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Diversity of Peloppiidae (Oribatida) in North America

Zoë Lindo^a

^aUniversity of Western Ontario, Department of Biology, Biology & Geological Sciences Building, London, Ontario, N6A 5B7, Canada.

ABSTRACT

Members of the oribatid mite family Peloppiidae are found throughout the Holarctic in subarctic and arctic habitats, and temperate and boreal forests, and while common, are rarely collected in high abundance. Pacific Northwest forest habitats of western Canada have high relative diversity of peloppiid mites representing species of the genera *Ceratoppia*, *Dendrozetes*, and *Metrioppia*. Many of these are newly described species that are seemingly endemic to the region. Here I review the status and diversity of Peloppiidae from North America, and summarize the distributions of described species. Despite recent efforts, significant work remains. Within *Ceratoppia* two widely-distributed and established species have considerable morphological variation, while the type specimens are missing or destroyed, making confirmation of new specimens difficult. For other genera, extensive review of the Canadian National Collections in Ottawa, Canada suggest there are at least four undescribed species of North American Peloppiidae – two potentially new species of *Paenoppia*, and new species each of *Parapyroppia* and *Pyroppia*.

Keywords Beringia, biogeography, North America, Oribatida, Pacific northwest, Peloppiidae

Introduction

The Peloppiidae are a family of non-pronotid brachypylid oribatid mites that consist of almost 80 species in 22 genera worldwide (Norton and Behan-Pelletier 2009); the family is recorded from arctic to tropical regions around the world. In the northern hemisphere, members of Peloppiidae are commonly found throughout the Holarctic in arctic and subarctic habitats, and temperate and boreal forests, and while common, are rarely collected in high abundance. Of the seven genera that are recorded for North America, *Ceratoppia* is the most commonly reported and is the most diverse genus with approximately 23 species worldwide, and nine species described from North America (Table 1). The second most diverse is *Metrioppia* with eight described species worldwide and four in North America (Lindo 2015). The genus *Pyroppia* has three described species in North America, only one of which is commonly encountered, while the genera *Dendrozetes*, *Metapyroppia*, *Paenoppia* and *Parapyroppia* have one described species each in North America (Table 1).

The characters that are used to differentiate genera of Peloppiidae include a combination of cheliceral form (chelate-dentate or pelopsiform), the shape of the lamellae and length of lamellar cusps, the conspicuousness of a straight sejugal apodeme, and pretarsus claw number (Norton and Behan-Pelletier 2009). Superficially, the Peloppiidae are known for their long thin lamellae with long cusps in *Ceratoppia*, but among members of the family lamellae can also be short or lack cusps, and a translamella can be present or absent. Here I present distributional data for the seven genera known from North America, with a focus on *Ceratoppia*, *Dendrozetes* and *Metrioppia* as these are the genera with the most information.

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Corresponding author
Zoë Lindo: zlindo@uwo.ca

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Table 1 Number of described species (world-wide and in North America) for the seven genera of the family Peloppiidae found in North America.

Genera	# Species Worldwide	# Species North America
<i>Ceratoppia</i>	~23	~9
<i>Dendrozetes</i>	2	1
<i>Metapyroppia</i>	2	1
<i>Metrioppia</i>	8	4
<i>Paenoppia</i>	1	1
<i>Parapyroppia</i>	3	1
<i>Pyroppia</i>	9	3

Ceratoppia Berlese

Ceratoppia is the most common and species-rich genus of Peloppiidae and is restricted to the northern hemisphere. Several species are Holarctic (Schatz 2006) and a total of nine (plus two subspecies) are known from North America (Lindo 2011). The main character states defining *Ceratoppia* among the Peloppiidae are chelate-dentate chelicerae, a conspicuous and straight sejugal apodeme, tridactyl pretarsus, and long lamellar cusps and bothridial setae. The main character states differentiating North American species of *Ceratoppia* are the number of hypostomal setae on the subcapitular mentum, and the number and expression of posterior notogastral setae; other diagnostic characters include the length of the lamellae and shape of the rostrum.

Of the North American species, the Holarctic *C. bipilis* (Hermann), and *C. quadridentata* (Haller) are best known. Both species are additionally represented by subspecies within their North American range: *C. bipilis spinipes* (Banks) (also *C. bipilis brevicuspis* (Jacot) — later synonymised with *C. bipilis* by Jacot (1936) — and *C. quadridentata arctica* Hammer, respectively (Marshall *et al.* 1987). In North America *C. quadridentata arctica* is more commonly reported than the nominate *C. quadridentata*, which is recorded only from Alaska (Bohnsack 1973); the latter record is likely *C. quadridentata arctica* as there is considerable variation reported within *C. quadridentata* (Aoki 1969), and *C. quadridentata arctica* is common in Alaska (Hammer 1955). Both *C. bipilis* and *C. quadridentata arctica* are widespread in arctic, subarctic, boreal and temperate areas, and overlap in the western subarctic and arctic areas (Alaska, Yukon, Northwest Territories, and Nunuvut) with *C. sexpilosa* Willmann, and *C. sphaerica* (L. Koch). The subspecies *C. bipilis spinipes* is recorded from eastern North America including Ontario, Connecticut, Maine, Maryland, New Hampshire, Virginia and West Virginia (Marshall *et al.* 1987). The validity of both subspecies *C. quadridentata arctica* and *C. bipilis spinipes* requires confirmation as both *C. bipilis* and *C. quadridentata arctica* display a wide variety of body size across their North American distributional range. Observed specimens of *C. bipilis spinipes* also display considerable variation in body size.

Lindo (2011) recently described five new species of *Ceratoppia* from Pacific coastal North America with overlapping distributions but differing in habitat preference. Three of these species were described primarily or solely from arboreal habitats (*C. longicuspis*, *C. tofinoensis*, *C. valerieae*), one species was collected solely from bark habitats (*C. offarostrata*), and one species collected solely from forest floor soils (*C. indentata*). Distributions of *C. indentata*, *C. longicuspis*, and *C. valerieae* span the North American Pacific coastline from north-central British Columbia, Canada, to north-central California State. It was noted that *C. indentata* has increasing morphological variation in the southern extent of its distribution. *Ceratoppia valerieae* has the most expansive distribution longitudinally, being found in arboreal habitats near the coast and dry ground habitats in interior Washington State and southern British Columbia. *Ceratoppia tofinoensis* is less commonly sampled and appears to be restricted to

coastal Oregon and Washington, and the west coast of Vancouver Island, British Columbia. The fifth species from western North America, *C. offarostrata*, named for a large ‘hump’ on the rostrum, is known only from a few locations on Vancouver Island and Haida Gwaii, British Columbia. Morphological variation in *C. offarostrata* on Haida Gwaii needs to be compared with that of *C. sphaerica*; the distributional patterns of *C. sphaerica* suggest this species is limited to arctic and subarctic areas in western Canada, however, *C. offarostrata* shares several character states, and may be a southern variant subspecies of *C. sphaerica*.

Dendrozetes Aoki

Dendrozetes is unique among the Peloppiidae in the following combination of character states: chelicerae chelate-dentate, sejugal apodeme conspicuous and straight, tridactyl pretarsus, lamellar cusps absent, and bothridial seta capitate. There are two described species, the first of which, *D. caudatus* Aoki, occupies arboreal habitats in northern Japan (Aoki 1970) and the second, *Dendrozetes jordani* Lindo Clayton & Behan-Pelletier, that also occupies arboreal habitats in coastal North America. The two species are differentiated by the number of prominent posterior setae (*h* series) with *D. caudatus* possessing two pairs, and *D. jordani* possessing a single pair. *Dendrozetes jordani* shares an arboreal habitat lifestyle with its congener, being found on bare branch tips of mostly conifer species, e.g. western hemlock (*Tsuga heterophylla* (Raf.) Sarg) (Winchester *et al.* 2008). *Dendrozetes jordani* has been collected only from seven locations, six of which are on Vancouver Island, British Columbia and the seventh in Washington State, however given its strictly arboreal habitats, it may be under-sampled and more widespread than records indicate.

Metapyroppia Woolley

Metapyroppia is represented by a single species in North America, the type-species *M. doratosa* Woolley from Tennessee State (Woolley 1969). Recently, Ermilov and Martens (2014) described a second species from Nepal. More importantly, these authors provided a rediagnosis of the genus, highlighting long lamellae with short cusps and rudimentary translamellae, and notogastral setae c_1 and c_2 (or their alveoli) located in a humeral position, similar to Liacaridae. The distributional range of *M. doratosa* remains unknown, and to my knowledge only the single type specimen exists; extensive review of the Canadian National Collection in Ottawa, Canada revealed no confirmed specimens, only specimens incorrectly identified as *Metapyroppia*.

Metrioppia Grandjean

Metrioppia is one of two genera within the Peloppiidae that possess pelopsiform chelicerae, being differentiated from the other, *Paenoppia*, by the shape of the lamellae (converging but not touching, and without translamellae). Worldwide, eight species of *Metrioppia* have been described; four of these (and one subspecies) are known from North America. The type-species, *Metrioppia helvetica* Grandjean, has a Holarctic distribution and occurs across the western arctic and subarctic of North America (Alaska, Yukon, Northwest Territories, and Nunuvut). The second, *M. serrata* (Sellnick) is known from Mexico and seems a different species based on original descriptions. However, type specimens of *M. helvetica* and *M. serrata* were unfortunately lost or destroyed (Marshall *et al.* 1987) and some confusion has developed in the literature. Hammer (1952) redescribed *M. helvetica*, originally under the name *C. microseta* Hammer, which she later synonymised (Hammer 1955); however no type-specimen of *C. microseta* exists (Marshall *et al.* 1987). This is unfortunate as both *M. helvetica* and *M. serrata* appear to have considerable morphological variation, and it is unclear whether *M. atlantica*

Jacot found in the eastern United States (Virginia, Illinois, North Carolina) represents a true species or a subspecies of *M. serrata* as suggested by Jacot (1938).

There are two west coast species of *Metrioppia*: *M. oregonensis* Woolley & Higgins, and *M. walbranensis* Lindo. Extensive sampling and museum records suggest they do not co-occur, with *M. walbranensis* having a very restricted distribution endemic to only a few valleys (<3000 km²) of intact old-growth temperate rainforest on Vancouver Island, British Columbia (Lindo 2015). *Metrioppia oregonensis* has been found both north and south of *M. walbranensis*, extending to northern California, where the southernmost specimens display morphological variation in body size (Walter and Norton 1984).

Paenoppia Woolley & Higgins

The genus *Paenoppia* is unique among the Peloppiidae in having a combination of pelopsiform chelicerae and lamellae that are close, or nearly touching, and / or connected by a translamellae. *Paenoppia* is monospecific with the holotype of *Paenoppia forficula* Woolley & Higgins and eight paratypes described from a single location in Colorado State. Unconfirmed records of *P. forficula* were reported from other locations in Colorado, and two locations in Oregon State including the H.J. Andrews Experimental Forest (Moldenke and Fichter 1988). In the Canadian National Collection in Ottawa, Canada, there exists two potentially new species of *Paenoppia*, one from the state of New Mexico and a second from two locations in Alabama – the latter possessing a translamella with a tooth.

Parapyroppia Pérez-Íñigo & Subías

The genus *Parapyroppia* has three described species worldwide, with *P. lamellata* (Ewing) described based on collections from the southern United States (Missouri). *Parapyroppia* is distinguished from other members of the Peloppiidae by the combination of monodactyl pretarsi, chelate-dentate chelicerae, a conspicuous and straight sejugal apodeme, and short lamellar cusps. *Parapyroppia* is most similar to *Pyroppia*, differing only in the number of pretarsal claws and shape of notogaster posteriorly (obtusely pointed in *Pyroppia*). Unconfirmed collections of *P. lamellata* are recorded for the west coast (Lindo 2010) and interior of British Columbia (Berch *et al.* 2007). The genus has also been reportedly collected from western Oregon, California, New Mexico, and Alberta. Whether specimens observed in western North America are *P. lamellata* is not confirmed, and may represent a new species. Specimens observed from all these locations share similar character states, in particular reduced notogastral setae and long lanceolate bothridial setae. In addition to the western species, there appears an undescribed species from eastern Canada (Ontario, Newfoundland) (Dwyer *et al.* 1997, 1998) that clearly possesses notogastral setae.

Pyroppia Hammer

Described species of *Pyroppia* in North America are recorded from subarctic and arctic areas: *P. lanceolata* Hammer was described based on material from Alaska (Hammer 1955), and also recorded in Yukon and Northwest Territories of Canada (Behan 1978), while *P. dentata* Krivolutsky, described from the Far East of Russia, has also been recorded in Alaska (Behan 1978). Undetermined *Pyroppia* have been recorded from both western (Berch *et al.* 2007) and eastern (Dwyer *et al.* 1997, 1998) Canada. The western species appear similar to descriptions of *P. lanceolata* except for possessing longer prodorsal setae and lacking distinct lamellar cusps. I have not observed specimens of *Pyroppia* from Newfoundland, Canada (Dwyer *et al.* 1997, 1998), but specimens from Maine USA, Nova Scotia and Ontario, Canada are clearly different from the western species. They exhibit longer, lanceolate bothridial setae and likely represent

a new species. That said, the specimens are very similar in appearance to the suggested undescribed species of *Parapyroppia* from eastern Canada (see above), except that they are tridactyl.

This raises a question about the distinctness of *Pyroppia* and *Parapyroppia*. In two cases I have observed single specimens of each genus, collected at the same sample location, which have very similar character states with the exception of pretarsal claw number. Intraspecific variability in claw number has been reported in *Acrotrititia ardua* (C.L. Koch) (Lions 1964), and *Ameronothrus schneideri* (Oudemans) (Boelé and van der Hammen 1982), however Shimano (2004) considered that variation in other traits was sufficient to consider monodactylous and bidactylous specimens of *A. ardua* to be separate species. Whether difference in claw number as the main morphological distinction warrants separating the genera *Parapyroppia* and *Pyroppia* will require close examination of the undescribed species from eastern North America, especially in locations where the two genera co-occur.

Discussion

There appears to be two ‘hot spots’ for Peloppiidae diversity in North America – subarctic and arctic areas of north-western North America suggestive of a Beringian or Holarctic distribution, and a west coastal endemic group. Behan-Pelletier (1999) noted that none of the North American high arctic oribatid mites are endemic to the area having Holarctic, or Beringian (Behan-Pelletier 1997), distributions. The Beringia land bridge was an important source of colonisation events for many mobile species, but the area also housed significant glacial refugia in the northwest of the main Canadian ice sheet. Sampling of subarctic and arctic areas of western North America has indeed focused on areas unglaciated during the Pleistocene, and the parsimonious explanation is that northern species are products of glacial refugia, which explains their similarity, but often slight morphological variation from Palaearctic conspecifics.

The west coast endemic groups are a bit harder to explain, with likely multiple factors contributing to the patterns of Peloppiidae diversity. Endemic and disjunct distributions of other taxa (e.g. plants (Soltis *et al.* 1997), mammals (Byun *et al.* 1997)) strongly suggest the presence of glacial refugia west (Haida Gwaii) and south (Washington / Oregon) of the Wisconsin glacial ice sheet. Subsequent colonisations from these glacial refugia are hypothesised to explain the uniqueness of species and genetic diversity in the North American west coast (Godbout *et al.* 2008). At the same time, long distance ocean rafting events across the Pacific potentially contribute to west coast Peloppiidae diversity. The similarity of several newly described species (e.g. *D. jordani*, *C. indentata*) to congeners from Japan (i.e. *D. caudatus*, and *C. incisa* Kaneko and Aoki, respectively) supports this. Ocean rafting is a common dispersal mechanism by marine organisms, however an extensive review by Thiel and Gutow (2005) found evidence of 12 non-marine Chelicerata species dispersing via rafting, as well as many species of fungi, vascular plants, and other terrestrial arthropods. Niedbala (1998) reported several species of *Atropacarus* and other ptychoid oribatid mites rafting on wood substrate among Pacific islands, while Coulson *et al.* (2002) demonstrated survival rates of *Camisia anomia* Colloff submerged in seawater. Both studies suggest ocean rafting is a highly probable mechanism of trans-oceanic dispersal. Considerably less is known about the Peloppiidae species in other parts of the continent, but clearly new species are likely to be discovered. Material in hand represents at least four undescribed species from eastern North America including two species of *Paenoppia*, and one species each of *Parapyroppia* and *Pyroppia*.

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