FINAL REPORT

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THE ENDANGERED SPECIES ACT, SECTION 6

TEXAS
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ENDANGERED AND THREATENED SPECIES CONSERVATION II

Project No. 42

Inventory of the Texas Trailing Phlox (Phlox nivalis ssp. txensis), with Emphasis on Management Concerns

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FINAL REPORT

STATE:	Texas **GRANT NO.:** E-2-2
GRANT TITLE:	Endangered and Threatened Species Conservation II
PERIOD COVERED:	February 1, 1995 to January 31, 1996
PROJECT NUMBER:	42
PROJECT TITLE:	Inventory of the Texas Trailing Phlox (*Phlox nivalis* ssp. *texensis*), with Emphasis on Management Concerns.
PROJECT OBJECTIVE:	All historical occurrences will be re-inventoried to assess overall population status. Permanent plots will be monitored before and after management activities at Sandyland Sanctuary in order to develop management prescriptions for the species.

ACCOMPLISHMENTS

See attached report.

SIGNIFICANT DEVIATIONS

None.

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Conservation Scientist V

April 30, 1996

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Section 6 Coordinator

30 April 1996
Date

Report to the Texas Parks and Wildlife Department on
Management Effects on *Phlox nivalis* Loddiges subsp. *texensis* Lundell
(Texas trailing phlox) during the 1992-1995 field seasons

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Report to the Texas Parks and Wildlife Department on Management Effects on *Phlox nivalis* Loddiges subsp. *texensis* Lundell (Texas trailing phlox) during the 1992-1995 field seasons

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ABSTRACT

Examination of the effects of various management regimes for *Phlox nivalis* Loddiges subsp. *texensis* Lundell (Texas trailing phlox) were undertaken in an attempt to determine which management practices could best be utilized to insure survival of the species. Specifically, two major questions concerning management were addressed: 1) What are the effects of prescribed burning on reproduction of Texas trailing phlox? 2) What are the effects of selective overstory canopy thinning on reproduction of Texas trailing phlox? With regard to question 1, assessment was made on the timing of prescribed burns, to determine whether or not this was important to reproduction of Texas trailing phlox. In addition, effects of various combinations of prescribed burn (different timing and sequences) with canopy thinning were assessed. Additional studies were undertaken to describe vegetation and edaphic factors that might be correlated with reproductive success of Texas trailing phlox. These two (management practices and vegetation preferences) were examined directly for their effects on trailing phlox, as well as indirect effects of management by its effects on vegetation. Searches for previously unreported localities and for plants in historical but not recently reported localities were undertaken.

Prescribed burning has a positive impact on growth parameters of Texas trailing phlox if the burn is conducted from November through May (early burn), but the burn may be detrimental if conducted from June through October (late burn). Overstory thinning appears to have little effect on growth of Texas trailing phlox except when combined with a late burn, where the effect is significantly negative. Transect sampling supported the results from plot sampling on management effects. In order to obtain optimum Texas trailing phlox growth, prescribed burns should be completed on a three to four year cycle.

Reproduction of Texas trailing phlox appears to be best at overstory canopy coverages of 5-25% and drops off dramatically at canopy coverages of more than 50%. Best growth of Texas trailing phlox appears to be at understory coverages of 25-80% relative to greater or lesser coverage percentages. Ideal shrub coverage for growth of Texas trailing phlox appears to be less than 40%. For optimal reproduction, the shrub coverage should be less than 25%.

The plants appear to grow best near the edges of deep sands, where moisture is available at depths of 0.5-2 m. Texas trailing phlox may be found on level or slightly sloping ground.

Number of stems and number of flowers appear to be good measure of how well Texas trailing phlox plants are growing and reproducing. Increased percent new growth, and increased stem lengths in phlox appear to be associated with stress due to shading or other stresses on the plants.

INTRODUCTION AND BACKGROUND INFORMATION

Texas trailing phlox (*Phlox nivalis* Loddiges subsp. *texensis* Lundell) was listed on 30 September 1991, as an endangered species under the Endangered Species Act of 1973, as amended (Blanchard 1991). Texas trailing phlox is also listed as endangered by the State of Texas. Although nineteen collections of Texas trailing phlox are reported in historical records, these appear to originate from only six definable population systems. Texas trailing phlox is presently known from three sites (one each in Tyler, Polk, and Hardin counties, Texas). It is reportedly endemic to sites with deep sandy soils, relatively open overstory canopy, and at least some groundcover in longleaf pine savanna. Vegetational reports suggest that Texas trailing phlox prefers intermediate seral stages rather than either very early successional or late successional stages. If the plant is tied to subclimax plant communities, maintenance and recovery of Texas trailing phlox will require active management. Texas trailing phlox appears primarily threatened by habitat loss. Factors contributing to habitat loss are housing developments, land clearing and site preparation for pine plantations and pasture, encroachment (due to fire suppression) of closed canopy forest on former open forests or savanna, herbicide drift, off road vehicle use, and activities associated with pipeline, powerline, railroad, and highway construction.

Examination of the effects of various management regimes for *Phlox nivalis* Loddiges subsp. *texensis* Lundell (Texas trailing phlox) were undertaken in an attempt to determine which management practices could best be utilized to insure survival of the species. Specifically, two major questions concerning management were addressed: 1) What are the effects of prescribed burning on reproduction of Texas trailing phlox? 2) What are the effects of selective overstory canopy thinning on reproduction of Texas trailing phlox? With regard to question 1, assessment was made on the occurrence, frequency, and timing of prescribed burns, to determine whether or not this was important to growth and reproduction of Texas trailing phlox. In addition, effects of various combinations of prescribed burn (different timing and sequences) with canopy thinning were assessed. Additional studies were undertaken to describe vegetation and edaphic factors that might be correlated with growth and reproductive success of Texas trailing phlox. These two (management practices and vegetation preferences) were examined directly for their effects on trailing phlox, as well as indirect effects of management by its effects on vegetation. Searches for previously unreported localities and for plants in historical but not recently reported localities were undertaken.

Wherry included *Phlox nivalis* in series *Subulatae* along with *P. subulata* L. and *P. oklahomensis* Wherry. Both of the latter species have similar gross morphological features to *P. nivalis*. Bogler (1992) expressed the opinion that based on Texas specimens of *P. oklahomensis*, *P. nivalis* is most similar to *P. oklahomensis*. The Texas specimens of *P. oklahomensis* are disjunct from the main range of that species (further north in Oklahoma), and located approximately equidistant between the main range of *P. oklahomensis* and the range of *P. nivalis* subsp. *texensis*. Bogler also cited three collections of *P. nivalis* from Louisiana and implied that these might represent *P. nivalis* subsp. *texensis*. Field and herbarium studies were undertaken to determine the taxonomic status of these plants.

Current studies have been undertaken to obtain data on phenology, perennial vs. deciduous vegetation, duration of flowers, number of flowers per plant, habitat characteristics, competing species, and effects of various management practices on these factors.

MATERIALS AND METHODS

Study Site

The primary study area for this research was the Roy E. Larsen Sandylands Sanctuary, owned and operated by the Texas Nature Conservancy (TNC) in Hardin County, Texas.

Additional information was recorded while visiting historical populations in Hardin, Polk, and Tyler counties. The data reported here come primarily from the Sandylands Sanctuary.

Units and compartments on the Sandylands Sanctuary are managed in a manner designed to restore native vegetation on different parts of the preserve, appropriate to the edaphic conditions present in each area. TNC retains records of management practices carried out on each compartment on the sanctuary. These records include dates of burning (including which areas actually burned successfully, as opposed to simply being scheduled for burning), and date and description of any overstory thinning activity that has taken place. Management records have been kept since TNC acquired the property. These records were used to determine past (within at least the most recent five years) management activities at each site where data were collected.

Additional field work was done at other current and historical sites for Texas trailing phlox in southeast Texas, as well as at sites for *Phlox nivalis* subsp. *nivalis*, *P. subulata* L., and *P. oklahomensis* Wherry in Florida, Kansas, Louisiana, North Carolina, Oklahoma, South Carolina, Texas, and Virginia. Herbaria were consulted at the Botanical Research Institute of Texas, Florida State University, Louisiana State University, Northeast Louisiana University, Sam Houston State University, Stephen F. Austin State University, and University of Texas--Austin.

Search for historical and new localities/plants

In addition to the study site (Larsen Sandylands), all historical sites in Hardin, Polk, and Tyler counties were visited during March and April 1993. In addition, a recently reported site from Tyler County was also visited in 1993. Data from previous reports contained in the Texas Natural Heritage Database were used to locate these sites. The newly discovered site in Polk County was visited in May 1995.

Information gathered at each of these sites, as well as from written documentation about these sites was used to supplement information from the Sandylands Preserve population to develop a habitat profile for Texas trailing phlox. This habitat profile was used to concentrate searches for new populations of Texas trailing phlox.

Morphology

Morphological studies were made of living plants as well as herbarium specimens. Written documents were also used to produce a comprehensive description of Texas trailing phlox. The majority of the information came from study of living plants.

Distribution

Texas trailing phlox is most often thought of as endemic to longleaf pine woodlands and savannas of southeast Texas (Hardin, Polk, and Tyler counties). The work of Bogler (1992) raised some questions as to the accuracy of this distribution. The nominal subspecies of *Phlox nivalis* (subsp. *nivalis*) has been reported in pine or oak barrens or scrub, on the Coastal Plain or Piedmont from Alabama to Florida, and north to Virginia.

Sites for *Phlox nivalis* subsp. *nivalis* and the questionable localities cited by Bogler were evaluated, most being visited, and others inquired about through correspondence with local botanists.

Taxonomy

Wherry included *Phlox nivalis* in series *Subulatae* along with *P. subulata* and *P. oklahomensis*. Both of the latter species have similar gross morphological features to *P. nivalis*. Bogler (1992) expressed the opinion that based on Texas specimens of *P. oklahomensis*, *P. nivalis* is most similar to *P. oklahomensis*. Bogler also cited three collections of *P. nivalis* from Louisiana and implied that these might represent *P. nivalis* subsp. *texensis*. Field and herbarium studies were undertaken to determine the taxonomic status of these plants. Field sites for all four taxa were visited. Herbarium specimens were examined representing all four taxa.

Reproductive biology

Current studies have been undertaken to obtain data on phenology, perennial vs. deciduous vegetation, duration of flowers, number of flowers per plant, habitat characteristics, competing species, and effects of various management practices on these factors.

For the purposes of this report, a plant is defined as a cluster of stems with no above ground connection to other groups of stems and separated from other such groups by at least 5 dm. The frequency of asexual reproduction in Texas trailing phlox is not known. It is possible that underground portions of the plants may be quite extensive, and that asexual reproduction is more common than sexual reproduction.

Effects of management on *Phlox* growth and reproduction

Texas trailing phlox was found in thirteen management units or subunits identified on the Sandylands Sanctuary. These management units represented six of eight possible management combinations for prescribed burn and selective overstory thinning. The management combinations studied were: [1] control (no active management within the past eight years); [2] early burn (site subjected to fire during the months of November through May); [3] late burn (site subjected to fire during the months of June through October); [4] overstory thinning/early burn (combination of [2] and [7]); [5] overstory thinning/late burn (combination of [3] and [7]); [6] overstory thinning/double burn (combination of [7] and [8]); [7] overstory thinning (removal of slash pine); and [8] double burn (site subjected to at least one each of early and late burn). In the summary analysis, statistics were also computed for the burn management regimes ([2] and [3]) for three segments of the year. These three segments were spring burn (February-May), summer burn (June-September), and winter burn (October-January).

Previous workers had permanently marked 56 Texas trailing phlox plants with paired metal rods that, in combination with a plot template, delimited 0.5 x 1 m plots including the marked plants. An additional three plots were established during the 1993 field season. These plots were originally distributed among the management treatments as follows: 6 in [1], 7 in [2], 8 in [3], 18 in [4], 3 in [5], 14 in [6], 0 in [7], and 3 in [8]. As management by The Nature Conservancy occurred on each plot throughout the study, assignments for phlox plots were adjusted accordingly for any changes in management on a plot versus its previous assignment. By the beginning of the 1995 field season, all plots had experienced some management action, thus no controls were remaining. However, data gathered on control plots in previous years provided a standard against which additional data could be compared. Each of these plots was sampled during the months of March-May 1992-1995 and data described below were recorded.

A map drawn on a standard grid representing the plot was produced each year for each phlox plant. This map included the location on the grid of all sexual reproductive structures (buds, flowers, senesced flowers, and fruits--and location of each stem terminus in plants with fewer than 30 stems), the boundaries of the plant, and compass orientation for the plot. In addition to the map, areal coverage, total number of branches, proportion of the branches that were new growth, longest diameter of the plant, shortest diameter of the plant, shortest, longest and mean stem height, number of buds, number of flowers, number of senesced flowers, and number of fruits were recorded for each Texas trailing phlox plant. Comparison of current data with data from the previous year for the same plants yielded changes in size of plants, number of stems, and reproductive outputs of plants. In addition, these change measures were used to derive a frequency of positive change for each plant in each year. Based on mortality of plants during the study, frequencies of death of phlox plants were computed for each management regime.

Additional data recorded from each 0.5 x 1 m plot were species and cover class (see Table 1) for all plant species found in the plot, total groundcover class, litter depth, litter composition (percentage pine, broadleaf, and grass), litter cover class, surface soil characteristics, depth to subsurface soil transitions (either by digging soil pits or using a metal probe), degree of slope, direction of slope, elevation relative to surrounding (5 m) area, and potential disturbances. In association with each plot, overstory trees, understory trees, and shrubs were sampled using the point quarter method and cover classes. Using cardinal compass directions from the center of the plot as dividing lines for the quarters, the nearest tree larger than 30 cm circumference at breast height (CBH) was measured, its species name, CBH, and distance from the plot recorded. An identical approach was used to sample understory trees (less than 30 cm CBH). Shrubs were sampled by recording the species name of, distance to, and areal coverage of the nearest shrub in each quarter.

Table 1. Cover class codes used to represent percentage of areal coverage for plants in samples.

Cover class	Percentage of coverage
1	<5
2	5-10
3	10-25
4	25-40
5	40-50
6	50-70
7	70-80
8	80-90
9	>90

Since no Texas trailing phlox had been reported from management combination [7] above, although sites having been treated with this combination were present on the preserve, an additional sampling procedure was completed in order to make comparisons among all management combinations. Five sampling sites, each 50 x 50 m, were randomly chosen within each management combination reflecting management activities during the previous five (5) years (1-8 above). Within each sampling site, six parallel belt transects (each 2 x 50 m, centerlines 10 m apart) were sampled for occurrence of trailing phlox. Number of plants and areal coverage of each trailing phlox plant encountered within the transect was recorded. Transects were sampled in the months of May-June 1992-1993. These transects were identical to the transects sampled during the previous year, therefore, change in number of plants as well as mean size of plants was also recorded. Transect sampling was discontinued in 1994 as there were no longer sites on the entire Sanctuary where canopy thinning had taken place in the absence of any additional management.

Data analysis.

Data were entered into the computer system at Sam Houston State University. Analysis of variance (including one-way and Scheffe multiple comparisons where appropriate) and Pearson correlations were the primary statistical tools used to assess relationships between management and edaphic factors, and Texas trailing phlox reproductive success. Correlations and significance tests were generated by the SAS Data Analysis System. Plant identification utilizes Correll & Johnston (1970) and Gould (1978). Nomenclature follows Harkum (1991).

RESULTS AND DISCUSSION

Search for historical and new localities/plants

Development of habitat profile

Field studies suggest that sandy surface soil, coupled with moisture bearing clays, or sandy clays at depths of 0.8-2 m provide the best soil structure for Texas trailing phlox. Such sites are often on the sandy (drier and usually upslope) side of transitions between sandy soils supporting pine (usually dominated by *Pinus palustris* P. Mill.) savanna and clay or sandy clay soils supporting a mixed forest of hardwoods and pines (usually *P. taeda* L.). Since Texas trailing phlox occurs on surface sand, the presence of subsurface clay or relatively impermeable sand layers is not always apparent by transition within short distances into impermeable surface soils. Such sites (surface sand with subsurface impermeability, but surrounded by deeper sand) do support populations of Texas trailing phlox, and are often associated with presence hardwoods (particularly *Carya texana* Buckl. and *Quercus falcata* Michx.) among the pines.

Slopes at sites of most plants are less than 5%, and aspect of slope appears not to be a critical factor in occurrence of Texas trailing phlox. The elevation is 9-75 m, and topography is nearly level. When the plants do occur on a slope, the tendency is for them to be in the middle levels of the slope rather than at top or bottom.

Ideal vegetation characteristics for Texas trailing phlox are an open canopy (5-25%) of pines, less than 40% coverage of subcanopy trees (pines and hardwoods), and less than 40% coverage of shrubs. Herbaceous coverage is greater than 50% where Texas trailing phlox grows best, with at least 30% of the herbaceous cover being grasses.

Historical locations

The historical locality west of Woodville in Tyler County was located. The population consists of four plants, each apparently healthy. Some flower color variation is expressed in this population which has not been observed at Larsen Sandylands. Presence of this variation suggests genetic information present in this population not present in the Sandylands populations. This population was most recently visited in December 1995 and its status has not changed.

The location in Polk County is on the Big Sandy Unit of the Big Thicket National Preserve. It consists of two plants near a highway right-of-way. These plants were discovered after a prescribed burn that had recently been conducted at the site.

Other historical localities in Hardin and Tyler counties could not be relocated. Particular attention was paid to historical sites on the Big Thicket National Preserve (Turkey Creek Unit) since this is a protected area and the location of plants had been relatively precisely located. However, extensive searches yielded no plants. It appeared that an extremely hot fire had burned most of the likely habitat within the several months before the survey was undertaken.

A reintroduction program for Texas trailing phlox into the Turkey Creek Unit of the Big Thicket National Preserve was undertaken. Forty plants were placed in the site in December 1995. These plants originated from cuttings of plants at Larsen Sandylands, the cuttings having been taken and nurtured by the Mercer Arboretum.

New locations

A previously unreported population of Texas trailing phlox was reported to the Texas Parks and Wildlife Department during early 1993. This population was visited near the end of the flowering season. The population consists of 25-35 individuals, some of them quite large. The area has been mown 1-4 times per year for the past several years and had been burned regularly in the past. The plants are in essentially a lawn situation scattered in a 12 x 15 m area on two adjoining lots in a cluster of houses in what had in the past been a site for a hunting lodge. Additional plants are found in a planter associated with a house on one of the lots. Plants in the population appear similar to Texas trailing phlox, but further study will be required to determine their taxonomic status.

Additional apparently previously unreported plants found at Larsen Sandylands were marked with flags, and their locations recorded. All are in the general vicinity of previously known individuals. Fewer than 200 plants were known from the Sandylands Sanctuary at the beginning of this study. The number of known plants is now nearly 500.

A population of Texas trailing phlox is maintained at the Mercer Arboretum. These plants originated from cuttings of plants at Larsen Sandylands.

Morphology

Description

Plants are evergreen. Texas trailing phlox forms clumps, but seldom forms mats. The plants are herbaceous or subshrubby. Stems spread along the ground surface, and are erect only for the terminal 2-15 cm. Leaves are needlelike to lanceolate, densely packed on the stem (producing an appearance somewhat like a juniper seedling), usually less than 1.5 cm long, and are more or less glandular pubescent. Older stems have smaller, darker green leaves, and typically lay directly on the ground surface. Young stems produce the flowers, have longer, slightly wider, and lighter green leaves, and are more or less erect. Inflorescences are 3-12 flowered cymes, subterminal on (typically) tallest stems. The corolla has five petals, each ca. 1 cm long, lavender to pink to magenta, darker near the throat. Fruits are achenelike, and apparently indehiscent.

Similar species

Vegetative plants look similar to *Loeflingia squarrosa* Nutt. However, *Loeflingia* is an annual with much lower density of leaves on the stem, and usually much smaller plants than Texas trailing phlox. Seedlings of *Juniperus virginiana* L. appear somewhat like single stems of Texas trailing phlox. However, the juniper seedling soon become obviously woody, leaf density is lower, and leaves have a darker green or even bluish cast to them, whereas leaves of Texas trailing phlox are bright green to yellowish green. Flower color is similar to that of *Verbena canadensis* (L.) Britt. which flowers at about the same time and can cause confusion with identification at a distance (more than 5 m). However, leaves and inflorescence structure are quite different and these two will not be confused upon closer examination.

Information on similar *Phlox* taxa is found in the section on taxonomy.

Distribution

Texas trailing phlox is one of two subspecies recognized in *P. nivalis*. Subspecies *texensis* is known from open pine woods in only three counties (Hardin, Polk, and Tyler) in southeast Texas. The nominal subspecies (subsp. *nivalis*) occurs in pine or oak barrens or scrub, on Coastal Plain or Piedmont from Alabama to Florida, and north to Virginia. Flowers of this subspecies are typically white or pale pink, with plants of forma *roseiflora* Fernald having deep rose or magenta flowers (Fernald 1970). Currently, the nearest known populations of subsp. *nivalis* to those of subsp. *texensis* are plants of subsp. *nivalis* more than 1000 km eastward in northern Florida.

Taxonomy

Texas trailing phlox belongs to the Polemoniaceae, which includes such plants as Sweet William, Jacob's Ladder, Texas Plume, and Phlox. First collected in 1931 in Hardin County by Elihu Whitehouse, and described by Lundell (1942) as *Phlox nivalis* subsp. *texensis*. Later (1945) realigned by Lundell as *P. texensis* (Lundell) Lundell. In a monographic treatment of Phlox, Wherry (1955) recognized the plant as *P. nivalis* subsp. *texensis*.

Wherry included *Phlox nivalis* in series *Subulatae* along with *P. subulata* L. and *P. oklahomensis* Wherry. Both of the latter species have similar gross morphological features to *P. nivalis.* Bogler (1992) expressed the opinion that based on Texas specimens of *P. oklahomensis, P. nivalis* is most similar to *P. oklahomensis.* The Texas specimens of *P. oklahomensis* are disjunct from the main range of that species (further north in Oklahoma), and located approximately equidistant between the main range of *P. oklahomensis* and the range of *P. nivalis* subsp. *texensis.* Bogler also cited three collections of *P. nivalis* from Louisiana and implied that these might represent *P. nivalis* subsp. *texensis.*

Texas trailing phlox is very similar to *Phlox nivalis* subsp. *nivalis.* According to Wherry (1955), the major difference between the two subspecies is the presence of minute glandular hairs found on subsp. *texensis* but absent from subsp. *nivalis.*

Based on field studies in Florida, North Carolina, Virginia, Kansas, Oklahoma, South Carolina, and Texas, as well as examination of herbarium specimens, the current author has concluded (contrary to Bogler's [1992] suggestions) that *Phlox nivalis* is much more similar to *P. subulata* than either of these species is to *P. oklahomensis.* Although the population of *P. oklahomensis* from Dallas County could not be located (apparently it has only been collected once) specimens from that population are clearly not distinct from *P. oklahomensis,* being quite similar to plants from populations in Kansas and Oklahoma. *Phlox oklahomensis* has much longer, broader leaves, rounded at the apices, and more widely spaced on the stem than does *P. nivalis.* In addition, *P. oklahomensis* forms more open clumps with longer stems than does *P. nivalis.*

Phlox subulata is similar in overall morphology to *P. nivalis,* but leaves of the former are somewhat more rounded at the apex, somewhat narrower, average slightly longer, and are somewhat more widely spaced on the stem than those of the latter. In addition, *P. subulata* is generally found on rocky substrates while *P. nivalis* is found in sandy soils. The Louisiana populations reported by Bogler to represent *P. nivalis* were not relocated during a field search. According to Dr. R. Dale Thomas (pers. comm. 1993) of Northeast Louisiana University, these collections probably represent either cultivated plants or plants that had recently escaped cultivation and should not be considered a part of the native flora. Bogler's (1992) suggestions that either the Texas plants of *P. oklahomensis* or the Louisiana plants of *P. nivalis* represent new records of *P. nivalis* subsp. *texensis,* should be discounted accordingly.

Reproductive biology

Studies were made to obtain data on phenology, perennial vs. deciduous vegetation, duration of flowers, number of flowers per plant, habitat characteristics, competing species, and effects of various management practices on these factors.

Little is known about reproduction of Texas trailing phlox. Flies, bees, and butterflies have been observed visiting flowers. Based on floral structure, butterflies are the most likely pollinators for this plant. If this is the case, factors affecting pollinators may be important in reproduction of Texas trailing phlox. It is not known if flowers of Texas trailing phlox are either obligate or facultative outcrossers. Typically, no more than one seed is produced per flower, and based on limited field observation, fruit set is low. Individual flowers last 1-4 days (often limited by rainfall which can damage the flowers). An individual plant may have 3-50+ flowers and (primarily depending on number of flowers, which is largely a function of size of the plant) may produce flowers over a period of 1-5 weeks. Seed germination has not been observed, but most likely occurs during the autumn or winter.

Asexual reproduction is likely very important for recruitment. Texas trailing phlox is readily reproduced by cuttings. During the course of this study, individual plants have been shown to "migrate" by growing new stems in a particular direction while older stems die out where the migration began. Typically, the direction of growth is toward a more open area, probably due to a response to light intensity. Under evenly shaded conditions, the plants become very dispersed (covering a large area, but having few stems). This pattern continues until the shade is reduced (in which case the plants respond by producing more stems) or until growth is reduced (probably due to lack of resources and often eventually resulting in death of the plant).

Most of the plants examined in this study survived throughout the four years of the study. In addition, each of these plants was known for at least two years before this study began. Therefore, Texas trailing phlox plants can live for at least six years. Most of the plants growing under favorable conditions have shown little change in their size or reproductive output, suggesting that longevity may be much greater than six years.

Apparently actively growing whenever sufficient rainfall and high enough temperatures occur together. New growth is most often seen in early spring (late February to late April) and late summer to early autumn (when rainfall increases relative to summer months). Flowering typically occurs from mid-March to mid-April, but may last well into May (especially when plants are burned between February and early May).

No information is available on the germination rate, elapsed time from germination to first flower production, seed dormancy requirements, length of seed viability, or seed dispersal agents. Plants are browsed by some animal (probably deer) and since the reproductive tips of branches are damaged by this activity, this browsing tends to reduce reproduction. Insect and/or fungal predators are not known.

Effects of management on *Phlox* growth and reproduction

Fire effects

Timing of fire

Prescribed burning was determined to have a beneficial impact on Texas trailing phlox growth and reproduction. However, burning late (June-October) appeared to have a negative impact on growth and reproduction of Texas trailing phlox, while burning early (November-May) had a pronounced positive impact compared to control plots (Table 2). Double burning generally had a negative impact on phlox growth, probably due to effects of the included late burn (which were greater in magnitude than those of the early burn). The only phlox growth parameters not following these patterns were percent new growth, and longer upright stems (mean, shortest, and longest). Greater percent new growth may be an indicator of stressed but still actively growing plants, while longer upright stems may be indicators either of stress, or plants growing under more favorable conditions. Burning also showed positive effects on changes (increases) in numbers of flowers, number of stems, and areal coverage of phlox plants over unburned sites although these were not significantly different.

Texas trailing phlox appears very well adapted to fire. Aboveground parts of the plant are typically destroyed by fire, but underground parts are apparently undamaged by typical prescribed burns, as new growth is apparent on shoots within two weeks after a spring burn. If fire occurs in April, even plants that had flowered before the fire will resprout and flower again in May. Plants burned during drier parts of the year may not respond as quickly with new sprouts. It is possible that the increased temperatures generally experienced during late burns may be above the threshold for Texas trailing phlox underground parts and thus account for the negative impact of such burns.

Table 3 shows the greatly increased frequency of death of Texas trailing phlox under conditions of no burning. Also shown is the increased risk of death associated with late burns as opposed to early burns.

Table 2. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with various prescribed burn treatments (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	control		burn		early burn		late burn		double burn	
	PC	SF	PC	SF	PC	SF	PC	SF	PC	SF
stem number	-				++		-+++	+++	-++	++
cover class	-					#	-&	#	-@	
areal coverage	-				@	#	-&	++	-*	@
% new growth	-				@	+		@	#	#
long diameter	-@		@				-&	+	-#	
short diameter	-		@		+	*	-+++	+++	-+	
mean stem length	-		#	@		+		#	@	&
shortest stem	-				@	@		@	++	#
longest stem	-		*	*	+	++				
total flowers					@		-++	++	-&	&
change in number of flowers	-									
change in area										
change in number of stems	-									

Table 3. Statistical summary of frequency of death of phlox plants under different prescribed burning regimes (combined 1992, 1993, 1994, and 1995 data).

	control	burn	early burn	late burn	double burn
number of plants	15	69	37	32	9
percent dead	20.0	1.4	0	3.1	0
standard deviation	41.4		0	17.7	0

Results from transect sampling corroborated results from plot sampling for effects of management practices (Table 4). Prescribed burn during the period November through May (early burn) provided significantly improved conditions over no management for Texas trailing phlox, both in terms of number of plants and mean size of plants. This advantage to early season burning also carried over to provide significant results from the combinations of early burning with overstory thinning (number of plants only), burning and overstory thinning (number of plants only), double burning and overstory thinning (number of plants only), and burning in general (both number of plants and mean plant size). Late (June through October) prescribed burning did not show the negative impact with this analysis that was seen from the plot data. Overstory thinning alone appears to have little effect based on both data sets.

Table 4. Statistical results of analysis of variance and Pearson correlations of number and areal coverage of Texas trailing phlox plants found on transects through sites treated by various management combinations (combined 1992 and 1993 data). Numbers representing management treatments are explained in the text. PC= Pearson correlation; SF=significance of F from ANOVA; bn=burn; change number=change in number of plants; change size=change in mean size of plants; burn=treated with either [2] or [3]; burn and clear= treated with either [4], [5], or [6]; +=significant at .1%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=80 for most except N=40 for change values.

Treatment	number of plants		mean plant size		change number		change size	
	PC	SF	PC	SF	PC	SF	PC	SF
[1]control	-		-		-		-	
burn	+	++	&	&	-		-	
[2]spring burn	*	++	&	*	-		-	
[3]summer burn			-		-		-	@
[4]spring bn thin	+	++						
[5]summer bn thin		@	-				-	
[7]thin			-					
[6]double bn thin	*	*	-		-		-	
[8]double burn			-		-		-	
burn and clear	+	++						

Frequency of fire

Table 5 shows that Texas trailing phlox responds to increased frequency of fire by producing more stems on the plants. This response does not significantly affect the areal coverage or cover class of the phlox plants, thus producing very compact plants with a high density of stems. High fire frequency also produces plants with greater proportions of new growth and shorter stems. No significant effect was seen on reproductive rate due to fire frequency.

Table 5. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with number of burns in the past 20 years (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	number of burns in past 20 years		
	PC	SF	Scheffe (greater/lesser) years
stem number	+++	*	
cover class			
areal coverage			
% new growth	-&	#	
long diameter			
short diameter			
mean stem length		@	
shortest stem	-++		
longest stem	-	#	
total flowers			
change in number of flowers			none
change in area			none
change in number of stems			none

Recency of fire

Phlox characters associated with positive measure of Texas trailing phlox growth and reproduction are typically negatively correlated with number of years since the most recent burn. This pattern holds true for years since the most recent burn (Table 6), years since most recent winter burn (Table 7), and years since most recent spring burn (Table 8). However, as shown in Table 9, the pattern is reversed for years since most recent summer burn. These data support the data presented above, indicating that burning during the summer can be detrimental to Texas trailing phlox.

Table 6. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with years since last burn (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	years since last burn		
	PC	SF	Scheffe (greater/lesser) years
stem number	-&		
cover class	-&		
areal coverage	-		
% new growth	-+	+++	
long diameter	-		
short diameter	-	*	
mean stem length	-	@	
shortest stem	+++	+++	
longest stem	-@		
total flowers	-*	*	
change in number of flowers			none
change in area			none
change in number of stems		@	none

Table 7. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with years since last winter burn (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	years since last winter burn PC	SF	Scheffe (greater/lesser) years
stem number			
cover class	-		
areal coverage	-	#	
% new growth		+++	
long diameter			
short diameter	-	&	
mean stem length	-	#	
shortest stem	@	+	
longest stem	-#	#	
total flowers		@	
change in number of flowers		#	none
change in area	-		none
change in number of stems		&	none

Table 8. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with years since last spring burn (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	years since last spring burn PC	SF	Scheffe (greater/lesser) years
stem number	-+++	++	
cover class	-#	@	
areal coverage	-		
% new growth	-	++	
long diameter	-		
short diameter	-		
mean stem length	-	*	
shortest stem	&	+++	
longest stem	-@	#	
total flowers	++	@	
change in number of flowers			none
change in area	-		none
change in number of stems			none

Table 9. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with years since last summer burn (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	years since last summer burn		
	PC	SF	Scheffe (greater/lesser) years
stem number	+++	&	
cover class	&		
areal coverage	@		
% new growth	-	+++	
long diameter	#		
short diameter	+++	+	
mean stem length		*	
shortest stem	-@	&	
longest stem	-	#	
total flowers	+++		
change in number of flowers	@		none
change in area			none
change in number of stems	*		none

Tables 10 and 11 summarize information concerning effects of elapsed time since the most recent burn. These data are from both the plot (Table 10) and transect (Table 11) sampling and the statistics coincide to suggest that most active growth takes place in the first two years after a burn. In addition, more than five years elapsed after a burn is associated with reduction in growth expressed by significantly greater percent new growth. These results suggest that for optimum Texas trailing phlox growth, prescribed burns should be completed on a three to four year cycle.

Table 10. Statistical results of analysis of variance and Pearson correlations of growth parameters for Texas trailing phlox as compared to most recent burn (from plot data). PC= Pearson correlation; SF=significance of F from ANOVA; +=significant at .1%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=115 for most except N=59 for change values.

Year of latest burn:	1987		1988		1989		1990		1991		1992	
phlox parameter	PC	SF	PC	SF	PC	SF	PC	SF	PC	SF	PC	SF
number of stems	-	@	-		-				#	#	#	#
cover class			-		-				-		-	
areal coverage	-		-		-							
% new growth	&	&	&	&					-		-	
longest diameter	-		-	@	-		-		-		-	
shortest diameter	-	@	-	@	-							
mean stem length				@					-		-	
shortest stem	-						-		*	++	*	++
longest stem						@		@	-		-	
number of flowers			-							@		@
change in number of flowers	-		-									
change in areal coverage	-		-		-							
change in number of stems	-		-		-							

Table 11. Statistical results of analysis of variance and Pearson correlations of growth parameters for Texas trailing phlox as compared to most recent burn (from transect data). PC= Pearson correlation; SF=significance of F from ANOVA; +=significant at .1%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%. N=115 for most except N=59 for change values.

Year of latest burn:	1987		1988		1989		1990		1991		1992	
phlox parameter	PC	SF	PC	SF	PC	SF	PC	SF	PC	SF	PC	SF
areal coverage		@		@	#	#		@	#	#	#	#
change in areal coverage							-		-&	&	-&	&
change in number of plants							-		-*	++	-*	++
number of plants				-					-		-	

Canopy thinning effects

Selective overstory thinning as a management tool appeared to have little significant effect on growth and reproduction of Texas trailing phlox (Tables 12 and 13). Similar results were seen based on data recording changes in areal coverage, numbers of flowers, and numbers of stems, in addition to the direct measures of the phlox plants.

While thinning procedures may be beneficial to overall management plans of the preserve, and possibly to long term success of Texas trailing phlox, they appear to have no significant short term positive impact on the plants. More importantly, thinning activity does not appear to have a negative impact on Texas trailing phlox. Effects of canopy thinning on phlox are most likely to be seen primarily by their effects on the canopy itself.

Table 12. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with selective overstory thinning treatment (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	control		thin	
	PC	SF	PC	SF
stem number	-		#	#
cover class	-			
areal coverage	-			
% new growth	-			
long diameter	-@			
short diameter	-			
mean stem length	-			
shortest stem	-			
longest stem	-			
total flowers				
change in number of flowers	-			
change in area				
change in number of stems	-			

Table 13. Statistical results of analysis of variance and Pearson correlations of number and areal coverage of Texas trailing phlox plants found on transects through sites treated by various management combinations (combined 1992 and 1993 data). Numbers representing management treatments are explained in the text. PC= Pearson correlation; SF=significance of F from ANOVA; bn=burn; change number=change in number of plants; change size=change in mean size of plants; burn=treated with either [2] or [3]; burn and clear= treated with either [4], [5], or [6]; +=significant at .1%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=80 for most except N=40 for change values.

Treatment	number of plants		mean plant size		change number		change size	
	PC	SF	PC	SF	PC	SF	PC	SF
[1]control	-		-		-		-	
[7]thin			-					
burn and clear	+	++						
[4]spring bn thin	+	++						
[5]summer bn thin		@	-				-	
[6]double bn thin	*	*	-		-		-	

Combined effects of fire and canopy thinning.

Combined effects of prescribed burn and overstory thinning largely reflect the results of individual effects of burning, but with lower significance levels (Table 14). Somewhat disturbingly, as shown in Table 15, frequencies of death of phlox plants were much higher under the late burn/canopy thinning combination than under other management combinations. The frequency of dead phlox plants under this management approached that for the no burning or thinning management regime. This higher risk of death under late burning/canopy thinning may be the result of higher (possibly lethal) fire temperatures given the combination of higher ambient temperatures during late burns with greater fuel loads from slash remaining after thinning.

Table 14. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with various combinations of prescribed burn with overstory thinning treatments (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	control		burn/thin		early/thin		late/thin		double/thin	
	PC	SF	PC	SF	PC	SF	PC	SF	PC	SF
stem number	-		#	&	*	++	-+++	++	-++	+
cover class	-		-				-*	#	-	
areal coverage	-					*	-++	&	-&	
% new growth	-									@
long diameter	-@					+	-+	@	-#	
short diameter	-					+	-+++	++	-+++	@
mean stem length	-						&	*	#	*
shortest stem	-						+++	+	+++	+
longest stem	-				-	@				#
total flowers							-@		-#	
change in number of flowers	-									
change in area										
change in number of stems	-									

Table 15. Statistical summary of frequency of death of phlox plants under different canopy thinning and prescribed burning regimes (combined 1992, 1993, 1994, and 1995 data).

	control	burn/thin	early burn/thin	late burn/thin	double burn/thin
number of plants	15	88	73	15	52
percent dead	20.0	3.4	1.4	13.3	5.8
standard deviation	41.4		11.7	35.2	23.5

Effects of *Phlox* habitat on *Phlox* growth and reproduction

Canopy

Number of plants was greatest in the overstory cover ranges of 25-80%. However, growth and reproduction of Texas trailing phlox appeared to be best at overstory canopy coverages of 5-25% and drops off dramatically at canopy coverages of more than 50% (Tables 16 and 17). This effect is most pronounced in reproductive rates and is also significant for number of stems. Although not statistically significant, the same trend is seen in cover class, areal coverage, length, and width of Texas trailing phlox plants. Significant negative correlations were observed between number of stems, cover class, and total flowers with overstory cover, indicating fewer stems and flowers produced under heavier overstory canopies. F test significance levels for all these parameters were .0001. Percent new growth is strongly positively correlated with overstory canopy cover, lending credence to the suggestion that percent new growth is an indicator of stress. As shown in

Table 17, new growth was especially common in plants under more than 70% overstory canopy, and greatly reduced under conditions with 40% or less overstory coverage.

These results on overstory effects seem incongruous when compared with the results on overstory thinning. However, much of the overstory thinning took place in relatively open (less than 70%) canopy coverages, and because of the timing of thinning and initiation of the study, no "before and after" comparisons have been possible.

The most common canopy trees associated with Texas trailing phlox are: *Pinus palustris*, *P. elliottii* Engelm., *P. taeda*, *Quercus incana* Bartr., *Carya texana*, *Q. falcata*, *Q. stellata* Wang.

Table 16. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with cover class of overstory trees (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	canopy cover	
	PC	SF
stem number	-+++	+
cover class	-+++	@
areal coverage	-@	#
% new growth	++	*
long diameter	-	
short diameter	-&	*
mean stem length	-#	@
shortest stem		
longest stem	-+	*
total flowers	-+++	+
change in number of flowers	-	
change in area		
change in number of stems		
freq. of positive change in number of flowers	-&	&
freq. of positive change in area		
freq. of positive change in number of stems	-@	

Table 17. Statistical results of Scheffe multiple comparison results for relationships between Texas trailing phlox growth parameters and cover class of overstory trees (combined 1992 and 1993 data). Threshold significance is 5%. N=115 for most except N=59 for change values.

phlox character	Scheffe (greater/lesser) canopy cover %
stem number	10-25/80-90,10-25/70-80,5-10/80-90,5-10/70-80,5-10/25-40
cover class	none
areal coverage	none
% new growth	70-80/25-40,80-90/25-40
long diameter	none
short diameter	none
mean stem length	none
shortest stem	none
longest stem	none
total flowers	5-10/>90,5-10/80-90,5-10/70-80,5-10/25-40
change in number of flowers	none
change in area	none
change in number of stems	none

Subcanopy

Data for effects of understory trees on growth and reproduction of Texas trailing phlox largely reflect those for overstory trees, with less dramatic effects. Correlations between understory tree cover and growth measurements on the phlox tend to be low, while many of the F statistics between these same pairs indicate highly significant relationships. This pattern is indicative of a nonlinear relationship, and appears to be due to the fact that Texas trailing phlox grows best under conditions of intermediate understory cover, doing poorly under very low or very high understory cover. Best growth of Texas trailing phlox appears to be at understory coverages of 40-80% (Table 19) relative to greater or lesser coverage percentages although the differences are not significant at the 5% level for most phlox features.

Understory associates are: *Q. incana*, *Q. stellata*, *Sassafras albidum* (Nutt.) Nees, *C. texana*, and *Ilex vomitoria* Ait.

Table 18. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with cover class of understory trees, and (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	understory cover	
	PC	SF
stem number	-	@
cover class	-	
areal coverage		
% new growth		
long diameter		
short diameter		
mean stem length		
shortest stem	&	#
longest stem		
total flowers	-	@
change in number of flowers	-	
change in area	-	-*
change in number of stems		
freq. of positive change in number of flowers		
freq. of positive change in area		
freq. of positive change in number of stems		

Table 19. Statistical results of Scheffe multiple comparison results for relationships between Texas trailing phlox growth parameters and cover class of understory trees (combined 1992 and 1993 data). Threshold significance is 5%. N=115 for most except N=59 for change values.

phlox character	Scheffe (greater/lesser) understory cover %
stem number	none
cover class	none
areal coverage	none
% new growth	none
long diameter	none
short diameter	none
mean stem length	50-70/>90,70-80/>90,40-50/>90
shortest stem	none
longest stem	none
total flowers	none
change in number of flowers	none
change in area	none
change in number of stems	none

Shrubs

Texas trailing phlox seems to grow best in plots where shrub coverage is less than 40%. Even though significant at 5% only for number of flowers, all population means for cover classes greater than 40% had a negative deviation from the global mean for total number of flowers, number of stems, and most other phlox growth parameters except percent new growth and stem length characters, which as discussed above, may be indicators of stress due to lack of sunlight. This view is supported by the significant increase in shortest stem length in sites with 80-90% shrub coverages as compared to sites with 25-40% shrub coverages. Reproduction is enhanced at even lower shrub coverage levels, being significantly greater at 10-25% coverages than any coverage above 40%.

Shrub associates are: *Q. incana*, *Rhus copallina* L., *I. vomitoria*, *Asimina parviflora* (Michx.) Dun., *C. texana*, *S. albidum*, *Toxicodendron radicans* (L.) O. Kuntze, *Stillingia sylvatica* L., *Ascyrum hypericoides* L., and *Callicarpa americana* L.

Table 20. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with shrub cover class (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	shrub cover PC	SF
stem number	-+++	*
cover class	-+	&
areal coverage	-#	#
% new growth		
long diameter	-	
short diameter	-+	&
mean stem length		
shortest stem	+++	+
longest stem	-@	
total flowers	-+++	*
change in number of flowers	-@	
change in area		@
change in number of stems		
freq. of positive change in number of flowers		
freq. of positive change in area		
freq. of positive change in number of stems		

Table 21. Statistical results of Scheffe multiple comparison results for relationships between Texas trailing phlox growth parameters and cover class of shrubs (combined 1992 and 1993 data). Threshold significance is 5%. N=115 for most except N=59 for change values.

phlox character	Scheffe (greater/lesser) shrub cover %
stem number	none
cover class	none
areal coverage	none
% new growth	none
long diameter	none
short diameter	none
mean stem length	none
shortest stem	80-90/25-40
longest stem	none
total flowers	10-25/80-90,10-25/70-80,10-25/40-50
change in number of flowers	none
change in area	none
change in number of stems	none

Herbs

Herbaceous groundcover for optimum growth of Texas trailing phlox appears to be 25-50% (Table 22). Herbaceous groundcover is primarily grasses, combined with a number of annual and perennial forbs.

Herbaceous associates are: *Ambrosia psilostachya* DC., *Berlandiera pumila* (Michx.) Nutt., *Solidago odora* Ait., *Solidago rugosa* Mill., *Andropogon virginicus* L., *Aristida longespica* Poir., *Panicum anceps* Michx., *Chamaecrista fasciculata* (Michx.) Greene, *Eupatorium compositifolium* Walt., *Centrosema virginianum* (L.) Benth., *Fimbristylis autumnalis* (L.) R. & S., *Krigia virginica* (L.) Willd., *Rudbeckia hirta* L., *Tradescantia hirsutiflora* Bush, *Euphorbia nutans* Lag., *Helianthemum carolinianum* (Walt.) Michx., *Hieracium gronovii* L., *Oxalis priceae* Small, *Lespedeza hirta* (L.) Hornem., *Hedyotis nigricans* (Lam.) Fosb., *Schizachyrium scoparium*, *Silphium gracile* Gray, *Tephrosia onobrychoides* Nutt., *Baptisia nuttalliana* Small, *Croton monanthogynus* Michx., *Stipa leucotricha* Trin. & Rupr., *Sisyrinchium rosulatum* Bickn., and *Liatris elegans* (Walt.) Michx. Most of these plants are common in similar areas in southeast Texas.

Table 22. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with herbaceous cover class (combined 1992, 1993, and 1994 data). Threshold significance for the Scheffe test is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	herbaceous cover		
	PC	SF	Scheffe (greater/lesser) cover %
stem number	++		
cover class	&		
areal coverage	++	*	
% new growth	-+++	*	
long diameter	*	&	
short diameter	+++	+	
mean stem length	+	&	
shortest stem	@		
longest stem	+++	+	
total flowers	&		
change in number of flowers		&	70-80/50-70
change in area		&	25-40/50-70
change in number of stems			none
freq. of positive change in number of flowers	&	@	none
freq. of positive change in area			
freq. of positive change in number of stems			none

Litter

Litter coverage is usually 80-100% at the sites of most phlox plants. The Scheffe tests showed significantly increased flowering of phlox plants when litter coverages are reduced to 50-70%. These reductions in litter cover are typically associated with fire.

Table 23. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with litter cover class (combined 1992, 1993, and 1994 data). Threshold significance for the Scheffe test is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	litter cover		
	PC	SF	Scheffe (greater/lesser) cover %
stem number	-*		
cover class	-+		
areal coverage			
% new growth	-#	#	
long diameter			
short diameter			
mean stem length			
shortest stem			
longest stem			
total flowers	-+++	#	
change in number of flowers		@	50-70/80-90,50-70/>90,50-70/40-50
change in area		&	none
change in number of stems	++	*	none
freq. of positive change in number of flowers		@	none
freq. of positive change in area			
freq. of positive change in number of stems			none

Although litter at sites of Texas trailing phlox is usually dominated by pine needles (probably due to the association with pines as canopy trees), excessive pine litter can have a detrimental effect on growth of the plants (Table 24). As little as 2.5 cm of pure pine needle litter can severely limit the growth of Texas trailing phlox.

Table 24. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with pine litter cover class (combined 1992, 1993, and 1994 data). Threshold significance for the Scheffe test is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	pine litter cover		
	PC	SF	Scheffe (greater/lesser) cover %
stem number	-		
cover class			
areal coverage	-#		
% new growth	+++	+	
long diameter	-		
short diameter	-&		
mean stem length	-		
shortest stem	-@		
longest stem			
total flowers			
change in number of flowers			none
change in area		*	none
change in number of stems	-		none
freq. of positive change in number of flowers		*	none
freq. of positive change in area			
freq. of positive change in number of stems			none

Hardwood litter appears to have a more detrimental effect on Texas trailing phlox growth than does pine litter. This effect may be due to the fact that when wet, the hardwood litter tends to compact much more easily than does the pine litter.

Table 25. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with broadleaf litter cover class (combined 1992, 1993, and 1994 data). Threshold significance for the Scheffe test is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	broadleaf litter cover		
	PC	SF	Scheffe (greater/lesser) cover %
stem number	-++	+	
cover class			
areal coverage			
% new growth	-		
long diameter	-		
short diameter	-		
mean stem length			
shortest stem			
longest stem	-		
total flowers	-+		
change in number of flowers	-*		none
change in area		#	none
change in number of stems	-@		none
freq. of positive change in number of flowers	-@	#	none
freq. of positive change in area			
freq. of positive change in number of stems			none

Grass litter appears to have the greatest positive effects on Texas trailing phlox of any litter type tested. The Scheffe tests clearly showed that high amounts of grass litter have a significantly greater positive impact on phlox growth than low levels of grass litter. This effect was most pronounced in the change in growth and reproduction of plants between field seasons.

Table 26. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with grass litter cover class (combined 1992, 1993, and 1994 data). Threshold significance for the Scheffe test is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	grass litter cover PC	SF	Scheffe (greater/lesser) cover %
stem number			
cover class	-		
areal coverage			
% new growth	-+++	+	
long diameter			
short diameter			
mean stem length			
shortest stem			
longest stem			
total flowers			
change in number of flowers			none
change in area		@	none
change in number of stems	+		none
freq. of positive change in number of flowers	@	++	80-90/5-10,80-90/<5,>90/<5
freq. of positive change in area			
freq. of positive change in number of stems	*	*	80-90/<5,80-90/5-10

Litter depths are optimally 1-3 cm at sites of Texas trailing phlox (Table 27). As shown by results of the Scheffe test, greater litter depth tends to cause the plants to spread (become larger) but often reduces the density of stems. In order for the plants to grow successfully, litter must either be thin (sparse), or not compacted.

Table 27. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of growth features of Texas trailing phlox with litter depth (combined 1992, 1993, and 1994 data). Threshold significance for the Scheffe test is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	litter depth		
	PC	SF	Scheffe (greater/lesser) depth (cm)
stem number			
cover class			
areal coverage	*	#	
% new growth			
long diameter	#		
short diameter	#	@	
mean stem length			
shortest stem	++	&	
longest stem	&		
total flowers			
change in number of flowers			none
change in area		+	5/2,5/3,5/4,5/1
change in number of stems	++		none
freq. of positive change in number of flowers	-&	&	none
freq. of positive change in area	-&	#	
freq. of positive change in number of stems	-@	#	none

Edaphic effects on Texas trailing phlox

Field studies suggest that sandy surface soil, coupled with moisture bearing clays, or sandy clays at depths of 0.8-2 m provide the best soil structure for Texas trailing phlox. Such sites are often on the sandy (drier and usually upslope) side of transitions between sandy soils supporting pine (usually dominated by *Pinus palustris* P. Mill.) savanna and clay or sandy clay soils supporting a mixed forest of hardwoods and pines (usually *P. taeda* L.). Since Texas trailing phlox occurs on surface sand, the presence of subsurface clay or relatively impermeable sand layers is not always apparent by transition within short distances into impermeable surface soils. Such sites (surface sand with subsurface impermeability, but surrounded by deeper sand) do support populations of Texas trailing phlox, and are often associated with presence hardwoods (particularly *Carya texana* Buckl. and *Quercus falcata* Michx.) among the pines.

Slopes at sites of most plants are less than 5%, steeper slopes show a negative influence on growth factors of Texas trailing phlox. The elevation is 9-75 m, and topography is nearly level. When the plants do occur on a slope, the tendency is for them to be in the middle levels of the slope rather than at top or bottom. Texas trailing phlox appears to have more positive growth factors on those plants on north and east facing slopes as opposed to those on south and west facing slopes.

Table 28. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with slope steepness (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	slope steepness	
	PC	SF
stem number		
cover class		
areal coverage	-	&
% new growth	-#	&
long diameter	-	@
short diameter	-	&
mean stem length	-@	
shortest stem		
longest stem	-	@
total flowers		
change in number of flowers		
change in area		
change in number of stems		

Table 29. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with slope aspect (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	slope aspect	
	PC	SF
stem number	-	&
cover class	-	
areal coverage	-	#
% new growth	@	@
long diameter	-	@
short diameter	-	*
mean stem length		@
shortest stem	+	*
longest stem		
total flowers	-	#
change in number of flowers		
change in area		
change in number of stems		

Table 30. Statistical results of analysis of variance and Pearson correlations of growth features of Texas trailing phlox with elevation on slope (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

phlox character	elevation on slope	
	PC	SF
stem number	-	#
cover class		
areal coverage		@
% new growth	-	&
long diameter		#
short diameter		
mean stem length		
shortest stem		
longest stem		#
total flowers		
change in number of flowers		
change in area		
change in number of stems		

Table 31. Scheffe multiple comparison results for relationships between Texas trailing phlox growth parameters and edaphic factors (combined 1992 and 1993 data). Threshold significance is 5%. slope=degree of slope; aspect=direction of slope; elevation=relative elevation to surrounding area. N=115 for most except N=59 for change values.

phlox character	slope	aspect	elevation
stem number	none	none	none
cover class	none	none	none
areal coverage	none	none	none
% new growth	none	none	none
long diameter	none	none	none
short diameter	none	none	none
mean stem length	none	none	none
shortest stem	none	none	none
longest stem	none	none	none
total flowers	none	none	none
change in number of flowers	none	none	none
change in area	none	none	none
change in number of stems	none	none	none

Effects of management on *Phlox* habitat

Fire effects

Timing of fire

Table 32 shows the greatest significant relationships between habitat characteristics and late or double burns. It is not clear in this case whether the habitat characteristics are caused by the timing of burns, or the burns have been timed as they have in order to affect the habitat characteristics. If the former is true, the results with respect to canopy cover and shrub cover seem largely opposite what might be expected. The latter may be true, since part of the ongoing management strategy is to use late season burns to reduce woody vegetation on the Larsen Sandylands, therefore areas with heavy canopy and understory are more likely to have been burned late in the year. Since most burns (even late in the season) do not kill canopy trees, and many of the understory trees will sprout from the roots (with the sprouts being counted as shrubs for at least 2-3 years after the burn), the observed result could therefore be explained. The increased herbaceous cover under late and double burns is largely explainable by increased amounts of grasses under such conditions.

Table 32. Statistical results of analysis of variance and Pearson correlations of habitat features of Texas trailing phlox with burn treatments (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

habitat character	control		burn		early burn		late burn		double burn	
	PC	SF	PC	SF	PC	SF	PC	SF	PC	SF
canopy cover	-				-	&	+++	+++	+++	+++
understory cover	#		-&	+			-	#		
shrub cover			-	@		@	+++	+++	+++	+++
herbaceous cover							-	&	-+++	++
litter cover	+++		+++	+++	-	&	+++	+++	&	+
pine litter cover										
broadleaf litter cover	#		-	#	-		+	+	&	+
grass litter cover	-@	#			@			@	-@	
litter depth	-&		#	&						

Frequency of fire

Canopy, understory, and shrub cover classes are all significantly reduced with greater frequency of burns during the past 20 years. Herbaceous cover , litter cover, pine litter cover, and litter depth are all significantly positively correlated with increased burn frequency. Broadleaf and grass litter cover are both reduced by greater burn frequencies.

Table 33. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of habitat features of Texas trailing phlox with burns in the past 20 years (combined 1992, 1993, and 1994 data). Threshold significance for Scheffe analysis is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

habitat character	burns in past 20 years		
	PC	SF	Scheffe (greater/lesser) years
canopy cover	-	&	none
understory cover	-+++	+	2/6,2/9,5/9
shrub cover	-++	++	2/6,2/8,2/9,2/3
herbaceous cover		#	none
litter cover	&	*	8/6
pine litter cover	+	+++	3/4,6/2,6/4,7/4,8/4,9/4,5/4
broadleaf litter cover	-++	+++	4/9,4/6,4/8
grass litter cover	-		none
litter depth	++	+++	9/6,9/4

Recency of fire

Canopy, understory, shrub, litter, broadleaf litter, and grass litter cover classes, as well as litter depth are all significantly positively correlated (Table 34) with longer times since the most recent fire. These results are all to be expected, although grass litter cover will likely decrease over longer time periods. Herbaceous cover is significantly reduced by long intervals without fire.

Results for interval since most recent winter burn (Table 35) largely parallel those for interval since most recent burn of any type. The primary differences are in the lesser effects of time since winter burn on canopy cover and broadleaf litter. Effect on grass litter cover is also reversed, probably due to the greater influence of the longer time periods apparent in the winter burn data set.

Results for most recent spring burn (Table 36) very closely mirror those for interval since most recent burn. Some of the significance levels vary, but the results are essentially the same.

Interval since most recent summer burn produces largely opposite effects (Table 37) to that since most recent burn overall, at generally lower significance levels. The most apparent exception to that pattern is in understory cover which is similar in both.

Table 34. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of habitat features of Texas trailing phlox with years since last burn (combined 1992, 1993, and 1994 data). Threshold significance for Scheffe analysis is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

habitat character	years since last burn PC	SF	Scheffe (greater/lesser) years
canopy cover	@	++	none
understory cover	+++	+++	17/1,17/2,16/2,5/1,5/2,4/2
shrub cover	+++	+++	17/2,17/1,16/2,16/1,5/1,4/1,3/1
herbaceous cover	-	+++	none
litter cover	&	+++	5/1,4/1,3/1
pine litter cover	-+++	+++	none
broadleaf litter cover	++	+++	none
grass litter cover	&	+++	2/5,2/3,2/4,2/1,2/6,5/1
litter depth	@	+++	4/1,3/1, 5/1

Table 35. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of habitat features of Texas trailing phlox with years since last winter burn (combined 1992, 1993, and 1994 data). Threshold significance for Scheffe analysis is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

habitat character	years since last burn		
	PC	SF	Scheffe (greater/lesser) years
canopy cover		#	none
understory cover	+++	+++	17/10
shrub cover	+++	+++	17/9,17/8
herbaceous cover	-	+++	none
litter cover	-&	+++	10/18,7/18,17/18,8/18,11/18,12/18,16/18
pine litter cover	-	+++	none
broadleaf litter cover		+	none
grass litter cover	-#	+++	12/16,12/9,12/18,15/18,17/18,10/18
litter depth		+++	7/9,7/18,16/8,16/11,16/9,16/18,10/18,17/18

Table 36. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of habitat features of Texas trailing phlox with years since last spring burn (combined 1992, 1993, and 1994 data). Threshold significance for Scheffe analysis is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

habitat character	years since last spring burn		
	PC	SF	Scheffe (greater/lesser) years
canopy cover	*	+	none
understory cover	+++	+++	17/1,17/7,17/2,16/2,5/1,5/7,5/2,4/2
shrub cover	+++	+++	17/1,17/7,16/1,16/7,5/1,5/7,3/1,4/1
herbaceous cover		+++	none
litter cover	++	+++	12/1,7/1,8/1,9/1,5/1,4/1
pine litter cover	-+++	+++	7/11,9/11,1/11,4/11,3/11,5/11
broadleaf litter cover	+++	+++	12/4,12/1,12/3,12/7,12/2
grass litter cover	+	+	2/5,2/3,2/8,2/7,2/4,2/1
litter depth		+++	4/11,4/2,4/1,3/1,7/1,5/1

Table 37. Statistical results of analysis of variance, Pearson correlations, and Scheffe multiple comparison results of habitat features of Texas trailing phlox with years since last summer burn (combined 1992, 1993, and 1994 data). Threshold significance for Scheffe analysis is 5%. PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

habitat character	years since last burn		
	PC	SF	Scheffe (greater/lesser) years
canopy cover	-+	+++	none
understory cover	@	&	17/3,17/12,17/11,16/12,16/11,5/12,5/11,4/12,4/11
shrub cover	-+	+++	4/7,4/18,4/8,4/9,5/7,5/18,5/8,5/9,17/9,3/9
herbaceous cover	#	+++	16/5,4/5
litter cover		-+++	5/9,5/18,4/9,4/18,7/9,7/18,8/18,17/9,17/18,10/18,3/9,3/18,16/18
pine litter cover	-	#	none
broadleaf litter cover	-	@	5/18
grass litter cover	-#	#	12/4,12/7,12/3,12/16,12/9,12/6,12/18,17/18,5/18,4/18
litter depth		-+++	16/5,16/4,16/12,16/8,16/9,16/11,16/18,7/9,7/18,3/18,17/18

Canopy thinning effects

Significant effects of canopy thinning on Texas trailing phlox habitat features were an increase in herbaceous cover, decrease in broadleaf litter cover, and increase in litter depth. These results may reflect a situation in which most of the canopy thinning took place in localities where phlox plants were not greatly stressed by shading.

Table 38. Statistical results of analysis of variance and Pearson correlations of habitat features of Texas trailing phlox with canopy clearing (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

habitat character	control		clear	
	PC	SF	PC	SF
canopy cover	-			
understory cover	#			
shrub cover				
herbaceous cover				#
litter cover	+++			
pine litter cover				
broadleaf litter cover	#		-#	
grass litter cover	-@	#		
litter depth	-&		&	&

Combined effects of fire and canopy thinning

Results of data analysis for combined effects of fire and canopy thinning parallel those for the fire management alone. Significance levels are somewhat lower for the combined effects than for the fire effects alone.

Table 39. Statistical results of analysis of variance and Pearson correlations of habitat features of Texas trailing phlox with burn and clear treatments (combined 1992, 1993, and 1994 data). PC= Pearson correlation; SF=significance of F from ANOVA; +++=significant at .01%; ++=significant at .1%; +=significant at .5%; *=significant at 1%; &=significant at 2.5%; #=significant at 5%; @=significant at 10%; -=negative correlation. N=163 for most except N=118 for change values.

habitat character	control		burn/clear		early burn/clear		late burn/clear		double burn/clear	
	PC	SF	PC	SF	PC	SF	PC	SF	PC	SF
canopy cover	-						+	+++	*	++
understory cover	#							@		
shrub cover					#		+++	+++	+++	+++
herbaceous cover				#			-@		-+	&
litter cover	+++						+	+	#	&
pine litter cover										
broadleaf litter cover	#		-#	#	-#	&				
grass litter cover	-@	#								
litter depth	-&		&	+	@	#				

CONCLUSIONS

Texas trailing phlox grows in three counties in southeast Texas in sandy surface soil, coupled with moisture bearing clays, or sandy clays at depths of 0.8-2 m. Slopes at sites of most plants are less than 5%, and aspect of slope appears not to be a critical factor in occurrence of Texas trailing phlox. The elevation is 9-75 m, and topography is nearly level. When the plants do occur on a slope, the tendency is for them to be in the middle levels of the slope rather than at top or bottom.

Ideal vegetation characteristics for Texas trailing phlox are an open canopy (5-25%) of pines, less than 40% coverage of subcanopy trees (pines and hardwoods), and less than 40% coverage of shrubs. Herbaceous coverage is greater than 50% where Texas trailing phlox grows best, with at least 30% of the herbaceous cover being grasses.

Three historically known populations of Texas trailing phlox have been relocated, one each in Hardin, Polk, and Tyler counties. Three additional populations in Hardin and Tyler counties could not be relocated. One of these latter three has been repopulated with plants grown from cuttings taken at Larsen Sandylands. A population of equivocal identity was located in Tyler County. Approximately 300 additional plants have been found at Larsen Sandylands.

The closest relative of Texas trailing phlox appears to be *Phlox subulata*. Texas trailing phlox is an evergreen clump-forming herb. Leaves are needlelike to lanceolate, densely packed on the stem. The corolla has five petals, each ca. 1 cm long, lavender to pink to magenta, darker near the throat. Fruits are achenelike, and apparently indehiscent. Typically, no more than one seed is produced per flower, fruit set is low. Individual flowers last 1-4 days (often limited by rainfall which can damage the flowers). Asexual reproduction is important for recruitment. Texas trailing phlox plants can live for at least six years. Flowering typically occurs from mid-March to mid-April, but may last well into May (especially when plants are burned between February and early May).

Prescribed burning was determined to have a beneficial impact on Texas trailing phlox growth and reproduction. However, burning late (June-October) appeared to have a negative impact on growth and reproduction of Texas trailing phlox, while burning early (November-May) had a pronounced positive impact compared to control plots (Table 2). Double burning generally had a negative impact on phlox growth, probably due to effects of the included late burn. The annual window for the negative influences of burning was further narrowed to include June-September. Texas trailing phlox appears very well adapted to fire. Aboveground parts of the plant are typically destroyed by fire, but underground parts are apparently undamaged by typical prescribed burns, as new growth is apparent on shoots within two weeks after a spring burn. Plants burned during drier parts of the year may not respond as quickly with new sprouts. It is possible that the increased temperatures generally experienced during late burns may be above the threshold for Texas trailing phlox underground parts and thus account for the negative impact of such burns. Texas trailing phlox plants have a greater probability of death under conditions of no burning.

Positive effects of burning were greatest three to five years after the burn. Negative effects of the burn generally were lost within three years after a burn, even a warm season burn. More than 5 years after a burn, negative influences of woody vegetation became more apparent.

Selective overstory thinning as a management tool appeared to have little significant effect on growth and reproduction of Texas trailing phlox. It is possible that the thinning which took place did not make a significant impact on overall canopy cover. This possibility was not addressed in this study since the thinning occurred before the study began. While thinning procedures may be beneficial to overall management plans of the preserve, and possibly to long term success of Texas trailing phlox, they appear to have no significant short term positive impact on the plants. Combined effects of prescribed burn and overstory thinning largely reflect the results of individual effects of burning, but with lower significance levels. The most common canopy trees associated with Texas trailing phlox are: *Pinus palustris*, *P. elliottii* Engelm., *P. taeda*, *Quercus incana* Bartr., *Carya texana*, *Q. falcata*, *Q. stellata* Wang. Effects of understory trees on growth and reproduction of Texas trailing phlox reflect those for canopy trees, with less dramatic effects. Understory associates are: *Q. incana*, *Q. stellata*, *Sassafras albidum* (Nutt.) Nees, *C. texana*, and *Ilex vomitoria* Ait. Texas trailing phlox grows best in plots where shrub coverage is less than 40%, reproduction being particularly enhanced at 10-25% coverage. Shrub associates are: *Q. incana*, *Rhus copallina* L., *I. vomitoria*, *Asimina parviflora* (Michx.) Dun., *C. texana*, *S. albidum*, *Toxicodendron radicans* (L.) O. Kuntze, *Stillingia sylvatica* L., *Ascyrum hypericoides* L., and *Callicarpa americana* L. Herbaceous groundcover for optimum growth of Texas trailing phlox is 25-50%. Herbaceous groundcover is primarily grasses, combined with a number of annual and perennial forbs. Litter coverage is usually 80-100% at the sites of most phlox plants and is at least 40% grass litter for optimum phlox growth.

MANAGEMENT RECOMMENDATIONS

Sites for Texas trailing phlox should be managed with frequent use of prescribed fire. Fires should be scheduled to occur primarily during the months of October through May. Fires at other seasons should be carefully monitored for intensity to prevent damage to Texas trailing phlox. Burns should occur on a cycle no longer than five years, preferably three or four years.

Timber harvest is compatible with the existence of Texas trailing phlox as long as no mechanical site preparation is employed, herbicides are not used, and harvesting is conducted in such a manner as to minimize soil disturbance. Periodic harvesting of canopy trees to maintain a canopy of less than 50% should benefit Texas trailing phlox.

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