

# BULLETIN OF AMERICAN ODONATOLOGY

**Distribution, Status and Ecology of *Cordulegaster sayi* Selys  
in Georgia, USA (Odonata: Cordulegastridae)**

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# Distribution, Status and Ecology of *Cordulegaster sayi* Selys in Georgia, USA (Odonata: Cordulegastridae)

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Key words: Odonata, *Cordulegaster sayi*, distribution, ecology, nymph, conservation status

## Abstract

*Cordulegaster sayi* is one of the most poorly known dragonfly species of the southeastern United States. Over a 13-year period (1996–2008), we documented *C. sayi* from 17 sites in 11 counties in southern Georgia, including nymph collections. At 11 (65%) sites, nymph habitat consisted of mucky seepages at the base of the slopes of xeric sandhills; at the remaining six sites, the habitat consisted of seepages on the slopes of steep hardwood bluffs above major streams (or within ravines associated with these bluffs). Salamanders of the genus *Pseudotriton* (*P. ruber* and *P. montanus*) are characteristic associates of *C. sayi* nymph habitats. Because nymph habitats are perennial seepages located downslope of Longleaf Pine (*Pinus palustris*)–Turkey Oak (*Quercus laevis*) sandhills, and because adults typically forage in these habitats, we consider *C. sayi* a Longleaf Pine ecosystem endemic.

## Introduction

Five of the nine species of cordulegastrid dragonflies native to North America are known from Georgia: *Cordulegaster bilineata* (Carle, 1983) (Brown Spiketail), *C. erronea* Hagen in Selys, 1878 (Tiger Spiketail), *C. maculata* Selys, 1854 (Twin-spotted Spiketail), *C. obliqua* (Say, 1840) (Arrowhead Spiketail), and *C. sayi* (Selys, 1854) (Say's Spiketail) (Beaton 2007). Although recent studies have increased our understanding of the distribution and biology of *Cordulegaster* species in Georgia (Mauffray & Beaton 2005; Beaton 2007), the distribution and ecology of the Coastal Plain endemic *C. sayi* remains poorly known. Specific details pertaining to the habitat requirements and nymph ecology of *C. sayi* in Georgia have not been published. This may be attributed to its early and brief flight season, specialized habitat requirements, the difficulty in finding *C. sayi* nymphs in the field, and the species' rarity (Dunkle 1989, 1994; Mauffray 1995; M.J. Westfall, Jr. pers. comm. 1997). Currently, *C. sayi* is listed as "Threatened" by the state of Georgia and is classified as "Vulnerable" on the IUCN Red List of Threatened Species; it has no listing status in the state of Florida.

Herein, we summarize our knowledge of *C. sayi* in Georgia based on collections and field observations made over a 13-year period. We describe in detail the nymph and adult habitat and present new information germane to the ecology of nymphs and adults—including the co-occurrence of *C. sayi* nymphs with salamander larvae. We also discuss the species relationship with the Longleaf Pine (*Pinus palustris*) ecosystem, and map the distribution of the species in Georgia and range-wide.

## Methods

We surveyed for *C. sayi* from 1996–2008, with the majority of our surveys conducted from 1996–1997 (Stevenson 1997) and from 2007–2008 (Beaton 2008). To locate *C. sayi* habitat (i.e., mucky seepage habitats associated with sandhills or mesic hardwood forests), we consulted aerial photos, U.S. Geological Survey topographic maps, and U.S. Department of Agriculture county-level soil survey maps. Because Coastal Plain seepages are novel, locally-distributed, and typically picturesque habitats, they leave an impression on those who visit them; thus, we also corresponded with private landowners and biologists in an effort to locate sites. We identified *Cordulegaster* nymphs using diagnostic characters given in Needham et al. (2000) and Carle (1983). *Cordulegaster sayi* nymphs can be distinguished from other *Cordulegaster* species native to the southeastern United States by the following combination of characters: median tuft of setae on frontal shelf sparse; 5 palpal setae; and 5–6 large and 3–4 small premental setae (Minter J. Westfall, Jr. pers. comm. 1997; Needham et al. 2000). Following Ferreras-Romero and Corbet (1999), we measured head width (maximum distance between the lateral margins of the compound eyes) and total body length (maximum distance between the mouthparts and the end of the cerci measured along the dorsal surface) soon after killing nymphs in isopropyl alcohol or hot water. At each site where we documented *C. sayi*, we listed representative canopy, sub-canopy, shrub, and herb layer plant species; we subsequently identified the natural community types present at each site in accordance with a comprehensive ecosystem classification (NatureServe 2008). Based on

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these vegetation associations, we classified *C. sayi* nymph habitat at each site as either a “sandhill–bay swamp seepage” or a “hardwood bluff–ravine seepage”. With respect to the upland habitats proximal to seeps, we defined “intact sandhills” as open-canopied or somewhat open-canopied xeric uplands on sandy soils dominated by Longleaf Pine (*Pinus palustris*), Turkey Oak (*Quercus laevis*), and Wiregrass (*Aristida stricta*) (Wharton 1978); such habitats often showed evidence of recent fire, and typically supported Gopher Tortoise (*Gopherus polyphemus*) populations. We defined “unintact sandhills” as disturbed, lightly developed, and/or fire-suppressed xeric uplands lacking these characteristic plant species. Salamander larvae were identified using Petranka (1998). We submitted precise locality data for our *C. sayi* observations to the Georgia Natural Heritage Program. Voucher specimens were deposited in the International Odonata Research Institute Collection at the Florida State Collection of Arthropods, Gainesville, Florida, USA.

## Results and Discussion

We found *C. sayi* at 17 sites in 11 Georgia counties (Figure 1). These totals include two new county records (Camden and Irwin) and two sites—one each in Evans and Tattnall counties—where *C. sayi* was found in the mid-1990s prior to our surveys (Mauffray 1995). At three of the sites, both adult and nymph *C. sayi* were found; at 11 sites we found only nymphs and at three sites we found only adults (Table 1). We classified 11 (64.7%) of our *C. sayi* localities as sandhill–bay swamp seepages and six (35.3%) as hardwood bluff–ravine seepages (Table 1). Intact sandhill habitat was present at ten (58.8%) of the sites (Table 1). Salamanders of the genus *Pseudotriton* including *P. montanus* (Mud Salamander) and/or *P. ruber* (Red Salamander) were found at 12 of the 15 sites (80.0%) where we located suitable or occupied *C. sayi* nymph habitat.

## Nymph Morphology and Ecology

The *C. sayi* nymphs that we collected conformed closely to descriptions in Needham et al. (2000). However, of a large series (n = 85) collected 7 July 1997 in Liberty Co., Georgia, some specimens possessed atypical setae counts: 4+5 palpal setae (n = 1); 5+6 palpal setae (n = 6); 5+5 prementals (n = 1); 5+6 prementals (n = 3); 6+7 prementals (n = 1). The remainder had typical counts of 5+5 palpal setae and 6+6 premental setae.

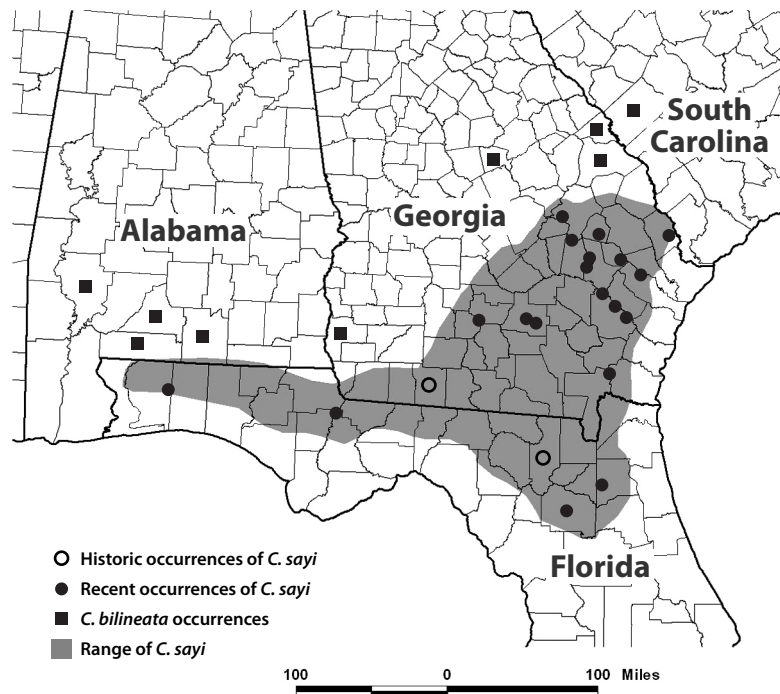


Figure 1: Range-wide distribution (shaded) of *Cordulegaster sayi*. Solid circles represent recent (1995–present) records; open circles represent historic records (Georgia as summarized in this article; Florida from Mauffray and Westfall, 1994; some circles represent more than one site). Solid squares are records of *Cordulegaster bilineata* sites close to range of *C. sayi*, as follows: Alabama from Tennesen et al. (1995) and Steve Krotzer (pers. comm., 2008); Georgia, Mauffray and Beaton (2005) and Giff Beaton (unpubl. data); South Carolina from Kondratieff and Pyott (1987).

Nymph collections made by Mauffray and Westfall (1994) and Stevenson (1997) indicate that *C. sayi*, like other cordulegastrids that have been studied, is semivoltine. In this study, we consistently collected a wide range of *C. sayi* size classes during each of our sampling events (irrespective of season), indicating that nymphs survive multiple years. By plotting the total lengths (TL) of 85 *C. sayi* nymphs collected at a single site on 7 July 1997, we attempted to discern the relationship between age and size cohorts (Figure 2). Although total length data is imprecise due to individual nymphs stretching or compressing their abdomens (Glötzher 2006), we believe that this sample is large enough to provide meaningful information. These data suggest that nymphs in their first summer, presumably recently hatched, reach a TL of only ca. 5 mm. By their second summer, most nymphs are 14–22 mm TL (with corresponding head-widths [HW] of 3.0–4.2 mm); a lesser peak evident in Figure 2 (nymphs 26–28 mm TL; 4.4–4.6 mm HW) may represent nymphs in their 3rd summer. Final (F-0) instars nearing emergence are from 34–40 mm TL and 7.5–7.6 mm HW.

It is difficult to estimate ages of nymphs after their second summer, perhaps due to split cohort development or variation in growth rates (Ferrerias-Romero & Corbet 1999; Glötzher 2006; Marczak et al. 2006). Although more inten-

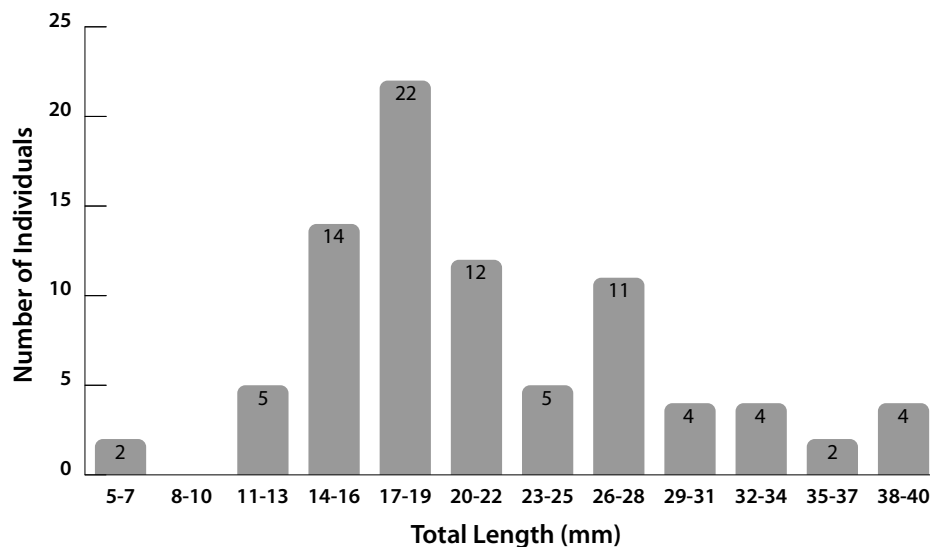


Figure 2: Size distribution (total length in mm) of *Cordulegaster sayi* nymphs (n = 85) collected 7 July 1997 in Liberty County, Georgia.

sive study is clearly needed, we suspect that nymphs emerge in the third or fourth year of life (see Glotzhober 2006 for a thorough discussion and literature review of cordulegastriid nymph development).

We collected *C. sayi* nymphs, which rest buried shallowly in muck, by turning, swirling, and sorting by hand saturated (“pudding-like”) or soupy, “slurry-like” muck. The cryptic nymphs would invariably reveal their presence as they kicked and feebly moved about. A number of nymphs that we collected were in shallow muck interlaced with the convoluted roots of Sweet Bay (*Magnolia virginiana*) and Loblolly Bay (*Gordonia lasianthus*). We found that using dipnets or rakes to haul mucky deposits to land is also effective in collecting *C. sayi* nymphs, but this method is discouraged because it is destructive to these small and fragile seepage habitats. At known sites, we typically captured nymphs within a few minutes of searching. At a Liberty Co., Georgia, site where numerous mucky hillside seepages are present on a north-facing Canoochee River bluff, the senior author collected 85 *C. sayi* nymphs on 7 July 1997. Only ca. 10% of the habitat was sampled; when this site was revisited in 2007, *C. sayi* nymphs of various size classes were found with little effort, suggesting that the species is still flourishing at this site.

The mucky seepages inhabited by *C. sayi* nymphs abound with invertebrate life, especially amphipods, annelids, and occasionally isopods or crayfish. Fish were absent from these seepages, and other species of odonate nymphs were virtually never encountered. Glotzhober (2006) similarly reported no fish and a paucity of other odonates from *Cordulegaster erronea* habitats in Ohio. We collected nymphs of three other *Cordulegaster* species during our surveys: *Cordulegaster bilineata*, *C. maculata*, and *C. obliqua*; two of these (*C. maculata*, *C.*

*obliqua*) occurred sympatrically with *C. sayi*. In areas of sympatry, nymphs of *C. sayi* and other *Cordulegaster* species are typically found in different habitats (Carle 1983; Westfall pers. comm. 1997). However, we did find *C. sayi* and *C. obliqua* nymphs syntopically at one site. Unlike Dunkle (1981), we never found *Tachopteryx thoreyi* (Gray Petaltail) and *C. sayi* nymphs together. We only documented *T. thoreyi* at one *C. sayi* site; however, we did not target this species and suspect that it was present at other *C. sayi* localities.

Salamanders are typically abundant in and near *C. sayi* habitats. We captured Southern Two-lined Salamander (*Eurycea cirrigerra*) larvae in syntopy with *C. sayi* nymphs at many sites. We also captured larvae and adults of the Spotted Dusky Salamander (*Desmognathus fuscus conanti*) in syntopy with *C. sayi* nymphs where their ranges overlap in the Altamaha and Savannah River basins. Notably, at most (85.7%) sites where we collected *C. sayi* nymphs we found larvae and adults (usually larvae) of the Red Salamander (*Pseudotriton ruber*) and/or Mud Salamander (*P. montanus*). Both of these salamanders are confirmed seepage denizens, with aquatic larvae that frequent mucky seepages (Means 2000; Stevenson 2008). In the Coastal Plain, Red Salamanders have a larval period of 18–24 months (Semlitsch 1983), while Mud Salamanders have a larval period of 15–17 months (Bruce 1975; Stevenson 2008). We posit that *Pseudotriton* species and other salamander species with aquatic larvae that inhabit mucky seepages may be important predators, prey, and/or competitors with *C. sayi* nymphs. Red Salamander larvae typically co-occur with nymphal *C. erronea* (Tiger Spiketail) in spring-fed streams habitats in Ohio, and it has been suggested that both are dominant predators of these habitats (Glotzhober 2006).

### Adult Ecology

We observed adult *C. sayi* from 8 March to 4 April. These observations are within the reported flight dates for the species (Needham et al. 2000). We observed adults feeding on nectaring hymenoptera in Turkey Oak sandhill habitats; adults in copulo in sandhill habitats on 4 April and on 6 April; and female *C. sayi* ovipositing in mucky seepages on 9 March and 2 April. At both sites where we

Table 1: Descriptive details for known *Cordulegaster sayi* sites in Georgia (see text). Legend: Y = yes; N = no; U = unknown due to lack of surveys; 1 = sandhill–bay swamp seepage; 2 = hardwood bluff–ravine seepage.

GA County	Site Name	Lat/Long*	Yr. Disc.	Adults	Nymphs	Nymph Habitat	<i>Pseudotriton montanus</i>	<i>Pseudotriton ruber</i>	Intact Sandhill
Camden	private tract	31.01° N, 81.90° W	2005	N	Y	2	Y	N	N
Candler	R.G. Daniels Prsrv. (TNC)	32.35° N, 82.03° W	1997	Y	N	1	U	U	Y
Coffee 1	private tract	31.53° N, 82.82° W	1996	N	Y	1	N	N	N
Coffee 2	private tract	31.49° N, 82.75° W	2000	Y	N	1	U	U	Y
Effingham	private tract	32.35° N, 81.25° W	1997	Y	Y	2	Y	N	N
Emanuel	Ohoopce Dunes Prsrv (TNC)	32.52° N, 82.45° W	1996	N	Y	1	N	Y	Y
Emanuel	Covena Tract (GA DNR)	32.49° N, 82.41° W	2008	N	Y	1	Y	Y	Y
Evans	Fort Stewart	32.11° N, 81.78° W	1995	Y	Y	1	Y	Y	Y
Irwin	private tract	31.50° N, 83.38° W	2008	N	Y	1	N	N	Y
Liberty	Fort Stewart	31.96° N, 81.56° W	1996	N	Y	2	Y	N	N
Tattnall 1	Gordonia-Alatamaha St. Pk.	32.08° N, 82.14° W	1985	N	Y	1	N	Y	N
Tattnall 2	private tract	32.04° N, 82.16° W	2008	N	Y	1	Y	N	Y
Toombs	private tract	32.29° N, 82.35° W	1997	Y	N	1	N	Y	Y
Wayne 1	private tract	31.78° N, 81.99° W	1996	Y	Y	2	N	Y	N
Wayne 2	private tract	31.67° N, 81.85° W	2008	N	Y	2	N	Y	N
Wayne 3	Penholoway Swamp WMA	31.55° N, 81.75° W	2008	N	Y	2	N	N	Y
Wayne 4	Penholoway Swamp WMA	31.55° N, 81.72° W	2008	N	Y	1	Y	N	Y

\* Precise coordinates not provided to protect habitat.

observed oviposition a nearly imperceptible flow of seepage water trickled over the muck where the female deposited her eggs. A female observed on 9 March oviposited in the manner described by Carle (1983), dipping her abdomen ca. 70 times at intervals of less than one second. At several sites we searched for, but were unable to find, exuviae of *C. sayi*.

### Habitat Description

All *C. sayi* nymph collections were made from 1st–2nd order mucky, perennial seepages (i.e., ground water springs originating from small, nearby sand aquifers issue water continuously year-round) surrounded by forest. The *C. sayi* seepages that we visited during a protracted drought (1998–2001) were flowing. Muck is partially decomposed organic matter (i.e., not inorganic clay and silt) formed by slow but steady decomposition of hardwood litter (Means 2000). Muck and peat deposits require constant water in which to form, otherwise they will decompose quickly (Means 2000). The peaty muck that comprises *C. sayi* nymph habitat is usually reddish-brown or brown in color; often a slight, nearly imperceptible current of water flows over the muck. These seepages form narrow (1–2 m wide) and shallow rivulets that flow downslope where they ultimately join 3rd order sand-bottomed streams or hardwood swamps in stream floodplains.

In Georgia, bay swamp (i.e., baygall) vegetation typically occurs adjacent to the mucky seeps inhabited by *C. sayi* nymphs. Canopy species include Sweet Bay (*Magnolia virginiana*), Swamp Red Bay (*Persea palustris*), Loblolly Bay (*Gordonia lasianthus*), Swamp Black Gum (*Nyssa biflora*) Tulip Poplar (*Liriodendron tulipifera*), and Loblolly Pine (*Pinus taeda*); characteristic shrubs include Sweet Pepperbush (*Clethra alnifolia*), Fetterbush (*Lyonia lucida*), Dog Hobble (*Leucothoe axillaris*) and Large Gallberry (*Ilex coriacea*). Other than sparse ferns (*Woodwardia* spp., *Osmunda* spp.), or occasionally Bog-moss (*Mayaca fluviatilis*), living green vegetation in the actual seeps is scant; lush growth of *Sphagnum* moss often fringes the margins of the seeps. Convoluted surface roots of bays and other trees are a hallmark of seepage environments. NatureServe (2008) classifies these communities as “Sandhill Swamp Black Gum Hillside Seepage Forest” (CEGL004645) and “Loblolly Bay Forest” (CEGL007044).

Eleven (64.7%) of our *C. sayi* localities are best described as “sandhill–bay swamp” seepages located at the base of gently sloping xeric sandhills; eight of these seepages may be further described as located at the base of aeolian dune-type sandhills (Ivester & Leigh 2003). In the Atlantic Coastal Plain of southeastern Georgia, large (up to 8 km long) parabolic-shaped ridges of deep (10–30 feet), excessively

well-drained sands (soil type: Kershaw) of aeolian origin are present along the northeastern side of major blackwater streams and their major tributaries (Wharton 1978; Ivester & Leigh 2003). Seepages are often located downslope from the porous sands of these ridges (Wharton 1978; D. Stevenson unpubl. data).

We classified nymph seepages for the remaining six (37.5%) *C. sayi* sites as “hardwood bluff–ravine” seepages. These seepages were located directly on steep, mesic bluffs (usually north-facing)—or within ravines incised into these bluffs, above major streams or their floodplains. Mature mixed hardwood forest communities, the beech-magnolia slope forests of Wharton (1978), characterize these habitats. Canopy dominants include American Beech (*Fagus grandiflora*), Southern Magnolia (*Magnolia grandiflora*), White Oak (*Quercus alba*), and Spruce Pine (*Pinus glabra*); sub-canopy components include American Holly (*Ilex opaca*) and Wild Olive (*Osmanthus americanus*); common shrub and ground cover species are Horse-sugar (*Symplocos tinctoria*), Giant Cane (*Arundinaria gigantea*), and Partridge Berry (*Mitchella repens*). NatureServe (2008) classifies these communities as “Atlantic Coastal Plain Acidic Loam Beech-Magnolia Forest” (CEGL007459). These habitats are uncommon and locally distributed in southern Georgia (Wharton 1978). Longleaf Pine sandhills are located upslope (i.e., atop these mesic bluffs) under natural conditions (Wharton 1978). Mauffray (1995) also reported *C. sayi* from steep-sided hardwood habitats in northern Florida.

### Distribution and Status

Prior to our surveys, *C. sayi* was reported from only three counties in Georgia, namely Thomas (Bick 1983), Evans, and Tattnall (Mauffray 1995). The original description of *C. sayi* by Selys (1854) was based on a specimen from Georgia without further data. Our surveys indicate that *C. sayi* is more widely distributed in southeastern Georgia than previously recognized, and document that the Vidalia Uplands physiographic province, a vast sandhill region where moderate relief produces numerous seepages (Wharton 1978), is an important area for this dragonfly. We documented *C. sayi* from the Alapaha, Altamaha, Ogeechee, Satilla, and Savannah River watersheds. Our Savannah River basin collection (seepage adjacent to Ebenezer Creek, Effingham County) is within 6.5 km of the South Carolina state line; however, suitable *C. sayi* mucky seepage habitats are not known from the adjacent lower Coastal Plain of South Carolina (D. Stevenson pers. obs.; Steve Bennett, South Carolina Department of Natural Resources, pers. comm. 2008).

As currently known, the Georgia range of *C. sayi* barely extends into the Upper Coastal Plain and does not extend into the Fall Line Sandhills physiographic province. Nor has the species been collected in extreme southwestern Georgia

or southern Alabama (Tennesen et al. 1995; S. Krotzer pers. comm. 2008). It appears to be replaced by its close relative *C. bilineata*, whose nymphs also inhabit mucky seepages, in the above-mentioned regions (Carle 1983). These two species have not been found to occur sympatrically; however, two adults that appear to be intermediate between *C. sayi* and *C. bilineata* were collected in southern Alabama, Escambia County, in 1993 by Steve Krotzer (Tennesen 2004).

We propose classifying *C. sayi* as a Longleaf Pine ecosystem endemic. Based on our observations and those of Mauffray (1995), and a review of USDA soil maps, the open-canopied upland habitats (required by foraging adults) upslope and adjacent to all known *C. sayi* nymph sites in Georgia are—or were historically prior to anthropogenic disturbance—dominated by Longleaf Pine–Turkey Oak sandhill communities. To our knowledge, this is also true for all *C. sayi* sites in Florida (Dunkle 1994; Mauffray 1995). The fact that only nine of our 16 *C. sayi* sites are within intact sandhill landscapes indicates that *C. sayi* populations may persist at sites where native uplands have been degraded (due to forestry practices, fire suppression, light residential development, etc.). At sites lacking good-condition sandhills, adult *C. sayi* are exploiting primitive roads, cutover, weedy fields, and similar anthropogenic light gaps (this study; also Dunkle 1994; Mauffray 1995). Habitat management practices on public lands and preserves that foster open-canopied sandhills (e.g., prescribed fire, selective thinning, hardwood control) also benefit *C. sayi*.

Presently, *C. sayi* is known from approximately 25 sites range-wide (this study; Bill Mauffray pers. comm. 2008). Our field experience suggests that the species is uncommon and locally distributed, albeit widespread, in southeastern Georgia.

Of the 17 known Georgia sites, eight are located on publicly-owned lands (two on a Department of Defense military installation, two on preserves owned by The Nature Conservancy, and four on state lands managed by the Georgia Department of Natural Resources). We concur with Bick’s (2003) designation of *C. sayi* as “Rare” (i.e., a species with a rare habitat type and/or a small geographic range) and recommend periodic monitoring of known sites and surveys for new sites.

### Acknowledgements

We are indebted to the late M.J. Westfall, Jr. for graciously sharing his expertise. Our *Cordulegaster* nymph specimen identifications were confirmed by M.J. Westfall, Jr. and by S. Krotzer. The senior author tips his odonate hunting cap to S. Roble for his endless support and encouragement. S. Krotzer assisted with field and habitat surveys. B. Mauffray was helpful throughout this study. K. Tassin and B. Willis-Stevenson assisted with surveys and in locating habitat. B. Albanese

was instrumental in supporting surveys for rare Odonata in Georgia. For helping in various ways, we thank J. Ambrose, J. Bailey, J. Caligiure, L. Carlile, the late M. Hopkins, Jr., J. Jensen, S. Krotzer, B. Mauffray, S. Osborn, and F. Snow. The manuscript was greatly improved by the editorial comments of K. Tennessen, S. Roble, and R. Glotzhober.

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