Mapping and Analysis of Rare Ancient Forests at Ft. Wolters, Texas

Final Report

D.W. Stahle, J.R. Edmondson, and R.D. Griffin
Tree-Ring Laboratory
Department of Geosciences
Ozark Hall 113
University of Arkansas
Fayetteville, AR 72701
479-575-3703
dstahle@uark.edu

October 11, 2007

Figure 1. An open-grown oak woodland at Ft. Wolters, Texas.

Introduction

Ft. Wolters is a 3,985 acre federal property licensed as a training facility to the Texas Army National Guard. This site is located in Parker and Palo Pinto counties near the transition between the Cross Timbers and blackland prairie biogeographical provinces (Kuchler 1964). This site has been heavily utilized for military training since World War II, however, some relatively undisturbed old-growth Cross Timber remnants still remain at this site (Figures 1-9). A network of roads transect the property along with fence lines, power lines, tank trails, firing ranges, and abandoned runways. Despite these impacts, surveys by the University of Arkansas Tree-Ring Laboratory indicate that some 89 hectares (222 acres) of old-growth Cross Timbers remain in several small parcels at Ft. Wolters.

Two locations at Ft. Wolters have particularly impressive remnants of the Cross Timbers. Training area IV, located in the northeast sector of Ft. Wolters, contains the largest parcel of remaining old-growth Cross Timbers (Figures 1-3, 5, 6). The old growth at this site covers some 38.7 hectares (95.7 acres), although it is fragmented by several dirt roads and tank tracks (Figure 3). Much of this site is a level open-grown woodland, with post oaks of all age classes and a dense understory of grasses (Figures 1, 5, 6). The tree species present at this location include post oak (Quercus stellata), blackjack oak (Quercus marilandica), cedar elm (*Ulmus crassifolia*), Texas ash (*Fraxinus texensis*), eastern red cedar (Juniperus virginiana), hawthorne (*Crataegus* sp.), Chittamwood (*Cotinus obovatus),* and hackberry (*Celtis laevigata*).

A second parcel of relatively undisturbed old-growth Cross Timbers is located on a steep, rocky slope in the southwest corner of the property in training area 1A. This remnant is some 4.3 ha in size (10.7 acres), but includes an outstanding example of old-growth post oak-blackjack oak dominated woodlands (Figures 4, 7-9). This report presents the results of our attempt to map these two high quality old-growth parcels on the Fort, to install two fixed plots for long-term forest monitoring within these parcels, and to document the species composition, age structure, and recruitment history of the old-growth woodlands within these plots.

Methods

The boundaries of the two high quality old-growth remnants in training areas IV and 1A were mapped based on field observations and laboratory analysis of aerial photographs. The results of this mapping effort are presented in Figures 2-4. The digital geo-referenced ESRI shape files, which include the outlines of the old growth parcels, are written in ArcGIS 9.2 on the CD attached with this report (i.e., Appendix 1a). We also attach the coordinates of the two fixed plots, all trees mapped in each plot, and their species, DBH, and basal areas as separate files on the attached CD (Appendix d-e).

Two 0.25 hectare (ha) fixed plots were installed within the two "best" old-growth parcels at Ft. Wolters. Plot A was installed on December 16, 2006, within the relatively flat open-grown woodlands in training area IV. Plot B was installed on February 18, 2007, within the steep, rocky woodlands in training area 1A. All trees (≥10 cm diameter at breast height, DBH) were identified to species, measured for DBH, and mapped using a laser range finder and GPS. Maps were generated in the laboratory from these field data using ArcGIS 9.2 (Figures 10 and 11). All saplings (i.e., stems

≥1.5 m in height, but <10 cm DBH) within each fixed plot were identified to species and counted.

All trees ≥10cm DBH were cored at both sites using a Swedish increment borer to obtain age structure, recruitment history, and tree-ring data for climate analysis. All cores were glued on wooden core mounts and then sanded with progressively finer grained sand paper to obtain a high-quality surface for microscopic analysis of the tree-rings. Core samples were grouped by species and precisely dated by visual cross dating with previously developed master tree-ring chronologies for northern Texas and southern Oklahoma (Stahle et al. 1985, Stahle and Cleaveland 1988). Cores that could not be precisely dated, were given a simple ring count to approximate tree age. The age structure and recruitment history for each plot are presented in Figures 12-14, and 17.

The dated post oak cores from both sites were measured for total ring width with a stage micrometer to the nearest 0.001mm. Cross-dating quality and potential dating errors were evaluated using COFECHA (Holmes 1983, Grissino-Mayer 2001). Detrended and standardized tree-ring chronologies were developed for each plot using the standardization program ARSTAN (Cook 1985, Cook and Krusic 2007: http://www.ldeo.columbia.edu/res/fac/trl/public/publicSoftware.html). The residual chronology from each site was then used for correlation and response function analyses to define the seasonal climate conditions most influential to post oak growth. The "residual" tree ring chronology is free of autocorrelation believed to arise from the year-to-year physiological persistence of tree growth and not from climate (Cook 1985). The monthly precipitation and temperature data were obtained for Texas Climate Division 3 where the sites are located (NOAA 2007).

The correlation and response function analyses were used to help select the optimal climate variable for reconstruction using the post oak chronologies from Ft. Wolters. The Palmer Drought Severity Index (Palmer 1965, Cook et al. 2007) integrates the effect of both precipitation and temperature on soil moisture balance and has been previously proven to be an effective model for the ring width response to climate conditions during and preceding the growing season. We obtained the monthly Palmer drought indices for Texas Climate Division 3 from NOAA (2007) for reconstruction exercises using the post oak chronologies.

Results

The results of the stem mapping, recruitment history, and climate analysis of tree growth at the two old-growth forest locations on Ft. Wolters are presented in Tables 1-3 and Figures 10-17. The boundaries of the remnant old growth woodlands at the level and steep sites were carefully mapped (training sites IV and 1A, respectively), along with the specific location of the 0.25 ha sampling sites (i.e., Plots A and B, Figures 2-4). The digital files that identify the boundaries of these old-growth parcels, and the fixed plots within, are included with this report (Appendix 1).

The two woodlands are very similar in tree species composition, recruitment history, and climate response, but differ by stem density, basal area, and in terms of the strength of the climate signal recorded by the derived tree ring chronologies. The open-grown nature of the woodland on the level site in Plot A is illustrated by the stem map

(Figure 10). Only five tree species were identified in this plot, and post oak was the overwhelming dominant (relative basal area = 75%, Table 1). Five tree species were also identified at the steep woodland site (Plot B, Figure 11), but the density of the stems and the basal area were both larger than measured at the level open-grown woodland (Tables 1 and 2).

The ratio of saplings to trees was 2.7:1 for all species at the level open-grown woodland, and only 2.1:1 at the steep woodland site (Tables 1 and 2), which is consistent with the broken canopy conditions at the level woodland that would permit greater solar radiation to the understory and favor higher levels of regeneration. However, there are interesting differences in the species composition of the tree and sapling layers at both locations. The relative frequency of post oak was 58% in the tree layer, but only 29% in the sapling layer at the level site (Plot A, Table 1). Cedar elm was almost as common as post oak in the sapling layer in this plot.

The difference between the tree and sapling layers was even more dramatic at the steep woodland site (Plot B, Table 2). The relative frequency of post oak declines from 63 to only 11% from the tree to sapling layers, and blackjack oak increases from 22 to 55% (Table 2). These trends might suggest that blackjack oak is posed to become a more important component of the canopy at this site, but this might be balanced by the differences in the longevity of the two species. The longevity of post oak is over twice that of blackjack oak in the two samples from Ft. Wolters (Figure 12), and may be as great as 3:1 elsewhere in the Cross Timbers (e.g., Clark 2003, Peppers 2004).

Post oak is the longest living tree species found at Ft. Wolters. Several post oaks over 150 years were documented in the two study plots, and at least one post oak was determined to be at least 200 years old (Figure 12). These age determinations are based on the dendrochronologically dated annual growth rings present on the core samples extracted from the trees found in the two plots. All of these age determinations underestimate the true age of the sample trees because all cores were extracted at breast height and do not document the germination age of the trees. Many of the oldest trees also suffered from heart rot, and their innermost rings were not recovered. We estimate that the true germination age of the oldest post oak at Ft. Wolters may exceed 250, the oldest cedar elm may exceed 200, and the oldest blackjack oak may approach 100 years in age.

The vegetation composition and age structure of the two study sites suggest that both old growth woodlands have not been heavily disturbed by human activity. Obvious roads, tank trails, and excavations are not present within either fixed plot (Plot A or B, Figures 10 and 11), and these disturbances have been excluded from the areas mapped as “old-growth Cross Timbers” in Figures 2-4. Tree species indicative of possible grazing impacts such as *Juniperus* and *Prosopis* are not present at problematic levels within either Plot A or B, but *Juniperus* does appear to be invading the disturbed and some of the old-growth woodlands at Ft. Wolters (e.g., Figure 4 and 13). The age distributions for the three major species at both sites are consistent with unaltered old-growth woodlands, with many young trees and fewer old trees (Figure 12). “Old” trees are present at both sites, even though the maximum longevity at Ft. Wolters varies from approximately 100 to 250 years, for blackjack oak and post oak, respectively (Figure

12). These data collectively document that relatively undisturbed old-growth woodlands do survive on select small parcels at Ft. Wolters, and may warrant special management considerations.

The old-growth woodlands on the steep site (Plot B) do have evidence for recent invasion by *Juniperus* (Figure 13). All juniper (≥10 cm DBH) within Plot B were cored (7 trees) and their inner rings date to the 1930s, 1950s, and 1960s (Figure 13). Outwardly there appears to have been episodes of juniper expansion into this woodland. In fact, the time sequence of repeat aerial photographs (not shown) illustrates the expansion of juniper in the area over the past 50 years. Cores were also extracted from selected junipers adjacent to Plot B and the inner ring dates of all available juniper cores indicate that most recruitment occurred after the mid-1950s (Figure 13, bottom). Many young saplings were also observed in and near Plot B, but were not cored. The heaviest juniper encroachment is along the dirt road off the east edge of Plot B (Figure 4). No old-growth juniper were located in Plot A, Plot B, or elsewhere on Ft. Wolters. The absence of isolated, rocky, fire-protected habitat in Plot B where the fire-sensitive *Juniperus* might achieve old age, suggests that the 20th century increase in *Juniperus* at Plot B is a recent human-mediated vegetation change. Management of this potentially problematic juniper invasion is recommended, including both mechanical removal and prescribed fire.

The tree-ring data derived for the post oak, blackjack oak, and cedar elm at the two sample sites can provide some insight into the recruitment history of these woodlands and the potential role of drought and wetness regimes in modulating the forest dynamics responsible for forest stand structure. When the tree-ring dated innermost rings for the three spcies are arranged chronologically, interesting recruitment patterns emerge ("recruitment" here refers to the emergence of the tree stem to breast height, ± 1.5m). The most obvious pattern is the strong pulse in recruitment beginning in the 1940's for all three species at the level site (Plot A) and for blackjack oak at the steep site (Plot B, Figure 14). Post oak appears to have recruited to the sapling layer (i.e., >1.5m height, but <10cm DBH) more or less continuously at the steep site (Plot B), but perhaps episodically at the level site, with gaps in recruitment from 1855-1880 and 1916-1944 (Plot A, Figure 14). Only 253 trees were core sampled from both sites (Tables 1 and 2), and additional sampling from these old growth woodlands will be required to confirm the apparent differences in post oak recruitment at these two sites [note that the absence of recruitment after ~1990 (Figure 14) is an artifact of the 10cm DBH minimum size criteria for core sampling].

The pulse of recruitment during the 1940's and 1950's may reflect a combination of natural vegetation dynamics, climate variability, and local land use activities. To provide a climate perspective on the vegetation history at Ft. Wolters, we developed tree-ring chronologies from the post oak core samples at both sampling locations. We used these chronologies to statistically model the monthly precipitation and temperatures variables important to post oak growth. We then used the post oak chronology from the steep site to develop a reconstruction of the Palmer drought severity index for comparison with the recruitment history for the three species summarized for both sites. Correlation and response function analyses (Fritts 1976) were used to define the monthly and seasonal climate variables important to post oak growth at both sites. Precipitation is positively correlated with post oak growth at both sites during the fall and winter prior to the onset tree growth, and during the spring and summer concurrent with growth (Figure 15). The strongest relationship between precipitation and growth appears to be during the early winter and spring, based on the results on the response function analysis (Figure 15). The strongest and most consistent negative relationship between temperature and tree growth occurs during the spring and summer concurrent with the growing season (Figure 15). However, both precipitation and temperature are more strongly correlated to post oak growth at the steep woodland (Plot B), based on the magnitude of the monthly correlation and response function coefficients (Figure 15). This pattern is consistent with classic dendroclimatic theory (Douglass 1941; Fritts 1976), which holds that the strongest climate influence on tree growth, and therefore the best proxies for climate reconstruction, tend to be found on steep, well-drained sites where soil moisture is most limiting and tree growth relies primarily on precipitation.

Because of the strong relationship with precipitation and temperature, the post oak chronology from the steep site (Plot B) was used to develop a tree-ring reconstruction of the PDSI for the north-central climate division of Texas (Division 3, NOAA 2007). The PDSI integrates the effects of both precipitation and temperature on soil moisture and has proven to be a useful index for tree ring reconstruction of past moisture conditions. The tree-ring chronology was calibrated with the May PDSI for the common period of 1931-2006 using bivariate regression. PDSI data available from 1895-1930 were used to check the accuracy of the reconstruction on independent data outside of the training period (i.e., verification). The results of calibration and verification exercises are illustrated in Figure 16 and Table 3. The single tree-ring chronology explains 56% of the variance in the May PDSI data from 1931-2006 (Table 3), although it underestimates the magnitude of the persistent droughts during the 1950’s and 1960’s (Figure 16). The reconstruction is well correlated with the independent May PDSI from 1895-1930, and passes the stringent reduction of error test with a positive value of 0.477 [the RE is approximately equal to the explained variance during the calibration interval (Fritts et al. 1990), indicating less than 10% loss in explained variance when the reconstruction is compared with independent data; Table 3]. Again, however, the reconstruction does underestimate the severity of the multi-year drought in the 1910s (Figure 16).

The reconstructed May PDSI extending from 1795-2006 is compared with the recruitment history for post oak, blackjack oak, and cedar elm at Ft. Wolters in Figure 17. The recruitment data for each species have been summed from the two individual sample sites in Figure 17. The reconstructed May PDSI is plotted along with a smoothed version to emphasize decadal climate variability in Figure 14. Note the drought of the 1950s, which in this estimate appears to have been the most persistent severe drought of the past 200 years. Notable wet episodes are reconstructed for the late 1860s, 1940s, and 1960s (Figure 17). The wettest single year of the entire reconstruction occurred in 1968, and the driest in 1971 (Figure 17).

The two-site total recruitment data for blackjack oak and post oak illustrate the recruitment pulse in the 1940s, 1950s, and 1960s. Several natural and anthropogenic factors might be responsible for this apparent recruitment pulse. The recruitment pulse began in the 1940s, following one of the wettest intervals in the instrumental (1895-2006) and reconstructed (1795-2006) May PDSI record (Figures 16 and 17). The late 1960s were also relatively wet, but the 1950s included six consecutive years of moderate to extreme drought (Figure 16). Nonetheless, these sub-decadal climate regimes may have interacted with fire and canopy conditions to stimulate germination and subsequently even recruitment among oaks at Ft. Wolters. However, the average age of blackjack oak (at breast height) in the Cross Timbers is only about 40 to 60 years (Clark 2003, Peppers 2004; and Figure 12), which may be creating the appearance of a recruitment pulse in the 1950s where it might only reflect the average demographic profile for the species.

The apparent recruitment pulse might also reflect land use changes associated with the creation and expansion of Ft. Wolters. Camp Wolters was established in 1925, but increased to 7500 acres during World War II (Minor 2007). If creation of Ft. Wolters resulted in reduced grazing and increased fire at the two study sites, especially during and soon after World War II, then these land use activities might have interacted with the wet climate conditions during the 1940s to stimulate oak recruitment. The continued occurrence of fire during the late 20th century has apparently favored continuing oak recruitment and native grass cover at the two old growth study sites, while preventing heavy encroachment by *Juniperus* and *Prosopis*, and other problematic forest and rangeland shrubs.

Conclusions

The survey data collected during this project indicate that relatively undisturbed old-growth Cross Timbers woodlands persists in several small parcels at Ft. Wolters, Texas. These parcels were mapped and vegetation data were collected at the two largest and outwardly most intact stands, both of which are dominated by post oak over 150 years old. The oldest tree-ring dated post oak in our sample was 210 years old, but the oldest post oak on the Fort are probably in the 250 year age class. The absence of recent grazing, along with the continued occurrence of low-intensity fire, appear to have prevented serious shrub invasion by *Juniperus* and *Prosopis* into the two most carefully studied old growth parcels (i.e., Plot A and B, and their immediately adjacent old-growth woodlands). *Juniperus* and *Prosopis* have become problematic in the native woodlands and rangelands of northcentral Texas (e.g., Smeins and Merrill 1988), and continued management of the old-growth remnants at Ft. Wolters will probably be required to prevent heavy invasion by *Juniperus* in the future. An apparent pulse in the recruitment of post oak and blackjack oak in the 1940s may reflect the interaction of climatic and fire conditions with the land use changes associated with the expansion of Ft. Wolters during World War II (especially the elimination of grazing animals).

The boundaries of the two largest and outwardly highest quality parcels of old growth found during the 2006 and 2007 field surveys of the University of Arkansas Tree-Ring Laboratory have been mapped with selected GPS points (Appendix 1). These two remnant forests are good examples of the presettlement native vegetation cover of the Western Cross Timbers in northcentral Texas (Dyksterhuis 1948), and deserve careful management consideration. The stem maps prepared for these two remnants provide baseline data against which future vegetation variability and change can be compared (Figures 10 and 11). We propose that both parcels, including the carefully mapped fixed plots (A and B), be included in the network of Research Natural Areas now under development by the Ancient Cross Timbers Consortium for Research, Education, and Conservation (www.uark.edu/xtimber).

References Cited

Clark, Stacy L., 2003. Stand Dynamics of an old-growth oak forest in the cross timbers of Oklahoma. Ph.D. dissertation, Oklahoma State University, Stillwater.

Cook, E.R., 1985. *A Time Series Approach to Tree-Ring Standardization*. Ph.D. dissertation. University of Arizona, Tucson, AZ

Cook, E.R., and P.J. Krusic, 2007. Program ARSTAN. www.ldeo.columbia.edu/res/fac/trl/public/publicSoftware.html

Cook, E.R., R. Seager, M.A. Cane, and D.W. Stahle, 2007. North American Drought: reconstructions, causes, and consequences. Earth Science Review 81:93-134.

Douglass, A.E., 1941. Crossdating in Dendrochronology. *Journal of Forestry* 39:824-828.

Dyksterhuis, E.J. 1948. The vegetation of the western Cross Timbers. *Ecological Monographs* 18:325-276

Fritts, H.C., 1976. *Tree Rings and Climate*. Academic Press, London.

Fritts, H.C., J. Guiot, and G.A. Gordon, 1990. Verification. In *Methods of Dendroclimatology*, edited by E.R. Cook and L.A. Kairiukstis. Kluwer Academic Publishers, Dondrecht. pp. 178-184.

Grissino-Mayer, H.D., 2001. Evaluating Crossdating Accuracy: a manual and tutorial for the computer program COFECHA. *Tree-Ring Research* 57:205-221.

Holmes, R. L., 1983. Computer-Assisted Quality Control in Tree-Ring Dating and Measurement", *Tree-Ring Bulletin* 43: 69-78.

Kuchler, A.W. 1964. *Potential Natural Vegetation of the Conterminus United States*. American Geographical Society, Special Publication 36.

Minor, D. 2007. Ft. Wolters. In: The Handbook of Texas Online. www.tsha.utexas.edu/handbook/online.

National Climatic Data Center. 2007. website. www.ncdc.noaa.gov/oa/ncdc.html. U.S. Department of Commerce, Washington, D.C.

Palmer, W.C. 1965. Meteorological Drought. Weather Bureau Research Paper 45, U.S. Department of Commerce, Washington, D.C.

Peppers, K.C. 2004. Old-Growth Forests in the Western Cross Timbers of Texas. Ph.D. dissertation. University of Arkansas.

Smeins, F.E. and Merrill, L.B. 1988. Long-term change in semi-arid grassland. In: Amos, B.B., Gehlback, F.R. (Eds.), *Edwards Plateau Vegetation*. Baylor University Press, Waco, TX, pp. 101–114.

Stahle, D.W., J.G. Hehr, G.C. Hawks, M.K. Cleaveland, and J.R. Baldwin, 1985. Tree-Ring Chronologies for the Southcentral United States. Tree-Ring Laboratory and Office of the State Climatologist, University of Arkansas. Fayetteville. 135pp.

Stahle, D.W., and M.K. Cleaveland, 1988. Texas Drought History Reconstructed and Analyzed from 1698 to 1980. *Journal of Climate* 1:59-74

Level Site – Plot A

Species	Number of Trees	Relative Frequency	Total Basal Area (m^2)	Relative Dominance
Post Oak	57	0.58	2.55	0.75
Blackjack Oak	24	0.24	0.49	0.14
Cedar Elm	16	0.16	0.33	0.09
Texas Ash	1	0.01	0.01	0.01
Hawthorne	1	0.01	0.01	0.01
Total	99	1.00	3.39	1.00

Species	Number of Saplings	Relative Frequency
Post Oak	77	0.29
Unknown	68	0.25
Cedar Elm	62	0.23
Texas Ash	23	0.09
Blackjack Oak	18	0.07
Chittamwood	15	0.05
Juniper	4	0.01
Hackberry	2	0.01
Hawthorne	1	<0.01
Total	270	1.00

Table 1. The species composition and dominance are listed for all trees ≥10cm DBH and saplings (<10cm DBH, ≥1.5m height) mapped in the 0.25 ha fixed plot at the level open-grown stand (Plot A). A total of 99 trees and 270 saplings were counted on the plot (sapling:tree ratio = 2.7:1 for all species). Post Oak was the most abundant (57 trees, relative frequency = 58%) and the most dominant (basal area = 2.55m^2, relative dominance 75%). Unlike the tree layer, post oak is not such a clear dominant in the sapling layer at this plot. Leaf-off conditions during the vegetation survey made the identification of small saplings difficult, and 68 were not identified to species (i.e., “unknown).

Steep Site – Plot B

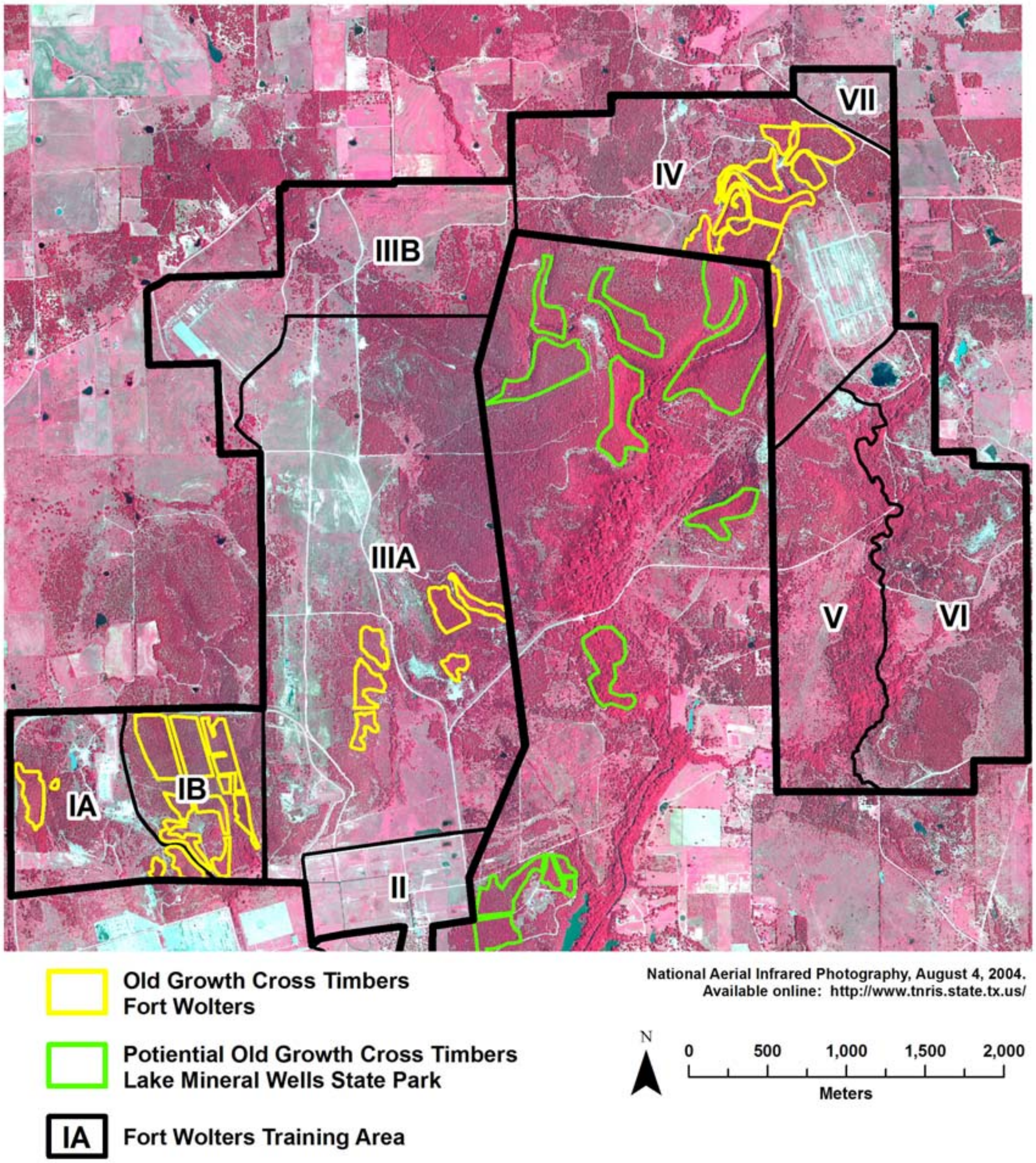
Species	Number of Trees	Relative Frequency	Total Basal Area (m^2)	Relative Dominance
Post Oak	97	0.63	3.85	0.82
Blackjack Oak	34	0.22	0.43	0.09
Cedar Elm	13	0.08	0.27	0.06
Juniper	2	0.01	0.02	0.01
Texas Ash	8	0.05	0.12	0.02
Total	154	1.00	4.68	1.00

Species	Number of Saplings	Relative Frequency
Blackjack Oak	164	0.55
Texas Ash	53	0.18
Cedar Elm	43	0.14
Post Oak	33	0.11
Unknown	5	0.02
Total	298	1.00

Table 2. The species composition and dominance for all trees ≥10cm DBH at the steep woodland site (Plot B). A total of 154 trees were counted and mapped at this site. Post oak was again the most abundant (97 trees, relative frequency = 63%) and most dominant tree species (basal area = $3.85m^2$, relative dominance = 82%). Although post oak dominates the tree layer in this plot, blackjack oak is the clear dominant of the sapling layer (relative frequency = 55%). Species diversity at this site is lower than the more open-grown Plot A.

Table 3. Calibration and verification statistics are tabulated for the reconstructed May PDSI for Texas Climate Division 3 using the residual chronology from Ft. Wolters, Plot B. [b_o = intercept, b_1 = slope, R^2_{adj} = explained variance adjusted downward for the loss of one degree of freedom; Durbin-Watson statistic indicates no significant autocorrelation in the residuals from regression; the Pearson correlation coefficient comparing reconstructed and observed May PDSI from 1895-1930 is significant; the sign test is favorable; and the reduction of error test indicates that the reconstruction model is skillful in estimating the independent observations (Fritts 1976, Stahle and Cleaveland 1988)].

Calibration 1931-2006 (n=76)				**Verification 1895-1930 (n=36)**			
					Sign Test		
b_o	b_1	R^2_{adj}	Durbin-Watson Statistic	Pearson Correlation	Pos.	Neg.	Reduction of error
-5.307	5.020	0.560	1.634	0.698	26	10	0.477



National Aerial Infrared Photography, August 4, 2004.
Available online: http://www.tnris.state.tx.us/

Figure 2. This map illustrates the areas identified as old growth Cross Timbers by the University of Arkansas Tree-Ring Laboratory (yellow polygons). Fixed study plots were established within the old growth polygons of training area IV (Plot A) and area IA (Plot B). The total area of old growth Cross Timbers mapped at Ft. Wolters 89 ha (within the yellow polygons). Possible areas of old-growth forest on Lake Mineral Wells State Park are also outlined (green polygons), based only on an examination of aerial photography.

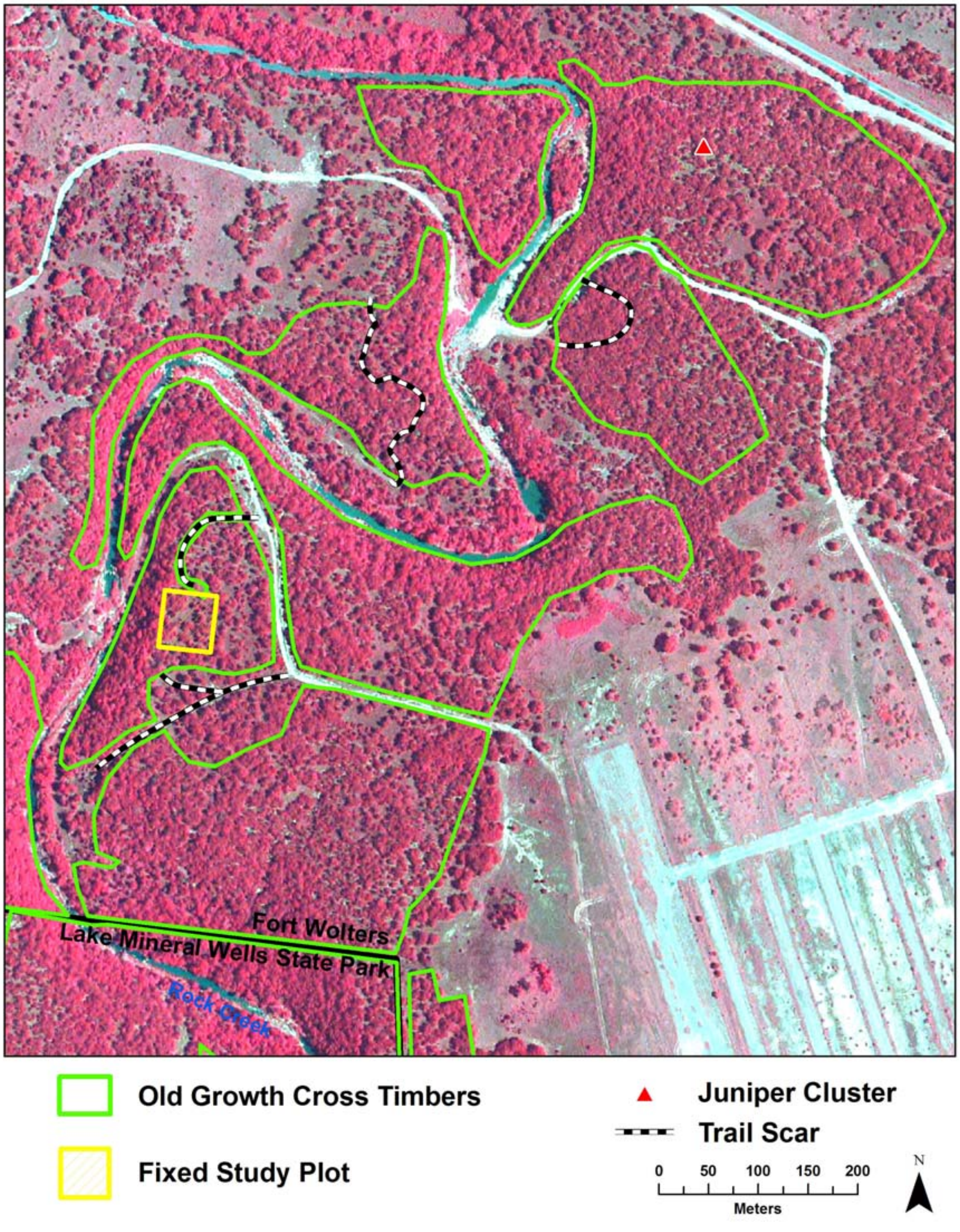


Figure 3. This map illustrates the old growth Cross Timber remnants mapped in training area IV. The total area of these remnants in training area IV is 38.7 ha (within the green polygons). The 0.25 ha fixed study plot is identified by the yellow square (Plot A, level site).

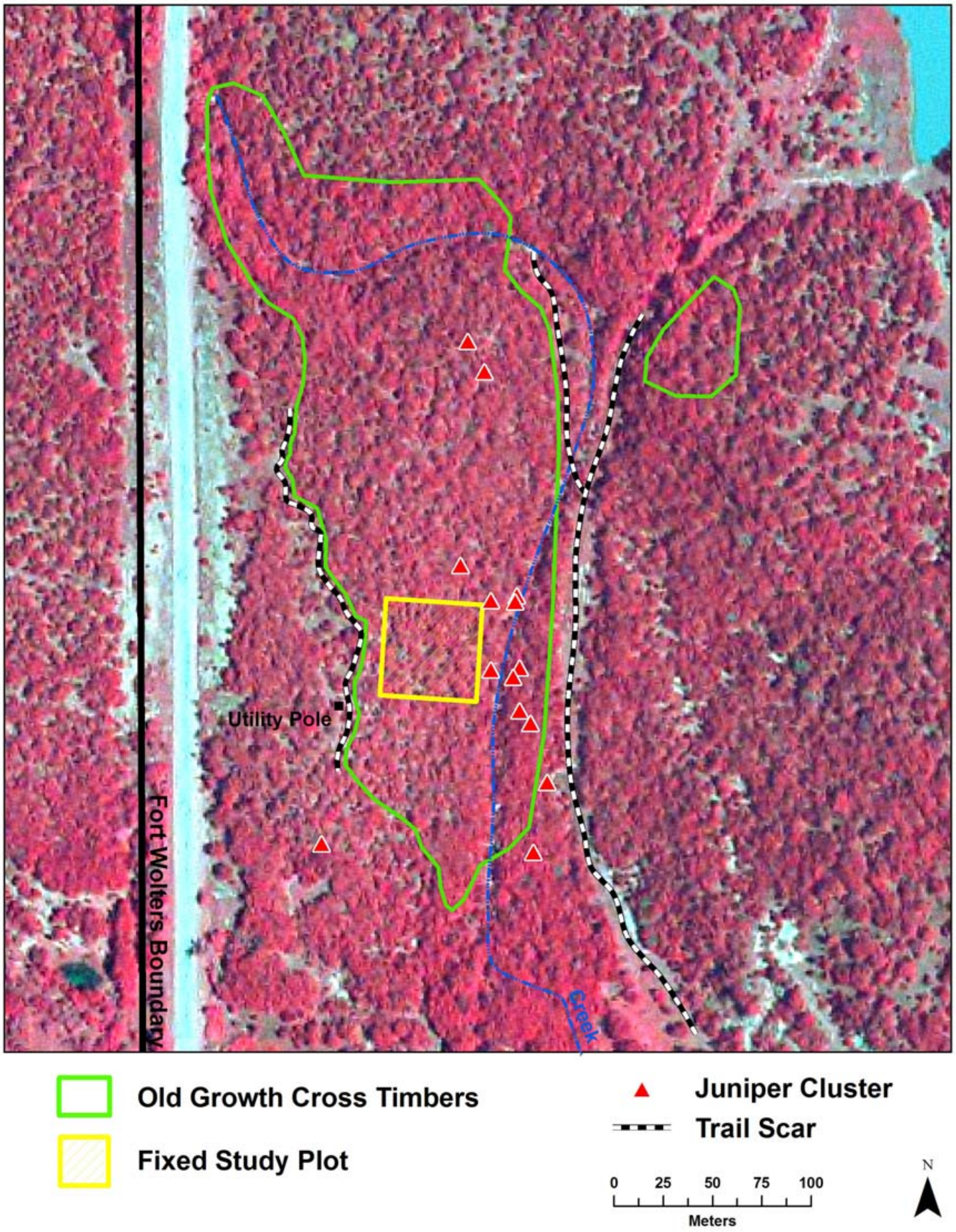


Figure 4. This map depicts the old growth Cross Timber remnants in training area 1A, which cover 4.3 ha (area within the two green polygons). The 0.25 ha fixed study plot is identified by the yellow square (Plot B, steep site). This area is experiencing some recent invasion by juniper (red triangles, and along the eastern margin of the large green polygon near the trail/road).

Figure 5. Old-growth post oak survive in this level woodland at Ft. Wolters (Plot A). Note the open tree canopy and thick understory grasses (including inland sea oats).

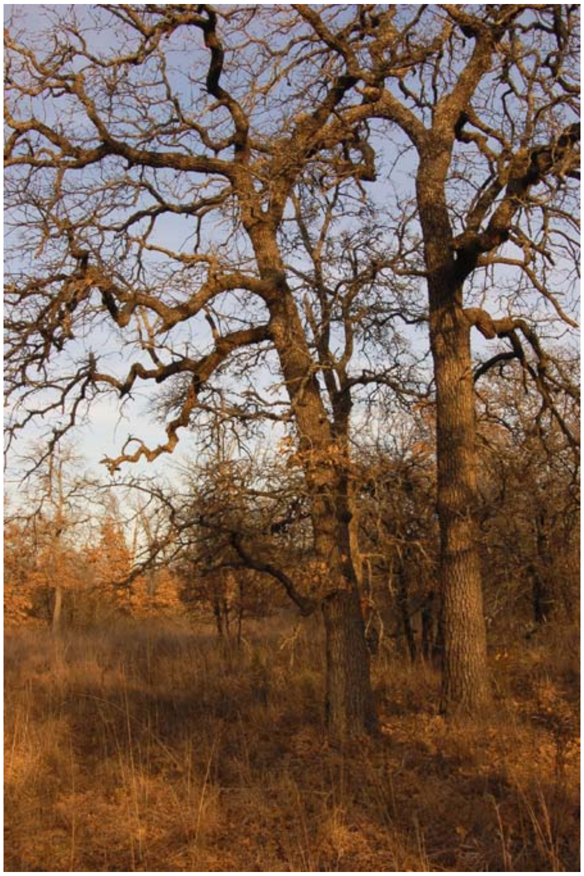


Figure 6. These two mature post oaks are located in fixed Plot A.

Figure 7. The Laser Atlanta Advantage Range Finder mounted on the tripod in the foreground was used along with a Trimble GeoXM GPS to map all trees to submeter accuracy. This mapping will facilitate future studies of vegetation change at Ft. Wolters. A portion of Plot B is illustrated in the photograph.

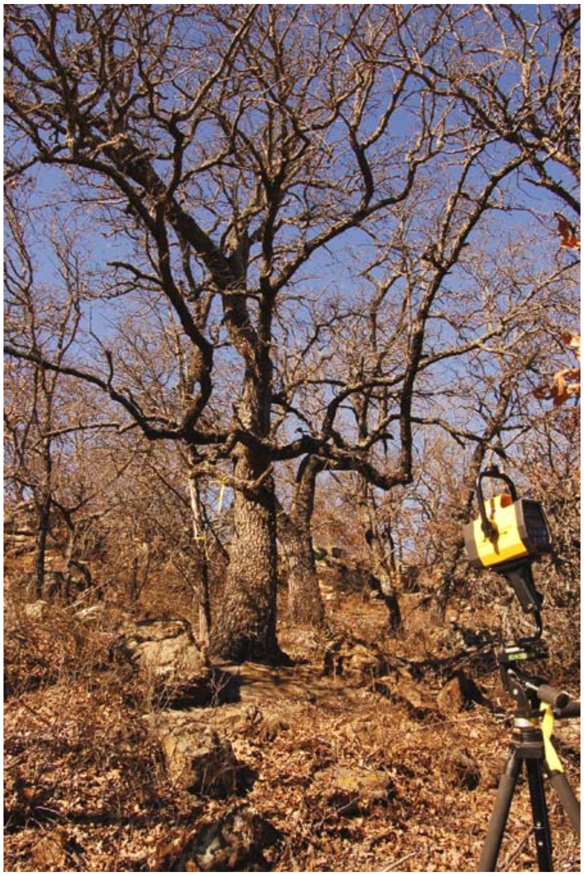


Figure 8. This image depicts the steep and rocky nature of the old growth in Plot B at Ft. Wolters.

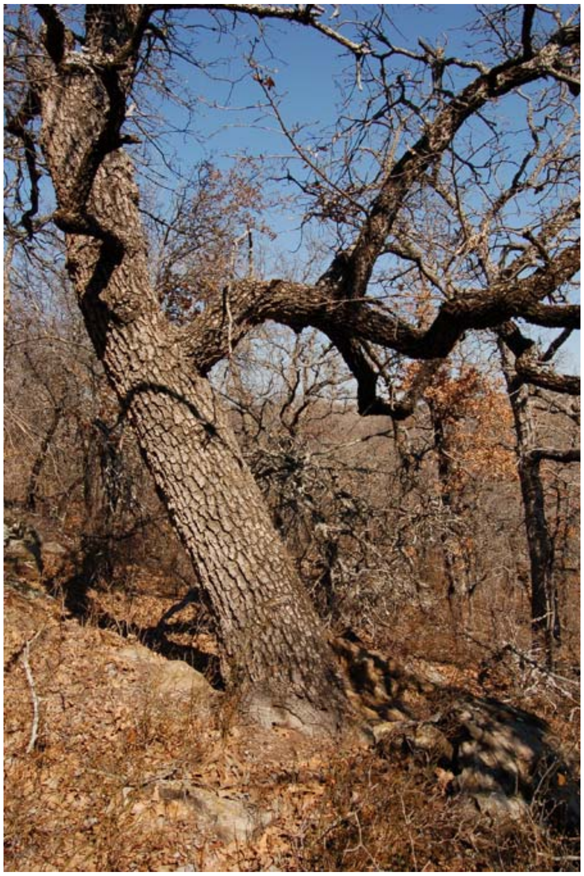
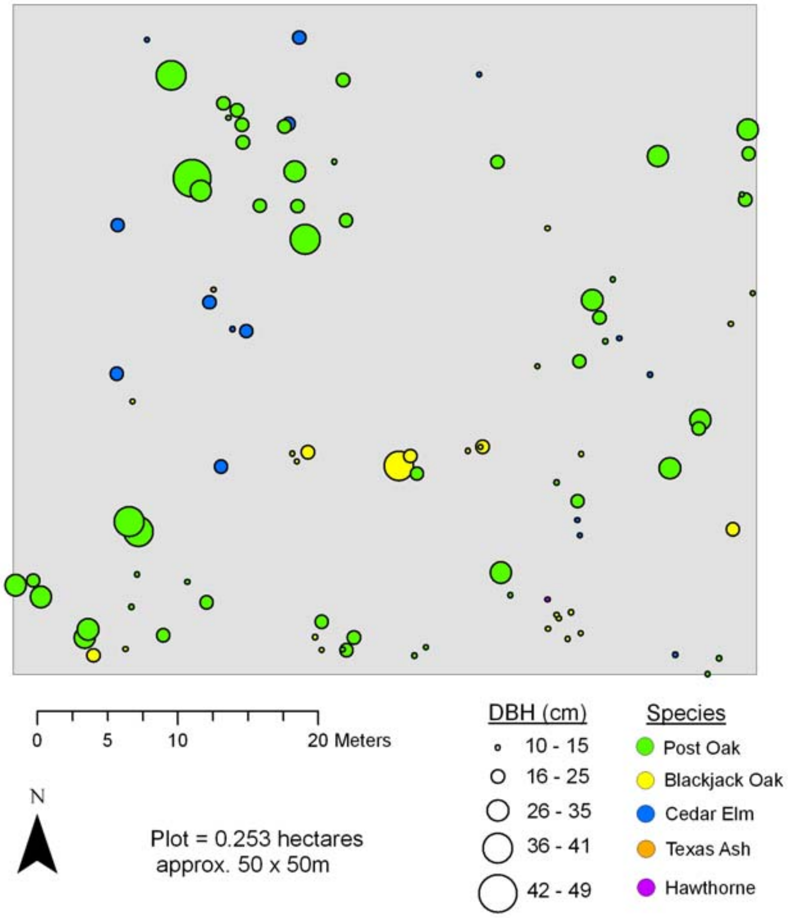


Figure 9. An old-growth post oak tree in Plot B.

Ft. Wolters
Parker County, Texas
Level Site - Plot A



Plot Corner Coordinates (UTM, WGS 1984, 14N)

NE	corner:	592053.10, 3638741.07 meters
SE	corner:	592053.10, 3638693.46 meters
SW	corner:	592000.01, 3638693.31 meters
NW	corner:	592000.01, 3638741.07meters

Figure 10. This is the 0.25 ha stem map prepared at the open woodland at Ft. Wolters (Plot A). Tree diameters are exaggerated to more clearly illustrate species composition. The understory includes grassy openings and small thickets of sapling (≤10cm DBH). This plot appears to be free of major human disturbance.

Ft. Wolters
Parker County, Texas
Steep Site – Plot B

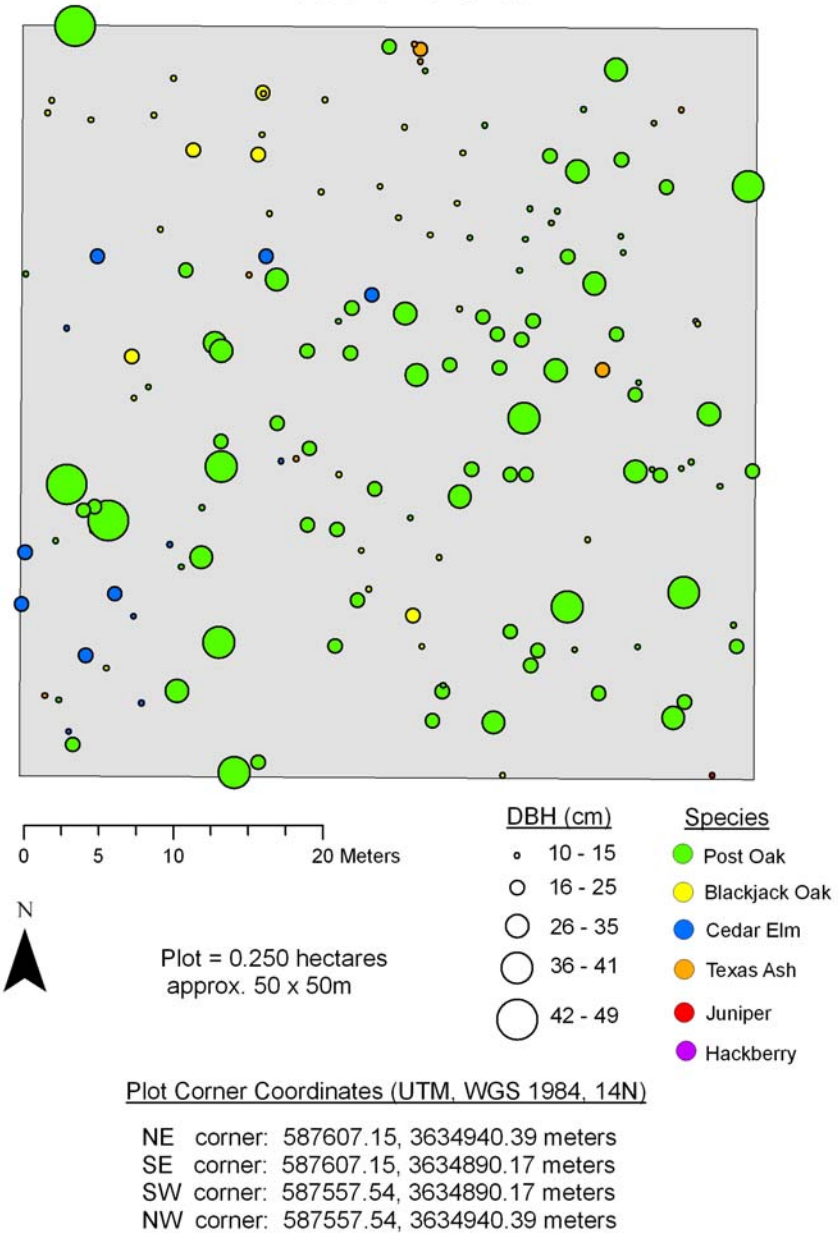


Figure 11. The 0.25 ha stem map prepared within the old-growth woodlands on the steep east-facing slope (Plot B). Note the higher density of stems compared with Plot A (Figure 10). This plot is also free of major human disturbance, but does appear to be experiencing a recent increase in juniper trees and saplings.

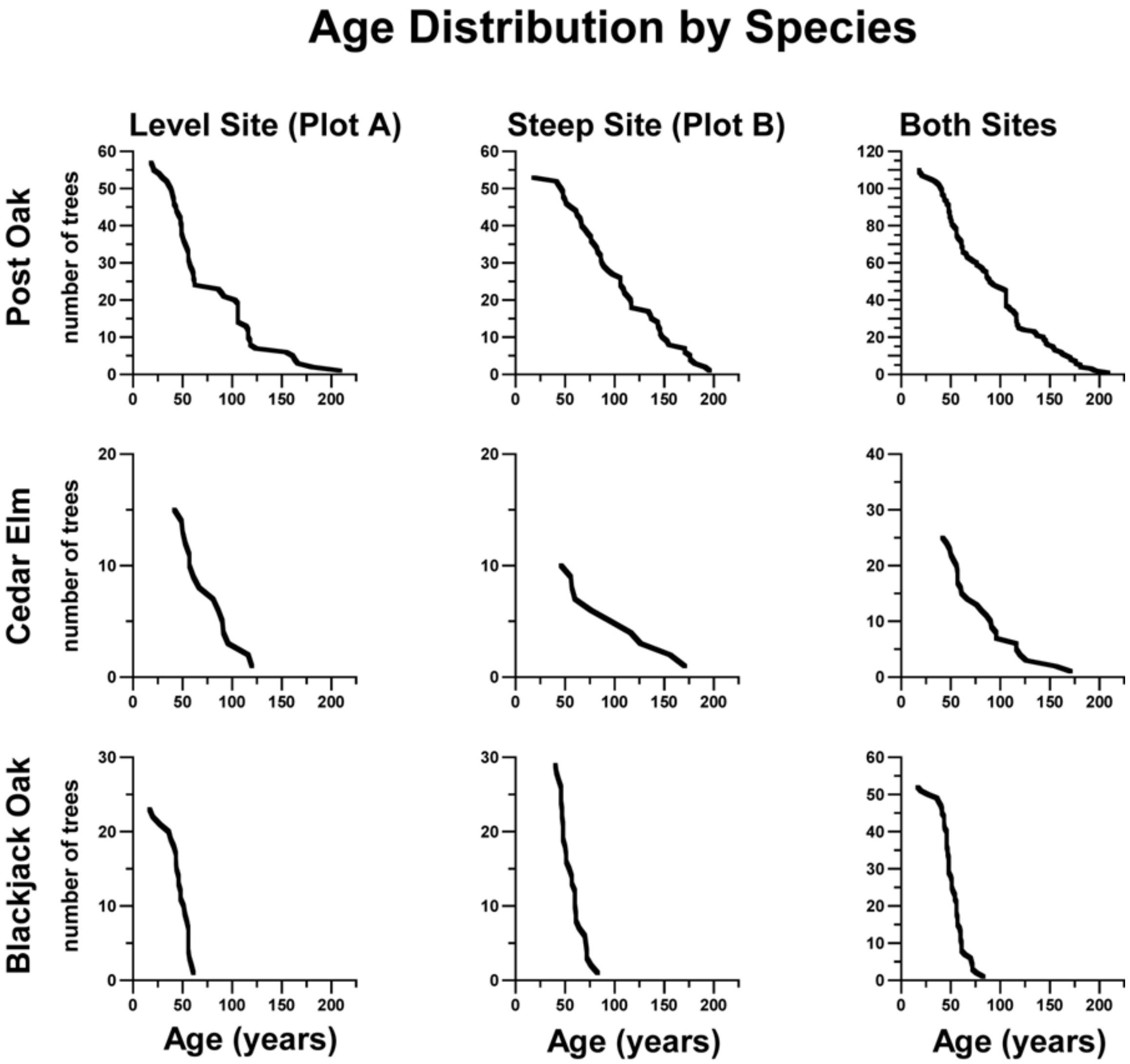


Figure 12. Age distributions for the three most common species at Ft. Wolters are presented above (for each plot, and for the combination of both plots). All ages are based only on the number of annual rings recovered on the core samples, and no corrections to true germination age were made for these illustrations.

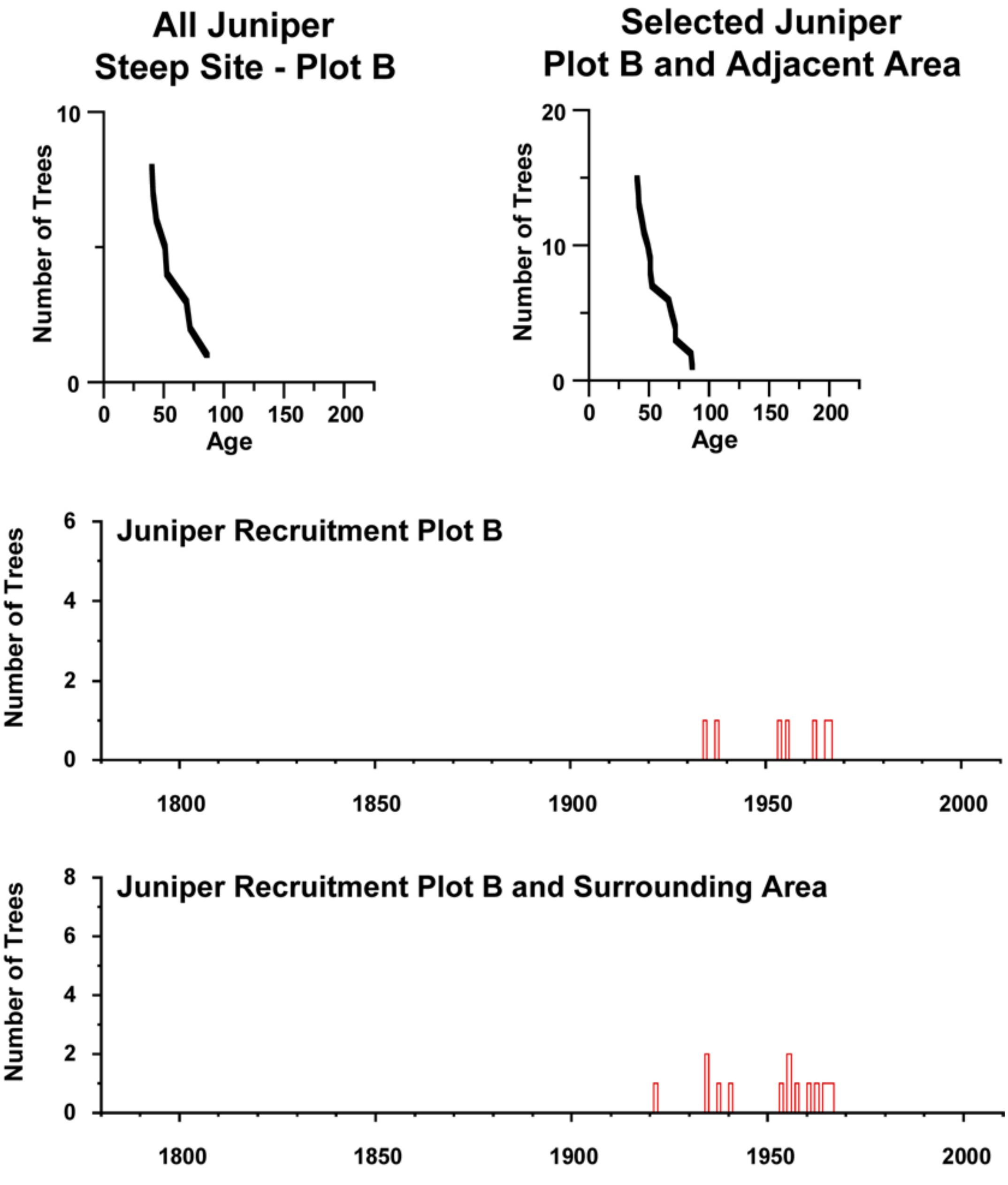


Figure 13. The age distribution of juniper trees (≥10 cm DBH) found within Plot B (top left). Additional juniper trees were cored near Plot B to better define this age distribution (top right). The recruitment history of juniper within Plot B is also illustrated (middle), along with all juniper recruitment in and near Plot B (bottom).

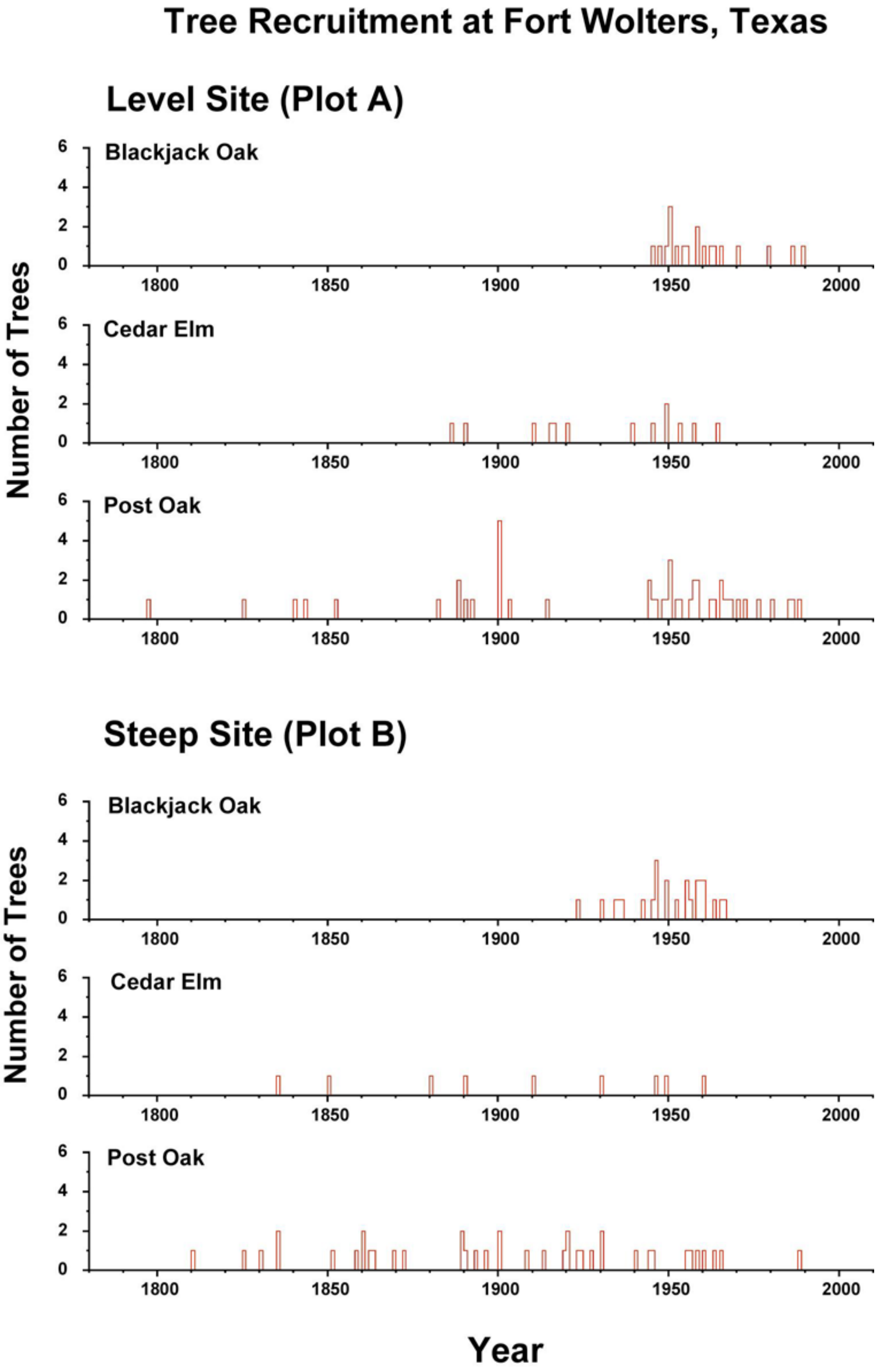


Figure 14. The history of tree recruitment in the two sample plots at Ft. Wolters, Texas, is illustrated for the three major tree species. Only trees with core samples reaching pith or near pith are included above. The oldest documented tree at this site recruited into the forest in the 1790s (post oak, Plot A).

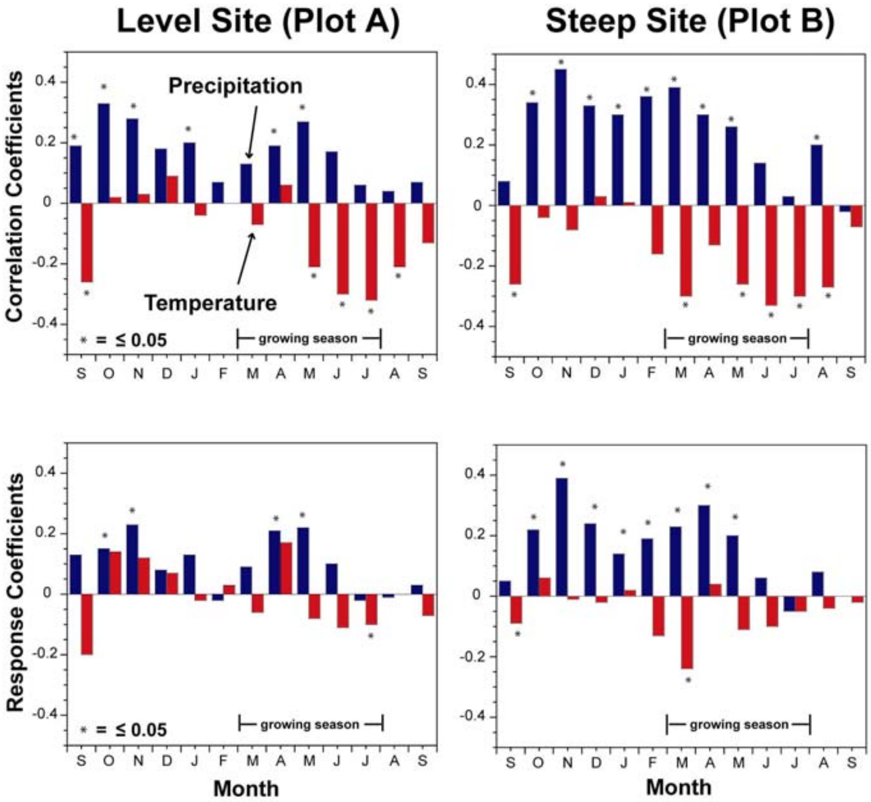


Figure 15. Correlation (top plots) and response function analyses (bottom plots, Fritts 1976) were performed on the two post oak ring width chronologies developed at each plot at Ft. Wolters. The residual chronology from each plot was compared with the monthly temperature and precipitation data from Texas Climate Division 3 for the period 1931 to 2006 (NOAA 2007). Monthly climate data from the previous September through the September concurrent with tree growth were compared with the residual tree ring chronology for both analyses. Significant coefficients are indicated with an asterisk. The growing season for post oak is also illustrated (generally March through July for radial growth).

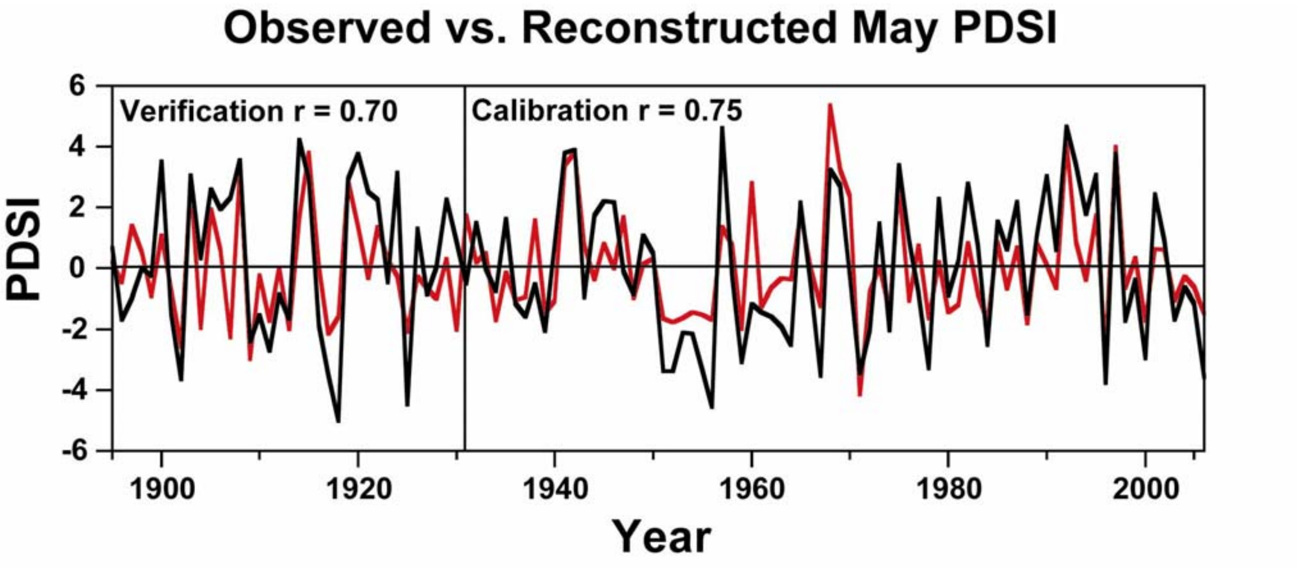


Figure 16. A time series plot of the instrumental (black) and tree-ring reconstructed (red) Palmer drought severity index for the month of May extending from 1895-2006 for Texas Climate Division 3 (northcentral Texas). The reconstruction was calibrated on the period from 1931-2006, and verified on independent May Palmer drought indices from 1895-1930 (calibration and verification statistics are listed in Table 3). The observed and reconstructed May PDSI data are well correlated during the calibration and verification periods.

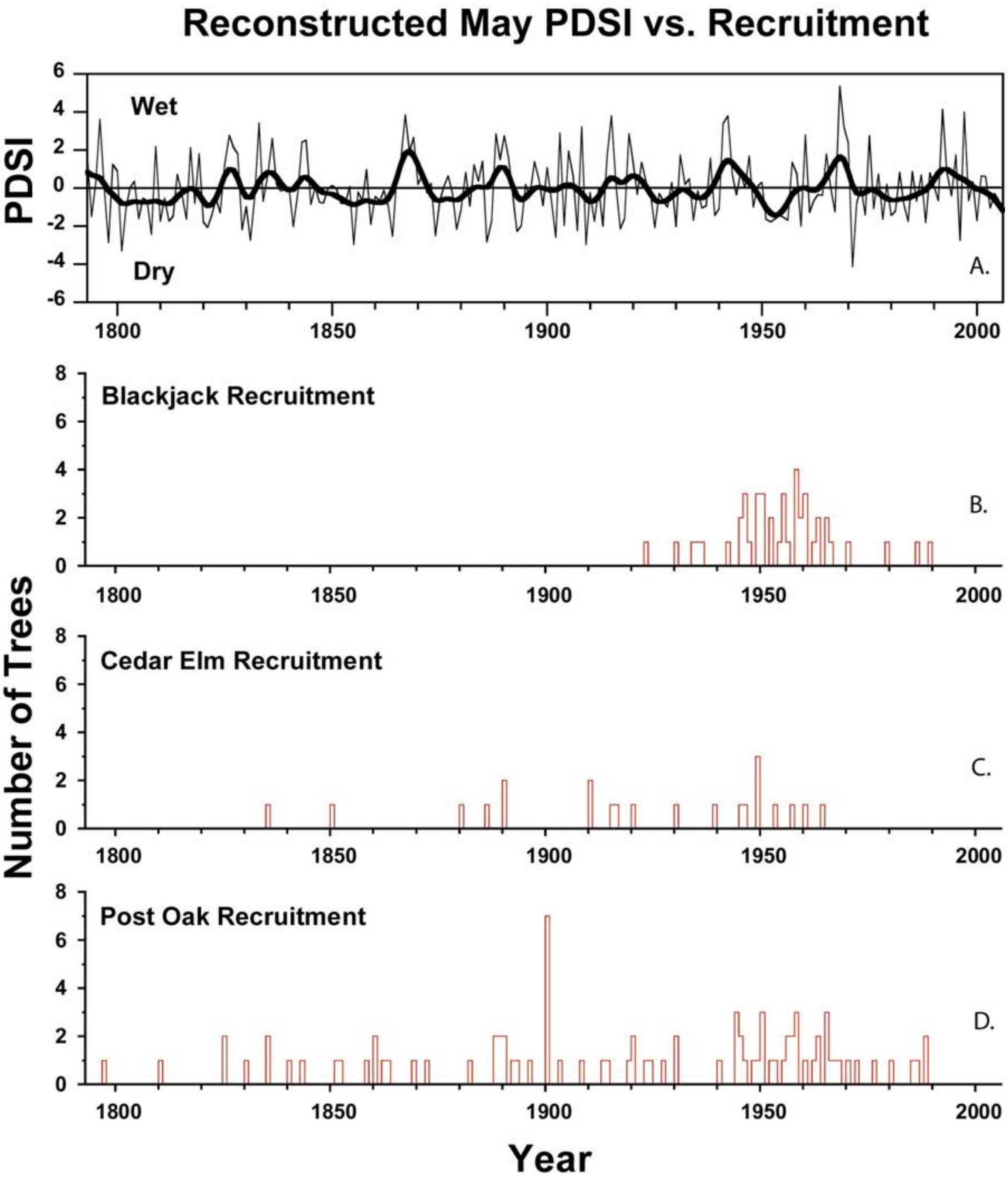


Figure 17. The tree-ring reconstructed May PDSI is plotted from 1795-2006 (annual values and a smoothed version emphasizing decadal variability, top). The tree-ring dated recruitment data totaled for both study sites (Plots A and B) are also plotted by calendar year for blackjack oak, cedar elm, and post oak (b-d, respectively, only for cores to pith or near pith).

Appendix 1 (a-e).

The .zip file entitled "ft_wolters_2007_uaf_data.zip" on the attached CD contains ESRI shapefiles generated by the University of Arkansas Tree-Ring Laboratory for the Fort Wolters Texas Army National Guard Training Facility during 2007. These files are referenced to the coordinate system UTM Zone 14 north, and the WGS 1984 datum and can be opened with Arc GIS 9.2. A brief explanation of each dataset is provided below, and further details on their development are provided in the final report for this research contract. For more information regarding these datasets, please contact:

Tree-Ring Laboratory
University of Arkansas
Fayetteville, AR 72701
(479)575-5809
http://uark.edu/dendro

A. "updated_ft_wolters_old_growth.shp"
This polygon shapefile indicates the approximate boundaries for the parcels of remnant old-growth Cross Timbers on Fort Wolters, as determined by the analysis of georeferenced historical aerial photographs using a GIS and intensive field-based surveys. This dataset was generated under contract in 2006, and refined in 2007.

B. "plot1_corners.shp"
This point shapefile includes the four corners of the first permanent old-growth vegetation survey plot installed at Fort Wolters.

C. "plot1_trees.shp"
This point shapefile includes the 102 trees (stems 10cm or greater in diameter at breast height) within the bounds of the first permanent old-growth vegetation survey plot.

D. "plot2_corners.shp"
This point shapefile includes the four corners of the second permanent old-growth vegetation survey plot installed at Fort Wolters.

E. "plot2_trees.shp"
This point shapefile includes the 159 trees (stems 10cm or greater in diameter at breast height) within the bounds of the second permanent old-growth vegetation survey plot.

Appendix 1b. UTM coordinates for the four corners of Plot A (file name “plot1_corners.shp”).

Corner	Northing	Easting	Elevation (m)
Northeast	3638733.842	592058.003	288.028
Northwest	3638745.283	592006.347	291.707
Southeast	3638687.754	592048.536	290.770
Southwest	3638693.310	592000.318	288.874

Appendix 1c. UTM coordinates for the 102 trees mapped in Plot A (File name = "Plot1_trees.shp"). This file also includes species, DBH (cm), basal area, and elevation (m) for each tree.

Tree	Species	DBH	Basal Area (sq. meters)	Northing	Easting	Elevation (m)
1	cedar elm	13	0.0155	3638717.9074	592015.6891	296.2627
2	cedar elm	11	0.0079	3638717.9074	592015.6891	295.9833
3	cedar elm	16	0.0202	3638717.7337	592016.6739	295.9658
4	cedar elm	25	0.0534	3638719.7877	592014.0593	296.9627
5	Texas ash	12	0.0114	3638720.6913	592014.3270	296.3326
6	cedar elm	16	0.0202	3638725.2880	592007.5129	297.5221
7	post oak	29	0.0619	3638727.7477	592013.4247	296.4723
8	post oak	49	0.1973	3638728.6481	592012.8386	296.5072
9	post oak	21	0.0382	3638726.6992	592017.6572	296.3326
10	post oak	38	0.1140	3638724.3138	592020.8801	295.9484
11	post oak	23	0.0455	3638726.6384	592020.3315	295.9833
12	post oak	21	0.0382	3638725.6462	592023.8048	295.9309
13	post oak	12	0.0114	3638729.8514	592022.9460	295.7040
14	post oak	26	0.0534	3638729.1176	592020.1182	296.0182
15	cedar elm	17	0.0202	3638732.5388	592019.7029	295.7040
16	post oak	18	0.0256	3638731.2188	592016.4420	296.0880
17	post oak	23	0.0382	3638732.4873	592016.3566	296.1055
18	post oak	13	0.0155	3638732.9645	592015.3869	296.1229
19	post oak	18	0.0256	3638733.5141	592016.0191	295.7040
20	post oak	18	0.0256	3638733.9967	592015.0445	295.2676
21	post oak	37	0.1140	3638735.9899	592011.3009	296.2102
22	cedar elm	13	0.0114	3638738.5323	592009.6221	296.2626
23	post oak	20	0.0316	3638732.3312	592019.4009	296.0706
24	cedar elm	23	0.0455	3638738.6930	592020.4579	295.7040
25	post oak	25	0.0455	3638735.6678	592023.5619	295.7040
26	cedar elm	10	0.0079	3638736.0491	592033.2763	295.7040
27	post oak	25	0.0534	3638729.8012	592034.5647	295.7040
28	blackjack oak	12	0.0114	3638725.0775	592038.1563	295.4945
29	post oak	35	0.1023	3638730.2351	592046.0338	294.9707
30	post oak	28	0.0619	3638732.1207	592052.4289	292.8662
31	post oak	18	0.0256	3638730.4114	592052.4804	294.3414
32	post oak	11	0.0079	3638727.4899	592052.0180	294.4462
33	post oak	19	0.0316	3638727.1290	592052.2306	294.4462
34	post oak	12	0.0114	3638721.4315	592042.8161	295.2500
35	post oak	28	0.0619	3638719.9511	592041.3327	295.5120
36	post oak	24	0.0455	3638718.7102	592041.8467	295.1275
37	cedar elm	10	0.0079	3638717.2128	592043.2637	295.0751
38	post oak	14	0.0155	3638717.0391	592042.2789	295.1275
39	post oak	22	0.0382	3638715.6000	592040.4337	295.3897
40	post oak	11	0.0114	3638715.2337	592037.4451	295.7040
41	cedar elm	10	0.0079	3638714.6404	592045.4375	295.9484
42	post oak	33	0.0912	3638711.3866	592049.0527	294.7607
43	post oak	24	0.0455	3638710.7744	592048.9113	295.0754

44	post oak	23	0.0455	3638709.0810	592055.7034	294.3938
45	post oak	15	0.0155	3638720.4513	592052.7925	294.1656
46	blackjack oak	12	0.0114	3638718.2577	592051.1998	295.3549
47	blackjack oak	18	0.0256	3638703.6290	592051.3646	294.4986
48	post oak	28	0.0619	3638707.9445	592046.8532	294.8131
49	post oak	31	0.0710	3638700.5134	592034.8203	295.1802
50	blackjack oak	10	0.0079	3638708.9779	592040.5654	295.5120
51	post oak	11	0.0079	3638706.9544	592038.8064	295.5120
52	post oak	21	0.0316	3638705.6214	592040.3120	294.5666
53	cedar elm	10	0.0079	3638704.2490	592040.2565	294.7250
54	cedar elm	10	0.0079	3638703.1495	592040.4732	295.4422
55	blackjack oak	16	0.0202	3638709.4908	592033.4981	295.4945
56	blackjack oak	14	0.0155	3638709.4559	592033.3994	295.8087
57	blackjack oak	11	0.0114	3638709.2202	592032.4879	295.8087
58	post oak	18	0.0256	3638707.5649	592028.8415	296.1233
59	blackjack oak	18	0.0256	3638708.8374	592028.3774	296.1935
60	blackjack oak	39	0.1140	3638708.1320	592027.5675	296.1233
61	blackjack oak	20	0.0316	3638709.1290	592021.0537	295.7040
62	blackjack oak	12	0.0114	3638709.0259	592019.9677	295.7040
63	blackjack oak	10	0.0079	3638708.4335	592020.3028	295.9309
64	cedar elm	24	0.0455	3638708.0958	592014.8769	295.7040
65	cedar elm	23	0.0382	3638714.7101	592007.4497	295.7040
66	blackjack oak	15	0.0202	3638712.7248	592008.5720	296.1055
67	blackjack oak	14	0.0155	3638712.7248	592008.5720	296.1055
68	post oak	12	0.0114	3638693.2837	592049.5656	288.4711
69	post oak	11	0.0079	3638694.4027	592050.3836	288.4362
70	cedar elm	11	0.0079	3638694.6838	592047.2573	288.1038
71	blackjack oak	14	0.0155	3638696.1775	592040.5145	288.7505
72	blackjack oak	13	0.0114	3638695.8029	592039.5873	288.7854
73	blackjack oak	12	0.0114	3638697.6858	592039.8271	289.0824
74	blackjack oak	14	0.0155	3638696.5123	592038.1775	288.5231
75	blackjack oak	15	0.0155	3638697.2318	592038.9361	288.4707
76	blackjack oak	14	0.0155	3638697.5105	592038.7911	288.4707
77	hackberry	13	0.0114	3638698.5985	592038.1629	288.4707
78	post oak	12	0.0114	3638698.9106	592035.5062	288.8553

79	post oak	14	0.0155	3638694.6173	592028.6527	289.4140
80	post oak	12	0.0114	3638695.1980	592029.4802	289.7283
81	post oak	11	0.0114	3638691.4792	592032.6010	289.4140
82	Texas ash	10	0.0079	3638692.0183	592029.2422	289.1696
83	post oak	16	0.0202	3638695.9070	592024.3534	289.2918
84	post oak	17	0.0202	3638694.9861	592023.8366	289.0996
85	post oak	15	0.0202	3638695.0271	592023.5252	289.7284
86	post oak	19	0.0316	3638697.0162	592022.0618	289.2744
87	blackjack oak	13	0.0155	3638695.9314	592021.5623	289.6584
88	blackjack oak	14	0.0155	3638695.0016	592022.0630	289.6235
89	post oak	18	0.0256	3638698.4114	592013.8674	289.4140
90	post oak	15	0.0155	3638699.8501	592012.4781	289.4140
91	post oak	41	0.1392	3638703.4468	592009.0048	289.4140
92	post oak	39	0.1140	3638704.1661	592008.3102	289.4140
93	post oak	14	0.0155	3638700.3878	592008.9094	289.0998
94	post oak	11	0.0114	3638698.0686	592008.4812	288.8203
95	post oak	35	0.1023	3638698.7802	592002.0529	289.0125
96	post oak	25	0.0534	3638699.9558	592001.5138	288.9951
97	post oak	26	0.0534	3638699.6255	592000.2403	289.4140
98	blackjack oak	11	0.0079	3638695.0537	592008.0631	289.4140
99	post oak	31	0.0710	3638696.4839	592005.4084	289.4140
100	post oak	32	0.0808	3638695.8690	592005.1600	289.4140
101	blackjack oak	21	0.0382	3638694.6223	592005.7790	289.7282
102	post oak	16	0.0202	3638696.0600	592010.7736	289.6584

Appendix 1d. UTM coordinates for the four corners of Plot B (file name = "plot2_corners.shp").

Corner	Northing	Easting	Elevation (m)
Northeast	3634935.248	587606.364	289.070
Northwest	3634942.940	587561.175	302.443
Southeast	3634886.159	587605.235	284.878
Southwest	3634892.646	587559.950	300.663

Appendix 1e. UTM coordinates for 159 trees mapped in Plot B (file name = “plot2_trees.shp”). This file also includes species, DBH (cm), basal area, and elevation (m) for each tree.

Tree	Species	DBH	Basal Area (sq. meters)	Northing	Easting	Elevation
1	5	10.1	0.0082	3634895.7640	587559.2759	295.9299
2	1	17.8	0.0250	3634892.4650	587561.1452	297.0667
3	3	10.2	0.0082	3634893.3540	587560.8699	296.2858
4	1	10.8	0.0092	3634895.4670	587560.1943	296.3480
5	3	17.1	0.0233	3634898.4260	587562.0038	296.7749
6	2	14.2	0.0159	3634897.5660	587563.3953	297.1709
7	3	13.3	0.0142	3634895.2630	587565.7300	297.7360
8	1	25.1	0.0501	3634896.0460	587568.1165	298.3023
9	1	23.6	0.0440	3634891.2820	587573.5371	300.5087
10	1	33.8	0.0902	3634890.5970	587571.9310	299.7944
11	1	35.5	0.1000	3634899.2970	587570.8971	299.6966
12	1	26.7	0.0567	3634904.9710	587569.7436	299.0262
13	1	11.7	0.0110	3634904.3350	587568.4022	298.5454
14	3	10.5	0.0089	3634905.8400	587567.6445	297.7406
15	1	41.5	0.1366	3634907.4520	587563.5228	296.6544
16	4	11.5	0.0106	3634906.7440	587562.4819	296.2408
17	3	16.2	0.0207	3634902.5480	587563.9635	296.8047
18	3	11.5	0.0106	3634901.0220	587565.2297	297.2958
19	3	16.7	0.0223	3634901.8650	587557.7224	295.5197
20	3	18.8	0.0279	3634905.3340	587557.9535	295.1172
21	1	12.7	0.0129	3634906.1040	587559.9986	295.9185
22	1	44.0	0.1528	3634909.8760	587560.7533	295.5245
23	1	19.6	0.0303	3634908.1420	587561.8798	296.0353
24	1	22.0	0.0382	3634908.3880	587562.6021	296.4133
25	2	15.2	0.0182	3634918.4560	587565.0795	300.0501
26	1	10.5	0.0089	3634916.4090	587566.2225	299.9707
27	2	10.0	0.0079	3634915.6570	587565.2611	299.7842
28	3	11.5	0.0106	3634920.3490	587560.7459	298.9083
29	1	10.4	0.0085	3634923.9850	587557.9974	296.1882
30	3	24.8	0.0485	3634925.1960	587562.8119	298.7663
31	2	14.7	0.0173	3634926.9830	587567.0197	300.2398
32	2	15.3	0.0187	3634932.3050	587569.2059	300.0430
33	2	12.2	0.0117	3634934.3360	587562.3610	297.6580
34	2	14.8	0.0173	3634935.6540	587559.7496	297.0489
35	2	12.1	0.0117	3634934.8100	587559.4571	297.1115
36	1	47.9	0.1818	3634940.6290	587561.2858	297.4545
37	2	11.8	0.0110	3634937.1380	587567.8836	299.4997
38	2	14.8	0.0173	3634934.6370	587566.5659	299.0700
39	2	16.4	0.0212	3634936.1730	587573.8719	300.9614
40	2	12.8	0.0129	3634936.0980	587573.8991	300.8500
41	2	11.2	0.0099	3634933.3440	587573.7970	300.8392
42	2	15.7	0.0197	3634932.0260	587573.5425	301.4138
43	1	24.0	0.0455	3634924.2680	587568.7192	300.3590
44	2	10.1	0.0082	3634928.0460	587574.3285	301.7919

45	2	10.5	0.0089	3634929.5150	587577.7624	302.5566
46	3	22.0	0.0382	3634925.1770	587574.1028	301.9197
47	5	12.2	0.0117	3634923.9460	587572.9491	301.9535
48	1	30.8	0.0749	3634923.6140	587574.7984	302.3874
49	1	27.5	0.0601	3634921.3310	587583.3904	303.9611
50	3	17.2	0.0233	3634922.5720	587581.1712	304.1355
51	1	22.6	0.0403	3634921.7280	587579.8119	303.1624
52	1	14.2	0.0159	3634920.8260	587578.9104	303.3817
53	1	16.2	0.0207	3634918.6950	587579.7342	302.9375
54	1	18.0	0.0256	3634918.8230	587576.8475	302.4080
55	1	18.8	0.0279	3634910.9070	587587.8443	305.3132
56	1	26.1	0.0542	3634909.0830	587587.0572	304.0703
57	1	14.8	0.0173	3634907.6300	587583.7641	304.5622
58	1	16.1	0.0207	3634909.5760	587581.3553	303.7564
59	2	12.2	0.0117	3634910.5590	587578.9590	303.2505
60	1	24.2	0.0462	3634912.2760	587576.9988	302.9223
61	5	12.2	0.0117	3634911.6210	587576.0950	302.9709
62	3	13.5	0.0146	3634911.4500	587575.0843	302.9906
63	1	17.8	0.0250	3634913.9880	587574.8500	302.6291
64	1	17.7	0.0250	3634907.1660	587576.8656	302.8460
65	1	17.5	0.0244	3634906.8620	587578.8213	303.1082
66	2	11.8	0.0110	3634905.4260	587580.4842	304.1334
67	2	13.8	0.0150	3634902.8720	587580.9510	303.4000
68	1	16.8	0.0223	3634902.1070	587580.1956	303.9682
69	1	20.3	0.0328	3634899.0280	587578.7120	303.4632
70	1	13.7	0.0150	3634908.3290	587569.7978	301.2390
71	1	34.1	0.0923	3634911.0810	587571.0804	301.0060
72	1	20.8	0.0341	3634912.7730	587571.0865	301.7287
73	1	26.4	0.0550	3634918.8470	587571.0670	300.9969
74	1	30.5	0.0739	3634919.3700	587570.6438	301.0882
75	2	10.5	0.0089	3634935.6880	587578.0338	291.1158
76	1	17.5	0.0244	3634939.2420	587582.3261	292.3852
77	5	17.8	0.0250	3634939.0730	587584.4326	292.9963
78	5	12.4	0.0121	3634939.4020	587584.0128	293.0135
79	5	11.7	0.0110	3634938.2540	587584.4105	293.3206
80	1	15.0	0.0178	3634937.5990	587584.7405	293.0847
81	2	10.4	0.0085	3634933.8360	587583.3667	292.8009
82	2	11.2	0.0099	3634929.8490	587581.7390	292.4532
83	2	11.0	0.0095	3634927.7520	587582.9601	293.0160
84	2	11.0	0.0095	3634926.5990	587585.0704	293.5939
85	2	11.7	0.0110	3634921.6510	587587.0176	294.2486
86	2	11.0	0.0095	3634928.7190	587586.8741	294.1590
87	1	10.2	0.0082	3634926.4030	587587.7278	294.1429
88	1	15.6	0.0192	3634917.8860	587586.3900	293.3484
89	1	36.4	0.1046	3634914.3310	587591.3400	293.8846
90	1	20.3	0.0328	3634917.6980	587589.7136	294.2557
91	1	20.3	0.0328	3634919.5820	587591.1746	294.6677
92	1	20.6	0.0335	3634919.9580	587589.5838	294.1387
93	1	24.1	0.0462	3634921.1060	587588.6048	294.0990
94	1	12.4	0.0121	3634924.2280	587591.0424	294.7050

95	1	13.3	0.0142	3634926.3190	587591.4327	294.9995
96	1	10.7	0.0092	3634928.3910	587591.7622	295.3894
97	1	13.6	0.0146	3634927.4120	587593.1716	295.5439
98	1	13.2	0.0138	3634928.2020	587593.5911	295.5733
99	1	28.1	0.0628	3634930.8770	587594.9298	295.8768
100	1	24.5	0.0478	3634931.9290	587593.0812	295.8762
101	1	20.1	0.0322	3634931.6620	587597.8790	296.5365
102	1	11.4	0.0103	3634935.0300	587595.3203	296.0885
103	1	28.5	0.0646	3634937.6960	587597.5182	296.8878
104	1	13.4	0.0142	3634934.1020	587600.0517	297.4915
105	1	13.8	0.0150	3634933.9790	587588.7250	294.4998
106	2	11.2	0.0099	3634932.1210	587587.2546	294.3196
107	5	13.3	0.0142	3634935.0060	587601.8941	288.8040
108	1	20.2	0.0322	3634929.8240	587600.8830	288.2595
109	1	33.8	0.0902	3634929.8690	587606.3734	288.7504
110	1	13.9	0.0155	3634926.5240	587597.8507	286.9207
111	1	11.4	0.0103	3634925.4260	587598.0052	287.0734
112	1	25.9	0.0534	3634923.3410	587596.0860	286.8033
113	1	16.3	0.0212	3634919.9460	587597.5649	287.3393
114	2	11.2	0.0099	3634920.8090	587602.8707	288.5772
115	2	10.0	0.0079	3634920.6620	587602.9965	288.5734
116	1	19.7	0.0309	3634925.1610	587594.2570	285.8639
117	1	23.8	0.0447	3634910.4830	587600.4740	293.5424
118	1	13.7	0.0150	3634910.8690	587599.9313	293.2080
119	1	27.8	0.0610	3634910.7600	587598.8166	293.2786
120	1	13.1	0.0138	3634910.9360	587601.8843	294.7033
121	1	12.8	0.0129	3634911.3930	587602.5353	295.0322
122	1	11.8	0.0110	3634909.7430	587604.4552	295.7746
123	1	27.7	0.0610	3634914.6170	587603.7220	295.0079
124	1	15.6	0.0192	3634910.7850	587606.6646	297.2367
125	1	19.5	0.0303	3634915.9010	587598.8073	294.3610
126	1	12.0	0.0114	3634916.7080	587599.0413	294.2954
127	1	31.3	0.0778	3634917.5460	587593.4676	292.9456
128	1	23.5	0.0440	3634920.8450	587591.9435	290.8129
129	1	21.2	0.0355	3634910.5660	587590.4483	291.9507
130	1	18.0	0.0256	3634910.5680	587591.5040	292.3153
131	2	14.2	0.0159	3634905.0000	587585.6841	291.0110
132	5	16.9	0.0228	3634917.5540	587596.6167	291.8383
133	2	16.9	0.0228	3634901.0860	587583.9102	290.8029
134	2	11.1	0.0099	3634898.9910	587584.5280	290.6689
135	1	20.3	0.0328	3634894.0950	587585.2431	290.3152
136	1	16.8	0.0223	3634896.0110	587585.8577	290.9340
137	1	11.9	0.0114	3634896.3800	587585.9437	290.9486
138	1	23.1	0.0425	3634900.0130	587590.4334	291.6197
139	1	23.3	0.0432	3634898.7310	587592.2677	292.3471
140	1	15.2	0.0182	3634897.7480	587591.7871	292.2774
141	1	28.9	0.0664	3634893.9500	587589.3271	292.0344
142	2	10.2	0.0082	3634890.4230	587589.9153	292.2088
143	1	35.0	0.0967	3634901.6700	587594.2371	292.7396
144	1	12.9	0.0133	3634898.7740	587594.7585	292.8875

145	1	20.0	0.0316	3634895.8960	587596.3596	293.6349
146	2	10.3	0.0085	3634906.1800	587595.6260	293.5305
147	1	13.3	0.0142	3634898.9810	587598.9782	294.2257
148	1	27.9	0.0619	3634894.2650	587601.3428	294.6864
149	4	13.1	0.0138	3634889.6540	587601.6551	295.1229
150	1	31.6	0.0788	3634886.9140	587600.1986	295.1137
151	1	18.2	0.0261	3634895.3210	587602.0886	295.2712
152	4	13.3	0.0142	3634890.4250	587603.9615	296.1282
153	4	15.5	0.0192	3634889.1610	587605.1938	296.5284
154	2	12.2	0.0117	3634887.5340	587606.5705	297.1061
155	1	39.3	0.1225	3634902.6340	587602.0720	294.9813
156	1	16.7	0.0223	3634899.0010	587605.5890	296.8396
157	1	11.6	0.0106	3634900.4490	587605.3725	296.8720
158	1	22.4	0.0396	3634905.4030	587607.2071	296.3955
159	1	26.8	0.0567	3634917.1980	587584.1590	297.2850