ANALYSIS OF WILLOW EXPANSION ALONG CROW CREEK ON F.E. WARREN AIR FORCE BASE, WYOMING

FINAL REPORT

Prepared by:

Dr George P. Jones, Ecologist
Wyoming Natural Diversity Database
University of Wyoming
P.O. Box 3381
Laramie, Wyoming 82071-3381

For:

Ms. Cathryn Pesenti
Environmental Management Flight
90 CES / CEVN
300 Vesle Drive
F. E. Warren Air Force Base, Wyoming 82005

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ACKNOWLEDGEMENTS

Rebekah Smith mapped the willow stands and tree stands along Crow Creek, Scott Laursen assisted with collecting the data on canopy cover and height, and Cathy Cooper compiled tables for the report. Their good work is appreciated.

INTRODUCTION

In 2000, the 90th Civil Engineering Squadron, F.E. Warren Air Force Base, U.S. Air Force, contracted with the University of Wyoming's Natural Diversity Database (WYNDD) to conduct several projects on the Base, including one to analyze the expansion of riparian willows (*Salix* spp.) in the past and collect data as a basis for documenting changes in the extent of shrubs in the future. The interest in this project stems from the possible influence of willow density and canopy cover on two federally listed threatened species in the riparian zones on the Base, the Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) and Preble's meadow jumping mouse (*Zapus hudsonius preblei*). The expansion of willow stands has been identified as a possible cause for the decline in numbers of the butterfly plant, while willows may benefit the mouse.

Colorado butterfly plant grows on the Base along Crow Creek, Diamond Creek, and an un-named drainage. Surveys by WYNDD show that the number of plants along Crow Creek, where the riparian zone is vegetated with willows, have declined since the late 1980s, while the numbers of plant along Diamond Creek and the un-named drainage (where willows are rare) have increased. Photographs taken on the ground (and, to some extent, aerial photographs) of the Crow Creek riparian area suggest that willow stands have increased in extent and height over the years. Furthermore, in most willow stands, the tallest stems are found in the center of the stand and plants are shorter with increasing distance from the center, suggesting that these stands are expanding.

The influence of willows is a function of the extent of willow stands and of the amount of canopy cover within those stands. Our original intent was to use aerial photographs to measure the extent of willow stands from successive years, then use those measurements to calculate the rate of change in willow extent during the past several decades and to compare changes in willow extent to timing of floods that may have either removed willows or promoted their growth. This historical information on extent of willows was to be augmented with information on height and density of willow stems collected along permanent transects in the willow stands.

Unfortunately, while some aerial photographs taken in past decades appear to show that the distribution of willows has changed, the resolution of the historical photographs is too poor to allow detailed measurements of the willow stands. This shortcoming was discovered when global positioning system (GPS) receivers were used to document the boundaries of willow stands, and those boundaries were then overlaid on recent aerial photographs. The GPS-measured boundaries correspond well with patterns on the photographs in some areas, but in a substantial part of the Crow Creek riparian zone, no shrub stands could be discerned on the photographs where on-the-ground observations showed them to be present. We concluded that the aerial photographs could not be used to make reliable estimates of willow expansion and contraction. Consequently, we modified our methodology, measuring the current extent of willow stands on the ground and then (as originally planned) collecting data on canopy density and height within those stands.

METHODS

DOCUMENTING THE EXTENT OF WILLOW STANDS

During summer 2001, Rebekah Smith of the Wyoming Natural Diversity Database (WYNDD) used a global positioning system receiver (GeoExplorer II, Trimble Surveying and Mapping Products, Sunnyvale CA) to record the boundaries of willow and tree stands along Crow Creek. (Defining a willow stand is arbitrary and discerning its boundary is somewhat subjective. We consider a willow stand to be an area of at least 100 square meters where willow canopy cover is at least 50% and gaps in the canopy are smaller than 100 square meters.) The boundaries were collected as line features, with positions recorded every 5 seconds. The field data were differentially corrected (Trimble Pathfinder Office 2.11, using files from the Casper Community Base Station) and the corrected files were edited to remove extraneous lines. These corrected locations were incorporated into a geographic information system (ArcView 3.2, Environmental Systems Research Institute, Redlands CA) as arc features, and polygons were then digitized manually over the arcs to produce a digital layer containing polygons of willow and tree stands.

Additional field reconnaissance showed that some of the willow stands delineated in 2001 are essentially continuous and without openings, and some are patchy and include grassy openings.

MEASURING WILLOW COVER

Willow canopy cover and height were measured at points along permanent sampling lines. In an effort to distribute the lines throughout the entire riparian zone of Crow Creek and among the habitats present therein, we placed sampling lines in each of three cover-types:

(1) Continuous willow stands. These stands were identified as willow polygons in the digital layer of willow distribution, and field reconnaissance indicated that openings in the willow canopy were smaller than ca. 100 square meters.

(2) Graminoid (i.e., grass, sedge, and rush) meadows without willows. These are the areas that were not identified as willow stands on the digital layer because they had not been delineated during field GPS sampling as willow or tree stands.

(3) Willow & graminoid mosaics. These are the areas identified as willow stands on the digital layer and shown by field reconnaissance to contain frequent openings ca. 100 square meters in area or larger.

Potential sampling lines were drawn in ArcView 3.2 using the black-and-white digital orthophotoquad and the digital layer of willow stands as background. The lines were located subjectively. Each line was drawn at least 5 m from the boundary of the polygon in which it was placed. The ends and any bends in each line were digitized as points, and the UTM coordinates of each point were recorded. These UTM coordinates were considered to be the preliminary locations for the sampling lines.

In the field, Scott Laursen and George Jones of the WYNDD staff used a GPS receiver to navigate to the preliminary locations. If necessary, the endpoints and any bends of a line were moved to assure that, in the judgement of the field crew, the line was restricted to a single cover type. A 50-meter, fiberglass surveyor's tape was stretched from one endpoint to

the other (with any necessary bends), and the UTM coordinates of the endpoints and bends were recorded as points with the GPS receiver. These coordinates are the final locations for the sampling lines.

Each line was 35 meters long and contained 7 sampling points. The first sampling point was located 5 meters from the starting point of the line, and subsequent points were located in 5-meter increments down the line (Figure 1). At each point, a spherical densiometer (Forest Densiometer Model-A, Robert E. Lemmon, Bartlesville OK) was used to estimate the density of the shrub canopy (Lemmon 1956). The densiometer was held 10 cm above the ground and four readings were taken at each point, two of them 180^o apart along the sampling line and the other two at right angles to the sampling line (Figure 1). Each reading was converted to an estimate of percent canopy cover, and the four estimates from a sampling point were averaged to give a single value for the point. The canopy cover values from the sampling points were averaged to give the estimate of average canopy cover along the line. The standard deviation of that estimate for the line was also calculated from the cover values for the sampling points.

At each point, a pole marked in decimeter increments was used to measure the height of the highest branch and the lowest branch on the shrub nearest the point. These measurements were used to represent the heights of the top and the bottom of the shrub canopy, respectively, at the sampling point. The estimates of height of the canopy top from the sampling points along a line were averaged to yield an estimate of average canopy height for the entire line, and the standard deviation was calculated from the estimates at the sampling points.

RESULTS

Figure 2 shows the extent of willow stands in the riparian zone of Crow Creek as of summer, 2001. As noted above, field reconnaissance showed that the area mapped as willow stands includes patches of herbaceous vegetation, dominated by grasses, sedges, and forbs, growing in openings in the willow canopy. Those openings are small relative to the area of actual willow canopy, generally covering less than 100 square meters.

Twenty-three sampling lines were established in the riparian zone (Figure 2), 11 of them in mixed willow and grass areas, 5 in grass vegetation, and 7 in continuous willow stands (Table 1). Average canopy cover on the sampling lines in the grass-dominated vegetation, which contains only scattered shrubs, was significantly lower than on the lines in continuous willow stands and lower than on most lines in the willow-and-grass areas (Figure 3a). Average canopy cover on lines in the willow-and-grass areas varied widely from line to line, but was generally lower than in the continuous willow stands. Estimates from individual sampling points along a line showed great variation, especially on along lines in the heterogeneous willow-and-grass areas (Figure 3b). Canopy cover was dense at most sampling points along lines in the continuous willow stands, but even there, some points fell in openings where the cover was sparse. A few points on lines in the grassy openings, which contain scattered shrubs, had dense cover.

Shrub canopy height showed little difference between the three cover types (Figure 4a), although minimum values were higher in the continuous willow stands than in the other two cover types (Figure 4b). Apparently, the scattered shrubs growing in the grass-dominated vegetation are nearly as tall as the shrubs in the continuous willow stands.

DISCUSSION

The data reported herein provide a basis for documenting changes in the extent of willow stands and in the amount and height of willows within those stands. Although we concluded that we could not discern the boundaries of shrub stands on black-and-white digital orthophotographs displayed in ArcView, different photographs or satellite images, or more sophisticated analysis of the photographs, might allow mapping of the shrub stands in the office. The main advantage of mapping in that manner would be the use of photos from past decades to show historical changes in extent of shrubs. And openings in the willow stands might be mapped more easily from photographs than on the ground. But mapping the boundaries of willow stands with a GPS receiver is, we believe, satisfactory for the purposes at hand, and it is relatively straightforward and easy: we found that the entire riparian zone of Crow Creek can be mapped by one person in two days.

The starting and ending points of our sampling lines can be located again with a GPS receiver, and estimates of shrub canopy and height can be made again from sampling points close to those we used. Some error in repeated samples is inevitable due to the impossibility of locating the starting and ending points of sampling lines with complete precision, of laying out the surveyor's rope (or other tape) exactly as we did, of precisely measuring the distances from the starting point of a line to the sampling points, and of reading the densiometer exactly as we did. But we believe that these errors should have a negligible effect on year-to-year comparisons. The sample unit is the sampling line, not the sampling points along it, and the value for the sampling line is calculated from the individual points. We think it unlikely that errors in locating the sampling points along a line and in reading the densiometer will be consistent enough to significantly affect the values for a line.

Canopy cover is so dense at most points in the continuous willow stands (Figure 3b) that we anticipate little change in the estimates from that cover type, although average canopy cover per line in that type may increase slightly as small openings fill in. Increases in willow cover along Crow Creek more likely will be reflected in higher average cover values for the lines in the willow-and-grass cover type and in the grass cover type, as willows fill the openings in the former and spread into the latter. The pattern of cover estimates from individual sampling points on those lines (Figure 3b) probably will shift upward. The point-to-point variation on lines in the willow-and-grass type probably will decline as openings fill in, but variation on lines in the grass type may increase (at least initially) as existing willow stands expand into the grass-dominated part of the riparian area. Spread of willow stands into grassy areas also will be reflected by an increase in the area mapped as willow stands (Figure 2).

LITERATURE CITED

Lemmon, Paul E. 1956. A spherical densiometer for estimating forest overstory density. Forest Science 2(1): 314-320.

FIGURES

Figure 1. Arrangement of the sampling points along a sampling line.

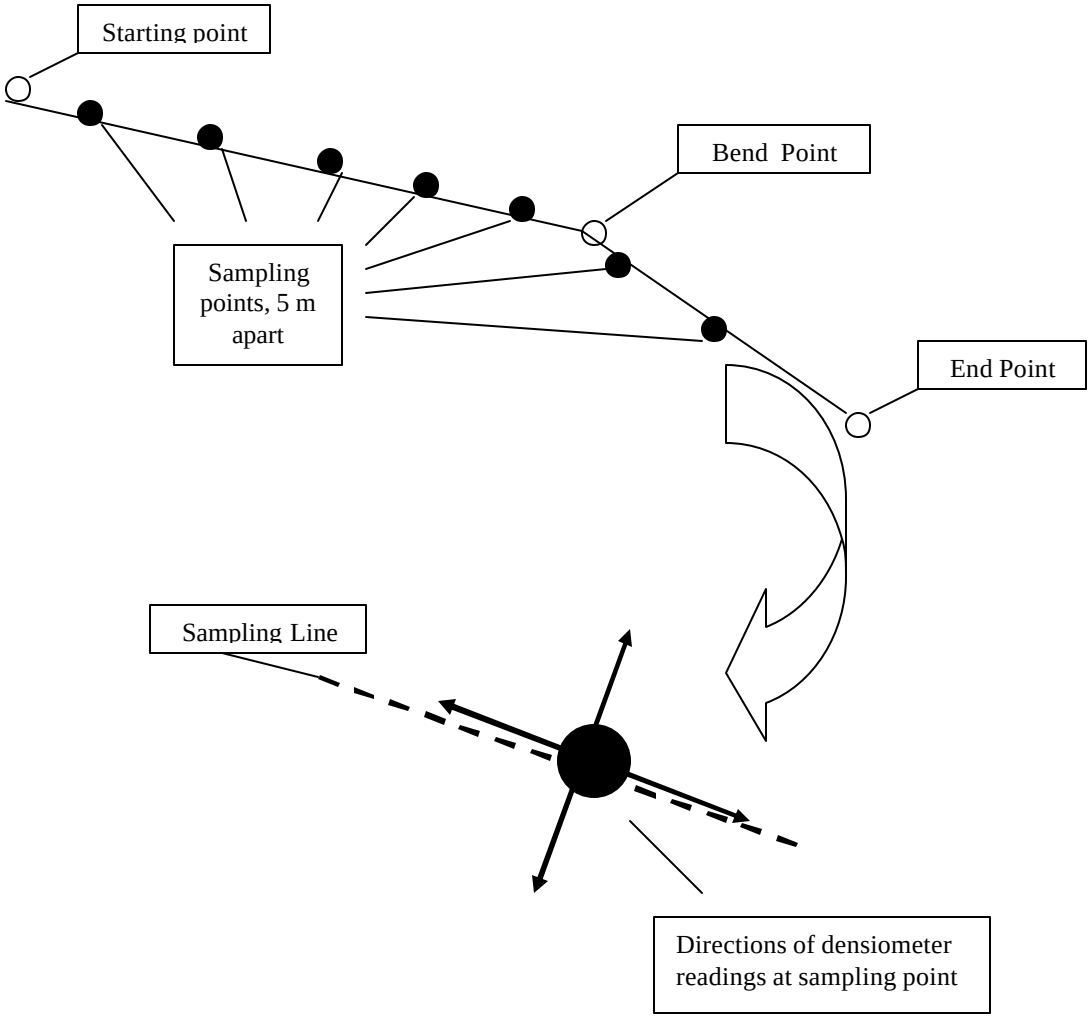
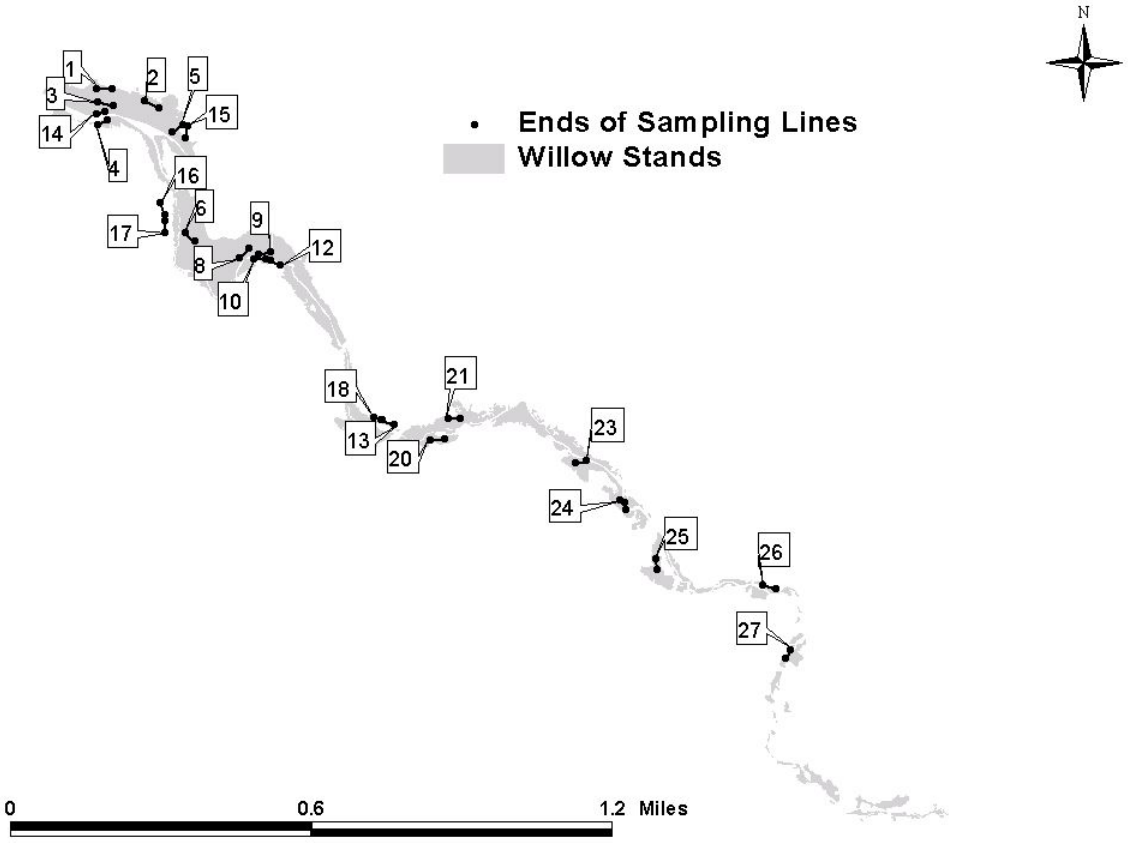


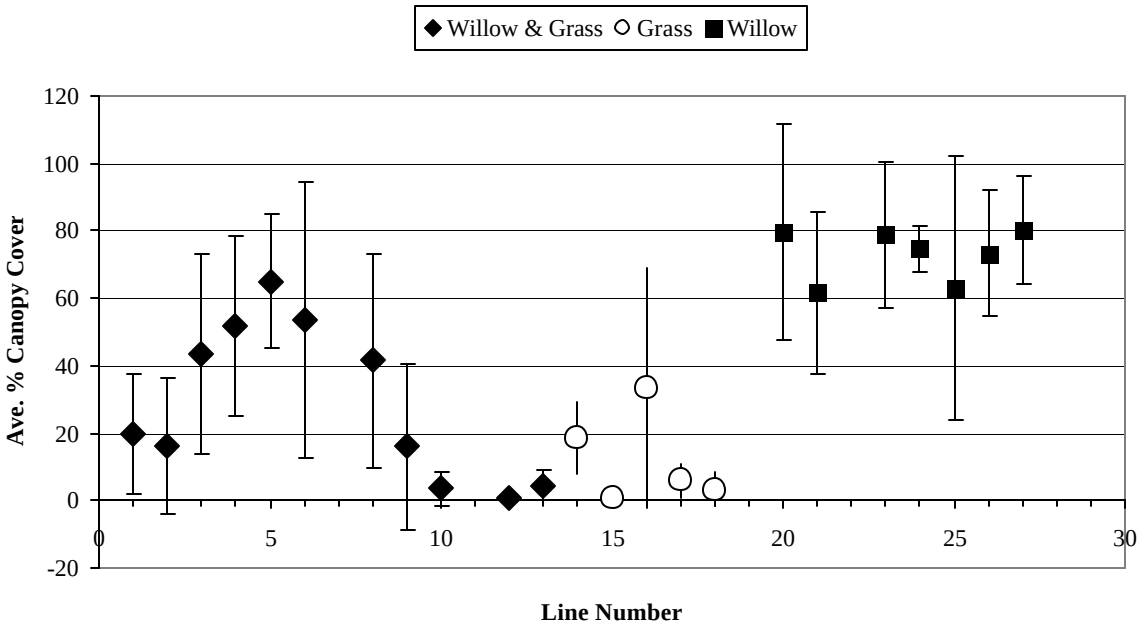
Figure 2. Locations of Sampling Lines in the Riparian Zone of Crow Creek.



The willow stands are contained in the digital file “wlw_polygon.shp” and the ends of sampling lines in the file “sampling lines ends.shp”, both of which accompany this report.

Figure 3a. Average Percent Canopy Cover for Each Sampling Line

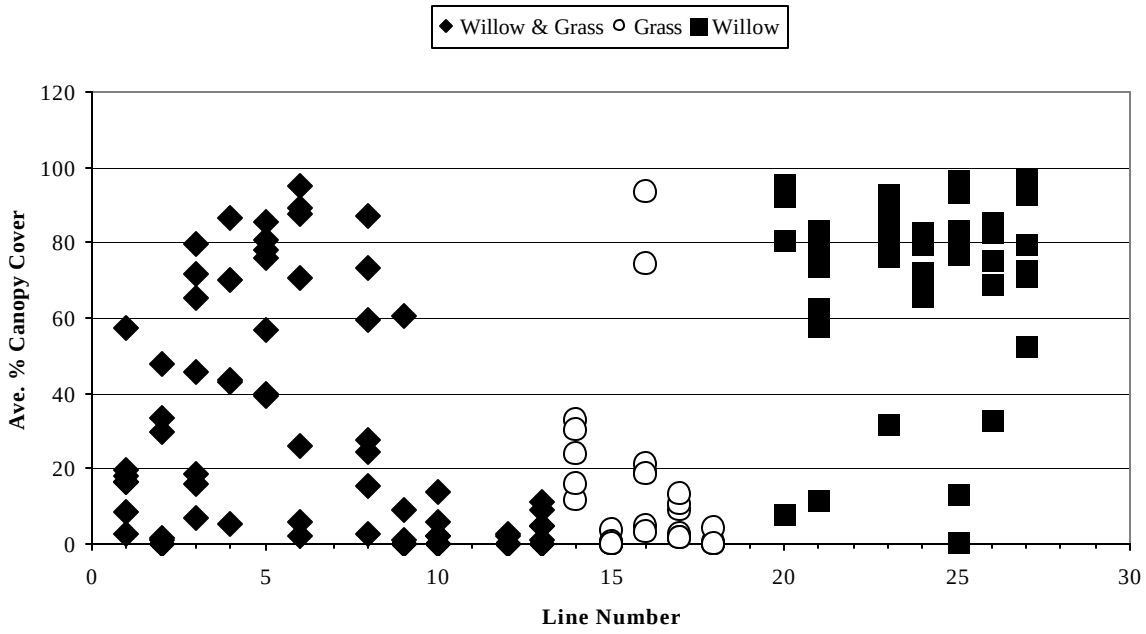
Each symbol is an average for a sampling line, calculated from the values from the sampling points along that line (show in Figure 3b). Bars show one standard deviation.



Data are in the file "Shrub Data.xls" that accompanies this report.

Figure 3b. Estimates of Percent Canopy Cover at Each Sampling Point on the Sampling Lines.

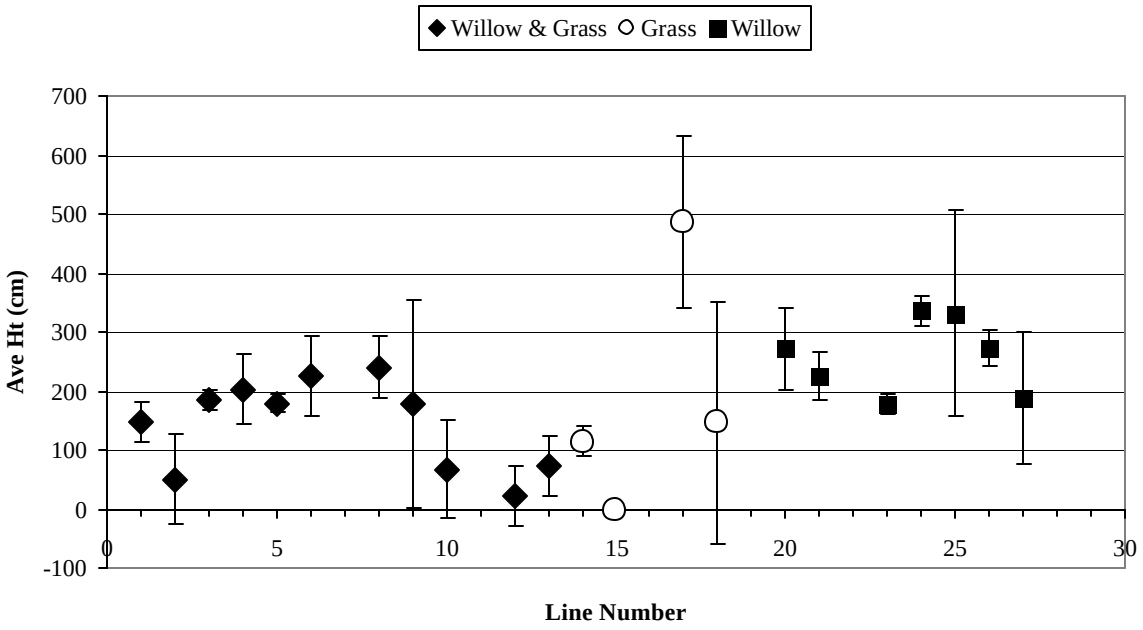
These are the values from which the averages and standard deviations in Figure 3a were calculated.



Data are in the file "Shrub Data.xls" that accompanies this report.

Figure 4a. Average Canopy Height on Each Sampling Line.

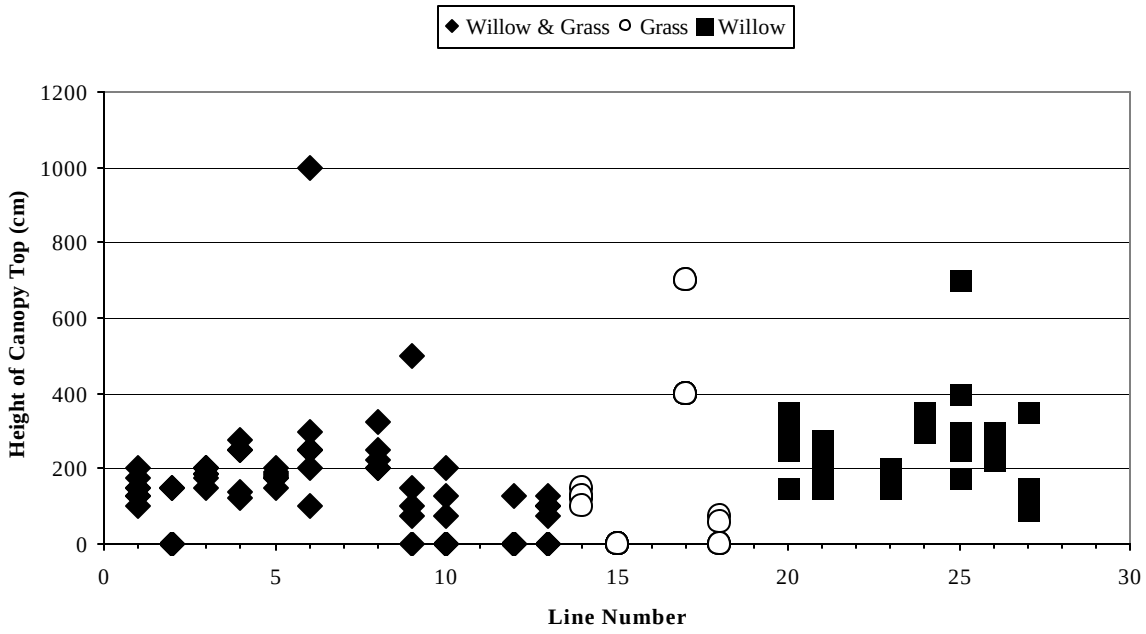
Each symbol is an average for a sampling line, calculated from the values from the sampling points along that line (show in Figure 3b). Bars show one standard deviation. Estimates of tree canopy height were removed from lines 2, 8, 10, and 16 to better reflect the height of the shrub canopy. See Table 2.



Data are in the file "Shrub Data.xls" that accompanies this report.

Figure 4b. Canopy Height at Each Sampling Point on the Sampling Lines.

Estimates of tree canopy height were removed from lines 2, 8, 10, and 16 to better reflect the height of the shrub canopy. See Table 2. These are the values from which the averages and standard deviations in Figure 4a were calculated.



Data are in the file "Shrub Data.xls" that accompanies this report.

TABLES

Table 1. Locations and types of sampling lines.

"northing" and "easting" are UTM coordinates in NAD83, Zone 13N. These data are in the digital file "Sampling lines ends.shp" that accompanies this report.

Line	Point	northing	easting	Cover Type
1	End	4556387	510334	Willow & Grass
1	Start	4556387	510284	Willow & Grass
2	End	4556325	510484.5	Willow & Grass
2	Start	4556348	510439	Willow & Grass
3	End	4556335	510337	Willow & Grass
3	Start	4556346	510289	Willow & Grass
4	End	4556286	510318	Willow & Grass
4	Start	4556274	510287	Willow & Grass
5	End	4556250	510528	Willow & Grass
5	Start	4556274	510561	Willow & Grass
6	End	4555897	510599	Willow & Grass
6	Start	4555927	510569	Willow & Grass
8	End	4555875	510773	Willow & Grass
8	Start	4555844	510744	Willow & Grass
9	End	4555865	510843	Willow & Grass
9	Start	4555858	510805	Willow & Grass
10	End	4555842	510826	Willow & Grass
10	Start	4555840	510790	Willow & Grass
12	End	4555823	510875	Willow & Grass
12	Start	4555838	510842	Willow & Grass
13	End	4555325	511195	Willow & Grass
13	Start	4555310	511237	Willow & Grass
14	End	4556313	510313	Grass
14	Start	4556308	510284	Grass
15	End	4556229	510570	Grass
15	Start	4556270	510576	Grass
16	End	4555985	510503	Grass
16	Start	4556021	510490	Grass
17	End	4555925	510505	Grass
17	Start	4555963	510502	Grass
18	End	4555332	511173	Grass
18	Start	4555324	511200	Grass

Table 1 (continued).

Line	Point	northing	easting	Cover Type
20	End	4555265	511401	Willow
20	Start	4555261	511353	Willow
21	End	4555328	511451	Willow
21	Start	4555328	511413	Willow
23	End	4555185	511819	Willow
23	Start	4555194	511854	Willow
24	End	4555037	511982	Willow
24	Middle	4555058	511978	Willow
24	Start	4555067	511962	Willow
25	End	4554879	512076	Willow
25	Start	4554846	512083	Willow
26	End	4554782	512463	Willow
26	Start	4554794	512422	Willow
27	End	4554561	512495	Willow
27	Start	4554585	512508	Willow

Table 2. Average canopy cover and canopy height on the 23 sampling lines.

Average cover values were calculated from the four densiometer readings at a point. Height was a single measurement at a point. Heights of tree canopies noted in the table were removed from the data displayed in Figure 4. These data are in the digital file "Shrub data.xls" that accompanies this report.

Line #	Ave. % cover for point	Ht. (cm) of canopy top	Notes
1	58	200	
1	18	175	
1	8	125	
1	3	100	
1	17	150	
1	17	150	
1	20	125	
2	0	0	
2	0	0	
2	2	0	
2	1	150	
2	48	150	
2	33	150	
2	30	8000	Cottonwood trees
3	7	150	
3	18	200	
3	16	175	
3	45	185	
3	80	185	
3	65	200	
3	71	200	
4	44	140	
4	70	250	
4	87	250	
4	5	120	
4	43	275	
5	78	175	
5	85	180	
5	57	175	
5	40	185	
5	39	150	
5	81	200	
5	76	190	

Table 2 (continued).

Line #	Ave. % cover for point	Ht. (cm) of canopy top	Notes
6	89	250	
6	88	250	
6	95	300	
6	71	250	
6	2	1000	
6	26	100	
6	6	200	
8	24	200	
8	74	325	
8	59	250	
8	87	200	
8	3	900	900 cm height is tree > 6 m away. Most canopy is shrubs to 300 cm high.
8	15	225	
8	28	900	900 cm height is tree > 6 m away. Most canopy is shrubs to 300 cm high.
9	60	150	
9	1	1500	large cottonwood 20 m away from transect
9	9	500	
9	0	0	
9	0	100	
9	0	75	
10	0	0	
10	2	75	
10	6	125	
10	0	0	
10	0	0	
10	14	200	
10	2	1000	cover = plains cottonwood ~ 10 m away
12	0	0	
12	0	0	
12	0	0	
12	0	0	
12	0	0	
12	2	125	
12	3		

Table 2 (continued).

Line #	Ave. % cover for point	Ht. (cm) of canopy top	Notes
13	9	125	
13	5	100	
13	5	100	
13	0	0	
13	0	0	
13	1	75	
13	11	100	
14	12	125	
14	33	120	
14	30	150	
14	24	130	
14	16	100	
15	0	0	
15	1	0	
15	0	0	
15	0	0	
15	4	0	
15	1	0	
15	0	0	
16	5	1000	Trees > or equal to 10 m from transect
16	3	800	
16	19	800	
16	21	800	
16	18	800	
16	93	800	
16	74	800	
17	9	700	
17	2	700	
17	3	400	
17	2	400	
17	2	400	
17	10	400	
17	13	400	
18	0	0	
18	1	75	
18	0	0	
18	4	60	
18	0	0	

Table 2 (continued)

Line #	Ave. % cover for point	Ht. (cm) of canopy top	Notes
20	95	300	
20	95	350	
20	81	350	
20	92	250	
20	8	150	
20	93	250	
20	95	250	
21	62	225	
21	58	250	
21	83	250	
21	63	275	
21	79	225	
21	74	200	
21	11	150	
23	82	200	
23	77	175	
23	93	175	
23	87	175	
23	92	180	
23	32	150	
23	90	200	
24	83	350	
24	70	350	
24	70	300	
24	80	300	
24	66	350	
24	82	350	
24	72	350	
25	83	250	
25	13	175	
25	1	250	
25	77	300	
25	94	400	
25	96	250	
25	78	700	
26	84	275	

Table 2 (continued).

Line #	Ave. % cover for point	Ht. (cm) of canopy top	Notes
26	85	225	
26	33	250	
26	84	300	
26	69	250	
26	76	300	
26	83	300	
27	71	150	
27	80	100	
27	93	125	
27	73	90	
27	53	150	
27	97	350	
27	95	350	

Table3. Digital files accompanying the report.

File Name	Type	Contents
few_will_bdy.shp	ArcView shape file (and associated files)	Boundaries of willow stands as polyline features, collected with GPS receiver and edited.
sample lines ends.shp	ArcView shape file (and associated files)	UTM coordinates (NAD83, Zone 13) of the final endpoints of the sampling lines.
wlw_polygon.shp	ArcView shape file (and associated files)	Boundaries of willow stands as polygon features, created from the file few_will_bdy.shp
Shrub data.xls	Microsoft Excel worksheet	Data on canopy cover and height, organized in different ways in different spreadsheets.