THE FRESHWATER COPEPOD GENUS *Mesocyclops* (Copepoda, Cyclopoida, Cyclopidae) IN VIETNAM

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ABSTRACT

The freshwater copepod *Mesocyclops* Sar, 1914, a species-rich genus within the family Cyclopidae Rafinesque, 1815, is common in tropical areas. In addition, the genus members are used for the biological control of mosquito larvae (*Anopheles, Aedes*) which are vectors for transmitting dengue fever. In Vietnam, a total of 11 *Mesocyclops* species have been recorded in inland freshwater bodies. Of which, one endemic species (*M. sondoongensis* Tran & Holyńska, 2015) and two species were described from Vietnam, namely *M. yenae* Holyńska, 1998; *M. ferjemurami* Holyńska & Vu, 2000. Diagnostic characteristics, habitat, and distribution of all 11 species are provided. Additionally, a pictorial key to all Vietnamese *Mesocyclops* is presented.

**Keywords:** Cyclopidae, *Mesocyclops*, biodiversity, pictoral key, taxonomy, Vietnam.

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INTRODUCTION

In the family Cyclopidae, the genus *Mesocyclops* Sar, 1914 is considered to be a cosmopolitan group, but more dominant in the tropics and more common in eutrophic water bodies. To date, 79 *Mesocyclops* species have been described (Hołyńska, 1997, 2000, 2006; Karanovic, 2006; Hołyńska and Stoch, 2012; Alekseev et al., 2013; Papa and Hołyńska, 2013; Tran and Hołyńska, 2015).

Many studies indicated that *Mesocyclops* species can kill larvae of *Anopheles* spp., *Aedes* spp. (Marten et al., 1989, 1994; Vu Sinh Nam et al., 1998). Thus, they are often used as biological control agents of mosquito larvae which is known as vectors for dengue transmission in Mexico, Brazil, Australia, India and Vietnam (Marten et al., 1989, 1994; Vu Sinh Nam et al., 1998, 2000, 2004).

In Vietnam, based on the species characteristics of the genus *Mesocyclops* as described by Sars (1914), Kiefer (1927) and Rylov (1948), Dang Ngoc Thanh (1977, 1980), Dang Ngoc Thanh et al. (1980, 2002) recorded only one species of *Mesocyclops leuckarti* (Claus, 1857) in inland freshwater bodies of Vietnam. However, Kiefer (1981) indicated that *M. leuckarti* was only distributed in the Palaearctic region including Europe, Russia, North China, South Korea and Japan, not extending to the tropic area. Compared to the diagnosis of *M. leuckarti* proposed by Kiefer (1981), the description and drawings by Dang Ngoc Thanh et al. (1980, 2002) has significant differences in antennule, caudal rami, thoracopod and especially seminal receptacles in females. These differences suggested that the presence of this species in Vietnam could be questionable.

Research on the genus *Mesocyclops* has been conducted in Vietnam on both taxonomic and applied aspects. In a joint project with the Central Institute of Hygiene and Epidemiology in Hanoi on the use of *Mesocyclops* in the biological control of *Aedes* (mosquitoes transmitting dengue fever) in Vietnam, Hołyńska (1997, 1998), and Hołyńska & Vu (2000) recorded 9 species of the genus *Mesocyclops* in freshwater of Vietnam, including: *Mesocyclops affinis* Van de Velde, 1987; *M. aspericornis* (Daday, 1906); *M. feriemurami* Hołyńska & Vu, 2000; *M. ogunnus* Onabamiro, 1957; *M. pehpeiensis* Hu, 1943; *M. shenzhenensis* Guo, 2000; *M. thermocyclopoides* Harada, 1931; *M. yenaee* Hołyńska, 1998 and *M. woutersi* Van de Velde, 1987. Of which, two were described as new to science: *M. yenaee* Hołyńska, 1998 from Hai Phong City and *M. feriemurami* Hołyńska & Vu, 2000 from Khanh Hoa Province. Hołyńska (1997, 1998, 2000) used the system of diagnostic features of the genus *Mesocyclops* of Van de Velde (1984) which was verified and now widely accepted in the world. Recently, Tran & Hołyńska (2015) described *M. sondoongensis* from the Son Doong cave, Quang Binh Province.

In studies following the diagnostics of the genus *Mesocyclops* proposed by Dang Ngoc Thanh et al., 1980, most specimens collected in Vietnam were identified as *M. leuckarti* (Claus, 1857) or *Mesocyclops* spp. (Hoang Dinh Trung & Phan Doan Dang, 2011; Vo Van Phu & Hoang Dinh Trung, 2012; Phan Doan Dang et al., 2011; Le Thi Nguyet Nga & Phan Doan Dang, 2013, 2015a,b, 2019). This resulted in the confusion and misunderstanding of the zooplankton biodiversity of Vietnam, and could caused mistakes in selecting biological control agents.

The paper aims to provide an updated review and identification key of the genus *Mesocyclops* in Vietnam, which will also facilitate further research on freshwater copepods of Vietnam.

MATERIALS AND METHODS

Freshwater copepod specimens were collected from various localities in Vietnam during the period of 2005–2019, using a 100 µm mesh-sized plankton net. Samples were fixed and stored in 70% ethanol and deposited in the Department of Aquatic Ecology, Institute of Ecology and Biological Resources (IEBR), Ha Noi, Vietnam. The specimens were observed with a differential interference contrast microscope (Nikon Eclipse Ni-U).
Illustrations were made with the aid of a camera lucida attached to the microscope. The following abbreviations are used, where required, throughout the text and figures: Endp = endopod; Exp = exopod; P1–P5 = swimming legs 1–5.

RESULTS AND DISCUSSION

Species composition

A total of 11 Mesocyclops species are recognized from inland freshwater bodies of Vietnam (Table 1). Of which, one species is considered to be endemic to Vietnam, *M. sondoongensis* Tran & Hołyńska, 2015 and two species (*M. yenae* Hołyńska, 1998, *M. feriemurami* Hołyńska & Vu, 2000) were described for the first time from Vietnam’s copepod fauna.

Table 1. List of species and distribution of the genus *Mesocyclops* in Vietnam

| STT | Taxon                                  | Geographic distribution in Vietnam |
|-----|----------------------------------------|-----------------------------------|
|     |                                        | I      | II     | III    | IV     | V      | VI     | VII    |
| 1   | *Mesocyclops affinis* Van de Velde, 1987 | +      | +      | +      | +      | +      |        |
| 2   | *Mesocyclops aspericornis* (Daday, 1906) | +      | +      | +      | +      | +      |        |
| 3   | *Mesocyclops augusti* Papa & Hołyńska, 2013 |        |        |        | +      |        |        |
| 4   | *Mesocyclops dissimilis* Defaye & Kawabata, 1993 | +      | +      |        |        |        |        |
| 5   | *Mesocyclops feriemurami* Hołyńska & Vu, 2000 |        |        |        |        | +      |        |
| 6   | *Mesocyclops ogunnus* Onabamiro, 1957   | +      | +      |        |        |        | +      |
| 7   | *Mesocyclops pehpeiensis* Hu, 1943      | +      | +      | +      | +      | +      | +      |
| 8   | *Mesocyclops sondoongensis* Tran & Hołyńska, 2015 |        |        |        |        | +      |        |
| 9   | *Mesocyclops thermocyclopoides* Harada, 1931 | +      | +      |        |        |        | +      |
| 10  | *Mesocyclops woutersi* Van de Velde, 1987 | +      | +      | +      | +      | +      | +      |
| 11  | *Mesocyclops yenae* Hołyńska, 1998     | +      | +      |        |        |        |        |

Abbreviations: I. Northeast region; II. Northwest region; III. Red River delta and North Central coast regions; IV. North Central mountains region; V. Central highlands region; VI. South Central coast; VII. Mekong River delta; * Species endemic in Vietnam.

Taxonomic part

**Order Cyclopoida** Burmeister, 1834

**Family Cyclopidae** Rafinesque, 1815

**Subfamily Cyclopinnae** Rafinesque, 1815

**Genus Mesocyclops** Sars, 1914

Typ species: *Cyclops leuckarti* Claus, 1857

Synonyms: *Cyclops* (Mesocyclops) Gurney, 1933: 286–287; *Mesocyclops* (Mesocyclops) Rylov, 1948: 292–293.

**Diagnosis:** Medium size Cyclopidae, cephalothorax oval or slightly elongated. Genital double-somite trapezoidal, slightly shrunk back. Seminal receptacle “T”-shaped, distal part dilated and almost sac-like. Caudal ramus cylindrical with two rami often parallel. Antennule 17-segmented, last segment ornamented with serrate hyaline membrane, with or without large notch. P1–P4 with 3-segmented rami. P1 basipodite with or without medial spine. P5 2-segmented, terminal segment with apical long seta and long inner spine.

In Vietnam, 11 species of this genus are currently known to be present.

**Mesocyclops affinis** Van de Velde, 1987

*Mesocyclops affinis* Van de Velde, 1987: 151–156, figs 15–27; Hołyńska, 200: 400–405, figs 25–27.

*Mesocyclops thermocyclopoides acutus* Dussart & Fernando, 1988: 254–255, figs 43–50; Red & Kay, 1992: 340–341, figs 4a–d. Synonymized by Hołyńska (1994).

*Mesocyclops thermocyclopoides-Dussart & Fernando, 1988 [partim]: 245–246, figs 8–10.

Type locality: A bomb hole, Madang Province, Papua New Guinea (Van de Velde, 1987).
**Diagnosis:** Serrate hyaline membrane on last antennulary segment extending far beyond implantation of medial seta of segment, with one large notch. Caudal spine pattern of antennary basipodite with an oblique row of tiny spinules starting at distal third of medial rim, group of short spinules near implantation of medial setae, group of relatively large spinules at laterodistal angle, spinules in longitudinal row near lateral margin and a row of oblique spinules next to long lateral spinules near base. Frontal surface of maxillary coxopodite with outgrowths. Lateral arms of seminal receptacle wide and short; transverse ducts directed to each other at a straight or nearly straight angle (not V-shaped) before connection with copulatory duct; copulatory duct straight or slightly curved. Caudal rami without medial hairs; spinules at implantation of lateral caudal setae present or absent and at implantation of lateralmost terminal setae always present; medially terminal seta about 2.5–3.5 times as long as lateralmost terminal seta.

**Specimens examined:** 15 ♀♀, 10 ♂♂ (IEBR-MESO-09-04), Sai Gon river, Ho Chi Minh City, VI, 2009, Tran D.L. leg.; 10 ♀♀, 6 ♂♂ (IEBR-MESO-11-01), a fish pond, Quang Nam Province, VII, 2011, Tran D.L. leg.; 20 ♀♀, 25 ♂♂ (IEBR-MESO-12-05), Cau river, Thai Nguyen Province, VIII, 2012, Tran D.L. leg.; 5 ♀♀, 1 ♂ (IEBR-MESO-15-10), Nhue river, Ha Nam Province, X, 2015, Nguyen T.C. leg.; 14 ♀♀, 5 ♂♂ (IEBR-MESO-19-01), Krong Kmar reservoir, Dak Lak Province, III, 2019, Dang V.D. leg.

**Ecology:** This species has been found in aquaculture ponds, reservoirs, lakes and rivers.

**Records from Vietnam:** Lai Chau, Ha Giang, Thai Nguyen, Phu Tho, Ha Nam, Nghe An, Quang Nam, Ninh Thuan, Dak Lak, Ho Chi Minh City, Kien Giang (this study), Bac Giang, Phu Tho, Hung Yen, Hai Phong, Nam Dinh, Ha Noi, Nghe An, Ha Tinh, Thua Thien-Hue, Da Nang, Khanh Hoa, Ho Chi Minh City, Dong Nai (Vu et al., 2000).

**Distribution:** Papua New Guinea (Van de Velde, 1987), Indonesia, Malaysia (Holyńska, 2000).

**Mesocyclops aspericornis** (Daday, 1906)

*Cyclops aspericornis* Dayad, 1906: 181–184, Pl. 14, figs 1–6.

**Mesocyclops aspericornis**-Kiefer, 1981: 172–173, Pl. 10; Van de Velde, 1984: 42–45, figs 28–29; Lim & Fernando, 1985: 83, figs 54–56; Holyńska, 2000: 392–398, figs 20–23; Gutiérrez-Aguirre et al., 2003: 1349–1361, figs 1–6.

**Mesocyclops leuckarti**-Kiefer, 1938: 60, figs 27–29.

**Mesocyclops iranicus** Lindberg, 1936: 12–16, figs 17–21. Synonymized by Ghenne & Fiers (2000).

**Type locality:** Bogor, Indonesia (Daday, 1906).

**Diagnosis:** Serrate hyaline membrane on last antennulary segment extending far beyond implantation of medial seta of segment, with one large notch at 1/3 distal part. Caudal spine ornamentation of antennary basipodite with an oblique row of small spines starting at distal third of inner margin, group of tiny spinules near implantation of medial setae, and a group of small spinules between proximal oblique and longitudinal spine rows. Frontal surface of maxillary coxopodite bearing a distinct row of hair-like spinules. P1 basipodite without medial spine; medial expansion of basipodite of P1–P4 with apical hairs; distal margin of P4 coupler bearing two small, triangular outgrowths. Pediger 5 with soft hairs laterally. Genital double-somite without hairs. Lateral arms of seminal receptacle wide and elongate; transverse ducts directed to each other at acute angle (V-shaped) before connection with copulatory duct; copulatory duct slightly curved. Caudal rami with medial hairs; spinules at implantation of lateral caudal and
lateralmost terminal setae present; medialmost terminal seta about 1.2–1.4 times as long as lateralmost terminal seta.

**Specimens examined:** 10 ♂♂, 30 ♀♀ (IEBR-MESO-09-02), Cau river, Thai Nguyen Province, IV. 2009, Tran D.L. leg.; 5 ♀♀ (IEBR-MESO-09-03), Nhue river, Ha Nam Province, IV. 2009, Tran D.L. leg.; 20 ♀♀, 15 ♂♂ (IEBR-MESO-09-16), Cai river, Kien Giang Province, XII. 2009, Tran D.L. leg.; 10 ♂♂, 10 ♀♀ (IEBR-MESO-18-07), Tram Chim National Park, Dong Thap Province, IX. 2018, Tran D.L. leg.

**Ecology:** This species has been found in various freshwaters bodies, such as aquaculture ponds, reservoirs, lakes and rivers, and especially favors the stagnant and eutrophic waters.

**Records from Vietnam:** Widely distributed.

**Distribution:** Thailand, Malaysia (Lim & Fernando, 1985), Indonesia (Daday, 1906; Dussart & Fernando, 1985), Philippines (Van de Velde, 1987; Holyńska, 2000), Papua New Guinea (Van de Velde, 1987), Australia (Brown et al., 1991; Holyńska & Brown, 2003), Ethiopia, Ghana, Nigeria (Van de Velde, 1984), Mexico, Colombia (Gutiérrez-Aguirre et al., 2003, 2006).

**Mesocyclops augusti** Papa & Holyńska, 2013

**Type locality:** Siloton lake, Mindanao, Philippines (Papa & Holyńska, 2013).

**Diagnosis:** Serrate hyaline membrane on last antennulary segment extending far beyond implantation of medial seta of segment, with one large notch. Caudal spine ornamentation of antennary basipodite with an oblique row of tiny spinules starting at distal third of inner margin, group of medium sized spinules near implantation of medial setae, spinules in longitudinal row near lateral margin and a row of oblique spinules next to long lateral spinules near base. Row of spinules present on frontal surface of maxillary coxopodite. P1 basipodite lacking medial spine; medial expansion of basipodite of P1–P4 with apical hairs; outgrowths small and acute on distal margin of P4 coupler. Pediger 5 pilose laterally, naked dorsally. Genital double-somite without hairs. Lateral arms of seminal receptacle wide and short; transverse ducts directed to each other at obtuse angle (not V-shaped) before connection with copulatory duct; copulatory duct strongly curved. Hindgut on anal operculum with oblique field of short spinules, and 1-1 row of long spinules near anterior margin of caudal rami. Caudal rami without medial hairs; spinules at implantation of lateral caudal and lateralmost terminal setae present; medialmost terminal seta about 2.6–2.8 times as long as lateralmost terminal seta.

**Specimens examined:** 5 ♀♀ (IEBR-MESO-17-06), Xa Huong lake, Tam Dao, Vinh Phuc Province, X. 2017, Nguyen T.C. leg.

**Ecology:** This species is found only in large freshwater bodies like lakes and reservoirs.

**Records from Vietnam:** Vinh Phuc (this study, Papa & Holyńska, 2013).

**Distribution:** Philippines (Mindanao) (Papa & Holyńska, 2013).

**Mesocyclops dissimilis** Defaye & Kawabata, 1993

**Mesocyclops dissimilis** Defaye & Kawabata, 1993: 121–126, figs 1–25; Ueda, Ishida & Imai, 1997: 64–66, figs 22–37.

**Type locality:** Biwa lake, Japan (Defaye & Kawabata, 1993).

**Diagnosis:** Serrate hyaline membrane on last antennulary segment extending far beyond implantation of medial seta of segment, with two large notches at distal third of segment. Caudal spine pattern of antennary basipodite with an oblique row of tiny spinules starting at distal third of inner margin, group of small spinules near implantation of medial setae, large spinules in longitudinal row near lateral margin and a row of oblique spinules next to long lateral
spinules near base. Row of spinules present on frontal surface of maxillary coxopodite. P1 basipodite lacking medial spine; medial expansion of basipodite of P1–P4 with apical hairs; outgrowths small and acute on distal margin of P4 coupler. Pediger 5 with lateral hairs only. Genital double-somite without hairs. Seminal receptacle with wide and short lateral arms; transverse ducts directed to each other at acute angle (V-shaped) before connection with copulatory duct; copulatory duct strongly curved. Caudal rami without medial hairs; spinules at implantation of lateral caudal and lateralmost terminal setae present; medialmost terminal seta about 2.7–2.9 times as long as lateralmost terminal seta.

**Specimens examined:** 25 ♀♀, 15 ♂♂ (IEBR-MESO-08-06), Pa Khoang lake, Dien Bien Province, VI, 2008, Tran D.L. leg.; 50 ♀♀♀, 50 ♂♂ (IEBR-MESO-12-02), Bat Chat lake, Lai Chau Province, V, 2012, Tran D.L. leg.; 6 ♀♀, 6 ♂♂ (IEBR-MESO-13-16), Cau river, Bac Giang, IV, 2013, Nguyen D.T. leg.

**Ecology:** Aquaculture ponds, lakes and river deltas, hilly and mountainous areas.

**Records from Vietnam:** Dien Bien, Lai Chau, Thai Nguyen, Hai Duong, Vinh Phuc (this study); Vinh Phu, 2000; 50 ♀♀♀, 50 ♂♂ (IEBR-MESO-11-02), Tra Khuc river, Quang Ngai Province, VII, 2011, Tran D.L. leg.; 37 ♀♀♀, 12 ♂♂ (IEBR-MESO-18-03), a reservoir in Cu Lao Cham Island, Quang Nam Province, III. 2018, Tran D.L. leg.

**Ecology:** Mainly inhabiting fish ponds and rivers in delta areas.

**Distribution:** Thailand (Alekseev & Sanoamuang, 2006).

**Mesocyclops ferjemurami** Holyńska & Vu, 2000

*Mesocyclops ferjemurami* Holyńska & Vu, 2000: 197–206, figs 1–4.

**Type locality:** Nha Trang, Khanh Hoa Province, Vietnam (Holyńska & Vu, 2000).

**Diagnosis:** Serrate hyaline membrane on last antennulary segment extending far beyond implantation of medial seta of segment, with one large notch at distal third of segment. Caudal spinule pattern of antennary basipodite with an oblique row of tiny spinules starting at distal half of medial rim, large spinules in longitudinal row near lateral margin and a row of oblique spinules next to long lateral spinules near base. Frontal surface of maxillary coxopodite without spinule ornamentation. P1 basipodite lacking medial spine; medial expansion of basipodite of P1–P4 with apical hairs; distal margin of P4 coupler with two large acute outgrowths. Pediger 5 and genital double-somite without hairs. Lateral arms of seminal receptacle elongated, transverse ducts meet at deep acute angle anterior to copulatory pore (V-shaped), copulatory duct slightly to strongly curved. Caudal rami without medial hairs; spinules at implantation of lateral caudal and lateralmost terminal setae present; medialmost terminal seta about 3.0 times as long as lateralmost terminal seta.

**Specimens examined:** 6 ♀♀ (IEBR-MESO-11-02), Tra Khuc river, Quang Ngai Province, VII, 2011, Tran D.L. leg.; 37 ♀♀♀, 12 ♂♂ (IEBR-MESO-18-03), a reservoir in Cu Lao Cham Island, Quang Nam Province, III. 2018, Tran D.L. leg.

**Ecology:** Mainly inhabiting fish ponds and rivers in delta areas.

**Records from Vietnam:** Quang Nam, Quang Ngai (this study); Khanh Hoa (Holyńska & Vu, 2000).

**Distribution:** Thailand (Alekseev & Sanoamuang, 2006).

**Mesocyclops ogunnus** Onabamiro, 1957

*Mesocyclops ogunnus* Onabamiro, 1957: 125–127, figs 7–12; Van de Velde, 1984: 31–36, figs 19–22; Dussart & Fernando, 1988: 250–251, figs 27–30; Reid & Kay, 1992: 338–339, figs 3d–f; Mirabdullayev, 1996: 96, figs 12–17; Holyńska, 1997: 27–30, fig. 4g; Holyńska, 2000: 398–400, figs 24a–f.

**Type locality:** Ogun river, Abeokuta, Nigeria (Onabamiro, 1957).

**Diagnosis:** Serrate hyaline membrane on last antennulary segment extending far beyond implantation of medial seta of segment, with one large notch. Caudal spinule pattern of antennary basipodite with an
oblique row of fine spinules starting at distal third of inner margin, row of large spinules near implantation of medial setae, spinules in longitudinal row near lateral margin, a row of oblique spinules next to long lateral spinules near base. Maxillulary palpus bearing a row of large spinules. Frontal surface of maxillary coxopodite bearing distinct a row of spinules. P1 basipodite without medial spine; medial expansion of basipodite of P1–P4 with apical hairs; distal margin of P4 coupler with two small obtuse or acute outgrowths. Pediger 5 pilose laterally and dorsally. Genital double-somite without hairs. Lateral arms of seminal receptacle wide and short; transverse ducts directed to each other at obtuse angle (not V-shaped) before connection with copulatory duct; copulatory duct strongly curved. Caudal rami without medial hairs; spinules at implantation of lateral caudal setae present or absent and at implantation of lateralmost terminal setae always present; medialmost terminal seta about 2.6–2.8 times as long as lateralmost terminal seta.

**Specimens examined:** 10 ♀♀, 5 ♂♂ (IEBR-MESO-12-01), Nhue river, Ha Nam, IV. 2012, Tran D.L. leg.; 8 ♀♀ (IEBR-MESO-14-07), Han river, Da Nang City, VIII. 2014, Tran D.L. leg.

**Ecology:** It lives in lakes, ponds and river deltas and hilly areas.

**Records from Vietnam:** Quang Ninh, Vinh Phuc, Ha Nam, Nghe An, Khanh Hoa, Dong Nai, Kien Giang (this study); Lang Son, Bac Giang, Hai Phong, Nam Dinh, Thu Thien-Hue, Da Dang, Khanh Hoa, Ninh Thuan, Ca Mau (Vu et al., 2000).

**Distribution:** Nigeria (Onabamiro, 1957; Van de Velde, 1984), Senegal, Mali, Mozambique, Ethiopia, Kenya (Van de Velde, 1984), Brazil (Reid and Pinto-Coelho, 1994), Uzbekistan (Mirabdullayev, 1996), China (Guo, 2000), Malaysia (Holynska, 2000), Papua New Guinea (Holynska, 2000), Thailand (Aleksieiev & Sanoamuang, 2006).

**Mesocyclops pehpeiensis** Hu, 1943

Mesocyclops leuckerti pehpeiensis Hu, 1943: 124–126, figs 2–4.
Mesocyclops sonoongensis Tran & Hołyńska 2015

Mesocyclops sonoongensis Tran & Hołyńska, 2015: 661–686, figs 2–56.

Type locality: Son Doong cave, Phong Nha-Ke Bang National Park, Quang Binh, Vietnam (Tran & Hołyńska, 2015).

Diagnosis: Serrate hyaline membrane of the last antennulary segment proximally extending to implantation of medial seta, without notch. Caudal surface ornamentation of antennal coxobasis with spinules in a longitudinal row along lateral margin not reaching height of insertion of exopodal seta; long curved row present, starting next to implantation of more proximal medial seta. Group of spinules present next to implantation of exopodite seta on frontal surface of antennal coxobasis. No spinules on frontal surface of maxillulary coxopodite. P1 basipodite with medial spine; medial expansion of basipodite of P1–P3 with apical hairs, medial expansion of P4 basis naked; distal margin of P4 coupler with two small triangular-shaped outgrowths. Pediger 5 and genital double-somite without hairs laterally and dorsally. Seminal receptacle with narrow lateral arms, transverse ducts directed to each other at obtuse angle next to copulatory pore (not V-shaped), copulatory duct short and slightly curved. Caudal rami without medial hairs; spinules at implantation of lateral caudal and lateralmost terminal setae present; medialmost terminal seta about 2.7 times as long as lateralmost terminal seta.

Specimens examined: 1 ♀ (holotype, IEBR-COP3410), 1 ♂ (allotype, IEBR-COP3411), 3 ♀♀ (paratypes, IEBR-COP3412–3414), 3 ♂♂ (paratypes, IEBR-COP3415–3417) and 25 ♀♀, 13 ♂♂ (IEBR-COP-AED0413.025), Son Doong cave, Quang Binh Province, IV. 2013; Tran D. L. leg.; 46 ♀♀, 28 ♂♂ (IEBR-COP-AED0413.026), Va cave, Quang Binh Province, IV. 2014, Tran D. L. leg.

Ecology: Living in underground water bodies in cave.

Records from Vietnam: Quang Binh (Son Doong cave, Va cave, Phong Nha-Ke Bang National Park, Quang Binh).

Distribution: Only known from Vietnam.

Mesocyclops thermocyclopoides Harada, 1931

Mesocyclops thermocyclopoides Harada, 1931: 161–162, figs 23–25; Kiefer, 1981: 153, 162–165, fig. 2, fig. 5; Van de Velde, 1987: 156, figs 28–30; Hołyńska, 1994: 100–109, figs 1–5; Ueda & Ishida, 1997: 46–48, figs 4–5; Hołyńska, 2000: 431–436, figs 47a–e, figs 48a–d, fig. 49a; Gutiérrez-Aguirre et al., 2003: 352–363, figs 1–6.

Mesocyclops cf. thermocyclopoides-Dahm & Fernando, 1993: 9–18, figs 5–6.

Mesocyclops thermocyclopoides acutus Dussart & Fernando, 1988: 254, figs 43–50; Reid & Kay, 1992: 340–341, fig. 4.

Type locality: Candidus lake, Taiwan (Harada, 1931).

Diagnosis: Serrate hyaline membrane on last antennulary segment extending far beyond implantation of medial seta of segment, with one large notch. Caudal spinule ornamentation of antennary basipodite with an oblique row of tiny spinules starting at distal half of medial rim, a row of large spinules
near implantation of medial setae, large spinules in longitudinal row near lateral margin, a row of oblique spinules next to long lateral spinules near base. Frontal surface of maxillary coxopodite bearing a distinct row of spinules. P1 basipodite without medial spine; medial expansion of basipodite of P1–P4 with apical hairs; outgrowths of P4 coupler small, obtuse. Pediger 5 with dorsal and lateral soft hairs. Genital double-somite with dorsal hairs in anterior half. Seminal receptacle with lateral arms wide and short; transverse ducts directed to each other at straight or nearly straight angle (not V-shaped) before connection with copulatory duct; copulatory duct varies from slightly to strongly curved. Caudal rami without medial hairs; spinules at implantation of lateral caudal and lateralmost terminal setae absent; mediallymost terminal seta about 3.0 times as long as lateralmost terminal seta.

Specimens examined: 13 ♀♀, 5 ♂♂ (IEBR-MESO-08-11) temporary pond, Ninh Tru, Ninh Thuan, XI. 2008, Nguyen D.T. leg.; 50 ♀♀, 50 ♂♂ (IEBR-MESO-11-03), West lake, Ha Noi, VII. 2011, Tran D.L. leg.; 15 ♀♀, 5 ♂♂ (IEBR-MESO-13-19), Cau river, Thai Nguyen Province, IV. 2013, Nguyen D.T. leg.

Ecology: Wide variety of habitats, such as aquaculture ponds, reservoirs, lakes and rivers.

Records from Vietnam: Dien Bien, Phu Tho, Thai Nguyen, Quang Ninh, Ha Noi, Nghe An, Da Nang, Ninh Thuan, Can Tho (this study); Lang Son, Quang Ninh, Bac Ninh, Bac Giang, Hung Yen, Phu Tho, Ha Noi, Nam Dinh, Ha Tinh, Da Nang, Ninh Thuan, Khanh Hoa, Dong Nai, Can Tho, Kien Giang (Vu et al., 2000).

Distribution: Taiwan (Harada, 1931), Myanmar, Malaysia, Indonesia (Holyńska, 1994, 2000); Japan (Ueda & Ishida, 1997), Thailand (Sanoamuang, 2002); China (Guo, 2000), Mexico (Gutiérrez-Aguirre et al., 2003).

Mesocyclops woutersi Van de Velde, 1987

Mesocyclops woutersi Van de Velde, 1987: 156–157, figs 31–44; Holyńska, 2000: 414–418, figs 35–37.

Mesocyclops guangxiensis Reid & Kay, 1992: 332–338, figs 1–2 (Synonymized by Holyńska, 1997).

Type locality: Coral gravel-pit, Madang Province, Papua New Guinea (Van de Velde, 1987).

Diagnosis: Serrate hyaline membrane on last antennulary segment extending far beyond implantation of medial setae of segment, with one large notch. Caudal spinule pattern of antennary basipodite with an oblique row of tiny spinules starting at distal third of inner margin, group of short spinules near implantation of medial setae, large spinules in longitudinal row near lateral margin and a row of oblique spinules next to long lateral spinules near base. Frontal surface of maxillary coxopodite bearing distinct a row of spinules. P1 basipodite lacking medial spine; medial expansion of basipodite of P1–P4 with apical hairs; distal margin of P4 coupler with two small obtuse or acute outgrowths. Pediger 5 with lateral hairs only. Genital double-somite without hairs. Seminal receptacle with wide and short lateral arms; transverse ducts directed to each other at acute angle (V-shaped) before connection with copulatory duct; copulatory duct strongly curved. Caudal rami without medial hairs; spinules at implantation of lateral caudal and lateralmost terminal setae absent; mediallymost terminal seta about 3.0 times as long as lateralmost terminal seta.

Specimens examined: 20 ♀♀, 12 ♂♂ (IEBR-MESO-09-05), Nui Coc reservoir, Thai Nguyen Province, VI. 2009, Tran D.L. leg.; 20 ♀♀, 20 ♂♂ (IEBR-MESO-12-13), Bien Ho lake, Gia Lai Province, X. 2012, Tran D.L. leg.; 50 ♀♀, 30 ♂♂ (IEBR-MESO-14-03), Son river, Quang Binh Province, IV. 2014, Tran D.L. leg.; 10 ♀♀, 6 ♂♂ (IEBR-MESO-16-06), ricefield, Tu Ki, Hai Duong Province, X. 2016, Dang V.D. leg.; 20 ♀♀, 7 ♂♂ (IEBR-MESO-18-09), Tram Chim National Park, Dong Thap Province, IX. 2018, Tran D.L. leg.

Ecology: This species has been found in various freshwaters bodies, such as
aquaculture ponds, reservoirs, lakes and rivers, and especially favors the stagnant and eutrophic waters.

**Records from Vietnam:** All provinces.

**Distribution:** Papua New Guinea (Van de Velde, 1987; Hołyńska, 2000), Laos (Reid & Kay, 1992), China (Guo, 2000), Japan (Australia (Hołyńska & Brown, 2003).

*Mesocyclops yena Holysńska, 1998*

*Mesocyclops yena Holysńska, 1998: 337–347, figs 1–26.

*Mesocyclops cf. yena Holysńska, 2000: 382–385, figs 14–15, figs 49b–c.

**Type locality:** Thua Thien-Hue, Viet Nam (Hołyńska, 1998).

**Diagnosis:** Serrate hyaline membrane on last antennulary segment extending beyond implantation of medial seta of segment, with one large notch. Caudal spine pattern of antennary basipodite with large spines in longitudinal row near lateral margin and a row of oblique spines next to long lateral spines near base; lacking oblique row of tiny spines starting at distal third of inner margin. No spines on frontal surface of maxillary coxopodite. P1 basipodite without medial spine; medial expansion of basipodite of P1–P2 with apical hairs, medial expansion of P4 basis naked; distal margin of P4 coupler with two large acute outgrowths. Pediger 5 and genital double-somite without hairs laterally and dorsally. Lateral arms of seminal receptacle elongated and curved backward; transverse ducts directed to each other at straight or nearly straight angle (not V-shaped) before connection with copulatory duct; copulatory duct straight. Caudal rami without medial hairs; spines at implantation of lateral caudal and lateralmost terminal setae present; medialmost terminal seta about 3.5–4.0 times as long as lateralmost terminal seta.

**Specimens examined:** 6 ♀♀, 2 ♂♂ (IEBR-MESO-16-09), Truoi lake, Thua Thien-Hue, X. 2016, Tran D.L leg.; 3 ♀♀, 1 ♂♂ (IEBR-MESO-11-02) a fish pond Duy Xuyen, Quang Nam Province, VII, 2011, Tran D.L leg.; 4 ♀♀ (IEBR-MESO-17-02), temporary pond, Thuy Nguyen, Hai Phong Province, III, 2017, Dang V.D. leg.

**Ecology:** Mainly inhabiting aquaculture pond, lake and river in delta area.

**Records from Vietnam:** Hai Phong, Thua Thien-Hue, Quang Nam (this study); Thua Thien-Hue (Hołyńska, 1998); Thua Thien-Hue, Hai Phong (Vu et al., 2000).

**Distribution:** Papua New Guinea (Hołyńska, 2000).

**DISCUSSION**

Previously, Dang Ngoc Thanh (1980), and Dang Ngoc Thanh et al. (1980, 2002) recorded only *Mesocyclops leuckarti* (Claus, 1857) in inland freshwater bodies of Vietnam. However, only Dang Ngoc Thanh et al. (1980) provided the description of this species based on Vietnamese specimens. Accordingly, *M. leuckarti* in Vietnam was recognized as: antennule with a comb-shaped hyaline plate, with a deep notch at 1/3 of distal part; caudal rami nearly parallel, length 3.0–3.5 times width, outer margin smooth; medialmost terminal seta of caudal ramus not exceeding half of the inner terminal seta; seminal receptacle T-shaped, distal part large, sac-like; lateral arms wide and straight; anterior margin of proximal part concave in the middle; P4 Endp-3 elongated, two apical spines approximately same length; intercoxal plate with two small process-like knobs; P5 2-segmented, distal segment with a long apical seta and a medial spine, apical seta 2.0 times as long as medial spine.

In the description of Dang Ngoc Thanh et al. (1980), there were some comments as follows: 1) “Intercoxal plate of P4 with two small process-like knobs, with small spine in tip” however, in *M. leuckarti*, intercoxal plate of P4 with two large acute outgrowths; 2) “Seminal receptacle T-shaped, anterior margin of proximal part concave in the middle” but figure 187-1 (page 319) of Dang Ngoc Thanh et al. (1980) do not exhibit this feature; 3) “Apical seta on distal segment of P5 2.0 times as long as medial spine” while the illustration in figure 187-5 showed the apical seta of P5 about 1.1 times as long as
The freshwater copepod genus *Mesocyclops*

**Pl. 1**

*Mesocyclops*

- P1 basipodite
  - Without medial spine
  - With medial spine
    - *M. sonoongensis*
      - Small, length/width ≤ 1
      - Ratio of length of medialmost terminal seta to lateralmost terminal seta: > 2.5 times
      - Medial expansion of P4 basipodite with hairs; Caudal surface of antennary basipodite ornamented with triangular group of spinules near lateral rim
    - *M. yenae*
      - Large, length/width > 1
      - Ratio of length of medialmost terminal seta to lateralmost terminal seta: < 1.5 times
      - Medial expansion of P4 basipodite without hairs; Caudal surface of antennary basipodite without triangular group of spinules near lateral rim

**Pl. 2**

- Caudal rami without medial hairs; Caudal surface of antennary basipodite without a group of spinules between proximal oblique and longitudinal spine row
  - *M. ferjemanurami*
- Caudal rami with medial hairs at whole length; Caudal surface of antennary basipodite with a spine group between proximal oblique and longitudinal spine row
  - *M. pehpeiensis*
  - *M. aspericornis*
Dorsum of pediger 5 and genital double-somite without hairs; Caudal surface of antennary basipodite with group of tiny spinules near implantation of medial setae

Pediger 5 and genital double-somite dorsally pilose; Caudal surface of antennary basipodite with a row of large spinules near implantation of medial setae

Transverse ducts meet at acute angle anterior to copulatory pore; copulatory duct strongly curved

Transverse ducts meet at obtuse angle anterior to copulatory pore; copulatory duct varies from straight to slightly curved

Spinules at implantation of lateral caudal and lateralmost terminal setae

Hindgut (proctodeum) only with group of tiny spinules; Serrate hyaline membrane on last antennular segment with two large notches

Hindgut with groups of tiny spinules and two rows of long spinules; Serrate hyaline membrane on last antennular segment with one large notch
The freshwater copepod genus Mesocyclops

medial spine; 4) There were no detailed descriptions or illustrations of the basopodite of antenna, copulatory pore, copulatory duct and seminal receptacle of female, which are important identifying features of this genus.

From above comparison, the identification of M. leuckarti collected in Vietnam might be incorrect. This could be due to the quality limitation of microscope when Dang Ngoc Thanh et al. (1980) did this work. This kind of misidentifications has also been found in Shen and Tai (1979) for Mesocyclops species in China as reported by Guo (2000). The species “M. leuckarti” in Vietnam is, therefore, more likely to be a different species of the genus Mesocyclops, and need to have further examination to confirm its taxonomic status.

Pictoral key to species of the genus Mesocyclops in Vietnam (Pl.1 and Pl.2)

CONCLUSION

To date, 11 copepods species of the genus Mesocyclops have been recorded in freshwater waters of Vietnam. Of these, one species is endemic to the Vietnam fauna (Mesocyclops sondoongensis Tran & Holyńska, 2015) and two species, Mesocyclops yenae Holyńska, 1998, Mesocyclops feriemurami Holyńska & Vu, 2000) were described for the first time from Vietnam’s copepod fauna.

Mesocyclops leukarti (Claus, 1857) is now removed from the list of known copepod species in Vietnam. The pictorial key to all Mesocyclops species in Vietnam are also presented and updated.

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