Section 6 Report Review

Attachment to letter dated MAR 2 7 2003

Project: Status Survey of Dwarf Pipewort

Final or interim report? Final Report

Job #: WER 64 **Grant #:** E-16

Reviewer's Station: Austin ES FO

Lead station was contacted and concurs with the following comments:
___ Yes ___ No _X_ Not applicable (reviewer is from lead station)

Interim Report	Final Report
___ is acceptable as is	_X_ is acceptable as is
___ is acceptable as is, but the comments below need to be addressed in the next report	___ is acceptable, but needs minor revision (see comments below)
___ needs revision (see comments below)	___ needs major revision (see comments below)

Comments:

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. E-16

Endangered and Threatened Species Conservation

Project WER64 -- Status Survey of Dwarf Pipewort (*Eriocaulon kornickianum*) in Texas

Prepared by: Michael H. MacRoberts and Barbara R. MacRoberts

John Herron
Program Director, Wildlife Diversity

Robert Cook
Executive Director

November 1st, 2002

FINAL REPORT

STATE: Texas **GRANT NO:** E – 16

PROGRAM TITLE: Endangered and Threatened Species Conservation

PERIOD COVERED: September 1, 1999 – August 31, 2002

PROJECT NUMBER: WER64

PROJECT TITLE: Status Survey of Dwarf Pipewort (*Eriocaulon kornickianum)* in Texas

PROJECT OBJECTIVE(S):

1. To review all records and search herbarium collections to pinpoint historical distribution of *E. kornickianum* in Texas and correct mistakes in records. To prepare a definitive annotated list for the species distribution in Texas.

2. To survey sites likely for this species, notably those on public lands. Surveys would center on historical records beginning with the Engeling WMA where a large population was discovered in 1990 and relocated in 1998 (B.R. MacRoberts & M.H. MacRoberts pers obs.). Other sites nearby, such as Coon Creek Club and East Texas Arboretum (Henderson County), will be examined with permission of the owners and with the help of the Texas Parks and Wildlife Department. Sites in Gillespie county will be surveyed with the help of the staff of the Botanical Research Institute of Texas. Aerial photographs will be used to locate likely habitat, which then will be explored.

PREPARED BY: Michael H. MacRoberts November 1st, 2002

APPROVED BY: _____ 11/25/02

Neil E. Carter Date
Federal Aid Coordinator
Texas Parks & Wildlife Department

STATUS REPORT ON *ERIOCAULON KOERNICKIANUM* (DWARF PIPEWORT) IN TEXAS.

August 31, 2002

Michael H. MacRoberts and Barbara R. MacRoberts

Bog Research, 740 Columbia, Shreveport, LA 71104 and Herbarium, Museum of Life Sciences, Louisiana State University in Shreveport, LA 71115.

Project WER26

TEXAS PARKS AND WILDLIFE
WILDLIFE DIVERSITY PROGRAM
SECTION 6

AUSTIN, TEXAS

STATUS REPORT ON *ERIOCAULON KOERNICKIANUM* (DWARF PIPEWORT) IN TEXAS.

August 31, 2002

Michael H. MacRoberts and Barbara R. MacRoberts

Bog Research, 740 Columbia, Shreveport, LA 71104 and Herbarium, Museum of Life Sciences, Louisiana State University in Shreveport, LA 71115.

INTRODUCTION

Eriocaulon koernickianum Van Heurck & Muell.-Arg., the most diminutive of the eleven North American eriocaulons, is widely disjunct in Arkansas, Georgia, Oklahoma, and Texas (Kral 2000)(Figure 1 and 2). It is a monoecious, outcrossing, annual whose limited genetic variation across its range suggests that recolonization may explain current distribution (Watson et al. in press). It is of conservation concern and is listed C2 federally and either S1 or S2 in all states where it occurs (Kral 2000, Kartesz and Meacham 1999, NatureServe 2002). In Georgia, north Arkansas, and one Texas site it is associated with 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 (MacRoberts and MacRoberts 2001, MacRoberts et al. 2002).

Between 1998 and 2002 we surveyed for and made observations on *E. koernickianum* in Texas. This report is summarizes our findings; it supercedes and supplants our previous reports (MacRoberts and MacRoberts 1999a, 1999b).

DISTRIBUTION

The first task in studying *E. koernickianum* in Texas was to find out what is known. 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. It was not possible even to ascertain whether or not there was a single verified location for *E. koernickianum* in the State.

CONFUSION ABOUT *E. KOERNICKIANUM* IN TEXAS: A REVIEW OF THE LITERATURE, UNPUBLISHED DOCUMENTS, ETC.

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. Modenke (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 does 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 (1974) 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, or in Element Occurrence Records (EOR) produced by such organizations as the Texas Natural Heritage Program (later 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 from the Big Thicket National Preserve (BTNP) but without specific comment or vouchers. Her plant collections have been examined by Larry Brown (pers. comm.; data on file BTNP), 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 (TOES) (1993) lists *E. koernickianum* for Brazos, Freestone, Leon, and Tyler counties but without vouchers or references. Kral (1983) gives a county dot map distribution showing Hardin and Brazos counties, again without vouchers or comment. The Texas Natural Heritage Program (TNHP) (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." Kral (2000) gives a distribution map, but it does not designate counties. There are six EORs for the taxon produced by Texas Parks and Wildlife; none is verified, and three are incorrect: these attributions especially illustrate the problems inherent in the failure to verify with voucher specimens and to annotate. Watson et al. (1994) show the general distribution of *E. koernickianum* without specific county locations and give no 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 Jackie Poole (Texas Natural Heritage Program) indicates that at that time there was no certainty about any *E. koernickianum* site in Texas!

CLEARING UP CONFUSION OF *E. KOERNICKIANUM* IN TEXAS.

We sifted all the literature, published and unpublished — including interoffice memos and interagency letters — and 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, and TAMU, were searched via the web and/or by correspondence with the curators or original collectors. We also 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.

We summarize the results below, giving the Texas Park and Wildlife EOCODE number

where available for further information (or misinformation). The distribution of these sites is given in the attached maps (Figures 3 and 4) and other information is summarized in Table 1,2, and 3.

In addition to reviewing this "literature," we undertook surveys for *E. koernickianum* at known sites, and by using other sources (aerial photos, local knowledge, etc), we explored additional possible sites. This took us over most of east Texas and to several locations in western Louisiana.

ANDERSON CO.: We have located *E. koernickianum* at three main sites on the Gus Engeling Wildlife Management Area (GEWMA) (Texas Parks and Wildlife Department) (Figure 5).

Andrew's Bog (EOCODE PMERI01040*003*TX). Vouchers have been collected since 1990 from several locations on the northern shore of this bog (*Bridges & Kindscher 13698* [TEX]; *MacRoberts & MacRoberts 3950* [VDB at BRIT]; *MacRoberts & MacRoberts 4099* [TEX] (Figure 6).

This site has been described by MacRoberts and MacRoberts (1998; see also Lodwick 1975). It is a deep muck/peat (quaking) bog, with a combination of hillside bog and marsh species, e.g., *Sarracenia alata, Eriocaulon decangulare, Iris virginica, Cladium mariscoides, Eleocharis* spp., *Rhynchospora* spp., *Juncus* spp., *Xyris* spp., and *Utricularia* spp. We found *E. koernickianum* at four locations. At Andrew's Bog, *E. koernickianum* occurs at the edges of the marshy/boggy community in very shallow, bare wet sands on animal trails and where hogs (and other mammals) have rooted and trampled and where the soils are wet but do not support high biomass and are open (Figure 7 and 8). The species is totally absent where biomass is high and shade occurs. It does not occur in the quaking areas of the bog but on the sandy edges. Upslope are xeric sandhills and post-oak savanna (MacRoberts et al. 2002). 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: *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, Hydrolea ovata, Linum striatum, Polygala sanguinea, Hibiscus moscheutos, 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 9 and 10).

Jim's Bog. (*MacRoberts & MacRoberts 4927* [TEX]) (Figure 6). This bog was regularly surveyed beginning in 1998. However, it was not until 2001, after considerable hog

rooting had opened it up, that *E. koernickianum* was found there and in fairly large numbers (up to 20 plants per meter square; hundreds of plants in total). By 2002, with additional severe pig rooting, only four plants were found in the entire bog.

Dale's Bog. (*MacRoberts & MacRoberts 4926* [TEX])(Figure 6). In 2001, five *E. koernickianum* plants were found in a one meter square area of this bog where pigs had rooted. No plants were found at this site in 2002.

We surveyed many other bogs and bog/marsh complexes on GEWMA but found no more *E. koernickianum*.

BRAZOS CO.: Wellborn site (EOCODE PMERI01040*002*TX) (Figure 11). 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 (*Parkes s.n.* [TAES, TAMU]). Monique Dubrule Reed (pers. comm.) has confirmed that these specimens are at TAMU, and Stephen Hatch (pers. comm.) that they are present at TAES. Because of no 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.

GILLESPIE CO.; Enchanted Rock. (*O'Kennon 11677* [BRIT], *MacRoberts, MacRoberts, & O'Kennon 4105* [TEX])(Figure 12). This site is on the south side of Enchanted Rock State Natural Area (Texas Parks and Wildlife). The O'Kennon specimen was collected on 19 June 1993 and the MacRoberts et al. specimen on 22 June 1999. This is the only known site for this species in the Edwards Plateau; all other Texas *E. koernickianum* sites occur in the Post Oak Savanna.

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 sites like this 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 (Figure 13).

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

Among associated species in the seep, dominants are *Utricularia cornuta, Allium* sp., *Hypericum mutilum*; also common are *Cyperus haspan, Scleria verticilata, Coreopsis basilis*, and *C. tinctoria*. Other associated species are *Cyperus elegans, C. acuminatus, C. squarrosa, Fuirena simplex* (?), *Hypericum reverchonii, H. gentianoides* (edge), *Sabatia*

formosa, Juncus marginatus, Juncus sp., *Ammania coccinea, Lechea tenuifolia, L. sans-sabeana* (upslope-edge), and *Dichanthelium oligosanthes* var. *scribnerianum*.

The total biomass at the site is not high. Looking down on the site, the ground can be seen clearly. *E. koernickianum* was scattered throughout, except at the edges; plants were not confined to animal tracks and disturbed areas (there were none). We took two one meter square plot samples: 60 plants in one; 50 plants in the other. Hence, there are probably at least 1000 *E. koernickianum* in this small seep.

Overall, flowering *E. koernickianum* tended to be diminutive (2.5 cm) (as were all species within the seepage area, *Utricularia cornuta* being about the tallest species on 22 June), although there were some well-grown individuals (6-7 cm) with flowering heads to 2 mm wide.

HARDIN CO.: 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 EOR 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. This "record" once had the EOCODE number EOCODE PMEI101040*003*TX.

HENDERSON CO.: Curtis Boyd Bog (aka Mr. Black's Bog) (*MacRoberts & MacRoberts 4482* [TEX]) (Figure 14). 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* 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 here were *Sarracenia alata, Viburnum nudum, Xyris* spp., *Rhynchospora* spp., *Asclepias rubra, Eriocaulon decangulare, E. texense, Vernonia missurica, Dichanthelium* spp., *Eupatorium rotundifolium, E. perfoliatum, Eleocharis* sp., *Polygala cruciata*.

Baker Lake Pitcher Plant Bog, Coon Creek Club. (*MacRoberts, MacRoberts & Cathey 4098* [TEX]) (Figure 15, 16). 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: *Sarracenia alata, Eriocaulon decangulare, Drosera* spp., *Lycopodiella appressa, Osmunda cinnamomea, O. regalis, Eleocharis* spp., *Juncus* spp., *Utricularia cornuta, U. subulata, Xyris* spp., *Hypericum mutilum*.

Tindel Bog. (*MacRoberts & MacRoberts 4952* [TEX]) (Figure 17). Three *E. koernickianum* 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 typical pitcher plant bog below xeric sandylands. Associates were *Sarracenia alata, Eriocaulon decangulare, Drosera* sp., *Lycopodiella appressa, Osmunda cinnamomea, O. regalis, Peltandra virginica, Saururus cernuus, Rhynchospora* spp., *Eleocharis spp., Scleria* spp., *Juncus*

spp., *Carex* spp., *Dichanthelium scoparium, Erianthus giganteus, Paspalum* sp., *Dichanthelium* spp., *Smilax* sp., *Xyris* spp., *Acer rubrum, Hydrocotyle* sp., *Ptilimnium* sp., *Vernonia missurica, Scutellaria integrifolia, Hypericum mutilum, Utricularia cornuta, U. subulata, Hybiscus moscheutos, Myrica cerifera, Boehmeria cylindica, Sphagnum.*

LEON CO.: A location reported by G. Ajilvsgi, but S. Orzell and others were unable to find *E. koernickianum* at this site. No voucher was given and no voucher seen; apparently no specimen was collected. Our information on this site is from unpublished correspondence among Texas Natural Heritage Program personnel and from our correspondence with J. Singhurst (EOCODE PMERI01040*004*TX).

LIMESTONE CO.: Perino's Site (*Perino 4258* [BRIT/SMU], *Singhurst 6887* [TEX])(EOCODE PMERI01040*001*TX) (Figure 18). 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. There has been a lot of confusion over the Perino specimen and site location. It was originally reported as 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 *Xyris* spp., *Fuirena simplex, Sphagnum* sp., *Asclepias rubra,* and other bog species. *Sarracenia* was not found at this site. The site is on private land.

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 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 *Hydrocotyle, Typha* (road ditch), *Betula,* a few *Rhynchospora* species not bog fidels, a *Carex, Hypericum mutilum* (the only species on Perino's list we saw except for a few *Rhexia*); *Hibiscus* were rank on lower part of the seep. These wetland species --- most of which are marsh or pond edge species --- were mixed with upland species such as *Tradescantia, Rudbeckia, Helianthus debilis,* and *Pycanthemum. 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 sites 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. 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 very hard 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 this 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). This 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* --- no voucher --- from the Big Thicket National Preserve and/or vicinity; the Preserve includes 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).

Although we made extensive efforts to find the type specimen in appropriate herbaria in Belgium, using letters and Internet, it was not found. In fact, we could never get the herbaria to respond to any of our inqueries.

VAN ZANDT CO.: Arc Ridge Ranch (*MacRoberts & MacRoberts 5018* [TEX]) (Figure 19). 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*. 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 *Eleocharis* sp., *Rhynchospora rariflora, Erianthes gigantea, Utricularia subulata, U. cornuta, Scleria* sp., *Eupatorium rotundifolium, Sphagnum, Acer rubrum, Dichanthelium* spp., *Drosera* sp., *Lycopodiella appressa, Acer rubrum, Nyssa biflora,* and *Myrica cerifera.* The area has not burned in living memory (Figure 20).

AREAS SEARCHED

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, but because of the sporadic and opportunistic nature of the species, re-searching these sites is advisable. 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.

It also should be reiterated that extensive surveys of bogs and wetland pine savannas (which appear to be ideal habitat for this species) have been carried out in west Louisiana and southeast Texas by numerous botanists for many years (see summary in MacRoberts and MacRoberts 2001) without discovering *E. koernickianum*.

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 not hostile to conservationists: Charles Ogilvie, Dan Broaddus, and Seabern Tindel.

HABITAT AND FIELD EXPERIMENTS/OBSERVATIONS

Texas habitat for *E. koernickianum* appears to be permanently wet seepage slopes or marsh/bog edges that are not dominated by tall vegetation. The species often occurs in disturbed areas such as animal trails and old pig rootings. The sites we have examined do not appear to differ significantly from those reported for Arkansas, Oklahoma, or Georgia, although there has not been any detailed comparison made among them (Watson and Uno 1991, Watson et al. 1994, Jones and Carpenter 1995). In Texas, *E. koernickianum* sites occur both adjacent to granite outcropping (as occurs in Georgia) and to xeric sandylands (as occurs in southern Oklahoma).

Soils. Soils are acidic and are similar to those found in other regions (Table 4, see also Watson et al. 1994; MacRoberts and MacRoberts 1998, 2001).

Annual or Perennial. Whether or not *E. koernickianum* is an annual or perennial appears to be disputed (Kral 2000; Watson et al. 1994, in press). In 2000 we marked 246 individual plants in 12 one meter square plots in Andrew's Bog (Gus Engeling Wildlife Management Area)to see if plants would come up at the identical spot the following year. In 2001, 96 plants came up in the study plots of which only four were at the same spots, and indication that *E. koernickianum* is an annual.

Population fluctuations. Since 1999, we estimated minimum population for three of the four sites at Andrew's Bog. These figures are based on transects with several one meter square plots and aim to estimate not total but minimal population. Results are given in Table 5. Wide fluctuations in numbers occurred, e.g., 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 (or lack thereof), and possibly drought.

Permanent plots. In 1999, we established two transects of five one meter square plots, each spaced at three meter intervals in two areas of Andrews Bog where *E. koernickianum* occurred (Table 6). "Plot 2" was continuously hammered by hogs and never had many plants. It was completely destroyed by pigs in 2002. "Plot 1" was in a moister area and did not get badly mauled by pigs until 2002, except for one of the sub-plots.

Exclosures. We established six one meter square exclosures and corresponding adjacent control plots in Andrew's Bog and counted *E. koernickianum* in each plot (12) over the next three years (Table 7). The exclosures 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 fire breaks for the other plots). The results are easily interpreted. 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, plots kept numbers up but in the third year the herbaceous rough (litter) was so great that *E. koernickianum* was shaded out. Plots 5 and 6 showed a reversal of this trend, perhaps because they had the most extensive rough and were shaded out in 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 the life cycle of *E. koernickianum* (Watson et al. 1994). Mild animal activity and fire are important: intensive pig rooting is detrimental to the species, as is fire suppression.

CONSERVATION STATUS

Watson et al. (1994) 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, little seed bank contribution to population growth and maintenance, 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): *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 shows 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 --- 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 incongruously associated with areas of high biomass indicating that it is sporadic and opportunistic, depending on specific conditions of soil, moisture, and cover. However, areas with what appears to be suitable habitat are without this species, indicating that its mode of dispersion may be limited (see Watson et al. 1994).

While Watson et al. (1994) 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 there; a lack of access to private land prevented us from ascertaining a more meaningful accessment 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 it 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), the fate of *E. koernickianum* remains very precarious. *Eriocaulon koernickianum* habitat requirements and life history characteristics make it very vulnerable.

Consequently, whether this species' Federal status should change or not remains an open question. Its habitat in Texas is being destroyed rapidly. Only four sites are on protectable land, and these are not yet fully protected.

MANAGEMENT

Management would appear to be simple: 1) Either remove hogs (and/or trampling livestock) or fence areas. 2) Introduce fire every 2 to 3 years.

SUMMARY

A large body of information and misinformation has developed on the Texas distribution of *E. koernickianum*. We have sifted it, including both published and unpublished reports down to agency interoffice memos. About half of the distribution reports (and EORs) are in error. We searched herbaria and sites from which *E. koernickianum* was reported (where possible), as well as other promising sites in Texas. We currently know of 10 vouchered sites where *E. koernickianum* either currently exists or has recently existed. All sites are either in the Edwards Plateau or Post Oak Savanna; none is in the Pineywoods as commonly believed (Hatch et al. 1990). How the type specimen collected by Charles Wright became associated with Tyler County remains unknown; where it was collected will probably remain a mystery.

The sites where *E. koernickianum* occurs range in size from a square meter to several hectares. Populations range from a few plants to thousands. And populations fluctuate wildly for reasons that are not altogether clear.

Of the 10 sites with known locations, four are protected on Texas Parks and Wildlife lands, one is on a private club's land that is partly managed by State wildlife biologists, and the others are on private land, mostly in bad condition. The future of the species in the western part of its range is precarious.

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The following individuals aided in this study: Dan Broaddus, Larry Brown, Jim Cathey, Jane Deisler, Gaylon Dingler, Lynn Drawe, Carl Frentress, Paul Harcombe, Stephen Hatch, Walter Holmes, Hayden Haucke, Bob Kral, Steve Lynch, Jim Neal, Guy Nesom,

Charles Ogilvie, Brian Ogilvie, Bob O'Kennon, Dale Prochaska, Monique Dubrule Reed, Scott Riddle, Gareth Rowell, Lynn Sherrod, Jason Singhurst, Bruce Sorrie, Connie Taylor, Billie Turner, Seabern Tindel, Mike Warnock, Linda Watson, Tom Wendt, and Lindsay Woodruff.

REFERENCES

Correll D.S. and M.C. Johnston. 1970. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

Hatch, S.L., K.N. Gandhi, and L.E. Brown. 1990. Checklist of the Vascular Plants of Texas. Texas A & M Experimental Station, College Station, Texas.

Jones, N. and B. Carpenter. 1995. Boehler seeps and sandhills site conservation plan. Unpublished report. The Nature Conservancy, Tulsa, Oklahoma.

Kral, R. 1966. Eriocaulaceae of continental North America north of Mexico. Sida 2:285-332.

Kral, R. 1983. A report on some rare, threatened, and endangered forest-related vascular plants of the South. Vol. I. Technical Publ. R8-TP 2. USDA Forest Service. Pp. 171-174.

Kral, R. 2000. Eriocaulaceae. In: Flora of North America. 22:198-210.

Lodwick, L.N. 1975. Net aerial primary production of three east Texas bogs. MS Thesis. Baylor Univeristy, Waco, Texas.

MacRoberts, B.R. and M.H. MacRoberts. 1998. Floristics of muck bogs in east central Texas. Phytologia 85:61-73.

MacRoberts, M.H. and B.R. MacRoberts. 1999a. Status report on *Eriocaulon kornickianum* in Texas. Unpublished report. U.S. Fish and Wildlife Service.

MacRoberts, M.H. and B.R. MacRoberts. 1999b. Status report on *Eriocaulon kornickianum* in Texas. Unpublished report. U.S. Fish and Wildlife Service.

MacRoberts, M.H. and B. R. MacRoberts. 2001. Bog communities of the West Gulf Coastal Plain: A profile. Bog Research Papers in Botany & Ecology 1:1-151.

MacRoberts, B.R., M.H. MacRoberts, and J.C. Cathey. 2002. Floristics of xeric sandylands in the post oak savanna region of east Texas. Sida 20:373-386.

Moldenke, H.N. 1937. Eriocaulaceae. North American Flora. 19, Pt. 1.

Moldenke, H.N. 1942. In Lundell, C.L. (ed.) Flora of Texas. Vol. 3, Texas Research Foundation, Renner, Texas.

Moldenke, H.N. 1947. Additional notes on the Eriocaulaceae. Phytologia 29:193-239.

Nature Serve Explorer 2001. An online encyclopedia of life (web application). Version 1.6. Arlington, Virginia.

Texas Natural Heritage Program. 1995. Special plant list. Unpublished report, Texas Parks and Wildlife Department. 28 pp.

Texas Organization for Endangered Species. 1993. Endangered, threatened and watch list of Texas plants. Publication 9. 32 pp.

Tucker, G. 1983. Status report of *Eriocaulon kornickianum*. Unpublished report submitted to U.S. Fish and Wildlife Service, Atlanta, Georgia.

Van Heurck, H. 1870. Observations Botanicae et descriptiones Plantarum Novarum Herbarii Van Heurckiani. Anvers/Berlin.

Walters, T.W. and R. Wyatt. 1982. The vascular flora of granite outcrops in the central mineral region of Texas. J. Torr. Botanical Club 109:344-364.

Watson, G. 1982. Vegetational survey of the Big Thicket National Preserve. Unpublished report,. Big Thicket National Preserve, Beaumont, Texas.

Watson, L.E. 1989. Status survey of *Eriocaulon kornickianum*, dwarf pipewort, in Oklahoma. Unpublished report. U.S. Fish and Wildlife Services, Tulsa, Oklahoma.

Watson, L.E. and G.E. Uno. 1991. Population biology and reproductive ecology of *Eriocaulon kornickianum*, Dwarf Pipewort in Oklahoma. Unpublished report. U.S. Fish and Wildlife Service: Albuquerque, New Mexico.

Watson, L.E. 1992. Divergence among disjunct populations of *Eriocaulon kornickianum*, dwarf pipewort: I. Morphology. U.S. Fish and Wildlife Service: Albuquerque, New Mexico.

Watson, L.E. 1995. Morphological and genetic divergence among disjunct populations of *Eriocaulon kornickianum*, dwarf pipewort. U.S. Fish and Wildlife Service: Albuquerque, New Mexico.

Watson, L.E., G.E. Uno, N.A. McCarty, and A.B. Kornkven. 1994. Conservation biology of a rare plant species, *Eriocaulon kornickianum* (Eriocaulaceae). Amer. J. Bot. 81:980-986.

Watson, L.E., A.B. Kornkven, C.R. Miller, J.R. Allison, N.B. McCarty, and M.N. Unwin. in press. Morphometric and genetic variation in *Eriocaulon koernickianum* Van Heurck & Mueller-Argoviensis (Eriocaulaceae): a disjunct plant species of the southeastern

United States. Castanea.

Table 1. Summary of information on confirmed *E. koernickianum* sites in Texas by counties. The population size numbers are based on field assessments at highest known population. Populations fluctuate radically.

County & site	Exact location known	First year located	Year last located	Population 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

*Protected sites managed by Texas Parks and Wildlife

Table 2. Statistics for *E. koernickianum* sites in Texas.

Site	Size of site in ha. (suitable habtat)	Area in which E.k. found (ha.)	Condition of site
Andrews	20.0	several	Good
Dale's	1.0	0.0001	Poor/Good
Jim's	0.4	0.2	Poor/Good
Wellborn	?	?	?
Enchanted Rock	0.0035-0.0045	0.0025	Good
Coon Creek	several	0.0001	Good
Curtis Boyd	1.0	0.0001	Poor
Tindel's	2.0	0.0001	Poor
Perino's	2.0	?	Very Poor
Arc Ranch	1.0	0.0001	Good

Table 3. Vouchered Texas *Eriocaulon koernickianum* locations.

ANDERSON CO.	
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 CO.	
Wellborn site	Parkes s.n. [TAES, TAMU]
GILLESPIE CO.	
Enchanted Rock	O'Kennon 11677 [BRIT]; MacRoberts, MacRoberts & O'Kennon 4105 [TEX]
HENDERSON CO.	
Curtis Boyd Bog	MacRoberts & MacRoberts 4482 [TEX]
Baker Lake Bog	MacRoberts, MacRoberts, & Cathey 4098 [TEX]
Tindel Bog	MacRoberts & MacRoberts 4952 [TEX]
LIMESTONE CO.	
Perino site	Perino 4258 [SMU]; Singhurst 6887 [TEX]
VAN ZANDT CO.	
Arc Ridge Ranch	MacRoberts & MacRoberts 5018 [TEX]

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.).

Site	pH	P	K	Ca	Mg	OM
Ek 2	4.3	6	81	257	57	1.8
Ek 4	4.1	6	82	279	59	1.8
Ek 6	4.1	10	111	447	98	2.0
Curtis Boyd	4.4	12	61	361	98	2.0

Table 5. Minimum population of *E. koernickianum* at three sites over four years at Andrews Bog.

Site	Range of plants in 1 m sq. plots	Minimum 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 6. Population data in ten one meter square plots over four years (Andrew's Bog, Anderson Co.)

SITE	Number of Plants				
	Center	North	South	East	West
PLOT 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
PLOT 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 7. Population numbers inside exclosure and outside exclosure in six plots.

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

Figure 1. Distribution of *Eriocaulon koernickianum* (distribution outside Texas based on literature and personal communications and not vouched for in this study).

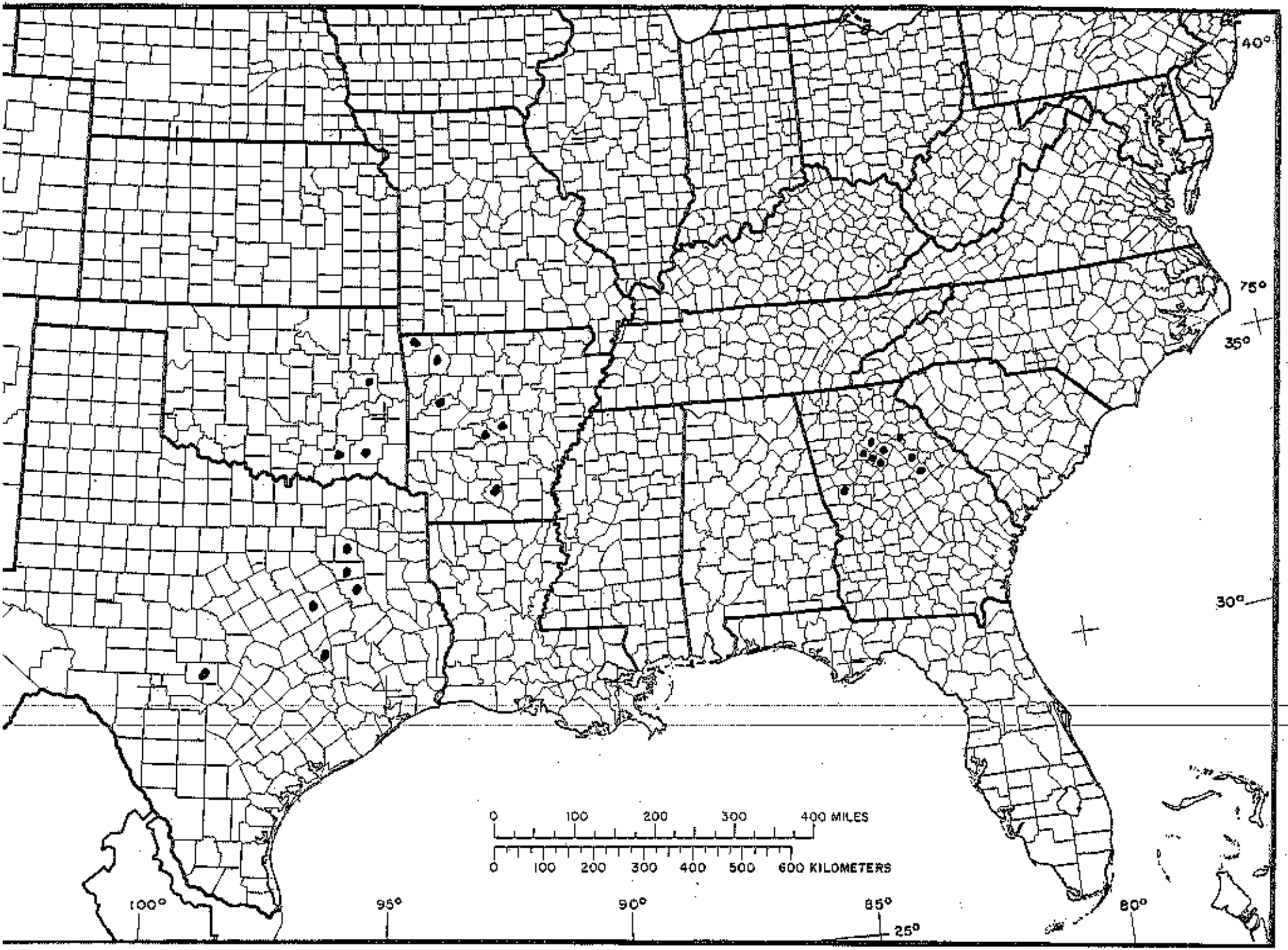

40°
75°
35°
30°
0 100 200 300 400 MILES
0 100 200 300 400 500 600 KILOMETERS
100°
95°
90°
85°
25°
80°

Figure 2. *Eriocaulon koernickianum* from Andrew's Bog, Anderson County. Natural size.

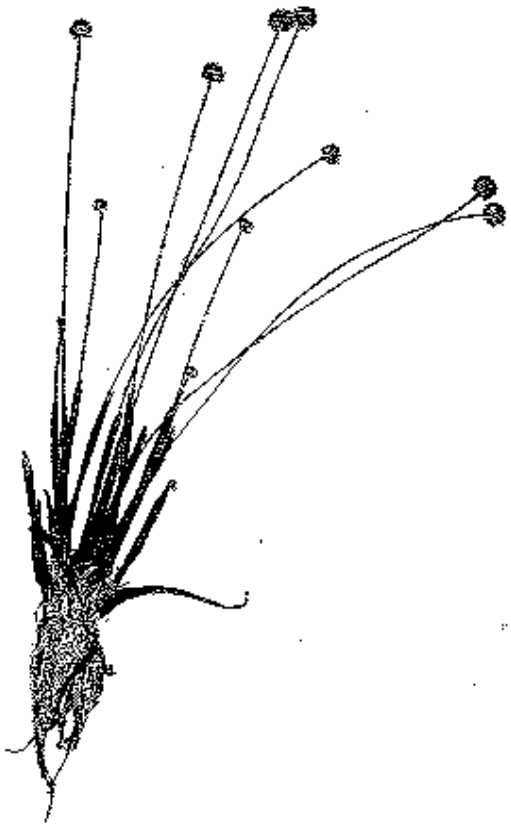


Figure 3. Texas counties.

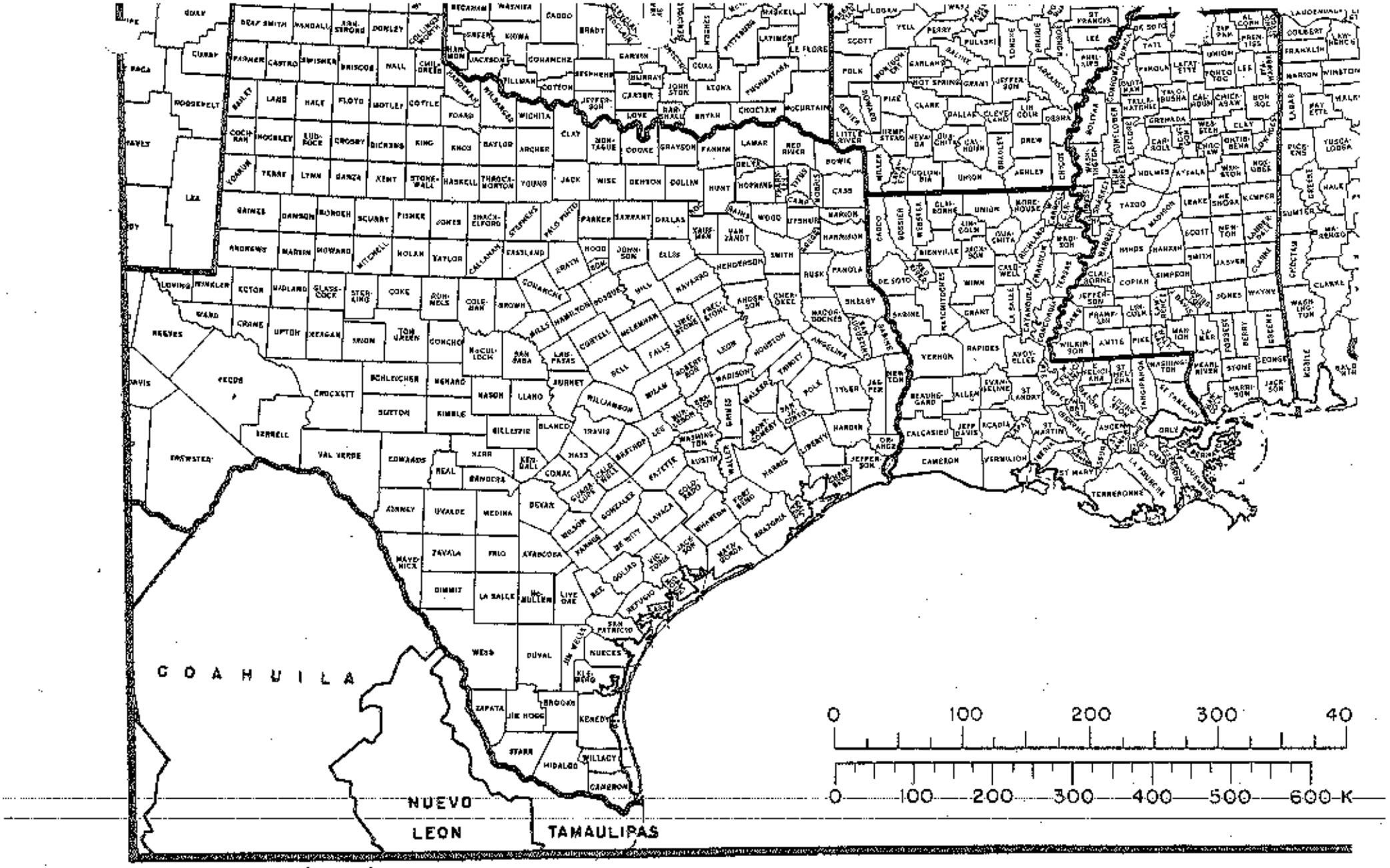
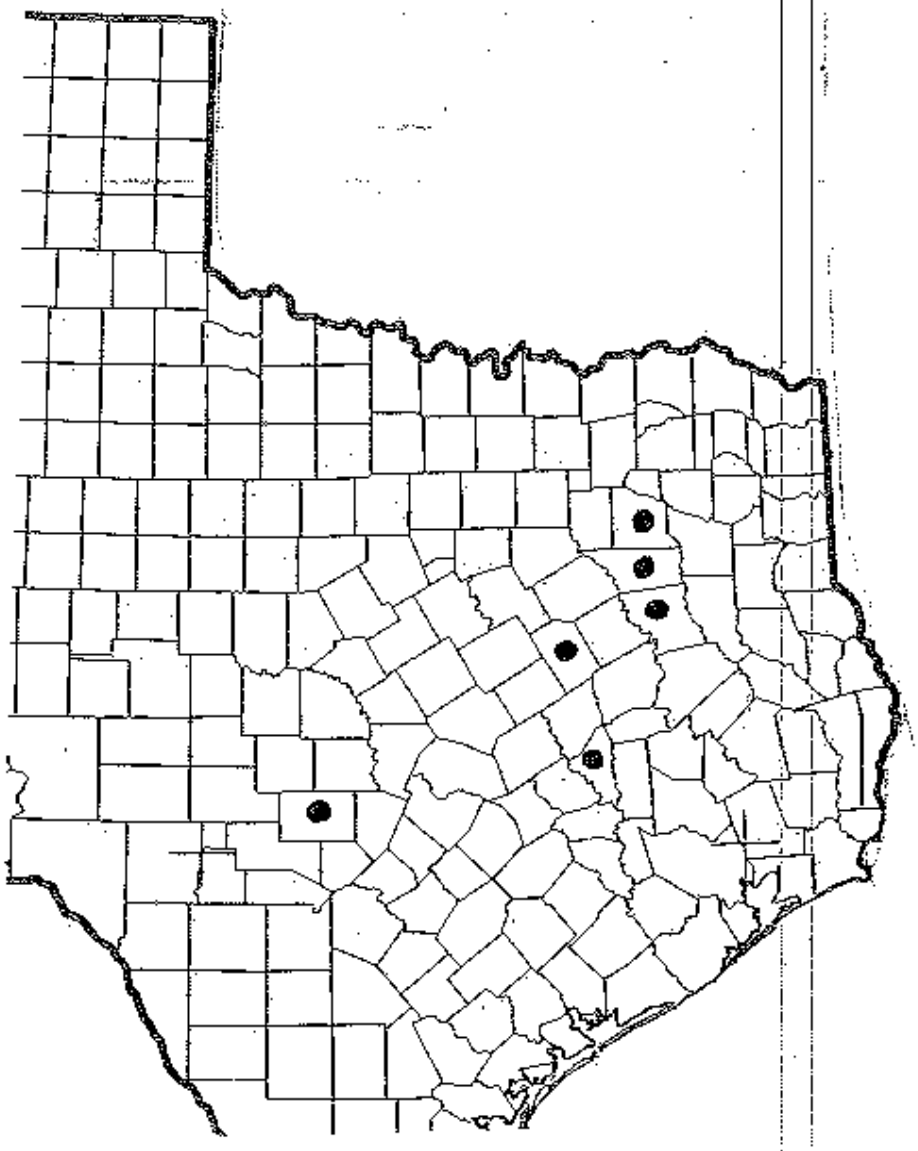
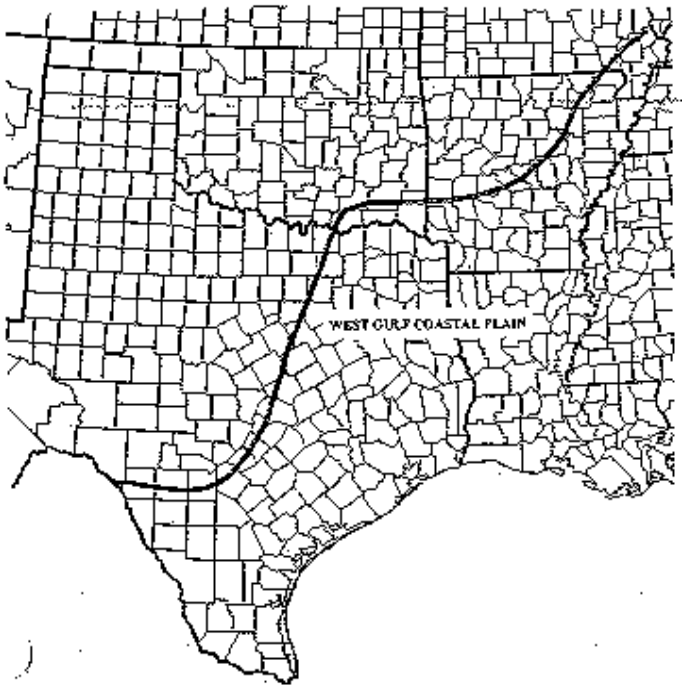
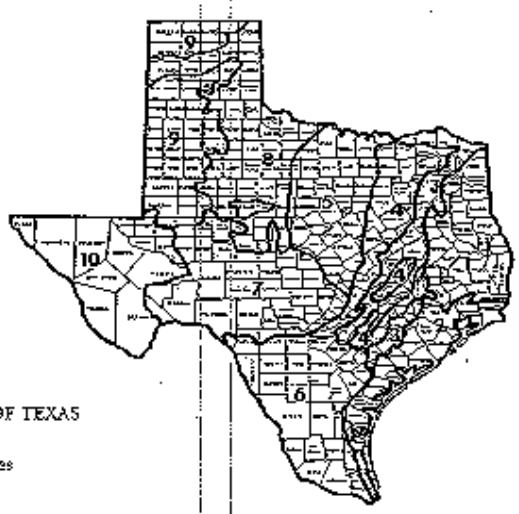

COAHUILA
NUEVO LEON
TAMAULIPAS
0 100 200 300 40
0 100 200 300 400 500 600 K

Figure 4. Vouched distribution of *Eriocaulon koernickianum* in Texas, with maps showing West Gulf Coastal Plain and vegetation areas of Texas (after Gould).







VEGETATIONAL AREAS OF TEXAS

1. Pineywoods
2. Gulf Prairies and Marshes
3. Post Oak Savannah
4. Blackland Prairies
5. Cross Timbers and Prairies
6. South Texas Plains
7. Edwards Plateau
8. Rolling Plains
9. High Plains
10. Trans-Pecos, Mountains and Basins

Figure 5. Gus Engeling Wildlife Management Area, Anderson Co.

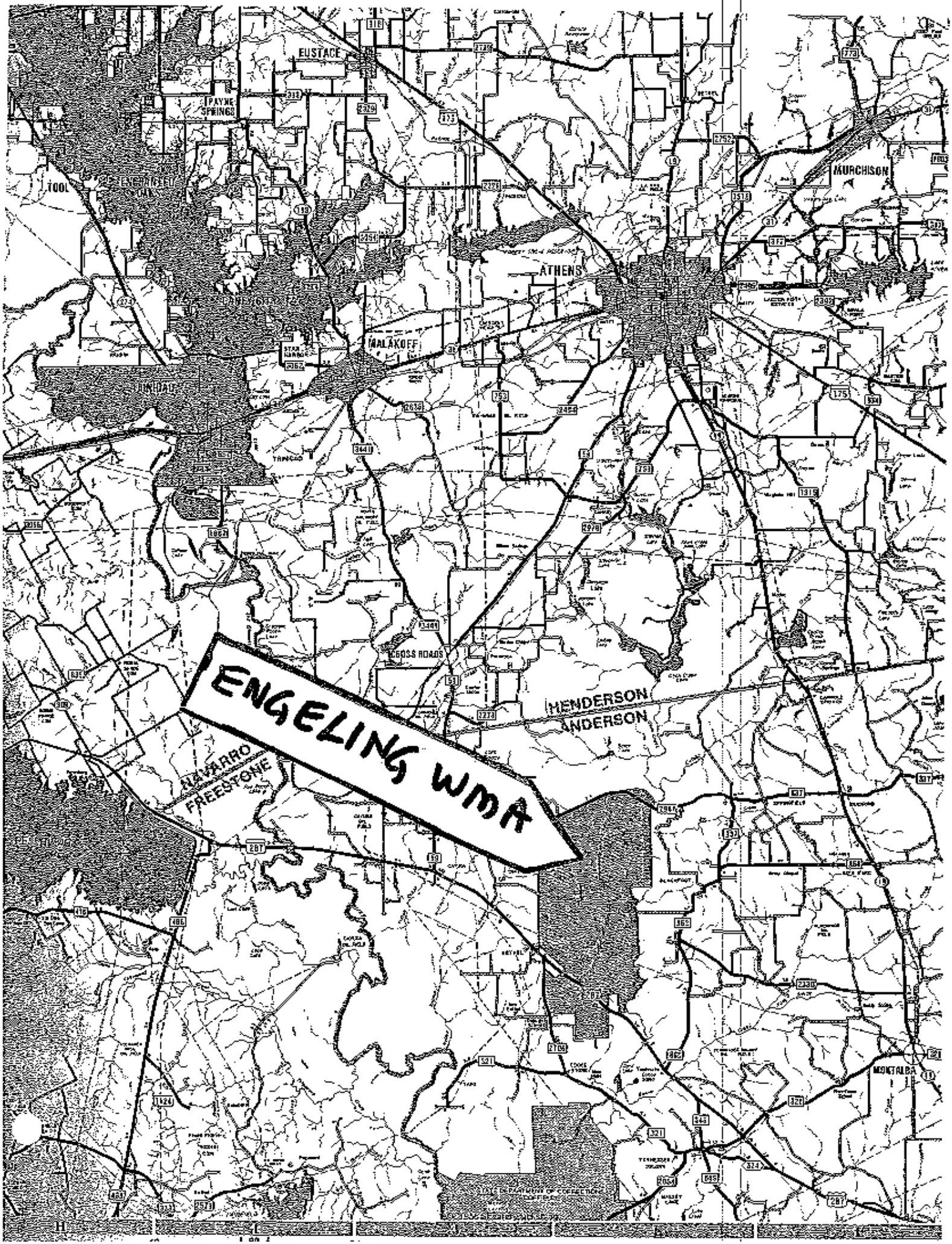

EUSTACE
PAYNE SPRINGS
TOOL
MURCHISON
ATHENS
MALAKOFF
TRINIDAD
CROSS ROADS
ENGELING WMA
HENDERSON
ANDERSON
NAVARRO
FREESTONE
MONTALBA

Figure 6. *Eriocaulon koernickianum* locations at Gus Engeling Wildlife Management Area.

GUS ENGELING WILDLIFE MANAGEMENT AREA

TENNESSEE COLONY, TEXAS
ANDERSON COUNTY

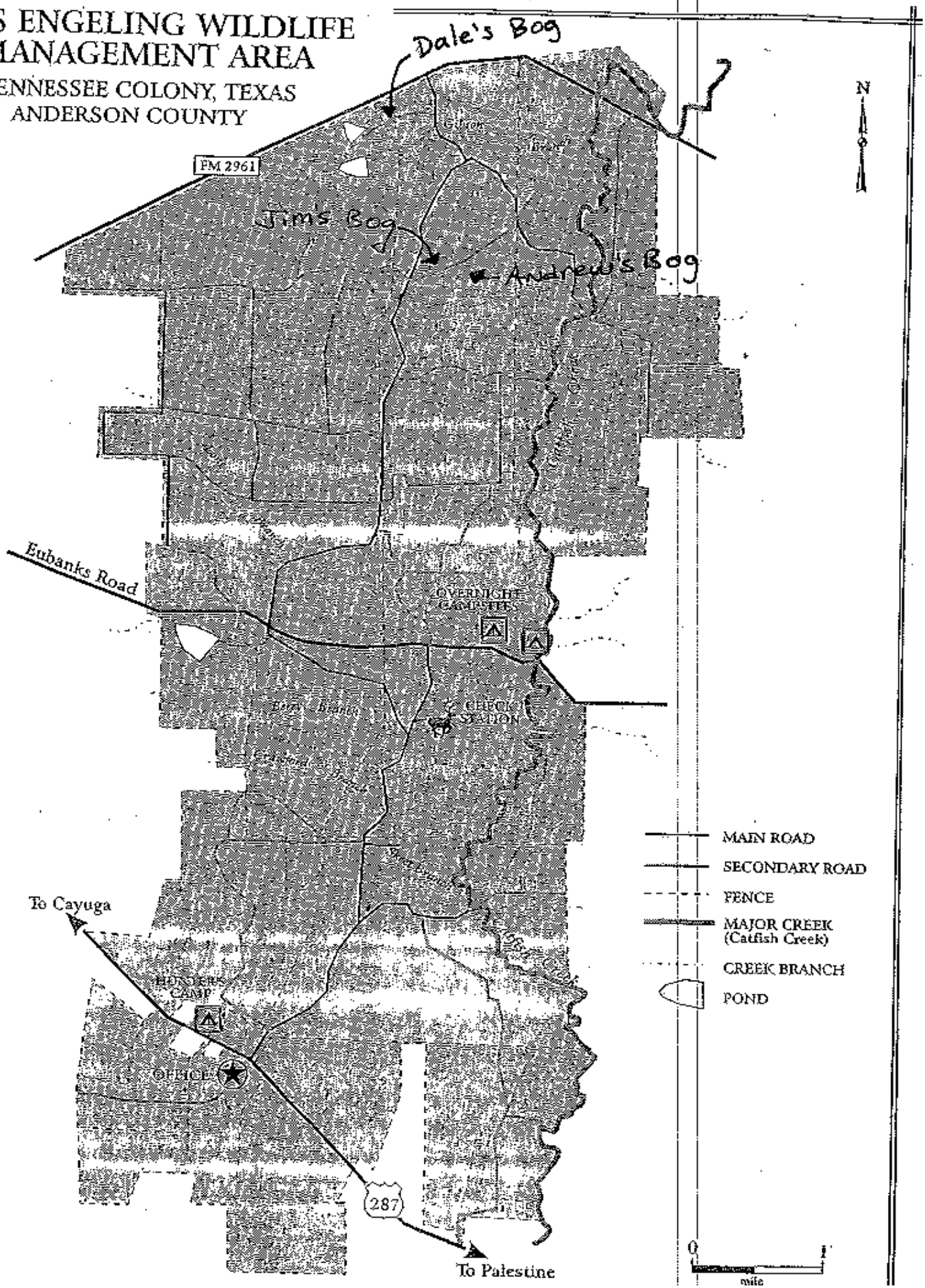


Figure 7. *Eriocaulon koernickianum* in natural habitat at Gus Engeling Wildlife Management Area.

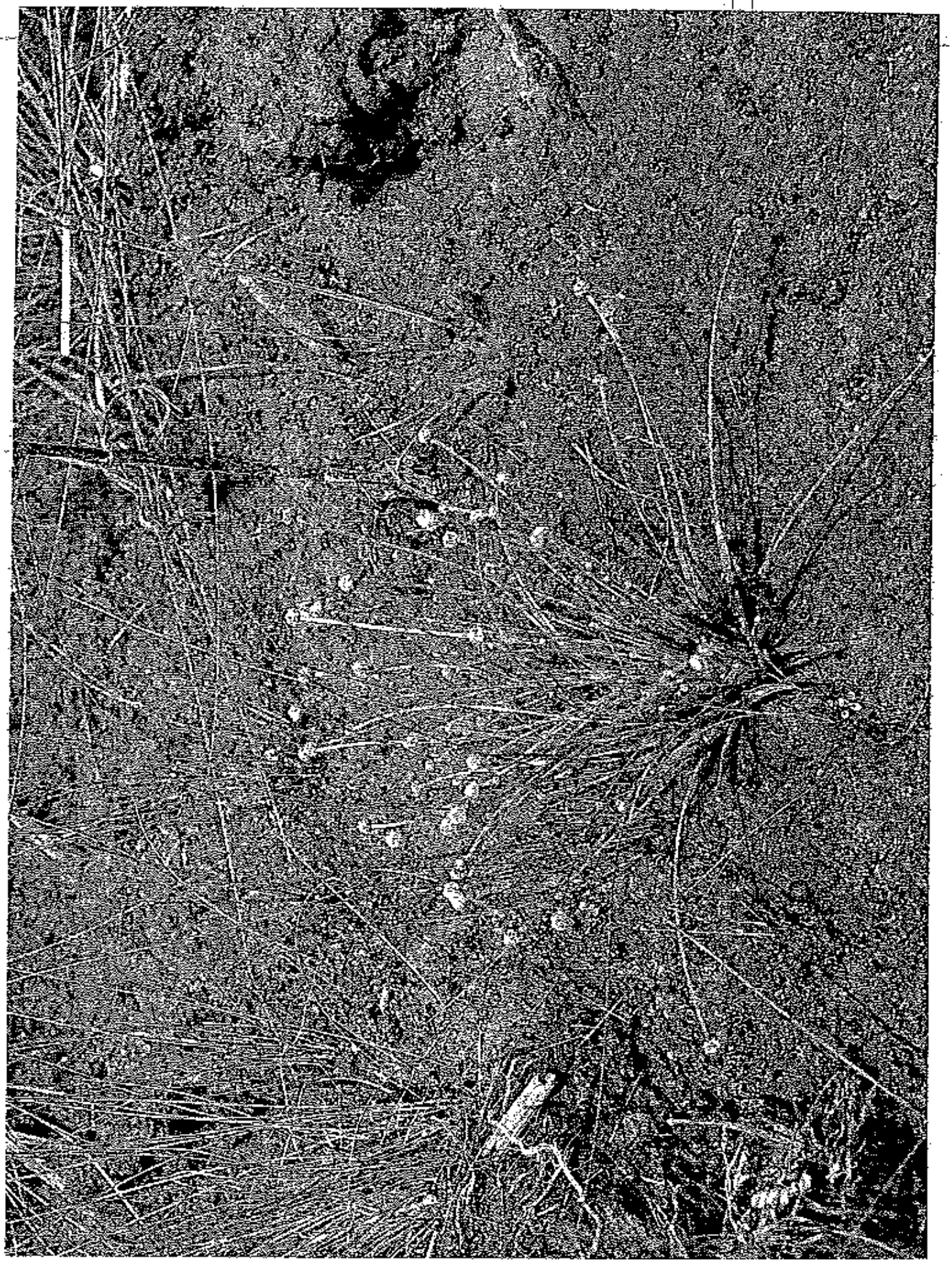


Figure 8. *Eriocaulon koernickianum* showing size.

Figure 9. *Eriocaulon koernickianum* habitat and exclosures at Gus Engeling Wildlife Management Area.

Figure 10. Closer view of *Eriocaulon koernickianum* habitat and exclosures at Gus Engeling Wildlife Management Area.

Figure 11. Brazos County: Wellborn site.

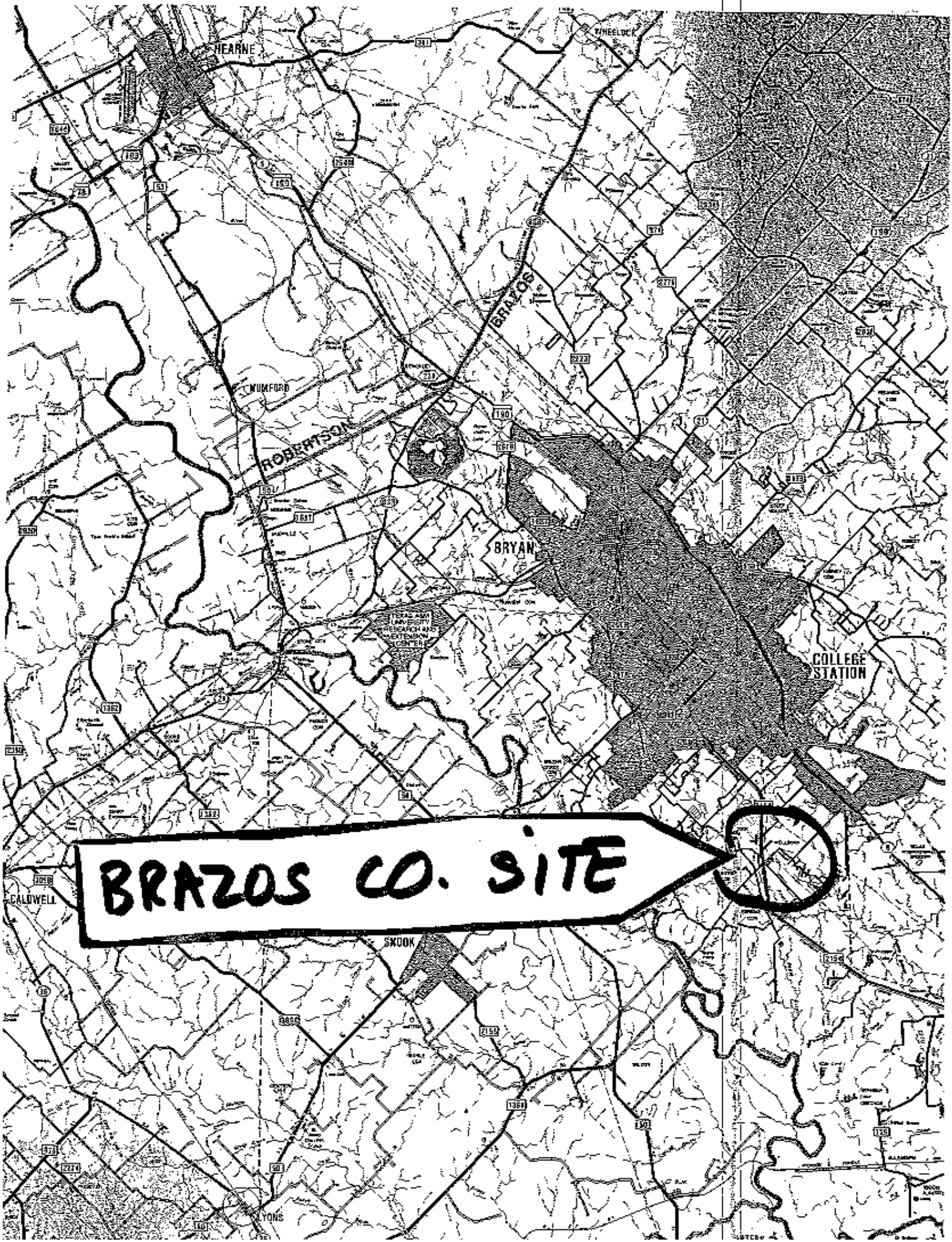

HEARNE
WHEELOCK
BRAZOS
MUMFORD
ROBERTSON
BRYAN
COLLEGE STATION
TEXAS A&M UNIVERSITY RESEARCH AND EXTENSION CENTER
BRAZOS CO. SITE
CALDWELL
SNOOK
LYONS

Figure 12. Gillespie County: Enchanted Rock site.

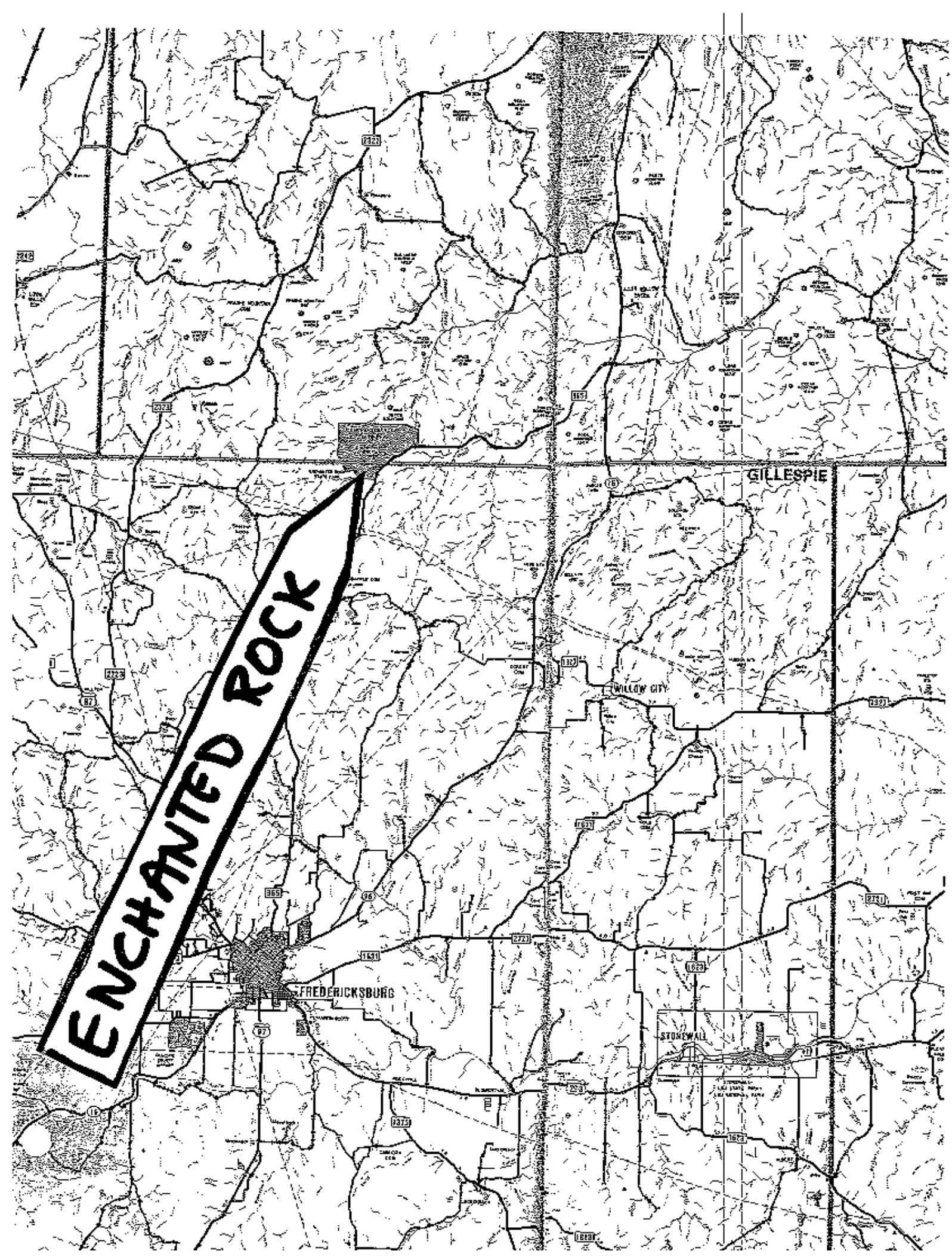

ENCHANTED ROCK
GILLESPIE
WILLOW CITY
FREDERICKSBURG
STONEWALL

Figure 13. *Eriocaulon koernickianum* habitat at Enchanted Rock. Flowers are *Utricularia cornuta*.

Figure 14. Henderson County: Curtis Boyd Bog.

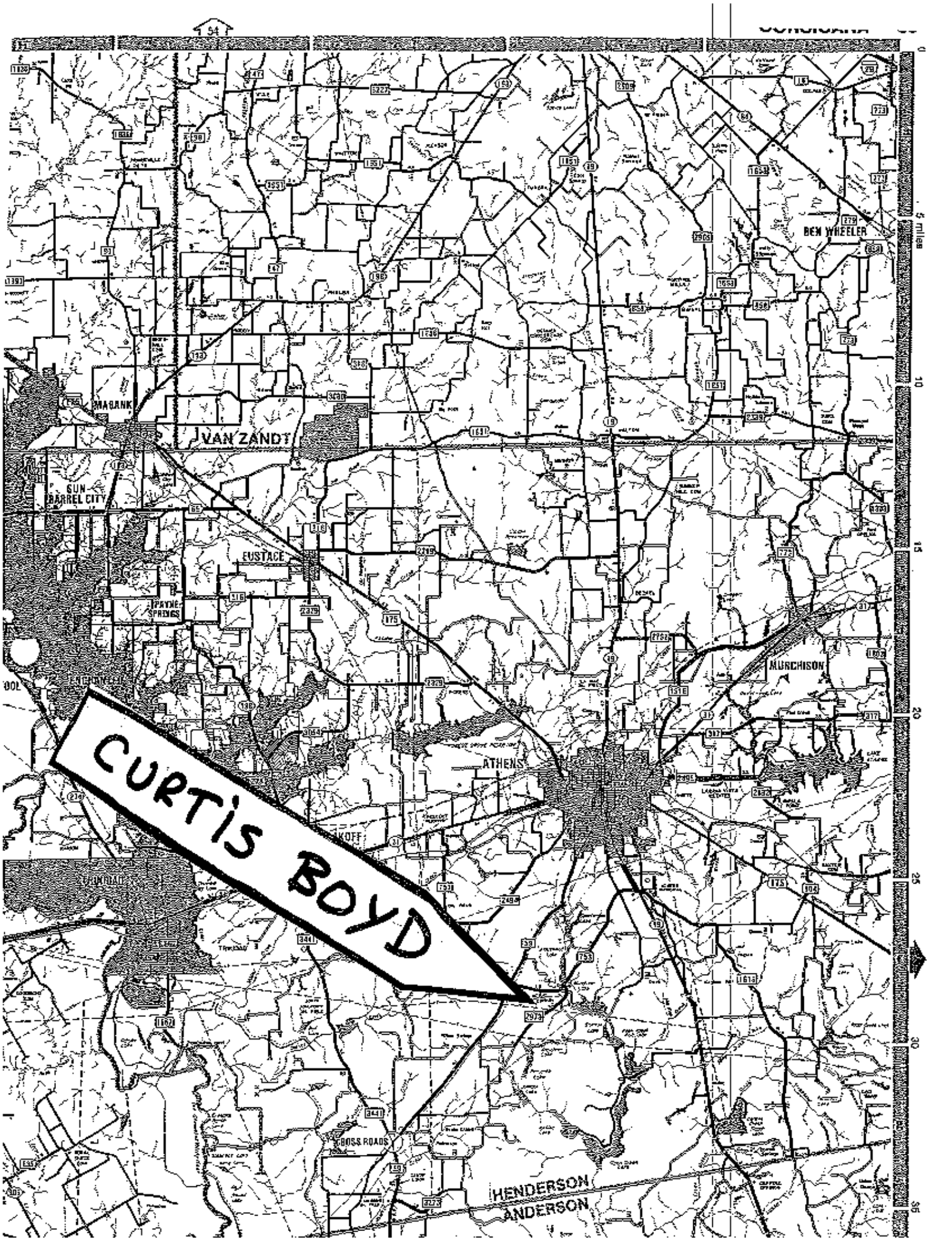

CURTIS BOYD
MABANK
VAN ZANDT
BEN WHEELER
SUN
BARREL CITY
EUSTACE
PAYNE SPRINGS
MURCHISON
ATHENS
CROSS ROADS
HENDERSON
ANDERSON
5 miles
10
15
20
25
30
35

Figure 15. Henderson County: Coon Creek Club.

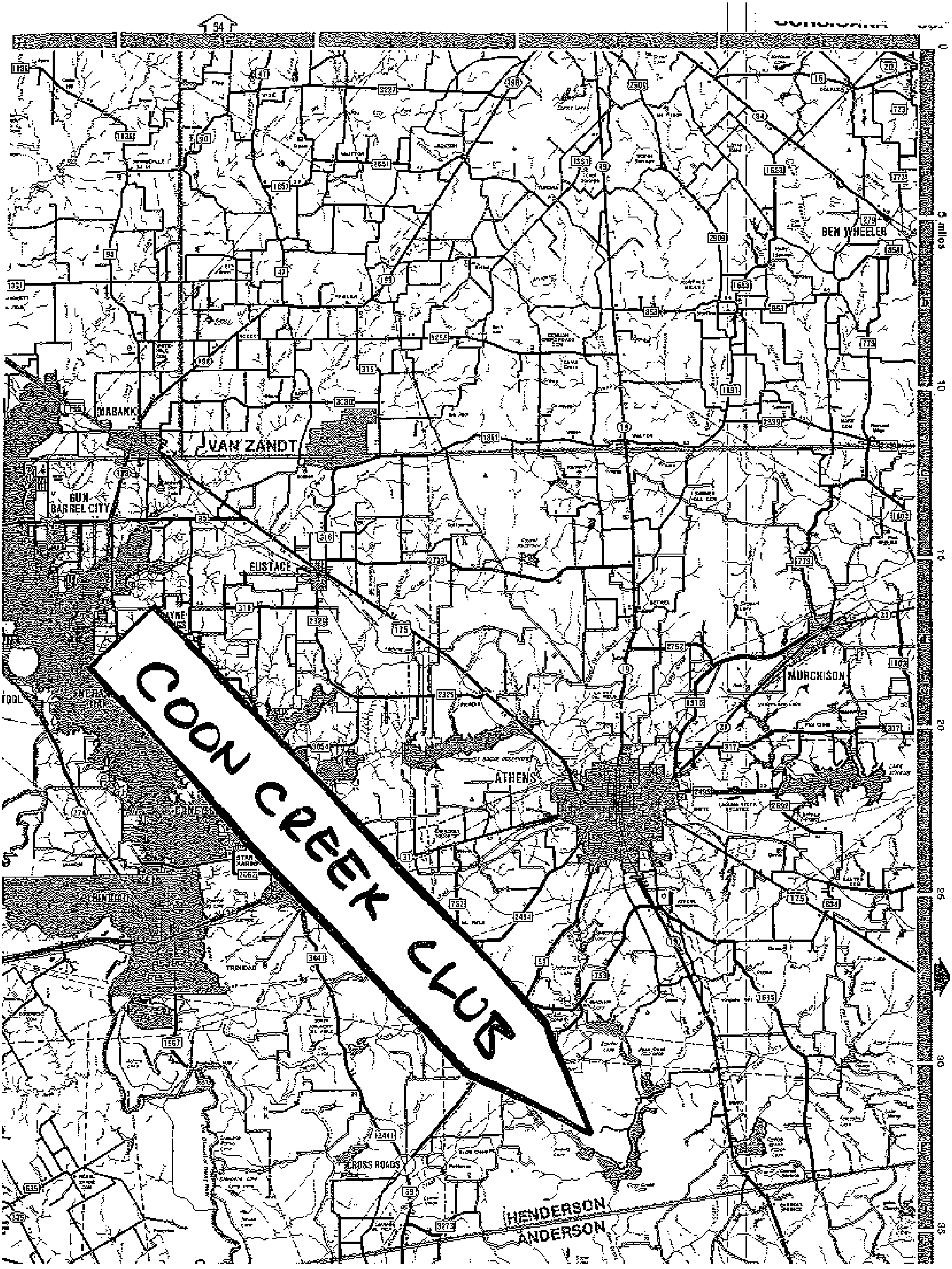

COON CREEK CLUB
VAN ZANDT
BEN WHEELER
MABANK
GUN BARREL CITY
EUSTACE
MURCHISON
ATHENS
TRINIDAD
CROSS ROADS
HENDERSON
ANDERSON
5 miles

Figure 16. Detail of Coon Creek Club showing Baker Lake Bog in northwest.

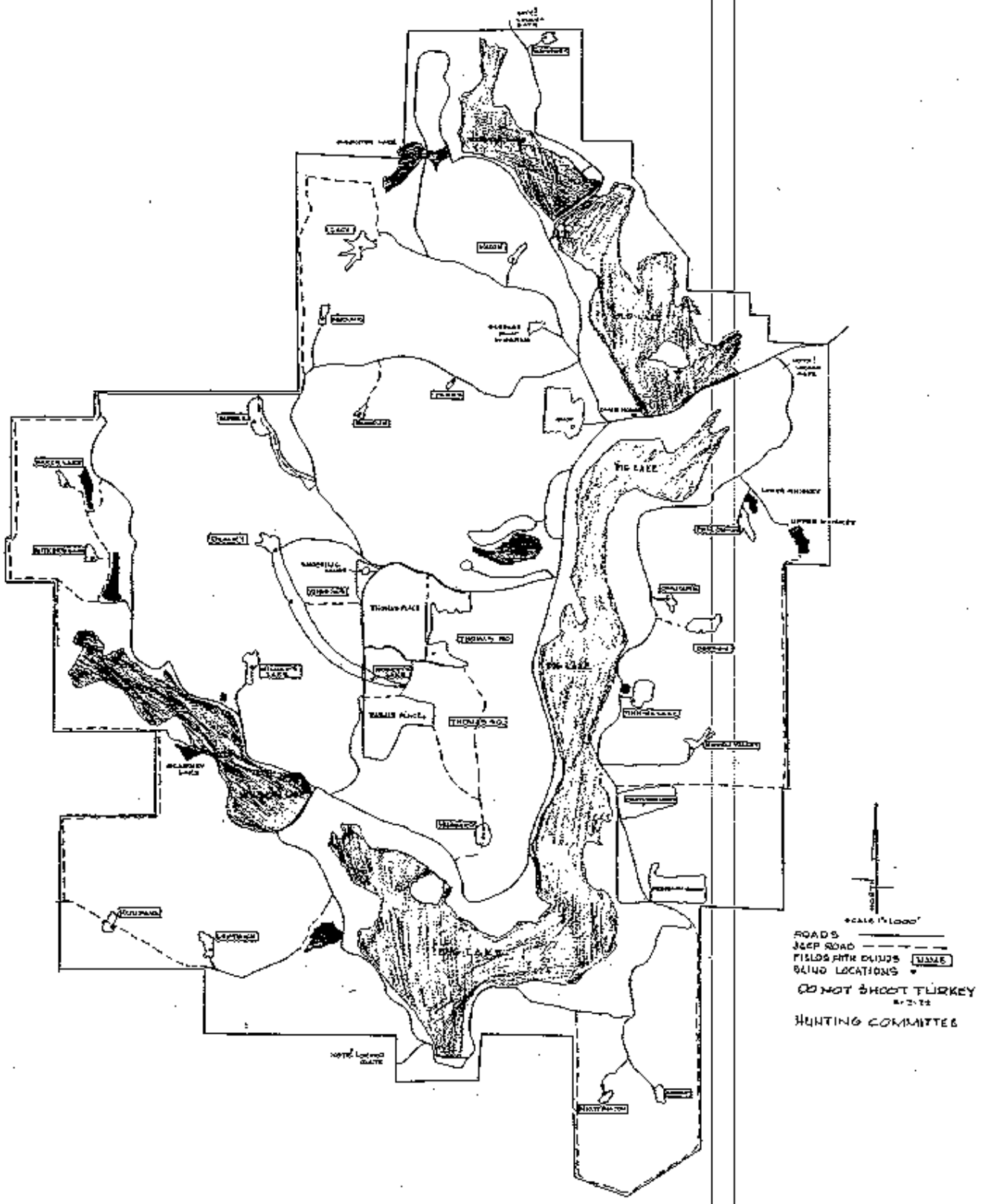

ROADS
JEEP ROAD
FIELDS WITH BLINDS
BLIND LOCATIONS
DO NOT SHOOT TURKEY
HUNTING COMMITTEE

Figure 17. Henderson County: Tindel Bog.

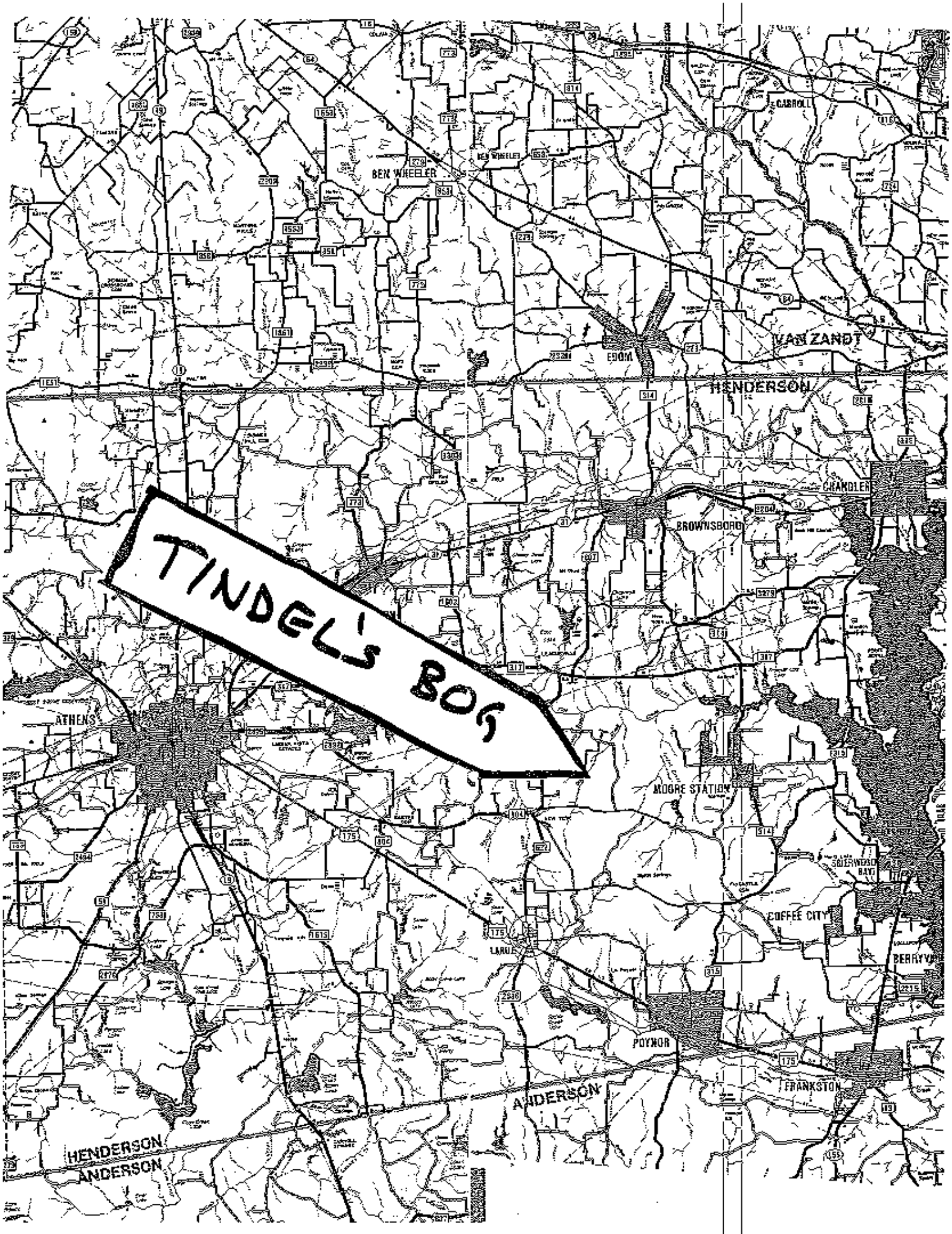

TINDEL'S BOG
BEN WHEELER
EDOM
VAN ZANDT
HENDERSON
CHANDLER
BROWNSBORO
ATHENS
MOORE STATION
CARROLL
COFFEE CITY
LARUE
POYNOR
FRANKSTON
ANDERSON
HENDERSON
ANDERSON

Figure 18. Limestone County: Perino site.

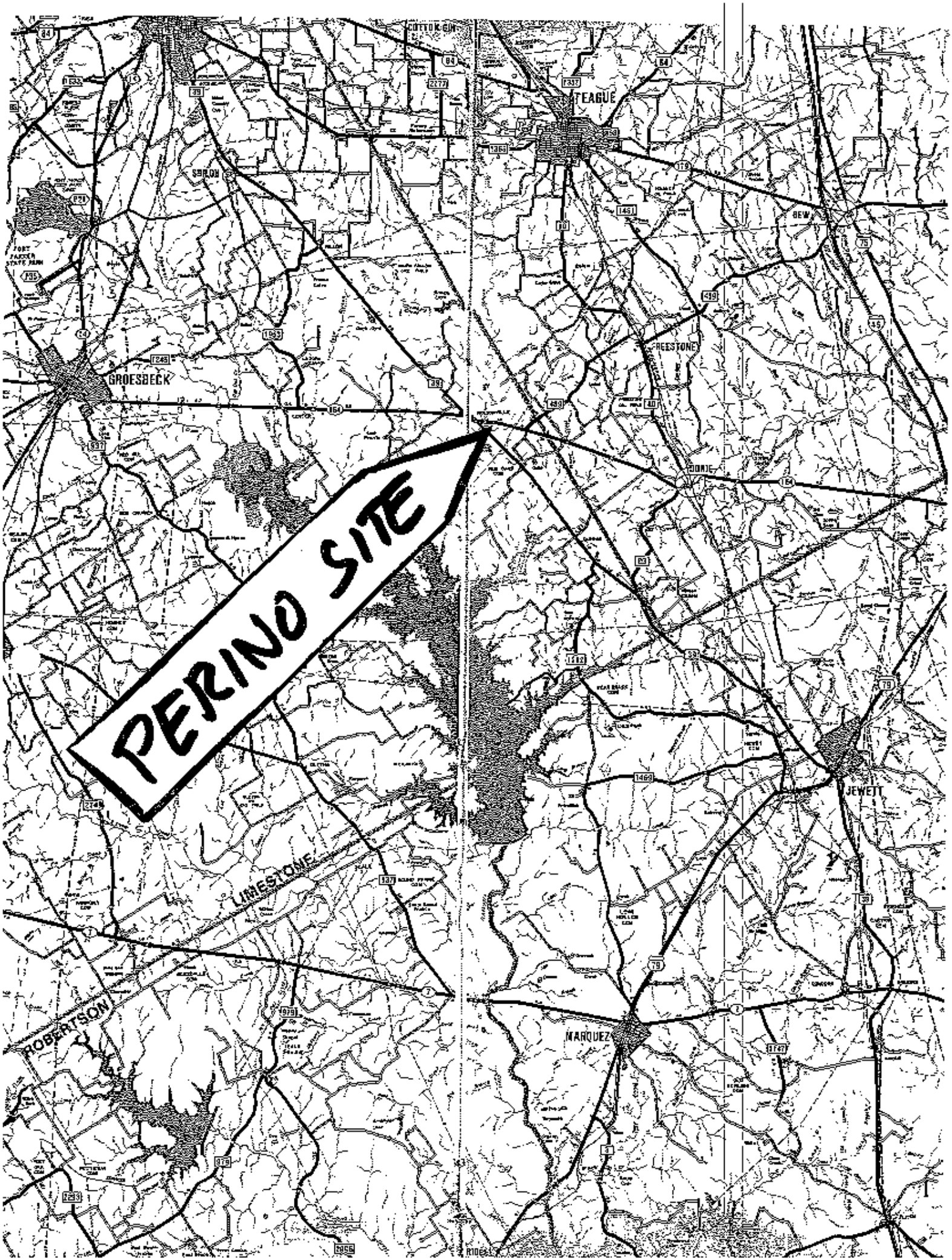

PERINO SITE
TEAGUE
GROESBECK
FREESTONE
JEWETT
MARQUEZ
ROBERTSON
LIMESTONE
SARLON
NEW
DONIE

Figure 19. Van Zandt County: Arc Ridge Ranch.

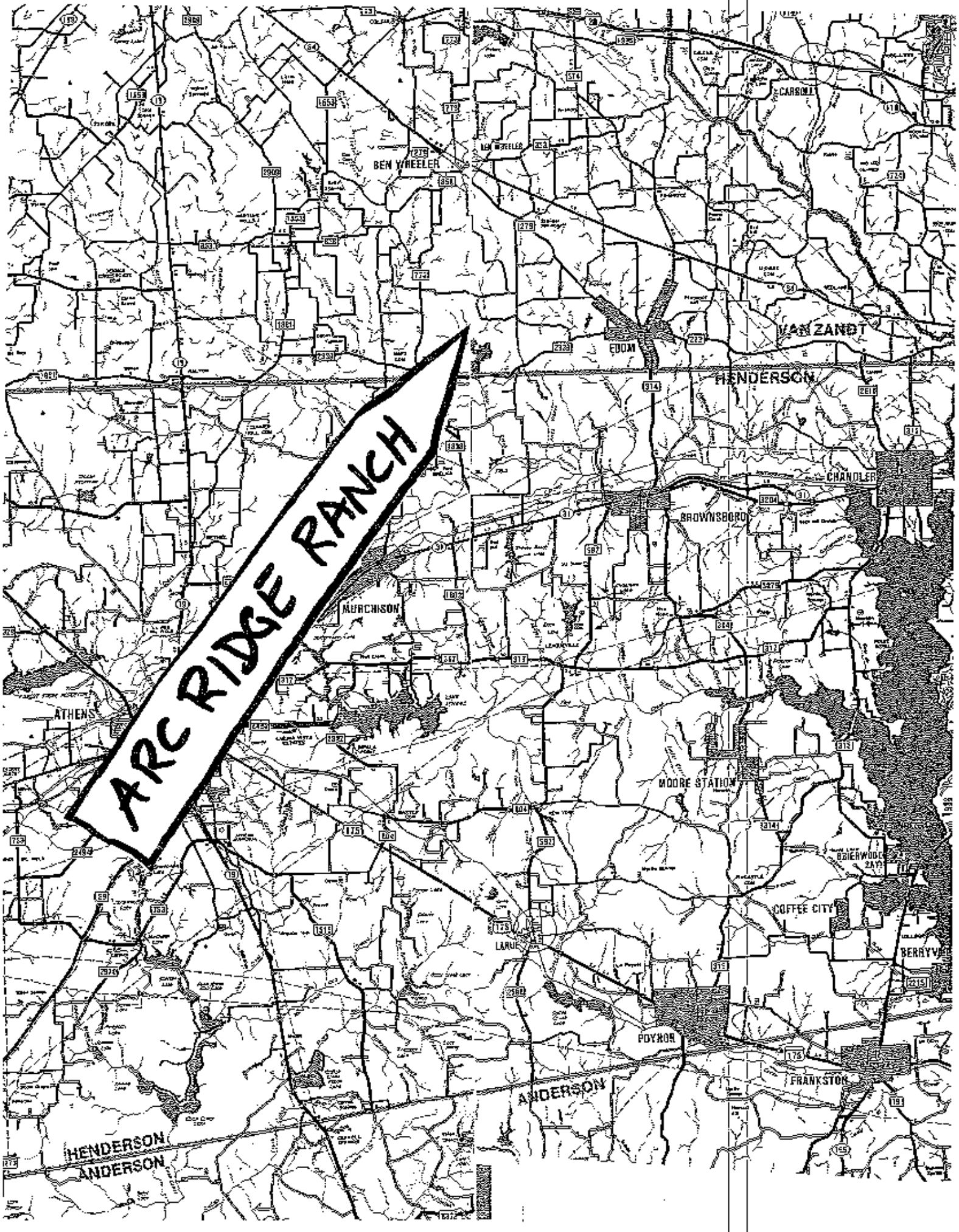
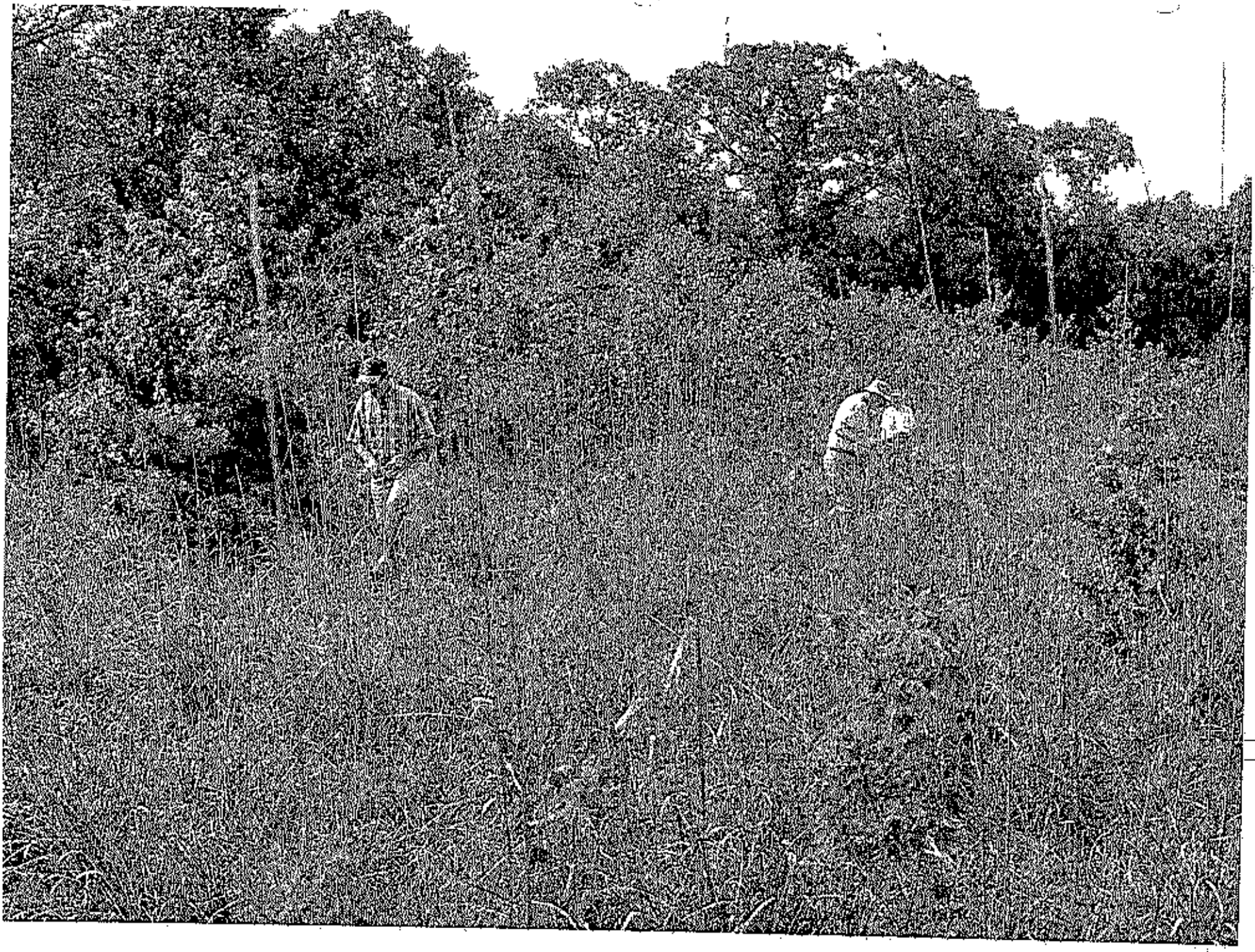

ARC RIXE RANCH
BEN WHEELER
VAN ZANDT
EDOM
HENDERSON
CHANDLER
BROWNSBORO
MURCHISON
ATHENS
MOORE STATION
COFFEE CITY
LARUE
POYNOR
FRANKSTON
ANDERSON
HENDERSON
ANDERSON

Figure 20. *Eriocaulon koernickianum* habitat at Arc Ridge Ranch, Van Zandt Co.



FLORISTICS OF XERIC SANDYLANDS IN THE POST OAK SAVANNA REGION OF EAST TEXAS

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ABSTRACT

This study describes the floristics, soils, and small-scale species richness of xeric sandylands of the post oak savanna region of east central Texas and maps the distribution of xeric sandylands throughout the West Gulf Coastal Plain. The interrelation of xeric sandylands to wetlands and their interest for regional conservation assessment are discussed.

Key Words: xeric sandylands, Post Oak Savanna, flora, Texas, Gus Engeling Wildlife Management Area.

RESUMEN

En este estudio se describe la florística, suelos, y riqueza de especies a pequeña escala de los lugares arenosos xéricos de la región de sabana post oak del centro este de Texas y se cartografía la distribución de los lugares arenosos xéricos de la llanura costera del West Gulf. Se discuten la interrelación de los lugares arenosos xéricos con los humedales y su interés para la evaluación de la conservación regional.

INTRODUCTION

During the past few years, we have been studying wetlands (muck bogs, upland marshes, baygalls, and seeps) in the post oak savanna region of east central Texas and southeastern Oklahoma (Nesom et al. 1997; MacRoberts & MacRoberts 1998b). These wetlands appear to be associated with xeric sandylands (variously referred to as oak-farkleberry sandylands [Ajilvsgi 1979], Post Oak-Black Hickory Series (Diamond et al. 1987], xeric sandylands [MacRoberts & MacRoberts 1994, 1995, 1996], Grossarenic Dry Uplands [Turner et al. 1999], Sand Post Oak - Bluejack Oak Alliance [Singhurst et al. 2000], and *Quercus incana* woodland alliance [Hoagland 2000]). These deep sands act as a reservoir or sponge holding water that feeds adjacent seeps and springs that are the headwaters for the area's wetlands and ultimately the streams and rivers. These upslope soils are porous and drain readily; rainwater percolates through the sand and moves down a gradient created by underlying impermeable or slowly permeable clays. Eventually, water seeps laterally out of the hillside (Martin & Smith 1991; Jones & Carpenter 1995; Drewa 1999; Summer 1999).

As part of our study of muck bogs, upland marshes, and their flora, we

studied these adjacent xeric sandylands since they are clearly the water source for these wetlands.

The primary objectives of this paper are to describe: 1) the distribution of xeric sandylands throughout the West Gulf Coastal Plain, 2) the floristics of this community in the post oak savanna region, 3) the small-scale species richness of this community, and 4) the soils upon which this community occurs.

In addition to our primary objectives for studying this community, we also are stimulated by a recent spate of national and regional conservation assessments (e.g., Diamond et al. 1997; Ricketts et al. 1999a, 1999b; Myers et al. 2000) that propose to pinpoint ecological "hotspots." These assessments are based on diversity, species richness, endemism, endangered species, and unique habitat availability. But, as is so often the case with such large-scale efforts, while some regions are well known, others are not. The post oak savanna region of east Texas is one of the poorest known. This is evident upon examining recent regional descriptions of the area (e.g., McNab & Avers 1994; Keys et al. 1995; Ricketts et al 1999a), where numerous factual errors lead to inaccurate assessments of the region's ecological "temperature."

THE SETTING

In Texas, the post oak savanna region (Fig. 1), consisting of about 30,000 sq. km, is gently rolling and hilly with elevations from 90 to 250 meters. Rainfall ranges from 75 to 115 centimeters. The Carrizo Sands are virtually coterminous with the region (McBryde 1933). Prairies are scattered throughout, notably in the south where some prairies are large (Smeins & Diamond 1983). The predominant floristic character of the region is southeastern without pines (Smeins & Diamond 1986). The area contains a diversity of plant communities, from hillside pitcher plant bogs, peat bogs, and upland marshes to open xeric sandylands and oak-hickory forests and woodlands. Characteristic communities within the post oak savanna region also occur to the east within the pineywoods (Marietta & Nixon 1983; Ward & Nixon 1992). How the post oak savanna region relates biotically to other regions in the area has yet to be studied in detail (Monk et al. 1990; Bryant et al. 1993; Skeen et. al. 1993); however, it appears to be floristically similar to adjoining regions (MacRoberts & MacRoberts pers. obs.) and has no vertebrate endemism (Telfair 1999).

McBryde (1933) conducted the only major floristic/edaphic study of the region. Subsequently, very little research has been done on the post oak savanna except for the inclusion prairies in its southern portion (Smeins & Diamond 1986).

Xeric sandylands are (or at least once were) very common in the Texas post oak savanna region, but they also occur in the pineywoods regions of southeastern Oklahoma, southwestern Arkansas, western Louisiana, eastern Texas,

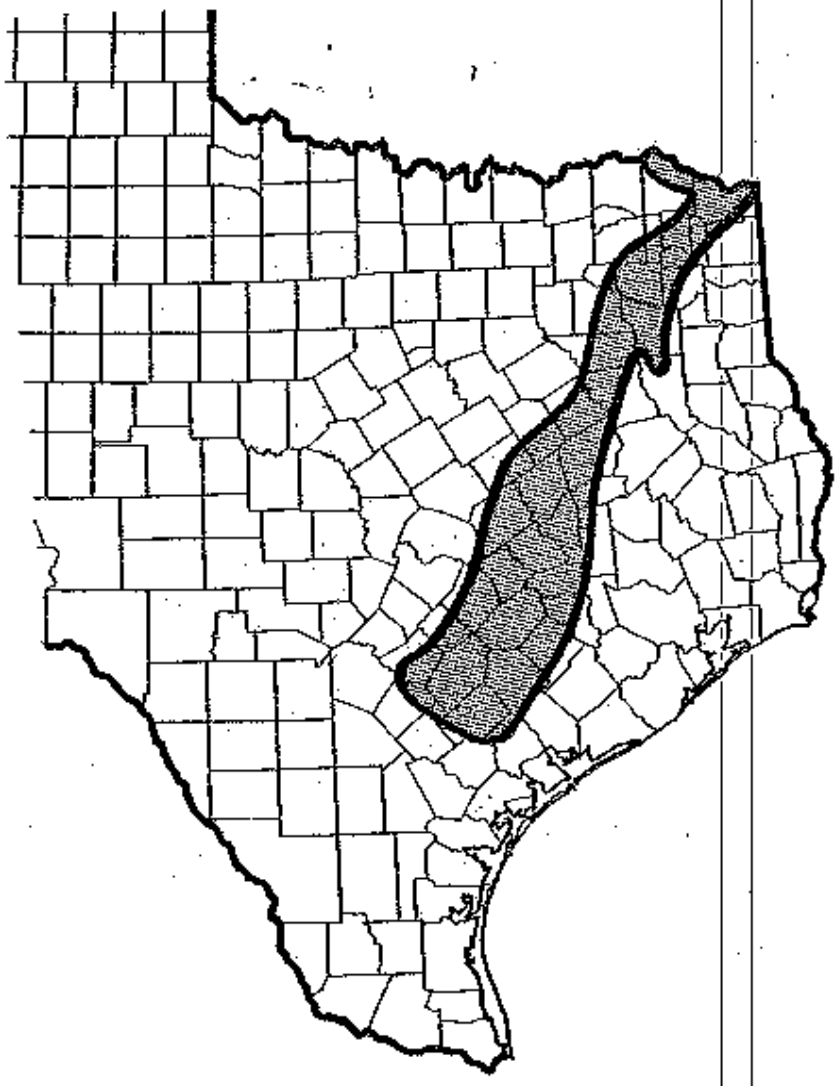

Fig. 1. Post oak savanna region of Texas.

and into the Coastal Bend of Texas (McBryde 1933; Jones 1977; Drawe et al. 1978; Taylor & Taylor 1978; Ajilvsgi 1979; Marks & Harcombe 1981; Louisiana Natural Heritage 1988; Bridges & Orzell 1989; Harcombe et al. 1993; Foti et al. 1994; MacRoberts & MacRoberts 1994, 1995, 1996; Jones & Carpenter 1995; Texas Natu-

ral Heritage Program 1995; Turner et al. 1999; Hoagland 2000). Homologues of xeric sandylands occur east of the Mississippi River (Stout & Marion 1993). It is generally assumed that oak savannas and xeric sandylands, like prairies, are kept open largely by fire (Smeins & Diamond 1986; Cutter & Guyette 1994). While encroachment of woody vegetation is ubiquitous in the absence of fire, there are many areas that remain open even when fire is suppressed, suggesting that edaphic conditions play an integral role. Characteristic tree species of xeric sandylands include *Quercus incana* W. Bartram, *Q. margarettiae* Ashe ex Small, *Q. stellata* Wangenh., and *Carya texana* Buckley, and a variety of fidel herbaceous species (see Methods for list). The area appears to be rich in plant endemism (Sorrie & Weakley 2001), and a large number of West Gulf Coastal Plain endemics are associated with this community, for example, *Brazoria truncata* (Benth.) Engelm. & A. Gray, *Palafoxia reverchonii* (Bush) Cory, *Paronychia drummondii* Torr. & A. Gray, *Pediomelum hypogaeum* (Nutt. ex Torr. & A. Gray) var. *subulatum* (Bush) J. W. Grimes, *Penstemon murrayanus* Hook., *Polanisia erosa* (Nutt.) H.H. Iltis, *Rhododon ciliatus* (Benth.) Epling, *Tetragonotheca ludoviciana* (Torr. & A. Gray) A. Gray ex Hall, *Tradescantia reverchonii* Bush, and *T. subacaulis* Bush.

METHODS

In order to develop an objective idea of the distribution of xeric sandylands, we selected 42 fidel species from the total list of species occurring in this community. We mapped these by county and parish over their ranges (Fig. 2). In the map, the number of fidels per county or parish is indicated in the legend. Parishes or counties with fewer than 10 species are left blank.

The 42 species chosen were *Astragalus leptocarpus* Torr. & A. Gray, *A. soxmaniorum* Lundell, *Berlandiera pumila* (Michx.) Nutt., *Brazoria truncata*, *Clematis reticulata* Walter, *Cnidoscolus texanus* (Muell.-Arg.) Small, *Coreopsis intermedia* Sherff, *Crataegus uniflora* Muenchh., *Croton argyranthemus* Michx., *Cyperus grayioides* Mohlenbrock, *Dalea phleoides* (Torr. & A. Gray) Shinners, *D. villosa* (Nutt.) Spreng., *Eriogonum longifolium* Nutt., *E. multiflorum* Benth., *Froelichia floridana* (Nutt.) Moq. (not distinguished from *F. gracilis* [(Hook.) Moq.]), *Hymenopappus artemisiifolius* DC., *Lithospermum caroliniense* (Walter ex J.F. Gmel.) MacMill., *Loeflingia squarrosa* Nutt., *Matelea cynanchoides* (Engelm.) Woodson, *Minuartia drummondii* (Shinners) McNeill, *Palafoxia hookeriana* Torr. & A. Gray, *P. reverchonii*, *Paronychia drummondii*, *Pediomelum digitatum* (Nutt. ex Torr. & A. Gray) Isely, *P. hypogaeum* var. *subulatum*, *Penstemon murrayanus*, *Phacelia strictiflora* (Engelm. & A. Gray) A. Gray, *Phlox drummondii* Hook., *Physalis mollis* Nutt., *Polanisia erosa* (Nutt.) H.H. Iltis, *Polygonella americana* (Fisch. & C.A. Mey.) Small, *Prunus gracilis* Engelm. & A. Gray, *Rhododon ciliatus*, *Selaginella arenicola* Underwood ssp. *riddellii* (Van Eselt.) R. M. Tryon, *Scutellaria cardiophylla* Engelm. & A. Gray, *Streptanthus*

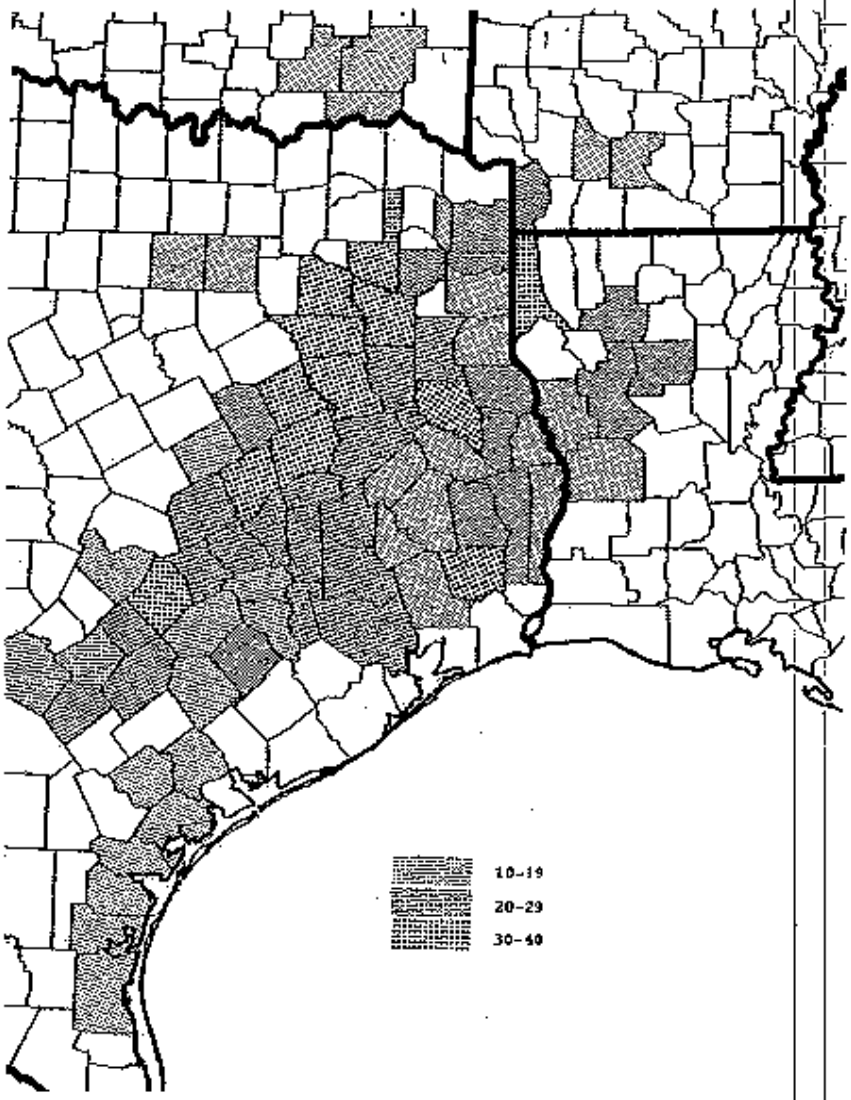

FIG. 2. Xeric sandylands species distribution (see text for key).

hyacynthoides Hook., *Stylisma pickeringii* (Torr. ex M.A. Curtis) A. Gray, *Talinum rugospermum* Holz., *Tetragonotheca ludoviciana*, *Tradescantia reverchonii*, *Yucca louisianensis* Trel., and *Zornia bracteata* J.F. Gmel. Sources for this information consisted of extensive herbarium searches, notably LSU, TAMU (both on line), ASTC, BRIT, Corpus Christi Museum of Science and History, LSUS,

SBSC, SHST, TEX, VDB, WWF; atlases (e.g., Smith 1988; Thomas & Allen 1993-1998; Turner in press), and a variety of literature (e.g., Jones 1977; Taylor & Taylor 1978; Singhurst 1996; Turner 1996; Nesom & Brown 1998) and unpublished sources (Billie Turner pers. comm.; Bruce Hoagland pers. comm.). We also made field searches throughout the West Gulf Coastal Plain to look for the species and the community *in situ*.

We surveyed the flora of xeric sandylands at Gus Engeling Wildlife Management Area (GEWMA), Anderson County, Texas, in the center of the post oak savanna region. The GEWMA occurs in the central part of the Trinity River drainage along Catfish Creek (Telfair 1988). This property consists of approximately 44 sq. km, of which 18 are the sand post oak-bluejack oak community (Singhurst et al. 2000). We established a single study plot measuring 50 m × 100 m (0.5 ha), within which was another single plot measuring 20 m × 50 m (0.1 ha) with two nested 3.16 m × 3.16 m plots (0.001 ha) and 6 nested 1 m × 1 m plots (0.0001 ha) in an opening in this community (see Peet et al. 1998 for plot design). The larger plot ran parallel to the topographic gradient and the adjacent downslope bog and was about 100 meters north of the edge of the bog and a few meters higher than the bog (see MacRoberts & MacRoberts 1998b, 1999; Singhurst et al. 2000 for a description of Andrew's Bog, GEWMA). We surveyed this area monthly from March to October 2000 and listed all plant species in each plot. This gave us information on both total floristics and species/area measures for comparison with similar measures from other plant communities. We estimated ground cover and measured vegetation height in the 0.0001 ha plots. We also surveyed several other xeric sandylands in other parts of the GEWMA. Plant nomenclature throughout this paper follows Kartesz and Meacham (1999). Voucher specimens are deposited at TEX.

We collected soil samples from the upper 15 cm of the two 0.001 ha plots and from the 0.1 ha plot for comparison with this community elsewhere in its range. These were analyzed by A & L Laboratories, Memphis, Tennessee. The soil at the study site is described as deep, well-drained acidic sandy Pleistocene terraces (Arenosa series, Typic Quartzipsammeents, Entisols) (Coffee 1975).

RESULTS

Figure 1 shows the location of the Post Oak Savanna region of East Texas in which xeric sandylands are located. Figure 2 shows the frequency of occurrence of the 42 xeric sandyland fidel species in parishes and counties in the West Gulf Coastal Plain. Counties and parishes with fewer than 10 species are left blank. Table 1 lists the species found within the 0.1 ha plot. Table 2 gives additional species in the 0.5 ha plot. Table 3 shows the number of species occurring in the 0.0001 ha, 0.001 ha, 0.1 ha, and 0.5 ha plots. Table 4 gives the ground cover and vegetation height in the six 0.0001 ha plots in May and August. Table 5 gives the soil information from the study plots.

TABLE 1. Species present in the 0.1 ha study plot at the Gus Engeling Wildlife Management Area (Anderson County, Texas).

AGAVACEAE: *Yucca louisianensis* Trel.
AMARANTHACEAE: *Froelichia floridana* (Nutt.) Moq.
ANACARDIACEAE: *Rhus aromatica* Aiton, *Toxicodendron radicans* (L.) Kuntze
APIACEAE: *Spermolepis divaricata* (Walter) Raf. ex Ser., *S. inermis* (Nutt. ex DC.) Mathias & Constance
AQUIFOLIACEAE: *Ilex vomitoria* Sol. in Aiton
ASCLEPIADACEAE: *Matelea cynanchoides* (Engelm.) Woods
ASTERACEAE: *Croptilon divaricatum* (Nutt.) Raf., *Evax candida* (Torr. & A. Gray) A. Gray, *Helianthus debilis* Nutt. ssp. *cucumerifolia* (Torr. & A. Gray) Heiser, *Krigia virginica* (L.) Willd., *Palafoxia reverchonii* (Bush) Cory, *Pyrrhopappus carolinianus* (Walter) DC., *Senecio ampullaceus* Hook, *Thelesperma filifolium* (Hook.) A. Gray
BRASSICACEAE: *Lepidium virginicum* L., *Streptanthus hyacinthoides* Hook.
CACTACEAE: *Opuntia humifusa* (Raf.) Raf.
CAPPARACEAE: *Polanisia erosa* (Nutt.) H. H. Iltis
CARYOPHYLLACEAE: *Loeflingia squarrosa* Nutt., *Paronychia drummondii* Torr. & A. Gray
CISTACEAE: *Helianthemum georgianum* Chapm., *Lechea mucronata* Raf., *L. tenuifolia* Michx.
COMMELINACEAE: *Commelina erecta* L., *Tradescantia reverchonii* Bush, *T. subacaulis* Bush
CONVOLVULACEAE: *Stylisma pickeringii* (Torr. ex M.A. Curtis) A. Gray
CRASSULACEAE: *Sedum nuttallianum* Raf.
CUPRESSACEAE: *Juniperus virginiana* L.
CYPERACEAE: *Carex cephalophora* Muhl. ex Willd., *C. retroflexa* Muhl. ex Willd., *Cyperus grayioides* Mohlenbrock
EUPHORBIACEAE: *Cnidoscolus texanus* (Muell.-Arg.) Small, *Croton argyranthemus* Michx., *C. capitatus* Michx., *C. glandulosus* L., *C. michauxii* G.L. Webster
FABACEAE: *Astragalus leptocarpus* Torr. & A. Gray, *Baptisia nuttalliana* Small, *Centrosema virginiana* (L.) Benth., *Chamaecrista fasciculata* (Michx.) Greene, *Dalea phleoides* (Torr. & A. Gray) Shinners, *Indigofera miniata* Ortega, *Mimosa nuttallii* (DC.) B.L. Turner, *Pediomelum digitatum* (Nutt. ex Torr. & A. Gray) Isely
FAGACEAE: *Quercus incana* W. Bartram, *Q. margarettiae* Ashe ex Small
HYDROPHYLLACEAE: *Phacelia strictiflora* (Engelm. & A. Gray) A. Gray
KRAMERIACEAE: *Krameria lanceolata* Torr.
LAMIACEAE: *Brazoria truncata* (Benth.) Engelm. & A. Gray, *Monarda punctata* L., *Rhododon ciliatus* (Benth.) Epling
LILIACEAE: *Allium canadense* L.
MOLLUGINACEAE: *Mollugo verticillata* L.
ONAGRACEAE: *Oenothera laciniata* Hill
PLANTAGINACEAE: *Plantago hookeriana* Fisch. & C.A. Mey.
POACEAE: *Andropogon ternarius* Michx., *Aristida desmantha* Trin. & Rupr., *A. lanosa* Muhl. ex Elliott, *Dichanthelium acuminatum* (Sw.) Gould & C.A. Clark, *D. oligosanthes* (Schult.) Gould, *Paspalum setaceum* Michx., *Triplasis purpurea* (Walter) Chapm., *Vulpia elliotea* (Raf.) Fernald
POLYGONACEAE: *Eriogonum multiflorum* Benth., *Rumex hastatulus* Baldwin.
PORTULACACEAE: *Talinum rugospermum* Holz.
ROSACEAE: *Rubus argutus* Link
RUBIACEAE: *Diodia teres* Walter
SCROPHULARIACEAE: *Nuttallanthus canadensis* (L.) D.A. Sutton
SOLANACEAE: *Physalis heterophylla* Nees
VISCACEAE: *Phoradendron tomentosum* (DC.) Engelm. & A. Gray

DISCUSSION

Xeric sandylands occur from southwest Arkansas and southeastern Oklahoma to central Louisiana and the Coastal Bend of Texas. The distribution of species numbers shown in Figure 2 results in part from differential collecting: Caddo Parish and Anderson County have been well collected while most of east Texas

TABLE 2. Species in the 0.5 ha plot not found in the 0.1 ha plot. Both plots at the Gus Engeling Wildlife Management Area (Anderson County, Texas).

Bulbostylis ciliatifolia (Elliott) Fernald	*Schizachyrium scoparium* (Michx.) Nash
Carya texana Buckley	*Scleria triglomerata* Michx.
Cenchrus spinifex Cav.	*Sisyrinchium albidum* Raf.
Corydalis micrantha (Engelm. ex A. Gray) A. Gray	*Trichostema dichotomum* L.
Glandularia canadensis (L.) Nutt.	*Vaccinium arboreum* Marshall
Mirabilis albida (Walter) Heimerl	*Verbascum thapsus* L.
Oenothera heterophylla Spach	*Vitis aestivalis* Michx.
Penstemon murrayanus Hook.	*Vitis rotundifolia* Michx.

TABLE 3. Species richness in xeric sandylands at the Gus Engeling Wildlife Management Area (Anderson County, Texas).

Plot size (ha)	No. of plots	Av. no. species (range)
0.0001	6	24.5 (19–28)
0.001	2	38.5 (35–42)
0.1	1	74
0.5	1	90

has not. Better sampling would undoubtedly fill in the picture, but the outlines are clear. We have observed the community *in situ* in Miller County, Arkansas; Bienville, Caddo, Natchitoches, Vernon, and Winn parishes, Louisiana; Atoka, Choctaw, and Pushmataha counties, Oklahoma; and Anderson, Angelina, Aransas, Bastrop, Caldwell, Cass, Cherokee, Colorado, Franklin, Gonzales, Guadulape, Hardin, Henderson, Jasper, Lee, Leon, Marion, Milam, Nacogdoches, Panola, Rusk, San Augustine, San Patricio, Shelby, Smith, Tyler, Upshur, Van Zandt, Wilson, and Wood counties, Texas. We have little experience with the Coastal Bend xeric sandylands (Drawe et al. 1978), but this community appears to have affinities with the more northern and eastern xeric sandylands and needs further study. Xeric sandlylands also occur in Hopkins, Navarro, Rains, and Williamson counties and appear to have once occurred on the boundary of Fannin and Grayson counties, Texas (Jason Singhurst, pers. comm.).

There were 74 species in the 0.1 ha plot and 90 species in the 0.5 ha plot. Other taxa in xeric sandylands at GEWMA that did not occur in our plots include *Aphanostephus skirrhobasis* (DC.) Trel., *Apocynum cannabinum* L., *Asclepias amplexicaulis* Sm., *Berlandiera pumila*, *Bouteloua hirsuta* Lag., *Delphinium carolinianum* Walter, *Descurainea pinnata* (Walter) Britton, *Eragrostis secundiflora* J. Presl., *Eriogonum longifolium*, *Hymenopappus artemisiifolius*, *Liatris elegans* (Walter) Michx., *Mirabilis albida*, *Oxalis priceae* Small, *Pediomelum hypogaeum* var. *subulatum*, *Physalis turbinata* Medik., *Polygonella americana*, *Scutellaria cardiophylla*, *Selaginella arenicola* ssp. *riddellii*, *Sideroxylon lanuginosum* Michx.

TABLE 4. Ground cover and vegetation height in six 0.0001 ha plots at the Gus Engeling Wildlife Management Area (Anderson County, Texas).

Plot (month)	Average height (cm)	Tallest height (cm)	Percent cover
1 (August)	20	40	20
(May)	10	55	20
2 (August)	20	30	20
(May)	10	25	30
3 (August)	20	40	20
(May)	15	35	30
4 (August)	15	50	15
(May)	10	20	20
5 (August)	20	40	20
(May)	15	30	40
6 (August)	20	45	25
(May)	15	30	40

TABLE 5. Soil characteristics of sample plots at the Gus Engeling Wildlife Management Area (Anderson County, Texas).

		Exchangeable ions (ppm)				
Sample	pH	P	K	Ca	Mg	Organic Matter%
1	4.9	26	27	172	18	1.0
2	4.8	21	20	97	14	0.8
3	4.4	24	18	80	10	0.8

Stillingia sylvatica Garden ex L., *Tetragonotheca ludoviciana*, *Tragia urticifolia* Michx., *Triodanis perfoliata* (L.) Nieuwl., and *Vicia ludoviciana* Nutt. (see also Singhurst et al. 2000).

The ground cover varied from about 15 percent to 40 percent throughout the growing season. Non-vegetated areas always prominently showed and vegetation was never tall. In general, biomass was low and sunlight was directly on the ground.

Species richness can be measured at many scales. At scales of 0.01 ha and larger, tropical rainforests are the most species rich. However, at scales below 0.001 ha and often 0.01 ha, temperate grasslands and open savannas of the southeastern United States are the most species rich. Values of between 20 and 40 species per 0.0001 ha occur but are very uncommon (Peet et al. 1983; Walker & Peet 1983; Peet & Allard 1993; Brewer 1998; Platt 1999). Peet et al. (1983) found that for a broad range of forest and woodland types, no community type exceeded 17 species per 0.0001 ha and none averaged over 13. Even tallgrass prairies, which were the highest, averaged only 18.

While very little information exists on species richness of West Gulf

Coastal Plain plant communities, the scant small-scale information available indicates that wetland pine savannas, bogs, and upland pine savannas average around 20 species in 0.0001 ha plots (Allen et al. 1988; MacRoberts & MacRoberts 1991, 1998a; Carr 2000).

In the light of these figures, it is interesting that the GEWMA xeric sandyland plots show higher species richness at small scales than virtually all other plant communities so far measured in the southeastern United States. These xeric sandylands also show a low "z" value (about 0.19), meaning that there is basically a species doubling for every 100-fold increase in area. In the present case, a 0.0001 ha plot contains roughly one-half of the species found in a 0.01 ha plot, and one-quarter the species found in a 1.0 ha plot (see MacArthur & Wilson 1967; Harris 1984 for discussion of "z" value).

The reason for such high species counts in these small-scale plots is not clear, except that, in this case, most species are relatively diminutive with a variety of growth forms (about 60 percent of the species are perennials), and many have very brief above-ground life histories. Species packing is therefore no problem.

The role of fire in maintaining plant communities is well understood (Platt 1999). In the absence of fire, many plant communities (e.g., prairies) are rapidly invaded by shrubs and trees (Packard & Mutel 1997). Oak-hickory savannas and xeric sandylands appear to require fire for natural maintenance (Cutter & Guyette 1994). We noticed in this study that, because of the long drought that the West Gulf Coastal Plain has been experiencing, there has been a significant die-off of woody vegetation, notably in the dryer areas. Fire, therefore, may not be the only important force preventing woody invasion. Periodic droughts may be another factor keeping xeric sandylands, as well as other communities, open.

Soils at GEWMA are virtually identical to soils tested from xeric sandyland sites in Louisiana and east Texas (MacRoberts & MacRoberts 1994, 1995, 1996). They are nutrient-poor and acidic. Soil conditions per se may also preclude woody invasion.

We have emphasized the floristics of xeric sandylands largely to develop baseline information, and we note that the species richness of this community is considerably greater than generally recognized. The hydrologic and geomorphologic properties of these xeric sandhills also are significant, as the water they supply underlies the existence of adjacent wetland communities—bogs, marshes, baygalls, and seeps.

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REFERENCES

Ajtovsgi, G. 1979. Wild flowers of the Big Thicket. Texas A&M Univ. Press, College Station.

Allen, C.M., C.H. Stagg, and S.D. Parris. 1988. Analysis of the vegetation in pitcher plant bogs in two baygalls at Ft. Polk in west central Louisiana. Proc. Louisiana Acad. Sci. 50:1–6.

Brewer, J.S. 1998. Patterns of plant species richness in a wet slash-pine (*Pinus elliottii*) savanna. J. Torrey Bot. Soc. 125:216–224.

Bridges, E.L. and S.L. Orzell. 1989. Longleaf pine communities of the West Gulf Coastal Plain. Natural Areas J. 9:246–263.

Bryant, W.S., W.C. McComb, and J.S. Fralish. 1993. Oak-hickory forests. In: W.H. Martin, S.G. Boyce, and A.C. Echternacht, eds. Biodiversity of the southeastern United States: upland terrestrial communities. John Wiley & Sons, New York. Pp. 143–201.

Carr, S. 2000. Composition and structure of pine-hardwood forests in central and northwest Louisiana. MS Thesis, Louisiana State University, Baton Rouge.

Coffee, O.R. 1975. Soil survey of Anderson County, Texas. U.S.D.A., Soil Conservation Service, Washington, D.C.

Cutter, B.E. and R.P. Guyette. 1994. Fire frequency on an oak-hickory ridgetop in the Missouri Ozarks. Amer. Midl. Naturalist 132:393–398.

Diamond, D.D., D.H. Riskind, and S.L. Orzell. 1987. A framework for plant community classification and conservation in Texas. Texas J. Sci. 39:203–221.

Diamond, D.D., C.D. True, and K. He. 1997. Regional priorities for conservation of rare species in Texas. Southw. Naturalist 42:400–408.

Drawe, D.L., S.D. Chamard, and T.W. Box. 1978. Plant communities of the Welder Wildlife Refuge. Contr. 5, Ser. B, Welder Wildlife Foundation, Sinton, Texas.

Drewa, P.B. 1999. Community structure and the effects of experimental fires on hardwood shrub species in southeastern longleaf pine savannas. Dissertation. Louisiana State University, Baton Rouge.

Foti, T., X. Li, M. Blaney, and K.G. Smith. 1994. A classification system of the natural vegetation for Arkansas. Proc. Arkansas Acad. Sci. 48:50–62.

Harcombe, P.A., J.S. Glitzenstein, R.G. Knox, S.L. Orzell, and E.L. Bridges. 1993. Vegetation of the longleaf pine region of the West Gulf Coastal Plain. Proc. Tall Timbers Fire Ecology Conference 18:83–104.

Harris, L.D. 1984. The fragmented forest. Univ. Chicago Press, Chicago.

Hoagland, B. 2000. The vegetation of Oklahoma: a classification for landscape mapping and conservation planing. Southw. Naturalist 45:385–420.

Jones, F.B. 1977. Flora of the Texas Coastal Bend. Mission Press, Corpus Christi.

Jones, N. and B. Carpenter. 1995. Boehler seeps and sandhill site conservation plan. Unpublished report, The Nature Conservancy, Tulsa.

Kartesz, J.T. and C.A. Meacham. 1999. Synthesis of North American flora. Version 1.0. North Carolina Botanical Garden, Chapel Hill.

KEYS, J.E., C.A. CARPENTER, S. HOOKS, F. KOENIG, W.H. MCNAB, W.E. RUSSELL, and M. SMITH. 1995. Ecological units of the eastern United States—first approximation. U.S. Dept. Agriculture, Forest Service, Atlanta.

LOUISIANA NATURAL HERITAGE PROGRAM. 1988. Natural communities of Louisiana. Unpublished report, Louisiana Dept. Fish and Wildlife, Baton Rouge.

MACARTHUR, R.H. and E.O. WILSON. 1967. The theory of island biogeography. Princeton Univ. Press, Princeton.

MACROBERTS, B.R. and M.H. MACROBERTS. 1991. Floristics of three bogs in western Louisiana. Phytologia 70:135–141.

MACROBERTS, M.H. and B.R. MACROBERTS. 1994. Floristics of a xeric sandyland in western Louisiana. Phytologia 77:414–424.

MACROBERTS, B.R. and M.H. MACROBERTS. 1995. Floristics of xeric sandhills in northwestern Louisiana. Phytologia 79:123–131.

MACROBERTS, B.R. and M.H. MACROBERTS. 1996. Floristics of xeric sandhills in east Texas. Phytologia 80:1–7.

MACROBERTS, B.R. and M.H. MACROBERTS. 1998a. Floristics of wetland pine savannas in the Big Thicket Preserve, southeast Texas. Phytologia 85:40–50.

MACROBERTS, B.R. and M.H. MACROBERTS. 1998b. Floristics of muck bogs in east central Texas. Phytologia 85:61–73.

MACROBERTS, M.H. and B.R. MACROBERTS. 1999. Status report on *Eriocaulon kornickianum* (dwarf pipewort) in Texas. Unpublished report, U.S. Fish and Wildlife Service, Jackson, Mississippi.

MARIETTA, K.L. and E.S. NIXON. 1983. Vegetational analysis of a post oak-black hickory community in eastern Texas. Texas J. Sci. 35:196–203.

MARKS, P.L. and P.A. HARCOMBE. 1981. Forest vegetation of the Big Thicket, southeast Texas. Ecol. Monogr. 51:287–305.

MARTIN, D.L. and L.M. SMITH. 1991. A survey and description of the natural plant communities of the Kisatchie National Forest: Winn and Kisatchie districts. Unpublished report, Louisiana Department of Wildlife and Fisheries, Baton Rouge.

MCBRYDE, J.B. 1933. The vegetation and habitat factors of the Carrizo Sands. Ecol. Monogr. 3:247–297.

MCNAB, W.H. and P.E. AVERS. 1994. Ecological subregions of the United States. U.S. Dept. Agriculture, Washington, D.C.

MEYERS, N., R.A. MITTERMEIER, C.G. MITTERMEIER, G.A.B. DA FONSECA, and J. KENT. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

MONK, C.D., D.W. IMM, and R.L. POTTER. 1990. Oak forests of eastern North America. Castanea 55:77–96.

NESOM, G.L., B.R. MACROBERTS, and M.H. MACROBERTS. 1997. A new plant community type in southeast Texas related to baygalls. Phytologia 83:371–383.

NESOM, G.L. and L.E. BROWN. 1998. Annotated checklist of the vascular plants of Walker, Montgomery, and San Jacinto counties, East Texas. Phytologia 84:107–153.

PACKARD, S. and C.F. MUTEL. 1997. The tallgrass restoration handbook. Island Press, Washington, DC.

PEET, R.K., D.C. GLENN-LEWIN, and J.W. WOLF. 1983. Prediction of man's impact on plant species diversity. In: W. Holzner, M.J.A. Werger, and I. Ikusima, eds. Man's impact on vegetation. W. Junk, Hague. Pp. 41–54.

PEET, R.K. and D.J. ALLARD. 1993. Longleaf pine vegetation of the southern Atlantic and eastern Gulf Coastal regions: a preliminary classification. Proc. Tall Timbers Fire Ecology Conference 18:45–88.

PEET, R.K., T.R. WENTWORTH, and P.S. WHITE. 1998. A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262–274.

PLATT, W.J. 1999. Southeastern pine savannas. In: R.C. Anderson, J.S. Fralish, and J.M. Baskin, eds. Savannas, barrens, and rock outcrop plant communities of North America. Cambridge Univ. Press, New York. Pp. 23–51.

RICKETTS, T.H., E. DINERSTEIN, D.M. OLSON, C.J. LOUCKS, W. EICHBAUM, D. DELLASALA, K. KAVANAGH, P. HEDAO, P.T. HURLEY, K.M. CARNEY, R. ABELL, and S. WALTERS. 1999a. Terrestrial ecoregions of North America. Island Press, Washington D.C.

RICKETTS, T.H., E. DINERSTEIN, D.M. OLSON, and C. LOUCKS. 1999b. Who's where in North America. BioScience 49:369–381.

SINGHORST, J.R. 1996. The status of nine endangered plant species of east Texas: historical, ecological, and phytogeographical notes. M.S. Thesis, Stephen F. Austin State University, Nacogdoches.

SINGHURST, J.R., J. CATHEY, D. PROCHASKA, H. HAUCKE, and W.C. HOLMES. 2000. Vascular flora of Gus Engeling Wildlife Management Area, Anderson County, Texas. Unpublished manuscript, Texas Parks and Wildlife, Austin.

SKEEN, J.N., P.D. DOEPP, and D.H. VAN LEAR. 1993. Oak-hickory-pine forests. In: W.H. Martin, S.G. Boyce, and A.C. Echternacht, eds. Biodiversity of the southeastern United States, upland terrestrial communities. John Wiley & Sons, New York. Pp. 1–33.

SMEINS, F.E. and D.D. DIAMOND. 1983. Remnant grasslands of the Fayette Prairie, Texas. Amer. Midl. Naturalist 110:1–13.

SMEINS, F.E. and D.D. DIAMOND. 1986. Grasslands and savannas of east central Texas: Ecology, preservation status and management problems. In: D.L. Kulhavy and R.N. Conner, eds. Wilderness and natural areas in eastern United States: a management challenge. Center for Applied Studies, Stephen F. Austin State University, Nacogdoches, Texas. Pp. 381–394.

SMITH, E.B. 1988. An atlas and annotated list of the vascular plants of Arkansas. Privately published, Fayetteville.

SORRIE, B.A. and A.S. WEAKLEY. 2001. Coastal plain vascular plant endemics: phytogeographic patterns. Castanea 66:50–82.

STOUT, J. and W.R. MARION. 1993. Pine flatwoods and xeric pine forests of the southern (lower) coastal plain. In: W.H. Martin, S.G. Boyce, and A.C. Echternacht, eds. Biodiversity of the southeastern United States, upland terrestrial communities. John Wiley & Sons, New York. Pp. 373–446.

SUMMER, R.M. 1992. Hydrology and geomorphology of Boehler seeps and sandhills: impacts of road construction. Unpublished report, The Nature Conservancy, Tulsa.

TAYLOR, J. and C.E. TAYLOR. 1978. Additions to the vascular flora of Oklahoma. Sida 7:361–368.

TELFAIR, R.C. II. 1988. Conservation of the Catfish Creek ecosystem: a national natural landmark in eastern Texas. Texas J. Sci. 40:11–23.

TELFAIR, R.C. II. 1999. Introduction: ecological regions of Texas: description, land use and wildlife. In: R.C. Telfair II, ed. Texas wildlife resources and land use. Univ. Texas Press, Austin. Pp. 1–39.

TEXAS NATURAL HERITAGE PROGRAM. 1995. Plant communities of Texas. Unpublished report. Texas Parks and Wildlife Department, Austin.

THOMAS, R.D. and C.M. ALLEN. 1993–1998. Atlas of the vascular flora of Louisiana. The Nature Conservancy, Baton Rouge.

TURNER, B.L. in press. Atlas of Texas plants. Sida, Botanical Miscellany.

TURNER, M.W. 1996. Systematic study of the genus *Brazoria* (Lamiaceae), and *Warnockia* (Lamiaceae), a new genus from Texas. Pl. Syst. Evol. 203:65–82.

TURNER, R.L., J.E. VAN KLEY, L.S. SMITH, and R.E. EVANS. 1999. Ecological classification system for the national forests and adjacent areas of the West Gulf Coastal Plain. The Nature Conservancy, Nacogdoches, Texas.

WARD, J.R. and E.S. NIXON. 1992. Woody vegetation of the dry, sandy uplands of east Texas. Texas J. Sci. 44:283–294.

WALKER, J. and R.K. PEET. 1983. Competition and species diversity of pine-wiregrass savannas of the Green Swamp, North Carolina. Vegetatio 55:163–179.