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A Range Extension for *Carex sartwellii* in Interior Alaska

Mark Winterstein[1, 4], Teresa N. Hollingsworth[2], and Carolyn Parker[3]

[1]Department of Biology and Wildlife, University of Alaska Fairbanks, 101 Murie Building, 982 N Koyukuk Drive, Fairbanks, Alaska 99775 USA
[2]Boreal Ecology Cooperative Research Unit, Pacific Northwest Research Station, United States Forest Service, P.O. Box 756780, University of Alaska Fairbanks, Fairbanks, Alaska 99775 USA
[3]Herbarium, University of Alaska Museum of the North, University of Alaska Fairbanks, 907 Yukon Drive, Fairbanks, Alaska 99775-6960 USA
[4]Corresponding author: mawinterstein@alaska.edu

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Our documentation of Sartwell's Sedge, *Carex sartwellii*, on nine shrinking lakes during fieldwork in the central Yukon Flats, Alaska, represents a range extension for this species. Previously, its range extended as far northwest as Yukon, Canada, with a reported, but lost collection, from Alaska in 1895. Two earlier collections from the Yukon Flats have been verified; one was misidentified as *Carex praegracilis* until 2007. *Carex sartwellii*'s assumed absence from Alaska and Yukon flora, misidentification of an earlier collection, and the remoteness of the Yukon Flats may have contributed to the rarity of its collection. In Alaska this species is morphologically similar to *C. praegracilis,* but can be distinguished using traits of the perigynia, leaf sheaths, and the production of true vegetative culms.

Key Words: Alaska; *Carex sartwellii*; Sartwell's Sedge; *Carex praegracilis*; Clustered Field Sedge; Yukon Flats; drying lakes; range extension

Introduction

In summer 2011, while studying shrinking lakes and plant succession in the Yukon Flats (Wahrhaftig 1965), interior Alaska, we observed a sedge, *Carex sartwellii* Dewey (Sartwell's Sedge), that we believed at the time to be undocumented in Alaska. We found *C. sartwellii* in 16 plots on nine shrinking lake basins in the southern portion of the Yukon Flats (Figure 1) and collected nine specimens from seven lakes as vouchers (Table 1). We found this species in two community types: wet/mesic graminoid forb meadows and open tall shrub meadows on lacustrine alkaline soils (Figure 2). These community types are the result of shrinking lakes, which have been documented across Alaska as a potential effect of climate change (Klein *et al*. 2005; Riordan *et al*. 2006; Roach *et al.* 2011; Rover *et al.* 2012).

Previous to our study, there had been only two documented collections of *C. sartwellii*, both from the Yukon Flats. Few studies have documented the flora in the Yukon Flats, Alaska (Johnson and Vogel 1966; Holloway and Alexander 1990; Talbot 1991; Heglund 1992; Larsen *et al.* 2004; Cortés-Burns and Carlson 2006). The remoteness and vastness of the region may have contributed to the rarity of collections, as field studies are logistically difficult. The area is accessible only by snow machine, boat, or small aircraft, and the terrain is difficult to cross on foot. Furthermore, the assumed absence of this sedge from Alaska and Yukon (Hultén 1941–1950) may have contributed to collections being misidentified as *Carex praegracilis* W. Boott (Clustered Field Sedge) and overlooked. *Carex sartwellii* was not included in the treatments of the flora of Alaska or Yukon (Hultén 1968; Welsh 1974; Cody 2000). A. A. Reznicek adapted a Cyperaceae key from the Flora of North America (Ball and Reznicek 2002) for Alaska (Reznicek 2012) that included *C. sartwellii*, and led to the correct identification of our collections.

Carex sartwellii has been documented from New York and Quebec to Colorado and Washington in the west, and north to Northwest Territories and Yukon (USDA 2014). The distribution in Figure 1 (inset map) is based on data from 168 specimens housed in 12 herbaria (Acadia University (ACAD) [3 records], University of Alaska Museum of the North (ALA) [3], University of Alberta Vascular Plant Herbarium (ALTA) [51], Canadian Museum of Nature Herbarium (CAN) [5], University of Connecticut (CONN) [3], Colorado State University (CSU) [2], Field Museum of Natural History (F) [16], Kansas State University (KSU) [7], Missouri Botanical Garden (MO) [1], University of Toronto Mississauga (TRTE) [1], University of British Columbia (UBC) [26], University of Manitoba (WIN)

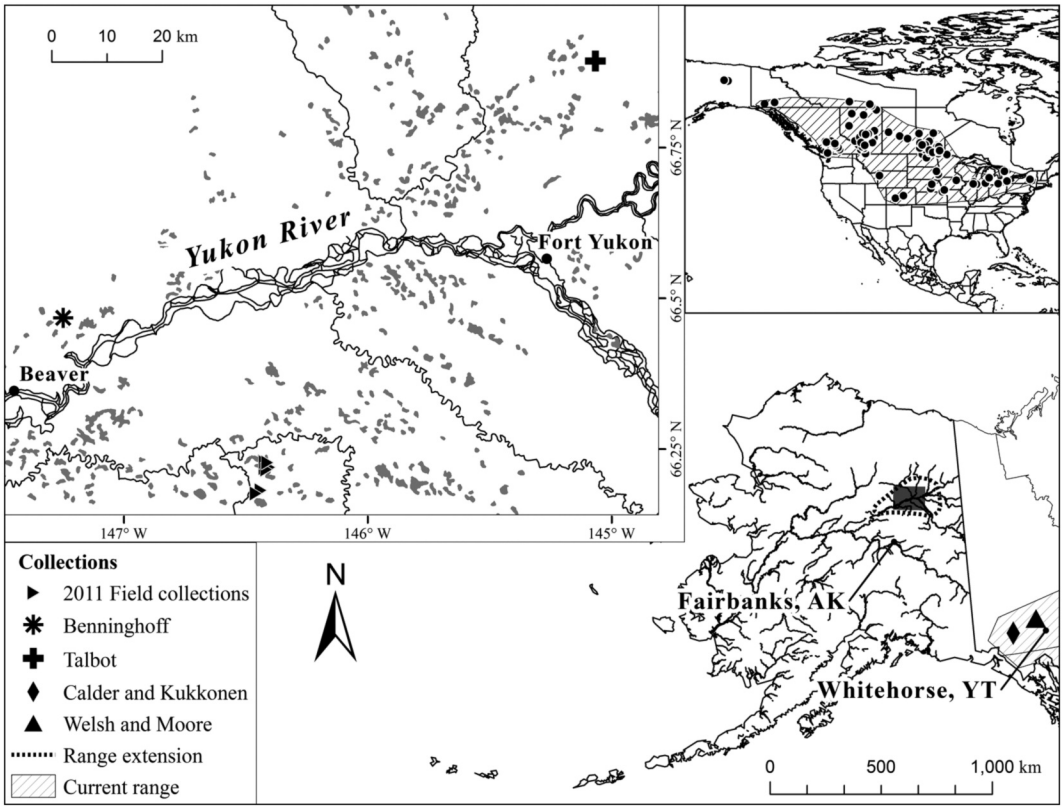

FIGURE 1. Alaska and adjacent Canada showing current range of *Carex sartwellii* including the location of collections in the Yukon Flats. The gray rectangle delineates the area of the expanded view of the Yukon Flats collections (inset, upper left). Black dots (•) on the range map (inset, upper right) indicate collections from the Yukon Flats, GBIF (2014), and Cody (1978).

TABLE 1. Location, date, and habitat of *Carex sartwellii* collections and observations from the Yukon Flats, Alaska.

Collector/ observer	Date	Location °N	Location °W	Community type	Vouchered specimens/ observations
M. Winterstein	17/7/2011	66.3511	146.4449	Open tall shrub meadow	Observed
M. Winterstein	17/7/2011	66.2313	146.3773	Graminoid meadow	ALA V174388
M. Winterstein	20/7/2011	66.2415	146.3662	Graminoid meadow	ALA V174256
M. Winterstein	20/7/2011	66.2414	146.3666	Open tall shrub meadow	ALA V174257
M. Winterstein	19/7/2011	66.2332	146.3587	Graminoid meadow	ALA V173222
M. Winterstein	21/7/2011	66.2420	146.3771	Graminoid meadow	ALA V174258
M. Winterstein	21/7/2011	66.2419	146.3774	Open tall shrub meadow	MICH
M. Winterstein	18/7/2011	66.2304	146.3677	Graminoid meadow	ALA V173223
M. Winterstein	18/7/2011	66.2306	146.3676	Open tall shrub meadow	ALA V173220
M. Winterstein	24/7/2011	66.1957	146.3940	Graminoid meadow	Observed
M. Winterstein	25/7/2011	66.1911	146.3901	Open tall shrub meadow	Observed
M. Winterstein	23/7/2011	66.1917	146.4141	Graminoid meadow	ALA V173221
M. Winterstein	23/7/2011	66.1911	146.4089	Open tall shrub meadow	Observed
M. Winterstein	28/7/2011	66.3562	146.4275	Graminoid meadow	Observed
M. Winterstein	28/7/2011	66.3567	146.4272	Open tall shrub meadow	Observed
M. Winterstein	28/7/2011	66.3545	146.4291	Graminoid meadow	Observed

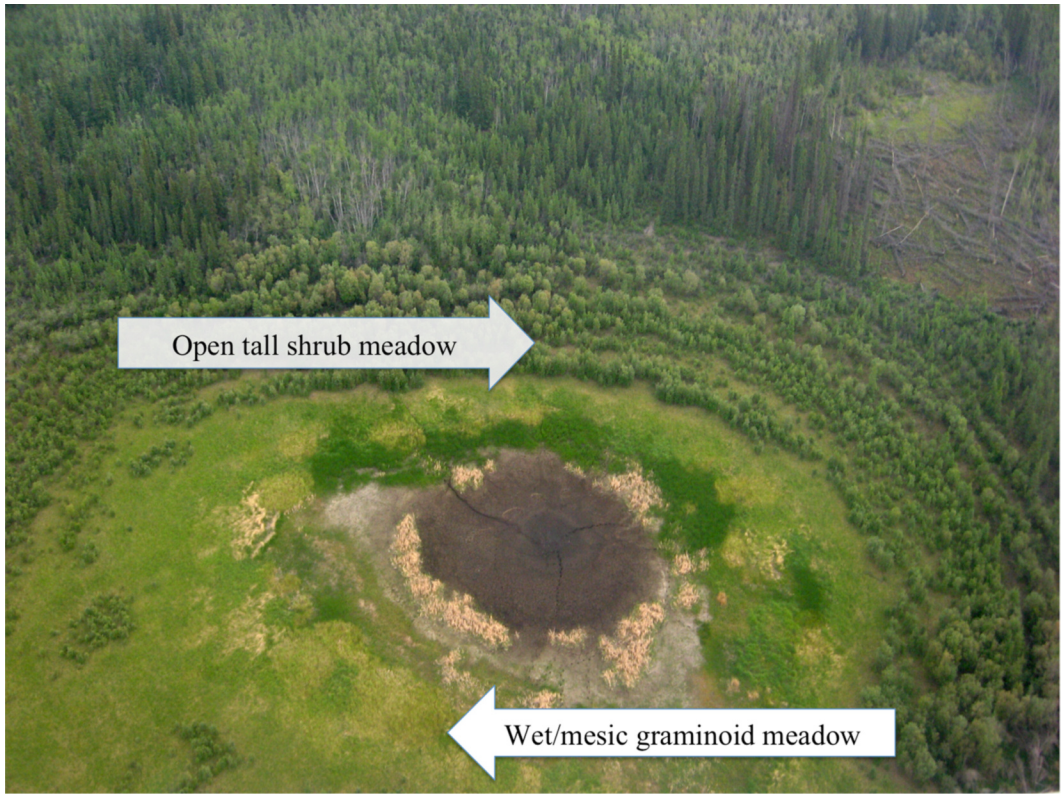

FIGURE 2. Drying lake in the central Yukon Flats, Alaska (66.33°N, 146.41°W). Arrows indicate community types where *Carex sartwellii* occurred within the lake basin. Photo: M. Winterstein.

[68]), extracted from the Global Biodiversity Information Facility (GBIF 2014), and two additional collections from Northwest Territories (Cody 1978) that are not in the GBIF database.

Here we describe the history of collection, ecology, and morphology of *C. sartwellii* in Alaska. Species names follow the Flora of North America (FNA 1993+). Common names follow Viereck and Little (2007) and the United States Department of Agriculture (USDA) Plants Database (USDA 2014). Herbarium abbreviations follow the Index Herbariorum (Thiers, continuously updated).

History of Collection of *Carex sartwellii* in Alaska and Yukon

The first report of *C. sartwellii* in Alaska occurred over a century ago. Kurtz (1895) reported its collection by Aurel Krause in 1882 on a grassy slope by the Klehini River near the village of Kloquan (Klukwan) in southeast Alaska. Hultén (1940) noted that Krause's collections from Alaska had been accessioned by Dr. Frederico Kurtz at the herbarium of the National University of Cordoba, Argentina (CORD), and duplicates were sent to the Botanical Garden and Botanical Museum (B) in Berlin, Germany. Hultén (1941–1950) mentioned the report of *C. sartwellii* by Kurtz (1895) under his treatment of *C. praegracilis*, but noted the specimens supporting this record at B were lost during World War II. However, no duplicate collection of *C. sartwellii* was found at CORD (G. E. Barboza, personal communication, 1 April 2015). Because no collection could be verified, Hultén referred this report to *C. praegracilis* because, at the time, *C. sartwellii* was thought not to occur north of British Columbia, Canada (Hultén 1941–1950).

In 1948, the first documented collection of *C. sartwellii* was made by William Benninghoff in the Yukon Flats near the village of Beaver (Figure 1), but it was misidentified as *C. praegracilis*, by Eric Hultén, until 2007 (Alaska: 12 miles North of Beaver, Chandalar Road, 10 July 1948, *Benninghoff 2104*, MICH 1430605, det. A. A. Reznicek; Figure 3). The second collection of *C. sartwellii* in the Yukon Flats was by Stephen Talbot in 1982 (Alaska: Yukon Flats National Wildlife Refuge, 66.88°N, 145.02°W, 13 August 1982, *Talbot B9-3*, SASK 149366, det. J. H. Hudson; Figure 1; Talbot 1991), 34 years after the Benninghoff collection and the only known collection at that time. Yet, at the time of our

FIGURE 3. Specimen (MICH 1430605) of *Carex sartwellii* collected by W. S. Benninghoff and identified and mapped as *C. praegracilis* in Hultén (1968). Photo: A. A. Reznicek.

determinations in 2012, it was still thought to be undocumented for Alaska according to two comprehensive taxonomic guides: the USDA Plants Database (USDA 2014) and the Flora of North America (Ball and Reznicek 2002).

The misidentification of early collections of *C. sartwellii* as *C. praegracilis* led to its assumed absence from Alaska and the Yukon flora for several decades. Hultén (1968) mapped the 1948 W. Benninghoff collection of *C. sartwellii* as *C. praegracilis* in his work Flora of Alaska and Neighboring Territories. Similarly, the only two occurrences of *C. sartwellii* from Yukon were collected in 1960 and 1968, but misidentified as *C. praegracilis*, until 2003 (Cody *et al.* 2005) and 2008, respectively (Yukon: Mile 26 road from Whitehorse to Dawson, 9 August 1960, *Calder & Kukkonen 28039*, ALA 43419, det. A. A. Reznicek; Yukon: Alaska Highway milepost 944, 3 July 1968, *Welsh & Moore 7763,* ISC 281218 (on permanent loan at ALA), det. A. A. Reznicek; Figure 1). Like the Alaska specimen, the misidentified Yukon collections were included as *C. praegracilis* in Flora of the Yukon Territory (Cody 2000), although Cody (2005) made an update to the flora to include the 1960 collection by Calder and Kukkonen, then correctly identified as *C. sartwellii.* Stanley Welsh, who made the 1968 collection of *C. sartwellii* in Yukon, also included this and the other misidentified specimens in the range description for *C. praegracilis*, in his work Anderson's Flora of Alaska and Adjacent Parts of Canada (Welsh 1974).

Ecology

Yukon Flats

The Yukon Flats are located to the north of the Yukon–Tanana Uplands (Nowacki *et al.* 2002) and to the south of the Eastern Brooks Range (Figure 1). They were formed by the alluvial fans of the Chandalar and Porcupine rivers and the floodplain of the Yukon River (Williams 1962). The region has a mixed geology of alluvial sediments and aeolian silts and sands, largely deposited during the Pleistocene (Williams 1962; Muhs *et al*. 2003). The area is covered with approximately 40 000 shallow closed basin lakes (Heglund and Jones 2003) and is underlain by discontinuous ice-poor permafrost (Nossov *et al*. 2013). The climate is continental with low precipitation, averaging 16.7 cm annually (Drury and Grissom 2008), and negative potential evapotranspiration (Oechel *et al.* 2000). The vegetation is boreal with patchwork stands of mixed *Betula neoalaskana* Sargent (Alaska Paper Birch) and *Picea glauca* (Moench) Voss (White Spruce), *Populus tremuloides* Michaux (Trembling Aspen) on ridges, and *Salix* spp. (Willow) scrub and *Picea mariana* (Miller) Britton, Sterns & Poggenburg (Black Spruce) in the lowlands (Williams 1955).

Shrinking lakes

Our collections suggest that *C. sartwellii* occurs in a community type that may have been rarer in the recent past. The continental climate of the region, low precipitation, and high potential evapotranspiration (Oechel *et al.* 2000), along with increased annual temperatures and growing season length because of climate change (Chapin *et al.* 2005), are contributing to changes in the hydrology of shallow basin lakes (Riordan *et al*. 2006; Roach *et al.* 2011; Rover *et al.* 2012). Seasonal and interannual shrinking of these lakes results in a distinctive pattern of concentric rings of plant communities (Figure 2). These communities are underlain by lacustrine sediments rich in carbonates and with high pH (Heglund and Jones 2003; M. W., unpublished data), which, in combination with the high potential evapotranspiration, create alkaline soils around the lake margins and a favourable habitat for *C. sartwellii* (Stewart and Kantrup 1972). These plant communities are organized along a moisture gradient and follow the general pattern: lake edge, wet graminoid, wet/mesic graminoid forb meadows, open tall shrubs, forest.

The soils where *C. sartwellii* was collected are of lacustrine origin, highly organic with abundant mollusc shells, moderate to basic pH ranging from 6.78 to 7.97 (M. W., unpublished data), and often with a salt crust on the surface. Although *C. sartwellii* is noted as being an obligate wetland species (Lichvar 2013), we found it on soils that were not inundated with water. This may indicate that the site is seasonally wet and that the lake margins fluctuate with spring snow melt. The species was not found at the lake edge in standing water, although it is possible that vegetative shoots may have been overlooked in some plots because of the infrequency of reproductive shoots (Reznicek and Catling 2002a) and unfamiliarity with the species at the time of sampling.

We found *C. sartwellii* growing in open mesic to wet graminoid/forb meadows and open tall shrub meadows (Figure 2). In wet to mesic graminoid meadows it was commonly associated with *Carex aquatilis* Wahlenberg var. *aquatilis* (Water Sedge), *Carex atherodes* Sprengel (Wheat Sedge), *Carex utriculata* Boott (Northwest Territory Sedge), *Geum macrophyllum* var. *pernicisum* (Rydberg) Raup (Large-leaved Avens), *Persicaria lapathifolia* (L.) Delarbre (Curlytop Knotweed), *Chenopodium rubrum* L. (Red Goosefoot), *Rubus arcticus* L. (Arctic Raspberry), *Rumex* spp. (dock), and *Calamagrostis* spp. (reedgrass). In open tall shrub meadows, it was commonly associated with *Salix bebbiana* Sargent (Bebb's Willow), *Salix pseudomonticola* C. R. Ball (Park Willow), *Calamagrostis canadensis* (Michaux) Palisot de Beauvois (Bluejoint), *Chamerion angustifolium* (L.) Scopoli subsp. *angustifolium* (Fireweed), and *Rubus arcticus* L. (Arctic Raspberry).

Morphology

Carex sartwellii (*Carex* sect. Holarrhenae) and *C. praegracilis* (*Carex* sect. Divisae) share many similar morphological traits (Reznicek and Catling 2002a,b). Both species have unisexual or androgynous spikes;

TABLE 2. Comparison of morphological characteristics of *Carex sartwellii* and *C. praegracilis*.

Characteristic	*C. sartwellii*	*C. praegracilis*
Perigynia	Veined on both faces, ovate	Veined abaxially, broadly ovate
Leaf sheath, front	Veined nearly to sheath apex	Smooth, lacking veins
Leaf sheath apex	Prolonged, 1–4.5 mm	Not prolonged
Vegetative shoots	Forms tall tristichously leaved vegetative shoots with distinct nodes and internodes, aphyllopodic	Leaves basal, no tall shoots

beaked perigynia of similar size and shape; an abaxial suture arising at the beak; and both are aphyllopodic and loosely rhizomatous. However, there are diagnostic differences that can be observed in the field to separate them. The four easily identifiable differences in morphology between the two species are in the venation of the perigynia, the leaf sheath fronts, the leaf sheath apices, and the presence of true vegetative stems in *C. sartwellii* (Table 2, after Ball and Reznicek 2002).

The perigynia of *C. sartwellii* are veined on both faces whereas, on *C. praegracilis*, they are only veined abaxially. The leaf sheath front is a region located opposite and just below the disarticulation point of the leaf blade from the culm. In *C. sartwellii*, green veins of the culm continue into the leaf sheath fronts nearly to the sheath apex and are uniform in appearance with the rest of the leaf sheath around the culm, whereas, in *C. praegracilis*, the leaf sheath fronts are veinless and membranous and differentiated from the rest of the leaf sheath. The apices of the leaf sheath fronts in *C. sartwellii* are prolonged 1–4.5 mm but they are not prolonged in *C. praegracilis.* Finally, *C. sartwellii* produces true vegetative culms that are tristichously leaved and have the distinctive venation described above on the leaf sheath fronts. *Carex praegracilis* does not produce vegetative stems, but produces a basal rosette of leaves when growing vegetatively. In addition, there are differences in the ligule, which is more pronounced in *C. sartwellii* (2.2–8 mm), than in *C. praegracilis* (0.6–2.6 mm).

Reznicek (2012) distinguishes the sections that include these two species in the Alaskan Cyperaceae with the following key:

40. Upper leaves of culms with fronts of sheaths green-veined essentially to apex, not differentiated from rest of sheath; true vegetative stems present . . . . . Sect. Holarrhenae [includes *C. sartwellii*]

40. Upper leaves of culms with fronts of sheaths with at least a narrow hyaline or whitish-hyaline band extending at least half length of sheath; vegetative shoots not true stems, consisting only of overlapping leaf sheaths . . . . . Sect. Divisae [includes *C. praegracilis*]

Conclusion

Based on the 1948 Benninghoff and 1982 Talbot collections, this species has occurred in Yukon Flats for some time, and our 2011 collections are not likely a result of a recently established population. It is likely that the vast terrain, limited access to the region, and few field studies have contributed to the rarity of collections over the years. Furthermore, if the lack of collections of *C. sartwellii* in the past were a result of misidentification as *C. praegracilis*, then we would expect more corrected identifications of *C. sartwellii* from Alaska at herbaria; yet this is not the case. However, the misidentification of the Benninghoff specimen by E. Hultén and Hultén's assumption (Hultén 1940–1951) that *C. sartwellii* did not occur north of British Columbia, Canada, did have a cascading effect on subsequent treatments of the flora in Alaska and Yukon (Hultén 1968; Welsh 1974; Cody 2000).

It may also be that this species is more abundant now because of increases in favourable habitat in the Yukon Flats as a result of climate change. It is unusual that there were only two single collections made in 63 years in the Yukon Flats, but we collected it at nine plots in seven lakes across a distance of approximately 15 km. We targeted drying lakes in our sampling efforts which likely increased our collections, but there are differences in the abundance of favourable habitat between the north and south sides of the Yukon River. The Benninghoff and Talbot collections were made on the north side of the Yukon River, where there are fewer drying lakes (Rover *et al.* 2012), whereas our collections were on the south side (Figure 1).

Our collections, the Benninghoff collection, and the Talbot collection represent separate populations from the nearest documented collections of *C. sartwellii*, which are about 850 km away in Yukon, Canada. What is not clear is whether, collectively, these are a fragmented population in the Yukon Flats or they are connected by habitat across the interior of Alaska to the collections in Yukon. For the extension of the range in Alaska, we outlined the geographic area of the Yukon Flats (Figure 1) because of its distinct climate (Oechel *et al.* 2000), geologic history (Wahrhaftig 1965; Muhs *et al.* 2003), and the pattern and extent of shrinking lakes (Riordan *et al.* 2006; Roach *et al.* 2011; Rover *et al.* 2012). These factors have created a patchwork of habitats for this species across the region. This sedge should be looked for in areas of similar habitats elsewhere in Alaska.

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