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A KEY TO THE IDENTIFICATION OF THE CYCLOPOID COPEPODS OF WISCONSIN, WITH NOTES ON THEIR DISTRIBUTION AND ECOLOGY

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INTRODUCTION

The cyclopoid copepods are an important group in the food webs of freshwater ecosystems. They are among the most common animals in the plankton and benthos of Wisconsin's lakes, rivers, and ponds.

Cyclopoids are adapted for grasping and siezing larger food particles as opposed to their relatives the calanoid copepods, which are primarily filter feeders on fine particles. Many of the cyclopoids are at least partially carnivorous, preying on rotifers, microcrustacea, chironomid midge larvae and other small invertebrates. Larger algae and detrital particles are a mainstay of the diet, especially for the younger life stages.

Reproduction is strictly sexual and males and females are produced in equal numbers. The uneven sex ratios often observed in cyclopoid populations are probably attributable to a shorter life span for the male. Males are very similar to the females, except they are smaller, possess geniculate first antennae, and a larger number of urosomal segments (Fig. 1). During copulation the male grasps the female with its geniculate antennae and places a pair of spermatophores on the venter of the female genital segment. Females carry the eggs in paired egg sacs. Adult females can be recognized by the enlarged genital segment and egg sacs when present.

After hatching of the egg, development consists of a series of 12 instars. The first six instars are termed nauplius instars. The cyclopoid nauplius possesses only 3 pairs of appendages at hatching but adds several more during its development. The second six instars are the copepodid instars, the last of which is the adult.Copepodids resemble the body form of the adult, but have a lesser number of urosomal segments, antennal segments, and periopods (legs). Adults have

4 pair of well-developed periopods, in addition to the cephalic appendages. A fifth pair of periopods, located on the last thoracic segment is much reduced in size. Variations in the form of the fifth legs are an important generic and species character.

Although the European cyclopoid fauna has been well studied (Gurney 1933; Rylov 1948; Dussart 1969), much work needs to be done on the North American fauna. Some of the most important early work in America was done by C. Dwight Marsh and his students in Wisconsin (Marsh 1893). However, since Marsh's time no taxonomic studies on Wisconsin cyclopoids have appeared until the present.

The existing keys to the North American fauna (Yeatman 1944, 1959; Pennak 1963) are difficult for the novice to use, because they require the investigator to examine the vestigial fifth legs and other morphological features which are not easily seen without dissection and mounting on a microscope slide. In this key an attempt has been made to avoid these difficult features wherever possible. Instead the key is based on easily seen features, such as the setation of the caudal rami, in order that most identifications can be made with a good quality dissecting microscope on formalin-preserved material. Morphological features which are not easily seen, unless the specimen is mounted, are included in the key in parenthesis. Nevertheless, in a few instances no easily seen features for the separation of closely related species are available (cf. Diacyclops thomasi and D. bicuspidatus). In these instances, notes on habitat preferences are provided to supplement the morphological distinctions and aid the investigator in rapid identification.

In using this key adult females should be selected, although adult males can also be used in most instances. Copepodids will not key out properly in many cases, because of the incompletely developed antennal segment number.

Dissection and slide mounting may sometimes be desirable or even necessary, and these procedures are a prerequisite for advanced taxonomic studies. Dissection is performed in a drop of polyvinyl lactophenol or glycerine on a microscope slide with a fine needle mounted at the end of a thin dowel. "Minuten nadelen" available from entomological supply dealers are ideal for this purpose. The urosome is separated from the prosome by a transverse cut. This permits an unobstructed view of the vestigial fifth legs and other urosomal structures. Other appendages may be dissected off and mounted in series on a slide. If glycerine is used as a mounting medium the specimen must be cleared first. Clearing can be performed by brief immersion in a hot 10% solution of potassium hydroxide. Polyvinyl lactophenol will clear specimens mounted on slides within a few days. All slide mounts should be sealed if they are to be kept. Clear fingernail polish works well for sealing coverslips, but commercial sealants are available from microscope supply dealers. If desired, the specimen may be stained with a small amount of chlorozol black E and/or lignin pink dissolved in the mounting medium.

This key has been based largely on lake plankton collections taken by the personnel of the Wisconsin Department of Natural Resources during their 1973-75 lake surveys. I have supplemented these with material from my own collections from lakes, ponds, and temporary waters. The fauna of temporary waters is the most poorly represented and investigators working in these habitats may find forms not covered in this key. The notes on distribution and ecology reflect both my own observations as well as readings in the literature.

The nomenclature used in this key is that of Dussart (1969).

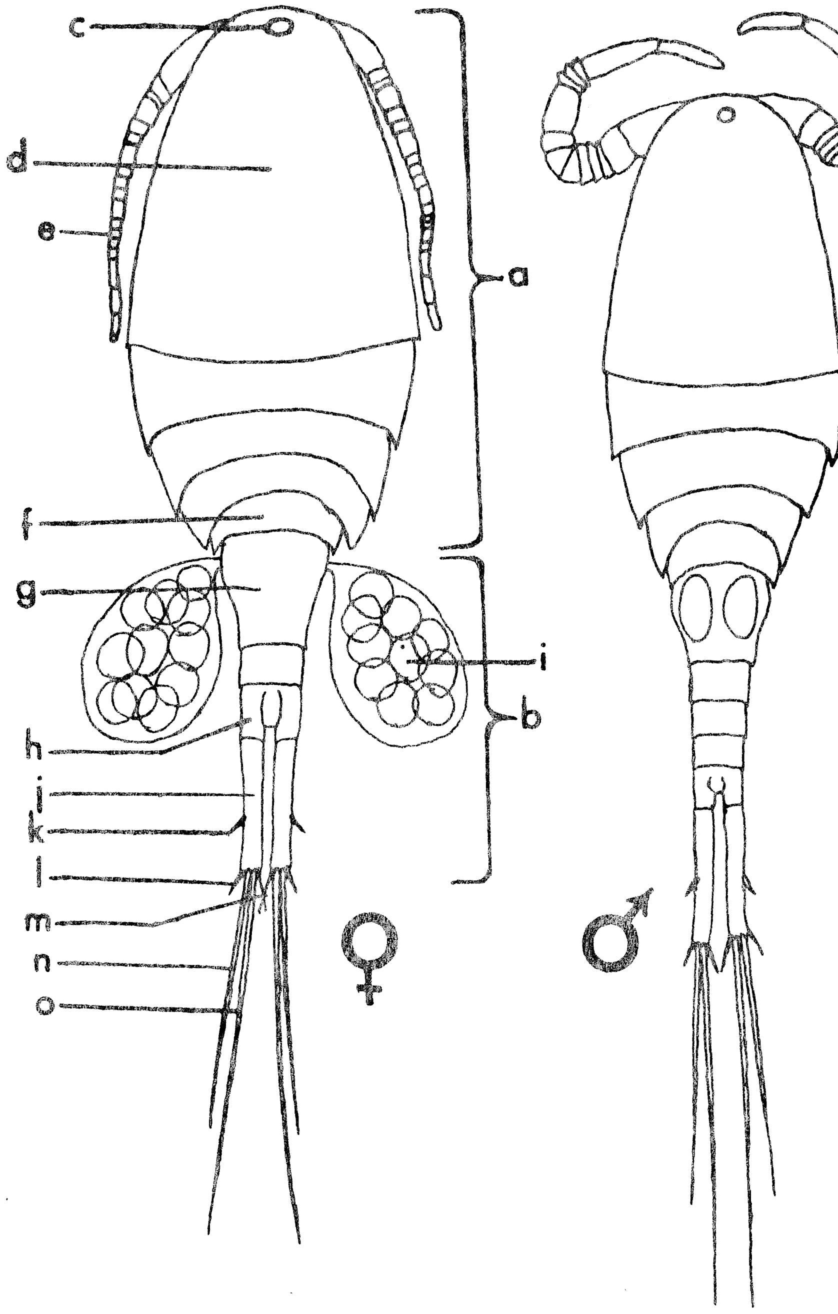

FIGURE 1. Anatomical features of a common cyclopoid copepod, Diacyclops thomasi. a. prosome (cephalothorax), b. urosome (abdomen), c. eye, d. cephalic segment, e. first antenna, f. last (4th) thoracic segment (leg 5 attached on ventral surface), g. genital segment, h. caudal furca, i. egg sac, j. caudal ramus, k. lateral bristle, l. outer apical bristle, m. inner apical bristle, n. median outer apical bristle, o. median inner apical bristle.

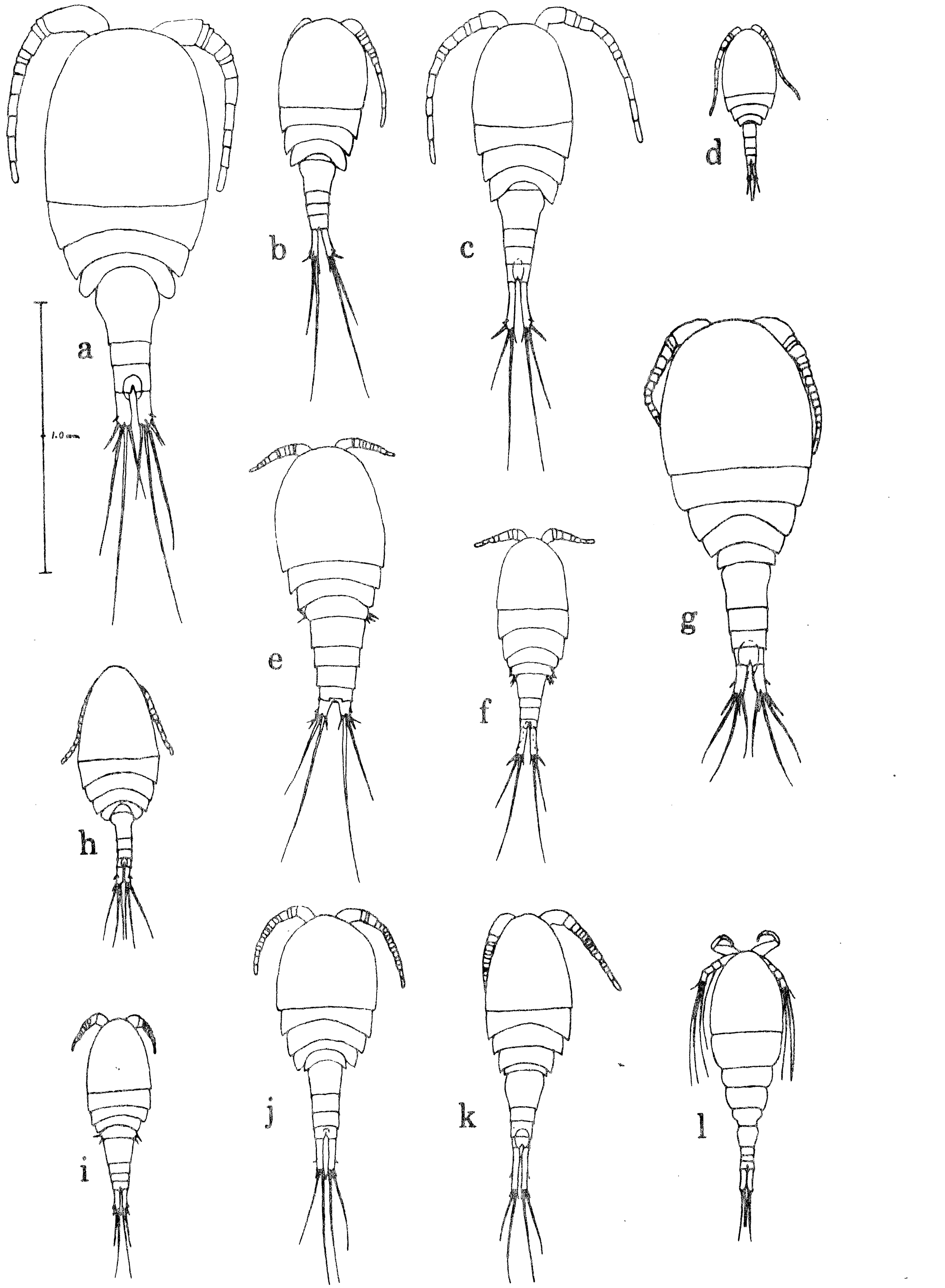

FIGURE 2. Common Wisconsin cyclopoid copepods (all figures are of females drawn from Wisconsin specimens). a. Macrocyclops albidus, b. Eucyclops serrulatus, c. E. speratus, d. Tropocyclops prasinus, e. Ectocyclops phaleratus, f. Paracyclops poppei, g. Mesocyclops e[illegible], h. Orthocyclops modestus, i. Microcyclops rubellus, j. Acanthocyclops vernal[illegible] k. Diacyclops thomasi, l. Ergasilus sp.

A KEY TO THE CYCLOPOID COPEPODS OF WISCONSIN

1a Caudal ramus armed with only 2 bristles ______ Ergasilus

1b Caudal ramus armed with 6 bristles ______ (Cyclopidae) 2

2a Inner apical bristle short, less than twice the length of the caudal ramus ______ 5

3a Inner apical bristle less than ½ the length of the median inner apical bristle ______ Macrocyclops, Homocyclops 16

3b Inner apical bristle more than ½ the length of the median inner apical bristle ______ 4

4a Large species (1.2 - 2.0 mm); caudal rami usually spread out to form a "V" (Leg 5 of 2 segments; 1st antenna of 17 segments) ______ Mesocyclops 18

4b Medium-size species (0.8 - 1.2 mm); caudal rami usually parallel, not spread. (Leg 5 of 3 segments; 1st antenna of 16 segments) ______ Orthocyclops modestus

5a First antennae short, about ½ the length of the first body (cephalic) segment ______ 6

5b First antennae almost as long or longer than the first body (cephalic) segment ______ 8

6a Width of caudal ramus is less than twice its length (Leg 5 is not distinct, being fused to the 5th metasomal segment, and is armed with 2 inner spines and an outer seta.) ______ Ectocyclops phaleratus

6b Width of caudal ramus is more than twice its length (Leg 5 composed of 1 distinct segment.) ______ 7

7a Median inner apical bristle as long or longer than urosome; outer apical bristle is a stout spine, much thicker than the inner apical bristle (Leg 5 with an inner spine and 2 outer setae.) ______ Paracyclops 19

7b Median inner apical bristle less than the length of the urosome; outer apical bristle is fine spine, not appreciably thicker than the inner apical bristle (Leg 5 armed with an apical seta and with or without an inner spine.) ______ Microcyclops, Cryptocyclops 21

8a Median inner and median outer apical bristles short, less than twice the length of the caudal ramus; small species (less than 0.8 mm) ______ Tropocyclops prasinus

8b Median inner apical bristle more than twice the length of the caudal ramus; medium and large size species (greater than 0.7 mm) ______ 9

9a Outer apical bristle is a very stout spine, considerably thicker than the inner apical bristle, females with a row of fine spinules along the outer margin of the caudal ramus (Leg 5 of 1 segment) ______ Eucyclops 22

9b Outer apical bristle not appreciably thicker than the inner apical bristle; both sexes without a row of fine spinules along the outer margin of the caudal ramus (leg 5 of 2 segments) ______ 10

10a Inner margin of caudal ramus with a row of fine hairs ______ 11

10b Inner margin of caudal ramus not hairy ______ 13

11a Caudal ramus with a longitudinal dorsal ridge ______ Cyclops scutifer

11b Caudal ramus without longitudinal dorsal ridge ______ 12

12a Large species (1.8 - 2.5 mm) (1st antenna of 17 segments) ______ Megacyclops latipes

12b Medium-size species (0.8 - 1.6 mm) (1st antenna of 12 segments ______ Acanthocyclops venustoides

13a Lateral bristle located at about the middle of the caudal ramus ______ Diacyclops (in part) 23

13b Lateral bristle located in the posterior third of the caudal ramus ______ 14

14a First antenna of 17 segments ______ 15

14b First antenna of 12 segments ______ Diacyclops crassicaudis brachycercus

15a Leg 5, terminal segment with short lateral or subterminal spur and a terminal seta ______ Acanthocyclops vernalis and its allies

15b Leg 5, terminal segment with a long terminal spine and a terminal seta ______ Diacyclops navus

Macrocyclops, Homocyclops

16a Inner lateral margin of caudal ramus with row of fine hairs (Hyaline membrane of last segment of first antenna strongly toothed) ______ Macrocyclops fuscus

16b Inner lateral margin of caudal ramus not hairy. (Hyaline membrane of last segment of first antenna smooth, not toothed __________ 17

17a Leg 5 of two segments (almost all lake-dwelling forms will key out here) __________ Macrocyclops albidus

17b Leg 5 of one segment __________ Homocyclops ater

Mesocyclops

18a Inner margin of caudal ramus with fine hairs (lateral spine of terminal segment of leg 5 longer than terminal seta; hyaline membrane on terminal segment of 1st antenna; a series of sharp teeth) __________ Mesocyclops edax

18b Inner margin of caudal ramus without fine hairs. (lateral spine of terminal segment of leg 5 shorter than terminal seta; hyaline membrane on terminal segment of 1st antenna with a deep round notch) (not as yet recorded in Wisconsin, but may occur) __________ Mesocyclops leuckarti

Paracyclops

19a First antenna of 8 segments (Caudal ramus with a longitudinal dorsal row of spinules) __________ Paracyclops poppei

19b First antenna of 11 segments __________ 20

20a Caudal ramus with a longitudinal dorsal row of spinules (not recorded in Wisconsin, but may occur) __________ Paracyclops yeatmani

20b Caudal ramus with a transverse dorsal row of spinules (not recorded in Wisconsin, but may occur) __________ Paracyclops affinis

Microcyclops, Cryptocyclops

21a Median inner apical bristle 4 to 5 times the length of the caudal ramus __________ Microcyclops rubellus

21b Median inner apical bristle only twice the length of the caudal ramus __________ Cryptocyclops bicolor

Eucyclops

22a Caudal ramus short, usually not more than 4 times as long as broad __________ Eucyclops serrulatus

22b Caudal ramus long, more than 5 times as long as broad __________ Eucyclops speratus

Diacyclops (in part)

23a Outer terminal spine of endopod of leg 4 more than twice as long as the inner terminal spine (lake-dwelling species) ____ Diacyclops thomasi

23b Outer terminal spine of endopod of leg 4 about $1\frac{1}{2}$ times as long as the inner terminal spine (temporary pond species) ____ Diacyclops bicuspidatus

NOTES ON DISTRIBUTION AND ECOLOGY

Family: Cyclopidae

Subfamily: Eucyclopinae

Homocyclops ater (Herrick) 1882

This species is endemic and widely distributed in North America, but not common. Herrick and Turner (1895) record it for Minnesota and Marsh (1909)for Wisconsin. Apparently it is a shallow water form occurring in flooded areas and ponds.

Macrocyclops albidus (Jurine) 1820

Common throughout the state, this species inhabits temporary waters, ponds, lakes, and rivers, where it is found most abundantly among macrophyte vegetation. Occasionally it is taken in limnetic plankton collections. This species is markedly eurythermal, being found throughout the year in most permanent water bodies. Fryer (1957) states that the adults are predaceous on small invertebrates. Its wide range in the world classes it as a cosmopolitan species. Most Wisconsin collections of Macrocyclops will be albidus.

Macrocyclops fuscus (Jurine) 1820

Recorded for Minnesota by Herrick and Turner (1895) and Wisconsin by Marsh (1909), this species is not nearly as common as M. albidus, to which its ecology is similar.

NOTE: Yeatmann includes Macrocyclops distinctus in his key. This species, of wide distribution in the world, has not been recorded from North America. It would key out in this key at 16a with M. fuscus, but would have the hyaline membrane of the last antennal segment smooth, not toothed.

Eucyclops serrulatus (Fischer) 1851

Common throughout the state in shallow benthos or macrophyte vegetation of temporary waters, ponds, lakes and rivers, E. serrulatus is found in permanent waters throughout the year and is occasionally taken in limnetic plankton collections. It is widely distributed in the world. This species has usually been referred to as Eucyclops agilis (Koch) in the American literature.

Eucyclops speratus (Lilljeborg) 1901

Often thought to be merely a variety of serrulatus, this form is considered to be a distinct species by Yeatman (1959) and Dussart (1969). E. speratus is usually considerably larger in size than E. serrulatus, and it appears more frequently in limnetic plankton collections.

Tropocyclops prasinus (Fischer) 1850

This small species occurs in the plankton of a great variety of lakes and ponds, including Lake Michigan. It is easily recognized by its somewhat calanoid body form and very long (for a cyclopoid) first antennae. During the summer it is often abundant in the warm surface waters of lakes. It also occurs throughout the winter in low numbers in many lakes. It is distributed throughout the state and widely in the world. The variety T.p. mexicanus can be seen in many populations and does not appear to be a valid subspecies.

Paracyclops poppei (Rehberg) 1880

P. poppei occurs in shallow waters, both temporary and permanent, usually in vegetation. It is found in littoral areas of lakes and

rivers. This is the most commonly recorded American species, and it has usually been referred to as *P. fimbriatus poppei*.

Paracyclops yeatmani Daggett and Davis 1974

A species recently described from Newfoundland (Daggett and Davis, 1974) which may occur elsewhere in North America. It was found in submerged *Sphagnum* moss.

Paracyclops affinis (G.O. Sars) 1853

Not recorded for Wisconsin, but Yeatman (1959) gives a questionable record for Quebec.

Ectocyclops phaleratus (Koch) 1838

The body of this species is flattened dorsoventrally. It occurs in temporary and permanent ponds and in the littoral of lakes and rivers where it typically creeps along the bottom. Its habits resemble those of some harpacticoid copepods. It is widely distributed both in Wisconsin and the world.

Subfamily: Cyclopinae

Cyclops scutifer Sars 1863

Not yet recorded for Wisconsin, this species has been taken from Lake Superior waters in Michigan (Selgeby, 1975). Typically found in the plankton of lakes in Canada and the northeastern U.S., it seems likely that *C. scutifer* may occur in some lakes in the northern portion of Wisconsin.

Acanthocyclops vernalis (Fischer) 1853

A species of quite variable morphology, *A. vernalis* is probably an assemblage of several closely related, morphologically similar species. The genus *Acanthocyclops* has been well studied in Europe, but the North American species have received little serious attention.

The papers by Lehmann (1903) and Price (1958) have shown that much of the morphological variation seen among individual populations may be attributed to development under different environmental conditions. S. I. Dodson (pers. comm.) believes that sensillae patterns on the body segments may be useful morphological features for distinguishing species of this genus as well as those of Diacyclops. A. vernalis (sensu latu) is found throughout the state in temporary waters, ponds, rivers, and lakes, either in the plankton or the benthos. It is typically found in the warmer months, but occasionally in the winter plankton of lakes.

Acanthocyclops venustoides (Coker) 1934

This species has been found in Ohio and Quebec (Yeatmann, 1959), but not yet recorded for Wisconsin. It may occur in temporary waters.

Megacyclops latipes (Lowndes) 1927

Taken from a series of semipermanent ponds in Ozaukee County and in temporary ponds in Iowa County. A very large species characteristic of small, shallow, detritus-filled bodies of water.

Diacyclops thomasi (S. A. Forbes) 1882

This is indeed one of the most common and widely distributed copepods in North America. In Wisconsin it is found in the plankton of permanent water bodies of all types, from shallow ponds and marshes to lakes, including Lake Michigan where it is the most common copepod species. In ponds and smaller lakes it appears as a winter species, encysting in the bottom muds in the C III stage during the summer (Birge and Juday, 1908; Carter, 1974). In lakes large enough to have a well-oxygenated, cold hypolimnion, it is found throughout the year (Torke, 1975). Almost all lakes in Wisconsin support large populations of this species. The adults and late copepodids are predaceous on other zooplankters (McQueen, 1969) and may be injurious to the larvae of fish (Davis, 1959). D. thomasi has been shown to

be the vector of a dracunculoid nematode parasite of salmon (Ko and Adams, 1969). D. thomasi is referred to in most of the North American literature as Cyclops bicuspidatus thomasi.

Diacyclops bicuspidatus (Claus) 1857

According to European authors this is a species of temporary waters. Forms similar or identical to this species were taken in temporary ponds in Sheboygan and Fond du Lac Counties.

Diacyclops navus (Herrick) 1882

Occurs in temporary and small permanent ponds in Canada (Watson and Smallman, 1971) and the northern U.S. (Yeatmann, 1959). Not yet recorded for Wisconsin, but probably occurs.

Diacyclops crassicaudis brachycercus (Kiefer) 1927

Our form may be distinct from the European crassicaudis. Taken in Fond du Lac County in very early spring in temporary ponds formed by melting snow.

NOTE: Other described and undescribed species of Diacyclops may occur in Wisconsin, especially in temporary waters.

Cryptocyclops bicolor (G. O. Sars) 1863

Listed as occurring in Wisconsin by Yeatmann (1959). A small littoral, bottom-dwelling species.

Microcyclops rubellus (Lilljeborg) 1901

A small littoral species which has been taken uncommonly in the plankton of shallow lakes. Its main habitat is probably shallow benthos.

Orthocyclops modestus (Herrick) 1883

A planktonic species of lakes typically found in the bottom waters. Usually not abundant in plankton collections but often present in

low numbers in both summer and winter. Distributed throughout the state and endemic to North America. Absent from the Great Lakes. Ecology little studied.

Mesocyclops edax (S.A. Forbes) 1891

This is a very common species in the summer plankton of most lakes, including the Great Lakes. It is generally absent during the winter, but occasional adult female specimens have been taken. The adults and copepodids of this large species are highly predaceous on other zooplankters (Confer, 1971), but may feed on algae as well.

Mesocyclops leuckarti (Claus) 1857

Not definitely recorded for Wisconsin, this European species has been reported from Ontario, Illinois, and elsewhere in North America.

NOTE: Thermocyclops, a genus closely allied to Mesocyclops, has two species which could conceivably occur in Wisconsin, Yeatman (1959) has reported T. dybowskii from Wyoming and Illinois, and T. cithonoides from Minnesota. The reader is referred to Yeatmann (1959) and Coker (1943) for their identification.

Family: Ergasilidae

Ergasilus, sp.

This genus is comprised of a number of species, the adult females of which are parasitic on the gills of fish. Free-living males and copepodids are occasionally taken in small numbers in lake plankton collections. In at least one species, E. chautauquaensis, adult ovigerous females are found in the non-parasitic form. There is no existing published key to the free-living stages of Ergasilus, however the key of Roberts (1970) provides a comprehensive treatment of the parasitic females.

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