Final Report to Texas Parks and Wildlife Department

Project title:

Ecological characterization and data base construction for the bracted twistflower (*Streptanthus bracteatus*)

TPWD Contract No. 418121

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Introduction

Streptanthus bracteatus, the bracted twistflower (Brassicaceae), is a rare annual plant endemic to five counties along the southeastern edge of the Edwards Plateau in central Texas (Poole et al. 2007). It currently has Candidate status under the US Endangered Species Act (USFWS 2013). Known threats include development, especially residential development; recreational activities, including mountain bikes and foot traffic; deer herbivory; low genetic variation; and reduced light levels due to canopy closure and understory thickening (Zippin 1997, Pepper 2010, Fowler et al. 2012, Leonard and Van Auken 2013, USFWS 2013).

The primary goals of this project were

• to improve our understanding of the habitat requirements of *S. bracteatus*, and

• to assemble a GIS data base that includes all known past and present *S. bracteatus* locations and ecological information for each location.

To achieve those goals, we proposed (1) to obtain a much-improved description of *S. bracteatus* habitat and (2) to create and an organized, geo-referenced, electronic data base for *S. bracteatus* that contains most of the available information about this species. Both of these goals have been met. In addition, we did a complete census of *S. bracteatus* plants at seven sites in 2012.

The data base, including metadata, has been submitted separately to Texas Parks and Wildlife Department (TPWD) as a set of ArcGis files and Excel files. We have consulted with TWPD staff, especially Cullen Hanks, to insure that these files are in formats that TPWD prefers. A soil map for each *S. bracteatus* site is in the ArcGIS data base. The soil data associated with each soil are in a flat file. Similarly, the locations of our 2012 vegetation survey plots and the location of each plant in our 2012 census are in the ArcGIS data base, with the data from each plot and each plant in flat files that use the same plot and plant IDs as the ArcGIS files. If requested, we will make this data base available to USFWS, City of Austin, City of San Antonio, and other appropriate entities.

The principal results of our study of *S. bracteatus* habitat requirements are summarized below. As stated in the original proposal, we expect these (1) to help guide searches for additional *S. bracteatus* populations; (2) to help guide the selection of sites for (re-)introductions to create additional, protected populations where there is a good chance that they will persist; and (3) to provide useful information for managers of *S. bracteatus* populations.

Summary of results and recommendations

• All parts of all sites known to be presently or formerly occupied by *S. bracteatus* are very close to the boundary between the Glen Rose Formation and the formation directly above it, which is either the Edwards Formation or (in the westernmost sites) the Devils River Formation. Many sites straddle this geological boundary. The average horizontal distance of plants from the boundary was only 843 m (0.52 mi) and the maximum was less than 10 km (less than 6 mi). Vertical distances to this geological boundary were also small: the average was 29 m (95 ft); sites varied from 85 m (279 ft) above the boundary to77 m (253 ft) below it. We suggest hypotheses to explain this very close association with this geological boundary. Whatever the cause of this association, searches for new populations and reintroduction projects should both be done close to this geological boundary.

• The soils in which *S. bracteatus* grows are mollisols and inceptisols typical of the region. The information available from the Soil Web Survey did not indicate anything unusual about the soils in which *S. bracteatus* lives.

• *S. bracteatus* sites differ widely in slope, from flat to quite steep, and in aspect.

• Sites with *S. bracteatus* tend to have relatively high species richness (for the region) in all three categories of plants we analyzed: herbaceous plants, understory woody plants, and overstory woody plants. We were not able to identify specific indicator species. We include species lists and their occurrences in this report.

• At the scale of our comparisons of the historically occupied areas of sites with unoccupied areas around them (10 or 50 m), we found few environmental differences other than those directly related to the position of the geological boundary. Slope, aspect, soil available water capacity, soil pH, soil organic matter, and soil clay content did not differ between occupied and unoccupied areas at this scale.

• We also compared presently occupied areas and neighboring unoccupied areas in plots ~ 15 m apart in seven of the sites. Unexpectedly, average soil depth was significantly less in occupied plots than in unoccupied plots, although the difference was slight; it is possible that there is less root competition in shallower soil.

• The absence of strong differences between occupied and unoccupied areas at the scale of 10 m, 15 m and 50 m suggest that the distribution of *S. bracteatus* plants within a site is probably due to dispersal, chance, and microsite (~ 0-20 cm) differences. However, we obviously cannot rule out a role for environmental variables about which we had no information.

• The apparent suitability of unoccupied areas around presently- and historically-occupied areas suggests that additional habitat, suitable but not now occupied, is available for *S. bracteatus* in many or even most of the known sites. This in turn suggests that presently-unoccupied areas within 50 m of presently-occupied areas or historically-occupied areas should be given as much protection as presently-occupied areas.

• Within some individual sites, we found upslope-downslope gradients of habitat quality, but the direction is not consistent between sites, so these gradients probably reflect local conditions rather than distance to the geological boundary or elevation per se.

• We found significant differences among sites in most of the variables we tested, and some significant regional differences.

• We found substantial differences among populations in the variables we used as non-destructive surrogates for seedset: probability of reproducing, number of siliques per plant, and summed silique length per plant. Stem herbivory reduced all of these. Protection for herbivores, especially deer, is strongly indicated.

• Number of siliques per plant is a reasonable substitute for measuring the length of each silique when time is limited. Either of these is more useful in assessing population status than plant height.

• Differences in site averages in number of siliques/plant were primarily due to the proportion of plants that made siliques in each site, which in turn was closely correlated with the proportion of plants that suffered stem damage from herbivores. This finding reinforces the need for protection from deer.

• The effects of deer herbivory were evidently strong enough to reverse the positive effects of higher light levels reported from experimental studies (Fowler et al. 2012, Leonard and Van Auken 2013). Plants in sites in which plants grew, on average, nearer to canopy edges experienced greater herbivore damage and set fewer seeds than plants in sites in which plants were, on average, further under the canopy and experienced less deer damage. It is very important to control deer before removing surrounding vegetation that may be protecting *S. bracteatus* from deer.

• This study was not designed to evaluate the status of *S. bracteatus*. We note, however, that during this study, most or all of one population (Cat Mountain) was extirpated, and we received unconfirmed word that half of another one was also extirpated (Hays). We confirmed earlier losses of substantial portions of a number of other populations, including major portions of Valburn and Mount Bonnell. Although 2012 was a ‘good year’ for *S. bracteatus*, many sites had very few plants.

Methods

<u>Census</u>

Sites. In late May, June, and early July of 2012, we collected demographic data on all plants in seven *S. bracteatus* sites in Travis, Medina, and Uvalde Counties (Table 1). Five of these populations were within the City of Austin in Travis County. We also collected demographic data from Garner State Park in Uvalde County and one site in Medina County (Medina 1, on Lower Lake Road). We had help with the censuses at several of these sites (Table 2).

Demographic data from two sites in Bexar County, Eisenhower Park and Rancho Diana, were collected by Wendy Leonard (Naturalist, San Antonio Parks and Recreation Department) and generously shared with us by permission of the San Antonio Parks and Recreation Department, which requested that the exact locations of these *S. bracteatus* populations not be released to the public. We therefore have good-quality demographic data from nine populations.

Due to high numbers of *S. bracteatus* individuals in Medina County, we were unable to collect demographic data on all of the plants in Medina 2 and Medina 3 (Tables 1 and 2). Therefore, in Medina 2 and Medina 3, we recorded location data (GPS waypoints) for clusters of individuals, and estimated the number of plants in each cluster and the approximate area of the cluster. We did not find any plants still alive in Medina 4. We therefore have at least some demographic data from eleven populations.

We did not have access to the Hays County population, nor to Bright Leaf in Austin. The Mesa population in Austin has been extirpated. We did not seek access to two privately-owned sites in Medina and Uvalde counties, Bear Bluff Ranch and Annandale Ranch, respectively. We did not visit the portion of the Eisenhower population that is, or was, outside the boundary of Eisenhower Park; its status is not known. The Mount Bonnell population once occupied adjoining private land as well as the City land it is now restricted to; that portion of the population was extirpated by residential development. Most of the former Valburn population was also extirpated by residential development. Since summer 2012, most or all of the Cat Mountain population has been extirpated by residential development.

Plant locations. To find plants, we generated maps of all known occurrences in the TPWD database for each of the ten sites we visited. In the field, we used both printed copies of these maps, and the same map data uploaded to a GPS unit, to re-locate historical locations. Every known historical occurrence area in each of the ten sites was intensively searched for plants, as well as an area ~ 15m around these known areas, with the exceptions noted above. Because of the intensity of this search, our numbers of plants per population are higher than those of most previous censuses (USFWS 2013).

A waypoint for each individual plant was recorded using a handheld Garmin Etrex GPS unit. To improve the accuracy of the GPS reading, the unit was placed at the base of a plant while it was being measured. A waypoint was only recorded after the uncertainty, according to the device output, was ≤ 5 m. Due to differences in site conditions (degree of canopy cover, local topography, etc.), the time required to achieve this level of accuracy varied. Each GPS point was visually inspected in ArcGIS using areal imagery to check its accuracy. GPS waypoints were recorded using the World Geodetic System (WPS 1984) in units of decimal degrees. Waypoints were later transformed to the Universal Transverse Mercator (UTM) system and units of meters to use in ArcGIS.

For each plant we recorded, in addition to a unique ID number and its location, three measures of plant size: height, number of siliques (seed pods), and the length of each silique. We also recorded the presence or absence of visual evidence of herbivory on different plant parts and the presence or absence of visible powdery mildew on the plant.

Plant height. Plant height was measured to the closest centimeter with a flexible tape measure, starting from the root crown (if exposed) or soil surface (if the root crown was not exposed) and ending at the apex of the longest shoot. If the plant was bending over, height was measured along the stem, so 'height' is actually length of the longest axis, not distance above the soil surface; the former provides a better measure of plant size. While most individuals had one main fruiting or flowering stalk, there were individuals that had grown offshoots either from near the base or at nodes further up the main shoot. In most cases this type of growth appeared to be a response to herbivory. For these individuals, we measured the longest total length (root crown or soil surface to tip of the longest offshoot) and recorded this length as the plant height. Care was taken not to over-handle plants and potentially damage them in the process. Therefore plant heights should be considered close approximations, not exact measurements. Leonard also measured height.

Reproduction variables. Because our census dates were relatively late, we did not encounter any plants that were still rosettes or were just beginning to bolt. A few plants had flowers but no siliques at the time of our census; we judge that these would not have had time to set seed, so they were considered not to have reproduced. Some of these plants were flowering late because they were regrowing after herbivory.

We counted the number of siliques on each plant. We included in these counts only siliques that were > 0.5 cm in length; Leonard also counted siliques but only included those that were ≥ 2 cm in length.

Silique lengths were measured from the apex of a pedicel to the apex of the silique. Later we summed the lengths of the siliques on each plant, producing a single variable, 'summed silique length', for each plant. Summed silique length is proportional to the number of seeds set (Fowler et al. 2012) but non-destructive and also much more practical to measure in the field.

The censuses by Leonard (Eisenhower Park, Rancho Diana) did not include silique lengths, only silique numbers. Some of these data were collected relatively early in the season, and therefore included plants that had not yet had time to send up a flowering stalk. We did not include these rosette-only plants in Table 18 nor in our statistical analyses.

Herbivory. We recorded herbivory separately on stems, on leaves, on flowers, and on fruit. Each of these four types of herbivory was scored as present, absent, or unknown on each plant. All aboveground plant parts were inspected. All visible types of herbivory were considered, including apparent insect damage (including leaf miners, galls, caterpillar presence and characteristic caterpillar damage along leaf edges) and apparent small mammal and deer damage. Nearly all of the plants that we surveyed were setting seed and had few to no leaves or flowers left, so leaf herbivory and flower herbivory had to be scored for them as unknown. Similarly, a few individuals had produced siliques but no longer had them on the plant, and therefore fruit herbivory had to be scored as unknown for them. For each herbivory variable, 'unknown' scores were not included in the percentages of Table 4 nor in the statistical analyses of that variable.

Powdery mildew. Each plant was inspected for powdery mildew, which was scored as present, absent, or unknown. All aboveground parts were inspected, including leaves (if present), shoots, flowers and siliques. It was difficult to determine whether powdery mildew was present on plants if the leaves were senescing or fallen, so mildew on these plants was scored as 'unknown'. Plants scored as 'unknown' for mildew were not used to calculate the percentage of plants with mildew in Table 4 nor in the statistical analyses of this variable.

Measuring plant height and silique length always involved physical contact between the plants and the data-collector. Latex gloves were used to measure plants that contained mildew and these were then disposed of. A fresh pair of gloves were used for each plant in this condition.

Other environmental variables. For each plant for which we had demographic data, we extracted some geological, soil, and topographic data from the online databases described below.

<u>Vegetation survey plots: occupied and unoccupied plots</u>

Plot location. In July and August of 2012, after census data collection, we returned to each of the same twelve sites at which we or Leonard obtained, or attempted to obtain (Medina 4), census data. We placed temporary center points in locations where clusters of *S. bracteatus* were known to have been present in 2012. These points ('occupied centers') centered circular plots that we call 'occupied plots'. For comparison, we also placed center points ('unoccupied centers') in nearby areas that were not occupied by *S. bracteatus*; we call the circular plots that these point centered 'unoccupied plots'.

The number of vegetation survey plots differed among sites (Table 2). Sites with larger areas occupied by plants had more occupied centers placed in them. For example, Mount Bonnell (21 plants present in 2012) had only six occupied centers, while Barton Creek (434 plants present) had 20 occupied centers. Sites also differed in both the number of distinct clusters of plants and distances between these clusters. We located at least one occupied center in each cluster.

Unoccupied centers were located by walking 15 meters in a random direction from an occupied center in a randomly selected direction (random numbers between 0 and 360 generated by SAS 9.3, SAS Institute, Cary, NC). If a point located in this fashion was within 5 m of an area known to have, or to have had, *S. bracteatus* in 2012 the process was repeated again with a new heading, starting once again from the original occupied center. Likewise, if the point was within 5 m of habitat that was clearly not suitable for *S. bracteatus* (e.g., a paved area), another random heading was selected. Sometimes it was not possible to locate an unoccupied center starting from a given occupied center.

Although we surveyed fewer unoccupied plots than occupied plots, at least one unoccupied center was placed in each site. Available habitat and the spatial pattern of *S. bracteatus* plants often prevented us from pairing an unoccupied center with each occupied center. At some sites, such as those along right-of-ways in Medina County, it was difficult to locate any unoccupied centers. Where the plants were 'sandwiched' between the road on one side and private property on the other, we placed unoccupied centers at each end of the site or cluster if there was suitable habitat there. In some habitats with many clusters of *S. bracteatus*, such as Barton Creek, time constraints limited the number of unoccupied centers.

Each occupied center and each unoccupied center acted as the center for three nested circular plots (Figure 1). Each set of three nested plots had radii of 0.5 m, 3 m, and 5 m, extending from the same center point. The 0.5 m radius plot was nested within the 3 m radius plot and the 3 m radius plot was nested within the 5 m radius plot.

We recorded each herbaceous species of vascular plant present in the 0.5 m radius plot; each woody species with one or more plants < 2 m tall (understory plants) in the 3 m radius plot, and each woody species with one or more plants > 2 m tall (overstory plants) in the 5 m radius plot. Some woody species, especially oak species and *Juniperus ashei*, often appeared as both understory and overstory plants in the same set of nested plots. For convenience, we include in the category ‘herbaceous species’ all graminoids and forbs, all non-woody vines (e.g., running or prostrate vines), and all succulents, including *Yucca rupicola*., *Opuntia* sp., and *Nolina* sp. but not *Dasylirion texanum*, which was classified as woody (Table 15).

Plants were recorded in a plot only if some or all of the stem base (if single-stemmed) or some or all of one or more stem bases (if multi-stemmed) was within a plot’s circular boundary. For example, if a tree had roots that were visible within a 5 m plot but no portion of the trunk fell within the plot, then that tree was not considered to be in that plot. An exception to this rule was made for vines and lianas (e.g., *Toxicodendron radicans*), which were considered to be in a plot if any part of the plant fell within or crossed the plot boundary.

Each species was given a four-letter code (Table 15). Note that these abbreviations are not always identical to the standard USDA PLANTS database codes.

Soil depth. Soil depth was measured in nine places in each 3 m radius plot. The depth-measuring instruments we used were 30 cm long, metal knitting needles with 1 cm and 5 cm intervals marked on their sides. A needle was forced into the soil vertically until it would penetrate no further (distance to refusal). One soil depth measurement was made at the center of each plot and eight other measurements were made on a grid around it on the compass directions (N, NE, E, etc.; Fig 2). The shortest distance between any two soil depth measurements was 1 m.

Distance to canopy edge. In the field, we estimated the distance in meters from the center of each plot to the nearest edge of continuous tree canopy. If the point was under closed canopy, it was given a negative value; if in the open, a positive value. Points under closed canopy that were more than 3 m from its edge were given a score of -4. No points in the open were more than 3 m from the nearest edge of closed canopy. Note that, because a score of -4 is actually a category, the averages reported in Table 15 are not truly averages. We report them only to provide an easy way to compare sites.

Canopy openness

In each of the sites in which we located vegetation survey plots, we also took hemispherical photographs of the canopy. They were taken in areas occupied by *S. bracteatus* under canopy conditions that were deemed representative of the site, but not necessarily associated with particular plant clusters or with plots. A maximum of four canopy photographs were taken at any given site (Table 2). We used a tripod-mounted, Nikon D70 Digital SLR camera with a Sigma 4.5mm circular fisheye lens that captures a full, 180º hemispherical image. For each photograph the camera was first leveled using a camera-mounted bubble level so that the lens pointed straight upwards and the top of the camera faced north (verified with a compass). The camera and tripod were set up to a height of approximately 30 cm from the ground. Percentage canopy cover was calculated from each of these photographs using Gap Light Analyzer 2.0 (Forest Ecology and Management Research Group, Simon Fraser University; (http://www.rem.sfu.ca/forestry/publications/downloads/gaplightanalyzer.htm). We report it as percentage canopy openness = 100 – canopy cover.

Electronic data bases

Cullen Hanks, a TPWD staff member, provided us with the complete TPWD electronic data base for *S. bracteatus*, including all location data through 2011 for all seventeen sites with useable location data. (A few early records of this species do not have useable location data.) The quality of the information in the TPWD data base varies widely, from specific plant locations (as geo-referenced points) to large polygons that simply indicate a general area. We note that, although the data base is maintained by TWPD, it includes data collected by many different people, including volunteers and staff members of several different agencies, over a long period of time. While any data are better than none, we strongly support Cullen Hank's initiative to standardize and improve data collection.

From these data and the data we collected in 2012, we created two sets of occupied polygons for each site (Fig. 3). One was directly based upon TPWD data, and is referred to in this report as TPWD-defined occupied area. The other was created by Gabriel De Jong using more conservative criteria, and is referred to in this report as GDJ-defined occupied area. The difference between the two is in the handling of the polygons in the TPWD data base. We were concerned that, for some polygons in some sites, the TPWD polygons covered areas that were unrealistically large. De Jong checked the original sources to get a sense of how confident we could be in the polygons that were drawn by TPWD. He also overlaid them on an aerial photograph layer in ArcGIS to make sure that polygons didn't cover unoccupied areas like roads and water that were present when the observations were made.

To convert point locations of *Streptanthus bracteatus* clusters in the TPWD data base to polygons, Gabriel De Jong used a different procedure. Points were given the same treatment by De Jong regardless of the definition of occupied polygons. The distances used to convert point locations of *Streptanthus bracteatus* clusters in the TPWD data base are given in Table 3. If there were more than 200 plants in a cluster an appropriate buffer size was set using the original written observations for each source feature and examination of the mapped points. These definitions were based upon his experience in the field and upon the 2012 census data. When there were multiple observations per source feature he used the observation with the most *S. bracteatus* plants to set the buffer size. If an account at a source feature did not mention numbers of individuals, he set the buffer size to 1 m, or omitted it if it was already contained within another source feature. If the resulting buffers covered landscape features like roads, water, or buildings that probably existed at the time the observation was made, the buffer was decreased in size until it no longer overlapped those landscape features.

Only 15 source features came in as lines or polylines. For those features he used accounts of observations and landscape context (maps) to draw appropriate polygons.

Geo-referenced topographic and geological data were downloaded from the United States Geological Survey (USGS) web site. Geo-referenced soil data were downloaded from the United States Department of Agriculture (USDA) Soil Web Survey. The Soil Web Survey provides geo-referenced soil maps. Information about soil properties from the same source is provided by the Web Soil Survey for each soil but is not otherwise location-specific.

Detailed information about how the location data and the soil, topographic, and geological data were incorporated into ArcGIS is provided in the folder with the GIS files.

All statistical analyses were done with SAS 9.3 (SAS Institute, Cary, NC).

Results and discussion

Site-level variables from online databases - all 17 sites

In general, the environmental variables we obtained from public databases had little within-site variation. Comparisons at the site level are limited by sample size: there are only 17 sites that are known to have, or to have had, natural populations of *S. bracteatus*. In addition, given the number of potentially important environmental variables and their correlations with one another, it is difficult to assign causality to any given environmental variable. However, the range of values that each of these variables takes are a powerful tool to guide searches for new populations and the selection of sites for introduction / reintroduction efforts.

Because we were uncertain of the spatial scales at which environmental variation would be present and important for *S. bracteatus*, we used two definitions of occupied areas in each site and two methods of calculating the unoccupied area in and around the occupied areas in each site. To define occupied area, we used the polygons in the TPWD data base ('TPWD-defined'), which were often very large, and more conservatively defined polygons constructed by Gabriel De Jong ('GDJ-defined') (see Methods). To define unoccupied areas we used either 10 m wide buffers or 50 m wide buffers around each occupied polygon.

On average, TPWD-defined occupied area was 63% larger than GDJ-defined occupied area in a site (44,484 m^2 versus 16,411 m^2 per site) (Fig. 4). The total area of each site, occupied plus unoccupied, was affected by the size of unoccupied area in each site but even more by the width of the buffer. The average total area ranged from 30,114 m^2 to 139, 588 m^2. Using the TPWD definition increased average total area by 50% (with 10 m buffers) or 27% (with 50 m buffers). Using the larger buffer width increased total area by 71% (using the GDJ definition of occupied area) or 57% (using the TPWD definition). As a percent of the occupied area, unoccupied area averaged 83% (GDJ definition and 10m buffer), 525% (GDJ definition and 50 m buffer), 35% (TPWD definition and 10 m buffer), or 68% (TPWD definition and 50 m buffer).

Overall, there were few differences between the occupied areas and the surrounding unoccupied areas within each site, whether the unoccupied areas were defined by a 10 m wide buffer or a 50 m wide buffer. This indicates that the exact location of plants within the general area of a site was probably not determined by these variables. Instead, spatial location within a site is probably due to some combination of dispersal, random events, and environmental variation at a smaller scale.

Geological formation boundary. All parts of all sites occupied by *S. bracteatus* were very close to the boundary between the Glen Rose Formation and the formation directly above it (Tables 4 and 5; Figs. 5, 6, and 7). This upper formation was the Edwards Formation (also known as the Edwards Group) in all but two sites; the Devils River Formation replaces the Edwards Formation in the westernmost part of the range of *S. bracteatus*. While limestone is the dominant rock type in all three formations, the Edwards and Devils River Formations are usually harder limestone than the Glen Rose Formation and often are the caprock over the Glen Rose Formation below them. The Glen Rose Formation tends to form a characteristic 'stair-stepped' topography due to its alternating harder and softer layers.

Using the more conservative of our two definitions of occupied area (GDJ-defined polygons, Table 4) and averaging the site averages, the overall average horizontal distance between polygons occupied by *S. bracteatus* and the formation boundary was 843 m (0.52 mi) (Fig. 5). This average value was greatly affected by one anomalous site in Hays County, which is 9237 m (5.74 mi) away from the boundary (on the Edwards side of it). Without that site, the average would be only 329 m (0.20 mi). In seven of the 17 sites, plants have been found on both sides of the boundary: note that kgr, the Glen Rose, and ked, the Edwards (or kdr, Devils River) are each less than 100% of the occupied area (Table 4). Using the less conservative definitions of occupied area (TPWD-defined polygons, Table 5, Fig. 5) only increases the average by 6 m to 849 m (325 m without the Hays County site).

The average vertical distance between occupied area and the formation boundary is even smaller (Table 4, Fig 6). If we assign positive distances to polygons above the boundary and negative distances to polygons below it, the average of the sites' average vertical distances was 5 m (16.4 ft) below the boundary. The average absolute distance from the boundary was 29 m (95 feet) (Table 4).

Maximum distances can potentially focus future searches for this species and for suitable reintroduction sites (Fig. 7). Setting aside the Hays County population, the maximum horizontal distance was 1854 m (1.15 mi; Medina 1 population; Tables 4 and 5). The maximum vertical distances were 85 m (279 ft) above the boundary (Annandale Ranch) and 77 m (253 ft) below it (Bright Leaf Preserve) (Tables 4 and 5).

The cause of the close association between *S. bracteatus* and this geological boundary is not known. We suggest two hypotheses. Our first hypothesis is that seepage rates of water may be higher at the geological boundary, providing *S. bracteatus* with slightly higher soil moisture levels. However, the Edwards Formation supports springs and seeps at many locations, not just at its lower boundary; why does *S. bracteatus* not grow higher up on the Edwards? As a second hypothesis, we speculate that the chemistry of the soils derived from, or strongly influenced by, the rocks of the lowest level of the Edwards Formation may be necessary for *S. bracteatus*. Downslope movement of rocks and/or sediment and/or movement of leachate downwards could then account for the presence of *S. bracteatus* on the Glen Rose just below the boundary. If this hypothesis is true, our best guess is that the critical factor is magnesium leaching out of dolomitized limestone.

Aspect. The southern populations are approximately evenly divided in aspect (Tables 6, 7, 8, and 9; Fig. 8). The Travis County sites are all on west-facing slopes. This may simply reflect local geology and topography, as all the populations fall along a single line. It is difficult to guess what environmental factor might favor a west-facing aspect. If higher light availability is important, one would expect a preponderance of south-facing aspects.

Slope. There is no evidence that slope per se limits *S. bracteatus* occurrence. Sites with *S. bracteatus* range from flat (0% slope) to steeply-sloped (maximum 41% or 48% slope, depending on how the occupied area is defined) (Tables 6, 7, 8, and 9; Fig. 9). Sites had significantly different average slopes ($P < 0.001$ regardless of the definition of occupied area or the width of the unoccupied area around it) but the occupied and unoccupied areas did not differ in average slope (analysis of variance [ANOVA]).

Elevation. Although the topography is often quite steep and rugged, there is not much difference in elevation in this region. *S. bracteatus* has been found growing from 157 m (515 ft) above sea level to 453 m (1486 ft) above sea level (Tables 6 and 7). Using the broader definition of occupied area, the range is slightly greater, 147 m to 458 m (Tables 8 and 9). Southern sites tend to be higher than Travis County sites, matching the general elevational trend in the region.

Soil types. The soils on which *S. bracteatus* has been found are typical of the eastern Edwards Plateau. The most common soil types in sites occupied by *S. bracteatus* were ustic (dry climate) mollisols and inceptisols, specifically calciustolls, haplustepts, and haplustolls (Tables 10, 11, 12, and 13). We did not find any evidence for any usual soils or indicator soils that might guide searches for this species or reintroduction site selection.

The unoccupied areas used for comparisons included a few soil types that the occupied areas did not, as would be expected from the larger extent of the unoccupied areas. However, these were a minor component of the total (Tables 10, 11, 12, and 13); in general the soil types of the occupied and unoccupied areas were similar.

Soil properties: pH, available water capacity, % organic matter and % clay

We identified soil pH, available water capacity, percentage organic matter, and percentage clay as soil variables likely to be important to *S. bracteatus* and available from the Soil Web Survey. In the Soil Web Survey data base, values for these variables are reported for each soil, rather than by location. We calculated averages for the occupied area of each site weighted by the area of each soil in the occupied area of that site. In the same way, we calculated averages for the unoccupied area in each site.

In general, soils were moderately alkaline, with an average pH value of 7.8; site averages for occupied areas ranged from 7.5 to 8.1 (Tables 10, 11, 12, and 13). Average available water capacity was 0.10; site averages ranged from 0.07 to 0.12. These relatively low available water capacity values are in line with the relatively low organic matter in these soils. Percentage organic matter had an average value of 4%; site averages ranged from 2% to 7%. Percentage clay averaged 37 or 38%, in line with the derivation of these soils from limestone bedrock. Percentage clay was more variable than the other soil variables: site averages ranged from 25% to 50% (GDJ definition of occupied area; Tables 10 and 11) or from 19% to 50% (TPWD definition of occupied area; Tables 12 and 13).

To compare regions and sites, and to compare occupied and unoccupied areas within sites, we used analysis of variance (ANOVA). Our initial model for each variable included region (northern counties or southern counties), site nested within region, occupation status (occupied or unoccupied), and the region x occupation status interaction. Site was treated as a fixed effect nested within region. Non-significant terms were then dropped to produce a final model for each variable. All calculations were done twice, once using the 10 m width definition of unoccupied area, and once using the 50 m width definition of unoccupied area. We only used the GDJ-defined occupied polygons, not the TPWD polygons, for this statistical analysis.

Two soil properties, pH and available water capacity, differed significantly only among sites. The definition of unoccupied area (10 m width or 50 m width) did not materially affect the results. Differences in pH among sites were highly significant ($F_{15,12} = 8.0$, $P = 0.0004$, for both widths). Differences in available water capacity among sites were also significant (10 m width: $F_{15,12} = 3.1$, $P = 0.03$; 50 m width: $F_{15,12} = 3.2$, $P = 0.03$).

The percentage organic matter in the soil differed significantly among regions (10 m width: $F_{1,14} = 7.7$, $P = 0.01$; 50 m width: $F_{1,14} = 8.0$, $P = 0.01$). It also differed significantly among sites within regions ($F_{14,12} = 7.5$, $P = 0.0006$, for both widths). Northern sites (Travis and Hays Counties) had on average less soil organic matter than southern (Bexar, Medina, and Uvalde Counties): 3.3% on average versus 5.7%.

The percentage clay in the soil did not differ significantly overall between northern and southern counties or between occupied and unoccupied areas, but there was an interaction between these two variables that reached significance using 50 m width unoccupied areas (10 m width: $F_{1,10} = 4.8$, $P = 0.0543$; 50 m width: $F_{1,10} = 5.6$, $P = 0.04$). Soil clay content was on average higher in the northern than in the southern counties, but occupied and unoccupied areas differed only in the northern counties (least squares means, 50 m width: northern occupied 34% clay, unoccupied 36% clay, southern occupied and unoccupied both 44% clay). Site differences were highly significant (10 m width: $F_{14,10} = 317.6$, $P < 0.0001$; 50 m width: $F_{14,10} = 86.3$, $P < 0.0001$). Because of the very large differences among sites, it seems likely that the differences between occupied and unoccupied areas in Travis and Hays Counties are not biologically important.

<u>Variables measured in 2012 in plots with and without plants (vegetation survey: 12 sites)</u>

Species richness. In general, *S. bracteatus* sites were relatively species-rich, at least in comparison with a typical *Juniperus ashei*-dominated site (i.e., ‘cedar brake’) in the same region. On average, there were 4.4 herbaceous species (including succulents and non-woody vines) per 0.5 m radius plot (5.7 species per m^2) (Table 14). There were, on average, 5.2 woody understory species per 3 m radius plot (0.18 per m^2) and 2.0 woody overstory species per 5 m radius plot (2.6 species per 100 m^2).

Species richness was analyzed using generalized linear models with Poisson distribution and log link function. Fit to the Poisson was confirmed by χ^2/df values < 1.0. In no instance was the site x plot type (occupied or unoccupied by *S. bracteatus*) significant and it was dropped from the models. Plot type itself was never significant in these reduced models, and it also was dropped. Region was not significant in the analyses of herbaceous species (a category that included succulents) nor in the analysis of woody understory species, and was dropped from those models. While region was significant in the analysis of woody overstory species and was therefore retained in that analysis, the region x plot type term was not and was dropped.

Sites differed significantly in the numbers of herbaceous species per plot ($F_{11,106}$ = 2.44, P = 0.0095). Sites also differed significantly in the numbers of woody understory species per plot ($F_{11,106}$ = 2.71, P = 0.0041). The number of woody overstory species per plot was significantly larger in the northern counties (Travis and Hays Counties) than in the southern counties (0.93 species per plot versus 0.50 species per plot, respectively; $F_{1,10}$ = 7.70, P = 0.0196). Differences in numbers of woody overstory species among sites within regions were not significant ($F_{10,106}$ = 0.92, P = 0.52).

Species. The most common overstory species present in plots occupied by *S. bracteatus* were *Juniperus ashei* (12 sites, 91% of plots), *Quercus virginiana* (= *Q. fusiformis*; 9 sites, 52 % of plots), *Diospyros texana* (6 sites, 25% of plots), *Sophora secundiflora* (5 sites, 15% of plots), and *Quercus buckleyi* (4 sites, 10% of plots) (Table 16; see Table 15 for species codes). The first three of these were also common in the understory. Other common understory woody plants were *Rhus virens* (7 sites, 38% of plots), *Berberis trifoliolata* (5 sites, 32% of plots), and *Acacia roemeriana* (5 sites, 32% of plots), and *Ageratina havanense* (5 sites, 30% of plots). All of these are common throughout the region except for *A. roemeriana*, which tends to be more common in the southern part of the region.

The most common herbaceous species present in plots occupied by *S. bracteatus* were *Parietaria pensylvanica* (8 sites, 58% of plots), *Carex planostachys* (9 sites, 28% of plots), *Scutellaria drummondii* (7 sites, 23% of plots), *Euphorbia cyathophora* (6 sites, 22% of plots), *Viguiera dentata* (4 sites, 23% of plots), *Zexmenia hispida* (7 sites, 20% of plots), and *Cynanchum barbigerum* (4 sites, 20% of plots) (Table 16). Our impression is that these data do not identify one or more indicator species. Instead, they suggest *S. bracteatus* is more likely to occur where there is a relatively rich understory flora.

The species present in unoccupied plots were not identical to those in the occupied plots, especially among the less common species, but overall the species composition of the two types of plots seemed similar (Tables 16 and 17).

Distance to canopy edge. Distance to continuous canopy edge was measured to the nearest meter, unless it was 4 meters or more, in which case it was recorded simply as 4 meters. Negative values represent plots under continuous tree canopy; positive values represent plots outside continuous canopy. This variable is therefore best understood as an ordinal variable, and the averages reported in Table 14 are not true averages.

For statistical analysis, we treated distance to canopy edge as a categorical variable. Due to some small sample sizes, we could not retain the 8 possible values (-4 through +3) as separate categories. Instead, we created a categorical variable, choosing categories to equalize sample sizes in each category and avoid very small sample sizes in any category. It had four categories: < -3 m, -3 m through -1 m, 0 m, and > 0 m. We analyzed this categorical variable with a generalized linear model with a multinomial distribution and a cumulative logit link function.

This categorical variable differed significantly among sites ($F_{11,103}$ = 4.89, P < 0.0001) but differences between occupied and comparison plots did not reach significance ($F_{1,103}$ = 2.67, P = 0.105). To understand this trend, we returned to the original data and calculated the median distance of each plot type X site combination, and then examined the distribution of these medians. Occupied plots had a larger median of medians (-0.5 versus -2.0) and a larger average median (-1.08 versus -1.38) than did unoccupied plots. In other words, there was a suggestive but non-significant trend for unoccupied plots to be further under the trees and occupied plots to be closer to the canopy edge or out in the sun. This trend is compatible with the findings of Fowler et al. (2012) and Leonard and Van Auken (2013) that *S. bracteatus* plants are favored by higher light conditions. There was a non-significant trend for regions to differ.

Soil depth. Unexpectedly, average soil depth was less in occupied plots than in unoccupied plots (Table 14). We analyzed this variable with a nested ANOVA that included region, site nested within region, plot type (occupied or unoccupied), and the region X plot type interaction. The site X plot type interaction was not significant and was dropped from the final model. There was a non-significant trend for regions to differ ($F_{1,10}$ = 2.92, P = 0.118); sites differed significantly ($F_{10,104}$ = 4.61, P < 0.001); plot types were also significantly different ($F_{1,104}$ = 9.05, P = 0.003); and the region X plot type interaction approached significance ($F_{1,104}$ = 3.08.92, P = 0.082). The adjusted mean soil depths (i.e., weighting each site equally) were 5.04 cm and 6.18 cm in occupied and unoccupied plots, respectively. Northern (Travis County) sites tended to have deeper soils and greater differences between occupied and unoccupied plots (adjusted means 5.8 cm and 7.6 cm, in occupied and unoccupied sites respectively) than did southern sites (adjusted means 4.3 cm and 4.7 cm, respectively).

We had expected that *S. bracteatus* plants would be more common where the soil was deeper, given the shallow soils and exposed bedrock of the sites it occurs in. It is possible that shallower soil reduces the competition from roots of other plants. When transplanting plants (Fowler et al. 2012) we found that we often had to adjust transplanting locations to find a pockets of soil deep enough to plant a seedling in, so perhaps at that smaller scale (~ 0-20 cm) relatively deeper soil pockets are more favorable.

Analysis of census data - five Travis County populations

We were able to obtain extensive census data in 2012 from five Travis County populations: Barton Creek, Cat Mountain, Mount Bonnell, Ullrich WTP, and Valburn (Table 18 and Table 19). The Mesa population is extirpated, and we were not able to get access to the Bright Leaf population, which in any case is almost extinct. The current Mount Bonnell and Valburn populations occupy only a small portion of their former extent, due to development of residential properties. Since we collected data, the Cat Mountain site (also known as the Far West site) has been developed as a residential property; we do not know if any plants remain there. As part of the census we also collected data from each plant on visible herbivory and powdery mildew.

The variable most closely correlated with seedset and therefore with individual fitness is the sum of the lengths of all the siliques (seed pods) on a plant, which is closely correlated with seedset (Fowler et al. 2012). In order to analyze this variable, however, we had to separate it into two variables: whether or not a plant reproduced and the summed silique length of reproductive plants. We analyzed whether or not a plant reproduced as a binary variable, using a generalized linear model with a binomial distribution and logit link function. In the subset of plants that had non-zero summed silique lengths, we log-transformed the summed lengths so as to obtain normally distributed residuals for ANOVA.

Differences among sites in the percent of plants that reproduced were highly significant ($F_{4,843}$ = 10.36, P < 0.0001). Valburn had the highest proportion of reproductive plants, followed in order by Mount Bonnell, Ullrich WTP, Cat Mountain, and Barton Creek. Differences among sites in summed silique length were also highly significant ($F_{4,396}$ = 7.55, P < 0.0001). Plants at Ullrich WTP had the greatest summed silique length, followed in order by Barton Creek, Valburn, Cat Mountain, and last of all Mount Bonnell. Although it is not suitable for statistical analysis, for comparisons among sites we can compute average summed silique length per plant by including plants whose summed silique length is zero in the average. Average summed silique length per plant calculated like this was, in order, Ullrich (13.3 cm), Valburn (12.7 cm), Cat Mountain (8.2 cm), Mount Bonnell (6.8), and Barton Creek (5.4 cm).

As expected, stem herbivory had a negative effect on whether or not a plant reproduced. Included in a generalized linear model along with site, it was highly significant ($F_{1,837}$ = 70.34, P < 0.0001). Stem herbivory is often by deer, who tend to eat the upper part of a stem together with its buds, flowers, or fruits (Zippin 1997). Pooling sites, 63% of plants that had not suffered stem herbivory had at least one silique, but only 33% of plants that had suffered stem herbivory had at least one silique. As expected, stem herbivory also reduced average summed silique length of plants that had siliques, from 11.6cm to 7.8 cm (back-transformed adjusted means from ANOVA). The negative effect of stem herbivory on summed silique length was significant only at Mount Bonnell (from 10.6 cm to 1.6 cm), and close to significant at Barton Creek (from 8.8 cm to 6.4 cm) (ANOVA of log[summed silique number], model included site, stem herbivory, and their interaction; site x stem herbivory term: $F_{4,391}$ = 2.6, P = 0.0356; contrast testing effect at Mount Bonnell: $F_{1,391}$ = 8.74, P = 0.0033; contrast testing effect at Barton Creek: $F_{1,391}$ = 3.37, P = 0.0673).

The visible presence of powdery mildew had no effect on whether or not a plant had siliques. Unexpectedly, the presence of powdery mildew was positively associated with summed silique length on plants that had siliques: in a model that also included site, it is was highly significant ($F_{1,322}$ = 12.16, P < 0.0006). Plants without mildew had on average 7.6 cm of siliques and plants with mildew had on average 11.7 cm of siliques (back-transformed adjusted means from ANOVA). There was no interaction between the effects of site and of mildew on summed silique length, but sites differed in disease rate, from Cat Mountain (90% of plants) to Mount Bonnell (19% of plants) (Table 18). The apparent positive effect of mildew upon seed set may be an artefact of the fact that larger plants were larger targets for fungal spores, or that it was easier to observe mildew on larger plants.

Because collecting detailed census data is time-consuming, we are interested in whether variables that can be measured more quickly can be substituted for measuring every silique.

Height is sometimes the fastest trait to measure in the field. Pooling all plants and including those without siliques, the Pearson correlation coefficient between height and silique number was only 0.38 and between height and summed silique length was only 0.50. The correlations were somewhat greater if only reproductive plants are included: 0.44 and 0.63, respectively, suggesting that recording whether or not a plant has siliques in addition to its height is worthwhile. The Pearson correlation coefficients between the number and the summed length of siliques per plant were much larger: 0.88 if all plants are included, 0.81 if only reproductive plants are included. We conclude that if time is limited, counting the number of siliques is a reasonable substitute for measuring their length. However, the resulting values will not be normal, nor will there be a simple transformation to make them normal, and they should not be analyzed with ordinary ANOVAs or regressions. We used a generalized linear model with a negative binomial distribution to analyze this variable; see below.

Analysis of census data - nine populations

In addition to the five Travis County populations, we were able to collect census data from two southern populations, Garner State Park and Medina 1, in 2012 (Table 1). Wendy Leonard of San Antonio Parks and Recreation Department generously shared her 2012 census data from Rancho Diana and Eisenhower State Park with us. From Leonard's census data, we have extracted the height and number of siliques. 43 of the 140 Rancho Diana plants were still rosettes when last recorded; we did not include these 43 plants in our analyses. Leonard's data did not include summed silique length, so we analyze silique number/plant in place of summed silique length/plant in this section.

We re-analyzed the proportion of plants that reproduced (i.e., had at least one silique) using this larger data set. Adding the additional populations did not decrease the strength of the differences among sites in the proportions of plants that reproduced (generalized linear model, binomial distribution, logit link; $F_{8,1073} = 9.74$, $P < 0.0001$). It increased the range of values: Medina 1, Rancho Diana, and Eisenhower had lower rates than any of the Travis County populations we censused (17%, 38%, and 38%, respectively), and Garner State Park (73%) had a higher rate than any Travis County population (Table 18).

Silique number differed strongly among these nine sites ($F_{8,1073} = 6.37$, $P < 0.0001$). By using a generalized linear model with the negative binomial distribution and log link function, we were able to include the zero values in the analysis and still have a good fit to the data (χ^2/df = 1.06). By including zeros, we obtain a value that is analogous to seedset averaged across all plants and therefore analogous to fitness. By this measure, individual fitness in 2012 was on average highest in Garner State Park (2.46 siliques/plant) and lowest in Medina 1 (0.36 siliques/plant) (Table 20).

Notice, however, that the populations with the most siliques per plant are not necessarily the ones setting the most seed (Table 20). The Barton Creek population, with only moderate fitness (1.08 siliques/plant) set by far the most seed because it was by far the largest population. The Mount Bonnell population, with moderate fitness but which now has very few plants, set the least seed. As an annual, *S. bracteatus* depends upon replenishing its seedbank in good years like

2012. It is doubtful that all of these populations were able to do that.

For seven of the nine sites we have herbivory data. Stem herbivory had a significant effect on silique number (generalized linear model, negative binomial distribution, log link function; stem herbivory term: $F_{1,936} = 26.83$, $P < 0.0001$; site x stem herbivory term: $F_{6,936} = 3.97$, $P = 0.0006$; site continued to be highly significant). We also have mildew data for the same seven sites. The effect of mildew on silique number was not significant.

There were four environmental variables with enough within-population variation to be analyzed for their effects on silique number: horizontal distance to geological boundary (0 m to 1867 m), vertical distance to the geological boundary (0 m to 65.8 m), vertical distance above and below the boundary (from - 65.8 m [65.8 below the boundary] to 37.5 [37.5 m above the boundary]), and mean slope of the cluster of plants 0.1% to 29.1%) (Table 19). They are correlated with one another, which makes sorting out their effects problematic. Some of these correlations are expected; for example, the positive correlation between vertical and horizontal distance to the boundary is to be expected (r = 0.24). A negative correlation between horizontal distance to the boundary and slope (r = -0.61) may also be a 'real' effect of the geology, or it may be fortuitous. Always retaining site in the model, and using a step-wise forward selection of terms by AIC to add environmental term, the best model includes vertical distance above and below the geological boundary ($F_{1,1064} = 8.52$, $P = 0.0036$) and a term reflecting differences among sites in the relationship between vertical distance and silique number (site x vertical distance term, $F_{8,1064} = 3{,}22$, $P = 0.0013$).

However, this relationship with the geological boundary may be an artefact of other within-site gradients. The relationship was negative at Barton Creek, Rancho Diana, and Ullrich WTP: plants below the boundary had more siliques (Fig 10). It was positive at Cat Mountain, Garner State Park, and Valburn. Eisenhower, Mount Bonnell, and Medina 1 did not have enough variation in distance to the geological boundary to detect a relationship. The inconsistency in direction suggests that the causal factor is probably not geology. Instead, it seems more likely that each of the six sites with measurable variation in distance to the geological boundary also had a gradient in the favorability of the environment related to elevation within the site. For whatever reason, upslope was more favorable than downslope at Cat Mountain, for example, and downslope was more favorable than upslope at Barton Creek.

<u>Site-level demographic variables and their environmental correlates - nine populations</u>

A number of environmental variables were measured in each site, but not for each plant: canopy openness and the environmental variables measured in the vegetation survey plots (see Methods). Site-level statistical tests are therefore appropriate to explore the relationships between these environmental variables and demographic performance, although the limited number of sites (9) for which we have data limits the power of this site-level analysis.

For these site-level statistical tests, we calculated a set of site-level demographic variables: (1) average number of siliques/plant, by averaging all plants in a site; (2) average number of siliques/reproductive plant, by averaging only those plants with at least one silique;

(3) proportion of plants that had at least one silique; (4) number of plants per site; (5) density of plants per site (number/occupied area); and, for the 7 sites for which we had herbivory data, (6) proportion of plants that had suffered stem herbivory, calculated from all plants for which we could score stem herbivory. We calculated site-level environmental variables by averaging the values recorded in the occupied plots of the vegetation survey. We used Spearman correlation coefficients because many of the variables were not normally distributed.

The average number of siliques per plant is our best estimator of fitness. It can be thought of as the product of two of the other demographic variables listed above: proportion of plants that had at least one silique X average number of siliques/reproductive plant (reproductive plant = plant that made at least one silique). Interestingly, the average number of siliques/plant in a site was closely related to the proportion of plants that reproduced ($r_s = 0.95$, $P < 0.0001$; Table 18) but much more weakly to the number of siliques/reproductive plant ($r_s = 0.55$, $P = 0.13$) (Table 18). Differences among sites in siliques/plant were therefore mostly determined by the proportion of plants that reproduced.

The average number of siliques per plant, and the proportion of plants that reproduced, were both significantly negatively related to the average number of woody understory species in the occupied survey plots ($r_s = -0.70$ and -0.78, respectively, $P < 0.05$, $N = 9$; Table 19) and to the average distance of survey plots to the canopy edge ($r_s = -0.72$ and -0.77, respectively, $P < 0.05$, $N = 9$). (Recall that distance to canopy edge was positive if a plot was out in the open, and negative if it was under the canopy.) In other words, plants were more likely to reproduce, and therefore on average had more siliques, in sites that had, on average, fewer woody understory species and in which *Streptanthus bracteatus* plants were, on average, further under the canopy (Figs. 11 and 12).

On first glance, the negative correlation between plant performance and distance to canopy edge appears to be incompatible with the experimental results of Fowler et al. (2012) and Leonard and Van Auken (2013), who found that higher light levels favored *Streptanthus bracteatus*. However, there is a likely explanation for this apparent inconsistency: white-tailed deer herbivory (and, at Garner State Park, exotic ungulates as well as white-tailed deer). The proportion of plants in a site that had suffered stem herbivore damage was strongly positively correlated with distance to canopy edge: sites in which the plants were on average further under the canopy suffered significantly less stem herbivore damage ($r_s = 0.86$, $P = 0.0137$, $N = 7$; Table 19, Fig. 13A). The correlation between proportion of plants that had suffered stem herbivore damage and the proportion of plants that were reproductive did not reach significance, but was negative ($r_s = -0.57$, $P = 0.18$, $N = 7$), consistent with this hypothesis (Fig 13B).

There is also an apparent contradiction with the vegetation survey results, in which there was a non-significant trend for unoccupied plots within a site to be further under the canopy than occupied plots. In six of the nine sites, the unoccupied plots were on average further under the canopy; in two they were on average closer to the edge. It may be that ≥3 m in from the canopy edge (the average unoccupied comparison plot in five of the nine sites was ≥3 m in from the canopy) is simply too dark for *S. bracteatus*.

The negative correlations between reproduction and woody understory species richness may be due to direct competition from shrubs and saplings reducing *S. bracteatus* fitness. If so, it is consistent with higher light levels favoring *S. bracteatus*. Alternatively, lower woody understory species richness may indicate a higher biomass of understory-height *J. ashei*. *J. ashei* is known to be effective as protecting small oaks from deer herbivory (Russell and Fowler 2004), and appears to serve the same protective role for *S. bracteatus* (N. Fowler, pers. obs.).

The effects of canopy openness were in the same direction as the effects of distance to canopy edge, that is, greater canopy openness tended to be associated with fewer siliques/plant, a lower proportion of plants that reproduced, and a higher rate of stem herbivore damage, but did not reach significance (Table 19). Given the small number of photographs per site, this lack of significance is perhaps not surprising.

Population size and density of plants were not significantly related to any other variables. The other factors that determine population size and density, including partial site development and recreational use of the site, probably overrode the effects of the environmental factors we measured. The remaining environmental factors we included in this site-level analysis, average soil depth, number of overstory species, and number of herbaceous species, were not significantly related at this scale to any of the other variables.

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We are very grateful to Ms. Wendy Leonard and the San Antonio Parks and Recreation Department for generously allowing us to use Wendy's census data from the Eisenhower Park and Rancho Diana populations. Information obtained from those data appears in the tables and analyses of this report.

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Tables

Table 1 site name	site ID	latitude[1]	longitude[1]	county	road address	managing entity
Barton Creek (also known as Greenbelt, or Barton Creek Greenbelt)	bar	613226.09	3349015.01	Travis	3918 S Mopac Expy. Svrd SB, Austin, TX 78735	Balcones Canyonlands Preserve, City of Austin Water Department; and City of Austin Parks and Recreation Department
Cat Mountain (also known as Far West)	cam	617186.71	3359169.95	Travis	4723 Far West Blvd, Austin, TX 78731	private
Eisenhower Park	eis	541385.93[3]	3277000.00[3]	Bexar	19399 NW Military Hwy, San Antonio, TX 78257	City of San Antonio Parks and Recreation Department
Garner State Park	gsp	428103.96	3273545.69	Uvalde	234 RR 1050, Concan, TX 78838	Texas Parks and Wildlife Department
Medina 1[2]	mmd	507568.58	3265428.36	Medina	Lower Lake Road, Rio Medina, TX 78066	private
Medina 2[2]	mnl	509679.99	3271825.50	Medina	159-299 County Road 270, Mico, TX 78056	private
Medina 3[2]	msd	510248.16	3268331.36	Medina	174-184 County Road 2702, Mico, TX 78056	private
Medina 4[2]	mfm	509745.07	3268428.84	Medina	Farm to Market 1283, Mico, TX 78056	private
Mount Bonnell	mtb	617978.73	3354994.96	Travis	3800 Mount Bonnell Rd., Austin, TX 78731	Balcones Canyonlands Preserve, City of Austin Water Department; and City of Austin Parks and Recreation Department
Rancho Diana	rad	531645.77[3]	3273669.48[3]	Bexar	Northside, San Antonio, TX 78023	City of San Antonio Parks and Recreation Department

Ullrich WTP (Ullrich Water Treatment Plant)	ull	616349.08	3352255.52	Travis	Forest View Dr, Austin, TX 78746	City of Austin Water Department
Valburn (also known as Bull Creek Park)	val	617130.85	3360313.59	Travis	7806 N Capital of Texas Hwy., Austin, TX 78731	private (in part); public part: Balcones Canyonlands Preserve, City of Austin Water Department; and City of Austin Parks and Recreation Department
[1] latitude and longitude are expressed in UTM 14N, NAD 1983 [2] the names Medina 1 through Medina 4 are new in this report [3] location of the property entrance, at the request of the San Antonio Parks and Recreation Department						

Table 1. Names, locations, and managing entity of the sites we visited. We did not visit the portion of the Eisenhower population that is, or was, outside the boundary of Eisenhower Park; its status is not known. The Mount Bonnell population once occupied adjoining private land as well as the City land it is now restricted to; that portion of the population was extirpated by residential development. Most of the former Valburn population was also extirpated by residential development. We list it here as in part private because the location of the boundary of Bull Creek Park is not clear and a few plants may be on the adjoining private land.

Table 2 site name	site id	observer(s) - census	observer(s) - vegetation survey	# of plants	# of vegetation survey plots		# of canopy photos
					occupied	unoccupied	
Barton Creek	bar	Gabriel De Jong	Gabriel De Jong, Chris Warren	434	20	11	4
Cat Mountain	cam	Gabriel De Jong, Walter Stewart	Gabriel De Jong, Walter Stewart	212	3	1	2
Eisenhower Park	eis	Wendy Leonard	Gabriel De Jong	40	4	2	3
Garner State Park	gsp	Karen Clary, Gabriel De Jong, Norma Fowler, Cullen Hanks, Jackie Poole	Gabriel De Jong	26	5	4	4
Medina 1	mmd	Karen Clary, Gabriel De Jong, Norma Fowler, Cullen Hanks, Jackie Poole	Gabriel De Jong	81	3	2	2
Medina 2	mnl	Karen Clary, Gabriel De Jong, Norma Fowler, Cullen Hanks, Jackie Poole	Gabriel De Jong	276[1]	5	3	3
Medina 3	msd	Karen Clary, Gabriel De Jong, Norma Fowler, Cullen Hanks, Jackie Poole	Gabriel De Jong	57[1]	4	4	3
Medina 4	mfm	[no plants found by us]	Gabriel De Jong	n/a	3	1	2
Mount Bonnell	mtb	Gabriel De Jong, Norma Fowler	Gabriel De Jong	21	6	1	2
Rancho Diana	rad	Wendy Leonard	Gabriel De Jong	140	10	3	3
Ullrich WTP	ull	Gabriel De Jong	Gabriel De Jong	92	10	3	3
Valburn	val	Gabriel De Jong, Walter Stewart	Gabriel De Jong	84	8	2	2
totals				1463	81	37	33

[1] these values based upon rapid estimates, not complete counts (see Methods)

Table 2. Census and vegetation survey sites: observers, numbers of plants present, numbers of vegetation survey plots occupied by

Streptanthus bracteatus and comparison unoccupied plots, and numbers of canopy photographs.

Table 3	
# of individuals in a cluster	buffer radius size (m)
1 - 5	1
6 - 10	2
11 - 20	3
21 - 40	5
41 - 60	10
81 - 100	20
101 - 150	25
151 - 200	35
200+	$\geq$ 40

Table 3. Distances used to convert point locations of *Streptanthus bracteatus* clusters in the TPWD data base to polygons. These definitions were used for TPWD clusters in both the TPWD-defined occupied areas and the GDJ-defined occupied areas. If there were more than 200 plants in a cluster an appropriate buffer size was set using the original written observations for each source feature and examination of the mapped points.

Table 4 site name	site ID	occupied area: formation % % ked	% kgr	% kdv	Edwards (or Devils River*) – Glen Rose boundary: avg horiz dist (m)	min horiz dist (m)	max horiz dist (m)	avg vert dist (m)	min vert dist (m)	max vert dist (m)	avg abs vert dist (m)	unoccupied area: 10 m width % ked	% kgr	% kdv	50 m width % ked	% kgr	% kdv
Annandale Ranch*	ann	0	0	100	934	934	934	85	85	85	85	0	0	100	0	0	100
Barton Creek	bar	67	33	0	306	22	698	-7	-27	21	16	70	30	0	75	0	0
Bear Bluff Ranch	bbr	8	92	0	50	50	50	-18	-18	-18	18	21	79	0	25	75	0
Bright Leaf Preserve	bri	0	100	0	485	330	705	-45	-77	-27	45	0	100	0	0	100	0
Cat Mountain	cam	0	100	0	225	30	319	-40	-66	-1	40	0	100	0	1	99	
Mesa	cro	0	100	0	644	439	844	-49	-52	-42	49	0	100	0	0	100	0
Eisenhower Park	eis	100	0	0	110	76	180	4	-2	10	5	100	0	0	100	0	0
Garner State Park[1]	gsp	0	99	1	125	50	248	-16	-52	61	34	0	90	10	0	83	17
Hays	hay	0	100	0	9237	9237	9237	-62	-62	-62	62	0	100	0	0	100	0
Medina 1	mmd	100	0	0	1383	912	1854	29	21	37	10	100	0	0	100	0	0
Medina 2	mnl	74	26	0	76	40	106	-2	-10	13	29	74	26	0	76	24	0
Medina 3	msd	100	0	0	107	0	341	10	-3	41	6	98	2	0	91	9	0
Medina 4	mfm	91	9	0	113	10	184	2	-19	15	10	81	19	0	60	40	0
Mount Bonnell	mtb	0	100	0	292	170	411	-8	-31	27	23	0	100	0	0	100	0
Rancho Diana	rad	100	0	0	285	270	300	34	27	41	34	100	0	0	100	0	0
Ullrich WTP	ull	27	73	0	20	0	80	2	0	11	2	43	57	0	58	42	0
Valburn	val	40	60	0	106	20	301	-11	-56	11	22	29	71	0	27	73	0
summary (N=17 sites)											85						
	avg	42	52	6	853	741	988	-5	-20	13		48	51	1	48	50	1
	min	0	0	0	20	0	50	-62	-77	-62		0	0	0	0	0	0
	max	100	100	100	9237	9237	9237	85	85	85		100	100	10	100	100	17
	med	27	60	0	225	50	319	-7	-19	13		43	57	0	58	42	0

[1] geological boundary is between the Devils River Formation and the Glen Rose Formation

Table 4. **Geological variables (GDJ definition of occupied area)**. The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus* or surrounding unoccupied area. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012, plus our own census data

collected in 2012. Each site was divided into occupied polygons and unoccupied areas around each polygon. The occupied polygons were created by De Jong (see Methods). The unoccupied areas were either 10m or 50 m in width around the occupied areas. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately. Geological data were obtained from USGS geological maps. *horiz dist*, horizontal distance to the nearest Glen Rose Formation / Edwards Formation boundary or (for two sites) the nearest Glen Rose Formation / Devils River Formation boundary. The Devils River Formation replaces the Edwards Formation in the westernmost part of the range of *Streptanthus bracteatus*. *vert dist*, vertical distance to the same boundary. Negative vertical distances were assigned to polygons below this boundary. *awc*, soil available water capacity; *om*, soil organic matter; *elev*, elevation. The bottom portion of the table has summary statistics calculated from the values in the upper portion. *avg*, average; *min*, minimum; *max*, maximum; *med*, median; *avg abs vert dist* (m), average absolute vertical distance from the boundary; *ked*, Edwards Formation; *kgr*, Glen Rose Formation; *kdv*, Devils River Formation (USGS abbreviations).

		occupied area									unoccupied area					
		Formation %			Edwards (or Devil's River*) – Glen Rose boundary						10 m width			50 m width		
Table 5 site name	Site ID	% ked	% kgr	% kdv	avg horiz dist (m)	min horiz dist (m)	max horiz dist (m)	avg vert dist (m)	min vert dist (m)	max vert dist (m)	% ked	% kgr	% kdv	% ked	% kgr	% kdv
Annandale Ranch*	ann	0	0	100	934	934	934	85	85	85	0	0	100	0	0	100
Barton Creek	bar	64	36	0	356	36	698	-2	-27	11	72	28	0	74	26	0
Bear Bluff Ranch	bbr	50	50	0	50	50	50	-18	-18	-18	21	79	0	25	75	0
Bright Leaf Preserve	bri	0	100	0	485	330	705	-41	-77	-20	0	100	0	0	100	0
Cat Mountain	cam	9	91	0	120	30	155	-21	-39	-8	8	92	0	9	91	0
Mesa	cro	0	100	0	645	424	844	-47	-56	-30	0	100	0	0	100	0
Eisenhower Park	eis	100	0	0	121	76	180	6	0	10	100	0	0	100	0	0
Garner State Park[1]	gsp	0	100	0	117	50	197	-34	-53	9	0	95	5	0	88	12
Hays	hay	0	100	0	9237	9237	9237	-69	-69	-69	0	100	0	0	100	0
Medina 1	mmd	100	0	0	95	10	166	-3	-23	10	72	28	0	56	44	0
Medina 2	mnl	75	25	0	1331	807	1854	20	8	31	100	0	0	100	0	0
Medina 3	msd	100	0	0	73	40	106	7	-7	20	74	26	0	75	25	0
Medina 4	mfm	94	6	0	113	0	341	8	-4	39	97	3	0	91	9	0
Mount Bonnell	mtb	0	100	0	278	206	349	-11	-24	2	0	100	0	0	100	0
Rancho Diana	rad	100	0	0	330	330	330	33	33	33	100	0	0	100	0	0
Ullrich WTP	ull	75	25	0	42	42	42	15	15	15	63	37	0	59	39	0
Valburn	val	39	61	0	113	28	301	-13	-56	11	29	71	0	27	73	0
summary (N=17 sites)																
	avg	47	47	6	849	743	970	-5	-18	8	43	51	6	43	51	6
	min	0	0	0	42	0	42	-69	-77	-69	0	0	0	0	0	0
	max	100	100	100	9237	9237	9237	85	85	85	100	100	100	100	100	100
	med	50	36	0	121	50	330	-3	-23	10	29	37	0	27	44	0

[1] geological boundary is between the Devils River Formation and the Glen Rose Formation

Table 5. **Geological variables (TPWD definition of occupied area)**. The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus* or surrounding unoccupied area. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into

occupied polygons and unoccupied areas around each polygon. The occupied polygons were provided by TPWD staff (see Methods). The unoccupied areas were either 10m or 50 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately. Geological data were obtained from USGS geological maps. *horiz dist*, horizontal distance to the nearest Glen Rose Formation / Edwards Formation boundary or (for two sites) the nearest Glen Rose Formation / Devils River Formation boundary. The Devils River Formation replaces the Edwards Formation in the westernmost part of the range of *Streptanthus bracteatus*. *vert dist*, vertical distance to the same boundary. Negative vertical distances were assigned to polygons below this boundary. *awc*, soil available water capacity; *om*, soil organic matter; *elev*, elevation. The bottom portion of the table has summary statistics calculated from the values in the upper portion. *avg*, average; *min*, minimum; *max*, maximum. *ked*, Edwards Formation; *kgr*, Glen Rose Formation; *kdv*, Devils River Formation (USGS abbreviations).

Table 6 site name	site ID	occupied area asp 1	asp 2	avg slope	min slope	max slope	avg elev	min elev	max elev	unoccupied area (10m width) asp 1	asp 2	avg slope	min slope	max slope	avg elev	min elev	max elev
Annandale Ranch	ann	N	N	11	11	11	452	452	452	N	N	10	9	11	453	452	454
Barton Creek	bar	W	S	16	0	28	192	183	202	W	N	18	0	50	192	171	217
Bear Bluff Ranch	bbr	N	N	23	0	41	354	327	382	E	S	19	0	40	355	327	385
Bright Leaf Preserve	bri	W	N	11	11	11	215	215	215	W	N	10	0	22	218	175	237
Cat Mountain	cam	W	N	16	5	28	194	186	206	W	N	16	0	41	191	168	231
Mesa	cro	W	S	8	2	14	189	187	194	W	N	8	0	16	188	180	199
Eisenhower Park	eis	S	S	13	13	13	366	366	366	W	N	10	0	19	365	359	374
Garner State Park	gsp	N	N	17	16	18	452	450	453	N	N	19	5	40	453	436	473
Hays	hay	N	N	18	18	18	376	376	376	N	N	15	0	21	377	371	382
Medina 1	mmd	E	S	8	0	28	325	307	337	W	N	17	0	59	310	282	342
Medina 2	mnl	S	S	9	4	13	414	409	420	N	N	8	0	29	414	370	466
Medina 3	msd	N	N	8	6	11	383	380	386	W	N	6	0	22	377	345	400
Medina 4	mfm	W	N	7	6	10	358	350	364	E	S	6	0	18	363	335	385
Mount Bonnell	mtb	W	N	27	12	39	209	196	224	W	N	26	0	62	204	152	239
Rancho Diana	rad	N	N	18	18	18	376	376	376	N	N	15	0	21	377	371	382
Ullrich WTP	ull	W	N	13	5	21	160	157	166	W	N	17	0	38	159	149	181
Valburn	val	W	N	15	5	26	231	222	237	W	N	19	0	47	236	184	270
summary (N=17 sites)																	
avg				14	8	20	304	297	310			14	1	33	303	279	326
min				7	0	10	160	157	166			15	0	29	310	292	342
max				27	20	41	452	452	453			6	0	11	159	149	181
med				13	6	18	325	307	337			26	9	62	453	452	473

Table 6. **Topographic variables (GDJ definition of occupied area, 10 m wide unoccupied areas)**. The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus or* surrounding unoccupied area. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into occupied polygons and unoccupied areas around each polygon. The occupied polygons were created by De Jong (see Methods). The unoccupied areas were 10 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately. Topographic data were obtained from USGS topographic maps. The bottom portion of the table has summary statistics

calculated from the values in the upper portion. *elev*, elevation; *avg*, average; *min*, minimum; *max*, maximum; *med*, median; *asp*, aspect. Aspect was categorized in two ways. *asp 1*: north (N), south (S), east (E), or west (W); *asp 2*: north or south.

Table 7 site name	Site ID	occupied area								unoccupied area (50m width)							
		asp 1	asp 2	avg slope	min slope	max slope	avg elev	min elev v	max elev	asp 1	asp 2	avg slope	min slope	max slope	avg elev	min elev	max elev
Annandale Ranch	ann	N	N	11	11	11	452	452	452	N	N	11	3	26	451	438	459
Barton Creek	bar	W	S	16	0	28	192	183	202	W	N	15	0	50	192	170	224
Bear Bluff Ranch	bbr	N	N	23	0	41	354	327	382	E	N	15	0	40	357	327	390
Bright Leaf Preserve	bri	W	N	11	11	11	215	215	215	W	N	10	0	27	214	171	241
Cat Mountain	cam	W	N	16	5	28	194	186	206	W	N	16	0	42	194	151	242
Mesa	cro	W	S	8	2	14	189	187	194	W	S	8	0	22	189	177	206
Eisenhower Park	eis	S	S	13	13	13	366	366	366	S	S	11	0	26	369	358	384
Garner State Park	gsp	N	N	17	16	18	452	450	453	N	N	18	3	43	451	421	486
Hays Co	hay	E	S	20	20	20	292	292	292	W	N	15	0	35	299	292	311
Medina 1	mmd	E	S	8	0	28	325	307	337	W	N	15	0	60	310	277	344
Medina 2	mnl	S	S	9	4	13	414	409	420	W	N	9	0	44	413	369	467
Medina 3	msd	N	N	8	6	11	383	380	386	W	N	8	0	31	376	340	404
Medina 4	mfm	W	N	7	6	10	358	350	364	E	S	8	0	28	360	331	385
Mount Bonnell	mtb	W	N	27	12	39	209	196	224	W	N	19	0	62	198	150	239
Rancho Diana	rad	N	N	18	18	18	376	376	376	E	N	15	0	22	376	356	390
Ullrich WTP	ull	W	N	13	5	21	160	157	166	E	S	15	0	56	163	147	185
Valburn	val	W	N	15	5	26	231	222	237	W	N	19	0	51	231	182	275
summary (N=17 sites)																	
avg				14	8	20	304	297	310			13	0	39	303	274	331
min				7	0	10	160	157	166			8	0	22	163	147	185
max				27	20	41	452	452	453			19	3	62	451	438	486
med				13	6	18	325	307	337			15	0	40	310	292	344

Table 7. **Topographic variables (GDJ definition of occupied area, 50 m wide unoccupied areas)**.. The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus or* surrounding unoccupied area. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into occupied polygons and unoccupied areas around each polygon. The occupied polygons were created by De Jong (see Methods). The unoccupied areas were 50 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site

separately. Topographic data were obtained from USGS topographic maps. The bottom portion of the table has summary statistics calculated from the values in the upper portion. *elev*, elevation; *avg*, average; *min*, minimum; *max*, maximum; *med*, median; *asp*, aspect. Aspect was categorized in two ways. *asp 1*: north (N), south (S), east (E), or west (W); *asp 2*: north or south.

Table 8 site name	Site ID	occupied area								unoccupied area (10 m width)							
		asp 1	asp 2	avg slope	min slope	max slope	avg elev	min elev	max elev	asp 1	asp 2	avg slope	min slope	max slope	avg elev	min elev	max elev
Annandale Ranch	ann	N	N	11	11	11	452	452	452	N	N	10	9	11	453	452	454
Barton Creek	bar	W	N	15	0	32	195	182	210	W	N	15	0	50	194	171	224
Bear Bluff Ranch	bbr	N	N	23	0	41	355	327	382	E	N	19	0	40	356	327	385
Bright Leaf Preserve	bri	W	N	11	11	11	215	215	215	W	N	10	0	22	218	175	237
Cat Mountain	cam	W	N	18	8	32	213	191	236	W	N	16	0	44	196	152	261
Mesa	cro	W	S	8	2	14	189	187	194	W	S	8	0	16	188	180	199
Eisenhower Park	eis	W	N	11	9	12	368	367	368	S	S	11	2	19	365	359	374
Garner State Park	gsp	N	N	21	16	27	451	445	458	N	N	19	3	40	446	425	473
Hays	hay	E	S	20	20	20	292	292	292	E	S	15	0	21	294	292	299
Medina 1	mmd	E	S	8	6	10	357	352	361	E	S	8	0	21	361	335	385
Medina 2	mnl	S	S	8	0	28	325	307	337	W	N	18	0	59	311	282	342
Medina 3	msd	N	N	8	3	13	409	403	416	N	N	8	0	29	414	370	466
Medina 4	mfm	W	N	8	4	12	382	376	386	W	N	6	0	22	377	345	400
Mount Bonnell	mtb	W	N	19	0	43	205	167	221	W	N	25	0	62	198	152	229
Rancho Diana	rad	E	N	16	0	22	376	367	387	E	N	17	0	21	376	366	387
Ullrich WTP	ull	N	N	16	0	48	163	147	185	E	S	11	0	54	160	147	185
Valburn	val	W	N	15	5	26	231	222	237	W	N	20	0	47	235	184	270
summary (N=17 sites)																	
avg				14	6	24	305	294	314			14	1	34	302	277	328
min				8	0	10	163	147	185			6	0	11	160	147	185
max				23	20	48	452	452	458			25	9	62	453	452	473
med				15	4	22	325	307	337			15	0	29	311	292	342

Table 8. **Topographic variables (TPWD definition of occupied area, 10 m wide unoccupied areas).** The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus or* surrounding unoccupied area. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into occupied polygons and unoccupied areas around each polygon. The occupied polygons were

provided by TPWD staff (see Methods). The unoccupied areas were 10 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately Topographic data were obtained from USGS topographic maps. The bottom portion of the table has summary statistics calculated from the values in the upper portion. *elev*, elevation; *avg*, average; *min*, minimum; *max*, maximum; *asp*, aspect. Aspect was categorized in two ways. *asp 1*: north (N), south (S), east (E), or west (W); *asp 2*: north or south.

Table 9 site name	site ID	occupied area asp 1	asp 2	avg slope	min slope	max slope	avg elev	min elev	max elev	unoccupied area (50 m width) asp 1	asp 2	avg slope	min slope	max slope	avg elev	min elev	max elev
Annandale Ranch	ann	N	N	11	11	11	452	452	452	N	N	11	3	26	451	438	459
Barton Creek	bar	W	N	15	0	32	195	182	210	W	N	14	0	50	196	170	236
Bear Bluff Ranch	bbr	N	N	23	0	41	355	327	382	E	N	15	0	40	357	326	390
Bright Leaf Preserve	bri	W	N	11	11	11	215	215	215	W	N	10	0	27	214	171	241
Cat Mountain	cam	W	N	18	8	32	213	191	236	W	N	16	0	48	199	151	265
Mesa	cro	W	S	8	2	14	189	187	194	W	S	8	0	22	189	177	206
Eisenhower Park	eis	W	N	11	9	12	368	367	368	S	S	11	0	26	369	358	384
Garner State Park	gsp	N	N	21	16	27	451	445	458	E	N	17	0	47	447	418	486
Hays County Pop	hay	E	S	20	20	20	292	292	292	W	N	15	0	35	299	292	311
Medina 1	mmd	E	S	8	6	10	357	352	361	E	S	9	0	28	359	331	385
Medina 2	mnl	S	S	8	0	28	325	307	337	W	N	15	0	60	310	277	344
Medina 3	msd	N	N	8	3	13	409	403	416	W	N	9	0	44	413	369	467
Medina 4	mfm	W	N	8	4	12	382	376	386	W	N	8	0	31	375	340	404
Mount Bonnell	mtb	W	N	19	0	43	205	167	221	E	S	19	0	62	193	148	229
Rancho Diana	rad	E	N	16	0	22	376	367	387	E	N	12	0	22	375	356	390
Ullrich WTP	ull	N	N	16	0	48	163	147	185	E	S	14	0	61	161	147	185
Valburn	val	W	N	15	5	26	231	222	237	W	N	19	0	51	230	182	275
summary (N=17 sites)																	
avg				14	6	24	305	294	314			13	0	40	302	274	333
min				8	0	10	163	147	185			8	0	22	161	147	185
max				23	20	48	452	452	458			19	3	62	451	438	486
med				15	4	22	325	307	337			14	0	40	310	292	344

Table 9. **Topographic variables (TPWD definition of occupied area, 50 m wide unoccupied areas).** The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus or* surrounding unoccupied area. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into occupied polygons and unoccupied areas around each polygon. The occupied polygons were provided by TPWD staff (see Methods). The unoccupied areas were 50 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately Topographic data were obtained from USGS topographic maps. The bottom portion of the table has

summary statistics calculated from the values in the upper portion. *elev*, elevation; *avg*, average; *min*, minimum; *max*, maximum; *asp*, aspect. Aspect was categorized in two ways. *asp 1*: north (N), south (S), east (E), or west (W); *asp 2*: north or south.

Table 10 site name	site ID	occupied area									unoccupied area (10m width)								
		% arg	% cal	% hep	% hol	% ust	pH	awc	% om	% clay	% arg	% cal	% hep	% hol	% ust	pH	awc	% om	% clay
Annandale Ranch	ann	0	100	0	0	0	8.1	0.08	3	30	0	100	0	0	0	8.1	0.08	3	30
Barton Creek	bar	10	66	7	0	17	7.7	0.10	2	27	12	62	5	0	21	7.7	0.10	2	27
Bear Bluff Ranch	bbr	0	0	0	68	32	7.8	0.07	4	30	0	0	0	69	31	7.8	0.07	4	30
Bright Leaf Preserve	bri	0	0	100	0	0	7.9	0.12	2	25	0	0	100	0	0	7.9	0.12	2	25
Cat Mountain	cam	0	0	100	0	0	7.9	0.12	2	25	0	0	100	0	0	7.9	0.12	2	25
Mesa	cro	0	0	100	0	0	7.9	0.12	2	25	0	0	100	0	0	7.9	0.12	2	25
Eisenhower Park	eis	0	0	0	100	0	7.5	0.08	7	50	0	00	0	100	0	7.5	0.08	7	50
Garner State Park	gsp	0	100	0	0	0	8.1	0.08	6	31	0	100	0	0	0	8.1	0.08	6	31
Hays County Pop	hay	0	0	0	100	0	7.5	0.07	7	50	0	0	0	100	0	7.5	0.07	7	50
Medina 1	mmd	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	7.5	0.08	7	50
Medina 2	mnl	0	1	0	99	0	8.0	0.12	4	38	0	9	0	100	0	8.0	0.12	4	38
Medina 3	msd	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	7.5	0.08	7	50
Medina 4	mfm	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	7.5	0.08	7	50
Mount Bonnell	mtb	0	0	100	0	0	7.9	0.12	2	25	0	0	100	0	0	7.9	0.12	2	25
Rancho Diana	rad	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	7.5	0.08	7	50
Ullrich WTP	ull	0	100	0	0	0	7.9	0.08	5	50	0	100	0	0	0	7.9	0.08	5	50
Valburn	val	0	86	11	3	0	8.0	0.12	3	39	0	42	51	7	0	8.0	0.12	3	39
summary (N=17 sites)																			
	avg	1	27	25	45	3	7.8	0.10	4	38	1	24	27	46	3	7.8	0.10	4	38
	min	0	0	0	0	0	7.5	0.07	2	25	0	0	0	0	0	7.9	0.08	4	38
	max	10	100	100	100	32	8.1	0.12	7	50	12	100	100	100	31	7.5	0.07	2	25
	med	0	0	0	3	0	7.9	0.08	4	39	0	0	0	7	0	8.1	0.12	7	50

Table 10. **Soil variables (GDJ definition of occupied area, 10 m wide unoccupied areas)**. The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus*. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into occupied polygons and unoccupied areas around those polygons. The occupied polygons were created by De Jong (see Methods). The unoccupied areas were 10 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap

area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately. Soil data were obtained from USDA Soil Web Survey. *arg*, argiustoll; *cal*, calciustoll; *hep*, haplustept; *hol*, haplustoll; *ust*, ustifluvent; *awc*, soil available water capacity; *om*, soil organic matter. The bottom portion of the table has summary statistics calculated from the values in the upper portion. *avg*, average*; min*, minimum; *max*, maximum; *med*, median.

Table 11 site name	site ID	occupied area									unoccupied area (50m width)									
		% arg	% cal	% hep	% hol	% ust	pH	awc	% om	% clay	% arg	% cal	% hep	% hol	% ust	% ucr	pH	awc	% om	% clay
Annandale Ranch	ann	0	100	0	0	0	8.1	0.08	3	30	0	100	0	0	0	0	8.1	0.08	3	30
Barton Creek	bar	10	66	7	0	17	7.7	0.10	2	27	12	59	4	0	0	25	7.7	0.10	2	27
Bear Bluff Ranch	bbr	0	0	0	68	32	7.8	0.07	4	30	0	0	0	69	0	31	7.8	0.07	4	30
Bright Leaf Preserve	bri	0	0	100	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Cat Mountain	cam	0	0	100	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Mesa	cro	0	0	100	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Eisenhower Park	eis	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Garner State Park	gsp	0	100	0	0	0	8.1	0.08	6	31	0	96	0	0	3	1	8.1	0.10	3	19
Hays County Pop	hay	0	0	0	100	0	7.5	0.07	7	50	0	0	0	100	0	0	7.5	0.07	7	50
Medina 1	mmd	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Medina 2	mnl	0	1	0	99	0	8.0	0.12	4	38	0	9	0	87	0	0	8.0	0.12	4	38
Medina 3	msd	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Medina 4	mfm	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Mount Bonnell	mtb	0	0	100	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Rancho Diana	rad	0	0	0	100	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Ullrich WTP	ull	0	100	0	0	0	7.9	0.08	5	50	0	100	0	0	0	0	7.9	0.08	5	50
Valburn	val	0	86	11	3	0	8.0	0.12	3	39	0	24	68	8	0	0	8.0	0.12	3	39

summary (N=17 sites)																			
avg	1	27	25	45	3	7.8	0.10	4	38	1	23	28	45	0	3	7.8	0.1	4	37
min	0	0	0	0	0	7.5	0.07	2	25	0	0	0	0	0	0	7.5	0.07	2	19
max	10	100	100	100	32	8.1	0.12	7	50	12	100	100	100	3	31	8.1	0.12	7	50
med	0	0	0	3	0	7.9	0.08	4	39	0	0	0	8	0	0	7.9	0.08	4	38

Table 11. **Soil variables (GDJ definition of occupied area, 50 m wide unoccupied areas)**. The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus*. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into occupied polygons and unoccupied areas around those polygons. The occupied polygons were created by De Jong (see Methods). The unoccupied areas were 50 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap

area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately. Soil data were obtained from USDA Soil Web Survey. *arg*, argiustoll; *cal*, calciustoll; *hep*, haplustept; *hol*, haplustoll; *ust*, ustifluvent; *ucr*, ustochrept; *awc*, soil available water capacity; *om*, soil organic matter. The bottom portion of the table has summary statistics calculated from the values in the upper portion. *avg*, average; *min*, minimum; *max*, maximum; *med*, median.

		occupied area										unoccupied area (10 m width)									
Table 12 site name	site ID	% arg	% cal	% hep	% hol	% ust	% ucr	pH	awc	% om	% clay	% arg	% cal	% hep	% hol	% ust	% ucr	pH	awc	% om	% clay
Annandale Ranch	ann	0	100	0	0	0	0	8.1	0.08	3	30	0	100	0	0	0	0	8.1	0.08	3	30
Barton Creek	bar	5	82	2	0	12	0	7.7	0.10	2	27	12	65	4	0	19	0	7.7	0.10	2	27
Bear Bluff Ranch	bbr	0	0	0	68	32	0	7.8	0.07	4	30	0	0	69	0	31	0	7.8	0.07	4	30
Bright Leaf Preserve	bri	0	0	100	0	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Cat Mountain	cam	0	0	100	0	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Mesa	cro	0	0	100	0	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Eisenhower Park	eis	0	0	0	100	0	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Garner State Park	gsp	0	95	0	0	1	4	8.1	0.10	3	19	0	90	0	0	6	4	8.1	0.10	3	19
Hays County Pop	hay	0	0	0	100	0	0	7.5	0.07	7	50	0	0	0	100	0	0	7.5	0.07	7	50
Medina 1	mmd	0	1	0	99	0	0	7.5	0.08	7	50	0	9	0	91	0	0	7.5	0.08	7	50
Medina 2	mnl	0	0	0	100	0	0	8.0	0.12	4	38	0	0	0	100	0	0	8.0	0.12	4	38
Medina 3	msd	0	0	0	100	0	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Medina 4	mfm	0	0	0	100	0	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Mount Bonnell	mtb	0	0	100	0	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Rancho Diana	rad	0	0	0	100	0	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Ullrich WTP	ull	0	100	0	0	0	0	7.9	0.08	5	50	0	100	0	0	0	0	7.9	0.08	5	50
Valburn	val	0	79	18	3	0	0	8.0	0.12	3	39	0	40	52	8	0	0	8.0	0.12	3	39
summary (N=17 sites)																					
	avg	0	27	25	45	3	0	7.8	0.10	4	37	1	24	31	41	3	0	7.8	0.10	4	37
	min	0	0	0	0	0	0	7.5	0.07	2	19	0	0	0	0	0	0	7.5	0.07	2	19
	max	5	100	100	100	32	4	8.1	0.12	7	50	12	100	100	100	31	4	8.1	0.12	7	50
	med	0	0	0	3	0	0	7.9	0.08	4	38	0	0	0	0	0	0	7.9	0.08	4	38

Table 12. **Soil variables (TPWD definition of occupied area, 10 m wide unoccupied areas)**. The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus*. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into occupied

polygons and unoccupied areas around those polygons. The occupied polygons were provided by TPWD staff (see Methods). The unoccupied areas were 10 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately. Soil data were obtained from USDA Soil Web Survey. *arg*, argiustoll; *cal*, calciustoll; *hep*, haplustept; *hol*, haplustoll; *ust*, ustifluvent; *ucr*, ustochrept; *awc*, soil available water capacity; *om*, soil organic matter. The bottom portion of the table has summary statistics calculated from the values in the upper portion. *avg*, average; *min*, minimum; *max*, maximum; *med*, median.

Table 13 site name	site ID	occupied area										unoccupied area (10 m width)									
		% arg	% cal	% hep	% hol	% ust	% ucr	pH	awc	% om	% clay	% arg	% cal	% hep	% hol	% ust	% ucr	pH	awc	% om	% clay
Annandale Ranch	ann	0	100	0	0	0	0	8.1	0.08	3	30	0	100	0	0	0	0	8.1	0.08	3	30
Barton Creek	bar	5	82	2	0	12	0	7.7	0.10	2	27	19	50	4	0	27	0	7.7	0.10	2	27
Bear Bluff Ranch	bbr	0	0	0	68	32	0	7.8	0.07	4	30	0	0	0	69	31	0	7.8	0.07	4	30
Bright Leaf Preserve	bri	0	0	100	0	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Cat Mountain	cam	0	0	100	0	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Mesa	cro	0	0	100	0	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Eisenhower Park	eis	0	0	0	100	0	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Garner State Park	gsp	0	95	0	0	1	4	8.1	0.10	3	19	0	81	0	0	7	11	8.1	0.10	3	21
Hays County Pop	hay	0	0	0	100	0	0	7.5	0.07	7	50	0	0	0	100	0	0	7.5	0.07	7	50
Medina 1	mmd	0	1	0	99	0	0	7.5	0.08	7	50	0	9	0	88	0	0	8	0.12	4.25	38
Medina 2	mnl	0	0	0	100	0	0	8.0	0.12	4	38	0	0	0	100	0	0	7.5	0.08	6.5	50
Medina 3	msd	0	0	0	100	0	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	6.5	50
Medina 4	mfm	0	0	0	100	0	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Mount Bonnell	mtb	0	0	100	0	0	0	7.9	0.12	2	25	0	0	100	0	0	0	7.9	0.12	2	25
Rancho Diana	rad	0	0	0	100	0	0	7.5	0.08	7	50	0	0	0	100	0	0	7.5	0.08	7	50
Ullrich WTP	ull	0	100	0	0	0	0	7.9	0.08	5	50	0	100	0	0	0	0	7.9	0.08	5	50
Valburn	val	0	79	18	3	0	0	8.0	0.12	3	39	0	24	68	8	0	0	8.0	0.12	3	39
summary (N=17 sites)																					
	avg	0	27	25	45	3	0	7.8	0.10	4	37	1	21	28	45	4	1	7.8	0.10	4	37
	min	0	0	0	0	0	0	7.5	0.07	2	19	0	0	0	0	0	0	7.5	0.07	2	21
	max	5	100	100	100	32	4	8.1	0.12	7	50	19	100	100	100	31	11	8.1	0.12	7	50
	med	0	0	0	3	0	0	7.9	0.08	4	38	0	0	0	8	0	0	7.9	0.08	4	38

Table 13. **Soil variables (TPWD definition of occupied area, 50 m wide unoccupied areas)**. The top portion of this table has site averages, calculated using polygons occupied by *Streptanthus bracteatus*. It is based on all known records of all known censuses of all known sites, provided as spatial (ArcGIS) data by Texas Parks and Wildlife Department in 2012. Each site was divided into occupied polygons and unoccupied areas around those polygons. The occupied polygons were provided by TPWD staff (see Methods). The unoccupied areas were 50 m in width. If the unoccupied area around one polygon overlapped another occupied polygon, the overlap area was deleted from the unoccupied area. The unoccupied areas were combined (fused) for each site separately. Soil data were obtained from USDA Soil Web Survey. *arg*, argiustoll; *cal*, calciustoll; *hep*, haplustept; *hol*, haplustoll; *ust*, ustifluvent; *ucr*, ustochrept; *awc*, soil available water capacity; *om*, soil organic matter. The bottom portion of the table has summary statistics calculated from the values in the upper portion. *avg*, average; *min*, minimum; *max*, maximum; *med*, median.

Table 14 site name	Site ID	occupied plots # herb spp	# understory spp	# overstory spp	dist-to-edge (m)	soil dep (cm)	canopy open (%)	unoccupied comparison plots # herb spp	# understory spp	# overstory spp	dist-to-edge (m)	soil dep (cm)
Barton Creek	bar	4.6	5.7	3.3	-2.2	4.4	25	4.6	5.6	3.3	-3.2	6.1
Cat Mountain	cam	4.0	4.0	1.7	-1.0	7.3	33	3.0	3.0	2.0	0.0	6.9
Eisenhower Park	eis	2.0	6.5	3.3	-0.3	6.2	30	3.0	4.0	1.5	-3.0	9.0
Garner State Park	gsp	4.0	2.6	2.0	-2.2	6.0	30	3.5	2.3	2.0	-2.3	4.4
Medina 1	mmd	4.7	7.7	1.7	-0.7	5.2	34	4.0	6.0	1.5	-1.5	7.9
Medina 2	mnl	2.0	5.0	1.6	1.6	3.7	61	3.0	6.3	1.3	1.7	3.3
Medina 3	msd	3.3	3.8	1.0	1.8	2.3	78	3.5	5.5	2.0	1.3	3.4
Medina 4	mfm	7.0	5.0	1.0	1.3	2.1	3	4.0	6.0	2.0	1.0	1.9
Mount Bonnell	mtb	4.7	5.5	2.5	-3.5	6.8	34	2.0	4.0	4.0	-4.0	9.8
Rancho Diana	rad	5.0	5.8	1.4	0.2	3.8	57	6.7	6.0	1.3	1.3	4.0
Ullrich WTP	ull	5.8	6.7	2.5	-2.6	5.0	30	3.3	6.0	3.7	-3.7	6.8
Valburn	val	6.4	3.6	2.4	-2.6	5.8	26	2.5	3.0	3.0	-4.0	8.4
summary (N=12 sites)												
	avg	4.4	5.2	2.0	-0.8	4.9	37	3.6	4.8	2.3	-1.4	6.0
	min	2.0	2.6	1.0	-3.5	2.1	3	2.0	2.3	1.3	-4.0	1.9
	max	7.0	7.7	3.3	1.8	7.3	78	6.7	6.3	4.0	1.7	9.8
	med	4.6	5.3	1.8	-0.8	5.1	32	3.4	5.6	2.0	-1.9	6.4

Table 14. Summary of information collected from **occupied and comparison unoccupied plots** in 12 sites (vegetation survey) and **canopy openness**. All values except canopy openness are averages of the plots in a site that were occupied by *Streptanthus bracteatus* (left portion of the table) or averages of the unoccupied comparison plots at the same site (right portion of the table). *spp*, species present at the time of data collection. *herb*, herbaceous plants, including succulents and non-woody vines; *understory*, woody plants < 2 m tall; *overstory*, woody plants > 2m tall; *dist-to-edge*, average distance from the plot center to the nearest edge between continuous tree canopy and open area. A plot under the canopy of a tree received a negative value of *dist-to-edge*; a plot not under a canopy received a positive value. *soil dep*, average depth to refusal (see Methods). *canopy open*, average canopy openness, i.e., average of percentage of 'sky pixels' as a total of all pixels in hemispherical photographs taken at each site (see Methods). The bottom portion of the table has summary statistics calculated from the values in the upper portion. *avg*, average; *min*, minimum; *max*, maximum; *med*, median.

Table 15 species code	species Name	common name	synonym	classification (woody or herbaceous[1])
abin	*Abutilon incanum*	Indian mallow		h
acbe	*Acacia berlandieri*	guajillo		w
acph	*Acalypha phleoides*	shrubby copperleaf		h
acra	*Acalypha radians*	cardinal's feather		h
acro	*Acacia roemeriana*	Roemer catclaw		w
acru	*Acourtia runcinata*	peonia	*Perezia runcinata*	h
aepa	*Aesculus pavia*	red buckeye		w
agha	*Ageratina havanensis*	Havana snakeroot	*Eupatorium havanense*	w
anme	*Anemia mexicana*	Mexican fern		h
arpe	*Arabis petiolaris*	rockcress		h
arpu	*Aristida purpurea*	purple threeawn		h
arsi	*Argythamnia simulans*	Plateau silverbush		h
bemy	*Bernardia myricifolia*	mouse ears		w
betr	*Berberis trifoliolata*	agarita	*Mahonia trifoliolata*	w
bocu	*Bouteloua curtipendula*	sideoats grama		h
boda	*Bouteloua dactyloides*	buffalograss	*Buchloe dactyloides*	h
bohi	*Bouteloua hirsuta*	hairy grama		h

bois	*Bothriochloa ischaemum*	King Ranch bluestem		h
capl	*Carex planostachys*	cedar sedge		h
cavi	*Calyptocarpus vialis*	straggler daisy		h
ceca	*Cercis canadensis*	redbud		w
cere	*Celtis laevigata var. reticulata*	netleaf hackberry		w
chme	*Chrysactinia mexicana*	damianita		h
chpr	*Chamaesyce prostrata*	prostrate sandmat		h
chte	*Chaptalia texana*	silver puff	*Chaptalia nutans*	h
coer	*Commelina erecta*	whitemouth dayflower		h
coho	*Condalia hookeri*	Brazilian bluewood		w
cote	*Colubrina texensis*	Texas hogplum		w
crfr	*Croton fruticulosus*	bush croton		h
crmo	*Croton monanthogynus*	prairie tea		h
cyba	*Cynanchum barbigerum*	bearded swallow-wort		h
date	*Dasylirion texanum*	Texas sotol		w
disp	*Dichanthelium sp.*	winter panicgrass		h
dite	*Diospyros texana*	Texas persimon		w
ersp	*Erigeron sp.*	fleabane		h
eucy	*Euphorbia cyathophora*	fire on the mountain		h

eyte	*Eysenhardtia texana*	Texas kidneywood		w
fopu	*Forestiera pubescens*	elbowbush		w
fore	*Forestiera reticulata*	netleaf swampprivet		w
frpe	*Fraxinus pennsylvanica*	green ash		w
frte	*Fraxinus texensis*	Texas ash	*Fraxinus americana var. texensis*	w
gaap	*Galium aparine*	cleavers		h
gaov	*Garrya ovata*	Lindheimer's silktassel		w
giin	*Giliastrum incisum*	cutleaf gilia	*Gilia incisa*	h
gygl	*Gymnosperma glutinosum*	gumhead		w
hete	*Heliotropium tenellum*	white heliotrope		h
ilvo	*Ilex vomitoria*	yaupon		w
ipli	*Ipomoea lindheimeri*	Lindheimer's morning glory		h
juas	*Juniperus ashei*	Ashe juniper		w
jupi	*Justicia pilosella*	Gregg's tubetongue		h
laho	*Lantana urticoides*	Texas lantana	*Lantana horrida*	w
lefr	*Leucophyllum frutescens*	purple sage, cenizo		w
lete	*Lespedeza texana*	Texas lespedeza		h
liru	*Linum rupestre*	rock flax		h
madr	*Malvaviscus arboreus var. drummondii*	Turk’s cap	*Malvaviscus drummondii*	h

mare	*Matelea reticulata*	netted milkvine		h
mefi	*Meximalva filipes*	Texas fan		h
mepo	*Medicago polymorpha*	bur clover		h
mibo	*Mimosa borealis*	fragrant mimosa		w
mure	*Muhlenbergia reverchonii*	seep muhly		h
nado	*Nandina domestica*	heavenly bamboo		w
noli	*Nolina lindheimeriana*	devil's shoestring		h
note	*Nolina texana*	Texas sacahuista		h
opli	*Opuntia lindheimeri*	Texas pricklypear	*Opuntia engelmannii var lindheimeri*	h
pape	*Parietaria pensylvanica*	pellitory		h
pasp	*Panicum sp.*	panicgrass		h
phco	*Phacelia congesta*	blue curls		h
poli	*Polygala lindheimeri*	shrubby milkwort		h
pttr	*Ptelea trifoliata*	wafer ash		w
qubu	*Quercus buckleyi*	Texas red oak		w
qusi	*Quercus sinuata*	shin oak		w
qust	*Quercus stellata*	post oak		w
quvi	*Quercus virginiana var. fusiformis*	Plateau live oak	*Quercus fusiformis*	w

rhar	*Rhus aromatica*	aromatic sumac		w
rhla	*Rhus lanceolata*	flameleaf sumac		w
rhvi	*Rhus virens*	evergreen sumac		w
runu	*Ruellia nudiflora*	wild petunia		h
saba	*Salvia ballotiflora*	shrubby blue sage		w
saro	*Salvia roemeriana*	cedar sage		h
scdr	*Scutellaria drummondii*	Drummond's skullcap		h
scsc	*Schizachyrium scoparium*	little bluestem		h
seli	*Senna lindheimeriana*	velvetleaf senna		w
sesc	*Setaria scheelei*	southwestern bristlegrass		h
siab	*Sida abutifolia*	spreading fanpetals	*Sida filicaulis*	h
sila	*Sideroxylon lanuginosum*	gum bully, gum bumelia		w
smbo	*Smilax bona-nox*	saw greenbrier		h
sose	*Sophora secundiflora*	mescal bean		w
sotr	*Solanum triquetrum*	Texas nightshade		h
syla	*Symphyotrichum lanceolatum*	white panicle aster		h
tora	*Toxicodendron radicans*	poison ivy		w
trbe	*Tragia betonicifolia*	betonyleaf noseburn		h
trbr	*Tragia brevispica*	shortspike noseburn		h

trra	*Tragia ramosa*	branched noseburn		h
trmu	*Tridens muticus var. muticus*	slim tridens		h
ulcr	*Ulmus crassifolia*	cedar elm		w
unkn	unknown			h
unsp	*Ungnadia speciosa*	Mexican buckeye		w
vide	*Viguiera dentata*	sunflower goldeneye		h
wete	*Wedelia texana*	hairy wedelia		h
wiho	*Allowissadula holosericia*	false Indianmallow	*Wissadula holosericea*	h
yuru	*Yucca rupicola*	twisted-leaf yucca		h
zehi	*Zexmenia hispida*	orange zexmenia	*Wedelia texana, W. hispida*	h
[1] succulents and non-woody vines were classified with herbaceous species; category is labeled 'herbaceous' for convenience				

Table 15. Vascular plant species recorded in the occupied plots and comparison unoccupied plots. Species in the 'herbaceous' category, including succulents and non-woody vines, were recorded only in the 0.5 m radius plots.

Table 16	site code														
species code	bar	cam	eis	gsp	mfm	mmd	mnl	msd	mtb	rad	ull	val	# of sites with species	# of plots with species	% plots with species
(a) herbaceous species (including succulents and non-woody vines)															
abin	3												1	3	4
acra								1					1	1	1
acru									1		1		2	2	2
anme				1									1	1	1
arpe					1								1	1	1
arpu	1		1		3	1		2		5	1		7	14	17
arsi	1												1	1	1
bocu					1	1		1		2			4	5	6
bois								1					1	1	1
capl	2	2	2	4		1	1		4	1	1	7	10	25	31
cavi									1			3	2	4	5
chme					1					3			2	4	5
chpr	4								1				2	5	6
chte	4	1								2			3	7	9
coer	3				1		1		4		3		5	12	15
crfr					2	2			1			2	4	7	9
crmo		1		1						4			3	6	7

cyba								1	1		4		3	6	7
disp	10		1	2	2				1		4	4	7	24	30
ersp										1			1	1	1
eucy	10	1		1				2	2	2	10		7	28	35
gaap	1												1	1	1
giin	2	1			1					4	5	1	6	14	17
hete				2									1	2	2
ipli	1												1	1	1
jupi								1			2		2	3	4
lete										1			1	1	1
liru				2									1	2	2
madr	5								1	1	3		4	10	12
mare	2		1						1			2	4	6	7
mefi								1					1	1	1
mepo											1		1	1	1
noli	1												1	1	1
note									1		1		2	2	2
opli						1						1	2	2	2
pape	17	2			1	2			3	6	10	6	8	47	58
pasp										3			1	3	4
phco	5						2	1		2	1		5	11	14
poli	2				1	1						5	4	9	11

runu						2							1	2	2
saro	1	1		1							3		4	6	7
scdr	2		1		1			1		6	1	7	7	19	23
scsc	3				2						3		3	8	10
sesc							2						1	2	2
siab						1				1		1	3	3	4
smbo		1											1	1	1
sotr	2												1	2	2
trbe	1	1		1					1		2	1	6	7	9
trbr	2			1						1	2		4	6	7
trra					1								1	1	1
unkn				4									1	4	5
vide	5	1							4			9	4	19	23
wiho							1						1	1	1
yuru			1				1	1	1				4	4	5
zehi	1		1		3	2	2			5		2	7	16	20
(b) understory woody species															
acbe				1									1	1	3
acro			1			1	3	4		3			5	12	32
aepa	1												1	1	3
agha	4					2			1		3	1	5	11	30

bemy	7			1		2		1			1		5	12	32
betr	7		2				1			1	1		5	12	32
ceca						1							1	1	3
cere								1					1	1	3
cote	3										1		2	4	11
date							3			2			2	5	14
dite	8	1	2	2	1	1	1			3		2	9	21	57
eyte	1							2		1			3	4	11
fopu	2									1			2	3	8
fore				3	1		1						3	5	14
gaov	1						1		1		3		4	6	16
gygl					1								1	1	3
juas	4	1	1	1		1	1	2		1			8	12	32
laho									1				1	1	3
lefr	2												1	2	5
mibo												1	1	1	3
nado											1		1	1	3
pttr	6				1						2		3	9	24
qubu												1	1	1	3
qusi							1				1		2	2	5
quvi	5					1	1	1					4	8	22
rhar	1										1		2	2	5

rhvi	3	1	1				2	4		2		1	7	14	38
saba								3					1	3	8
seli			1				2	3		1			4	7	19
sose	6			1	1	2	3	2	1	3	3		9	22	59
tora						1							1	1	3
unsp	1				1						1		3	3	8
(b) overstory woody species															
acro							1			2			2	3	4
cere	1		1										2	2	2
coho	1												1	1	1
dite	12		1				1		2	2	2		6	20	25
frpe											1	2	2	3	4
gaov									1			2	2	3	4
juas	20	3	4	5	3	3	4	2	6	6	10	8	12	74	91
pttr	1										1	1	3	3	4
qubu	3	2		1								2	4	8	10
qusi	1			1								2	3	4	5
qust	1												1	1	1
quvi	17		3	3		2	1	2	3		9	2	9	42	52
rhvi	1								1				2	2	2
sose	4						1		2	3	2		5	12	15

ulcr	3		4										2	7	9

Table 16. Species present in each site in the occupied plots. See Table 15 for species codes and Table 1 for site ID codes. Note that the same woody species may appear both as an understory species and as an overstory species in the same site.

Table 17	site code													
species code	bar	cam	eis	gsp	mfm	mmd	mnl	msd	mtb	rad	ull	val	# of sites with species	# of plots with species	% plots with species
(a) herbaceous species (including succulents and non-woody vines)															
abin					1								1	1	3
acph	2												1	2	5
acra							1	1					2	2	5
acru	4										1		2	5	14
anme				2									1	2	5
arpu							2	3		2			3	7	19
arsi	2												1	2	5
bocu					1			2		2			3	5	14
boda										1			1	1	3
bohi	1												1	1	3
capl	2	1	1	4		1	1			1	1	1	9	13	35
chpr	1												1	1	3
coer	3								1		1		3	5	14
crfr					1		1	1					3	3	8
crmo						1				2	1		3	4	11
disp	4		1					1		1		2	5	9	24
eucy	5						1				1		3	7	19

giin	2		1							1			3	4	11
hete				1			1						2	2	5
jupi											1		1	1	3
laho									1				1	1	3
liru				1									1	1	3
madr	1								1		1		3	3	8
mare	4	1											2	5	14
mure										2			1	2	5
pape	9		1							2	1		4	13	35
pasp	1												1	1	3
phco	1							1					2	2	5
poli	1										1	1	3	3	8
runu						2							1	2	5
saro				1								1	2	2	5
scdr			1					1		1			3	3	8
scsc			1	1			1				1		4	4	11
siab					1			2		2			3	5	14
smbo						1							1	1	3
sotr	1												1	1	3
syla						2							1	2	5
trbe		1											1	1	3
trbr	1			1									2	2	5

trmu	2									1			2	3	8
unkn				2									1	2	5
vide	4												1	4	11
wete						1							1	1	3
yuru				1						1			2	2	5
zehi							1	2		1			3	4	11
(b) understory woody species															
acbe				1									1	1	3
acro			1			1	3	4		3			5	12	32
aepa	1												1	1	3
agha	4					2			1		3	1	5	11	30
bemy	7			1		2		1			1		5	12	32
betr	7		2				1			1	1		5	12	32
ceca						1							1	1	3
cere								1					1	1	3
cote	3										1		2	4	11
date							3			2			2	5	14
dite	8	1	2	2	1	1	1			3		2	9	21	57
eyte	1							2		1			3	4	11
fopu	2									1			2	3	8
fore				3	1		1						3	5	14

gaov	1						1		1		3		4	6	16
gygl					1								1	1	3
juas	4	1	1	1		1	1	2		1			8	12	32
laho									1				1	1	3
lefr	2												1	2	5
mibo												1	1	1	3
nado											1		1	1	3
pttr	6				1						2		3	9	24
qubu												1	1	1	3
qusi							1				1		2	2	5
quvi	5					1	1	1					4	8	22
rhar	1										1		2	2	5
rhvi	3	1	1				2	4		2		1	7	14	38
saba								3					1	3	8
seli			1				2	3		1			4	7	19
sose	6			1	1	2	3	2	1	3	3		9	22	59
tora						1							1	1	3
unsp	1				1						1		3	3	8
(b) overstory woody species															
acro								1		1			2	2	5
cere					1			1					2	2	5

dite	8								1	1	2		4	12	32
frpe											1		1	1	3
frte											1		1	1	3
juas	11	1	2	4	1	2	3	4	1	2	3	2	12	36	97
qubu	1			2							2	2	4	7	19
qusi				1								1	2	2	5
quvi	8	1	1	1		1	1	2	1		2	1	10	19	51
sila	1												1	1	3
sose	5								1				2	6	16
ulcr	2												1	2	5

Table 17. Species present in each site in the unoccupied plots. See Table 15 for species codes and Table 1 for site ID codes. Note that the same woody species may appear both as an understory species and as an overstory species in the same site.

Table 18 site name	site ID	avg height (cm)	avg silnum[1]	avg silsum (cm)[1]	% rep	% stem herb	% leaf herb	% fruit herb	% no herb	% in excl	% mildew
Barton Creek	bar	40.2	2.6	13.0	42	42	48	17	10	1	41
Cat Mountain	cam	47.1	2.4	19.0	43	83	0	3	1	20	90
Eisenhower Park[2]	eis	43.0	2.1	*	38	*	*	*	*	100	*
Garner State Park	gsp	34.8	3.4	19.6	73	42	81	4	8	0	15
Medina 1	mmd	42.2	2.1	16.8	17	74	0	14	0	0	60
Medina 2	mnl	*	*	*	*	*	*	*	*	0	*
Medina 3	msd	*	*	*	*	*	*	*	*	0	*
Medina 4	mfm	*	*	*	*	*	*	*	*	0	*
Mount Bonnell	mtb	45.0	1.9	10.3	67	24	56	28	14	0	19
Rancho Diana	rad	24.9	2.7	*	26	*	*	*	*	0	39
Ullrich WTP	ull	61.2	3.1	26.0	51	52	25	11	2	99	73
Valburn	val	31.4	2.5	15.7	81	35	44	14	8	0	22
summary (N=7 to 12 sites)											
	avg	41.1	2.5	17.2	49	50	36	13	6	18	45
	min	24.9	1.9	10.3	17	24	0	1	0	0	15
	max	61.2	3.4	26.0	81	83	81	28	14	100	90
	med	42.2	2.5	16.8	43	42	44	14	8	0	40

[1] average of plants with at least one silique > 0.5 cm
[2] does not include plants, if any were present, outside the Park boundary
* data not collected

Table 18. Summary of **information collected from individual plants** at each site. Calculated from data collected in 2012; see Table M3 for names of data collectors. The bottom portion has summary statistics calculated from the values in the upper portion. For example, 41.1 cm height is the average of nine site averages, not the overall average of all plants in the study; this gives equal weight to each site in spite of differences among sites in numbers of plants present. Only plants with at least one silique > 0.5 cm long were included in the calculations of average number of siliques/plant and and average summed silique length/plant for this table. *silnum*, average number of siliques per plant; *silsum*, average of summed total length of all siliques on a plant. To calculate *silsum*, the lengths of all siliques on a single plant were added together, and then these sums were averaged across reproductive plants in a site. *% rep*, percentage of plants that formed at least one silique > 0.5 cm long. *% stem herb*, *% leaf herb*, etc, percentage of plants with visible herbivory of that type; *% mildew*, percentage of plants with visible powdery mildew; *% in excl*, percentage of plants in herbivore exclosures; *avg*, average; *min*, minimum; *max*, maximum; *med*, median.

Table 19 site name	Site ID	geo boundary horiz dist (m)	geo boundary vert dist (m)	soils pH	soils awc	soils % om	soils % clay	topography avg slope (%)	topography min slope (%)	topography max slope (%)	topography avg elev (m)	topography min elev (m)	topography max elev (m)
Barton Creek	bar	132	-14	8.0	0.09	1.58	15	22	0	40	184	175	203
Cat Mountain	cam	261	-44	7.9	0.12	2	25	15	1	24	191	183	197
Eisenhower Park	eis	84	0	7.5	0.08	6.5	50	6	6	6	364	364	364
Garner State Park[1]	gsp	105	-35	8.2	0.08	6	31	15	14	15	457	456	459
Medina 1	mmd	1856	27	7.5	0.08	6.5	50	0	0	0	332	332	332
Medina 2	mnl	75	6	7.5	0.08	6.5	50	7	0	13	399	383	412
Medina 3	msd	83	9	7.5	0.08	6.5	50	8	6	10	384	383	384
Mount Bonnell	mtb	278	24	7.9	0.12	2	25	14	0	25	239	238	239
Rancho Diana	rad	299	37	7.5	0.08	6.5	50	14	14	14	381	381	381
Ullrich WTP	ull	6	0	7.9	0.08	4.5	50	15	0	30	156	150	168
Valburn	val	73	-16	7.9	0.12	2	25	18	0	36	238	221	246
summary (N=11 sites)													
	avg	296	-1	7.7	0.09	4.60	38.2	12	4	19	302	297	308
	min	6	-44	7.5	0.08	1.58	15.4	0	0	0	156	150	168
	max	1856	37	8.2	0.12	6.50	50.0	22	14	40	457	456	459
	med	105	0	7.9	0.08	6.00	50.0	14	0	15	332	332	332

[1] geological boundary is between the Devils River Formation and the Glen Rose Formation

Table 19. **Geological, soil, and topographic variables from 2012 census locations**. The top portion of this table has site averages, calculated from the values at the location of each *Streptanthus bracteatus* plant (not plots) in 2012. The bottom portion has summary statistics calculated from the values in the upper portion. Values were obtained or calculated from USGS geological and topographic maps and USDA Soil Web Survey data. *geo boundary*, the Edwards Formation - Glen Rose Formation (or the Devils River Formation - Glen Rose Formation boundary, in Garner State Park); *horiz dist*, horizontal distance to the nearest Glen Rose Formation - Edwards Formation boundary or the nearest Glen Rose Formation - Devils River Formation boundary. The Devils River Formation replaces the Edwards Formation in the westernmost part of the range of *Streptanthus bracteatus*. *vert dist*, vertical distance to the same boundary. Negative vertical distances were assigned to each plant below this boundary. *awc*, soil available water capacity; *om*, soil organic matter; *elev*, elevation; *avg*, average; *min*, minimum; *max*, maximum; *med*, median.

Table 20 site name	site ID	avg # siliques /plant	# plants[1]	# siliques /population
Barton Creek	bar	1.08	434	470
Cat Mountain	cam	1.05	212	222
Eisenhower Park	eis	0.80	40	32
Garner State Park	gsp	2.46	26	64
Medina 1	mmd	0.36	81	29
Mount Bonnell	mtb	1.24	21	26
Rancho Diana	rad	1.04	92	96
Ullrich WTP	ull	1.58	92	145
Valburn	val	2.00	84	168
summary (N = 9 sites)				
	avg	1.29	120	139
	med	1.08	84	96
[1] excluding rosette plants at Rancho Diana				

Table 20. Average silique number per plant (zeros included), and siliques/population.

Figures

Fig. 1. Schematic diagram of a vegetation survey plot.

Fig. 2. Schematic diagram of locations of soil depth measurements.

Fig. 3. Ullrich WTP site map, showing GDJ-defined occupied area, TPWD-defined occupied area and plant locations in 2012 census

Fig. 4. Occupied areas and total areas, with 10 and 50 m buffers defining the unoccupied areas, and the definitions of occupied areas, for all sites.

Fig. 5. Average, minimum, and maximum horizontal distance from the geological boundary at each site.

Fig. 6. Average, minimum, and maximum vertical distance from the geological boundary at each site.

Fig. 7. Map of known sites, and 2 km and 9.3 km distances to the Edwards Formation – Glen Rose Formation or the Devils River Formation – Glen Rose Formation boundary.

Fig. 8. Aspect of each site, using different definitions of occupied and unoccupied area.

Fig. 9. Average, minimum, and maximum slope at each site.

Fig. 10. Within-site variation in silique number in relationship to vertical distance from the geological boundary.

Fig. 11. Demographic variables versus average distance to canopy edge. The more negative, the further under the canopy; positive values are outside the canopy. Reproductive plants are those with at least one silique.

Fig. 12. Demographic variables versus average number of woody understory species per occupied vegetation survey plot. Reproductive plants are those with at least one silique.

Fig. 13. A. Proportion of plants with stem herbivore damage versus distance to canopy edge. The more negative, the further under the canopy; positive values are outside the canopy. We did not have data on herbivory from the two Bexar County populations. B. Proportion of plants that were reproductive versus proportion of plants that had stem herbivory damage.

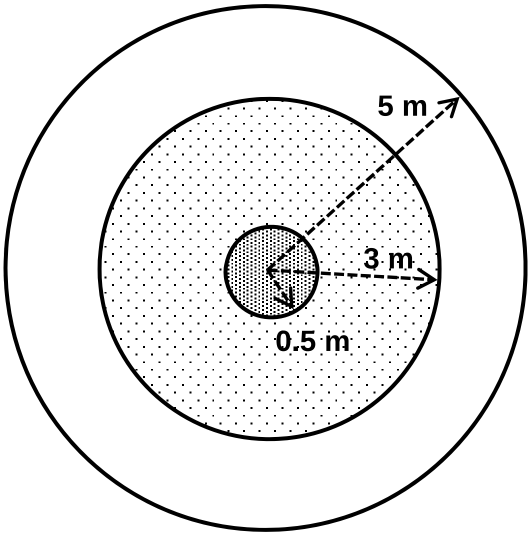


Fig. 1 Layout of vegetation survey plots. Herbaceous plants, shrubs and trees were surveyed within 0.5, 3, and 5 m radius plots, respectively. Not to scale.

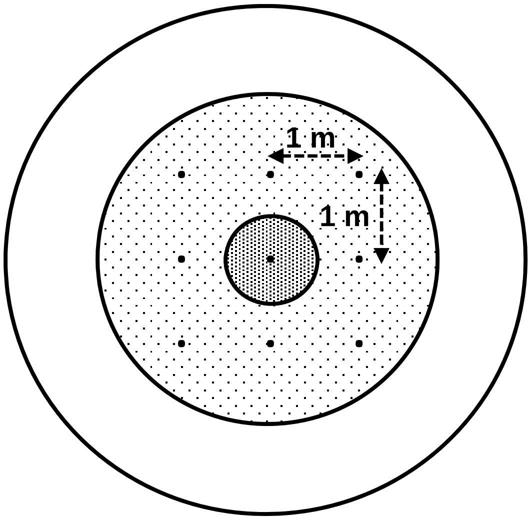


Fig. 2. Locations of soil depth measurements (dark dots) within a vegetation survey plot. Not to scale.

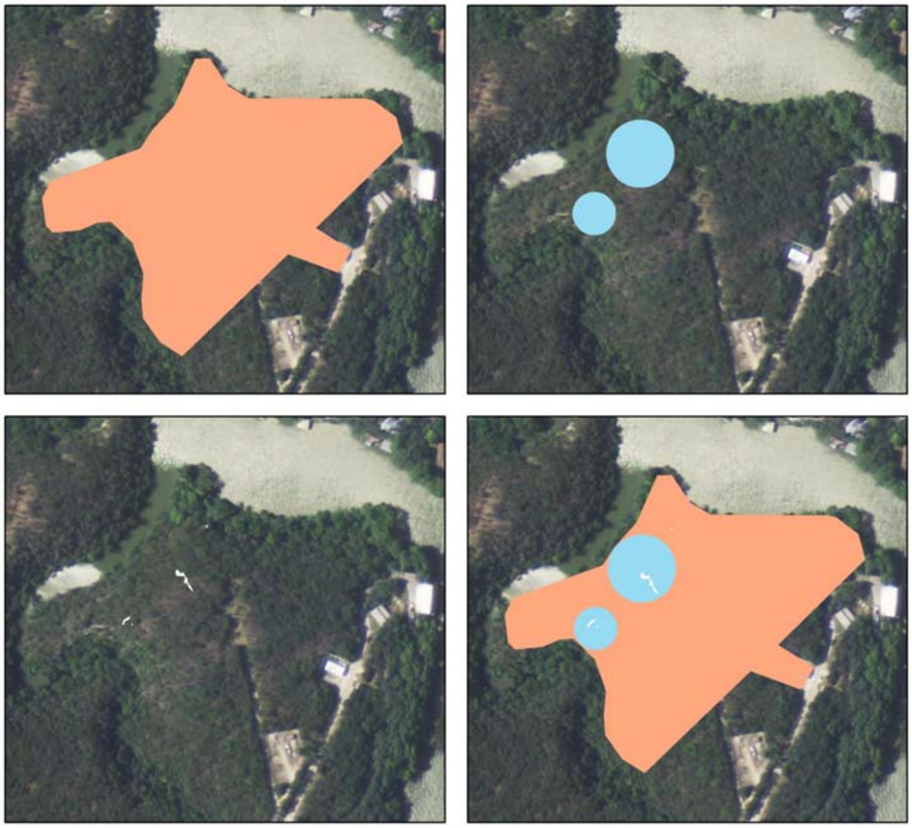


Figure 3. Ullrich WTP site map, showing GDJ-defined occupied area, TPWD-defined occupied area and plant locations in 2012 census. Upper left, TPWD-defined occupied area in orange. Upper right, GDJ-defined occupied area in blue. Lower left, plant locations in 2012 in white. Bottom right, all three layers.

Figure 4

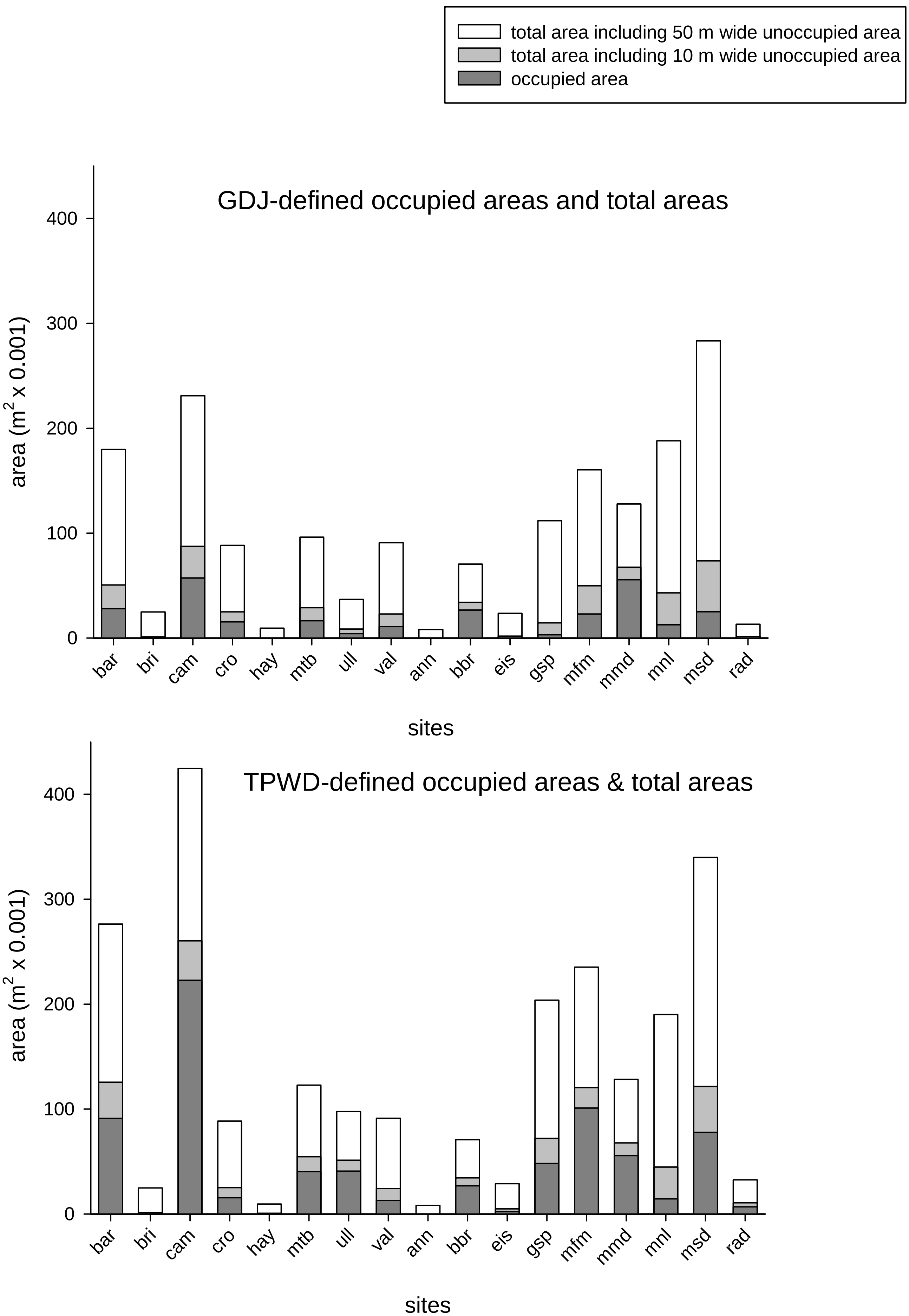

total area including 50 m wide unoccupied area
total area including 10 m wide unoccupied area
occupied area
GDJ-defined occupied areas and total areas
area (m2 x 0.001)
0
100
200
300
400
bar
bri
cam
cro
hay
mtb
ull
val
ann
bbr
eis
gsp
mfm
mmd
mnl
msd
rad
sites
TPWD-defined occupied areas & total areas
area (m2 x 0.001)
0
100
200
300
400
bar
bri
cam
cro
hay
mtb
ull
val
ann
bbr
eis
gsp
mfm
mmd
mnl
msd
rad
sites

Figure 5

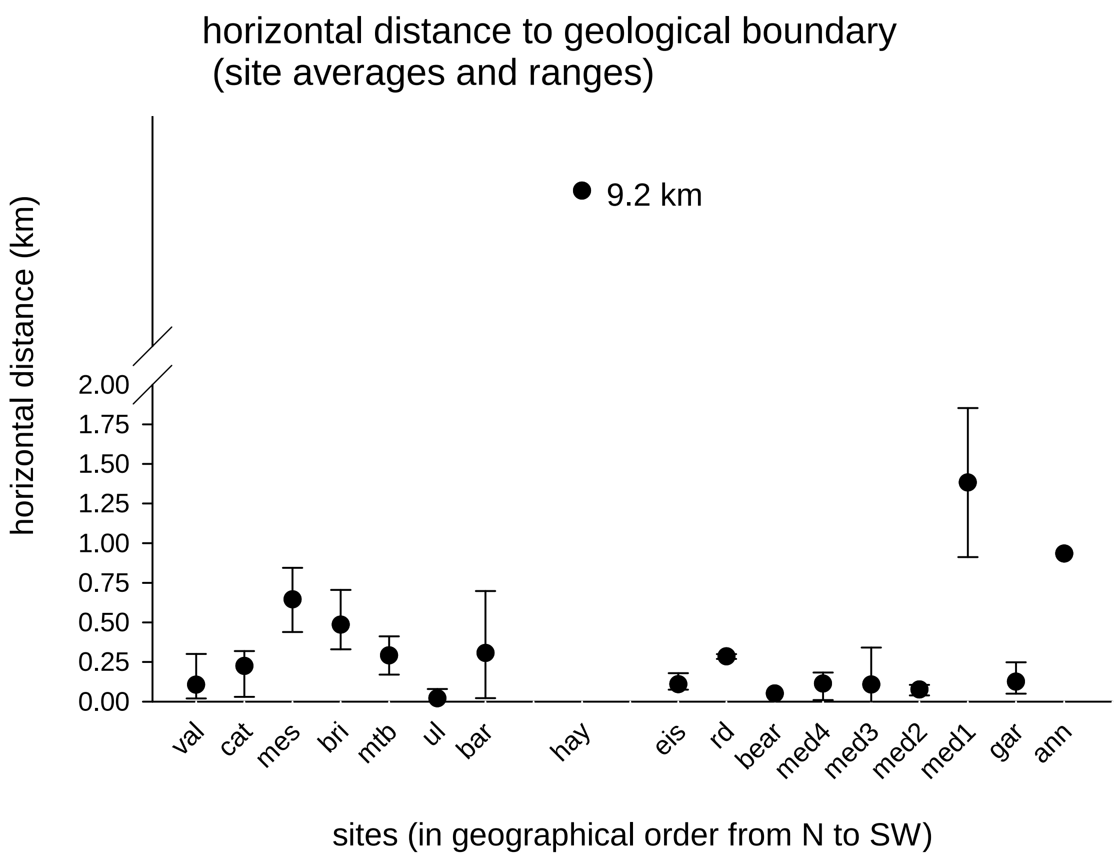
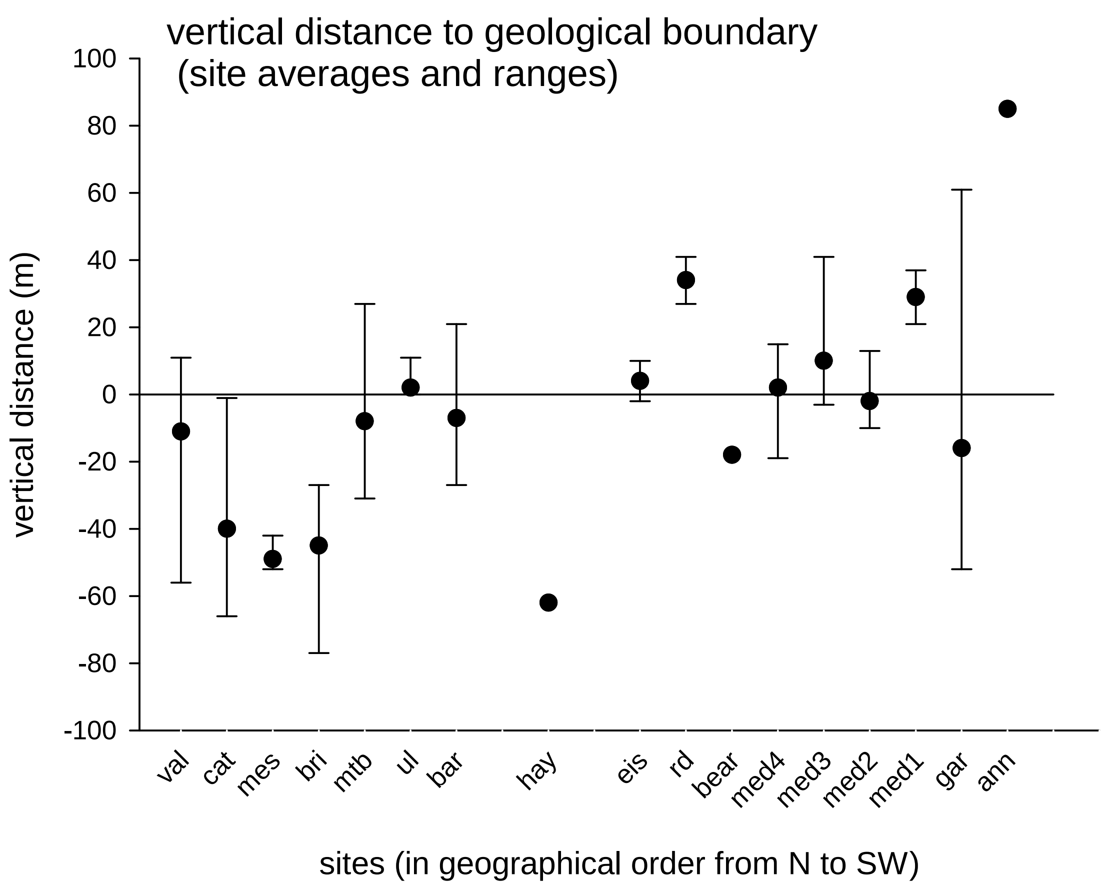

horizontal distance to geological boundary
(site averages and ranges)
9.2 km
horizontal distance (km)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
val
cat
mes
bri
mtb
ul
bar
hay
eis
rd
bear
med4
med3
med2
med1
gar
ann
sites (in geographical order from N to SW)

Figure 6


vertical distance to geological boundary
(site averages and ranges)
vertical distance (m)
100
80
60
40
20
0
-20
-40
-60
-80
-100
val
cat
mes
bri
mtb
ul
bar
hay
eis
rd
bear
med4
med3
med2
med1
gar
ann
sites (in geographical order from N to SW)

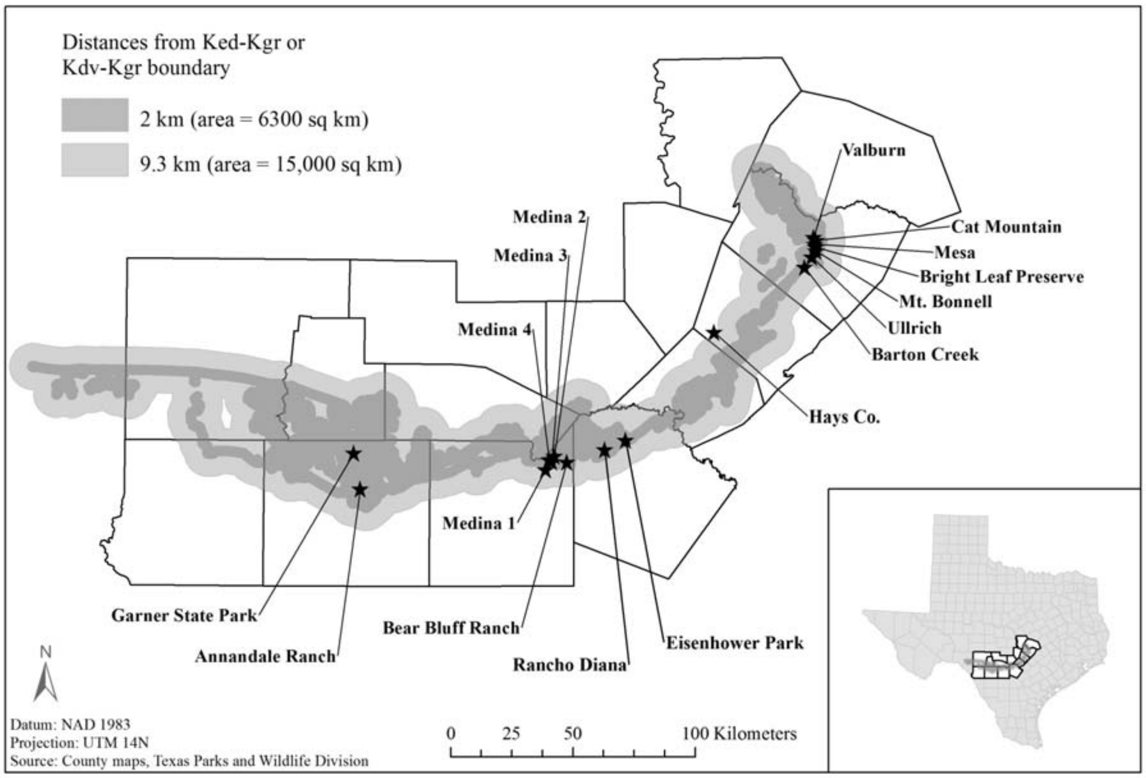
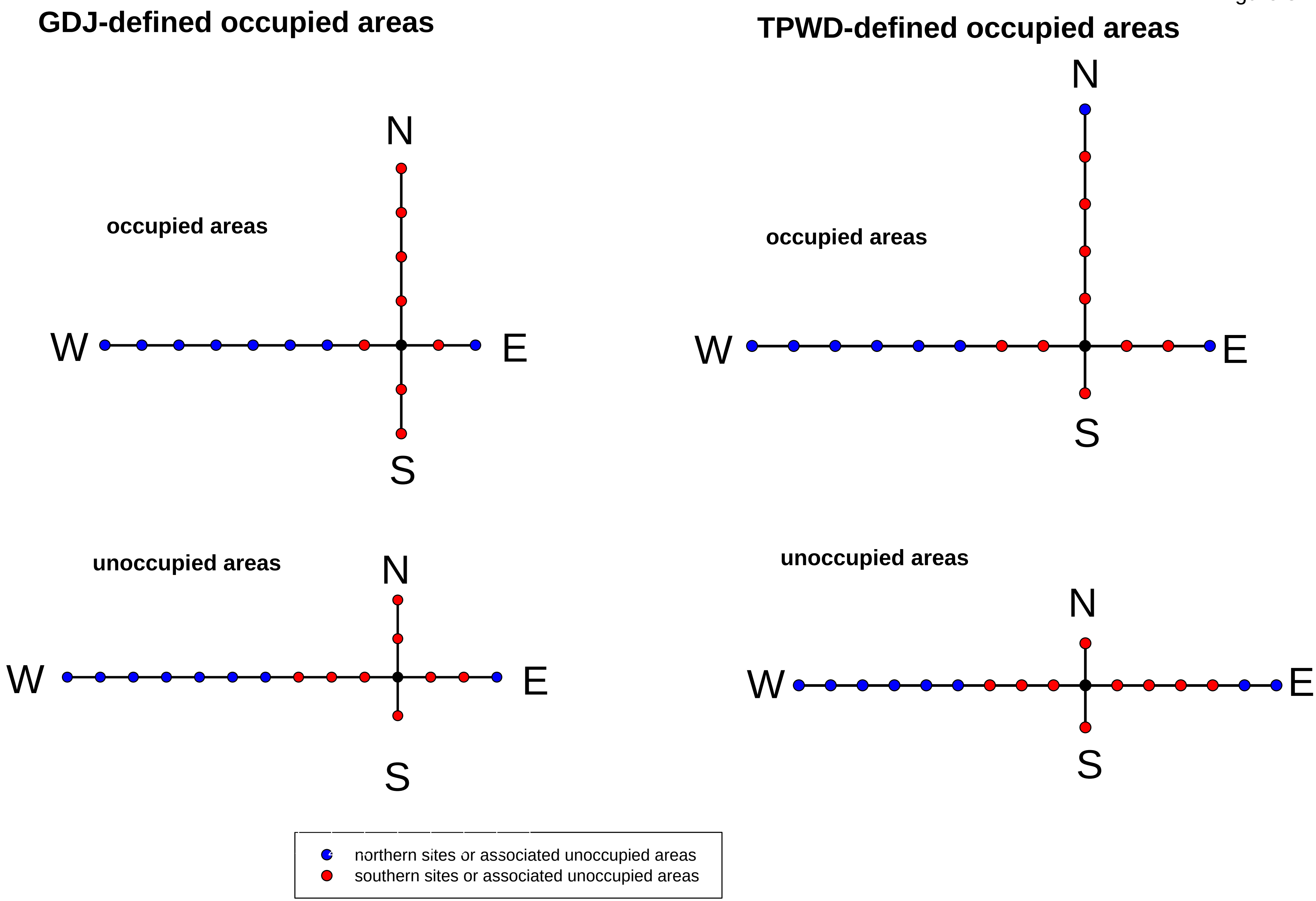
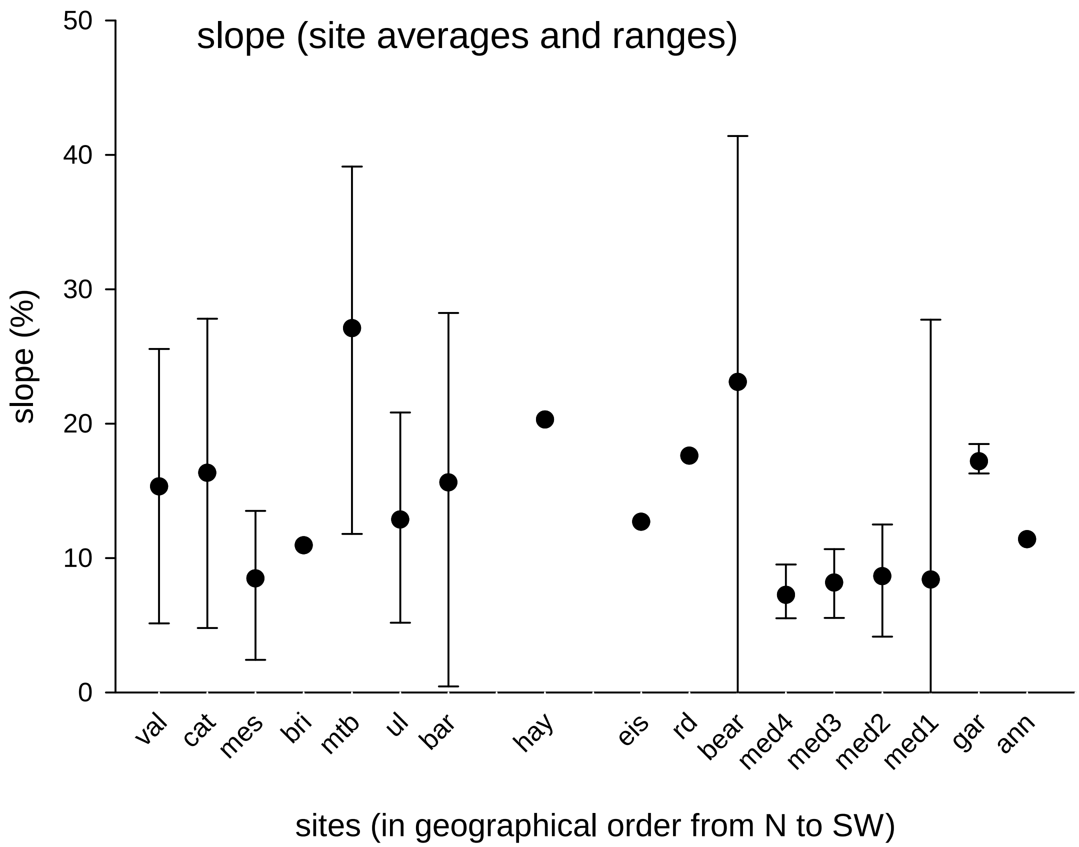


Figure 7. Stars: known sites. Dark shading: 2 km from the Edwards Formation – Glen Rose Formation or the Devils River Formation – Glen Rose Formation boundary. Light shading: 9.3 km from the same boundary.



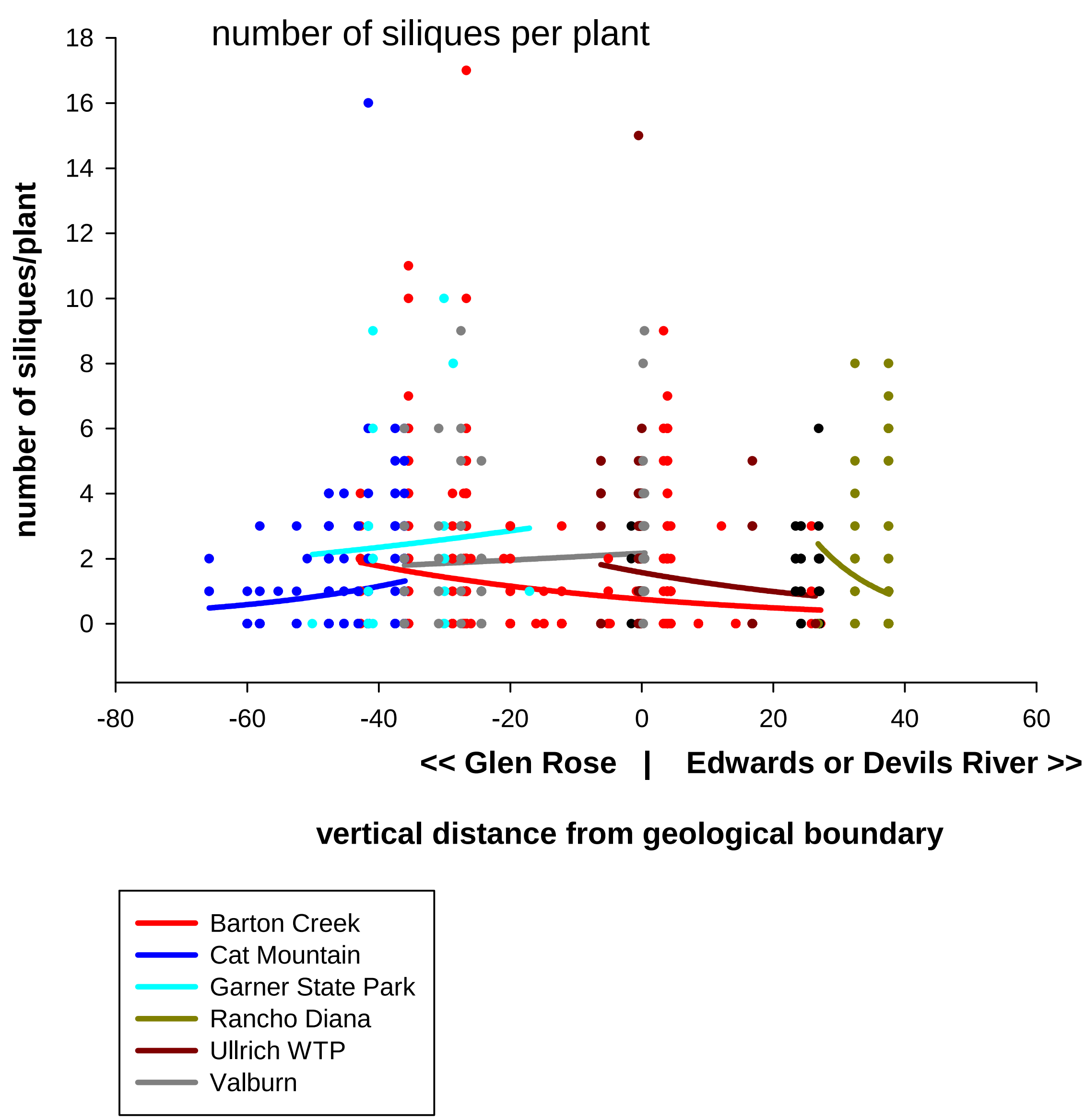
Each dot represents the dominanant aspect of one site (upper diagrams) or the 50 m wide unoccupied area around one site (lower diagrams)

Figure 9



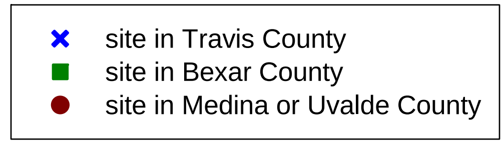
slope (site averages and ranges)
slope (%)
50
40
30
20
10
0
val
cat
mes
bri
mtb
ul
bar
hay
eis
rd
bear
med4
med3
med2
med1
gar
ann
sites (in geographical order from N to SW)

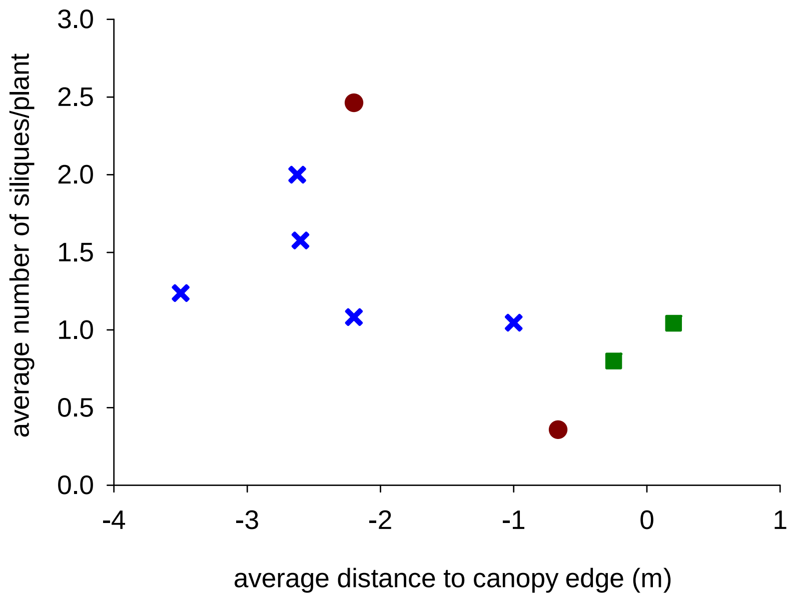
Figure 10



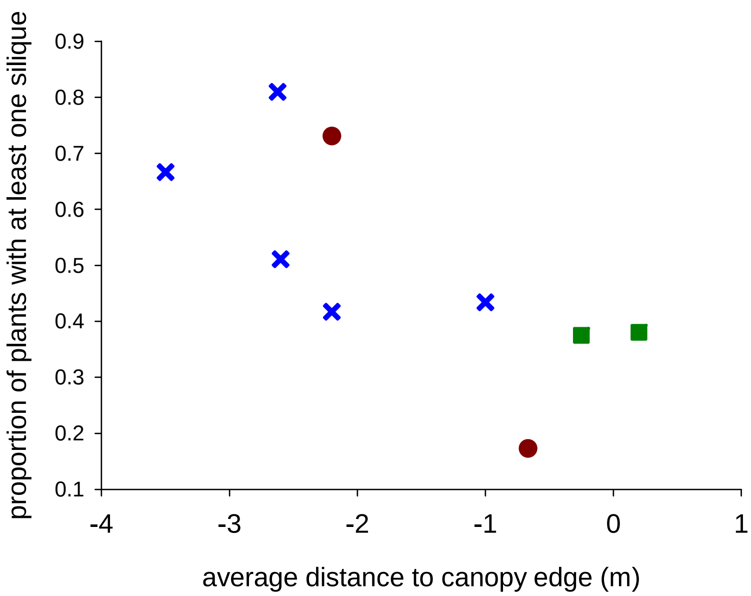
number of siliques per plant
number of siliques/plant
18
16
14
12
10
8
6
4
2
0
-80
-60
-40
-20
0
20
40
60
<< Glen Rose | Edwards or Devils River >>
vertical distance from geological boundary
Barton Creek
Cat Mountain
Garner State Park
Rancho Diana
Ullrich WTP
Valburn

Figure 11

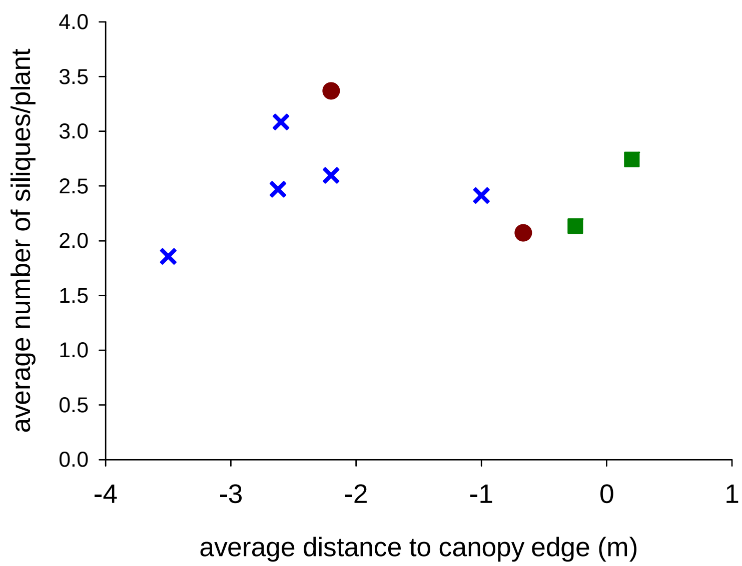




siliques/plant
versus average distance to canopy edge
r_S = -0.72, *P* = 0.03

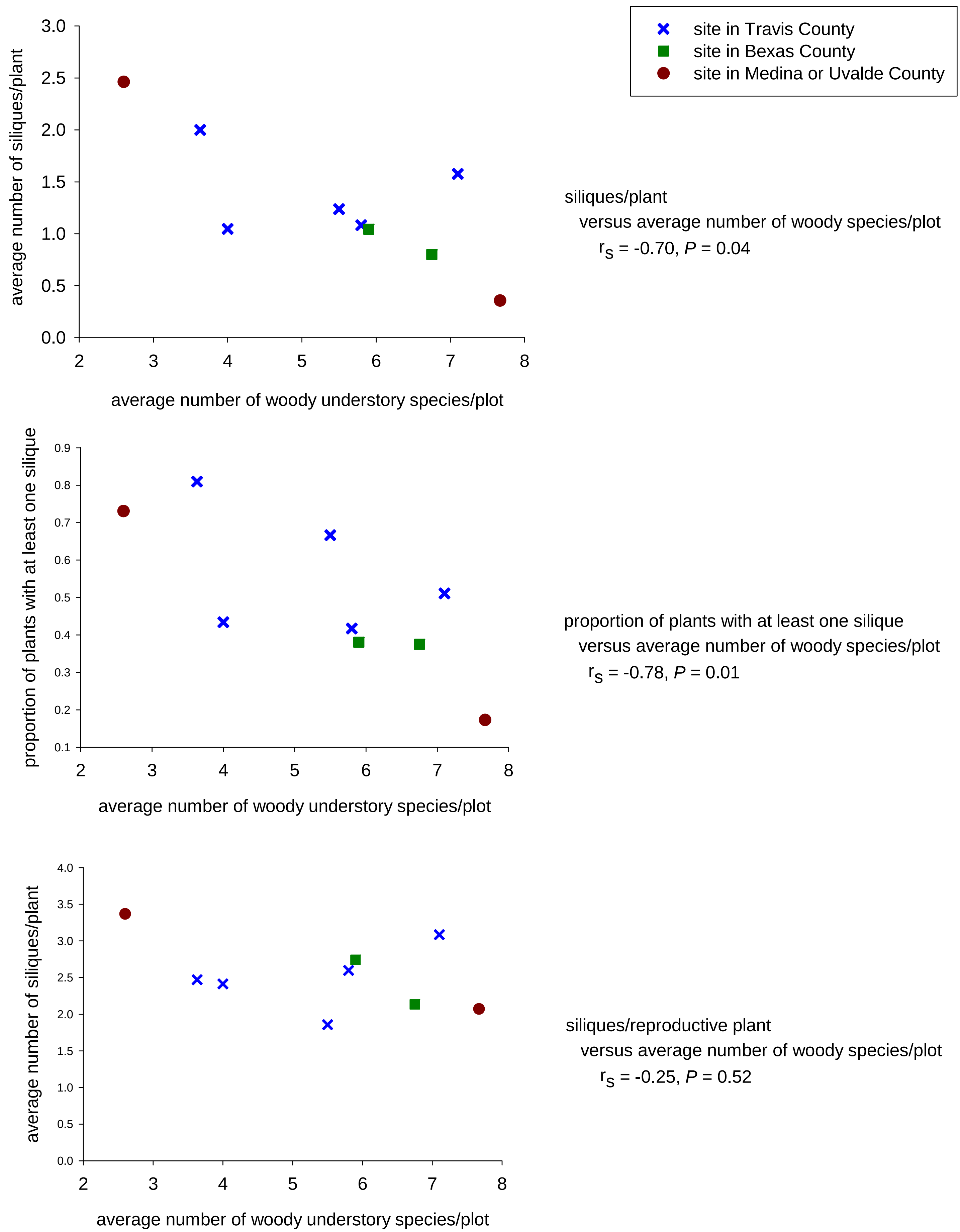


proportion of plants with at least one silique
versus average distance to canopy edge
r_S = -0.77, *P* = 0.02



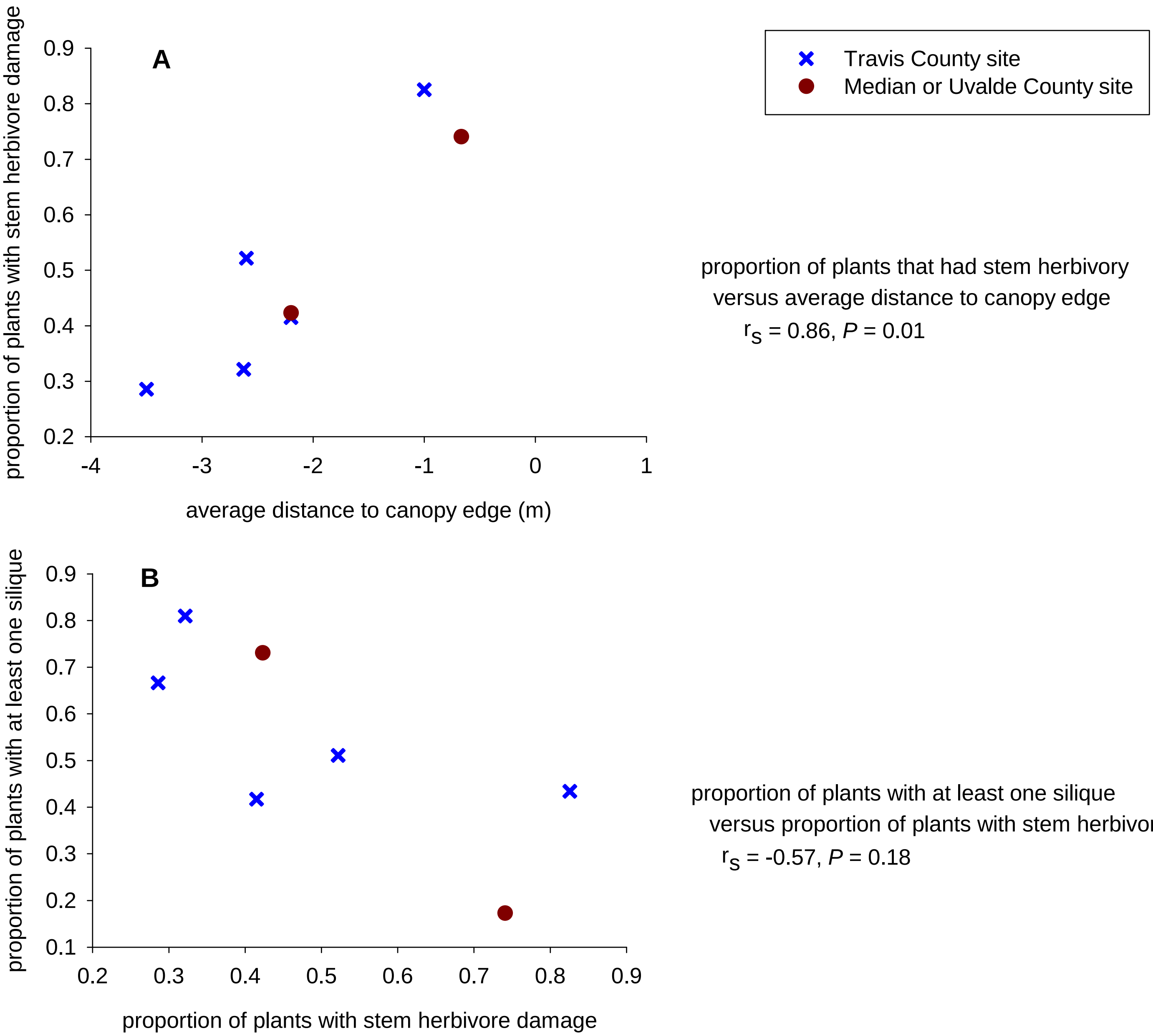
siliques/reproductive plant
versus average distance to canopy edge
r_S = -0.07, *P* = 0.86

Figure 12



site in Travis County
site in Bexas County
site in Medina or Uvalde County
average number of siliques/plant
average number of woody understory species/plot
siliques/plant
versus average number of woody species/plot
r_S = -0.70, *P* = 0.04
proportion of plants with at least one silique
average number of woody understory species/plot
proportion of plants with at least one silique
versus average number of woody species/plot
r_S = -0.78, *P* = 0.01
average number of siliques/plant
average number of woody understory species/plot
siliques/reproductive plant
versus average number of woody species/plot
r_S = -0.25, *P* = 0.52

Figure 13



proportion of plants that had stem herbivory versus average distance to canopy edge
$r_S = 0.86$, $P = 0.01$

proportion of plants with at least one silique versus proportion of plants with stem herbivore damage
$r_S = -0.57$, $P = 0.18$