Juncus snowii (Juncaceae), a New Rare Species Endemic to the Altamaha Grit of Georgia, U.S.A.

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Abstract. A new species, *Juncus snowii* W. M. Knapp & R. Carter (Juncaceae), is described from two counties of the Altamaha grit, a sandstone formation in the coastal plain physiographic province of Georgia, U.S.A. This new species resembles other members of *Juncus* L. sect. *Ozophyllum* Dumort. but is readily distinguished by a combination of characters including its typically annual life history, diminutive habit, and small capsules and tepals. The type locality is an area of geologic interest that supports a unique assemblage of rare and endemic plant species. Color photographs are provided for the new species, as well as preliminary conservation status assessments using NatureServe criteria (Critically Imperiled with extinction [G1]) and IUCN Red List criteria (Vulnerable [VU D2]).

Key words: annual, Georgia, IUCN Red List, Juncaceae, *Juncus*, NatureServe.

Juncus L. (Juncaceae) is a widespread genus of approximately 315 species worldwide (Kirschner, 2002). *Juncus* sect. *Ozophyllum* Dumort. (= subgenus *Septati* Buchenau) is the most diverse section in the genus, consisting of approximately 84 species, with 32 in North America (Brooks & Clements, 2000; Kirschner, 2002). This section is most species-rich in the eastern United States, southwestern Europe, and the Far East. Recent studies have resulted in the recognition of two new species in section *Ozophyllum* from the southeastern United States: *J. fascinatus* (M. C. Johnst.) W. M. Knapp and *J. paludosus* E. L. Bridges & Orzell.

The Altamaha grit, or more accurately the Altamaha Formation, are unusual outcroppings of sandstone in the Coastal Plain Physiographic Province of North America of fluvial or upper estuarine origin from the Middle Miocene (Huddlestun, 1988). These are known for a unique assemblage of rare, unusual, endemic to near-endemic plant species, including *Elliottia racemosa* Muhl. ex Elliott, *Marshallia ramosa* Beadle & F. E. Boynton, *Nolina georgiana* Michx., *Penstemon dissectus* Elliott, and *Portulaca biloba* Urb., and putatively undescribed species of *Isoetes* L., *Lilium* L., and *Oxalis* L. The *Isoetes* is currently under study by Peter Schafran and Lytton Musselman, and the *Oxalis* is under study by the second author of this paper. Other associates include *Bigelowia nuttallii* L. C. Anderson, *Croton willdenowii* G. L. Webster, *Dichanthelium commutatum* (Schult.) Gould, *Hypericum gentianoides* (L.) Britton, Sterns & Poggenb., *Geocarpon uniflorum* (Walter) E. E. Schill., *Nothoscordum bivalve* (L.) Britton, *Pinguicula caerulea* Walter, *Polygala chapmanii* Torr. & A. Gray, *Rhynchospora saxicola* Small, *Ilex vomitoria* Aiton, *Isoetes* sp., *Lindernia monticola* Nutt., *Selaginella* P. Beauv. sp., *Paspalum plicatulum* Michx., *Phemeranthus* Raf. sp., *Polygala* L. sp., *Sphagnum cyclophyllum* Sull. & Lesq., *Sporobolus floridanus* Chapm., *Steinchisma hians* (Elliott) Nash, and *Utricularia cornuta* Michx.

While conducting fieldwork in the Altamaha grit of Georgia with Frankie Snow, Carter collected a diminutive and typically annual species of *Juncus* (Figs. 1–3) that he could not identify (Carter, 2015). Carter sent this material to Knapp, who has published various treatments of the genus in eastern North America (Knapp, 2016; Sorrie & Knapp, 2022) and who immediately suspected that it was an undescribed species. A close examination of the recent global monograph of the genus (Kirschner, 2002) was undertaken to eliminate the possibility that this was a non-native species of unknown origin, but no species included here matched the features of this *Juncus*. Measurements of this diminutive *Juncus* were taken and compared to described taxa of section *Ozophyllum* in the Flora of North America (Brooks & Clemants, 2000; Knapp, 2016; Sorrie & Knapp, 2022). To eliminate the possibility that this entity had been previously described, type specimens of currently synonymized names were examined.

In this paper we describe the new species, discuss morphological differences between it and its most morphologically similar species, provide a key to species,

Version of record first published online on 23 April 2024.
doi: 10.3417/2024872 Novon 32: 70–76.

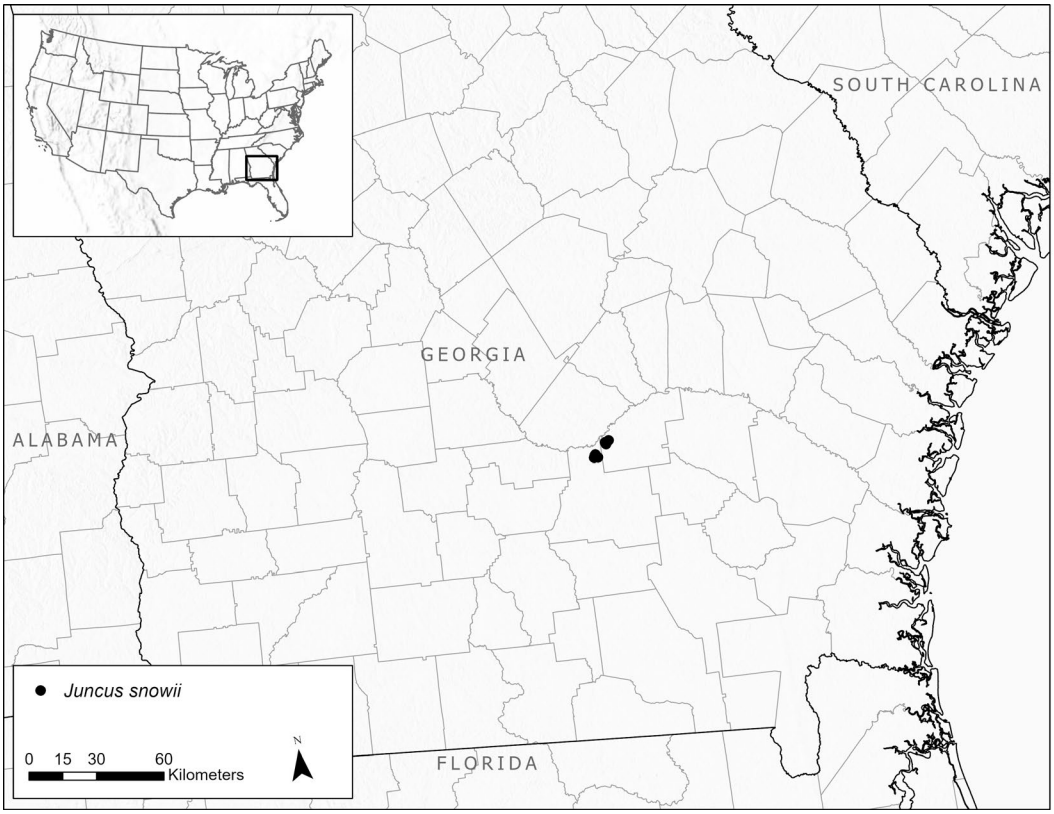

Figure 1. Map of the southeastern United States, with inset showing Georgia. Black dots are the known locations of *Juncus snowii* W. M. Knapp & R. Carter.

and describe its apparently narrow ecological niche. Due to habitat sensitivity, we have redacted the precise locations of the paratypes. These are available upon request. Herbaria acronyms follow Thiers (2023+). NatureServe conservation status assessment was conducted following Faber-Langendoen et al. (2012), and IUCN conservation status assessment was conducted following IUCN (2022). Calculations of area of occupancy and extent of occurrence were made using GeoCat (Bachman et al., 2011).

Juncus snowii W. M. Knapp & R. Carter, sp. nov. TYPE: U.S.A. Georgia: Coffee Co., Broxton Rocks Nature Preserve, 4 May 2019, *R. Carter & F. Snow 23650* (holotype, NCU!; isotypes, BRIT!, FLAS!, GA!, GH!, MO!, NY!, PRA!, US!, VSC!). Figures 2–4.

Diagnosis. *Juncus snowii* W. M. Knapp & R. Carter differs from *J. debilis* A. Gray in being an annual (vs. perennial) and having usually fewer heads per culm (1 to 5 vs. 3 to 50), usually smaller inner tepals (1.9–2.1 mm vs. 2.0–2.5 mm), and smaller capsules (2.4–2.5 mm vs. 2.8–4.2 mm).

Plants annual, rarely perennial, 5–27 cm tall, caespitose. *Rhizomes* lacking, cataphylls absent. *Leaves* terete, rounded in cross section, 19–58 × 0.4–0.9 mm; unitubular septate, septa externally obscure to ± distinct in dry condition; apex acute; *auricles* 0.5–1.2 mm, truncate, scarious. *Inflorescence* of 1 to 5 heads, 1.2–7 × 0.8–4.5 cm; heads widely spaced on branches, turbinate to obconic or hemispheric, 5- to 10-flowered, 0.5–0.6 mm diam.; lowest inflorescence bract green becoming reddish-brown, leaf-like, linear, spreading to erect, 0.3–1.5 cm, shorter than the inflorescence. *Flowers* with outer tepals subequal, lanceolate-subulate, green to reddish, 2–2.3 mm, acuminate; inner tepals 1.9–2.1 mm; stamens 3, concealed by tepals; anthers 0.5–0.6 mm; filaments 0.3–0.4 mm; style 0.1–0.2 mm; stigmas 0.2–0.3 mm. *Capsules* light brown to stramineous, unilocular, 2.4–2.5 mm, equaling to slightly exceeding perianth, acuminate, valves completely separating apically at dehiscence. *Seeds* pale reddish-brown, ovoid to broadly ovoid, 0.3–0.4 × 0.1–0.2 mm, apiculate, surface reticulate; appendages absent. Figures 2, 4.

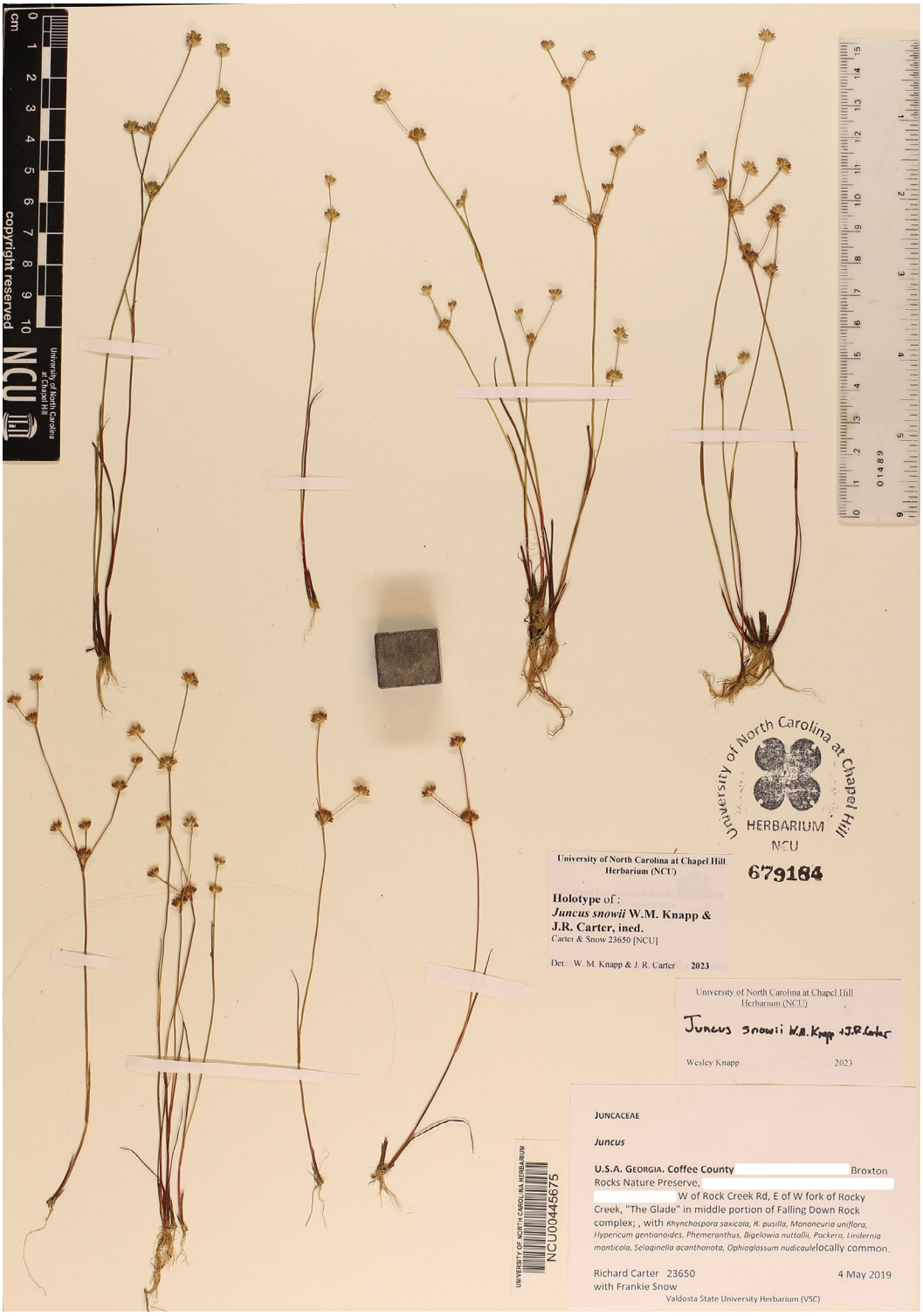

Figure 2. Holotype specimen of *Juncus snowii* W. M. Knapp & R. Carter (*R. Carter & F. Snow 23650*, NCU).

Figure 3. In situ and habitat photos of *Juncus snowii* W. M. Knapp & R. Carter. Habit of mature plants (left panel), habitat (upper right), leaf auricle (bottom right), glomerules (mid-bottom), and mature capsule with tepals (bottom center). Photos taken by J. R. Carter.

Distribution and habitat. This new species is currently known only from a two-county area of the Altamaha grit of Georgia (Fig. 1). The Coastal Plain Physiographic Province has recently been recognized as a global biodiversity hotspot (Noss et al., 2015) of which *Juncus snowii* is yet another endemic species. *Juncus snowii* is an ephemeral heliophyte that grows in open, seasonally wet seeps where a thin layer of soil has accumulated over relatively flat expanses of sandstone (Fig. 3). The very harsh conditions associated with summer drought in this microhabitat prevent colonization by perennial species and all but a few highly adapted, specialized annuals. Although this is a harsh environment, we are confident the species here described is not merely an environmentally induced form of another *Juncus* species. *Juncus snowii* is morphologically distinct from all other *Juncus* species.

Provisional conservation status. *Juncus snowii* is known from fewer than five locations. All four known subpopulations of *J. snowii* are on properties owned and managed by The Nature Conservancy and the Georgia Department of Natural Resources, which helps ensure the species' long-term viability. Fire is used in the management of three of these sites, but it is currently unknown if the appropriate fire frequency and intensity will be maintained in perpetuity. The management history and future conservation possibilities of the fourth site are unknown. Although climate change will undoubtedly have an impact on *J. snowii*, any discussion about how this will affect its long-term viability is speculative given how little we know of the species' ecology.

The area of occupancy is 20 km^2. The extent of occurrence is calculated as 11.7 km^2; according to IUCN methodology (IUCN Standards and Petitions Committee, 2022), if the EOO is less than the AOO, the EOO should be set as equal to the AOO to ensure consistency with the definition of AOO as an area within the EOO. Given the extremely narrow geographic distribution and the small number of occurrences (four), the species qualifies for a NatureServe Global Rank of G1, Critically Imperiled (Faber-Langendoen et al., 2012). Under the IUCN Red List criteria (IUCN Standards and Petitions Committee, 2022), we propose a preliminary IUCN Red List Assessment of Vulnerable [VU D2]. Any future documentation of negative population trends, increased threats, or lapses in appropriate fire management that would degrade habit quality would likely change the assessment toward Endangered under the B criteria.

Etymology. We are delighted to name this new species in honor of Frankie Snow, indefatigable biologist who has devoted much of his life to the study of the biota and natural history of Altamaha grit outcrops, especially those in the vicinity of Broxton Rocks.

Vernacular name. Snow's rush.

Notes. *Juncus snowii* is morphologically distinct from all other species in section *Ozophyllum* and warrants recognition using the morphologic species concept. Further survey work in the Altamaha grit may reveal more populations, but it is unlikely to occur in other areas outside this specific and very rare habitat. Although the Altamaha grit is a well-surveyed habitat

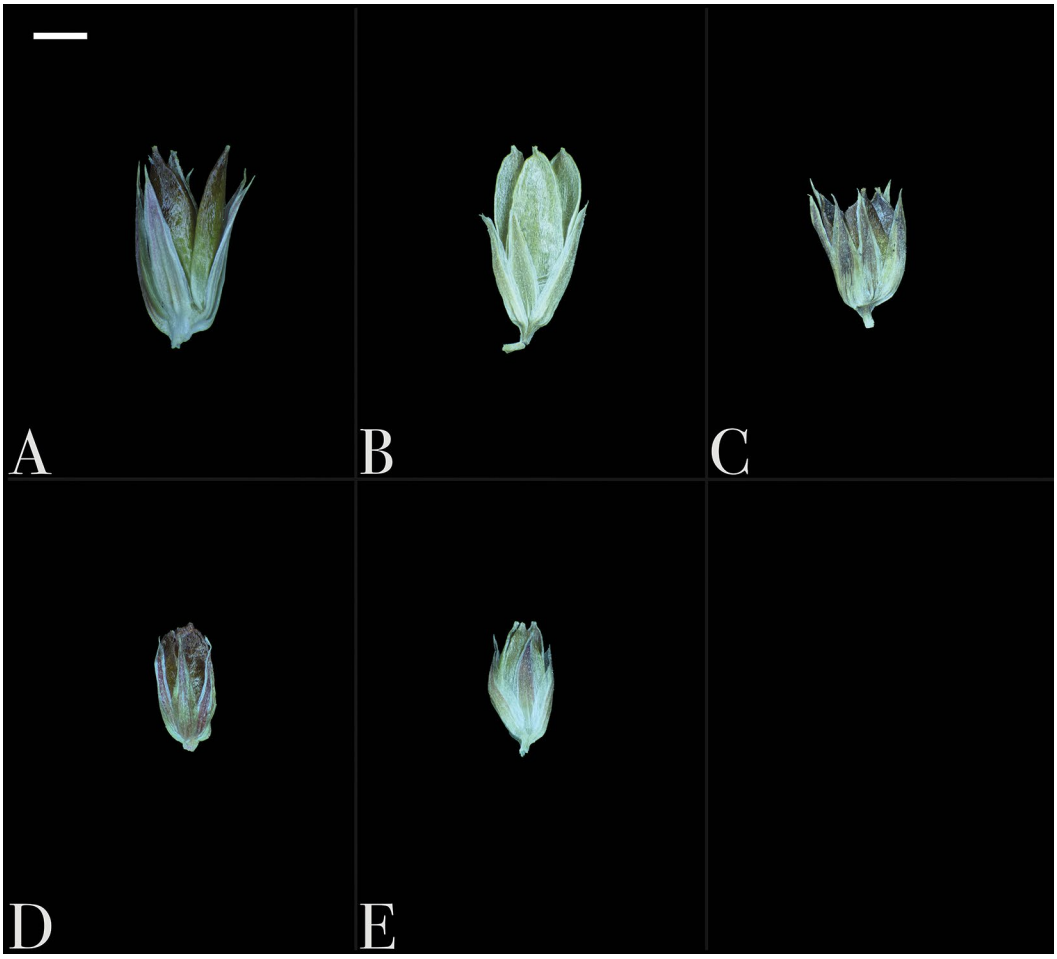

Figure 4. Comparison of capsules and tepals of five *Juncus* L. species. —A. *Juncus acuminatus* Michx. (*B. Sorrie 12941*, NCU). —B. *Juncus debilis* A. Gray (*A. Radford & W. Batson 37034*, NCU). —C. *Juncus nodatus* Coville (*R. Kral 46775*, NCU). —D. *Juncus elliottii* Chapm. (*H. Ahles & J. Haesloop 26551*, NCU). —E. *Juncus snowii* W. M. Knapp & R. Carter (*R. Carter 23650*, VSC). Scale bar = 1 mm.

(Harper, 1906a, 1906b), it is understandable that this diminutive plant was overlooked. Not only is *Juncus* undercollected and understudied, its small, generally annual, inconspicuous habit makes it easy to overlook, as it is often obscured by surrounding vegetation.

Frankie Snow and the second author have been conducting field surveys to document the morphologic variation, ecology, geographic extent, and life history of *Juncus snowii* since 2014. Over these nine years, only one small cluster of *J. snowii* has been observed that displays an apparently perennial habit (*Carter & Snow 23668*). These plants were collected from an area of deep soil accumulation that allowed the plants to persist overwinter. These individuals match all the morphologic traits of *J. snowii* but differ in a taller, more robust habit. The robust and apparently perennial plants were growing near typical annual plants of *J. snowii* (*Carter & Snow 23669*). These apparently perennial and robust plants were observed in 2019 and have not been relocated despite additional surveys.

Juncus snowii differs from all other members of the genus by having a combination of leaves with complete cross-septate bands that are externally obscured, small capsules, small tepals, and an annual life history with the exception of one gathering that displays perennial traits (see additional comments below). *Juncus snowii* is readily distinguishable from morphologically similar species by a suite of characters (Table 1). Most notable among the characters that distinguish *J. snowii* are its annual habit and diminutive size. It is only the third known annual species of the section (Kirschner, 2002). The other annual species of the section, both of which

Table 1. Characters of *Juncus snowii* W. M. Knapp & R. Carter compared to morphologically similar species. All measurements are in mm, unless explicitly stated.

	J. acuminatus	*J. debilis*	*J. elliottii*	*J. nodatus*	*J. snowii*
Life history	perennial	perennial	perennial	perennial	annual*
Culm height	10–80 cm	10–25 cm	30–90 cm	30–100 cm	5–27 cm
Root tubers	absent	absent	present	absent	absent
Leaf septa	faint bands	faint bands	faint bands	prominent rings	faint bands
Heads per culm	5 to 20	3 to 50	40 to 100	30 to 250	1 to 5
Inner tepal length	2.6–3.6 mm	2.0–2.5 mm	2.4–2.9 mm	1.7–2.2 mm	1.9–2.1 mm
Capsule color	light brown to stramineous	light brown to stramineous	chestnut brown	light brown to stramineous	light brown to stramineous
Capsule length	2.8–3.6 mm	2.8–4.2 mm	2.4–2.8 mm	1.9–2.5 mm	2.4–2.5 mm

*One collection has been made of apparently perennial material (see discussion).

are encountered in Europe, are *J. pygmaeus* Rich. ex Thuill. and *J. tingitanus* Maire & Weiller. *Juncus pygmaeus* has much larger, cleistogamous flowers. *Juncus tingitanus* has unequal inner and outer tepals, and anthers not much shorter than filaments. The similar species of eastern North America with three stamens include *J. acuminatus* Michx., *J. debilis*, *J. elliottii* Chapm., and *J. nodatus* Coville. A comparison of capsule and tepal morphology shows each species is distinct (Fig. 4). *Juncus snowii* differs from most of these species in having usually much shorter fruiting stems, sometimes as little as 5 cm in total height (Table 1, Figs. 2, 3), and from *J. acuminatus* in having smaller capsules and smaller tepals (Table 1, Fig. 4). *Juncus debilis* has many overlapping characters but has larger tepals (on average) and larger capsules, which exceed the perianth by roughly 1–1.5 mm (Table 1, Fig. 4). *Juncus acuminatus* has larger tepals and capsules. *Juncus elliottii* has root tubers, longer tepals, and deep chestnut brown capsules (Table 1, Fig. 4). Lastly, *J. nodatus* has leaves with prominent ring-like septate bands and more flowering heads per culm (Table 1).

Paratypes. U.S.A. **Georgia:** Coffee Co., Broxton Rocks Nature Preserve, 16 May 2014, *Carter & Snow 21663* (VSC); 12 May 2016, *Carter & Snow 22650* (NCU, NY, US); 12 May 2016, *Carter & Snow 22652* (VSC); 4 May 2019, *Carter & Snow 23656* (NCU, US, VSC); 4 May 2019, *Carter & Snow 23657* (NCU, VSC); Rock House Falls, 16 Nov. 2017, *Carter & Snow 23144* (MO, NCU, NY, PRA, US, VSC); Trulove Tract, 25 Apr. 2018, *Carter & Snow 23161* (BRIT, GA, VSC); Jeff Davis Co., Flat Tub Wildlife Management Area, 4 May 2019, abnormally large plants displaying apparently perennial habit, *Carter & Snow 23668* (GA, NCU, US, VSC); plants displaying typical annual growth form, *Carter & Snow 23669* (GA, NCU, US, VSC), 4 May 2019, *Carter & Snow 23661* (NCU); 4 May 2019, *Carter & Snow 23662* (NCU); Piney Grove Church Rd. & Rocky Hammock Landing Rd., 18 June 2017, *Carter & Snow 22984* (NCU, VSC).

The key below distinguishes species of *Juncus* sect. *Ozophyllum* from the southeastern United States that may be most readily confused with *J. snowii*, those with heads of three to 15 flowers, three stamens per flower, and seeds lacking long tails. The key is adapted from Key E in Sorrie and Knapp (2022). Stamens persist in fruiting material and can be observed by peeling back the tepals from the capsule.

Key to *Juncus* sect. *Ozophyllum* of the Southeastern United States with Heads of 3 to 15 Flowers and Lacking Long-tailed Seeds, with Three Stamens

1. Mature capsules about 1/3 longer than perianth (roughly 1–1.5 mm longer) . . . . . *J. debilis* A. Gray
1′. Mature capsules equaling or barely exceeding perianth.
  2. Roots with terminal tubers; capsules deep chestnut brown . . . . . *J. elliottii* Chapm.
  2′. Roots lacking tubers; capsules light brown to stramineous.
    3. Leaves with conspicuous septa forming prominent rings; heads 30 to 250 per culm . . . . . *J. nodatus* Coville
    3′. Leaves with obscured leaf septa; heads 1 to 20.
      4. Perennial; tepals 2.6–3.6 mm long; capsules 2.8–3.6 mm long . . . . . *J. acuminatus* Michx.
      4′. Annual (rarely perennial); tepals 1.9–2.1 mm long; capsules 2.4–2.5 mm long . . . . . *J. snowii* W. M. Knapp & R. Carter

Acknowledgments. We thank The Nature Conservancy for allowing the second author permission to collect specimens, and Tall Timbers Research Station and the Valdosta State University Foundation for financial support. We thank Chris Tracey for his assistance in creating Figure 1 and we thank Derick Poindexter (UNC-Chapel Hill) for assistance in creating Figure 4. We thank Carol Ann McCormick and Shanna Oberreiter (UNC-Chapel Hill) for herbarium assistance. We thank Aaron Floden (MO) for his presubmission review

of this manuscript. The first author thanks the Helen C. Frick Foundation for their continued support of NatureServe Botany and the BAND Foundation for providing critical funding for the conservation status assessments of this southeastern grassland species. We thank Amanda Eberly and Diana Soteropoulos for their assistance with NatureServe and IUCN Conservation Status Assessments.

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