

Mites of the genus *Histiostoma* on *Chamberlinius hualienensis* Wang, 1956, a recent invasive species of millipede in Japan from Taiwan

Milben der Gattung *Histiostoma* auf *Chamberlinius hualienensis* Wang, 1956, einer invasiven Art eines taiwanesischen Tausendfüßlers in Japan

VICTOR BENNO MEYER-ROCHOW & KAZUMI TAGAMI

Summary: The invasive polydesmid millipede *Chamberlinius hualienensis* Wang, 1956 has been known to occur on the Japanese Izu Island of Hachijojima since 2002. Several mass outbreaks of the species have been reported and during the 2015 outbreak all the specimens that were examined had deutonymphs of an unidentified mite of the genus *Histiostoma* on their bodies. The species was morphologically compared with deutonymphs of related *Histiostoma* species of the 'Feroniarum-group'. The species *Histiostoma abietes* and *Histiostoma formosana* share the largest number of traits with the Hachijojima species. However, *H. abietes* occurs only in Europe and its hosts are beetles, while *H. formosana* does occur in Taiwan, but has an association with the termite *Coptotermes formosanus* and is considerably smaller than the Hachijojima species. Since the latter was not present on any *C. hualienensis* millipedes collected in Taiwan, the possibility exists that it is a species new to Japan (or not described from anywhere else) and that it occurred on Hachijojima prior to the Taiwanese millipede's arrival and then switched its host or added a new one, namely *C. hualienensis*. A detailed description combined with a molecular characterization of the Hachijojima species is planned.

Keywords: Phoresy, necromeny, Paradoxosomatidae, parasites, Myriapoda, mass aggregations, deutonymphs

Zusammenfassung: Der invasive polydesmide Tausendfüßler *Chamberlinius hualienensis* Wang, 1956 ist seit 2002 auf der japanischen Izu-Insel Hachijojima heimisch. Mehrere Massenausbrüche der Art wurden bekannt und Tiere, die während des 2015er Ausbruchs untersucht wurden, besaßen ausnahmslos Deutonymphen einer nicht identifizierten Milbenart der Gattung *Histiostoma* auf ihren Körpern. Diese Nymphen wurden morphologisch verglichen mit anderen der verwandten 'Feroniarum-Gruppe'. Die Arten *Histiostoma abietes* und *Histiostoma formosana* teilten die meisten Charaktere mit der Hachijojima-Art. Allerdings ist *H. abietes* nur von Europa bekannt, wo ihre Wirte Käfer sind, während *H. formosana* zwar in Taiwan vorkommt, aber die Termiten *Coptotermes formosanus* als Wirt benutzt und erheblich kleiner ist als die Hachijojima-Art. Da Letztere nicht auf taiwanesischen Tausendfüßlern angetroffen wurde, besteht die Möglichkeit, dass die Hachijojima-Art neu für Japan (oder eine unbeschriebene Art) ist und auf Hachijojima schon vorkam, bevor *C. hualienensis* auftrat und dann auf diesen neuen Wirt wechselte oder ihn als zusätzlichen Wirt akzeptierte. Eine detaillierte Beschreibung zusammen mit einer molekularen Charakterisierung der Hachijojima-Art ist geplant.

Schlüsselwörter: Phoresie, Necromenie, Parasiten, Paradoxosomatidae, Myriapoda, Massenausbruch, Deutonymphs

1. Introduction

Individuals belonging to various species of the subclass Acari (a paraphyletic group with

at least two independent and likely unrelated lineages within the class Arachnida) are frequently associated with larger arthropods (O'CONNOR 1982). Being arthropods them-

selves, albeit of very small size, those of the fraction of the 55,000 species of mites described to date which form associations with larger arthropods, involve insects as hosts in 95% of all known cases. The remainder, engaging with arachnids, crustaceans, myriapods and even molluscs, have much less frequently been paid attention to (PARÉ & DOWLING 2012). Such mite/insect associations can be of four kinds: a) accidental or environmental; b) phoretic or commensalistic; c) parasitic (primarily as ectoparasites, but in some cases also as endoparasites); and d) necrophilic (WIRTH 2009).

Regarding mites on myriapods, the decision as to which species ought to be called commensals or parasitic is far from clear. Captive giant African millipedes often harbour one or several *Julolaelaps* species, mites of the Anactinotrichida, which were assumed to be commensals, but the incidence of such mites on free-ranging African millipedes was only 48% and the fact that some mites have been found embedded in the millipedes' cuticle raises doubts as to their benign nature (PARÉ & DOWLING 2012). The same authors list as common associates of free-ranging julid and non-julid millipedes in Eastern North America and Western Europe mites of the following genera: *Sancassania*, *Rhizoglyphus*, *Schwiebia*, *Cosmoglyphus*, *Holostapis*, *Phauladinychus*, *Histiostoma*, and *Thyreophagus*. Other myriapod-associated mite species mentioned by FARFAN & KLOMPEN (2012) for the USA and PARÉ & DOWLING (2012) for captive millipedes include *Chetochelacarus mamillatus*, *Lophonotacarus minutes*, *Diplodocaptes transkeiensis* and all stages of *Neotenogynium malkini*; the latter occurring on neotropical spirostreptid millipedes, while trombidiform larvae of *Milliorombidium millipodum* are known to feed on the haemolymph of diplopods. Species of the genus *Histiostoma* are Actinotrichida and generally regarded as phoretic and associated with a large variety of insects, especially beetles (WIRTH et al. 2016; KLIMOV & KHAUSTOV 2018; BERON 2021). During the

phoretic phase astigmat deutonymphs may not feed. However, some species are necromenic, which according to WIRTH (2009) means that they have a phoretic phase, but then feed and further develop in association with the host arthropod's cadaver (Fig. 1).

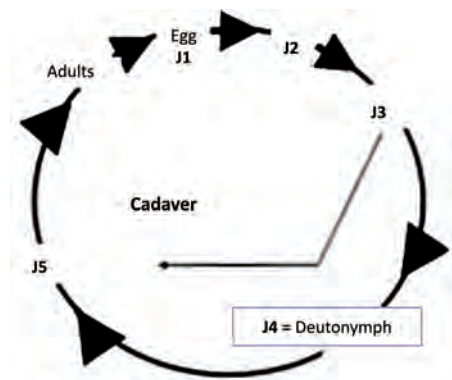


Fig. 1: Typical life cycle of a necromenic *Histiostoma* species (modified after WIRTH 2009).

Abb. 1: Typischer Lebenszyklus einer nekromenischen *Histiostoma*-Art (modifiziert nach WIRTH 2009).

The mites, which form the subject of this paper and were discovered on the polydesmid millipede *Chamberlinius hualienensis*, are necromenic in life style. When in the months of September-December many thousands of millipedes migrated and assembled in two different places on “Hachijojima”, with an area of about 70 km² the largest of the Izu Islands in Japan, the senior author of this paper documented this mass outbreak (Fig. 2 A, B) and collected data on the behaviour of the migrating individuals and their associations with other animals (MEYER-ROCHOW 2015). All of the examined individuals, whether male or female, contained nematodes in their guts (CARTA et al. 2018) and tiny deutonymphs of an unknown species of *Histiostoma* on their bodies (Fig. 2 C, D). Attempts to identify the species that the mites represented and how the latter managed to become associated with the alien millipede from Taiwan on the 2,000 km distant Japanese island of Hachijojima, are

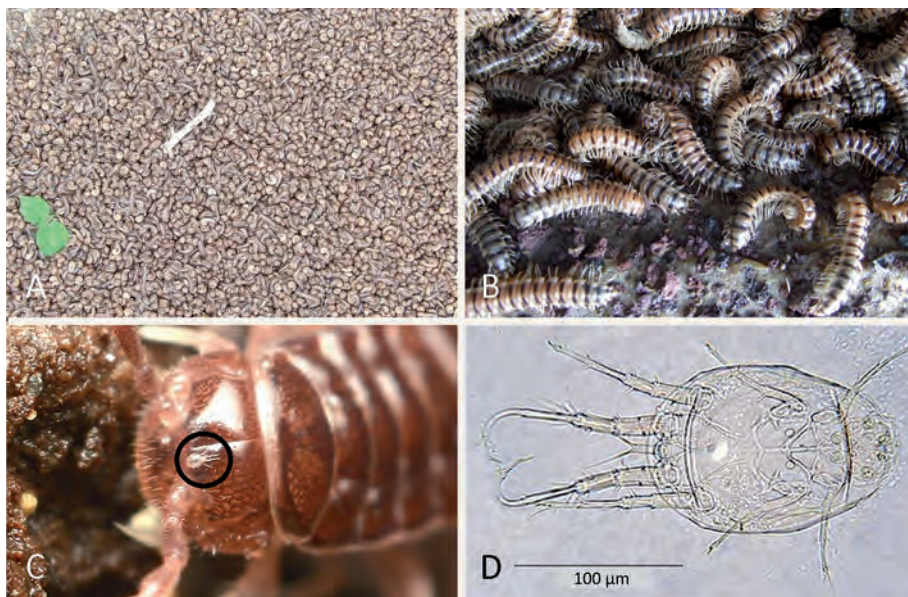


Fig. 2: **A** Aggregations of well over 100,000 individuals of the Taiwanese polydesmid *Chamberlinius bualienensis* were reported from the Izu Island Hachijojima (Japan) (MEYER-ROCHOW (2015). A small green plant (on the lower left) and a piece of a twig (centre) are surrounded by millipedes. **B** On all the bodies of male and female individuals of this polydesmid from Hachijojima, deutonymphs of a species of *Histiostoma* were present, but on individuals from Taiwan such histiostomids were absent. **C** One deutonymph of *Histiostoma* sp. (circle) can be seen clinging to the head of a live adult *C. bualienensis* millipede. **D** Individual deutonymph of the unidentified *Histiostoma* sp.

Abb. 2: **A** Ansammlungen von weit über 100.000 Individuen der taiwanesischen Polydesmiden-Art *Chamberlinius bualienensis* wurden von der Izu-Insel Hachijojima (Japan) gemeldet (MEYER-ROCHOW 2015). Eine kleine Pflanze (links unten) und ein Stück eines Zweiges (Mitte) sind von Tausendfüßlern umgeben. **B** Auf allen Männchen und Weibchen dieses Tausendfüßlers aus Hachijojima waren Deutonymphen einer *Histiostoma*-Art vorhanden, aber auf Individuen aus Taiwan fehlten diese. **C** Deutonymphe von *Histiostoma* sp. (Kreis), die sich am Kopf eines lebenden *C. bualienensis* festhält. **D** Deutonymphe der nicht identifizierten *Histiostoma* sp.

the subjects of this paper. The investigation has to be seen as somewhat preliminary, as it is based only on morphological comparisons with related species of the genus *Histiostoma* and not any molecular data, which regrettably have not been available.

2. Material and methods

Male and female specimens of the millipede *Chamberlinius bualienensis* were collected by the senior author during the day as well as at night on the Izu Island of Hachijojima as part of a study of the millipedes' mass aggregation in autumn (MEYER-ROCHOW

2015). Live specimens were examined under a binocular microscope within two hours of capture. Deutonymphs of a single species of the mite genus *Histiostoma* were always present on the bodies of the millipedes. Specimens of the mite were sent to Dr HANS-BERT SCHIKORA in Bremen (Germany), who took photographs of the mite, but was unable to provide a name for the species (Fig. 2 D). In order to identify the species, infected millipedes were taken by the second author to his lab at Tsukuba University in Japan, where the deutonymphs of the *Histiostoma* mites were allowed to complete their development and turn into

adults. The specimens were reared according to methods that had been successful in other cases (TAGAMI & KUWAHARA 2005; TAGAMI 2007). More than 100 specimens were ultimately available and studied under a light microscope with a phase contrast function (Nikon, Kabophot-2, Tokyo) equipped with a drawing tube (Nikon, 1.25x, Tokyo).

For detailed morphological observations live specimens of all stages were cleared with Keifer's solution (KEIFER 1953) in a small Syracuse dish for 30-120 min. Following clearance, a drop of gum chloral was added to the dish and mixed thoroughly. The specimen was then transferred to a drop of fresh gum chloral on a glass slide for a few minutes to acclimate and then gradually added to the final mounting solution. The latter was diluted with the cleaning solution into which the specimen had been immersed. Finally, the specimens were mounted on another glass slide with fresh gum chloral, covered with a cover slip and heated overnight to eliminate excess water before sealing at 50 °C on a hot plate. Nomenclature for idiosomal setae follows GRIFFITHS et al. (1990) and for leg setae GRANDJEAN (1939). Material of *C. hualienensis* for comparative analyses was obtained from Taiwan in 2017 and examined for deutonymphs in the same way as the material from Hachijojima.

3. Results and discussion

Diplopodes are known to be hosts to a few *Histiostoma* species (FARFAN & KLOMPEN 2012), of which *H. feroniarum*, *H. sapromyzarum*, *H. litorale*, and *H. julorum* seem to be the most common ones (BERON 2021). Millipede species of the Julidae appear to be the preferred hosts, whereas Polydesmidae are rarely mentioned as hosts and do not feature at all in the list of mite morphospecies associated with millipedes in the USA (Table 3 in FARFAN & KLOMPEN 2012). None of the four millipede-associated *Histiostoma* species, mentioned above, are known from Japan,

although *H. feroniarum* and *H. sapromyzarum* are almost cosmopolitan and known from, for example, Europe, South East Asian countries and Australia, while *H. julorum* and *H. litorale* are confined to northern Europe (BERON 2021). In our morphological comparison between the various likely *Histiostoma* candidates we, therefore, focused on species with shared traits and hosts, and then scrutinized the species' distribution.

The morphological characteristics of the unknown *Histiostoma* sp., using *Chamberlinius hualienensis* on Hachijojima as its host, may be summarised like this: smooth back; with few very short body hairs. Legs: 1st leg long and thin; hairs knotty with spoon-like tips, rather typical of species in the "Feroniarum-group" (SCHEUCHER 1957). For more quantitative details see the data given in Tabs 3, 4, 5 under the column headed "Traits". Species in the "Feroniarum-group" include: *H. abietis* Scheucher, 1957; *H. alphaticum* Fain, 1974; *H. bakeri* Hughes & Jackson, 1958; *H. campanula* Oudemans, 1914; *H. continuata* Mahunka, 1978; *H. coronatum* Mahunka, 1978; *H. elzingai* Mahunka, 1978; *H. feroniarum* Dufour, 1839; *H. formosana* Phillipsen & Coppel, 1977; *H. furcata* Mahunka, 1975; *H. guanophilum* Mahunka, 1982; *H. humiditatis* Vitzthum, 1927; *H. beinemani* Hill & Deahl, 1978; *H. insulare* Oudemans, 1914; *H. ionicum* Mahunka, 1977; *H. janosi* Mahunka, 1975; *H. julorum* Koch, 1814; *H. longipes* Oudemans, 1911; *H. louisianae* Woodring, 1963; *H. litorale* Oudemans, 1914; *H. mahunkai* Fain, 1974; *H. maritimum* Oudemans, 1914; *H. moralesi* Mahunka, 1978; *H. myrmicarum* Scheucher, 1957; *H. pickaxeae* Eraky & Shoker, 1995; *H. pierrestrinati* Mahunka, 1982; *H. piscium* Fain & Lambrechts, 1985; *H. polaki* Oudemans, 1914; *H. puncticeps* Mahunka, 1963; *H. polyptori* Oudemans, 1914; *H. rimosa* Mahunka, 1963; *H. sapromyzarum* Dufour, 1839; *H. strinati* Mahunka, 1978; *H. tetanolabi* Tagami & Halliday, 2013; *H. uxorial* Mahunka, 1974; *H. natanabei* Kurosa, 2002.

Total agreement in connection with body size and leg measurements of our species

with corresponding data of any of the related species does not exist, but partial agreements with regard to some of the traits are apparent in connection with some species and are given in the tables in bolded numbers (see Tabs 1-3). The two species that agree with our species in more traits than any other *Histiostoma* species are *H. abietis* and *H. formosana*. The third most similar would be *H. bakeri*, but it is known only from some parts of the USA and uses insects as hosts. The remainder of the “Feroniarum-group”

Tab. 1: Morphological comparison between body and leg measurements of the unidentified species from Hachijojima (*Histiostoma* sp.) with related species of the “Feroniarum-group”. Close agreements are given in bold letters, while widely disparate figures are given in italics.

Tab. 1: Morphologischer Vergleich zwischen Körper- und Beinmaßen der nicht identifizierten Art aus Hachijojima (*Histiostoma* sp.) mit verwandten Arten der “Feroniarum-Gruppe”. Starke Übereinstimmungen sind fett, unterschiedliche Maße kursiv gedruckt .

Trait	<i>H. sp.</i>	<i>H. feroniarum</i>	<i>H. julorum</i>	<i>H. littorale</i>	<i>H. sapromyzarum</i>	<i>H. abietis</i>
Body length (µm)	174±27	178		285-340	170-250	160-165
Body width (µm)	131±30	130		-	-	120
Leg 1: length	72±7	58	66	65	68	72
Leg 1: distal	39±4	29	31	34	36	40
Leg 2: length	60±3	45	48	52	54	61
Leg 2: distal	28±2	25	25	24	29	32
Leg 3: length	43±3	33	41	43	47	44
Leg 4: length	46±1	36	46	47	56	48

Tab. 2: Morphological comparison between body and leg measurements of the unidentified species from Hachijojima (*Histiostoma* sp.) with related species of the “Feroniarum-group”. Close agreements are given in bold letters, while widely disparate figures are given in italics.

Tab. 2: Morphologischer Vergleich zwischen Körper- und Beinmaßen der nicht identifizierten Art aus Hachijojima (*Histiostoma* sp.) mit verwandten Arten der “Feroniarum-Gruppe”. Starke Übereinstimmungen sind fett, unterschiedliche Maße kursiv gedruckt .

Trait	<i>H. sp.</i>	<i>H. alphaticum</i>	<i>H. bakeri</i>	<i>H. campanula</i>	<i>H. continuata</i>	<i>H. coronatum</i>
Body length (µm)	174±27	166	174	211	170	139
Body width (µm)	131±30	122	120	140	110	95
Leg 1: length	72±7	66	66	74	94	-
Leg 1: distal	39±4	30	34	34	51	45
Leg 2: length	60±3	54	52	53	81	-
Leg 2: distal	28±2	22	24	23	43	40
Leg 3: length	43±3	54	44	51	75	76
Leg 4: length	46±1	50	45	50	73	65

Tab. 3: Morphological comparison between body and leg measurements of the unidentified species from Hachijojima (*Histiostoma* sp.) with related species of the “Feroniarum-group”. Close agreements are given in bold letters, while widely disparate figures are given in italics.

Tab. 3: Morphologischer Vergleich zwischen Körper- und Beinmaßen der nicht identifizierten Arten aus Hachijojima (*Histiostoma* sp.) mit verwandten Arten der “Feroniarum-Gruppe”. Starke Übereinstimmungen sind fett, unterschiedliche Maße kursiv gedruckt.

Trait	<i>H. sp.</i>	<i>H. elzingai</i>	<i>H. formosana</i>	<i>H. furucata</i>	<i>H. guanophilum</i>	<i>H. humitatis</i>
Body length (µm)	174±27	130-140	127±12	190-224	209-238	140
Body width (µm)	131±30	-	97±7	127-134	131-164	100
Leg 1: length	72±7	91	71	94	95	70
Leg 1: distal	39±4	44	37	46	53	25
Leg 2: length	60±3	62	58	78	84	52
Leg 2: distal	28±2	27	27	32	40	24
Leg 3: length	43±3	83	45	73	91	45
Leg 4: length	46±1	74	48	71	95	42

showed no more than maximally 3 or 4 agreements with traits of our unidentified mite from Hachijojima and therefore were no longer considered in our morphological comparisons of closely related species.

The *Histiostoma* mite that uses *C. bualienensis* on Hachijojima does not seem to be a native of Taiwan as the *C. bualienensis* millipedes (which are native to Taiwan) collected on that island contained exceedingly few mites of only one species and that species was quite dissimilar from the one present on the millipedes collected on Hachijojima. This finding suggests the intriguing possibility that a species of *Histiostoma* already present on Hachijojima before the arrival of *C. bualienensis* on the island in 2002, either switched its host or added a new host to its necromenic life style. There are *Histiostoma* spp. known that use more than one species as a host, but the *Histiostoma* we found on the Hachijojima millipedes has not previously been reported from Japan and therefore could represent a new species still to be described in detail. The presence of mites on a millipede may not be based on specificity, but on locality. This assumes that mites are specific to a certain area or type of host habitat. As FARFAN & KLOMPEN (2012) conclude: "In this case a wide range of hosts occurring in the preferred habitat/locality might be suitable as phoretic host." Predictions for the locality hypothesis require that individual mite species are occurring on a number of different millipede host species, but for our Hachijojima *Histiostoma* species that information does unfortunately not exist. In fact, no histiotomatid mites have been reported from any species of millipede in Japan before.

In terms of known species that most closely resemble our Hachijojima *Histiostoma* sp., we identified from the "Feroniarum-Group" these two: *H. abietis* Scheucher, 1957 and *H. formosana* Phillipsen & Coppel, 1977. The former, however, is known only from Europe (but could, of course, have made it

to Hachijojima through unintended spreading) and is known to use bark beetles and not diplopods as hosts. There is no description of the adults of that species and the species identification of *H. abietis* has been based only on the description of the morphology of a deutonymph from the beetle *Ips curvidens*. Even though its morphology agrees in many ways with that of our deutonymph, ecological and biogeographic differences abound. Deutonymphs and females of *H. formosana* are known, but this histiotomatid has only been described from a species of the Taiwanese termite *Coptotermes formosanus* Shiraki and is not known to associate with diplopods. Unfortunately the holotype of *H. formosana* is unavailable (and possibly lost); moreover, its mouthparts are simpler than those of our Hachijojima species and the hair lengths and positions on the ventral side also differ.

A final identification and description of the Hachijojima species, collected from the invasive *C. bualienensis* from Taiwan, is envisaged to be completed in the future. The species may turn out to be a hitherto undescribed species of the genus *Histiostoma*, but we aim to include in the comparison with other related species a description of the adults.

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Prof. Dr. Victor Benno Meyer-Rochow
(corresponding author)
Department of Ecology and Genetics
University of Oulu (Oulun Yliopisto)
SF-90140 Oulu
Finland
and
Department of Plant Medicals
Agricultural Science & Technology Research
Institute
Andong National University
Andong GB36729
Republic of Korea
E-Mail: meyrw@gmail.com
Prof. Dr.Kazumi Tagami
Laboratory of Environmental Health
Division of Health & Sport Sciences
University of Tsukuba
Tsukuba
Ibaraki 305-8574
Japan
E-Mail: globotuberum@yahoo.co.jp

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