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Juncus fascinatus (Juncaceae), a new combination in *Juncus* sect. *Ozophyllum* and notes on morphologically similar species

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Abstract

Research of the morphologic variation within *Juncus* (Juncaceae) sect. *Ozophyllum* has revealed the need for a new combination, *Juncus fascinatus*. Univariate and multivariate statistical analyses show that *J. fascinatus* is morphologically distinct from *J. validus*. *Juncus fascinatus* is described, illustrated, and compared to the superficially similar species *J. paludosus, J. polycephalos,* and *J. validus*. *Juncus fascinatus* is endemic to 25 counties in north-central and southeastern Texas whereas *J. validus* is more widespread and weedy. *Juncus fascinatus* is distinguished from *J. validus* by a united capsule apex at dehiscence, capsule length, inner and outer tepal length, length by which the capsule exceeds the tepals, and inflorescence length and width. *Juncus validus* is ecologically distinct from *J. fascinatus* and has shown a rapid range expansion throughout the southeastern United States and into the Mid-Atlantic. *Juncus validus* is most likely non-native west of the Mississippi River. The morphologically similar *J. paludosus* is reported from Alabama, Georgia, Louisiana, and South Carolina for the first time. *Juncus polycephalos* is reported from Kansas.

Key words: principal components analysis, cluster analysis, endemic, morphology, conservation concern, *Juncus validus*

Introduction

Juncus Linnaeus (1753: 325, Juncaceae) is a cosmopolitan genus of approximately 315 species. *Juncus* sect. *Ozophyllum* Dumortier (1827: 142) (=subg. *Septati* Buchenau 1875: 406) is the largest section in the genus and comprises approximately 84 species with 32 species in North America (Brooks & Clemants 2000, Kirschner 2002). This section is most diverse in eastern North America, southwestern Europe and the Far East. Members of section *Ozophyllum* are distinguished as having septa that form complete bands across the leaves and flowers lacking subtending bracteoles (=eprophyllate).

Juncus validus was described by Coville (1895: 305). Though there has been some debate about the appropriate name for this species (Kirschner & Drábková 2007) it has been universally accepted as distinct from other members of section *Ozophyllum*. Marshal C. Johnston described *J. validus* var. *fascinatus* (Johnston 1964: 313) and named it after its type locality, Enchanted Rock, a unique natural area spanning Gillespie and Llano Counties, Texas. Johnston (1964) distinguished var. *fascinatus* based upon its diminutive inflorescence of 2–5 cm, with heads 6–15 flowered, and capsules remaining united at the apex at maturity.

Authors of treatments and floras vary in their recognition of *J. validus* var. *fascinatus*. Treatments focusing on Texas (Jones *et al*. 1997, Diggs *et al*. 1999, Turner *et al*. 2003) and many broader geographic treatments (Brooks & Clemants 2000, Kirschner 2002) all recognize var. *fascinatus*. It is unclear if treatments from other States and regions that do not list any varieties within *J. validus* are disputing the legitimacy of var. *fascinatus* or are not being explicit in listing var. *validus* (Godfrey & Wooten 1979, Gleason & Cronquist 1991, Yatskievych 1999, Wunderlin & Hensen 2003). No study has been published examining this taxon and all treatments that recognize this variety cite the characters published by Johnston (1964).

While working toward the Juncaceae treatment for the *New Manual of Vascular Flora of the Northeastern United States and Adjacent Canada* (Naczi & collaborators in prep.) and revising the *Juncus* treatment for the *Flora of the Southern and Mid-Atlantic States* (Sorrie & Knapp 2012), I examined material matching the description of var. *fascinatus*. This material was strikingly distinct from typical *J. validus* and I concluded a reevaluation of this taxon was in order. It is also apparent widespread confusion surrounds the identification of two morphologically similar species

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of *J.* section *Ozophyllum, J. paludosus* Bridges & Orzell (2008: 294) and *J. validus*, and a morphologically similar species of section *Iridifolii* Snogerup & Kirschner (1999: 382), *J. polycephalos* (Michaux 1803: 192). This confusion stems from many factors including confusing or poorly constructed keys and the fact *J. paludosus* was only recently described (Bridges & Orzell 2008).

Here I present the results of a morphological study of *J. validus* from throughout its geographic range. I then present a taxonomic revision of *J. validus* including a key, illustrations, description, representative specimens and provide illustrations of superficially similar species to assist in proper identification.

Materials and Methods

I studied the morphology, geographic distribution, and habitat of *J. validus* in the field from 2002–2014 at as many sites as possible. My knowledge of *J. fascinatus* is from herbarium specimens and literature. I have studied *J. validus* in Alabama, Georgia, Delaware, Maryland, Mississippi, North Carolina, South Carolina, and Virginia. I have studied nearly 600 specimens from throughout the geographic range of *J. fascinatus* and *J. validus* from the following 22 herbaria: BALT, BRIT, Cylburn Arboretum Herbarium, DOV, FLAS, FSU, GA, KANU, LL, LSU, MARY, MO, NA, NCU, NY, PH, SMU, TAWES, TEX, WILLI, US, and VDB. Herbarium abbreviations follow Index Herbariorum (2014) with the exception of the Cylburn Arboretum Herbarium (4915 Greenspring Ave, Baltimore, MD 21209, U.S.A.). I created distribution maps based on herbarium specimens; every mapped symbol is based on at least one voucher specimen.

I selected a representative subset of specimens for analysis. I used only mature, complete collections. These collections represented the full range of morphologic variation and are from throughout the geographic range of the two species. Specimens measured are denoted by an asterisk (*) after the herbarium acronym in the citations of representative specimens.

Statistical Analysis

A set of 55 complete specimens (22 *J. fascinatus* and 33 *J. validus*) from throughout the geographic and morphological range of *J. validus* were chosen for detailed morphologic analysis. Specimens measured for analysis came from unique populations. This helped prevent artificially weighing the morphology of any particular population in the dataset. Given the limited number of specimens discovered and the restricted geographic range of *J. fascinatus* only 22 specimens of this species were suitable for measurement. After careful review of all literature and examination of hundreds of herbarium specimens a list of 10 potentially diagnostic characters was developed (Table 1). I measured all of these characters on ten specimens each of the two taxa recognized by the most inclusive taxonomic and floristic treatments (e.g., Brooks & Clemants 2000, Kirschner 2002). I included those characters whose loadings were >0.5 on principal components analysis in future analysis. I then measured these characters (Table 1) on an additional 35 specimens. Summary statistics including means, standard deviation, and ranges were calculated for each character.

TABLE 1. List of all characters examined with the component loadings and percent variance explained by the first two Principal Components.

Characters Examined	Loading 1	Loading 2
Inner tepal length	0.796	0.184
Outer tepal length		
Capsule length		
Length capsule exceeds inner tepals	0.812	-0.361
Length capsule exceeds outer tepals	0.730	-0.581
Inflorescence length	0.823	0.408
Inflorescence width	0.889	0.264
Inflorescence length/width ratio		
Longest primary branch of the inflorescence		
Longest secondary branch of the inflorescence		
Percent Total Variance Explained	65.8	14.8

When multiple individuals were present on a single sheet, I measured all characters from a single individual. When measuring a character that was present more than once per individual (e.g., capsule length), I measured the one with the greatest value. Measurements were only taken from mature specimens. Inflorescence length was measured from the base of the inflorescence bract to the tip of the inflorescence. Inflorescence width was measured at the widest point of the inflorescence. Capsule length was measured from the base of the capsule to the tip and was often aided by removing the capsule from the tepals. Inner and outer tepals were measured from the base of the tepal to the tip.

I submitted all characters to Pearson Correlation Analysis. When two characters were highly correlated ($r > 0.7$), the character with the higher component loading (as determined by Principal Component Analysis) was retained. The other character was excluded from multivariate statistical analysis in order to avoid weighting potentially redundant morphologic characters.

I conducted statistical tests on the measurements using Systat version 12 (SPSS 2007). An Analysis of Variance (ANOVA) was conducted to test the null hypothesis that there is no morphologic discontinuity between *J. fascinatus* and *J. validus.* A Principal Component Analysis (PCA) determined the amount of morphological variation in the data set and the characters that are most diagnostic to *J. fascinatus*. Before conducting PCA the dataset was standardized so each variable would have a mean of 0 and a standard deviation of 1. A Cluster Analysis (CA) determined which specimens were the most morphologically similar by grouping each specimen by its overall phenetic similarity. The CA examined all 55 specimens using Euclidean distance and average linkage. Such methods have been useful in similar studies (Saarela *et al*. 2003, Kjaer *et al*. 2004, Knapp & Naczi 2008).

Geographic distribution

I calculated latitude and longitude coordinates for each specimen studied based on label data using Google Maps (2014). Species locations were compiled in Microsoft Excel for Mac (2011) and mapped using ArcMap 10 (ESRI 2010). This data was sorted by date and mapped to show known collection locations by date for *J. validus*. To be as inclusive as possible in searching for early collection records of *J. validus*, I conducted searches on the Alabama Plant Atlas website (2014), which searches nine Alabama Herbaria, and the Tomas M. Pullen Herbarium website (2014), which searches the collections of MISS.

Results

Correlation analysis

The Pearson Correlation Analysis revealed many characters to be highly correlated ($r > 0.7$). Length of the longest primary inflorescence branch and length of the longest secondary branch of the inflorescence are highly correlated to the total inflorescence length ($r = 0.94$, $p<0.0001$ & $r = 0.95$, $p<0.0001$, respectively). Length of the longest primary inflorescence branch and length of the longest secondary branch of the inflorescence are also highly correlated to the total inflorescence width ($r = 0.80$, $p<0.0001$, & $r = 0.80$, $p<0.0001$, respectively). Inner tepal length was highly correlated to outer tepal length ($r = 0.84$, $p<0.0001$). Capsule length was highly correlated to inner tepal length, outer tepal length, and the length the capsule was exerted beyond the inner tepals ($r = 0.85$, $p<0.0001$ $r = 0.80$, $p<0.0001$; & $r = 0.84$, $p = 0.0002$, respectively). The length of the longest primary inflorescence branch, length of the longest secondary inflorescence branch, length of the outer tepals and the capsule length are excluded from multivariate statistical analysis because their component loadings are less than the loadings for the characters with which they are highly correlated.

Univariate analysis

The ANOVA (Table 2) showed the characters accounting for the most morphologic dissimilarity between taxa. These were: inner tepal length, inflorescence width, and inflorescence length. The characters with the two highest *F*-values were plotted graphically (Fig. 1) and reveal no overlap between groups. This shows that by using inner tepal length and inflorescence width *J. fascinatus* and *J. validus* can be distinguished.

Multivariate analysis

A scatter plot of the scores of components I and II from PCA reveals two distinct groups (Fig. 2). The first two principal components account for 80.6% of the variation. Component I accounts for 65.8% of the variation and component II accounts for 14.8% (Table 1). The variables with the highest loadings on component I are inflorescence

width, inflorescence length, and capsule length exposed beyond inner tepals, in descending order. The variables with the highest loadings on component II are the capsule length exposed beyond outer tepals, inflorescence length, and the capsule length exposed beyond outer tepals, in descending order. A dendrogram resulting from the Cluster Analysis (CA) shows two groups (Fig. 3). No specimens were incorrectly clustered. All specimens of *J. fascinatus* cluster together and all specimens of *J. validus* cluster together.

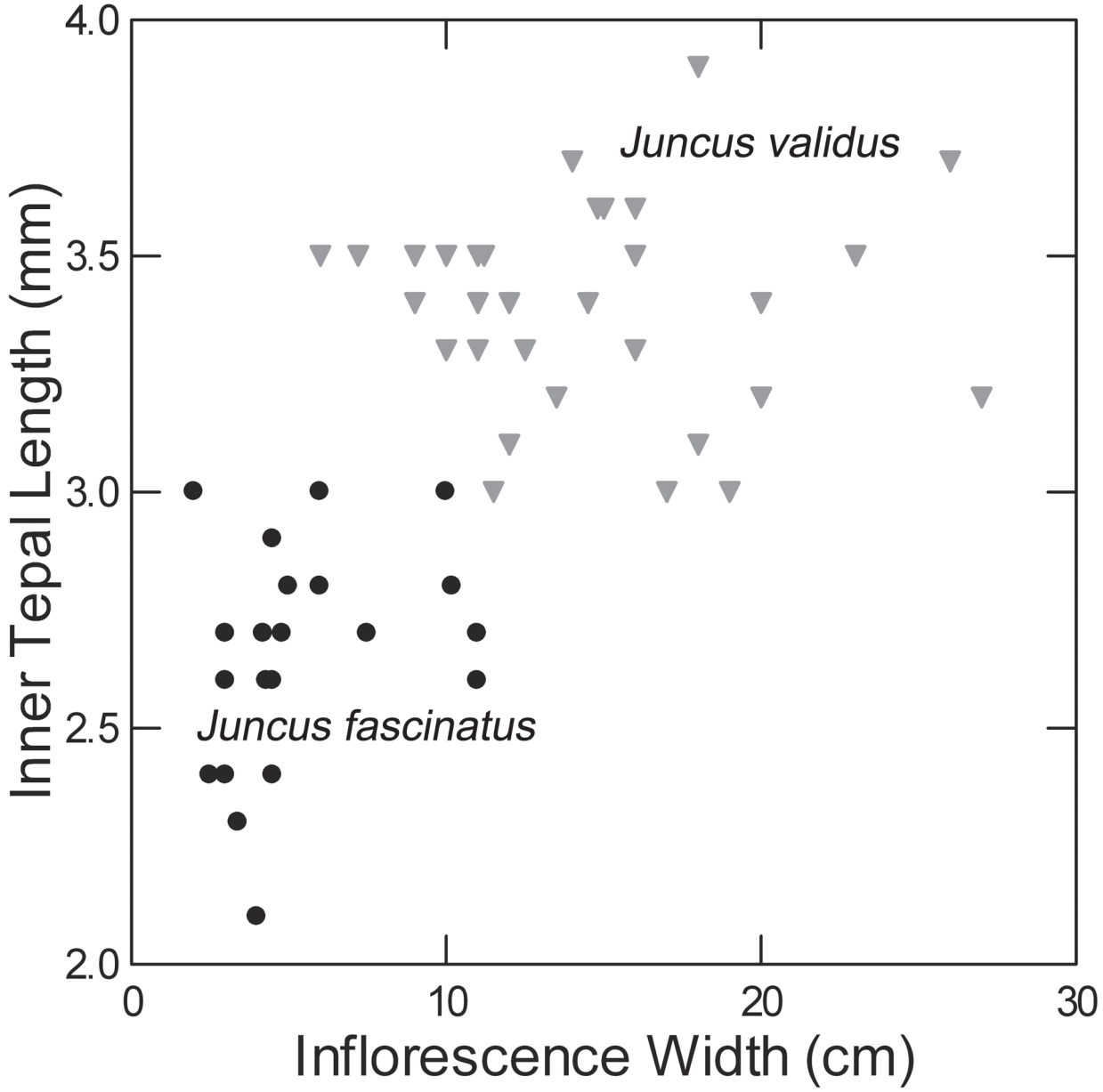

FIGURE 1. Scatterplot of the two most important characters (inflorescence width and tepal length) for distinguishing *J. fascinatus* from *J. validus* as revealed by ANOVA. Circles represent *J. fascinatus* (N = 22) and triangles represent *J. validus* (N = 33).

Morphological characters

Juncus fascinatus is easily distinguished from *J. validus* by a number of morphological characters. *Juncus fascinatus* has a capsule apex that remains united at maturity (Fig. 4), whereas the capsule of *J. validus* separates into three distinct portions at maturity (Fig. 5). The inflorescence is shorter (4.6–13 cm) and narrower (2.5–8.1 cm) in *J. fascinatus*, giving a much more congested look than the longer (13.3–25.9 cm) and wider (9.4–19.4 cm) inflorescence of *J. validus* (Figs. 4 & 5, Table 2). The capsules of *J. fascinatus* are shorter (3.5–4.3 mm) compared to the larger capsules (4.7–5.5 mm) of *J. validus* (Figs. 4 & 5, Table 2). The inner and outer tepals are shorter (2.4–2.8 mm & 3.1–3.9 mm, respectively) in *J. fascinatus* than the longer inner and outer tepals (3.2–3.6 & 3.8–4.4, respectively) of *J. validus* (Figs. 4 & 5, Table 2). The capsule is also less exserted beyond the inner and outer tepals in *J. fascinatus* (0.8–1.6 mm & 0.1–0.9 mm, respectively) than *J. validus* (1.4–2.2 mm & 0.7–1.3 mm, respectively; Figs. 4 & 5, Table 2).

TABLE 2. Morphologic characters measured on *J. fascinatus* and *J. validus* showing mean ± 1 standard deviation and range (in parentheses) for each character. N = sample size. Within a row all means differ significantly with each other (P <0.0005).

Character (mm)	*J. fascinatus* (N = 22)	*J. validus* (N = 33)	ANOVA *F*
Inner tepal length	2.6 ± 0.2	3.4 ± 0.2	147.9
	(2.4–2.8)	(3.2–3.6)	
Inflorescence width (cm)	5.3 ± 2.8	14.4 ± 5.0	56.8
	(2.5–8.1)	(9.4–19.4)	
Inflorescence length (cm)	8.8 ± 4.2	19.6 ± 6.3	44.6
	(4.6–13.0)	(13.3–25.9)	
Length capsule exceed inner tepals	1.2 ± 0.4	1.8 ± 0.4	26.2
	(0.8–1.6)	(1.4–2.2)	
Length capsule exceed outer tepals	0.5 ± 0.4	1 ± 0.3	22.8
	(0.1–0.9)	(0.7–1.3)	

TABLE 3. Earliest known specimen of *Juncus validus* from each State.

Year	State	County	Collector, Collector number, (Herbarium)
1842	Texas	Harris	*Lindheimer s.n.* (MO)
1853	Arkansas	[none indicated]	*Bigelow s.n.* (US)
1868	Oklahoma	[none indicated]	*Palmer 318* (US)
1890	Mississippi	Lee	*Tracy 1587* (US)
1898	Louisiana	Bienville Parish	*C. Ball 257* (US)
1909	Missouri	Jasper	*Palmer 2300* (MO)
1912	Alabama	Mobile	*Bartlett 3200* (BALT, NCU)
1913	Kansas	Cherokee	*Leterman s.n.* (US)
1937	Georgia	Heard	*Pyron & McVaugh 1748* (GA)
1956	Florida	Gadsden	*Redfern 2192* (NY)
1956	South Carolina	Beaufort	*Ahles 15620* (NCU)
1957	North Carolina	Onslow	*Ahles 28143* (NCU)
1964	Maryland	Harford	*Baltars 4433* (Cylburn, US)
1965	Tennessee	McNairy	*Rogers 33627* (NCU)
1967	Virginia	Isle of Wright	*Harvill 17062* (US)
2006	Illinois	Alexander	*Mohlenbrock 18991* (MO)
2006	Delaware	Sussex	*Longbottom et al. 7586* (DOV, PH)

Juncus fascinatus and *J. validus* are routinely confused with other morphologically similar species. To assist in correct identification, illustrations for *J. paludosus* (Fig. 6) and *J. polycephalos* (Fig. 7) are provided. The leaves of *J. polycephalos* are incompletely septate giving the leaf surface a wrinkled appearance (Fig. 7) whereas the other species have complete septa. *J. fascinatus* (Fig. 4) and *J. validus* (Fig. 5) have superficially inconspicuous septa whereas *J. paludosus* (Fig. 6) has conspicuous ring-like septa. I have also identified new auricle characters to assist in identification of species. The auricles of *J. polycephalos* are much shorter and poorly developed when compared to the long ligule present in *J. fascinatus* (Fig. 4), *J. paludosus* (Fig. 6), and *J. validus* (Fig. 5).

Geographic distribution

Juncus fascinatus is a narrow endemic to 25 counties of north-central and southeastern Texas (Fig. 8). This range is much smaller and restricted than *J. validus* (Fig. 9). Label data reveals *J. fascinatus* occurs along streams and seeps, whereas *J. validus* is a weedy species of wet roadsides, ditches, and power lines. The collection of *J. fascinatus* from Bowie County, Texas, appears out of range. It is based upon two Eggert collections with identical labels from "wet places N. Texarkana, 22 July1896, *s.n.*" (MO) and "9 June 1898, *s.n.*" (MO). Eggert also collected *J. validus* in 22

July1896. The labels for the 22 July 1896 specimens of *J. fascinatus* and *J. validus* are identical, suggesting this could be the result of a labeling error.

The collection database compiled for *J. validus* contains data from 574 specimens. Mapping by date shows the range has expanded through the southeast and into the mid-Atlantic (Fig. 9, Table 3). The number of unique pre-1900 collections I have seen is 27; five from Arkansas, four from Louisiana, one from Mississippi, four from Oklahoma, and 13 from Texas. This suggests a natural range of the south-central United States and, possibly, into the southeastern United States. I compiled the earliest records per State to help illustrate the spread of this species (Table 3) and created individual maps showing the known range, over four time periods; pre-1900, pre-1930, pre-1970 and pre-2014 to help illustrate the changes in specimen documentation over time (Fig. 9). Searches of the Alabama Plant Atlas website (2014), the Thomas M. Pullen Herbarium website (2014) and physical searches by A. Floden at the University of Tennessee (UTENN) revealed no specimens earlier than those in Table 3.

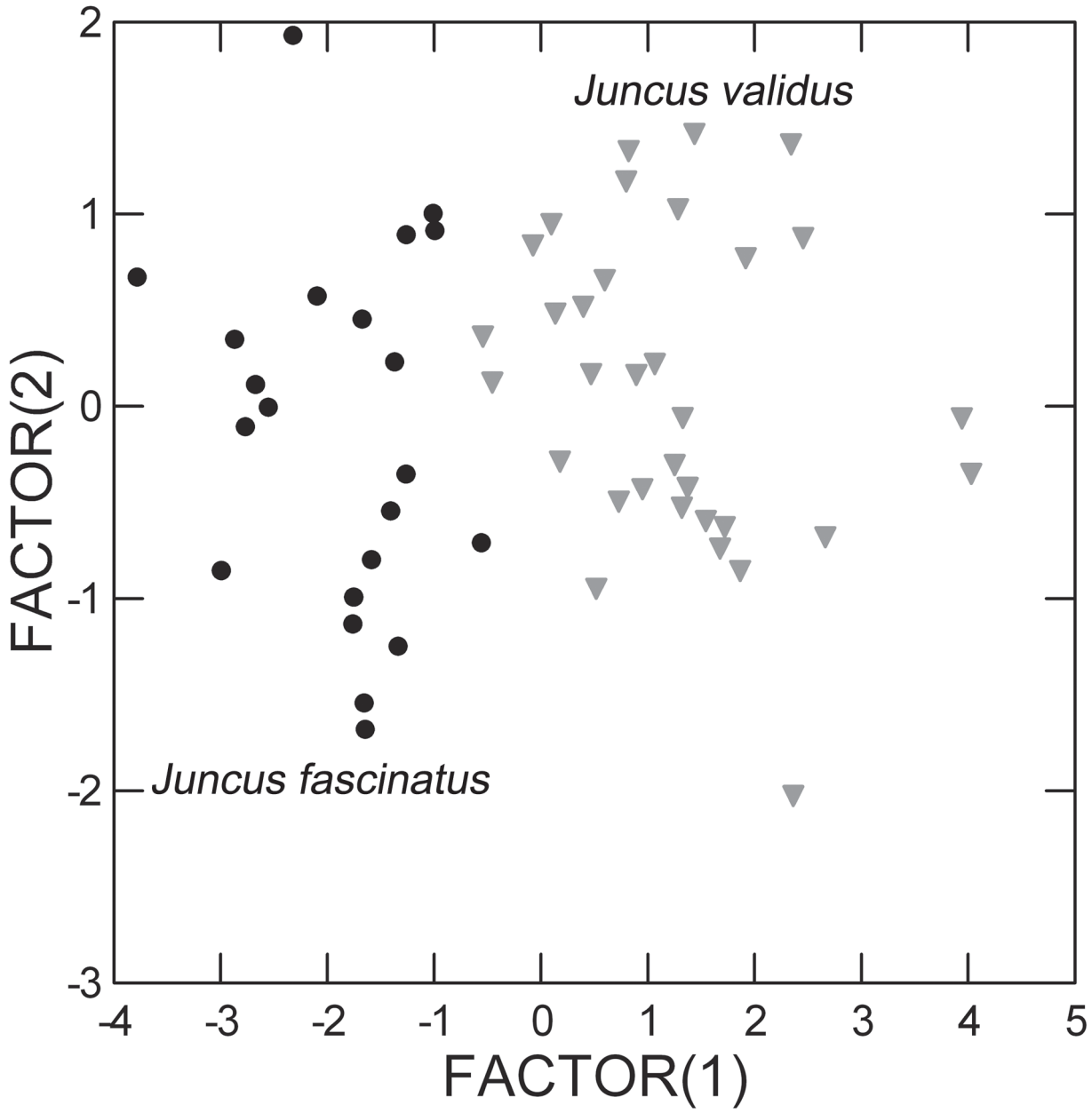

FIGURE 2. Scatterplot of the factor scores of PCA loadings I and II of 55 specimens. Circles represent *J. fascinatus* (N = 22) and triangles represent *J. validus* (N = 33).

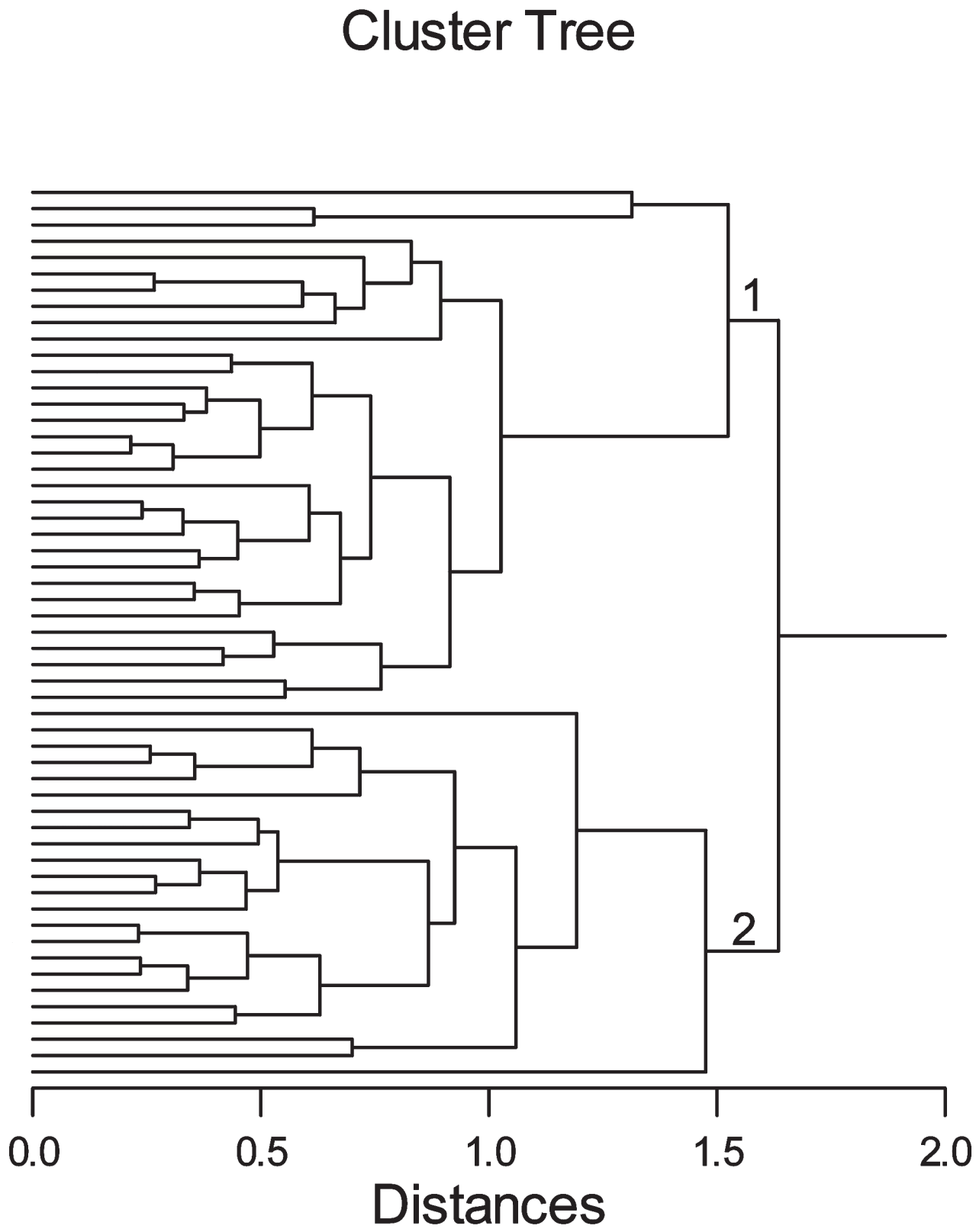

FIGURE 3. Cluster Analysis of the 55 specimens measured. *J. validus* = group 1, and *J. fascinatus* = group 2.

New records of other species

Examination of specimens as part of this study also resulted in the discovery of new records for *J. paludosus* from Alabama (*C. Mohr s.n.*, US; *S. Orzell & E. Bridges 20312*, FLAS), Georgia (*W. Duncan 1290*, FLAS; *R. Thorne 4709* NY, *R. Thorne 4575*, US; *V. McNeilus 01–266*, NY), Louisiana (*G. Giltner 72*, LSU; *A. Dufrene & B. Rhodes 2887V60–4*, LSU), and South Carolina (*R. Godfrey & R. Tryon 484*, NY). *Juncus polycephalos*, a species of the

southeastern coastal plain, is documented from a single markedly disjunct collection from Harvey Co., Kansas (*L. Harms 1228* KANU).

FIGURE 4. Specimen of *Juncus fascinatus* (A) with inserts showing mature capsule (B), leaf ligule (C) and leaf septa (D). Specimen and leaf morphology image *R. Fleetwood 10361* MO, ligule image *D. Correll & I. Johnson 17284* FSU, capsule image *B. Tharp 10559* FSU. Scale bar = 1 mm.

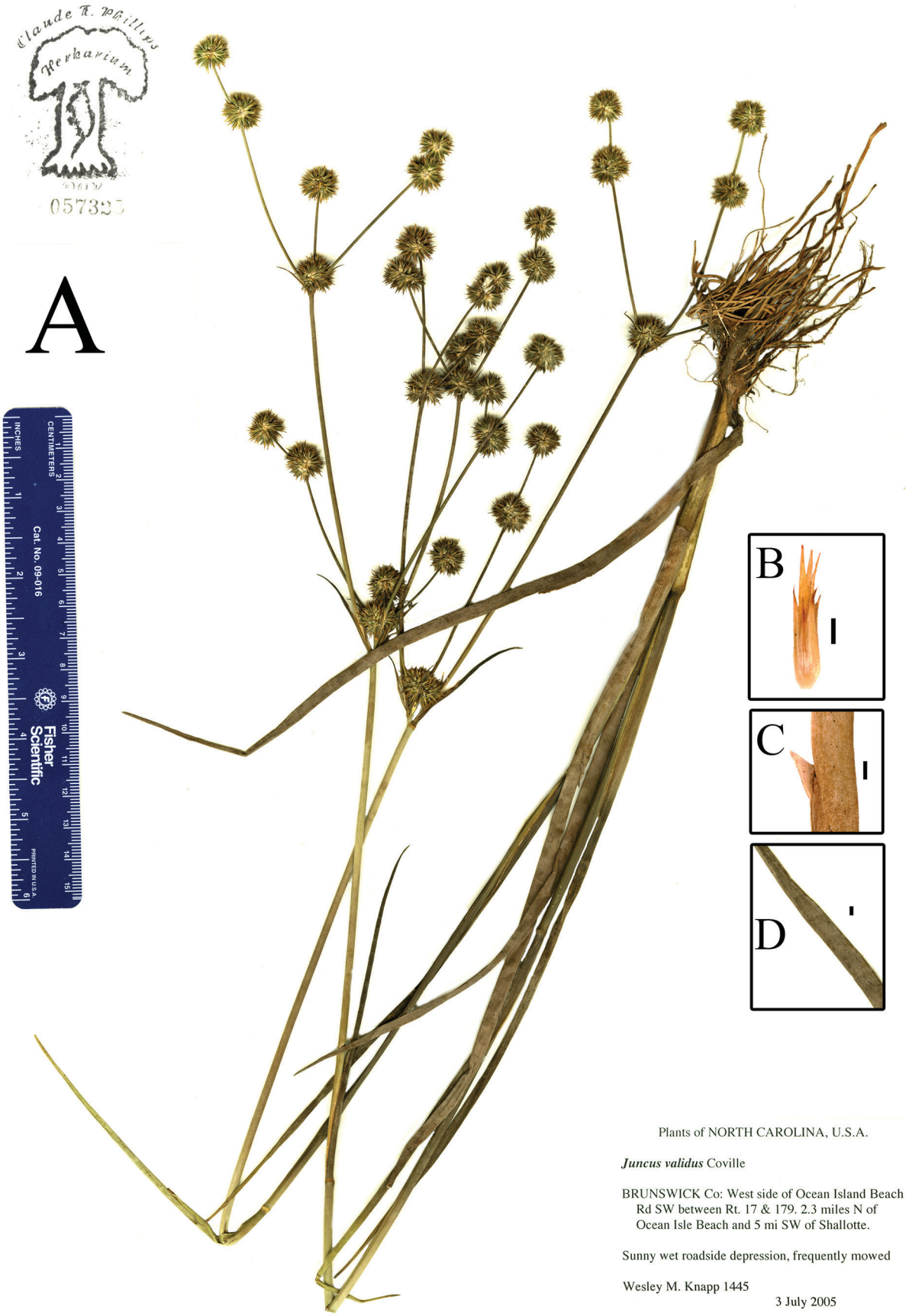

FIGURE 5. Specimen of *Juncus validus* (A) with inserts showing mature capsule (B), leaf ligule (C) and leaf septa (D). Specimen, ligule, and leaf morphology image *Knapp 1445* DOV and capsule image *McNeilus 98-484* DOV. Scale bar = 1 mm.

FIGURE 6. Specimen of *Juncus paludosus* (A) with inserts showing mature capsule (B), leaf ligule (C) and leaf septa (D). Specimen and leaf morphology image *G. Giltner 72* LSU, capsule image *S. Orzell & E. Bridges 20312* FLAS, and ligule image *L. Anderson 10582* FSU. Scale bar = 1 mm.

FIGURE 7. Specimen of *Juncus paludosus* (A) with inserts showing mature capsule (B), leaf auricle (C) and leaf septa (D). Specimen photo *R. Kral 96539B* DOV, capsule and auricle *A. Curtis 4940* DOV. Scale bar = 1 mm.

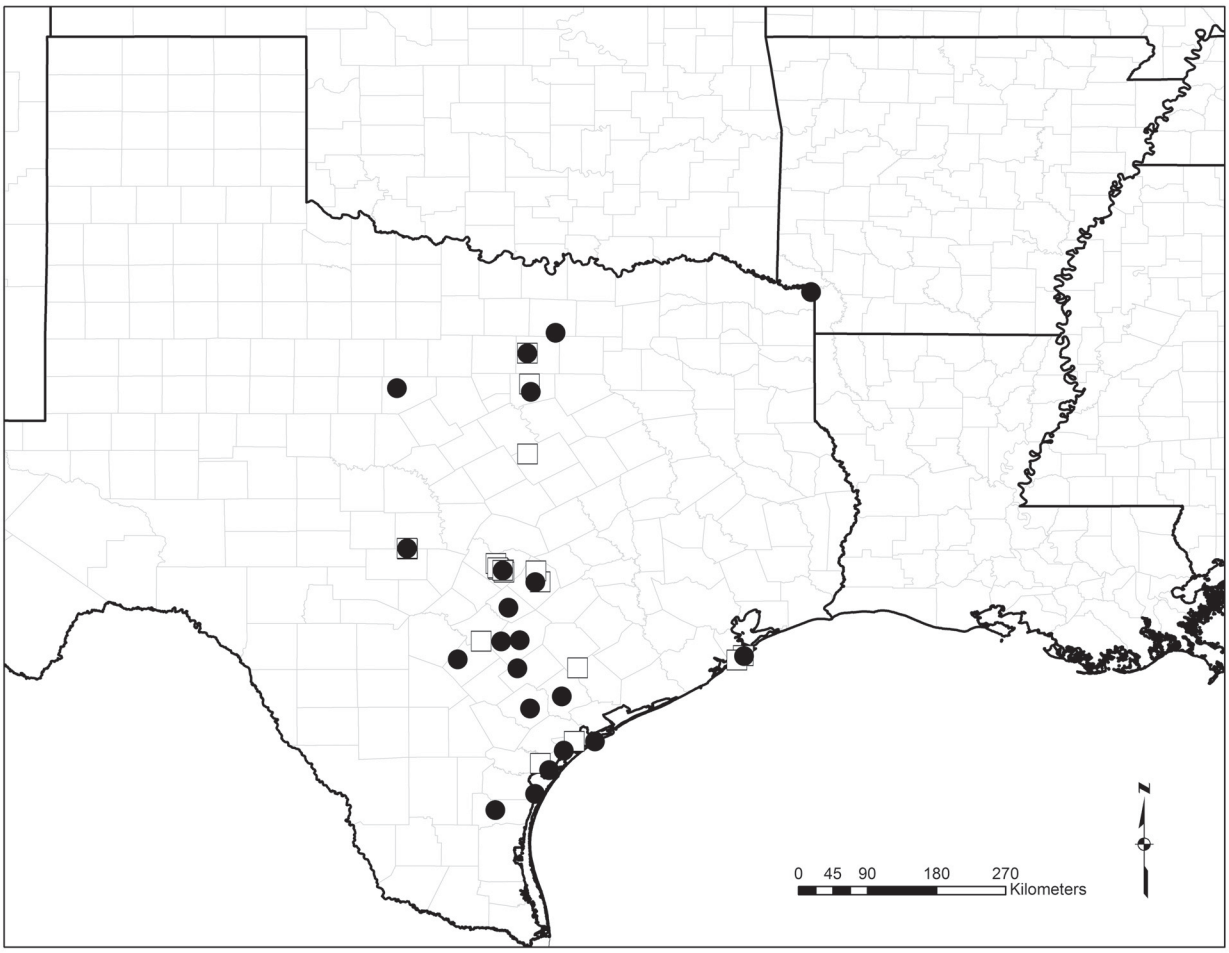

FIGURE 8. Geographic distribution of *J. fascinatus*. Circles represent the locations of specimens measured for analysis. Squares represent locations of specimens not measured.

Discussion

Morphologic characters can easily and reliably distinguish *J. fascinatus* from *J. validus*. Given there is no overlap in morphology between taxa, *J. fascinatus* is best treated as a distinct species. Given how distinct *J. fascinatus* is from *J. validus* it is somewhat surprising it had not been recognized at the species level before. This is probably due to the confusion surrounding *J. polycephalos*. Most specimens of *J. fascinatus* were initially identified as *J. polycephalos*, presumably based upon similar capsule morphology. *Juncus polycephalos*, however, is classified in section *Iridifolii*, which is likely paraphyletic (Kirschner 2000), but circumscribed as having ensiform leaves with incomplete leaf-septa (Kirschner 2002). Confusion between *J. polycephalos* and members of section *Ozophyllum* (*J. fascinatus, J. paludosus* and *J. validus*) is common throughout the range of *J. validus*.

NatureServe (2014) gives S- (State) and G- (Global) ranks of S4/G4 (apparently secure) for *J. fascinatus* [=*J. validus* var. *fascinatus*]. This S-rank appears incorrect. Of seven botanists I polled who work in Texas only one was directly familiar with this species. Additionally, I have seen only three collections dated post- 1980 (*W. Carr 7548* BRIT, *W. Carr 23452* BRIT, & *W. Carr 11994* TEX). If the rank of S4/G4 is correct the populations that exist must be large and overlooked. I recommend this species be considered a priority for inventory in Texas so that accurate S- and G-ranks may be determined. Given the uncertainty of numbers and sizes of extant populations the IUCN Red List category of Data Deficient (DD) is most appropriate (IUCN 2012).

Inferring the geographic range of a species based on herbarium records can be risky. In this case, I believe it accurately documents a clear trend that *J. validus* has spread over time and its nativity should be questioned in much of its current range (Fig. 9). Currently, only the States of Delaware, Maryland, and Virginia consider *J. validus* non-native

(NatureServe 2014, Knapp *et al*. 2011). The States of Kansas, Kentucky and Missouri list *J. validus* as S1 (critically imperiled) and North Carolina lists *J. validus* as S2 (imperiled, NatureServe 2014). I strongly advise the States of Kentucky and North Carolina to drop *J. validus* as a conservation priority. Given the very early collections of *J. validus* in eastern Kansas and western Missouri, it is likely native to these States; however, recent documentation in eastern Missouri and now its addition to the Illinois flora suggest its range is expanding here. Protection for this species should be weighed carefully in Missouri and Kansas. I believe the single pre-1900 collection from Mississippi is the first documentation of this species' spread eastward. This hypothesis is further supported by the presence of only two specimens from east of the Mississippi River pre-1930 (Table 3, Fig. 9). The decades of most rapid range expansion appear to be the 1950s and 1960s when *J. validus* was first documented in Florida (eight locations), Maryland (one location), North Carolina (nine locations), South Carolina (four locations), Tennessee (two locations), and Virginia (one location, Table 3). Additionally, Mississippi had only two locations pre-1950, yet in the 1950s and 1960s an additional 12 locations were documented. *Juncus validus* has been reported from Kentucky, but no specimens could be located for this study (NatureServe 2014). A similar pattern of range expansion was published for *J. diffusissimus* (Lamont & Young 2005).

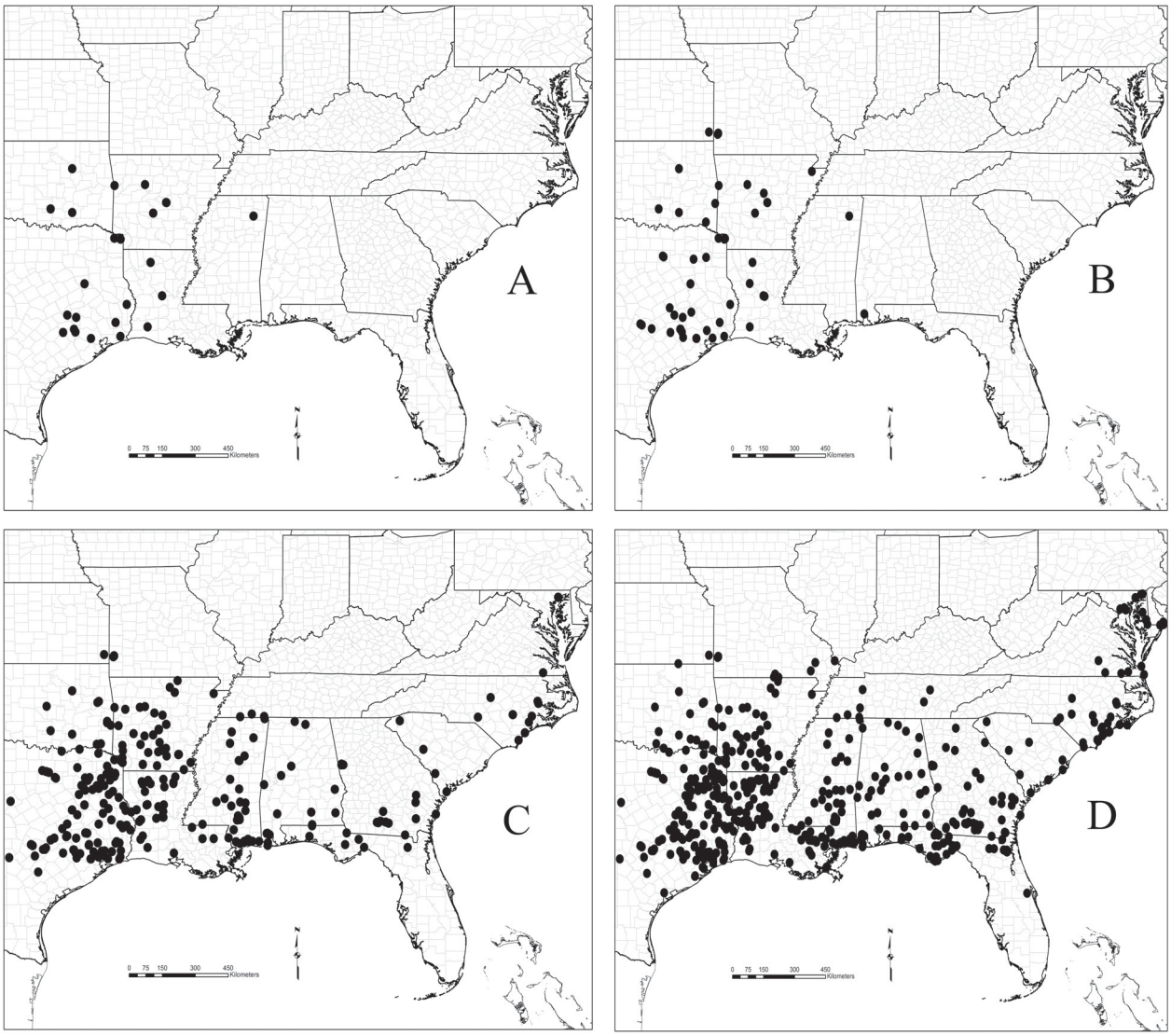

FIGURE 9. Geographic range of *J. validus* over time. A: Specimens dated pre-1900. B: Specimens dated pre-1930. C: Specimens dated pre-1970. D: Specimens dated pre-2014.

The same confusion that clouded the proper taxonomic rank of *J. fascinatus* also surrounded *J. paludosus*, which was recently described as a Florida endemic (Bridges & Orzell 2008). Before its description, nearly all specimens of *J. paludosus* were identified as *J. polycephalos*. The discovery of *J. paludosus* specimens from Alabama, Georgia,

Louisiana, and South Carolina expand the known range of this species outside of Florida. *Juncus paludosus* is not considered rare in Florida (Bridges and Orzell 2008), but it seems rare outside of Florida having only been documented from the eight specimens cited above.

Manuals universally spell *J. polycephalos* with a –us ending (*J. polycephalus*; e.g., Gleason & Cronquist 1991, Brooks & Clemants 2000), but this spelling is incorrect. The genus name has a –us ending, but Michaux chose to use the –os ending for the species (1803). Although Michaux's choice is not a preferred one, the epithet is not correctable (K. Gandhi pers. comm.). *Juncus polycephalos* is predominantly a species of the Atlantic Coastal Plain found from North Carolina south to Florida, and west to Texas. A single inland specimen from Kansas (*Harms 1228* KANU) was seen. It is possible this specimen is the result of a labeling error, given it is approximately 965 km (600 miles) disjunct from the next closest known population in eastern Texas. The location of this specimen, "Sand dune pond area 3.5 mi N of Burrton", is an area of significance known to support 38 species of rare vascular plants, including *J. scirpoides* Lamarck (1789: 267), suggesting it could be naturally occurring here (C. Morse pers. comm. Feb. 2014).

Taxonomic treatment

Juncus fascinatus (M.C. Johnston) W. Knapp, *comb*. et. *stat. nov*. BASIONYM: *Juncus validus* var. *fascinatus* M.C. Johnston (1964: 313). TYPE:—U.S.A. Texas. Llano Co.: edge of stream at base of Enchanted Rock, 29 June 1957, *D.S. Correll & I.M. Johnston 17284* (holotype LL!, isotype FSU!)

Perennials, 35–85 cm tall, rhizomatous or subcaespitose. Rhizomes short-creeping, 2 mm in diameter, not tuberous, horizontal, branched. Cataphylls absent; leaves flat, elliptical in cross section, laterally compressed, 2–4.5 mm wide, 11.5–25 mm long, tip acute, unitubular septa externally obscure to ±distinct in dry condition; auricles 0.8–1.3 mm long, acute, membranous. Lower bract leaf-like, green becoming castaneous, linear, 3–13 cm long, shorter than or surpassing than the inflorescence, erect or more commonly spreading to reflexed; other bracts castaneous, linear to lanceolate, 0.9–3 mm long. Inflorescence of 3–20 heads, 2.8–15(–20) cm long, 2–11 cm wide, relatively narrow and congested in appearance; heads spherical, 45–80 flowers per head, 12–15 mm in diameter. Tepals sub-equal, lanceolate-subulate, green to reddish, acuminate, inner tepals 2.4–3 mm long, outer tepals 3–4 mm long. Stamens 3, concealed by tepals; anthers 0.3–0.5 mm long; filaments 1.2–1.5 mm long; style ±absent, ca. 0.1 mm long; stigmas 0.3–0.4 mm long. Capsules unilocular, lanceolate in outline 3–4.5 mm long, tapering to a subulate beak of 0.5–1.4 mm long, stramineous, equaling to exceeding perianth; valves fused apically at dehiscence. Seeds ovoid to broadly ovoid, apiculate, 0.3–0.6 × 0.2–0.3 mm, pale brown, reticulate; appendages absent.

Representative specimens examined (* = specimen examined for statistical analysis):—UNITED STATES OF AMERICA. Texas: [no county indicated], 1888, *G. Nealley s.n.* (US). Aransas Co., loose sand, Goose Island State Park, 4 August 1954, *M. Johnston 541251* (TEX*); pond in open woodlands N of Aransas Co. airport, 7 June 1958, *D. & H. Correll 18985* (LL); Aransas National Wildlife Refuge, sandy depressions ca. 2 mi W of headquarters, 15 May 1961, *F. Jones 4806* (TEX). Bastop Co., 14 August 1936, *B. Tharp 10504* (TEX*); Civilian Conservation Corp Plant Project, Bastrop State Park, November–December 1936, [no collector given] *s.n.* (TEX, US); ca. 0.5 mi NW of entrance to Greenbriar Free School and 1.9 air miles NW of Railroad trestle at Sayersville, 13 June 1986, *W. Carr 7548* (BRIT). Bowie Co., wet places N. Texarkana, 22 July 1896, *H. Eggert s.n.* (MO*); 9 June 1989, *H. Eggert s.n.* (MO). Burnet Co., Granite, Mountains, Fairland, 7 May 1920, *B. Tharp 128* (TEX, US). Caldwell Co., 19 June 1927, *E. Bogusch 10555* (TEX*). Calhoun Co., Civil War trench about half way across Matagorda Island, 19 July 1973, *R. Hartman & J. Smith 3635* (TEX*). Denton Co., Post Oak Belt, ca. 6 mi. N of Grapevine, 2 August 1946, *E. Whitehouse 16433* (SMU*). DeWitt Co., western DeWitt County, 20 July 1941, *M. Riedel s.n.* (MO, TEX*). Eastland Co., ca. 2 mi E of Cisco, 20 June 1946, *B. Warnock 46390* (TEX*). Galveston Co., Galveston Island, 30 May 1924, *B. Tharp 2882* (LL, NA, NCU); 0.75 mi S of San Luis Pass Rd on Steward Beach Rd, 15 August 1966, *J. Mears 756* (TEX*). Headquarters Falveston [*sic*] Island State Park, 9 June 1973, *R. Fleetwood 10361* (MO). Goliad Co., N of Sarco Creek 100–300 ft. E of main road to Rincon Pasture, 17 June 2004, *W. Carr 23452* (BRIT*). Gonzales Co., marsh, *10 June 1926, E. Bogusch 2230* (TEX*). Guadalupe Co., Halff Ranch, 2 mi E of Leesville, 15 August 1940, *W. Kellogg 35* (TEX*, PH); Red Sand 7 mi S of Sequin, 16 July 1958, *D. Correll & I. Johnston 19680* (LL, NA, UNC). Johnson Co., wet places N. Buchanan, 13 June 1898, *H. Eggert s.n.* (MO). Cleburne, 30 August 1929, *E. Whitehouse s.n.* (TEX*); Horseshoe Lake, 7 June 1937, *Drushel 10620* (US*). Kleberg Co., eastern part of Laureles Division of King Ranch, 7 July 1954, *M. Johnston 541184* (TEX*). Llano Co., Enchanted Rock, 13 June 1930, *E. Whitehouse s.n.* (TEX*);

Enchanted Rock, 4 August 1930, *E. Whitehouse 9198* (TEX); gravelly streambed of Sandy Creek, S of campground at Enchanted Rock, 23 July 1976, *M. Butterwick & J. Lamb 2957* (TEX). McLennan Co., Patton, 22 July 1929, *B. Tharp s.n.* (TEX). Nueces Co., N side of Yorktown Blvd and E of Flour Bluff Dr., Naval Auxiliary Landing Field, Waldron, 8 June 1992, *W. Carr 11994* (TEX*). San Patricio Co., marshy field, Aransas Pass, 31 May 1968, *F. Gould 12532* (LL, PH). Tarrant Co., low wet sandy ground, 3 August 1921, *A. Ruth 906* (NY, US); shallow water below Lake Worth Dam, 1 August 1940, *W. McCart 2125* (TEX*). Travis Co., 1 mi beyond Montopolis bridge on Del Valle Rd, 25 May 1921, *B. Tharp 952* (NY); 4 June 1921, *B. Tharp 949* (NY, PH, TEX); Austin, 3 June 1921, *B. Tharp s.n.* (MO); Colorado River, Austin, 10 August 1936, *B. Tharp s.n.* (MO, NY, US); Colorado River, Austin, 10 August 1936, *B. Tharp 10559* (FSU, LL*); Colorado River, Austin, 17 May 1937, *B. Tharp 10552* (MO, NY); Colorado River, Austin, 17 May 1937, *B. Tharp 10558* (MO, TEX); Colorado River, Austin, 17 May 1937, *B. Tharp s.n.* (MO, NY); Colorado River, Austin, 19 May 1939, *B. Tharp 44307* (MO, NY, NCU, TEX, BRIT). Victoria Co., 14 June 1923, *B. Tharp 2205* (TEX*). Wilson Co., 4.75 mi NW of Floresville, 24 June 1935, *V. Cory 15061* (NY*).

Juncus validus Coville (1895: 305). TYPE:—U.S.A. Arkansas. Fort Smith to Choctaw Agency, 3 December 1887, *J. Bigelow s.n.* (lectotype LE!, designated by Kirschner & Drábková 2007: 603)

Perennials, 40–100 cm tall, rhizomatous or subcaespitose. Rhizomes short-creeping, 2 mm in diameter, not tuberous, horizontal, branched. Cataphylls absent; leaves flat, elliptical in cross section, laterally compressed, 3–5 mm wide, 11.5–25 cm long, unitubular septa externally obscure to ±distinct in dry condition; tip acute; auricles 1–3 mm long, acute, membranous. Lower bract leaf-like, green becoming castaneous, linear, 5–13 cm long, shorter than or surpassing than the inflorescence, erect or more commonly spreading to reflexed; other bracts castaneous, linear to lanceolate, 1–3 mm long. Inflorescence of 9–48 heads, 10–39(–45) cm long, and (6–)9–27 cm wide, wide and loose in appearance; heads spherical, 45–80 flowers per head, 12–15 mm in diameter. Tepals sub-equal, lanceolate-subulate, green to reddish, acuminate, inner tepals 3–3.9 mm long, outer tepals 3.8–5 mm long. Stamens 3, concealed by tepals; anthers 0.5–0.6 mm long; filaments 1.2–1.8 mm long; style ±absent, ca. 0.1 mm long; stigmas 0.3–0.4 mm long. Capsules unilocular, lanceolate in outline 4.4–6 mm long, stramineous, obviously exceeding perianth; valves completely separating at dehiscence. Seeds ovoid to broadly ovoid, apiculate, 0.4–0.6 × 0.2–0.3 mm, pale brown, reticulate; appendages absent.

Representative specimens examined (* = specimen examined for statistical analysis):— UNITED STATES OF AMERICA. Alabama: Calhoun Co., stream at culvert, Pellham Range, Fort McClellan Military Post 10 mi WNW of Anniston, 25 July 1979, *R. Haynes 7470* (NY*). Mobile Co., shore and vicinity, Munroe Park on Mobile Bay, 23 Sep 1912, *H. Bartlett 3200* (BALT*, NCU). Arkansas: Whipple's exploration from Fort Smith to the Rio Grand, 22 July–23 July 1853–1854, *J. Bigelow s.n.* (US). Bradley Co., pond margins, Banks, 4 July 1939, *D. Demaree 19538* (MO*). Columbia Co., margins of shallow water in ditches and ponds, Magnolia, 26 June 1957, *D. Demaree 39211* (FSU*). Johnson Co., bottoms of Piney Creek, Knoxville, 13 August 1939, *D. Demaree 19918* (MO*). Delaware: Sussex Co., Bethany Beach along Rt. 1 ca. 0.5 mi N of Fred Hudson Rd, 2 July 2006, *Longbottom et al. 7586* (DOV, PH). Florida: Gadsden Co., roadside ditch, ca. 1.0 mi W of the Ochlockonee River along US 20, 6 June 1956, *P. Redfern Jr 2192* (NY). Johnson Co., ditch 7 mi S of Wacissa near Rt 59, 22 June 1976, *R. Godfrey 75143* (MO*). Liberty Co., Johnson's Juniper Swamp 7 mi S Bristol on SR 379, 15 August 1967, *S. Olson & E. Bishop s.n.* (FSU*). Orange Co., ditch beside Wheeler Rd, Christmas, 29 July 1992, *D. Hanf s.n.* (FLAS*). Walton Co., marshy borders of swampy woodland ca. 2 mi W of Paxton, 26 June 1964, *R Godfrey 64387* (FSU). Georgia: Echols Co., wet sandy woods 1.3 mi N of GA-FL line, 8.0 mi SW of Fargo, 21 July 1969, *W. Faircloth 5885* (MO*). Heard Co., moist soil over flat granite rock, 4 mi SW of Franklin, 30 May 1937, *J. Pyron & R. McVaugh 1748* (GA). Lanier Co., low area along Rt. 37 ca. 1.0 mi E of Lakeland, 28 June 1998, *V. McNeilus 94–484* (DOV). Illinois: Alexander Co., muddy shore across from preserve managers house, Horseshoe Lake, 22 May 2006, *R. Mohlenbrock 18991* (MO). Kansas: Cherokee, [no collection date, but label says "purchased in 1913"], *G. Letterman s.n.* (US). Louisiana: Bienville Parish, low clay soils, Arcodia, 10 August 1898, *C. Ball 257* (US). Jackson Parish, swampy woods beside LA 34, one mi S of Eros, 19 September 1972, *R. Thomas & P. Cicala 31895* (FLAS*). Sabine Parish, 1 mi above spillway at waters edge of Toledo Bend reservoir, Lake Charles, 5 July 1970, *G. Giltner 457* (LSU*). Tangipahoa Parish, wet roadside ditch along LA 1067 0.5 mi N of I-12 overpass and 3 SW of Robert, 12 June 1978, *C. Allen 8182 & K. Vincent 1238* (BALT*). Maryland: Harford Co., ditch along railroad ca. 0.75 mi SE of Abington, 15 August 1969, *E. Baltars 4433* (US). Wicomico Co., N and S of Rt 313 1.5 mi W the town of Maryldel, 27 July 2005, *W. Knapp 1550* (DOV*). Mississippi: Jones Co, highline right-of-way 10 mi S of Laurel, 2 July 1963, *J. Teer s.n.* (FSU*). Lafayette Co., Hurricane Creek, 9 mi NW of Oxford, 24 July 1958, *S. McDaniel 970* (MO*). Lee Co., Tupelo, 6 September 1890, *S. Tracy 1586* (US). Missouri: Jasper Co., wet

sandy soil N of North Fork Spring River, Neck City, 20 June 1909, *E. Palmer 2300* (MO); wet sandy soil, Alba, 7 July 1909, *J. Palmer 2430A* (MO*). Wayne Co., Judy & Mic Plunkett Farm, 37°04'25', N 090°11'14"W, 8 July 2008, *A. Brant & J. Plunkett 6655* (MO*). North Carolina: Beaufort Co., waste place near US 17, 1 mi SW of Washington, 6 July 1958, *A. Radford & W. Batson Jr. 36101* (FSU*). Brunswick Co., W side of Ocean Isle Beach Road between Rt. 17 & 179, 2.3 mi N of Ocean Isle Beach and 5 mi SW of Shallotte, 3 July 2005, *W. Knapp 1445* (DOV*). Onslow Co., flat pine-oak woods 3.3 mi NE of Haw, 14 June 1957, *H. Ahles et al. 28143.* Oklahoma: chiefly on the False Washita between Fort Cobb and Fort Arbuckle, 1868, *E. Palmer 318* (US). McCurtain Co., roadside ditch 4 mi W & 1.4 mi S of Haworth, 5 July 1983, *C. Taylor 31934* (LSU*). South Carolina: Beaufort Co., roadside ditch 3.5 mi NW of Old Hilton Head Ferry landing, NNE of Bluffton, 28 June 1958, *H. Ahles et al. 15620* (NCU). Charleston Co., Santee Coastal Reserve, Washo Reserve west end at Rt 71, 16 July 1992, *S. Hill 23753* (NY*). Tennessee: Benton Co., roadside seep, 3.8 mi W of jct of US 70 and US 641, W side of Camden, 3 Aug 1980, *D. & B. Webb 3226* (NY*). Cumberland Co., low exposed roadside along Rt 70N at Mayland, 24 July 1999, *V. McNeilus 99–539* (DOV*). Hardin Co., roadside ditch on N side of TN 69, 1.1 mi W of jct TN 69 and TN 104, 2.5 mi W of Saltillo, 1 July 1982, *D. Webb 4614* (NY*). McNairy Co., 8 mi E of Hardeman, McNairy Co. line, wet ditch, 22 June 1965, *K. Rogers 33627* (NCU). Texas: Bastrop Co., local in disturbed clearing, 2.5 air miles N or jct of Rt 21 and F.M. 1441, 27 June 1988, *W. Carr 9016* (TEX)*. Bowie Co., Texarkana, 9 July 1923, *B. Tharp 2209* (TEX*). Caldwell Co., spring-summer, *J. McBryde s.n.* (TEX*). Gryson Co., Waterloo Lake 1 mi SW of Denison, 21 Oct 1949, *E. Bonn 51–454* (TEX*). Harris Co, wet shady woods near Houston, May & June 1842, *F. Lindheimer s.n.* (MO). Leon Co., roadside ditch Normangee State Park, 12 June 1946, *D. Correll & H Correll 12649* (FSU*). Van Zandt Co., moist sands of bog margin, 2.5 mi SE of Ben Wheeler, 19 June 1955, *R. Kral 1200* (FSU*). Virginia: Isle of Wright Co., sandy pine barren about 3 mi SE of Franklin, 16 July 1967, *A. Harvill 17062* (US).

Key to morphologically similar species of *Juncus* sect. *Ozophyllum* and *J. polycephalos* (sect. *Iridifolii*) of North America, north of Mexico.

1 Leaves with incomplete septate bands; auricles poorly developed, <0.5 mm. ***Juncus polycephalos* Michaux**
- Leaves with complete septate bands; auricles well developed, >0.5 mm, forming a distinct ligule. 2
2 Capsules separating at maturity into three distinct portions. 3
- Capsules remaining united at apex at maturity, forming a prominent beak of >0.5 mm. 5
3 Largest tepals 4–5 mm long; leaves laterally compressed. ***Juncus validus* Coville**
- Largest tepals 2.9–4 mm long; leaves terete. 4
4 Capsules 3.5–5 mm long, exceeding tepals; culms 0.4–3 dm. ***Juncus nodosus* Linnaeus** (1762: 466)
- Capsules 3–3.5 mm long, slightly included within or equaling tepals; culms 2.5–8.5 dm. ***Juncus bolanderi* Engelmann** (1868: 470)
5 Leaves laterally compressed, flattened, elliptical in cross-section, septate bands of leaves often externally obscure. ***Juncus fascinatus* (M.C. Johnston) W. Knapp**
- Leaves strictly terete, rounded or channeled, circular in cross-section, septate bands of leaves often prominent and ring-like. 6
6 Culms 4–8 mm in diameter near base, usually > 80 cm tall; inflorescence usually >15 cm tall with > 25 heads; longest leaf blade >25 cm long and >3 mm wide. ***Juncus paludosus* E.L. Bridges & Orzell**
- Culms 1–3 mm in diameter near base, usually <80 cm tall; infl. usually <10 cm tall, with <25 heads; longest leaf blades <25 cm long and <2 mm in diameter. 7
7 Uppermost leaf blade well developed, equaling to longer than its sheath; heads spherical to lobed; tepals green to straw-colored, nearly equal in length; basal leaf sheaths and cataphylls straw-colored to brown. ***Juncus scirpoides* Lamarck**
- Uppermost leaf blade poorly developed, much shorter than its sheath; heads strictly spherical; tepals reddish to reddish brown, the inner tepals somewhat shorter than outer; basal leaf sheaths and cataphylls deep reddish purple. ***Juncus megacephalus* Curtis** (1835:132)

Representative specimens examined of *J. paludosus* and *J. polycephalos*

Juncus paludosus E.L. Bridges & Orzell

UNITED STATES OF AMERICA. Alabama: Mobile Co., sandy swamps, 30 August 1896, *C. Mohr s.n.* (US). Houston Co., wet roadside through swampy forest N side of Cowarts Creek bridge on AL 55, ca. 1 mi NW of Grangeburg, 5.6 mi SE of Cottonwood, 1 Aug 1992, *S. Orzell & E. Bridges 20312* (FLAS). Florida: Franklin Co., floodplain edge of small island in Jackson River, 4.5 air mi NW of Appalachicola, 21 May 1987, *L. Anderson 10582* (FSU). Georgia: Bartow Co., moist soil at North Cat Pond, 4.5 mi E 33° S of Adairsville, 11 Aug 1951, *W. Duncan 12920* (FLAS). Calhoun Co., moist pineland, 3 mi E of Cordray's Pond, 14 June 1947, *R. Thorne 4709* (NY). Glynn Co., roadside ditch at Super 8 Motel, Brunswick, 11 June 2001, *V. McNeilus 01–266* (NY). Louisiana: Lafourche Parish, 5 mi NE of Raceland, US Highway 90 in roadside ditch, 26 April 1970, *G. Giltner 72* (LSU). Terrebone Parish,

coastal marsh, 29.520158°N, 90.9150489°W, 21.2 mile SW of Morgan City, 24 July 2009, *A. Dufrene & B. Rhodes 2887V60–4* (LSU). South Carolina: Berkeley Co., Santee Canal, NW of Bonneau, 12 July 1939, *R. Godfrey & R. Tryon 484* (NY).

Juncus polycephalos Michaux

UNITED STATES OF AMERICA. Florida: ditches near Jacksonville, 13 July 1894, *A. Curtis 4940* (DOV). Georgia: Thomas Co., S side of Thomasville E of "Loop' 319 junction, 31 May 2005, *R. Kral 96539B* (DOV). Kansas: Harvey Co., sand dune pond area, 3.5 mi N of Burrton, plants scattered and rare, 7 September 1963, *L. Harms 1228* (KANU).

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