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Distribution of the American milliped genus *Boraria* Chamberlin, 1943: Introductions of *B. stricta* (Brölemann, 1896) in New York and *B. infesta* (Chamberlin, 1918) in Connecticut; indigenous occurrence of *B. profuga* (Causey, 1955) in Louisiana (Diplopoda: Polydesmida: Xystodesmidae).

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Abstract. The southern Appalachian millipeds *Boraria stricta* (Brölemann, 1896) and *B. infesta* (Chamberlin, 1918) (Diplopoda: Polydesmida: Xystodesmidae) have become established in Westchester Co., New York, and Hartford Co., Connecticut, respectively. Only three individuals are available for the latter, but *B. stricta* has established a reproducing population in southern New York state. This species is also recorded from Bland Co., Virginia, in the Ridge and Valley Physiographic Province. *Boraria profuga* (Causey, 1955) comprises two allopatric populations, one in Montgomery Co., Arkansas, and the other in Ouachita Parish, Louisiana. Distributional records and gonopod drawings are presented for these species plus *B. deturkiana* (Causey, 1942).

Key Words. Mianus River Gorge Preserve, Arkansas, Appalachians, Blue Ridge, Piedmont Plateau, North Carolina, Virginia, Tennessee, Ouachita Physiographic Province.

Introduction

The xystodesmid milliped genus *Boraria* Chamberlin, 1943 (Diplopoda: Polydesmida: Xystodesmidae), comprises three species in the southern Blue Ridge and western Piedmont Plateau Physiographic Provinces of the United States (US) – *B. stricta* (Brölemann, 1896), *B. infesta* (Chamberlin, 1918), and *B. deturkiana* (Causey, 1942) – and one, *B. profuga* (Causey, 1955), in the Ouachita Physiographic Province, Arkansas. The western borders of the Appalachian species coincide with that of the Blue Ridge Province in eastern Tennessee, and except for *B. infesta* in Monroe Co., Tennessee, the distribution of *B. stricta* encompasses the others and constitutes that of the genus in this region. Both *Boraria* and *B. stricta* extend southward from Floyd Co., Virginia, to northern Dawson and northeastern Lumpkin counties, Georgia, spreading eastward to the Blue Ridge Escarpment in Virginia and the west/westcentral Piedmont Plateau in the Carolinas. Additionally, an allopatric population of *B. stricta* inhabits the Kings/Crowders Mountain inselberg, which straddles the border of the Carolinas in the Piedmont Plateau west of Charlotte, some 64 km (40 mi) east of the Blue Ridge population (Hoffman 1950, 1965, 1969, 1999; Chamberlin and Hoffman 1958; Hoffman and Shear 1969; Filka and Shelley 1980; Shelley 2000; Snyder 2008). *Boraria infesta* occurs throughout much of the Blue Ridge in North Carolina, extending eastward to Wilkes Co., in the western Piedmont Plateau, and northward to Mt. Rogers, Grayson Co., Virginia, and *B. deturkiana* ranges northwestward from Macon/Jackson counties, North Carolina, to Sevier Co., in the Tennessee half of the Great Smoky Mountains National Park (GSMNP) (Loomis 1944; Hoffman 1950, 1999; Shelley 2000; Snyder 2008). *Boraria profuga* is known only from the type series, collected at Mt. Ida, Montgomery Co., Arkansas (Causey 1955, Chamberlin and Hoffman 1958, Hoffman and Shear 1969, Hoffman 1999).

As with most xystodesmids, species of *Boraria* are diagnosed primarily by the configurations of the gonopods, which replace the 8th legs (anterior pair on segment 7) in males. They project anteriad from the aperture, lie parallel *in situ*, and possess acicular prefemoral processes that roughly parallel the longer, dominant acropodites. Species are distinguished by apical acropodal differences, pigmentations, and subtle aspects of body forms (Hoffman 1965, Hoffman and Shear 1969, Filka and Shelley 1980). All four species have been amply revised, redescribed, and illustrated (Hoffman 1965, Hoffman and Shear 1969), so further taxonomic treatments are not necessary. However, new records expand distributions of the Appalachian species; *B. profuga* has been rediscovered near the type locality; and an allopatric population exists in northern Louisiana. Furthermore, both *B. stricta* and *B. infesta* have been discovered in New England, constituting the second and third northeastern introductions of a southern Appalachian diplopod, the first being *Cleidogona nantahalae* Shear, 1972 (Chordeumatida: Cleidogonidae) in Connecticut and Rhode Island (Shear 1972, Shear and Shelley 2004). We publish these records to update known occurrences. Repository codens are **AMNH**, American Museum of Natural History, New York, NY; **FSCA**, Florida State Collection of Arthropods, Gainesville; **NCSM**, North Carolina State Museum of Natural Sciences, Raleigh; **USNM**, National Museum of Natural History, Smithsonian Institution, Washington, DC; **UMMZ**, University of Michigan Museum of Zoology, Ann Arbor, and **VMNH**, Virginia Museum of Natural History, Martinsville.

Boraria stricta (Brölemann, 1896) (Fig. 1-2, 5)

Distribution. *Boraria stricta*, the only representative in South Carolina and Georgia, occupies a large, continuous area with one and perhaps two proximate allopatric populations and a distant introduced one. The continuous area extends, north/south, from northern Floyd Co., Virginia, to northern Lumpkin Co., Georgia; east-west, it ranges from the western Piedmont Plateau of North Carolina (Wilkes, Burke, and Rutherford counties) and the westcentral Piedmont of South Carolina (Union and Spartanburg counties) to the western periphery of the Blue Ridge Province in Virginia and Tennessee (Fig. 13). The milliped has not been encountered in Tennessee south of the GSMNP, so the area encloses the indigenous occurrences of both *B. infesta* and *B. deturkiana* except for the Monroe Co., Tennessee, locality of the former. In addition to the allopatric population in the Kings/Crowders Mountains Inselberg, the Bland Co. locality, around 48 km (30 mi) west of the main area, may represent such in Virginia. This record establishes the genus and species in the Ridge and Valley Physiographic Province and suggests occur-



Figures 1-4. *Boraria* spp. **1)** A cluster of *B. stricta* under leaves on saturated substrate at Mianus River Gorge Preserve, Westchester Co., New York. **2)** An individual of *B. stricta* climbing a log at this site; note the juvenile in the depression left of center. **3)** A tributary of the Mianus River in the Preserve showing leaf litter and the surrounding deciduous forest, an ideal environment for *B. stricta*. **4)** *B. infesta* from Avon, Hartford Co., Connecticut.

rence in the Appalachian Plateaus Province (Allegheny Mountains) in southern West Virginia, only 9.6 km (6 mi) to the northwest (Fig. 12-13).

The New York population, some 704 km (440 mi) to the north-northeast (Fig. 12), constitutes the first record of *B. stricta* outside the general southern Appalachian region. In the 115 years since its description (Brölemann 1896), copious samplings in suitable environments to the north in Virginia, Maryland, Pennsylvania, and New York have not yielded a single individual of *B. stricta*, so its occurrence in Mianus River Gorge Preserve (MRGP) can only be interpreted as a rare, intra-continental, human aided introduction that has established a reproducing population.

Published records. *Virginia:* *Floyd, Franklin, Grayson, and Patrick counties* (Chamberlin and Hoffman 1958; Hoffman 1965, 1999). *Tennessee:* *Blount, Greene, Johnson, and Sevier counties* (Chamberlin and Hoffman 1958, Hoffman 1965). *North Carolina:* *Alexander, Ashe, Avery, Buncombe, Burke, Caldwell, Clay, Cleveland, Gaston, Graham, Haywood, Henderson, Jackson, Macon, Madison, Mitchell, Rutherford, Swain, Transylvania, Watauga, Wilkes, and Yancey counties* (Chamberlin and Hoffman 1958; Hoffman 1965, 1999; Filka and Shelley 1980, Shelley 2000). *South Carolina:* *Oconee and York counties* (Hoffman 1965, Filka and Shelley 1980). *Georgia:* *Dawson and Rabun counties* (Chamberlin and Hoffman 1958; Hoffman 1965, 1999).

New records. *Virginia:* *Bland Co.*, 2.4 km (1.5 mi S Suiter, M, 26 April 1980, D.W. Ogle (VMNH)). *Floyd Co.*, Twin Falls, 2.6 km (1.6 mi) W Copper Hill, M, 2 July 1974, D. Surface (VMNH).

Tennessee: Coker Co., Great Smoky Mountains National Park (GSMNP), Cosby Picnic Area, M, 19 June 1976, R.M. Shelley (NCSM). *Sevier Co.*, GSMNP, Roaring Fork Motor Nature Loop near Gatlinburg, M, 19 June 1976, R.M. Shelley (NCSM).

South Carolina: Spartanburg Co., Croft State Park, M, 20 August 1976, R.M. Shelley (NCSM). *Union Co.*, 10.2 km (6.4 mi) NW Union, F, 2 May 1977, R.M. Shelley (NCSM).

Georgia: Dawson Co., Amicalola Falls State Park, 2M, 16 April 1978, R.M. Shelley, R.E. Ashton (NCSM). *Habersham Co.*, Tallulah Falls, M, April 1891, L.M. Underwood (USNM); and Cornelia, M, 11 July 1978, R.M. Shelley, W.B. Jones (NCSM). *Lumpkin Co.*, 15.4 km (9.6 mi) NE Dahlonega, 3M, 3 juvs., 16 April 1978, R.M. Shelley, R.E. Ashton (NCSM).

New York: Westchester Co., Bedford, MRGP (41° 11' 11.5"N, 73° 37' 15.4"W), 10M, 9F, 2 juvs., 30 April 2010, C. Nagy (NCSM, FSCA). **Introduced Population, New State Record.**

Remarks. The apically subhastate gonopods (Fig. 5), coupled with the bimaculate, yellow/black color pattern and the relatively narrow body proportions (Fig. 1-2) distinguish *B. stricta* from congeneric species and sympatric xystodesmids. It inhabits deciduous leaf litter and typical xystodesmid environments (Shelley 1981, Shelley and Whitehead 1986) but is unique in tolerating saturated, muddy/mucky biotopes (Fig. 3) even with small amounts of standing water. Hoffman (1965) characterized *B. stricta* as "more nearly semiaquatic than any other milliped I know," and a likely spot to encounter it is on or beside a trail at a stream/creek crossing (Hoffman 1950, personal observations of RMS).

Mianus River Gorge Preserve (<http://www.mianus.org/>) is located approximately 1.6 km (1.0 mi) south of Bedford, New York, 41.6 km (26 mi) northeast of the Bronx, and 24 km (15 mi) north-northwest of Stamford, Connecticut. In 2000, a xystodesmid with the color pattern and body proportions of *B. stricta* was first observed in the damp, cool gorge habitat, which consists primarily of post-agricultural oak-hickory woodlands and old-growth eastern hemlock stands, and hence is similar to the milliped's native Appalachian environments. Based on known distributions, the only xystodesmids expected in southern New York are *Apheloria virginienensis corrugata* (Wood, 1864), *Sigmoria (Rudiloria) trimaculata trimaculata* (Wood, 1864), and *Pleurolooma flavipes* Rafinesque, 1820 (Bailey 1928; Blake 1931; Jacot 1938; Chamberlin 1940; Eaton 1943; Hoffman 1949, 1951, 1957, 1999; Shelley 1980; Kevan 1983; Shelley and Whitehead 1986), but the photo posted on the Bugguide website (<http://bugguide.net/node/view/37>) quickly eliminated the first two. With variable size and body proportions (Shelley 1980), *P. flavipes* was a possibility, so in summer 2009, CMN sent the Gorge sample to RMS, who recognized *B. stricta*, which constitutes its first record outside the southern Appalachian region, some 704 km (440 mi) to the south-southwest. Residential yards in the Gorge neighborhood are extensively landscaped with ornamental gardens and nursery plants, the probable source of the original introduction. The Preserve was systematically surveyed for *B. stricta* in 2008-09 using the mustard solution method of Hale (2007); density estimates of 4.1 ± 13.9 individuals/m² (mean \pm SD) throughout the area and 1.74 ± 2.93 individuals/m² at streamside plots (via visual and cover searches) indicate rapid population growth after introduction, which was at least 11 years ago based on the aforementioned first sighting in MRGP. Searches at nearby preserves in Westchester Co. (Ward Pound Ridge, Westmoreland Sanctuary, Greenburgh Nature Center, Teatown Lake Reservation, and Cranberry Lake) and Greenwich Audubon, Fairfield Co., Connecticut, have not yielded *B. stricta*. It is commonly found in moist conditions under logs and in streambeds in MRGP but also inhabits non-riparian hardwood uplands and old-growth eastern hemlock stands that are comparatively dry and virtually devoid of deciduous vegetation. Staff and student researchers at the Preserve are investigating the ecological impact of *B. stricta* on native species; monitoring this population and determining its extent in Westchester Co. constitute worthy projects for regional nature clubs and high school biology classes. Population ecology studies would also be productive.

***Boraria infesta* (Chamberlin, 1918) (Fig. 4. 6-7)**

Distribution. *Boraria infesta* occupies a single, continuous area that is almost exclusively in the Blue Ridge and primarily in North Carolina. It extends, north-south, from southern Grayson Co., Virginia, to Transylvania Co., North Carolina, and then spreads westward into eastern Monroe Co., Tennessee. The eastern border coincides with the Blue Ridge Escarpment but spreads into the western Piedmont Plateau in Wilkes Co., North Carolina. The western border adheres to the North Carolina/Tennessee

border, crossing into the latter state in Carter, Greene, Sevier, and Monroe counties (Fig. 13). As with *B. stricta*, the Connecticut locality can only represent an intra-continental introduction from the indigenous area, some 960 km (600 mi) to the southwest (Fig. 12).

Published records. *Tennessee:* Carter, Monroe, and Sevier counties (Chamberlin 1918, Chamberlin and Hoffman 1958, Hoffman 1965). *North Carolina:* Alleghany, Ashe, Avery, Buncombe, Graham, Haywood, Henderson, Jackson, McDowell, Mitchell, Transylvania, Watauga, Wilkes, and Yancey counties (Chamberlin 1918; Chamberlin and Hoffman 1958; Hoffman 1965, 1999; Hoffman and Shear 1969; Shelley 2000).

New records. *Virginia:* Grayson Co., Lewis Fork Trail, along Fox Creek, M, 27 May 1984, R.W. Baumann, C.R. Nelson (NCSM).

Tennessee: Greene Co., along Paint Creek, M, 25 May 1950, R.M. Snider (UMMZ).

Connecticut, Hartford Co., Avon, in leaves and pine needles on side of Hunter Rd., M, 2F, 25 April 2010, A. and P. Wilson (NCSM). **Introduced Population, New State Record.**

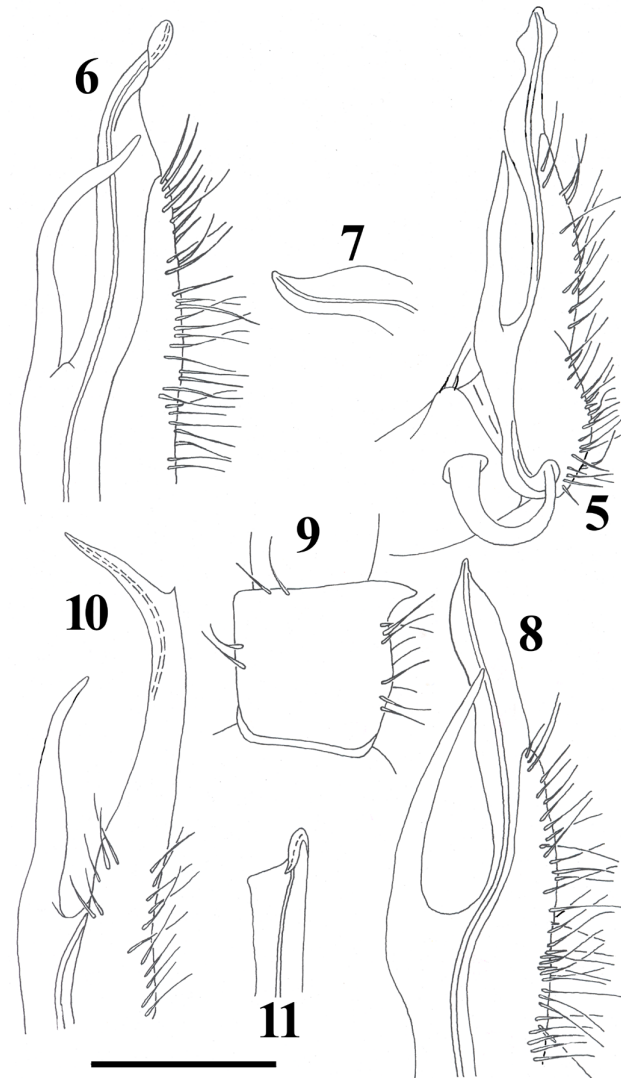
Remarks. A year after identifying the MRGP sample of *B. stricta*, RMS received the Connecticut sample of *B. infesta*, characterized by red paranota and the ventromedially directed acropodal apex (Fig. 4, 6-7), from the last two authors; three individuals were sent out of a dozen or so discovered. Residents along Hunter Rd. were familiar with the milliped, suggesting an established population in northcentral Connecticut. Again, investigating the extent of the *B. infesta* introduction constitutes a worthy project for a regional biology student.

***Boraria deturkiana* (Causey, 1942) (Fig. 8-9)**

Distribution. Characterized by ventrally spined postgonopodal coxae and by the apically prolonged acropodite (Fig. 8-9), *B. deturkiana* occupies a subcircular range in southwestern North Carolina and the GSMNP in Tennessee. The few new records do not materially expand the known distribution (Fig. 13); we include them along with gonopodal and coxal illustrations so that all four species of *Boraria* are treated and illustrated together.

Published records. *North Carolina:* Haywood, Jackson, Macon, and Swain counties (Causey 1942; Chamberlin and Hoffman 1958; Hoffman 1965, 1999). *Tennessee:* Blount and Sevier counties (Causey 1942; Chamberlin and Hoffman 1958; Hoffman 1965, 1999).

New records. *North Carolina:* Haywood Co., Pisgah National Forest near Shining Rock Ridge, M, F, 24 June-2 July 1961, D. and P. Weems (FSCA). *Jackson Co.,* headwaters of Wolf Cr., M, 3 July 1949, R.L. Humphries (NCSM). *Swain Co.,* GSMNP, Clingman's Dome, 2M, F, H.A. Pilsbry (USNM).



Figures 5-11. *Boraria* spp., anatomical features. **5)** *B. stricta*, left gonopod of male from Westchester Co., New York, medial view. **6)** *B. infesta*, telopodite of left gonopod of male from Hartford Co., Connecticut, medial view. **7)** Apex of acropodite of the same, sublateral view. **8)** *B. deturkiana*, telopodite of left gonopod of male from Sevier Co., Tennessee, medial view. **9)** Coxa of midbody leg of the same, ventral view. **10)** *B. profuga*, telopodite of left gonopod of male from Ouachita Par., Louisiana, anteromedial view. **11)** Apex of acropodite of the same, medial view. Scale line = 0.50 mm for Fig. 5-8 and 10-11, 0.90 mm for Fig. 9.

Tennessee: *Sevier Co.*, GSMNP, Greenbrier Cove, 2F, 13 June 1942, H.S. Dybas (USNM).

***Boraria profuga* (Causey, 1955)** (Fig. 10-11)

Distribution. *Boraria profuga* comprises two allopatric populations, one in the Ouachita Plateau of Montgomery Co., Arkansas, and the other some 298 km (180 mi) to the southeast in the Gulf Coastal Plain of Ouachita Parish, Louisiana (Fig. 12). As individuals were found exactly four years apart in exactly the same spot, the Louisiana population may be larger and cover a more extensive area. Field work is needed in Ouachita, neighboring parishes, and intervening Arkansas counties, which have received little attention and may or may not harbor the milliped.

Published records. *Arkansas: Montgomery Co.* (Causey 1955, Chamberlin and Hoffman 1958, Hoffman and Shear 1969, Hoffman 1999).

New records. *Arkansas: Montgomery Co.*, no further locality, 3M, F, 31 March – 8 April 1956, S. Finklestein (FSCA); and near Joplin, 16.8 km (10.5 mi) ESE Mt. Ida, Gap Creek Picnic Area, Ouachita National Forest (34° 54'N, 93° 47'W), M, 27 November 2009, C.T. McAllister (NCSM).

Louisiana: Ouachita Par., Monroe, 1410 Forsythe St., M, 31 December 1974, and “on wet porch after three days of rain,” 6M, 2F, 31 December 1978, J.E. and M.R. Cooper (NCSM). **New State Record.**

Remarks. *Boraria profuga* is diagnosed by the variably enlarged, distolateral acropodal shoulder (Fig. 10-11). According to Causey (1955), the type series, collected at Mt. Ida, Montgomery Co., Arkansas, on 14 April 1954, consisted of three males, three females, and one juvenile. The male holotype was deposited in the AMNH, where it remains today, and the remaining specimens, the only designated paratypes, were housed in her personal collection, which was transferred to the FSCA in 1979. Two male, two female, and one juvenile paratypes are present today in the FSCA, so apparently, one female is lost. The FSCA also contains specimens collected in 1956 from Montgomery Co. in general.

Despite intensive sampling in the Ouachita National Forest in and around Montgomery Co. by Dr. Causey and CTM and associates, *B. profuga* was not encountered there again, or anywhere in Arkansas, until 2009, a span of 53 years. The lone individual, discovered under a large rock on sandy to sandy loamish soil in an oak/hickory forest, proves that the Ouachita population still exists and should be expected in western Garland Co., only 4.5 km (2.8 mi) to the east. However, *B. profuga* is difficult to find there and seems legitimately rare; it may warrant formal conservation status, which has never been accorded a diploid.

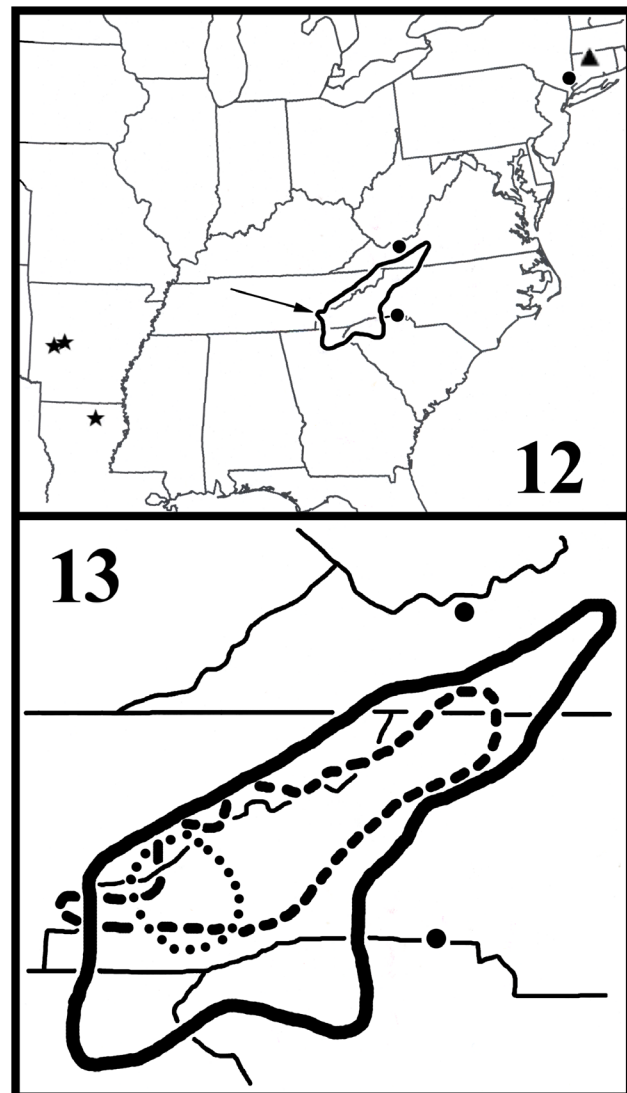


Figure 12-13. Distributions of *Boraria* spp. **12)** Dots, *B. stricta*; Triangle, *B. infesta*; Stars, *B. profuga*. The area of concentration in the southern Appalachian region corresponds to the range of *B. stricta* and encloses *B. infesta* and *B. deturkiana* except for the southern protrusion into Tennessee, denoted by the arrow, which represents *B. infesta*. **13)** Distributions of *Boraria* spp. in the general southern Appalachian region. Heavy bold line and separated dots, *B. stricta*; dashed line, *B. infesta*; dotted line, *B. deturkiana*.

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