New records of *Orussus minutus* Middlekauff, 1983 (Hymenoptera: Orussidae) represent a significant western range expansion

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**Abstract**

**Background**

*Orussus minutus* is an uncommonly collected parasitoid sawfly known from the eastern United States.

**New information**

We report specimens *Orussus minutus* Middlekauff, 1983, from Arkansas, Iowa, Minnesota, and Manitoba, which represent new state and province records and significantly expand the known range of the species west from previous records; provide collection information for unpublished specimens housed in the United States National Museum collection, which includes new state records for West Virginia and Michigan; and report two specimens housed in the Biological Museum at Lund University that represent new state records for Connecticut.

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Keywords

Symphyta, Range expansion, Buffalo National River, new state record

Introduction

Orussidae have long interested entomologists because of their parasitoid larvae, which are unique among non-apocritan Hymenoptera, phylogenetically important position between basal Hymenoptera ("Symphyta") and Apocrita, and because they are rarely collected (Middlekauff 1983, Pesarini and Turrisi 2003, Vilhelmsen 2003).

Middlekauff (1983) provided an excellent review of the literature concerning the feeding biology and hosts of orussid larvae. Briefly summarized, a number of authors reported orussid larvae develop in wood (Harrington 1887a, Konow 1902, Gaulle 1906) and associate with beetle and sawfly larvae (Wachtl 1882, Rudow 1909). Harrington (1887b) first hypothesized that orussid larvae may be parasitoids, though he considered it more likely they fed on wood. Rohwer (1912) and Burke (1918) provided convincing evidence that orussids are parasitoids as they reported Orussus larvae pupating in old cerambycid larval galleries and attacking buprestid larvae. Subsequent authors investigated oviposition behavior and larval feeding; they found that adult female orussids deposit eggs into frass-filled galleries of and directly onto larvae of wood-boring Coleoptera and Hymenoptera and that larval orussids feed upon those larvae (Cooper 1953, Rawlings 1957, Powell and Turner 1975). Currently, Orussidae are known or suspected to parasitize Buprestidae, Cerambycidae, Siricidae, and Xiphydriidae (Table 1).

| Host family   | Reference                                                                 |
|---------------|---------------------------------------------------------------------------|
| Buprestidae   | Wachtl 1882, Harrington 1887a, Burke 1918, Ahnlund and Ronquist 2001, Wachtl 1882, Harrington 1887a, Burke 1918, Powell and Turner 1975, Ahnlund and Ronquist 2001, Vilhelmsen and Smith 2002 |
| Cerambycidae  | Rohwer 1912, Powell and Turner 1975, Hellrigl 1984, Ahnlund and Ronquist 2001 |
| Siricidae     | Gourley 1951, Rawlings 1957, Powell and Turner 1975, Vilhelmsen and Smith 2002 |
| Xiphydriidae  | Rudow 1909                                                                 |

Ashmead (1896) published the first phylogenetic hypothesis of Hymenoptera and placed Oryssidae (=Orussidae) transitionally between sawflies and other Hymenoptera. Recent phylogenetic analyses of morphological characters (Rasnitsyn 1988, Vilhelmsen 1997, Vilhelmsen 2000, Vilhelmsen 2001, Ronquist et al. 1999, Schulmeister 2003b), large molecular datasets and combined molecular and morphological datasets (Schulmeister 2003b, Heraty et al. 2011, Sharkey et al. 2011) have corroborated the placement of Orussidae (and Paroryssidae when fossil taxa are included) as sister to Apocrita. For
relationships within Orussidae, the most robust phylogenetic analysis was produced by Vilhelmsen (2003). His analysis recovered most genera as monophyletic, though Vilhelmsen abandoned the use of subfamilies and tribes, as “[e]nforcing a strictly cladistics classification at these levels would require recognition of many redundant taxa without enhancing the information content”.

Orussidae are uncommonly collected and rare in collections. For example, despite a cumulative 25,000 trapping hours (314 separate 1–2 week collection events) using Malaise traps over the last five years by the authors around Arkansas, no additional specimens beyond the three reported herein were captured with this trapping method and David Smith (USDA, SEL), who has had success collecting orussids in Malaise traps (e.g., Smith 2006, Smith 2008, Barrows and Smith 2014), has only collected 33 specimens of *O. minutus* in 35 years of collecting with an average of 15 Malaise traps set per year (David R. Smith, pers. comm. 18 August 2015). Additionally, new species continue to be described, even in heavily collected areas such as California (e.g., Vilhelmsen 2005, Blank et al. 2010, Vilhelmsen et al. 2014). Several species are known only from one or a few localities and specimens and the known ranges of many species continue to expand as new specimens are collected (Ahnlund and Ronquist 2001, Vilhelmsen and Smith 2002, Pesarini and Turrisi 2003, Pesarini and Turrisi 2006, Choi and Suh 2011).

*Orussus* is represented five species in North America north of Mexico: *O. occidentalis* (Cresson, 1879) has been reported from Southern British Columbia east to Ontario, south in the western United States to southern California, Nevada, and New Mexico; *O. thoracicus* (Ashmead, 1898) has been reported from Colorado, Washington, Oregon, and California; *O. sayii* (Westwood, 1835) has been reported from Ontario south to Louisiana, west to Indiana; *O. terminalis* (Newman, 1838) has been reported from New England and Ontario west to Iowa and Illinois, south to Maryland; and *O. minutus* (Middlekauff, 1983) has been reported from New York to Georgia west to Illinois (Middlekauff 1983, Vilhelmsen 2003, Blank et al. 2010, Vilhelmsen et al. 2013).

**Materials and methods**

Two orussids (1 male, 1 female) were collected along the Buffalo National River in the lower collector of an aerial SLAM (sea-land-air-Malaise) trap (MegaView Science Co., Ltd., Taichung, Taiwan) and a black multifunnel trap (ChemTica International, S.A., Heredia, Costa Rica); a third specimen (1 female) was collected via aerial netting in the Kessler Mountain Reserve. Both localities are mixed secondary deciduous forest dominated by oak and hickory that were logged approximately 80–100 years ago. Specimens were identified to species using published keys (Middlekauff 1983, Vilhelmsen et al. 2014) and have been deposited in the University of Arkansas Arthropod Museum.

Stereomicrographs of the Arkansas specimens were taken with a Cannon EOS 40D camera (Tokyo, Japan) attached using a Diagnostic Instruments DD20NLT 2.0X camera mount (Sterling Heights, Michigan, USA) to a Nikon SMZ1500 stereomicroscope (Tokyo,
Japan). The micrographs were processed and final plates arranged in Adobe Illustrator (San Jose, California, USA).

DNA of one Arkansas specimen (MS 13-0413-047, #138295) was sequenced for comparison with previously characterized *Orussus*. Genomic DNA was extracted from a single mid-leg using the Qiagen DNeasy Tissue kit (Qiagen, Inc., Valencia, California), following manufacturer’s instructions. PCR was conducted using the primers LR-J-13017 (5’- TTACGCTGTATCCTAA-3’) and LR-N-13398 (5’-CACCTGTATTAACAAAAACAT-3’) (Kambhampati and Smith 1995), which amplify an approximately 415 bp portion of the 16S rRNA region of the mitochondrial genome. Reaction conditions were 94°C for 2 min, followed by 40 cycles of 94°C for 45 s, 48°C for 1 min, and 72°C for 1 min, with a final 5 min extension step at 72°C. Amplified DNA was purified, concentrated with PES 30k centrifugal filter devices (VWR, Radnor, PA) and sent for direct sequencing in both directions (Eurofins MWG Operon, Huntsville, Alabama).

David R. Smith kindly provided label information for specimens housed in the United States National Museum; previously unpublished specimens are reported herein. Additional unpublished specimens were found by searching the databased collection of Lund University Biological Museum (Lund University 2015), BugGuide (Hatfield 2008, Alexander 2011, Liberta 2014, Zhang 2014), and Flickr (King 2014).

Published locality data for Figure 3 was compiled from Cooper (1953), Middlekauff (1983), Smith (2006), Barrows and Smith (2014).

Institution abbreviations follow Evenhuis (2015) and are as follows: United States National Museum (USNM), University of Arkansas Arthropod Museum (UAAM), Lund University, Sweden (MZLU).

### Taxon treatment

**Orussus minutus** Middlekauff, 1983

| Scientific Name | Middlekauff, 1983 |
|----------------|-------------------|
| Kingdom        | Animalia          |
| Phylum         | Arthropoda        |
| Class           | Insecta           |
| Order            | Hymenoptera      |
| Family          | Orussidae         |
| Genus           | Orussus           |
| Specific Epithet | minutus           |
| Scientific Name Authorship | Middlekauff, 1983 |
| Country        | United States    |
| Country Code   | US                |
| State Province | Arkansas          |
| County         | Newton            |
| Localit        | Buffalo National River, Steel Creek |
| Location Remarks | 80-100 year old mature second-growth Eastern mixed deciduous forest dominated by oak (Quercus) and hickory (Carya) |
|verbatim Coordinates | 36°02.218' N, 93°20.439 W; decimalLatitude: 36.036967; decimalLongitude: -93.34065; georeference protocol: GPS |
| sampling protocol | black Lindgren multifunnel trap; eventDate: 201313-4-13; individualCount: 1; lifeStage: adult; catalogNumber: 138295; recordedBy: Michael J Skvarla; identified By: Michael J. Skvarla; dateIdentified: 2014; language: en; collectionID: MS 13-0413-047; institution Code: UAAM; basisOfRecord: Preserved Specimen |

**Materials**

a. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specific epithet: minutus; scientific name authorship: Middlekauff, 1983; country: United States; country code: US; state province: Arkansas; county: Newton; locality: Buffalo National River, Steel Creek; location remark: 80-100 year old mature second-growth Eastern mixed deciduous forest dominated by oak (Quercus) and hickory (Carya); verbatim coordinates: 36°02.218' N, 93°20.439 W; decimal latitude: 36.036967; decimal longitude: -93.34065; georeference protocol: GPS; sampling protocol: black Lindgren multifunnel trap; event date: 2013-04-13; individual count: 1; life stage: adult; catalog number: 138295; recorded by: Michael J Skvarla; identified by: Michael J Skvarla; date identified: 2014; language: en; collection ID: MS 13-0413-047; institution code: UAAM; basis of record: Preserved Specimen

b. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*;
specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Arkansas; county: Newton; locality: Buffalo National River, Steel Creek; locationRemarks: 80-100 year old mature second-growth Eastern mixed deciduous forest dominated by oak (Quercus) and hickory (Carya); verbatimCoordinates: 36°02.314' N, 93°20.425 W; decimalLatitude: 36.038567; decimalLongitude: -93.34041; georeferenceProtocol: GPS; samplingProtocol: SLAM canopy trap, lower collector; eventDate: 201313-4-13; individualCount: 1; lifeStage: adult; catalogNumber: 138296; recordedBy: Michael J. Skvarla; identifiedBy: Michael J. Skvarla; dateIdentified: 2014; language: en; collectionID: MS 13-0413-060; institutionCode: UAAM; basisOfRecord: PreservedSpecimen

c. scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Arkansas; county: Washington; locality: Fayetteville, Kessler Mountain Reserve, Wino Trail; locationRemarks: 80-100 year old mature second-growth Eastern mixed deciduous forest dominated by oak (Quercus) and hickory (Carya); verbatimCoordinates: 36°02'19.45" N, 94°13'01.98" W; decimalLatitude: 36.038611; decimalLongitude: -94.216944; georeferenceProtocol: GoogleEarth; samplingProtocol: hand collected with net; eventDate: 41755.00; individualCount: 1; lifeStage: adult; recordedBy: Amber Tripodi; identifiedBy: Michael J. Skvarla; dateIdentified: 2014; language: en; institutionCode: UAAM; basisOfRecord: PreservedSpecimen
d. scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Warren; locality: Skyland Estates; locationRemarks: 4 km NNW of Linden; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1985-4-20/1985-4-27; individualCount: 1; lifeStage: adult; recordedBy: T. P. Nuhn; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
e. scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Warren; locality: Skyland Estates; locationRemarks: 4 km NNW of Linden; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1996-4-27/1996-5-12; individualCount: 1; lifeStage: adult; recordedBy: T. P. Nuhn; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
f. scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; locality: Great Dismal Swamp National Wildlife Refuge; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1965-4-16/1965-4-17; individualCount: 1; lifeStage: adult; recordedBy: P. J. Spangler; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
g. scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Louisa; locationRemarks: 4 mi
south of Cuckoo; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1989-4-26/1989-5-12; individualCount: 1; lifeStage: adult; recordedBy: J. Kloke & D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

 scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Louisa; locationRemarks: 4 mi south of Cuckoo; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1989-5-27/1989-6-7; individualCount: 1; lifeStage: adult; recordedBy: J. Kloke & D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

 scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Fairfax; locality: Holmes Run; locationRemarks: ~1/4 mi NW jct. Gallows Rd & I-495; verbatimCoordinates: 38°50'N, 77°12'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1990-4-22/1990-4-28; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

 scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Fairfax; locality: Holmes Run; locationRemarks: ~1/4 mi NW jct. Gallows Rd & I-496; verbatimCoordinates: 38°50'N, 77°12'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1990-3-11/1990-3-17; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

 scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Fairfax; locality: Holmes Run; locationRemarks: ~1/4 mi NW jct. Gallows Rd & I-497; verbatimCoordinates: 38°50'N, 77°12'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 2008-4-13/2008-4-19; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

 scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Fairfax; locality: Holmes Run; locationRemarks: ~1/4 mi NW jct. Gallows Rd & I-498; verbatimCoordinates: 38°50'N, 77°12'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 2008-4-3-2008-4-9; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
New records of Orussus minutus Middlekauff, 1983 (Hymenoptera: Orussidae) ...
specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Essex; locationRemarks: 1 mi southeast of Dunsville; verbatimCoordinates: 37°52'N, 76°48'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1999-4-22/1999-4-3; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
t.
scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Essex; locationRemarks: 1 mi southeast of Dunsville; verbatimCoordinates: 37°52'N, 76°48'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1999-5-17/1999-5-17; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
u.
scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Essex; locationRemarks: 1 mi southeast of Dunsville; verbatimCoordinates: 37°52'N, 76°48'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1999-3-20/1999-3-20; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
v.
scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Essex; locationRemarks: 1 mi southeast of Dunsville; verbatimCoordinates: 37°52'N, 76°48'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1999-3-2/1999-3-2; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
w.
scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Essex; locationRemarks: 1 mi southeast of Dunsville; verbatimCoordinates: 37°52'N, 76°48'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1999-4-19/1999-4-19; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
x.
scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Essex; locationRemarks: 1 mi southeast of Dunsville; verbatimCoordinates: 37°52'N, 76°48'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1999-4-22/1999-4-22; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen
y.
scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Essex; locationRemarks: 1 mi
New records of *Orussus minutus* Middlekauff, 1983 (Hymenoptera: Orussidae)...

southeast of Dunnsville; verbatimCoordinates: 37°52'N, 76°48'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1999-4-3/1999-4-19; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

z. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Essex; locationRemarks: 1 mi southeast of Dunnsville; verbatimCoordinates: 37°52'N, 76°48'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 1999-5-6/1999-5-20; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

aa. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Virginia; county: Fairfax; locality: Great Falls Park; verbatimCoordinates: 38°59.4'N, 77°15.26'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 2000-4-19/2000-5-2; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

bb. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: West Virginia; county: Hardy; locationRemarks: 3 mi northeast of Mathias; verbatimCoordinates: 38°55'N, 78°49'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 2000-5-1/2000-5-15; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

c. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: West Virginia; county: Hardy; locationRemarks: 3 mi northeast of Mathias; verbatimCoordinates: 38°55'N, 78°49'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 2001-4-1/2001-5-14; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

d. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: West Virginia; county: Hardy; locationRemarks: 3 mi northeast of Mathias; verbatimCoordinates: 38°55'N, 78°49'W; georeferenceProtocol: label; samplingProtocol: Malaise trap; eventDate: 2007-5-4/2007-5-21; individualCount: 1; lifeStage: adult; recordedBy: D. R. Smith; identifiedBy: David R. Smith; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

e. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United
New records of Orussus minutus Middlekauff, 1983 (Hymenoptera: Orussidae) ...
au. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Pennsylvania; county: Lehigh; verbatimCoordinates: 40.45855, -75.473198; decimalLatitude: 40.45855; decimalLongitude: -75.473198; georeferenceProtocol: label; samplingProtocol: Lindgren multifunnel trap; eventDate: 2012-5-31; individualCount: 1; lifeStage: adult; recordedBy: Sam Louenwirth; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

ar. scientificName: *Orussus minutus* Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: *Orussus*; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Pennsylvania; county: Bedford; verbatimCoordinates: 40.04287, -78.36906; decimalLatitude: 40.04287; decimalLongitude: -78.36906; georeferenceProtocol: label; samplingProtocol: Lindgren multifunnel trap; eventDate: 2012-5-15; individualCount: 1; lifeStage: adult; recordedBy: Nathan Delp; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

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New records of Orussus minutus Middlekauff, 1983 (Hymenoptera: Orussidae) ...
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New records of Orussus minutus Middlekauff, 1983 (Hymenoptera: Orussidae) ...
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scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Pennsylvania; county: Franklin; verbatimCoordinates: 39.93097, -77.637695; decimalLatitude: 39.93097; decimalLongitude: -77.637695; georeferenceProtocol: label; samplingProtocol: Lindgren multifunnel trap; eventDate: 2011-4-21; individualCount: 1; lifeStage: adult; recordedBy: L. Donovall; language: en; institutionCode: USNM; basisOfRecord: PreservedSpecimen

bq. scientificName: Orussus minutus Middlekauff, 1983; kingdom: Animalia; phylum: Arthropoda; class: Insecta; order: Hymenoptera; family: Orussidae; genus: Orussus; specificEpithet: minutus; scientificNameAuthorship: Middlekauff, 1983; country: United States; countryCode: US; stateProvince: Connecticut; county: New London; municipality: Groton; georeferenceProtocol: label; eventDate: 17695.00; individualCount: 2; lifeStage: adult; recordedBy: Anton Jansson; institutionCode: MZLU; basisOfRecord: PreservedSpecimen

Distribution

New York south to Georgia west to Manitoba, Iowa, and Arkansas.

Analysis

The Arkansas specimens were identified morphologically as Orussus minutus Middlekauff, 1983 (Figs 1, 2). The 16S rRNA sequence (GenBank #KM379143) was a 99.5% match with an existing O. minutus sequence (EF032174), differing by two base pairs.

Discussion

The Arkansas specimens and those shared as photographs on Bugguide and Flickr significantly expand the known range of O. minutus westward (Fig. 3). Morphological determination of the Arkansas specimens was confirmed by genetic data and the species is easily identified due to its small size and distinct markings, so it is highly unlikely the photographed specimens are not O. minutus.

Many of the USNM specimens were collected by David R. Smith during 35 years of Malaise trapping specifically for sawflies. However, most recently collected specimens, especially those from Pennsylvania, were found as non-target species during various exotic species monitoring programs that utilized Lindgren multifunnel traps (David Smith, pers. comm., 28 Aug. 2015). The abundance of these specimens emphasize the utility of examining, or at least collecting and sending to the appropriate specialist, non-target
species in mass trapping surveys, such as was suggested by Skvarla and Holland (2011). Precise figures for the number of traps and amount of effort that was involved in the Pennsylvania surveys is unavailable, so we are unable to compare the efficiency of Malaise trapping compared to Lindgren funnel trapping; however, the number of *O. minutus* that were collected in Lindgren funnel traps suggests that it may be a useful tool for collecting *Orussus*.

Figure 1.
*Orussus minutus*, female

- **a**: Lateral habitus
- **b**: Dorsal habitus
- **c**: Head
- **d**: Ventral abdomen
Given the current records, *O. minutus* is likely present throughout most of Eastern North America. The concentration of specimens from northern Virginia and Pennsylvania reflect collecting effort and specimen recognition rather than true abundance and further collecting in the southeastern United States and Canada should produce additional specimens from those areas.

Finally, records found through Bugguide and Flickr join a growing list of discoveries made via citizen science and social media websites (e.g., Otto and Hill 2011, Winterton et al. 2012, Gonella et al. 2015) and help underscore the importance of such resources in descriptive biology and natural history.

Figure 2.
*Orussus minutus*, male

*a*: Lateral habitus
*b*: Dorsal habitus
*c*: Head
*d*: Ventral abdomen
Acknowledgements

We thank David Smith for providing the collection data for the USNM specimens and his willingness and enthusiasm to discuss sawflies; Christer Hansson for providing the collection data for the MZLU specimens and Lund University for digitizing their collection; Danielle Fisher for her assistance in sorting trap material and finding the first specimen; Clinton Trammel for laboratory assistance; and Lars Vilhelmsen, Stephen Blank, and Andy Deans for their helpful comments and corrections. This project and the preparation of this publication was funded in part by the State Wildlife Grants Program (Grant # T39-05) of the U.S. Fish and Wildlife Service through an agreement with the Arkansas Game and Fish Commission.

References

- Ahnlund H, Ronquist F (2001) Den röda parasitiväxtstekelns (*Orussus abietinus*) biologi och förekomst i Norden. Entomologisk Tidskrift 122: 1-11.
- Alexander Y (2011) Parasitic Wood Wasp? - Orussus minutus. http://bugguide.net/node/view/506553/bgimage. Accession date: 2015 8 18.
- Ashmead WH (1896) The phylogeny of Hymenoptera . Proceedings of the Entomological Society of Washington 3: 323-336.
- Barrows E, Smith D (2014) Sawflies (Hymenoptera, Symphyta) of three Mid-Atlantic Parks in the George Washington Memorial Parkway, U.S.A. Journal of Hymenoptera Research 39: 17-31. DOI: 10.3897/jhr.39.7907
Blank S, Vilhelmsen L, Smith D (2010) *Ophrynon* (Hymenoptera: Orussidae) in California: diversity, distribution and phylogeny. Insect Systematics & Evolution 41 (1): 3-27. DOI: 10.1163/139956009x12550095535756

Burke HE (1918) *Oryssus* is parasitic. Proceedings of the Entomological Society of Washington 19: 87-89.

Choi W-Y, Suh K-I (2011) First record of the genus *Stirocorsia* (Orussidae: Hymenoptera) from Korea. Korean Journal of Systematic Zoology 27 (3): 268-270. DOI: 10.5635/KJSZ.2011.27.3.268

Cooper KE (1953) Egg gigantism, oviposition, and genital anatomy: their bearing on the biology and phylogenetic position of *Orussus*. Proceedings of the Rochester Academy of Science 10: 38-68.

Evenhuis NL (2015) Abbreviations for Insect and Spider Collections of the World. http://hbs.bishopmuseum.org/codens/codens-inst.html. Accession date: 2015 8 26.

Gaulle J.d (1906) Catalogue Systématique and Biologique des Hymenopteres de France. La Feuille des Jeunes Naturalistes 36: 137-141.

Gonella PM, Rivadavia F, Fleischmann A (2015) *Drosera magnifica* (Drosieraceae): the largest New World sundew, discovered on Facebook. Phytotaxa 220 (3): 257. DOI: 10.11646/phytotaxa.220.3.4

Gourley ES (1951) Notes on insects associated with *Pinus radiata* in New Zealand. Bulletin of Entomological Research 42: 21-22. DOI: 10.1017/s0007485300025116

Harrington H (1887a) Further observations on *Oryssus sayi*. Canadian Entomologist 19: 239-240. DOI: 10.4039/Ent19239-12

Harrington H (1887b) *Oryssus sayi*, Westwood. Canadian Entomologist 19 (5): 81-86. DOI: 10.4039/Ent1981-5

Hatfield MJ (2008) Orussus minutus. http://bugguide.net/node/view/244986/bgimage. Accession date: 2015 8 18.

Hellrigl K (1984) *Orussus abietinus* Scop. (Hym., Orussoidea) als Parasit der Larvae des Wellenbockes *Semanotus undatus* L. (Col., Cerambycidae). Anzeiger für Schädlingskunde 57 (5): 97-98.

Heraty J, Ronquist F, Carpenter J, Hawks D, Schulmeister S, Dowling A, Murray D, Munro J, Wheeler W, Schiff N, Sharkey M (2011) Evolution of the hymenopteran megaradiation. Molecular Phylogenetics and Evolution 60 (1): 73-88. DOI: 10.1016/j.ympev.2011.04.003

Kambhampati S, Smith PT (1995) PCR primers for the amplification of four insect mitochondrial gene fragments. Insect Molecular Biology 4: 233-236. DOI: 10.1111/j.1365-2583.1995.tb00028.x

King S (2014) Orussus minutus. https://www.flickr.com/photos/minnesotameadowhawk/14193634907/in/photolist-o2mifR-o2iSmv-o21Fh6-nCf6ae. Accession date: 2015 8 18.

Konow FW (1902) Systematische Zusammenstellung der bisher bekannt geworden Chalastogaster (p. 81). Zeitechr. syst. Hym. Dipt. 2: 49.

Liberta A (2014) Unknown Hymenoptera. http://bugguide.net/node/view/975717. Accession date: 2015 8 18.

Lund University (2015) http://www.biomus.lu.se/en/entomological-collections. Accession date: 2015 8 18.
• Middlekauff WW (1983) A Revision of the Sawfly Family Orussidae for North and Central America (Hymenoptera: Symphyta, Orussidae). University of California Press, Berkley, ix + 46 pp.
• Otto JC, Hill DE (2011) An illustrated review of the known peacock spiders of the genus Maratus from Australia, with descriptions of a new species (Araneae: Salticidae: Euophryinae). Peckhamia 96 (1): 1-27.
• Pesarini F, Turrisi GF (2003) Orussus taorminensis (Trautmann, 1922) (Hymenoptera, Orussidae), new to Iberian Peninsula and to Africa. Boletín de la Asociación española de Entomología 27: 93-98.
• Pesarini F, Turrisi GF (2006) Interesting records of sawflies from Italy (Hymenoptera, Symphyta: Xyelidae, Pamphiliidae, Siricidae, Orussidae,Cimbicidae, Diprionidae). In: Blank SM, Schmidt S, Taeger A (Eds) Recent Sawfly Research: Synthesis and Prospects, Chapter: Interesting records of sawflies from Italy (Hymenoptera, Symphyta: Xyelidae, Pamphiliidae, Siricidae, Orussidae,Cimbicidae, Diprionidae). Goecke & Evers, Keltern, 331-336 pp. DOI: 10.13140/2.1.3755.1682
• Powell JA, Turner WJ (1975) Observations on oviposition behavior and host selection in Orussus occidentalis (Hymenoptera: Siricoidea). Journal of the Kansas Entomological Society 48: 299-307.
• Rasnitsyn AP (1988) An outline of evolution of the hymenopterous insects. Oriental Insects 22: 115-145.
• Rawlings GB (1957) Guiglia schauinslandi (Ashmead) a parasite of Sirex noctilio (Fabricius) in New Zealand. New Zealand Entomologist 90 (1125): 35-36.
• Rohwer SA (1912) Studies in the woodwasp superfamily Orysssoidea, with descriptions of new species. Proceedings of the U.S. National Museum 43: 141-148. DOI: 10.5479/si.00963801.43-1925.141
• Ronquist F, Rasnitsyn AP, Roy A, Eriksson K, Lindgren M (1999) ) Phylogeny of the Hymenoptera: A cladistics reanalysis of Rasnitsyn’s (1988) data. Zoologica Scripta 28: 13-50. DOI: 10.1046/j.1463-6409.1999.00023.x
• Rudow DR (1909) Lebensweise der Holzweepen Siricidae . Int. Ent. Zeit. 3 (24): 135.
• Schulmeister S (2003a) Review of morphological evidence on the phylogeny of basal Hymenoptera (Insecta), with a discussion of the ordering of characters. Biological Journal of the Linnean Society 79 (2): 209-243. DOI: 10.1046/j.1095-8312.2003.00232.x
• Schulmeister S (2003b) Simultaneous analysis of basal Hymenoptera (Insecta): introducing robust-choice sensitivity analysis. Biological Journal of the Linnean Society 79 (2): 245-275. DOI: 10.1046/j.1095-8312.2003.00233.x
• Sharkey M, Carpenter J, Vilhelmsen L, Heraty J, Liljeblad J, Dowling AG, Schulmeister S, Murray D, Deans A, Ronquist F, Krogmann L, Wheeler W (2011) Phylogenetic relationships among superfamilies of Hymenoptera . Cladistics 28 (1): 80-112. DOI: 10.1111/j.1096-0031.2011.00366.x
• Skvarla MJ, Holland JD (2011) Nontarget insects caught on emerald ash borer purple monitoring traps in Western Pennsylvania. Northern Journal of Applied Forestry 28 (4): 219-221.
• Smith DR (2006) List of the sawflies (Hymenoptera: Symphyta) of Virginia. Banisteria 28: 3-23.
• Smith DR (2008) Hymenoptera (Insecta) of Plummars Island, Maryland: Symphyta and selected families of Apocrita. Bulletin of the Biological Society of Washington 15 (1): 160-167. DOI: 10.2988/0097-0298(2008)15[160:HIOPIM]2.0.CO;2

• Vilhelmsen L (1997) The phylogeny of lower Hymenoptera (Insecta), with a summary of the early evolutionary history of the order. Journal of Zoological Systematics and Evolutionary Research 35 (2): 49-70. DOI: 10.1111/j.1439-0469.1997.tb00404.x

• Vilhelmsen L (2000) Before the wasp-waist: comparative anatomy and phylogenetic implications of the skeleto-musculature of the thoraco-abdominal boundary region in basal Hymenoptera (Insecta). Zoomorphology 119 (4): 185-221. DOI: 10.1007/pl00008493

• Vilhelmsen L (2001) Phylogeny and classification of the extant basal lineages of the Hymenoptera (Insecta). Zoological Journal of the Linnean Society 131 (4): 393-442. DOI: 10.1111/j.1096-3642.2001.tb01320.x

• Vilhelmsen L (2003) Phylogeny and classification of the Orussidae (Insecta: Hymenoptera), a basal parasitic wasp taxon. Zoological Journal of the Linnean Society 139 (3): 337-418. DOI: 10.1046/j.1096-3642.2003.00080.x

• Vilhelmsen L (2005) Chalinus albitibialis, a new species of Orussidae (Insecta, Hymenoptera) from Morocco. Zootaxa 880: 1-7.

• Vilhelmsen L, Smith DR (2002) Revision of the ‘ophryopine’ genera Argentophrynopus gen. n., Guiglia Benson, Kulcania Benson, Ophrella Middlekauff, Ophrynopus Konow, and Stirocorsia Konow (Hymenoptera: Orussidae). Insect Systematics & Evolution 33 (4): 387-420. DOI: 10.1163/187631202X00217

• Vilhelmsen L, Smith D, Liu Z, Blank S (2014) Discovery of new species confirms Oriental origin of Orussus Latreille (Hymenoptera: Orussidae). Insect Systematics & Evolution 45 (1): 51-91. DOI: 10.1163/1876312x-00002087

• Vilhelmsen L, Blank SM, Costa VA, Alvarenga TM, Smith DR (2013) Phylogeny of the ophrynopinae clade revisited: review of the parasitoid sawfly genera Ophrella Middlekauff, Ophrynopus Konow and Stirocorsia Konow (Hymenoptera: Orussidae). Invertebrate Systematics 27: 450-483. DOI: 10.1071/IS13006

• Wachtl FA (1882) Beiträge zur Kenntniss der Biologie Systematik und Synonymie der Insecten. Wiener Entomologische Zeitung 1 (12): 294-298.

• Winterton S, Guek HP, Brooks S (2012) A charismatic new species of green lacewing discovered in Malaysia (Neuroptera, Chrysopidae): the confluence of citizen scientist, online image database and cybertaxonomy. ZooKeys 214: 1-11. DOI: 10.3897/zookeys.214.3220

• Zhang M (2014) Orussus minutus. http://bugguide.net/node/view/940592/bgimage. Accession date: 2015 8 18.