STATUS AND MANAGEMENT OF *ERIOCAULON KOERNICKIANUM* (ERIOCAULACEAE) IN TEXAS

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ABSTRACT

A large body of information and misinformation has developed on the distribution of *Eriocaulon koernickianum* (Dwarf Pipewort) in Texas. We have sifted it, including both published and unpublished reports down to agency interoffice memos. About half of the distribution reports are in error. We searched herbaria and sites where *E. koernickianum* was reported, as well as other promising sites in Texas. We currently know of ten vouchered sites where *E. koernickianum* either currently exists or has recently existed. All sites are either in the Edwards Plateau or Post Oak Savanna regions; none is in the Pineywoods region. How the type specimen collected by Charles Wright became associated with Tyler County in east Texas remains unknown; where it was collected will probably remain a mystery.

The sites where *E. koernickianum* occurs range in size from less than a square meter to several hectares. Populations range from a few plants to thousands. And population numbers fluctuate wildly from year to year for reasons that are not altogether clear. It appears that the species is disturbance dependent and cannot tolerate shade or major ground disturbance such as hog rooting.

Of the ten known locations, four are protected on Texas Parks and Wildlife lands; the others are on private land and are mostly in bad condition. The future of the species in Texas is precarious.

KEY WORDS: *Eriocaulon koernickianum*, Eriocaulaceae, Dwarf Pipewort, Texas, rare species.

Figure 1. *Eriocaulon koernickianum* from Andrew's Bog, Gus Engeling Wildlife Management Area, Anderson County.

INTRODUCTION

Eriocaulon koernickianum Van Heurck & Muell.-Arg., Dwarf Pipewort, the most diminutive of the eleven North American eriocaulons (Figure 1), is widely disjunct in Arkansas, Georgia, Oklahoma, and Texas (Kral 2000)(Figure 2). It is a monoecious, outcrossing annual whose limited genetic variation across its range suggests that recolonization may explain current distribution (Watson et al. 2002). It is of conservation concern and is listed G2 (imperiled) federally and either S1 or S2 (critically imperiled/imperiled) in all states where it occurs (Kral 2000, NatureServe 2005). In Georgia, north Arkansas, and at one Texas site it occurs in moist depressions in granite outcrops; in south Oklahoma, south Arkansas, and most Texas sites, it is associated with bogs, marshes, and sandy seepage slopes below xeric sandylands (Jones and Carpenter 1995, MacRoberts and MacRoberts 2001, MacRoberts et al. 2002a).

Between 1998 and 2002, we surveyed for and made observations on *E. koernickianum* in Texas. We also examined the published and

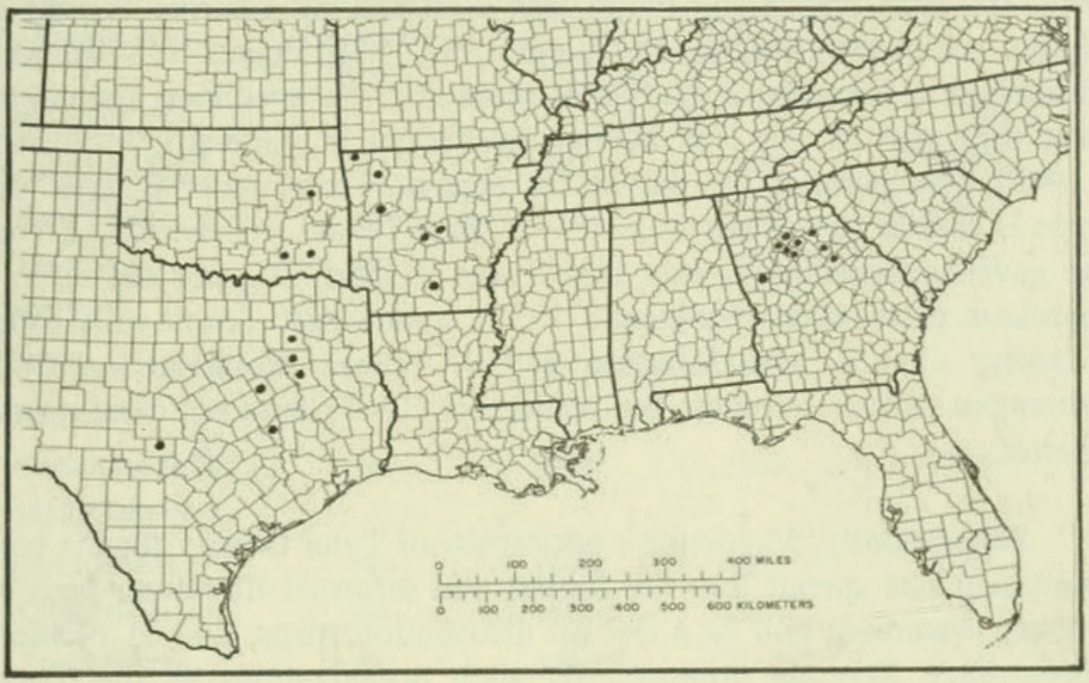

Figure 2. Distribution of *Eriocaulon koernickianum* (distribution outside Texas based on literature and personal communications and not vouched for in this study. Texas locations vouchered).

unpublished records relating to this species. This paper summarizes our findings previously reported in unpublished, largely non-circulating reports (MacRoberts and MacRoberts 1999a, 1999b, 2002). Some of the information in those reports has been omitted (notably maps showing specific site locations) since *E. koernickianum* is a rare species. Some of the information in our reports has now been incorporated into publications and other reports, correcting some previous distribution errors (e.g., Turner et al. 2003, Carr 2004, Texas Parks and Wildlife 2004). Nonetheless, since the bulk of the information in our reports is not accessible and is perhaps of interest to the general botanical community, we have decided to publish it.

DISTRIBUTION

We discovered, on surveying the published and unpublished literature and talking with botanists and ecologists, that considerable confusion exists about the Texas distribution of this species. The confusion begins

with the type specimen, which was collected by Charles Wright in Texas sometime between 1837 and 1852. Van Heurck (1870), who described it, recorded it as "Texas orientali;" the specimen apparently was then part of the Van Heurck herbarium in Antwerp. Moldenke (1942), after pointing out that he had seen no Texas material, says "the type is said to have been collected in 'East Texas' [=Tyler Co.]..." but he gave no explanation why East Texas = Tyler Co., nor did he in a previous publication (Moldenke 1937) equate east Texas with Tyler County. Correll and Johnston (1970) repeat Moldenke's (1942) statement almost verbatim, but Moldenke (1947) does not clear up the matter.

Subsequently, Moldenke's attribution of Tyler County for the type specimen has spread into the formal and informal literature, both as written statement and as a dot on distribution maps, and in Element Occurrence Records produced by such organizations as the Texas Natural Heritage Program (now Texas Parks and Wildlife). Kral's (1966) county dot distribution map for *E. koernickianum* in Texas shows it occurring in Brazos, Tyler, and Polk counties, but Kral does not comment or give vouchers. Geraldine Watson (1982) reports it for the Big Thicket National Preserve but without specific comment or vouchers. Her plant collections have been examined by Larry Brown (pers. comm.; data on file Big Thicket National Preserve), but he found no *E. koernickianum* among them. Tucker (1983), in a dot distribution map, shows *E. koernickianum* in Polk and Brazos counties but without comment or vouchers. Texas Organization for Endangered Species (1993) lists *E. koernickianum* for Brazos, Freestone, Leon, and Tyler counties but without vouchers or references. Kral (1983) gives a county dot map showing Hardin and Brazos counties, again without vouchers or comment. The Texas Natural Heritage Program (1995) reports *E. koernickianum* from "Anderson, Brazos, Limestone, Leon (?), and Tyler (H) Counties." The "?" is unexplained; "H" refers to an historical occurrence: "not observed or collected within fifty years," which is presumably the Charles Wright specimen from "Tyler Co." Hatch et al. (1990) report it from the pineywoods region of east Texas. Kral (2000) gives a distribution map, but it does not designate counties. There are six Element Occurrence Records for the taxon produced by Texas

County & site	Exact location known	First year located	Year last located	Pop. size
ANDERSON				
Andrew's Bog*	yes	1990	2002	2500+
Dale's Bog*	yes	2001	2002	5
Jim's Bog *	yes	2001	2002	100+
BRAZOS				
Wellborn	no	1947	1947	?
GILLESPIE				
Enchanted Rock*	yes	1993	1999	1000+
HENDERSON				
Baker Lake	yes	1999	1999	3
Curtis Boyd Bog	yes	1999	2001	3
Tindel's Bog	yes	2001	2001	3
LIMESTONE				
Perino's site	yes	1979	1995	7-8
VAN ZANDT				
Arc Ridge Ranch	yes	2001	2002	20

Table 1. Summary of information on confirmed *Eriocaulon koernickianum* sites in Texas by counties. The population numbers are based on field assessments at highest known population. Populations fluctuated radically. *Protected sites managed by Texas Parks and Wildlife.

Parks and Wildlife; none is verified, and three are incorrect. Watson et al. (1994) show the general distribution of *E. koernickianum* but without specific county locations or vouchers. Watson and Uno (1991) state that there were no recently confirmed populations in Texas but that it was known historically from four sites, and a 1994 correspondence among L. Watson (Oklahoma Natural Heritage Inventory), C. Norquist (U.S. Fish and Wildlife), and J. Poole (Texas Natural Heritage Program) indicates that at that time there was no certainty about any *E. koernickianum* site in Texas!

Site	Size of site in ha. (suitable habtat)	Area in which species found (ha.)	Condition of site
Andrew's Bog	20.0	several	Good
Dale's Bog	1.0	0.0001	Poor/Good
Jim's Bog.	0.4	0.2	Poor/Good
Wellborn	?	?	?
Enchanted Rock	0.0035-0.0045	0.0025	Good
Baker Lake	several	0.0001	Good
Curtis Boyd	1.0	0.0001	Poor
Tindel Bog	2.0	0.0001	Poor
Perino site	2.0	?	Very Poor
Arc Ridge	1.0	0.0001	Good

Table 2. Characestics of *Eriocaulon koernickianum* sites in Texas.

In order to determine the distribution of *E. koernickianum* in Texas, we searched *Eriocaulon* collections in the following herbaria: TEX, BRIT, VDB at BRIT, ASTC, SBSC, SHST, WWF, Corpus Christi Museum, and collections held at Rice University. Three other herbaria, BAYLU, TAES, LSU, and TAMU, were searched via the web and/or by correspondence with the curators or original collectors. We sifted all the literature, published and unpublished --- including interoffice memos and interagency letters, and we contacted many of the principals involved in *E. koernickianum* work, for example, Linda Watson (Miami University) and Jason Singhurst (Texas Parks and Wildlife). We ground-truthed all sites that could be located.

Nomenclature for species referred to in this paper follows Kartesz and Meacham (1999), and authorities can be read in that work.

ANDERSON CO.: We have located *E. koernickianum* at three sites on the Gus Engeling Wildlife Management Area (Texas Parks and Wildlife Department).

Figure 3. *Eriocaulon koernickianum* habitat at Andrew's Bog, Gus Engeling Wildlife Management Area, Anderson County.

Andrew's Bog (EOCODE PMERI01040*003*TX) (EOCODE records refer to Texas Parks and Wildlife records). Vouchers have been collected since 1990 from several locations on the northern shore of this bog (see Tables 1, 2, and 3 for further information about all sites where *E. koernickianum* is found).

This site has been described by MacRoberts and MacRoberts (1998, 2001; see also Lodwick 1975) (Figure 3). It is a deep muck/peat (quaking) bog, with a combination of hillside bog and marsh species, e.g., *Cladium mariscoides*, *Eleocharis* spp., *Eriocaulon decangulare, Iris virginica, Rhynchospora* spp., *Juncus* spp., *Sarracenia alata, Utricularia* spp. and *Xyris* spp. We found *E. koernickianum* at four locations. At Andrew's Bog, *E. koernickianum* occurs at the edges of the marshy/boggy community in bare wet sands on animal trails and where hogs (and other mammals) have rooted and trampled in the past and where the soils are wet but do not support high biomass and are open. The species is totally absent where biomass is high and shade occurs. It does not occur in the quaking areas of the bog where

COUNTY and site	Vouchers
ANDERSON	
Andrew's Bog	*Bridges & Kindscher 13698* [TEX]; *MacRoberts & MacRoberts 3950 [VDB at BRIT], 4099 [TEX].*
Dale's Bog	*MacRoberts & MacRoberts 4926* [TEX]
Jim's Bog	*MacRoberts & MacRoberts 4927* [TEX]
BRAZOS	
Wellborn site	*Parkes s.n.* [TAES, TAMU]
GILLESPIE	
Enchanted Rock	*O'Kennon 11677* [BRIT]; *MacRoberts, MacRoberts & O'Kennon 4105 [TEX]*
HENDERSON	
Baker Lake Bog	*MacRoberts, MacRoberts, & Cathey 4098* [TEX]
Curtis Boyd Bog	*MacRoberts & MacRoberts 4482* [TEX]
Tindel Bog	*MacRoberts & MacRoberts 4952* [TEX]
LIMESTONE	
Perino site	*Perino 4258* [SMU-BRIT]; *Singhurst 6887* [TEX]
VAN ZANDT	
Arc Ridge Ranch	*MacRoberts & MacRoberts 5018* [TEX]

Table 3. Vouchered Texas *Eriocaulon koernickianum* locations.

vegetation is dense and "soils" are predominantly organic muck but only on the sandy edges. Upslope are xeric sandhills and post-oak savanna (MacRoberts et al. 2002a). According to E.L. Bridges (undated memo to L.E. Watson), in 1990 *E. koernickianum* "was abundant after fire" indicating that removal of coarse overtopping vegetation is ideal for this species.

Species abundance in 12 one meter square plots where *E. koernickianum* was found is as follows from most common to least common: *Eleocharis tortilis, Rhynchospora* spp., *Dichanthelium scoparium, Scleria reticularis/triglomerata, Hypericum mutilum, Dichanthelium scabriusculum, Vernonia missurica, Rhexia virginica, Helianthus angustifolius, Eupatorium rotundifolium, E. perfoliatum, Iris virginica, Ludwigia* sp., *Boltonia diffusa, Juncus* sp., *Lycopus rubellus, Panicum virgatum, Xyris torta, Paspalum*

praecox/plicatulum, Sphagnum sp., *Hydrolea ovata, Linum striatum, Polygala sanguinea, Hibiscus moscheutos,* and *Lonicera japonica.* The maximum height of vegetation in these 12 plots averaged 0.75 m (range 0.5-1.2 m), with an average height of 0.30 m (range 0.2 - 0.5 m). Vegetation cover in the 12 plots averaged 80% (range 60 - 100%). Figure 3 shows typical habitat.

Jim's Bog. This bog was regularly surveyed beginning in 1998. However, it was not until 2001, after moderate hog rooting had opened it up, that *E. koernickianum* was found there and in fairly large numbers (up to 20 plants per square meter; hundreds of plants in total). By 2002, with additional severe pig rooting, only four plants were found in the entire bog.

Dale's Bog. In 2001, five *E. koernickianum* plants were found in a one square meter area of this bog where pigs had rooted. No *E. koernickianum* was found at this site in 2002.

We surveyed many other bogs and bog/marsh complexes on Gus Engeling Wildlife Management Area but found no additional *E. koernickianum* populations.

BRAZOS CO.: Wellborn site (EOCODE PMERI01040*002*TX). The exact location is not recorded on the herbarium label, but the specimens were collected near Wellborn, Texas. There are four specimens listed for the TAES and TAMU herbaria web site, with dates 12-18 May 1947. Monique Dubrule Reed (pers. comm.) has confirmed that these specimens are at TAMU, and Stephen Hatch (pers. comm.) that they are present at TAES. Due to a lack of specific site directions, this site cannot be relocated. Its fate, therefore, is unknown. The habitat is not recorded. It is (was) undoubtedly on private land.

FREESTONE CO.: Reports from this county are mistaken; see Limestone County.

Figure 4. *Eriocaulon koernickianum* habitat at Enchanted Rock, Gillespie County. Flowers are *Utricularia cornuta.*

GILLESPIE CO.; Enchanted Rock. This site is on the south side of Enchanted Rock State Natural Area (Texas Parks and Wildlife)(Figure 4) and is the only known site for this species in the Edwards Plateau.

We visited the site with Bob O'Kennon on 22 June 1999. It is a permanent hillside seep on grus (decomposing granite gravel-sand, with bare granite outcropping within it) (Walters and Wyatt 1982). The site is small and covers only about 0.0035 - 0.0045 ha. O'Kennon has looked for other similar sites in the area but has found none. Private lands around Enchanted Rock have not been surveyed; there are other granite hills in the area. O'Kennon says the site has not changed since he first saw it in 1984; possibly it has increased slightly in size.

Surrounding and upslope habitat is desert scrub: e.g., *Aesculus arguta, Aloysia gratissima, Commelina* sp., *Echinocerus* spp., *Eriogonum annuum, E. tenellum, Froelichia gracilis, Gnaphalium* spp., *Hedeoma drummondii, Opuntia* spp., *Palafoxia* sp., *Quercus stellata, Q. fusiformis,* and *Yucca* sp.

Among associated species in the seep, dominants are *Allium* sp., *Hypericum mutilum* and *Utricularia cornuta*; also common are *Coreopsis basilis* (edge), *C. tinctoria, Cyperus haspan,* and *Scleria verticillata*. Other less common species are *Ammania coccinea, Cyperus acuminatus, C. elegans, C. squarrosa, Dichanthelium oligosanthes* var. *scribnerianum, Fuirena simplex* (?), *Hypericum reverchonii, H. gentianoides* (edge), *Juncus acuminatus, J. marginatus, Lechea sans-sabeana* (upslope-edge), *Lechea tenuifolia*, *Sabatia formosa* and Nostock algae. The *Utricularia* was dominant.

The total biomass at the site is not high. Looking down on the site, the ground can be seen clearly. *Eriocaulon koernickianum* was scattered throughout, except at the edges. We took two one meter square plot samples: 60 plants in one; 50 plants in the other. Hence, there were probably at least 1000 *E. koernickianum* in this small seep.

HARDIN CO.: (EOCODE PMEI101040*003*TX.). This report turned out to be a misidentified *Lachnocaulon anceps*. It apparently got into the literature through a Rare Plant Study Center report, University of Texas, Austin. Our information on this is from an annotated Element Occurrence Record Report-Texas Natural Heritage Program and from unpublished correspondence among Natural Heritage personnel. The original report was based apparently on a Cory specimen collected in 1947.

HENDERSON CO.: Curtis Boyd Bog (aka Mr. Black's Bog). In our previous communications (MacRoberts and MacRoberts 1999a, 1999b), we reported conflicting information about the occurrence of *E. koernickianum* at this site. However, in 2000 we located three *E. koernickianum* plants in this bog. The site is on private land and has not been burned in many years. The biomass is very high, and the *E. koernickianum* were found in disturbed areas that were open to sunlight. It is a hillside pitcher plant bog below xeric sandylands. Typical species were *Asclepias rubra, Dichanthelium* spp., *Eleocharis* sp., *Eriocaulon decangulare, E. texense*, *Eupatorium rotundifolium, E. perfoliatum, Polygala cruciata*, *Rhynchospora* spp., *Sarracenia alata, Vernonia missurica, Viburnum nudum,* and *Xyris* spp.

Baker Lake Pitcher Plant Bog, Coon Creek Club. We searched this and closely adjacent sites in May 1999. Three *E. koernickianum* were found. The site was prescribe burned in 1998 and 1999. It has typical muck bog species. The site is on private land. Associated species were: *Drosera* spp., *Eleocharis* spp., *Eriocaulon decangulare, Hypericum mutilum, Juncus* spp., *Lycopodiella appressa, Osmunda cinnamomea, O. regalis, Sarracenia alata, Utricularia cornuta, U. subulata,* and *Xyris* spp.

Tindel Bog. Three *E. koernickianum* plants were found at this site, which is on private land. It is heavily grazed by cattle and most of the bog is badly rutted and damaged. It is a pitcher plant bog with some marsh species below xeric sandylands. Associates were *Acer rubrum, Boehmeria cylindica, Carex* spp., *Dichanthelium scoparium, Drosera* sp., *Eriocaulon decangulare, Eleocharis spp., Hibiscus moscheutos, Hydrocotyle* sp., *Hypericum mutilum, Juncus* spp., *Lycopodiella appressa, Morella cerifera, Osmunda cinnamomea, O. regalis, Paspalum* sp., *Peltandra virginica, Ptilimnium* sp., *Rhynchospora* spp., *Saccarum giganteum, Sarracenia alata, Saururus cernuus, Scleria* spp., *Scutellaria integrifolia, Smilax* sp., *Sphagnum* sp., *Utricularia cornuta, U. subulata, Vernonia missurica,* and *Xyris* spp.

LEON CO.: (EOCODE PMERI01040*004*TX). A location for *E. koernickianum* reported by Geyata Ajilvsgi was searched by Steve Orzell and others but it was not found. Apparently no voucher was collected. Our information on this site is from unpublished correspondence among Texas Natural Heritage Program personnel and from our correspondence with Jason Singhurst.

LIMESTONE CO.: Perino's Site (EOCODE PMERI01040*001*TX). This site is a hillside bog from which *E. koernickianum* has been collected twice: by Perino in July 1979 and by Singhurst in June 1994. The site is on private land. There has been a lot of confusion over the Perino specimen and site location. It was originally reported to be in Freestone County but directions led to Limestone County. Some of the grey literature indicates that the Perino specimen is at TAES, not

BRIT-SMU (Watson 1989, 1992, 1995): it is at BRIT-SMU. Also, Perino's collection number is sometimes incorrectly given as 4528, instead of 4258. Singhurst (pers. comm. 18 Sept. 1998) relocated the site in 1994 and "collected only two individuals ... due to scarcity of this taxa at site." He said (pers.comm. 28 June 1999) that he saw 7 or 8 plants. Singhurst (letter 25 April 1998) revisited the site in 1995 and found the plants still "holding on." Associated taxa included *Asclepias rubra*, *Fuirena squarrosa, Sphagnum* sp., *Xyris* spp., and other bog species. *Sarracenia alata* was not found at this site.

We visited this site on 21 June 1999 but found no *E. koernickianum*. The site is a very wet seepage slope below a deep sand (Carrizo formation) hill, which is now a hay field. In the seepage area, we found almost none of the associated species listed either by Perino: e.g. *Fuirena, Xyris*, or by Singhurst: notably *E. decangulare*. The site was covered with a rank growth of grasses, including introduced grasses from the adjacent hay field, and several *Cyperus* and *Juncus* species. The seepage slope was heavily disturbed by cattle. Typical species were *Carex* sp., *Betula*, *Hibiscus, Hydrocotyle, Hypericum mutilum*, *Rhexia*, *Rhynchospora*, and *Typha*. These wetland species --- most of which are marsh or pond edge species --- were mixed with upland plants, such as *Helianthus debilis, Rudbeckia, Pycnanthemum*, and *Tradescantia. Eryngium prostratum*, a species that occurs in several habitats and which is not particularly associated with hillside bogs, occurred at the site but there was no *E. integrifolium*, a typical bog species. *Rumex* species were also present. Overall the site was highly disturbed and weedy. This description comports with Singhurst's some years earlier (letter dated 25 April 1998) in which he said that "this site is in bad shape, over grazed and needs conservation attention immediately." Singhurst (pers. comm. 28 June 1999) also stated that the site was bush hogged and attempts were made to drain it in 1995 through 1997.

Singhurst (pers. comm. Nov. 10, 2005) revisited the site on 18 September 2005 and found only "one area of sphagnum left" and "no *Eriocaulon* although *E. decangulare* was common at the site in 1994." From Singhurst's description of the site, it was in worse shape in 2005

Figure 5. *Eriocaulon koernickianum* habitat at Arc Ridge Ranch, Van Zandt County.

than it was in 1999. Clearly, it was once a viable bog; it is now severely degraded.

If there are *E. koernickianum* still present at this site, they will be difficult to find. The biomass is high and it is hard to search.

POLK CO.: This county appears on some distribution dot maps for *E. koernickianum*, which certainly is an error (Kral 1966, Tucker 1983; see also Watson et al. 1994). To our knowledge, there is no report for Polk County other than these dot maps.

TYLER CO.: (EOCODE PMERI01040*005*TX). This is where the Charles Wright type specimen is supposed to have been collected (see Van Heurck 1870, Moldenke 1942, and Correll and Johnston 1970). The Wright specimen was not seen by Moldenke, Correll and Johnston, or Kral (Kral pers. comm.) and its provenance remains unknown. A note in Tucker (1983) says: "Type specimen --- Texas, apparently without locality or date, collected by Charles Wright, in Herb. DC. et Van Heurck (type not seen by author of this report; preceding

information taken from a handwritten note in the *Eriocaulon* folder at New York Botanical Garden)." But according to Tucker, nothing is said about "Tyler Co." Geraldine Watson (1982) has reported *E. koernickianum* from the Big Thicket National Preserve but did not collect a voucher. The Preserve is in both Tyler and Hardin counties. Our (and others) extensive surveys of what appears to be suitable habitat in this region (wetland pine savanna and hillside bogs) has revealed no *E. koernickianum* (MacRoberts and MacRoberts 2001; MacRoberts et al. 2002b; Brown et al. 2005).

Although we attempted to find the type specimen in appropriate herbaria in Belgium, we never received a response to any of our inqueries.

VAN ZANDT CO.: Arc Ridge Ranch. There are several beaver ponds on this private holding. We surveyed many of these and in a grassy area at the shallow end of one pond found a few *E. koernickianum* (Figure 5). The *E. koernickianum* at this site persisted through at least two years. This pond did not begin to form until about 20 years ago: before it had been largely an open bog. Plants common in the area in which *E. koernickianum* was found were *Acer rubrum, Dichanthelium* spp., *Drosera* sp., *Eleocharis* sp., *Saccarum giganteum, Eupatorium rotundifolium, Lycopodiella appressa, Morella cerifera, Nyssa biflora, Rhynchospora rariflora, Scleria* sp., *Sphagnum* sp., *Utricularia cornuta,* and *U. subulata.* The area has not burned in decades.

We have reported above on the sites where *E. koernickianum* has been reported and on sites where it has been found. Our surveys during the period 1998 to 2002 extended from Caddo Parish to Vernon Parish in Louisiana, from Bowie and Wood counties to Hardin and Gillespie counties in Texas, and into southeastern Oklahoma. Dozens of sites were thoroughly or partly searched. Some of the more important areas searched are Hilltop Estates, Leon County; Arc Ridge Ranch, Van Zandt County; and Gus Engeling Wildlife Management Area, Anderson County. Extensive surveys of bogs and wetland pine savannas (which appear to be ideal habitat for this species) have been carried out in southwest Louisiana and southeast Texas by numerous

Site	pH	P	K	Ca	Mg	OM
Ek 2	4.30	6.0	81.0	257.0	57.0	1.80
Ek 4	4.10	6.0	82.0	279.0	59.0	1.80
Ek 6	4.10	10.0	111.0	447.0	98.0	2.00
Curtis Boyd	4.40	12.0	61.0	361.0	98.0	2.00

Table 4. Soils of selected *Eriocaulon koernickianum* sites (OM = Organic matter). Ek 2, 4, 6 are from Andrew's Bog (Anderson Co.) and Curtis Boyd = Curtis Boyd Bog (Henderson Co.).

botanists for many years without discovering *E. koernickianum* (see summary in MacRoberts and MacRoberts 2001).

Access to private land was the biggest problem in this survey. Virtually all thorough searches were made on public land (e.g., Big Thicket National Preserve, Gus Engeling Wildlife Management Area) or on private lands whose owners are favorable to conservationists.

SOILS, LIFE HISTORY, AND POPULATION

At Andrew's Bog, Gus Engeling Wildlife Management Area, we made observations on soils and population dynamics of *E. kornickianum*. These are reported here.

Soils. We collected soil samples from the upper 15 cm from four sites (three from Andrew's Bog and one from Curtis Boyd Bog, Henderson County) and had them analyzed by A. & L. Laboratories, Memphis, Tennessee. Table 4 presents the results. Soils are acidic and in general nutrient poor. They are similar to those found in other West Gulf Coastal Plain bogs (Watson et al. 1994; MacRoberts and MacRoberts 2001).

Annual or Perennial. Whether or not *E. koernickianum* is an annual or perennial appears to be uncertain (Kral 2000; Watson et al. 1994). In 2000, we marked 246 individual plants in 12 one meter square plots to see if plants would come up at the identical spot the following year. In

Year/Site	Range of plants in 1 m sq. plots	Estimated plants at site
1999		
1	0-16	1000
2	0-18	500
3	0-30	1000
2000		
1	0-21	1000
2	0-10	100
3	0- 1	10
2001		
1	0-26	1000
2	0-15	500
3	0-27	1000
2002		
1	0- 9	250
2	0-13	200
3	0-33	400

Table 5. Estimated population over four years of *Eriocaulon koernickianum* at three sites at Andrews Bog.

2001, 96 plants came up in the study plots but only four were at the same spots, an indication that *E. koernickianum* is an annual. Additionally, *E. keornickianum* appeared suddenly at sites that had previously been thoroughly surveyed with no plants found, indicating a considerable seed bank at the Gus Engeling sites (see below).

Population fluctuations. Since 1999, we estimated the population for three sites at Andrew's Bog. We randomly set one meter square plots in each area, counted plants in the plots, and estimated the *E. koernickianum* population by multiplying by total area. Results are given in Table 5. Wide fluctuations in numbers occurred. For example, Site 3 had 1000 plants in 1999, 10 in 2000, 1000 in 2001, and 400 in 2002. Variables include pig rooting (always a reduction in numbers after severe pig rooting), fire (lack thereof), and possibly drought.

SITE/YEAR	Number of Plants per Plot				
	1	2	3	4	5
Transect 1.					
1999	13	15	12	16	0
2000	16	4	21	15	1
2001	17	6	26	20	3
2002	9	0	3	9	9
Transect 2					
1999	7	0	0	1	1
2000	0	1	0	0	0
2001	2	1	0	0	2
2002	0	0	0	0	0

Table 6. *Eriocaulon koernickianum* in ten one meter square plots in two transects over four years (Andrew's Bog).

Permanent plots. In 1999, we established two transects each with five one meter square plots spaced at three meter intervals in two areas of Andrews Bog where *E. koernickianum* occurred and counted the plants in each until 2002. The results are given in Table 6. Transect 2 was continuously rooted by pigs and never had many plants. It was completely destroyed by pigs in 2002. Transect 1 was in a moister area and did not get badly mauled by pigs until 2002.

Exclosures. In 2000, we established six one meter square hog exclosures and corresponding adjacent one meter square unprotected plots just outside the exclosures and counted *E. koernickianum* in each plot over three years. The plots were established in areas with significant numbers of *E. koernickianum.* Uncontrolled variables were fire, which burnt plots 5 and 6 in February 2002 (hog damage acted as a fire break for the other plots). The results are given in Table 7. Unprotected plots were largely destroyed by pigs in both 2001 and 2002 except for Plot 1 in 2001. Protected plots fared better: for two years, most plots kept numbers up but in the third year the herbaceous vegetation was so thick that *E. koernickianum* was shaded out. In Plots

5 and 6, this trend was advanced more rapildly perhaps because these plots had the most extensive vegetation growth and were shaded out in

Number 1.	Inside	Outside
2000	11	7
2001	14	8
2002	0	0
Number 2.		
2000	13	15
2001	15	0
2002	4	0
Number3.		
2000	26	26
2001	28	3
2002	5	0
Number 4		
2000	52	53
2001	27	0
2002	3	3
Number 5.		
2000	13	4
2001	1	0
2002	1	6
Number 6.		
2000	7	19
2001	0	0
2002	0	3

Table 7. *Eriocaulon koernickianum* numbers inside exclosure and outside exclosure in six plots (Andrew's Bog).

one year. The fire of February 2002, however, did not immediately reverse these trends, except for outside Plot 5.

Further observations where pigs, fire, moisture, and herbaceous growth are controlled will be necessary to piece together the importance of these factors in the life history of *E. koernickianum,* but our observations support the views expressed elsewhere: disturbance is important in *E. koernickianum* life cycle (Watson et al. 1994). Mild animal activity and fire are important: intensive pig rooting is detrimental to the species, as is fire suppression.

CONSERVATION

Watson et al. (1994, 2002) in their study of *E. koernickianum* in Oklahoma, found that many factors are contributing to the decline of this species including an annual or weak perennial life history, no vegetative reproduction, low seed set, limited seed bank contribution to population growth and maintenance --- however, our observations at the Gus Engeling sites indicate that seed bank must be quite large to drive the massive population fluctuations we observed --- genetic homogeneity, a restricted habitat, and poor competition abilities. As they said: "without intervention, western populations of *E. koernickianum* are doomed to extinction" (Watson et al. 1994:985). In our work, we have concentrated on the latter two factors, and our findings substantially concur with those of Watson et al. (1994, 2002): *E. koernickianum* is intolerant of shading, which indicates that over most of its range it benefits from disturbance (fire and *minor* animal activity). Our research with exclosures indicates that two years without appropriate disturbance is all that the species can tolerate. After two years, overtopping vegetation becomes dense and numbers plummet. Minor pig rooting opens areas, but major pig rooting leads to the destruction of the plants. The role of fire *alone* has not been explored, but anecdotal results indicate that it suffices to keep habitat open. Given its requirements (open, moist soils), *E. koernickianum* seems to be associated with areas of high biomass suggesting that it is sporadic and opportunistic and depends on specific conditions of soil, moisture, and cover. However, the species is absent from habitat that appear to be suitable which indicates that its dispersal may be limited (see Watson et al. 1994).

While Watson et al. (1994, 2002) reported a decline in populations in the western part of the species range, our surveys have doubled the known Texas sites and have increased the known counties where it occurs from four to six. We do not doubt that additional surveys (notably on private land) would uncover more sites because habitat is known to be present; a lack of access to private land prevented us from more meaningfully assessing of the status of this species in Texas. Nonetheless, mere presence on private land means little since there are no guarantees for its conservation there. Further, all known populations on private land are very small. Unless *E. koernickianum* is protected and managed, especially under the changed conditions that have followed European settlement (e.g., fire suppression, heavy cattle grazing and trampling, feral hog rooting), its fate remains very precarious. *Eriocaulon koernickianum* habitat requirements and life history characteristics make it very vulnerable.

Management would appear to be simple: 1) either remove hogs (and/or trampling livestock) or fence areas, 2) introduce fire every two to three years.

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