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Coreopsis bakeri (Asteraceae; Coreopsideae), a new species from Florida, USA

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Abstract

Coreopsis bakeri (Asteraceae; Coreopsideae), an early blooming and very narrow-leaved perennial restricted to rare limestone glade habitats in northern Florida, is described as new. The plants most closely resemble *Coreopsis lanceolata*, a common species of the southeastern U.S., but have narrower, glabrous, and infolded leaves. In addition to phenotypic differences, the two species show divergence at two nuclear genes, the nuclear ITS and ETS regions, and for two chloroplast intergenic spacers (*psbA-trnH* and *rpl32-trnL*). Because of the rarity of *C. bakeri* and the very limited extent of its distinctive habitat, this species is in urgent need of protection. In addition, *C. lanceolata* is found in open areas near the limestone glades, and poses a potential threat through competition or hybridization.

Introduction

An early blooming species of *Coreopsis* L. (Asteraceae) with narrow, infolded, glabrous leaves from Jackson County, Florida, has been under observation for a number of years. Plants of this species are restricted to remnants of limestone glade habitats (Johnson *et al.* 2013). The glade plants most closely resemble *Coreopsis lanceolata* Linnaeus (1753: 908), a widespread, somewhat weedy species that has apparently had significant range expansion along fields and roadsides following disturbance by humans and as escapes from cultivation (Smith 1976; Weakley 2015). The glade plants have been shown to differ from *C. lanceolata* in both phenotypic (Johnson *et al.* 2013) and molecular characters (Schilling *et al.* 2014).

The limestone glade habitat is rare in Florida, found only in a few places in Jackson and Gadsden counties, where it forms the southeastern outpost of a series of calcareous prairies and glades found across the southeastern U.S. (Johnson *et al.* 2013). The calcareous openings in Florida are dominated by a member of the sedge family, *Schoenus nigricans*, not found on any of the other upland calcareous openings in the Southeast and are denoted as “Florida upland glades” by Johnson *et al.* (2013), to distinguish them from the classical “limestone cedar glades” found in Tennessee and surrounding states (Baskin & Baskin 2000). This community is designated as “upland glade” by the Florida Natural Areas Inventory and as “panhandle Florida limestone prairie” by NatureServe and given the highest rarity ranking (G1S1).

Coreopsis is a genus of about 35 species (Strother 2006) but its composition, boundaries, and particularly separation from *Bidens* L. have fluctuated and still remain unclear (Mort *et al.* 2008; Tadesse & Crawford 2014). Within the genus, *C.* section *Coreopsis* is well characterized by having 5-lobed disc corollas, cuneate and 4–5-toothed ray flower corollas, leaves with entire margins, and attenuate pales (Smith 1976). The nine species currently recognized in the section are native to eastern North America (Smith 1976; Crawford *et al.* 1990). The section is well supported as monophyletic based on molecular sequence data (Crawford & Mort 2005), but there are few differences among individual species for the nuclear ribosomal ITS region (Schilling *et al.* 2014). Many species of *C.* sect. *Coreopsis* are associated with open habitats, such as prairies, glades, and woodland edges. Isolated glades provide the opportunity for evolutionary divergence, and a new taxon, *C. grandiflora* var. *inclinata* Allison in Allison & Stevens (2001: 162), was recently described from the Ketona glades in the Bibb Co., Alabama region.

The Florida upland glade plants of *Coreopsis* differ slightly but consistently in morphology from *C. lanceolata*, and all other related species of *Coreopsis*. These differences are maintained in common gardens (Johnson *et al.* 2013).

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In addition to their phenotypic distinctions, data from molecular analyses presented here also show them to have slight but consistent genetic differences, suggesting that they have been reproductively isolated for long enough to diverge at the molecular level. We therefore propose treating them as a distinct, localized species, *Coreopsis bakeri*.

Materials and methods

Plants of *Coreopsis bakeri* were germinated from field-collected seed and grown at the University of Tennessee greenhouse facility and in an outdoor garden for morphological assessment and breeding studies. Of 16 plants grown from four different original seed collections, only three plants (one in the greenhouse, two in the outside garden) bloomed during the two year period of observations. Heads of the greenhouse plant were bagged to test for self-compatibility, and two heads were crossed with heads of *C. lanceolata* brought in from garden plants grown elsewhere.

Leaf material from three populations of *Coreopsis bakeri* was used for DNA extractions, and a survey was conducted of populations of *C. lanceolata* and other members of *C.* sect. *Coreopsis* using primarily herbarium material at TENN (Appendix). Extractions of genomic DNA were performed using the DNeasy Plant Mini Kit (Qiagen, Valencia CA). Results for the nuclear ITS region have been reported previously (Schilling *et al.* 2014), and sequences were also obtained for subsets of the samples for a portion of the nuclear ETS region using the primers 18S-ETS and Ast-1, as described in Schilling (2011). Several plastid intergenic spacer regions were also surveyed, including *trnH-psbA*, *trnL-trnL-trnF*, *trnQ-rps16*, and *rpl32-trnL*, using primers and conditions as described in Shaw *et al.* (2005; 2007). All DNA sequencing was performed with the ABI Prism BigDye Terminator Cycle Sequencing Ready Reaction kit, v. 3.1 (Perkin–Elmer/Applied Biosystems, Foster City, California, USA) and electrophoresed and detected on an ABI Prism 3100 automated sequencer (University of Tennessee Molecular Biology Resource Facility, Knoxville, Tennessee, USA). The initial sequence data text files were edited following comparison with the same data displayed in four-color electropherograms before they were analyzed further. Sequence alignment was performed manually. GenBank accession numbers are provided in the Appendix.

Results

Seeds of *Coreopsis bakeri* germinated readily without special treatment in less than a week, and the resulting plants retained their morphological distinctiveness compared to plants of *C. lanceolata* when grown in both the greenhouse and the garden in Tennessee. The leaves of plants of *C. bakeri* were narrower, infolded, usually unlobed, and had completely glabrous surfaces compared to those of *C. lanceolata*, consistent with the previous report (Johnson *et al.* 2013). Bagged heads of *C. bakeri* failed to produce filled cypselae (achenes). In contrast, the two heads that were crossed with heads of *C. lanceolata* produced filled cypselae; when planted, these germinated readily and produced vigorous seedlings (which are still under observation.) This result suggests that *C. bakeri* is self-incompatible, and that there is no barrier to hybridization between it and *C. lanceolata*.

The ETS sequences of samples of *Coreopsis bakeri* were almost identical to those obtained from samples of *C. lanceolata*, but differed at position "38" (relative to the 3' end of the 18S rDNA) by having an unambiguous A in contrast to the A/C polymorphism observed in *C. lanceolata* and other samples of *C.* sect. *Coreopsis*. This change mirrors the difference observed in the ITS sequences between *C. bakeri* and *C. lanceolata*, where *C. bakeri* was monomorphic for a length polymorphism at one position, and had a positional polymorphism (vs. fixed base) at a second compared to *C. lanceolata* (Schilling *et al.* 2014). Surveys of single samples of *C. bakeri* and *C. lanceolata* for several plastid spacer regions, including the *rpl16* intron, *trnF-trnL-trnL*, and *trnQ-rps16* regions gave identical sequences. The new data for the *rpl16* intron, as well as for a portion of *matK*, failed to support the results reported by Crawford & Mort (2005) showing a sample of *C. lanceolata* as distinct from other members of *C.* sect. *Coreopsis* for these markers. For two other regions, *trnH-psbA* and *rpl32-trnL*, there were differences between *C. bakeri* and *C. lanceolata* for lengths of poly-A regions and a single bp difference in the *rpl32-trnL* spacer. These results collectively showed small but consistent differences between *C. bakeri* and *C. lanceolata*, suggesting that although these are closely related they are genetically distinct species.

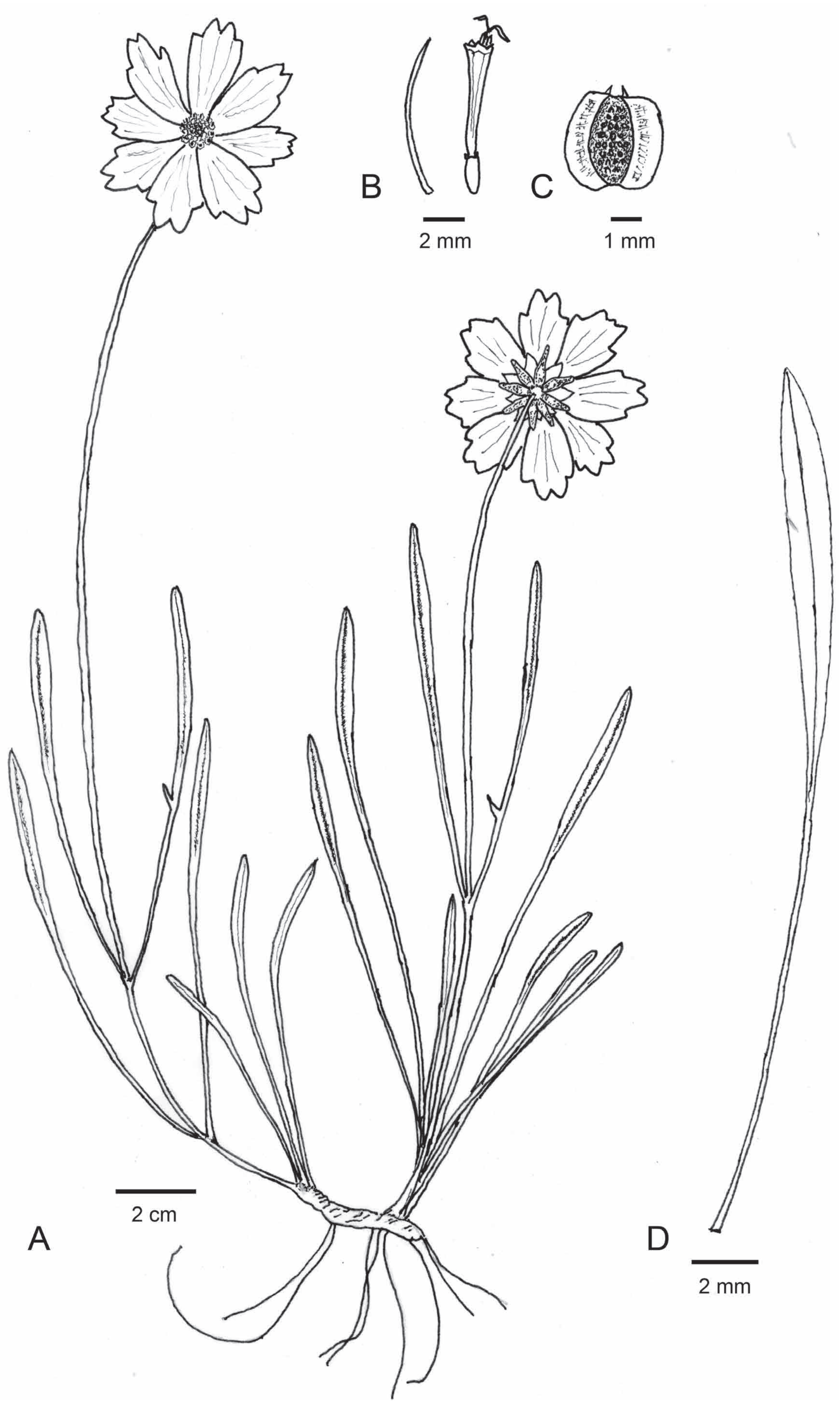

FIGURE 1. A–D. *Coreopsis bakeri*. A. Habit. B. Pale, Disk flower. C. Cypsela (achene). D. Leaf.

Taxonomy

Key to separate *Coreopsis lanceolata* and *C. bakeri*

1. Leaves linear-oblanceolate, infolded, unlobed, with surfaces completely glabrous .... *Coreopsis bakeri*
\- Leaves oblanceolate, flat to slightly incurved, the larger often basally lobed, surfaces at least shortly pubescent along veins...*Coreopsis lanceolata*

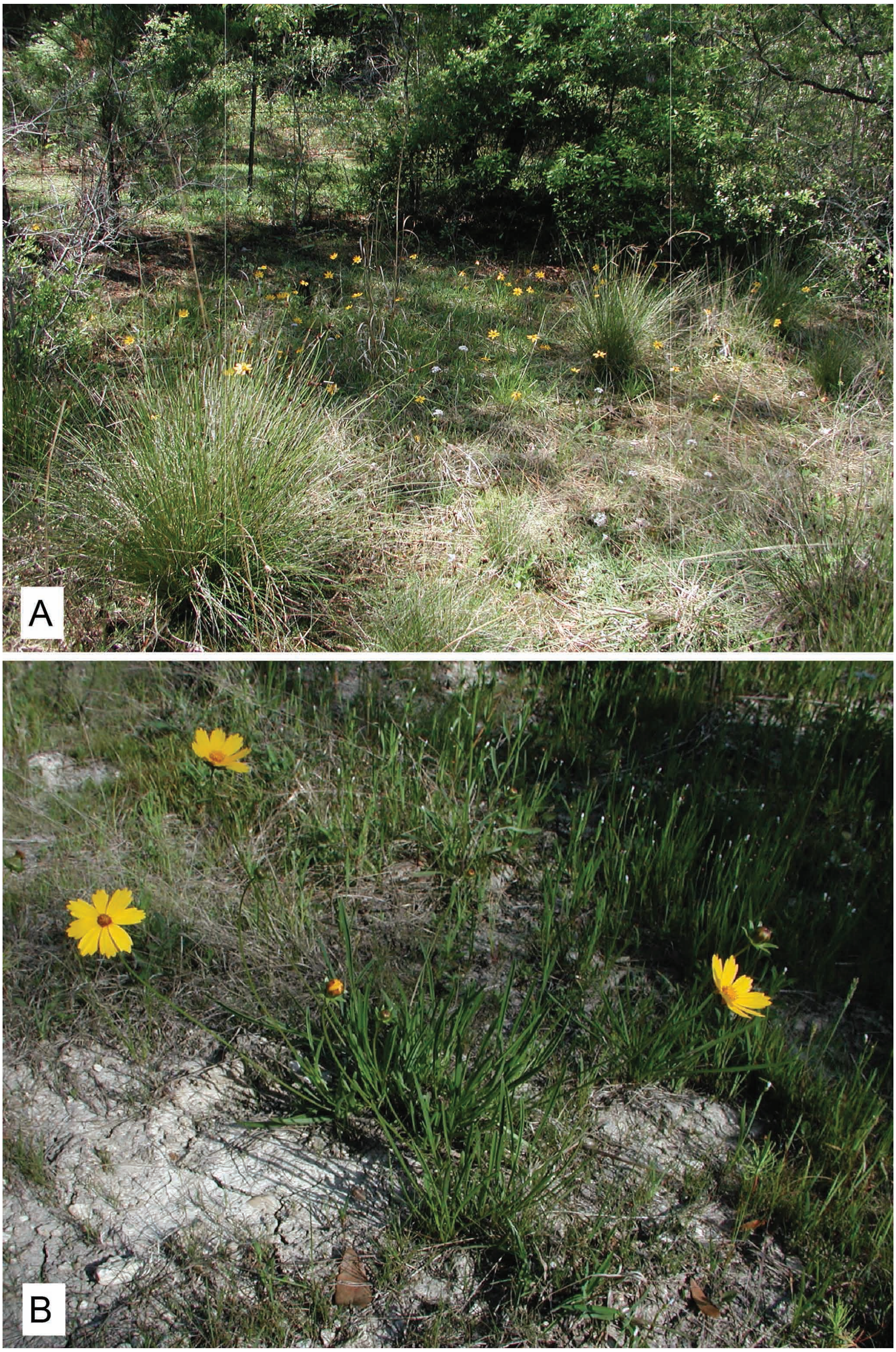

FIGURE 2. A–B. *Coreopsis bakeri*. A. Habitat, with blooming plants. B. Plants in bloom, showing substrate with exposed bare rock. Photographs taken by A. Johnson.

Coreopsis bakeri E. Schill., **sp. nov.**

Type:—USA. Florida: Jackson County, "Brooks 1" limestone glade. 30.81273° N, –85.25771° W; 48 m elev., 18 April 2013, *A. F. Johnson with W. Baker 10623* (holotype: FSU!; isotype: TENN!).

Diagnosis:—Resembling *Coreopsis lanceolata*, but differing by having narrower, infolded, unlobed, and completely glabrous leaf blade surfaces.

Laxly erect perennial 20–35 cm tall. Stems clustered, arising from a caudex 1–3.5 cm long, leafy below but elongate and naked above. Stems and peduncles ridged, glabrate, shortly papillose, 1.5–2 mm wide at base. Flowering stems with 1–2 pairs of leaves below the peduncles. Leaves linear to narrowly oblanceolate, usually unlobed or with 1–2 small lateral lobes, 11–29+ × 0.3–1.4 cm and 15–30 × as long as wide, infolded, stiff, surfaces glabrous, margins with a few minute appressed cilia. Heads usually solitary, peduncles 15–30 cm long, heads ca 4–5 cm wide between tips of opposite rays. Outer phyllaries narrowly ovate and attenuate, 6.5–8 × 2.5–3 mm; inner phyllaries ovate, acute, 9–11 × 3.5–4 mm. Ray flowers yellow, ligules 2–2.5 cm long, shallowly 4–5 toothed at apex. Disk flowers yellow, 5-lobed, 3.5–5 mm long. Chaffy bracts flat, long-attenuate, 7–8 mm long. Cypsela bodies blackish, papillose, 3–3.4 mm long, 1.4–1.8 mm wide; awns 0.5–0.9 mm long; wings brownish, 0.7–1.4 mm wide, entire. Chromosome number: unknown. Flowering March–April; fruiting June. Fig. 1, 2.

Additional specimens examined (paratypes):—USA, Florida, Jackson Co (in vicinity of town of Marianna): "Williams 2" limestone glade, 30.819035° N; –85.282282° W, 28 April 2009, *A.F. Johnson 10353a with Wilson Baker* (FSU); "Williams 3" limestone glade, 30.81791° N, –85.279409° W, 28 April 2009, *A.F. Johnson s.n. with W. Baker* (FSU); "west of SR 73" limestone glade, 30.779349° N, –85.275165° W, 28 April 2009, *A.F. Johnson 10360a with W. Baker* (FSU); "old car" limestone glade, 30.823771° N, –85.258544° W, 25 June 2008, *A.F. Johnson 10239a with W. Baker* (FSU); "Brooks 1" limestone glade, 30.812453° N, –85.257063° W, 25 March 2006, *L.C. Anderson 21598* (FSU).

Etymology:—The species is named for Florida naturalist, Wilson Baker, who, with Steve Leonard, discovered many of the Florida upland glades and some of their associated rare species in the 1980s and has worked with the owners to allow botanists access to them ever since.

Distribution and ecology:—USA, Florida, apparently endemic to Jackson County (Fig. 3). *Coreopsis bakeri* is consistently present on all nine known Jackson County glades, often in those portions with the thinnest soil or where bare rock is exposed (Fig. 2), in association with *Sporobolus vaginiiflorus* and *Rhynchospora divergens*. It was also found on five possible former glades—areas that had been altered by soil disturbance followed by the invasion of centipede grass (*Eremochloa ophiuroides*), a turf-forming lawn grass with which most other glades species cannot compete. It has not been found in other habitats in Jackson County, or on glades in Gadsden County (where *C. lanceolata* does occur; Johnson *et al.* 2013). Glades in the two counties are about 40 km apart, separated by the floodplain of the Apalachicola River, and occur on different geological substrates.

The Florida upland glade habitat of *Coreopsis bakeri* is largely in private ownership and is highly vulnerable to alteration. Only one of the nine known Jackson County glades has conservation status—a small glade on the property of Florida Caverns State Park. Since the nine glades were identified, two have been destroyed by mining and one damaged by plowing for a food plot. The remaining glades would probably best be protected by either conservation easement or purchase and addition to the state park. In view of its limited habitat and distribution, *C. bakeri* would likely warrant a G1S1 ranking by NatureServe, and an "endangered" ranking by the US Fish and Wildlife Service. In addition to habitat loss, another threat to the continued existence of *C. bakeri* may be posed by the presence of its congener, *C. lanceolata,* either through direct competition or by genetic assimilation through hybridization. Although *C. lanceolata* is now widespread in the eastern U.S., its original distribution has been suggested to be the central and southwestern U.S. (Cronquist 1980), making its nativity in Florida unclear. *Coreopsis lanceolata* has been documented to be a problem invasive in Japan (Saito & Okubo 2012), demonstrating its ability to occupy new habitats. Furthermore, our results that document successful crossing between *C. bakeri* and *C. lanceolata* coupled with those of Smith (1976), who reported relatively high fertility in some crosses between *C. lanceolata* and other members of *C.* sect. *Coreopsis*, suggests the potential for gene flow between the two species. Thus, further studies and monitoring of populations of *C. lanceolata* in the near vicinity of those of *C. bakeri* are needed.

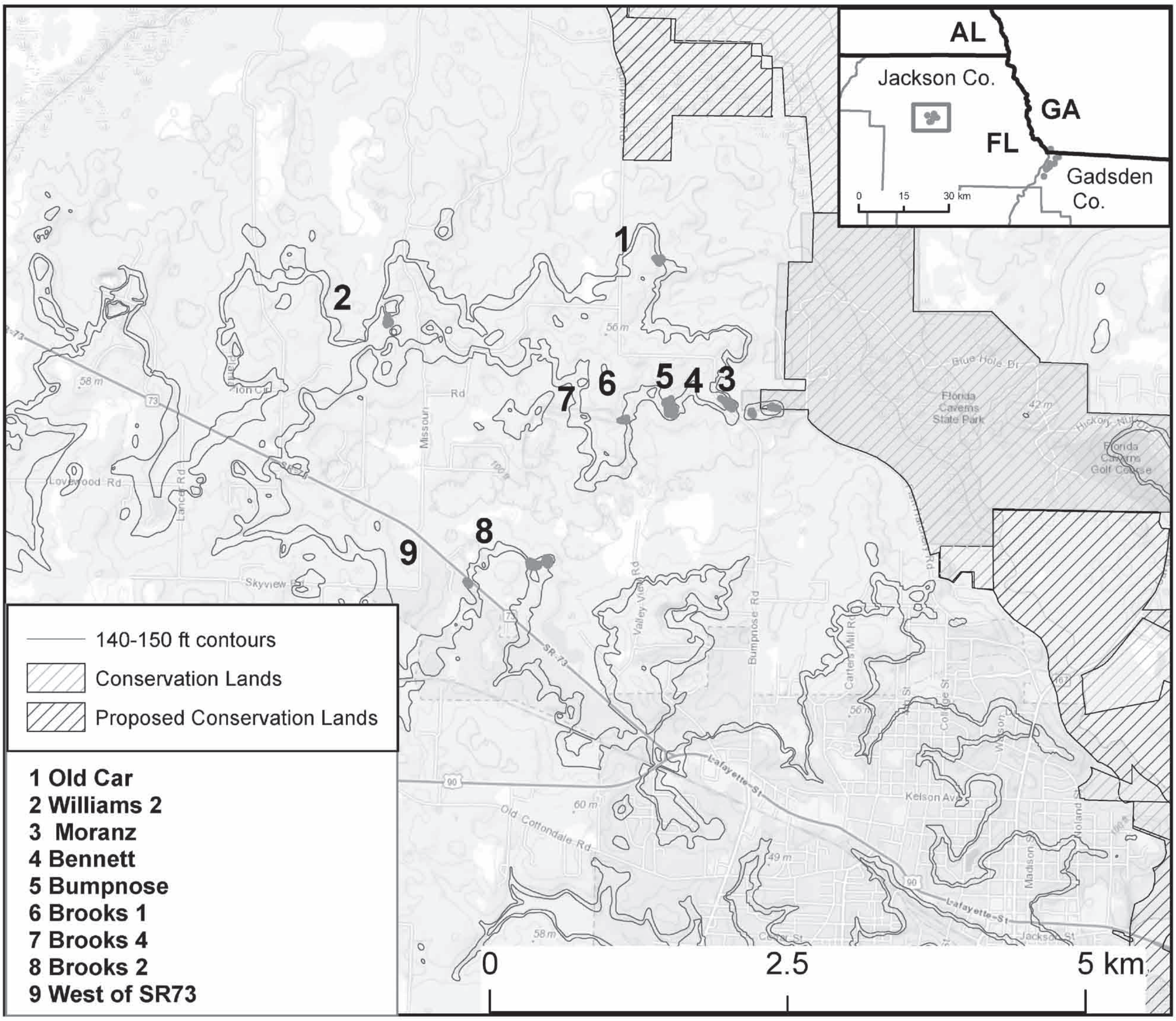

FIGURE 3. Map showing locations of the nine known populations of *Coreopsis bakeri* in Jackson Co., northern Florida, USA.

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Appendix

Samples of *Coreopsis* analyzed for DNA sequence data, vouchers at TENN. GenBank numbers in parenthesis in following order: ETS; *psbA-trnH*; *rpl32-trnL*; *trnL-trnL-trnF* (tabC-tabF primers); *rpl16* intron; *trnQ-rps16*. ***C. auriculata*** L.: *Schilling 10-DNA3016* (KR817822; KR817850;-;-;-;-); *Estes & Beck 7659* (KR817823; KR817851;-;-;-;-); ***C. bakeri*** E.E.Schill.: *Johnson 10239a* (KR817824; KR817852; KR817883; KR817895; KR817879; KR824947); *Johnson s.n.* (KR817825; KR817853; KR817885;-;-;-); *Johnson 10623a* (KR817826; KR817854; KR817886;-;-;-); ***C. basalis*** S.F. Blake: *Schilling 13-DNA 3815* (KR817827; KR817855; KR817881; KR817893; KR824945); ***C. delphiniifolia*** Sherff: *Wofford & Clebsch 91-19* (KR817828; KR817856;-;-;-;-); ***C. grandiflora*** Hogg. ex Sweet var. ***grandiflora***: *DeSelm s.n. 5/14/06* (KR817829; KR817857;-;-;-;-); *Schilling 13-DNA3816* (KR817830; KR817858;-;-;-;-); Estes & Beck 7618 (KR817831; KR817859;-;-;-;-); ***C. grandiflora*** Hogg ex Sweet var. ***inclinata*** J.R. Allison: *Allison 12086* (KR817832; KR817860; KR817882; KR817894; KR817878; KR824946); ***C. lanceolata*** L. var. ***lanceolata***: McCoy s.n.(KR817833; KR817861;-;-;-;-); *Johnson10371a* (KR817834; KR817862; KR817884; KR817896; KR817880; KR824948); *Thomas 88326* (KR817835; KR817863; KR817887;-;-;-); *Thomas 159401* (KR817836; KR817864; KR817889;-;-;-); *Souza 88-164* (KR817837; KR817865;-;-;-;-); *Schilling 13-DNA3813* (KR817838; KR817866;-;-;-;-); *Schilling 13-DNA3814* (KR817839; KR817867;-;-;-); ***C. lanceolata*** L. var. ***villosa*** Michx. : *Godfrey 55430* (KR817840; KR817868; KR817890;-;-;-); *Schmidt 97-132* (KR817841; KR817869; KR817891;-;-;-); *Stutts 351* (KR817842; KR817870; KR817892;-;-;-); ***C. latifolia*** Michx.: *Patrick et al. 4978* (KR817843; KR817871;-;-;-;-); *Murrell et al 948a* (KR817844; KR817872;-;-;-;-); ***C. pubescens*** Ell.: *Estes et al. 9326* (KR817845; KR817873;-;-;-;-); *Estes 9237* (KR817846; KR817874;-;-;-;-); ***C. tinctoria*** Nutt.: Estes 4897 (KR817847; KR817875;-;-;-;-); ***C. tripteris*** L.: *Floden 1719* (KR817848; KR817876;-;-;-;-); *Estes & Beck 8481* (KR817849; KR817877;-;-;-;-).