermocyclops crassus	32	25	18	67	98	30	18	11	35
Thermocyclops cf. schmeili	-	-	-	-	-	-	2	-	-
Tropocyclops prasinus	22	-	30	9	-	20	38	11	15
Total No. Species in Habitat	12	4	10	6	3	6	9	7	8

close to the bottom, and among vegetation, near the edge of habitats. The larger net was used to obtain samples in open water, by throwing and hauling in for a diagonal haul, or by dragging behind a boat for a diagonal haul. Vertical samples were taken in deep water with the larger net. The concentrated samples were fixed in 10% formalin and stored.

In all, 528 samples from East and West Malaysia and 38 samples from Singapore were studied. This included 130 samples from tin mining pools collected by Jothy (1968) from West Malaysia.

The Cyclopoida were sorted using a M8 wild stereo microscope. Individual specimens for detailed study were dissected either in glycerine or Polyvinyl Lactophenol tinted with Lignin pink (Edward Gurr, London). Drawings were made with a camera lucida.

471 samples were used to make a census of all the Cyclopoida present in the samples. The Singapore samples which came mainly from fishponds, were not used in this analysis (Table 1).

List of Species

The following 15 species were recorded in the samples:

Macrocyclops fuscus (Jurine, 1820)
Macrocyclops distinctus (Richard, 1887)
Macrocyclops albidus (Jurine, 1820)
Eucyclops serrulatus (Fischer, 1851)
Tropocyclops prasinus Fischer, 1860)
Paracyclops fimbriatus (Fischer, 1853)
Paracyclops affinis (Sars, 1863)
Ectocyclops phaleratus (Koch, 1838)
Metacyclops minutus (Claus, 1863)
Cryptocyclops bicolor Sars, 1863)
Microcyclops dengizicus (Lepeschkin, 1900)
Microcyclops varicans (Sars, 1863)
Mesocyclops leuckarti (Claus, 1857)
Thermocyclops crassus (Fischer, 1853)
Thermocyclops cf. *schmeili* (Poppe and Mrázek, 1895)

In addition to the 'true' freshwater species we found some specimens of *Cyclopina* and *Halicyclops* in a few of our samples. This is not surprising since there is a considerable incursion of tidal saline waters into many Malaysian rivers. The paucity of halophile Cyclopoida in our samples is due to the avoidance of tidally influenced areas in our sampling.

All the species listed except for the three common species, *Mesocclops leuckarti, Thermocyclops crassus* and *Microcyclops varicans,* appear to be new records for this region. However there may be references to some of the other species in the scattered limnological literature.

Notes on Selected Species

Macrocyclops albidus

This large species is characterised by the structure of the furca (Fig. 2), the shape of the receptaculum seminis (Fig. 3), the membrane on the terminal segments of the antennule (Fig. 4) and the distinctive endopodite of leg 4 (Fig. 5).

This species is distributed on all continents (Gurney, 1933 and Rylov, 1963). According to Kiefer & Fryer (1978), it is a characteristic member of the zooplankton in temperate regions. It also inhabits the macroplytic vegetation in the littoral of lakes and a variety of small water bodies. In addition it is found in both warm and cold springs and wells (Rylov, 1963).

Our material is restricted to a single locality: Stream, Kuala Tahan, Taman Negara (National Park), Pahang Malaysia and a single sample taken on 12 April 1974. Rylov (1963) states that this species has been repeatedly recorded from flowing waters. It is rare in the tropics but it has been recorded in neighbouring Java (Gurney, 1933).

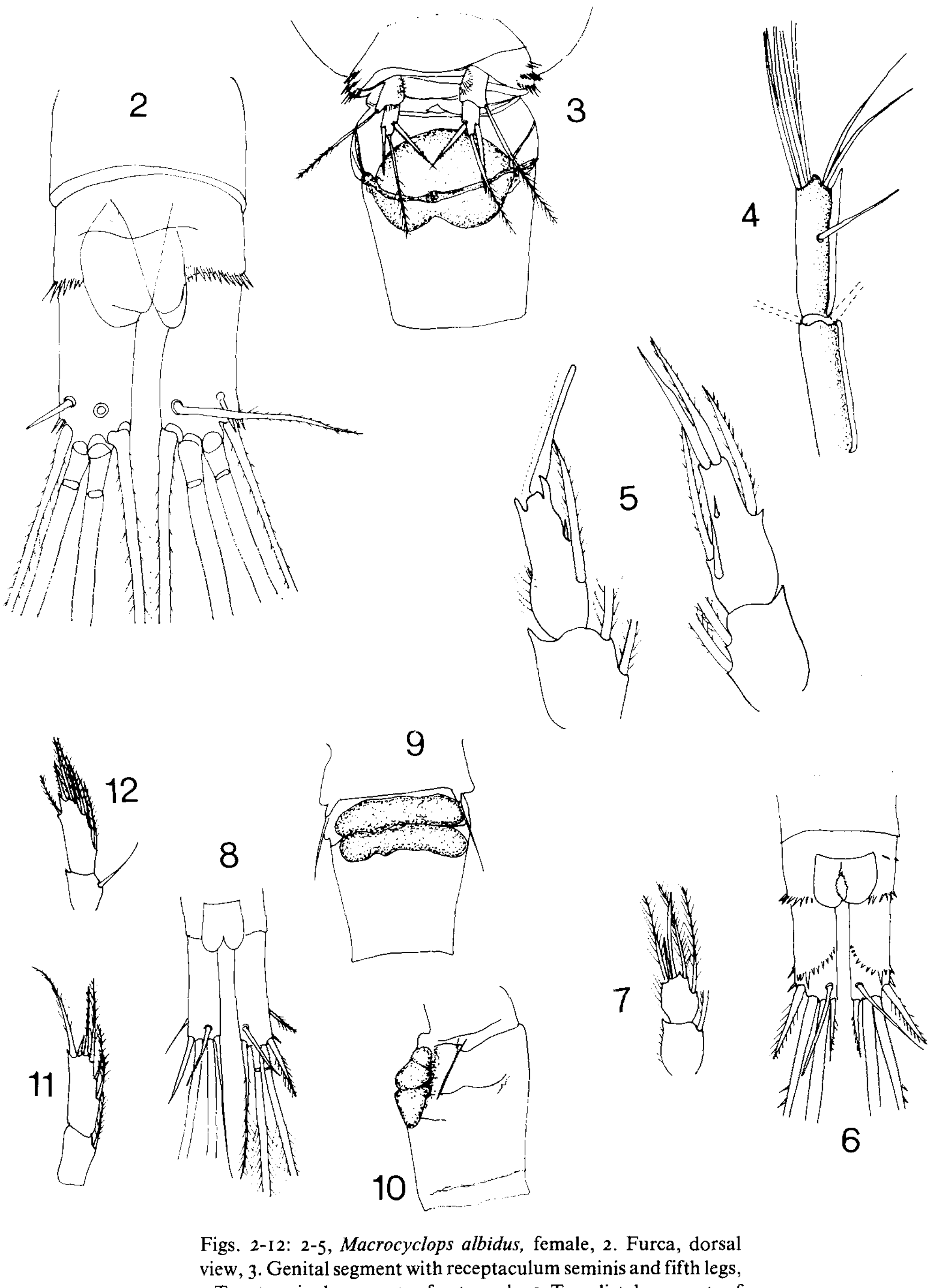
The two other species of *Macrocyclops, M. distinctus* and *M. fuscus* were also very rare in our samples (Table 1). The genus *Macrocyclops* is quite rare in the tropics, whereas it is relatively common in the sub-tropical and temperate region (Gurney 1933). Rylov (1963) mentions that all four species of the genus *Macrocyclops* occur in the Oriental region including the Javanese endemic, *M. neuter.* However, our studies on the zooplankton of South East Asia show that the genus, though represented by all four species is extremely rare (Fernando, 1974; Mamaril & Fernando, 1978 and unpublished data). Kiefer (1933) also found few samples containing the genus in this extensive study of Indonesian Cyclopoida.

Paracyclops affinis

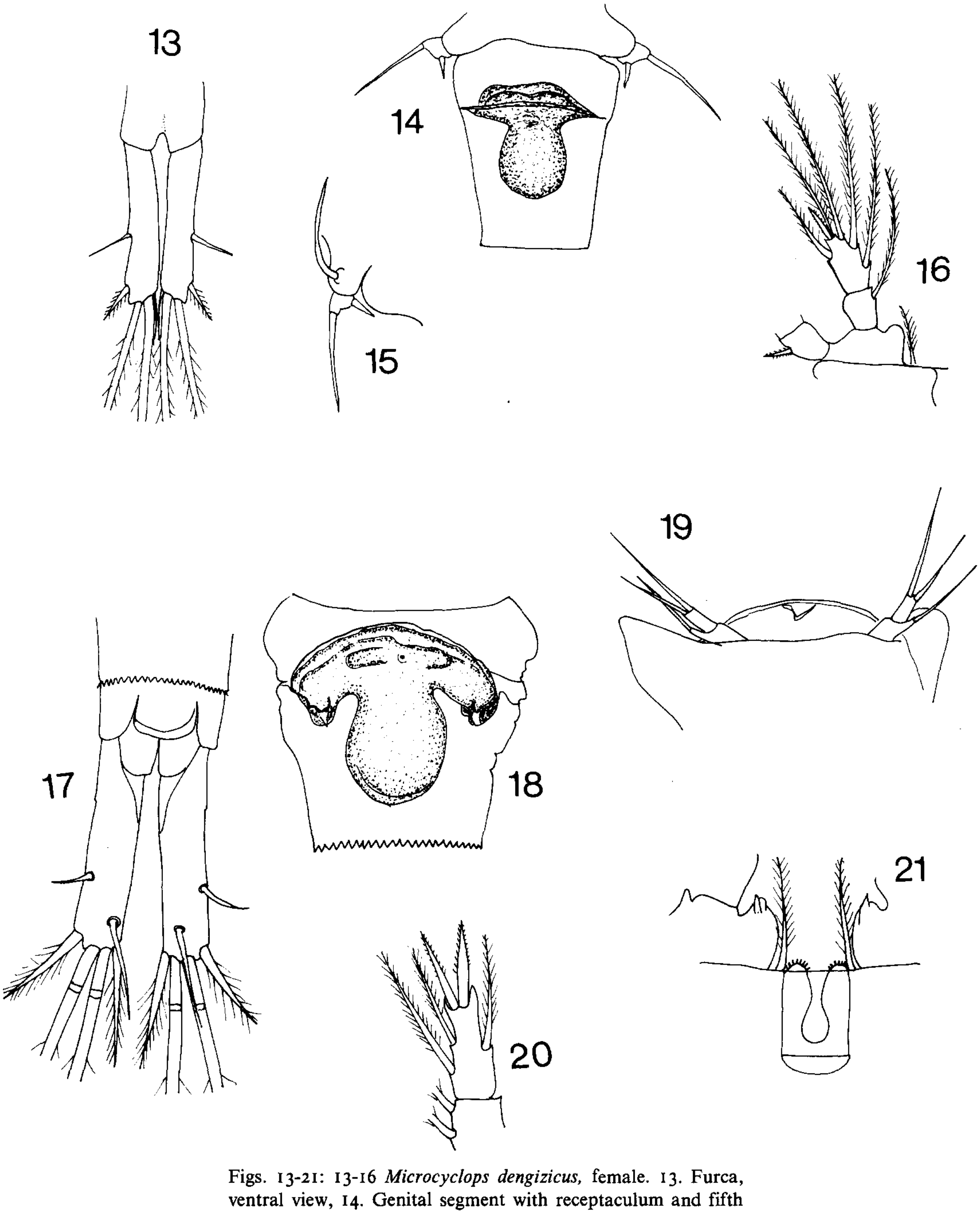
Two distinctive features of this species, namely the structure of the furca (Fig. 6) and the two distal joints of leg 4 endopodite (Fig. 7), are shown.

This is a typical benthic form, inhabiting the macrophyte zone in the littoral of lakes and various types of shallow stagnant water bodies (Gurney 1933, Rylov 1963).

This is a widely distributed species. It is found in the whole of Europe, Central and Southern Asia, Afric, North



Figs. 2-12: 2-5, *Macrocyclops albidus,* female, 2. Furca, dorsal view, 3. Genital segment with receptaculum seminis and fifth legs, 4. Two terminal segments of antennule, 5. Two distal segments of endopodite of fourth leg - right and left side, 6. and 7. *Paracyclops affinis,* female, 6. Furca, dorsal view, 7. Two distal joints of endopodite of fourth leg, 8-12. *Cryptocyclops bicolor,* 8. Furca, dorsal view, 9. Genital segment with receptaculum seminis and fifth legs, ventral view, 10. Genital segment with receptaculum seminis and fifth leg, lateral view, 11. Terminal portion of endopodite of fourth leg.



Figs. 13-21: 13-16 *Microcyclops dengizicus,* female. 13. Furca, ventral view, 14. Genital segment with receptaculum and fifth legs, ventral view, 15. Fifth leg, 16. Endopodite of fourth leg, 17-21. *Thermocyclops* cf. *schmeili,* female, 17. Furca, dorsal view, 18. Genital segment with receptaculum seminis, ventral view, 19. Fifth legs and fifth thoracic segment, 20. Terminal joint of endopodite of fourth leg, 21. Connecting lamella of the fourth pair of legs.

America and Australia (Gurney, 1933; Rylov, 1963). According to Gurney (1933), Fernando (1980a) and Mamaril & Fernando (1978), it is not as common in the tropics as its related species *Paracyclops fimbriatus.* The present study also reinforces the evidence that both these species of *Paracyclops* are rare species in tropical waters.

Our material came from a marsh in Dungun, Trengganu and two ponds near the Sandakan-Labuk Road, Sabah.

Cryptocyclops bicolor
Sometimes placed in the genus *Microcylops* (Rylov 1963), this species can be distinguished by the structure of the furca (Fig. 8), the shape of the receptaculum seminis (Figs. 9 and 10) and the endipodites of leg 3 (Fig. 11) and leg 4 (Fig. 12).

This species lives in shallow water bodies overgrown with macrophytes, and in the littoral macrophyte zone of lakes. It is a warm water stenotherm, and occurs in habitat that dry up like rice fields (Rylov, 1963). Two of the five samples it occurred in were from rice fields (Table 1).

This species is distributed in the whole of Eurasia, North America and Africa (Gurney, 1933; Rylov, 1963). More recently it has been recorded in Thailand by Boonsom (1970) and Bricker *et al.* (1978). It is probably confused with the very common *Microcyclops varicans,* especially in the tropics.

Microcyclops dengizicus
This species can easily be confused with the much commoner *Microcyclops varicans.* It can, however, be distinguished by the structure of the furca (Fig. 13), the shape of the receptaculum seminis (Fig. 14), the detailed morphology of leg 5 (Fig. 15) and the structure of the endopodite of leg 4 (Fig. 16).

Rylov (1963) noted that this species is typically found in brackish lakes and large brackish ponds. He considers it a halobiont and typical of the desert zone. Its occurrence in six small habitats (Table 1), in Penang Island which is not desert, is therefore interesting. However, all the habitats; four small pools and two buffalo wallows, were in low lying areas where infiltration of saline water would occur.

This species has been recorded from India, Haiti, Egypt, U.S.A. and U.S.S.R. This is the first record from the Indo-Malaysian area. However, it is probably widely distributed in this region.

Thermocyclops cf. *schmeili*
We found a female with egg sacs of this interesting species. Unfortunately we made a preparation of the specimen before we realized that it was probably a hitherto undescribed species. We could not therefore measure it very accurately. However since it has many interesting morphological features close to *Thermocyclops schmeili,* we have listed it as *T.* cf. *schmeili* and given a short illustrated description.

Antennules 17 jointed. We were unable to detect a hyaline membrane on either of the two terminal segments. The spine formula of the swimming legs is the same as in other members of the genus *Thermocyclops.* Fifth leg is also typical of the genus (Fig. 19). The ratio of the length to breadth of the furcal ramus (Fig. 17) was 4.1 : 1.0. The receptaculum seminis (Fig. 18) is similar to that of *Thermocyclops hastatus* Kiefer andt *T. trichophorus* Kiefer.

The ratio of the length to breadth of the genital segment was 0.84 : 1.0 The ratio of length to breadth of the third segment of the endopodite of the fourth leg was 2. 14 : 1. The lengths of the terminal spines of endopodite 3 of the fourth leg inner spines outer spines was 1.02 ; 1.0.

In all these features it belong to the *schmeili* group according to the descriptions and comparisons of Sewell (1957) and Einsle (1970).

The possibility that our material belongs to a new species is suggested by some distinctive morphological differences from hitherto described members of the *schmeili* group. These are: The sides of the membrane connecting the fourth pair of legs (Fig. 21) bears a pair of unique circular outgrowths, armed with 8 tiny spines. While this resembles the structure found in other members of the genus *Thermocyclops,* it is nevertheless distinctive. Also the proportional lengths of the distal segment of the eudophodite of the fourth leg and the inner terminal spine (Fig. 20) is distinctive.

Species Composition in Different Habitats

Of the fifteen species recorded, *Mesocyclops leuckarti* and *Thermocyclops crassus,* were found in all types of habitats (Table 1). *Microcyclops varicans* was missing only in open waters of mining pools and lakes, while *Thermocyclops crassus* was much commoner in open waters, i.e. reservoirs and mining pools (Table 1). *Tropocyclops prasinus, Eucyclops serrulatus* and *Ectocyclops phaleratus* are found predominently in littoral and benthic samples and are fairly common. The other nine species are rare. *Microcyclops dengizicus* is restricted to saline habitats. The rest were recorded mainly in small habitats and are probably littoral.

Table 2. Number of freeliving freshwater Cyclopoida recorded in different regions of the world. Only species numbers, modified slightly from various authors are given. Sub-species, varieties and forms are not included. Areas are classified as tropical-subarctic or in two or more of these categories. Sampling levels are classified as L = Low; E = Extensive and I = Intensive.

AREAS	Number of species recorded	Number of authors	Sampling level	Remarks *Unpublished = data collected by one of us (C.H.F.) Data from various sources adapted to reflect uniform treatment
A. TROPICAL				
Burma	8	1	L	Includes additional unpublished record
East Malaysia	6	1	L	
Haiti	13	Few	E	Includes unpublished data
Kampuchea	12	1	L	Includes additional unpublished record
Indonesia	37	many	E, I	Extensive sampling gave fewer species (unpublished)
Philippines	7	1	L	
Singapore	4	1	E	Human densities extremely high. Hardly any freshwaters without intensive eutrophication
Sri Lanka	13	many	E, I	
West Malaysia	15	Few	E, I	
Tropical Asia	20	Few	E	Based on unpublished data (estimate), excluding endemics
Vietnam	15	1	E	Only Southern Region
B. SUB-TROPICAL				
Cuba	23	Few	E, I	
Mexico	17	Few	L	
Nepal	10	Few	L	
C. TEMPERATE				
Britain	35	many	E, I	
D. SUB-TROPICAL – SUB-ARCTIC				
Continental Europe	83	many	E, I	North Africa to Scandinavia
U.S.A.	48	many	E, I	Includes Alaska
U.S.S.R.	73	many	E, I	Includes probable occurrences
E. TEMPERATE – SUB-ARCTIC				
Scandinavia	35	many	E, I	
Ontario, Canada	22	Few	E, I	
Europe	over 100 included endemics	many	E, I	
F. SUB-TROPICAL – TEMPERATE				
Japan	31	many	E, I	
G. TROPICAL – TEMPERATE				
India	47	many	E	

Kiefer, 1967. Limnofauna Europaea, Gustav Fischer, Stuttgart, Copepoda: pp. 173-185 gives the distribution of Cyclopoida in Europe. Each area has over 30 species. Apart from quantitative differences, the species composition of temperate and tropical faunas is different.

In temperate regions there are a number of true limnetic species of Cyclopoida (Kiefer & Fryer, 1978). In tropical South East Asia the only limnetic species *Thermocyclops crassus* and *Mesocyclops leuekarti* are also eurytopic (Fernando 1980a, 1980b, 1981). In Malaysia *Thermocyclops crassus* is the only species found predominantly in the limnetic zone (Table 1). This is similar to what has been found in Sri Lanka by Fernando (1980a). Lai & Chua (1976) found only the two species *Thermocyclops crassus* and *Mesocyclops leuckarti* in two Malaysian reservoirs.

The largest number of Cyclopoida were found in ponds, marshes, rice fields and miscellaneous habitats (Table 1). All these had an abundance of macrophytes and were often shallow. This meant that both littoral and benthic forms were more likely to be collected in sampling these habitats. Fernando (1977) found that rice fields, ponds and marshes in South East Asia had a richer cyclopoid fauna than open waters. Fernando *et al.* (1979), list Copepoda (mainly Cyclopoida), only slightly less often than Cladocera in the rice field aquatic fauna reported on a worldwide basis.

Remarks on Zoogeography

There are a number of cosmopolitan or widely distributed species among freshwater Cyclopoida (Gurney, 1933; Rylov, 1963). Ten of the fifteen Malaysian species belong to this category (Rylov, 1963). The large number of endemic species of *Eucyclops* and *Microcyclops* recorded from the Oriental region (Rylov, 1963), did'not occur in our samples in Malaysia. Perhaps this is due to a difference in our definition of species.

Certain genera of Cyclopoida are rare or absent from tropical freshwaters. These are the genera *Cyclops* and *Acanthocyclops.* Both these genera have many limnetic species (Kiefer & Fryer, 1978). It is interesting to note that there is a similar paucity of species of Cladocera belonging to predominently limnetic genera *Daphnia, Polyphemus, Holopedium,* and *Leptodora,* in tropical freshwaters (Fernando, 1980a).

Latitudinal Variation in Species Number

In Table 2, we have drawn up a provisional set of numbers of species of freshwater free-living Cyclopoida in some selected regions of the world. The list of areas includes strictly tropical, sub-tropical, temperate and subarctic regions. Also, areas spanning two or more of these latitudinal zones are included because of the nature of the data available.

The nomenclature of Cyclopoida at the species level has been in a very fluid state. The more conservative systematists, like Gurney (1933) and Rylov (1963), are generally followed in more recent works, e.g. Dussart (1969) and also by Wilson & Yeatman (1959). There still remains however the problem of subspecies and varieties which are subject to rapid change. In drawing up our list, we have used species numbers but omitted sub-species and varieties given by previous authors. The number of species has been slightly modified in some cases but the number in an area or country has been maintained essentially what has been reported.

Recent studies on chromosome numbers of Cyclopoida by Einsle (1975) and Chinappa & Victor (1979a, 1979b) offer some possibilities for a more satisfactory naming of species. But data is not available on many of the species still.

The data used in Table 2 are drawn mainly from the following publications: Dumont & Van de Velde (1977); Dussart (1969); Fernando (1974); Harding & Smith (1970); Kiefer (1933, 1936, 1939); Lindberg (1941, 1949a, 1949b, 1952, 1954a); Mamaril & Fernando (1978); Rylov (1963); Shirota (1963); Smith & Fernando (1979a, b 1980) and Ueno (1973).

To compare the freshwater cyclopoid Copepoda species numbers in different latitudes one must choose areas of similar size and level of investigation. At the present time we do not have the data to do such a comparison. However if we take the tropical areas which have been studied intensively, we have only Indonesia, Sri Lanka and the present paper (Malaysia and Singapore). Perhaps Haiti can be classed in this category too. For the subtropics, only Cuba has been investigated intensively. In the case of temperate and sub-arctic regions, we have far more comprehensive data.

Comparing the number of species in different latitudes we find that the tropics have relatively few species of Cyclopoida, Copepoda in freshwater as compared to subtropical and temperate regions (Table 2). The exception in the tropics seems to be Indonesia with nearly 30 species. However a recent study of over 125 samples from Java, Sumatra, Borneo, Bali and Celebes by one of us (C.H.F.) yielded only 16 Cyclopoida. The endemics were not recorded. The higher numbers of species in Kiefer's (1933) paper from a smaller area of Indonesia (Java, Sumatra and Bali) reflects a less conservative nomenclature and perhaps a greater diversity of habitats on his samples.

The fewer Cyclopoida in tropical freshwaters as compared to temperate freshwaters, goes contrary to the normal effects of latitude on species number. Fernando 1980a, 1980b, 1981c) has shown this phenomenon to occur also in the Cladocera. The generally held view is that the predation pressure by fish in the tropics is higher thereby eliminating the larger species. It is true that the larger Cladocera and Copepoda are missing or rare in tropical freshwaters, especially lakes and reservoirs. However, Sprules & Hothby (1979) have shown that in addition to the smaller size of tropical zooplankters, there is a dearth of carnivorous crustacean zooplankters in the tropics. This study used tropical data from previously published work and data collected by one of us (C.H.F.).

The rarity or absence of limnetic genera of crustacean zooplankton coupled with the small size and non-carvinorous nature of tropical crustacea raises many interesting questions. Few answers seem satisfactory to explain all these features at the same time.

It is likely that the lack of a continuous lake system in the tropics, both in space and time, the ability to survive on plant material throughout the year in the tropics, fish predation and physical factors, like the even high temperatures perennially, could account for latitudinal differences in the species and size composition of Cyclopoida.

The present comparison is seriously limited by the lack of adequate data for the tropics. Many factors besides latitude may operate in an area to restrict or enhance Cyclopoida species diversity. Singapore for example shows a low species number in spite of extensive sampling. Here we have the effect of high human densities on the aquatic fauna. Alfred (1961) records that 38 of the indigenous freshwater fishes have been eliminated in Singapore in the present century.

Summary

An intensive and extensive study of cyclopoid copepods in Malaysian and Singaporean freshwaters yielded 15 species. Ten of the fifteen species are cosmopolitan or very widely distributed. One is a halophile. Missing from the faune were two genera: *Cyclops* and *Acanthocyclops*, which are represented in temperate regions by many true limnetic species. The limnetic species in Malaysia are also eurytopic. The most diverse cyclopoid fauna was found in habitats which were shallow and with macrophytic vegetation.

The relative paucity of Cyclopoida in tropical freshwaters as compared to temperate and even sub-tropical freshwaters raises many interesting questions.

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References

Alfred, E. R. 1961. The Singapore freshwater fishes. Malay. Nat. J. 15: 1-19.

Anon. 1965. Report of the Tropical Fish Culture Research Institute, Batu Barendam, Malacca for 1965. pp. 24-26.

Boonsom, J. 1970. (Preliminary report of freshwater plankton found in Thailand) (in Thai). Annual Report Fish. Res. Unit. Inland Fisheries Division, Department of Fisheries, Bangkok, Thailand, pp 191-221.

Bricker, K. S., Wongrat, L. & Gannon, J. E. 1978. Composition and distribution of crustacean plankton in twelve water bodies in Thailand. Kaesetsart University Fishery Research Bulletin, 10: 1-14.

Chinappa, C. C. & Victor, R. 1979a. Achiasmatic meiosis and complex heterozygosity in female cyclopoid copepods (Copepoda, Crustacea). Chromosoma 71: 227-236.

Chinappa, C. C. & Victor, R. 1979b. Cytotaxonomic studies on some cyclopoid copepods (Crustacea, Copepoda) from Ontario, Canada, Can. J. Zool. 57: 1597-1604.

Dumont, H. & Van de Velde, I. 1977. Report on a collection of Cladocera and Copepoda from Nepal. Hydrobiologia, 53: 55-65.

Dussart, B. 1969. Les copépodes des eaux continentales. Cyclopoides et Biologie. N. Boubee et Cie, Paris. 292 pp.

Dussart, B. 1974. Biology of inland waters in humid tropical Asia In: Natural Resources of Humid Tropical Asia: Natural Resources Research (UNESCO). 12: 331-353.

Einsle, U. 1970. Études morphologiques sur des espèces de Thermocyclops (Crust. Cop.) d'Afrique et d'Europe. Cah. O.R.S.T.O.M. Ser. Hydrobiol. 4: 13-38.

Einsle, U. 1975. Revision der Gattung Cyclops s. str. speriell der abyssorum gruppe. Mem. Ist. Ital. Idrobiol. 32: 57-219.

Fernando, C. H. 1974. A guide to the freshwater fauna of Ceylon (Sri Lanka), Supplement 4. Bull. Fish. Res. Stn. Sri Lanka (Ceylon) 25: 27-81.

Fernando, C. H. 1977. The ecology of the aquatic fauna of rice fields with special reference to South East Asia. GEO-ECO-TROP 1: 169-188.

Fernando, C. H. 1981 a. Lake and reservoir ecosystems in South East Asia (Oriental Region) In: Lake and reservoir ecosystems, Frieda B. Taub (Edit.), Elsevier, North Holland, Amsterdam.
Fernando, C. H. 1980a. The freshwater zooplankton of Sri Lanka, with a discussion of tropical freshwater zooplankton composition. Int. Rev. ges. Hydrobiol. 65: 85-125.
Fernando, C. H. 1980b. The species and size composition of tropical freshwater zooplankton, with special reference to the Oriental Region (South East Asia). Int. Rev. ges. Hydrobiol. 65: 411-425.
Fernando, C. H. Furtado. J. I. Lim, R. P. 1979. The aquatic fauna of the world's rice fields. Wallaceana Supplement 2: 1-105, Kuala Lumpur.
Gurney, R. 1933. British Freshwater Copepoda 3: 29-384. Ray Society, London.
Harding, J. P. & Smith, W. A. 1960. A key to the British freshwater cyclopoid and calanoid copepods. Scient. Publ. FBA 18: 53 pp.
Johnson, A. 1975. The microfauna of the University of Singapore pond. J. Singapore National Acad. Sci. 4: 100-105.
Jothy, A. A. 1968. Preliminary observations of disused tin mining pools in Malaysia and their potential for fish production. Indo-Pacific Fish. Council, Occasional Paper 69/11: 1-21.
Kiefer, F. 1933. Die freilebenden Copepoden der Binnengewässer von Insulinde. Arch. Hydrobiol. Suppl. 12:519-621.
Kiefer, F. 1936. Freilebende Suss- und Salzwasser-Copepoden von der Insel Haiti. Arch. Hydrobiol. 30: 263-317.
Kiefer, F. 1939. Scientific results of the Yale North India Expedition. Biological Report No. 19. Freilebende Ruderfusskrebse (Crustacea, Copepoda) aus Nordwest und Sudindien (Pandschab, Kaschmir) Ladak Nilgirigebirge Mem. Indian Mus. 13: 83-203.
Kiefer, F. & Fryer, G. 1978. Das Zooplankton der Binnengewässer. 26: 1-380, Stuttgart.
Lai, H. C. & Chua, T. E. 1976. Limnological features of Muda and Pedu reservoirs with an observation on their suitability for fish culture. Malaysian Agric. J. 50: 480-501.
Lai, H. C. & Fernando, C. H. 1978. The freshwater Calonoida (Crustacea: Copepoda) of Singapore and Peninsular Malaysia. Hydrobiologia 61: 113-127.
Lim, R. P. & Furtado, 1975. Population changes in the aquatic fauna inhabiting the bladderwort, Utricularia flexuosa Vahl., in a tropical swamp, Tasek Bera, Malaysia. Verh. Internat. Verein. Limnol., 19: 1390-1397.
Lim, R. P. in press. Population changes in the aquatic invertebrate fauna of rice fields in Tanjung Karang, Malaysia. Proc. 5th Internat. Soc. Trop. Ecol. Kuala Lumpur.
Lindberg, K. 1941. Cyclopides (Crustacés, Copépodes) de l'Inde VIII-X. Rec. Indian Mus. 43: 471-496.
Lindberg, K. 1949a. Contributions de l'etude des Cyclopides (Crustacés, Copépodes). Kungl. Fysiogr. Sallsk. Lund. For 19: 98-121.
Lindberg, K. 1949b. Cyclopides (Crustacés, Copépodes) de la Birmanie. Bull. Soc. Zool. Fr. 74: 38-47.
Lindberg, K. 1952. Cyclopides (Crustacés, Copépodes) du Royaume du Cambodge. Bull. Inst. Sci. Nat. Belg. 28: 1-16.
Lindberg, K. 1954a. Cyclopides (Crustacés, Copépodes) d'Iles du Pacifique sud (Mélanésie et Micronésie) et de Borneo. Kungl. Fysiogr. Sallsk. Lund. For. 24: 161-174.
Lindberg, K. 1954b. Cyclopides (Crustacés, Copépodes) du Mexique. Ark. Zoo. 7: 459-489.
Mamaril, A. C. & Fernando, C. H. 1978. Freshwater zooplankton of the Philippines (Rotifera, Cladocera and Copepoda), Bull. Natural Applied Science, Univ. Philippines, Manila 30: 109-211.
Mizuno, T. & Mori, S. 1970. Preliminary hydrobiological survey of some Southeast Asian Inland waters, Biol. J. Linn. Soc. 2: 77-117.
Rylov, V. M. 1963. Fauna of the U.S.S.R. Crustacea, Vo. 3. Freshwater Cyclopoida, English Transl. Israel Program Scient. Transl. 314 pp.
Seymour-Sewell, R. B. S. 1957. A review of the sub-genus Thermocyclops Kiefer of the genus Mesocyclops Sars, with a description of a new form of Mesocyclops (Thermocyclops) schmeili, Poppe and Mràzek. Rec. Indian Mus. 55: 69-119.
Shirota, A., 1963. The plankton of South Vietnam. Publ. Overseas Technical Cooperation Agency, Japan 462 pp. and 27 pp.-appendix.
Smith, K. E. & Fernando, C. H. 1978a. A guide to the freshwater calanoid and cyclopoid copepod crustacea of Ontario. Univ. Waterloo. Biol. Ser. 18: 1-74.
Smith, K. E. & Fernando, C. H. 1978b. The freshwater calanoid and cyclopoid copepoda of Cuba. Can. J. Zool. 56: 2015-2023.
Smith, K. E. & Fernando, C. H. 1980. Guía para los Copepodes (Calanoida y Cyclopoida) de las aquas dulcis de Cuba. Academia de Ciencias de Cuba, Havana, 1-28.
Spandl, H. 1925. Entomostraken von Borneo. Ann. Natur. Mus. Wien. 38: 89-95.
Sprules, W. G. & Holtby, L. B. 1979. Body size and feeding ecology as an alternative to taxonomy for the study of limnetic zooplankton community structure. J. Fish. Res.Bd. Canada, 36: 1354-1363.
Šrámek-Hušek, R. 1953. Ňasi Kanonožci (Copepoda of freshwaters), in Czech., Praha, 61 pp.
Sudzuki, M. 1973. Fauna and flora of South East Asia. Malaysian animals and plants most commonly found. RESAM, Penang, Malaysia. 209 pp.
Ueno, M. 1973. [Freshwater Biology of Japan] (Japanese), Tokyo, 760 pp.
Wilson, M. S. & Yeatman, H. C. 1959. Copepoda In: Freshwater Biology, W. T. Edmondson (Edit.) John Wiley, New York, pp. 735-815.