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FIRST RECORD AND LONG-TERM ESTABLISHMENT OF THE ORDER EMBIOPTERA IN WASHINGTON STATE

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Abstract.—Specimens of *Haploembia* sp. (Embioptera: Oligotomidae) were found in 2005 in a rural area of the Columbia Basin next to the Snake River. This is the first verified record of Embioptera in Washington State and one of the northernmost in the world. Subsequent collections 16 years later at the same site show that the population is still present. In 2005, specimens were found only at the original locality. However, starting in 2020, specimens of *Haploembia* were reported in multiple nearby urban and suburban areas of Washington State and Oregon on the citizen science website iNaturalist.org. Characters of collected specimens and a lack of males across 2005 and 2021 suggest the species in the Columbia Basin region is *Haploembia* cf. *tarsalis* (Ross).

Key Words: webspinner, new record, introduced species, distribution

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Embioptera, or webspinners, are a rarely collected or detected group of insects in some areas with dry climates because they are cryptically enclosed in silken webs beneath rocks and logs. The approximately 400 identified species of Embioptera are primarily tropical to subtropical, known to only reach as far north in the New World as 40 °N latitude (Northern California and Southern Oregon), and in the Crimea region of the old world, they reach 45 °N (Edgerly 2018, Miller et al. 2012, Ross 1940). Within the continental US, three families, six genera, and 13 species of Embioptera are currently known (Stehr 1987). All Embioptera have enlarged hind femora, apterous females, and silk glands in the basitarsi of the fore legs (Ross 1940). Embioptera are generalist herbivores that will consume almost any available plant matter, but few are economic pests (Ross 1957, 2000; Argaman and Mendel 1991). Introductions of Embioptera into California, Florida, and Texas are well documented (Arnett 2000; Ross 1940, 1944, 1957, 1984a, 1984b); however, there are no published records of Embioptera in Washington State or worldwide north of 45 °N Latitude. Presented here are the

first verified records of Embioptera in Washington State, the northernmost in North America and worldwide.

Materials and Methods

On February 19, 2005, at Almota, Whitman County, Washington State (46.7018 °N, 117.4774 °W) at approximately 200 m above sea level, a single embiopteran was found free-living by author RTC inhabiting rocky cliffs along the Snake River. The specimen was not identified until returned from the field. Since embiopterans were not known to occur as far north as Washington State, the association of webbing with insect was initially overlooked. After the specimen was identified as an embiopteran, a subsequent expedition to the same area was mounted on Feb. 22, 2005, to attempt to locate additional specimens and to record habitat characteristics. Nine specimens were collected on the second trip (four to begin a laboratory colony, five for preservation), and numerous web tubes were found between rocks. The laboratory colony was active for almost three years before it was destroyed by placing it in the freezer to kill all the individuals.

On September 30, 2021, two of the authors (RTC and RJO) returned to the Almota site to survey for Embioptera and determine if the population was still present. Six immature specimens were found in web tubes under rocks. Web tubes were ubiquitous under every rock turned over, though specimens were harder to locate. Two specimens were preserved, and the remaining specimens were used to establish a second laboratory colony.

After the September 2021 expedition, RTC and RJO searched for current distribution records of Embioptera and determined that author AS located Embioptera on July 8, 2020, in a vacant lot in the city of Kennewick, Benton County, Washington State (46.2133 °N, 119.2023 °W) and in an adjacent vacant lot 40 m south on July 9, 2020. Author AS submitted photographs of the insects to the citizen science website iNaturalist.org. On this website, members of the public worldwide post photos of organisms and suggest taxonomic identifications. In 2021–2022, author AS made iNaturalist.org submissions of Embioptera from the original Kennewick location and two other locations in the city (next to irrigation canal, 46.1841 °N, 119.1781 °W; suburban neighborhood under a log, 46.1849 °N, 119.1516 °W) and one in Burbank, Walla Walla County, Washington State (next to parking lot adjacent to Snake River, 46.2142 °N, 119.0185 °W). Author AS also collected several additional Embioptera on January 23, 2022, next to the Burbank location (46.2123 °N, 119.0165 °W) for identification by RTC. Another observation of Embioptera was reported in the region by an iNaturalist.org user in November 2021 in Stanfield, Umatilla County, Oregon, 50 km south of Kennewick (under a brick in a suburban yard, 45.7890 °N, 119.2242 °W). Hence, all currently known records of Embioptera in Washington State are clustered in the Southeast area of the state in the Columbia basin.

Morphological characteristics (i.e., basitarsal papillae of the hind legs, diagnostic characteristic for *Haploembia*) and symmetry of genitalia (Ross 1940, 1966) of specimens were observed and recorded using a stereomicroscope. Photographs were taken with a Canon EOS 6D DSRL camera and a Macropod Pro imaging system. We used a Stackshot 3× Cognisys device and combined individual images with the Zerene Stacker software (Zerene Systems, LLC) and the Pmax method. The distribution map was generated using SimpleMappr (Shorthouse 2010) and modified using standard graphic editors.

Results

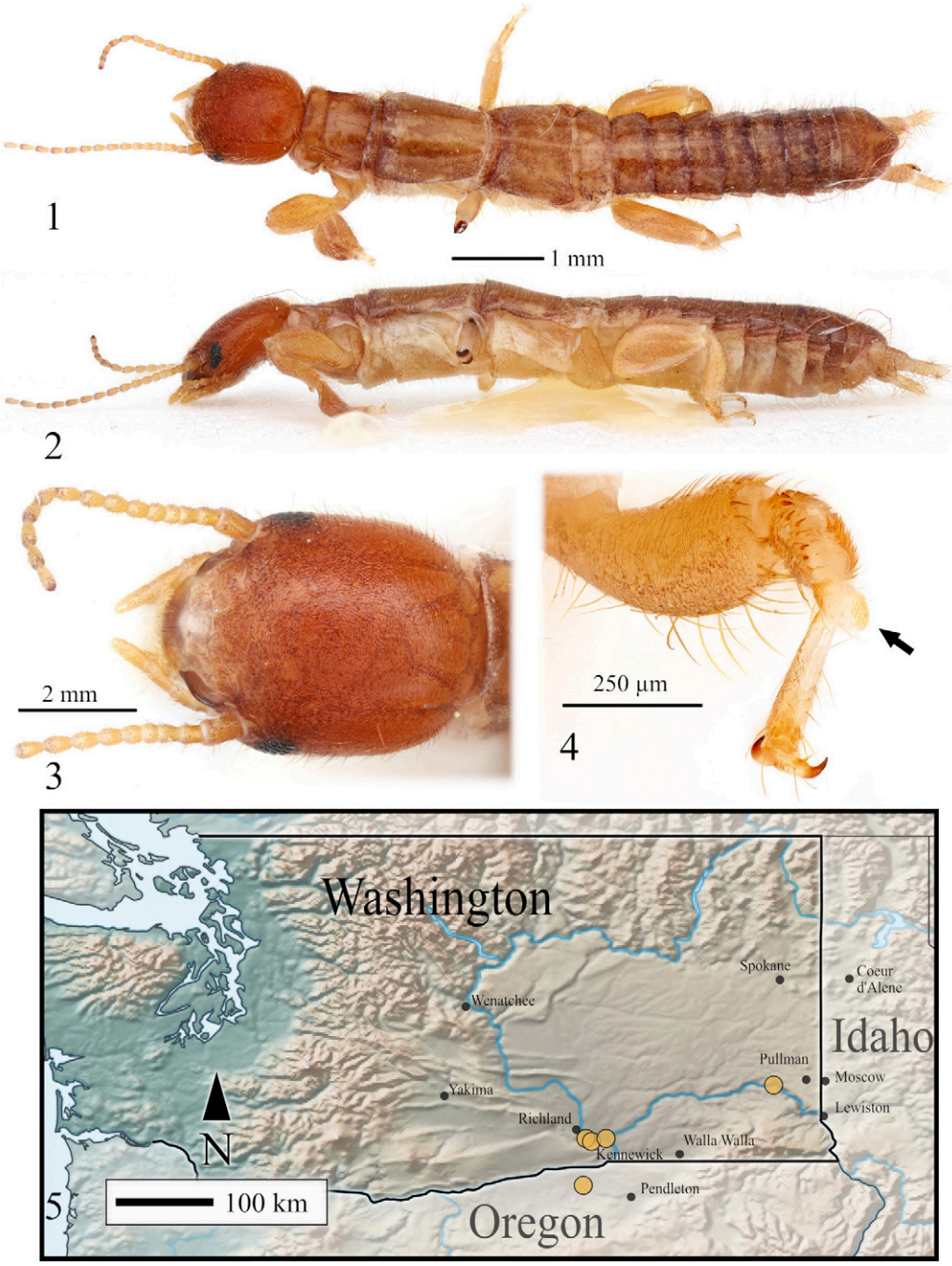
All of the wild-collected and laboratory colony individuals were apterous and did not have highly asymmetrical genitalia. Specimens collected in 2005 (Almota), 2021 (Almota), and 2022 (Kennewick) were determined by author RTC as female *H.* cf. *solieri* (Rambur, 1842) or *H.* cf. *tarsalis* (Ross, 1940) (Figs. 1–5) based on morphological characteristics. Determination was made based on the presence of a second basitarsal lobe on the ventral side of the hind tarsus (Fig. 4). Hodson et al. (2014) and Kelly et al. (2018) show that *Haploembia solieri* and *Haploembia tarsalis* are cryptic species; the former is sexual and the latter parthenogenetic. Because no males were found in collections or laboratory colonies, the Embioptera were likely parthenogenetic, suggesting that populations present in the region are *H. tarsalis*. Additionally, specimens from Washington collections are uniformly light in color, matching *H. tarsalis* from California collections (Kelly et al. 2018). Specimens from each of the three collections have been deposited in the insect museum at Washington State University (Almota 2005, WSUC00002416; Almota 2021, WSUC00002414 and WSCU00002415; Kennewick 2022, WSCU00002417).

In 2005, specimens of *H.* cf. *tarsalis* were only found at the original collection site. Collection attempts at the Almota site in winter and spring 2005 from upriver above a dam between Wawawai Canyon WA (46.636 °N, 117.374 °W) and Steptoe Canyon WA (46.451 °N, 117.205 °W) failed to retrieve additional specimens, and no webbing was found. Access to locations downriver from Almota was not possible since few roads reach the river, and crossing private, posted cattle grazing land would be necessary.

Evidence of habitats used by Embioptera varied between years and locations. Web tunnels from the winter 2005 field trip were only found in vertical cracks between rocks where there was grass or other vegetation growing. Removal of rocks from the base of the cliff face revealed many tubes on the vertical surface and virtually none on the horizontal. These observations were consistent with *H. solieri*'s characteristic habit of forming web tubes in rock crevasses (Ross 2000). However, collections in late summer 2021 found few web tubes in the vertical surfaces between rocks along the cliff face, and abundant tubes under rocks that had fallen to the ground. In addition, the recent records from iNaturalist.org include observations of Embioptera under logs, rocks, or bricks in urban or suburban environments. During the 2021 expedition to the Almota site, searches from upslope along the road away from the river did not find any web tubes under rocks; webbing was only discovered between train tracks and the Snake River where grasses, deciduous trees, or bushes were present.

Discussion

The embiopteran *H. tarsalis* is native to the Mediterranean, but it (or the cryptic species *H. solieri,* native to the same area) has spread worldwide to locations including the Southwestern US (Ross 2000, Hodson et al. 2014) and Japan (Nozaki et al. 2018). Other introductions of Embioptera on imported plant material have been reported from glasshouse botanical gardens in the UK (Salisbury et al. 2019), corroborating Ross's (1984a, 1984b, 2000) suggestion that Embioptera are easily invasive. The arrival and spread of *H. tarsalis* in Washington State may be related to aspects of human activity, successful establishment may be related to microclimates, and recent regional detections in the Columbia Basin were due to public observations of nature enthusiasts



Figs. 1–5. *Haploembia* cf. *tarsalis* (Ross, 1940) collected at Almota, WA. 1, Habitus, dorsal view. 2, Habitus, lateral view. 3, Head, frontal view. 4, Hind tarsus. 5, Map of known collection locations in the Pacific Northwest. The depicted specimen is deposited in the Washington State University Insect Collection (WSUC) and associated with voucher code WSUC00002414.

on iNaturalist.org. The webbing observed at Almota in 2021 was ubiquitous and found under every rock at the site, suggesting that a large population of Embioptera are present there.

The arrival of Embioptera in the Columbia Basin region may be associated with human-built transportation networks. There are a few similarities between the sites where Embioptera are now reported in Washington (five total: Almota, Burbank, and three sites in Kennewick) and Oregon (Stanfield). Four sites are < 1.1 km from railroad tracks (Almota, Burbank, one Kennewick, and Stanfield). Three sites are < 1 km from abandoned (one Kennewick) or active (Almota, Burbank) grain handling operations. In addition, all sites are < 16 km from the Columbia or Snake Rivers (Fig. 5).

The area of Almota where Embioptera are established is much different from the original habitat of the Snake River before it was dammed and flooded. Before the Lower Granite Dam was built at Almota, there was a small town with a grain mill and apple orchards in the flood plain of the Snake River. It is possible that *H. tarsalis* were transported with rootstocks; Ross (1957, 2000) reported that Embioptera introduction can occur with transportation of plants, and tropical species are commonly intercepted in shipments of tropical orchids and pineapples. The Oregon–Washington Railroad and Navigation Company rail line, directly above the first specimen discovery site, has been in operation since between 1906 and 1917 (Landes 1917). Also, when the Lower Granite Dam was built between 1970 and 1975, soil, rocks, and other building supplies were transported up the river and dumped along the banks of the Snake River. Ross (2000) suggested that Embioptera may be transported to new locations in materials dumped ashore by commerce activities, so dam construction may have been responsible for their introduction and establishment at Almota. In addition, there has been a grain mill at the base of the road leading to the dam, approximately 250 m from the initial collection site since 1919. Occasionally, Embioptera have been found consuming stored products (Ross 2000).

At the urban and suburban sites in Kennewick, Burbank, and Stanfield, where Embioptera have been reported on iNaturalist.org starting in 2020, the potential mode of introduction is difficult to ascertain. The Oregon–Washington Railroad and Navigation Company rail line went through Kennewick since sometime before 1906 (Anonymous 1906). The region also has a history of orchards and agriculture that required importation of rooted plants. Sites where Embioptera were reported on iNaturalist.org tended to be near railroad tracks (three of the five sites), suggesting that transport of construction supplies or other goods provides a means of arrival for Embioptera. Similarly, the first detection of *Haploembia* in East Asia was in a port city on an artificial island of Japan (Nozaki et al. 2018). Overall, this supports the observation that new introductions of Embioptera are often associated with commerce (Ross 2000). Generally, Embioptera are a tropical group limited to warm regions of the world, so it is noteworthy to detect them in Washington State, the furthest North any Embioptera have yet been verified. Climatically, all Embioptera locales reported in Washington have Mediterranean-like climates; summers are hot and dry, and winters are generally mild. The specific locations that Embioptera were found in Washington State may have microhabitats suitable for establishment and growth of populations, but restricted enough to prevent spread to less suitable areas. The collection location in Almota is a cliff that faces South, immediately adjacent to the Snake River; winter

days typically are warm, and the sun heats the rocks most days. A heat island effect in the urban and suburban locales reported on iNaturalist.org may similarly provide suitable microclimate for Embioptera.

Recent detection of Embioptera in cities up to 170 km from the first record in 2005 at Almota suggest that *H. tarsalis* may be more widely and historically distributed than previously known. The detections reported on iNaturalist.org since 2020 may reflect relatively recent spread. Alternatively, crowd-sourced documentation of biodiversity may have spurred detection of Embioptera in areas where they were long-established, but overlooked by experts. The website iNaturalist.org has proven useful for connecting the public with experts to detect other rare species (Wilson et al. 2020, Winterton 2020, Mesaglio et al. 2021), and the enormous scale of citizen scientist observation power can make considerable contributions to biodiversity research (Callaghan et al. 2021). However, iNaturalist records often need expert verification to ensure scientific accuracy (Hochmair et al. 2020). Hence, continuing citizen scientist and expert observation could complement each other to facilitate documentation of current and changing distributions of Embioptera.

Further searches in the Pacific Northwest's warm arid regions could clarify the current distribution of Embioptera in the region and their association with railroads, grain processing operations, and rivers. Citizen science observations have considerable potential to contribute to such efforts. Further study could also clarify the ecological effects of introduced Embioptera. *Haploembia* spp. and other embiopterans are increasingly detected outside of their native ranges (Nozaki et al. 2018, Kočárek et al. 2021), yet their effects on ecosystems remain unknown.

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