Willow and cottonwood development adjacent to planted and unplanted freshwater marshes

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Introduction

Black willow (*Salix nigra* Marsh.) and eastern cottonwood (*Populus deltoides* Marsh.) are members of the pioneer, moist-site tolerant regeneration guild of the central hardwood forest, which is characterized by species that require a wet seedbed for germination, have wind-dispersed seeds, and are shade intolerant (Sutherland et al., 2000). Both species are characteristic woody plants of riparian areas. Willow and cottonwood establishment is dependent on periodic flooding and the presence of bare soil (Scott et al., 1996; Auble and Scott, 1998). In addition to shade intolerance, interspecific competition restricts cottonwood establishment to unvegetated sites (Cooper et al., 1999).

This research was conducted to compare the willow and cottonwood component of two constructed wetlands, one that was initially planted and one that was not. Willow and cottonwood productivity was expected to be greater in the unplanted wetland because the seedlings should have experienced less shading and interspecific competition than in the planted wetland.

Methods

The developing riparian forests examined in this study were located adjacent two constructed marshes at the Olentangy River Wetland Research Park. In May 1994, Wetland 1 was planted with 2400 individuals of 13 native wetland plant species, while wetland 2 was left unplanted (Mitsch et al., 1998). The vegetation in each kidney-shaped wetland was subsequently allowed to develop without any plant management for the next eight growing seasons. The woody component formed a narrow strip around the open water and herbaceous plant core of each wetland and was widest at the concaves of each ‘kidney’ (Figure 1).

The woody component in the concave of each wetland was sampled in November 2001. Twelve 0.91-m transects at 10-m intervals were sampled perpendicular from the water edge of each wetland. All woody stems within transects were tallied and identified. The diameter of each tree taller than 1.4 m (4.5 ft; hereafter “overstory”) was measured at that height, and the diameter of each tree under that height (hereafter“understory”) was measured at the root collar (Danzer et al., 2001). Basal area was calculated from the diameter of each tree and summed for each transect. Transect length, defined as the distance between the trees closest to and furthest from the water edge in each transect, was recorded. These transect lengths were not converted to area estimates for stem density and basal area analyses because of the large potential bias in area were one seedling to be found several meters outward from the majority of the trees, which were always found in the first 1 to 3 m of each transect. Because an equal area was sampled within the transects of each wetland and between wetlands, stem count and basal area were calculated per transect rather than per area. Relative stem density and basal area best allowed for an unbiased comparison between transects and wetlands. Species composition (percent of stems of the same species) and species diversity (Shannon-Weiner Index) were also calculated for each transect.

Species composition, basal area, stem density, and species diversity were compared between the planted and unplanted wetlands using paired t-tests (paired by transect number). An a value of 0.05 was used for all significance tests.

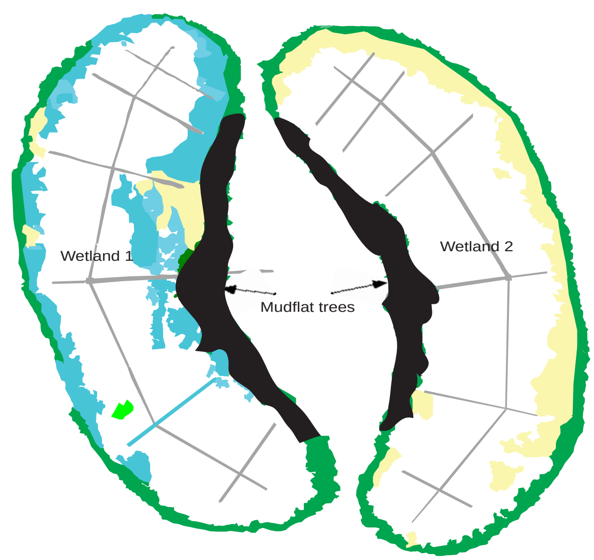

Figure 1. Map of Olentangy River Wetland Research Park, showing the two constructed marshes and the developing forests on mudflats between experimental wetlands.

Table 1. Percent of trees that are cottonwood and willow in transects on wetland transects in mudflats of two experimental wetlands (W1 = planted wetland; W2 = unplanted wetland)

	Cottonwood		Willow	
Trans	W1	W2	W1	W2
1	63	100	0	0
2	57	43	43	35
3	71	18	0	78
4	13	78	61	17
5	41	63	47	22
6	13	52	40	45
7	44	54	53	36
8	40	64	40	25
9	51	73	42	24
10	57	61	43	39
11	31	42	66	55
12	50	38	40	48
Mean	39	0.57	40	35

Table 2. Species diversity (Shannon Weiner index) and number of stems per transect.

	Species Diversity		# of Stems	
Trans	W1	W2	W1	W2
1	0.66	0.00	8	7
2	0.68	1.06	7	23
3	0.90	0.64	28	76
4	1.14	0.69	23	36
5	1.15	1.06	64	49
6	1.60	0.82	30	58
7	0.79	1.03	111	59
8	1.25	0.94	35	36
9	0.94	0.65	59	49
10	0.68	0.67	14	94
11	0.76	0.83	29	62
12	0.94	1.07	10	80
Mean	0.96	0.79	34.8	52.4

Results

Willow and eastern cottonwood were the most abundant tree species in the regenerating forests, together accounting for greater than 90% of the stems (Appendix 1). Red maple (*Acer rubrum* L.), silver maple (*Acer saccharinum* L.), sycamore (*Platanus occidentalis* L.), elm (*Ulmus* spp.), and boxelder (*Acer negundo* L.) were the most abundant subdominants. Willow comprised 39% of the stems in the planted wetland and 35% in the unplanted, while cottonwood comprised 40% of the planted and 57% of the unplanted. No significant difference was found in willow (paired-t = 0.683, df_{11}) or cottonwood (paired-t = 0.166, df_{11}) composition between the two wetlands (Table 1). Species diversity (Table 2) also did not differ between the two wetlands (paired-t = 0.125, df_{11}).

A mean 34.8 ± 15.7 (95% confidence interval) total stems per transect were found in Wetland 1 and 52.4 ± 12.8 in Wetland 2. Wetland 2 had a significantly greater number of overstory cottonwoods (paired-t = 0.041, df_{11}), understory cottonwoods (paired-t = 0.004, df_{11}), and understory willows (paired-t = 0.125, df_{11}). Number of overstory willow stems did not differ between wetlands (paired-t = 0.125, df_{11}). Wetland 2 had roughly ten times the total basal area as the Wetland 1 (Figure 2).

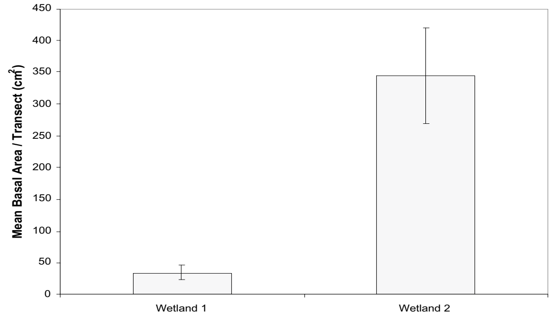

Figure 2. Mean basal area (cm^2) per transect of all tree species combined in Wetland 1 (planted) and Wetland 2 (unplanted). Error bars represent standard error of the mean.

Discussion

The originally unplanted wetland (Wetland 2) had significantly more willows and cottonwoods than the planted wetland (Wetland 1), and the trees were also larger. Because the understory and overstory classes were defined by height, it can also be concluded that the unplanted wetland had a greater number of taller trees than the planted wetland. This evidence supports Cooper et al.'s (1999) conclusion that interspecific competition is an important factor in cottonwood establishment. Many of the trees in the planted wetland likely germinated later and experienced more shading and competition than those in the unplanted wetland; that explains why tree productivity was less. In fact, Weihe (1996) observed that both cottonwood and willow densities were greater in the unplanted wetland (Wetland 2) during the first two years after planting.

Competition is not the only factor that affects willow and cottonwood establishment. The presence of a moist seedbed is also essential (Scott et al., 1996). Because the two wetlands have similar basin geomorphology and have experience similar inflows for their 6.5 years of existence as of this study (Mitsch et al., 2000), differences in seedbed moisture were likely minimal. Nutrient inflows are also similar, as both wetlands receive inflow from the same source. Differences in nutrient availability or soil bed moisture should not explain differences in woody plant productivity between the two wetlands.

Seed dispersal is another factor that can limit forest regeneration. The intensity of seed dispersal for trees whose seeds are wind-dispersed, such as those of cottonwoods and willows, is related to dispersal distance and height of source trees but also depends on wind intensity and direction (Smith et al., 1997). Both wetlands likely received their seeds from the adjacent bottomland hardwood forest, which has a density of 22 cottonwood and 5.5 willow trees per ha (Marshall, 2001). The wetlands are bordered by the bottomland forest on the north edge (65 m away). Wetland 2 is also bordered by the bottomland (approximately 160 m away) on the east side. Because the regenerating wetland forests are only 20 m apart and a pattern in stem count was not seen by transects, seed availability does not appear to explain the differences in tree regeneration between the two wetlands.

Animals can also affect forest regeneration. Muskrats can have large impacts on biomass, diversity, and stem density of wetland plants (Connors et al., 2000; Smirnov and Tretyakov, 1998). Willow is a preferred food of muskrats. If muskrats were more abundant in the planted Wetland 1, they could have accounted for the lower observed productivity in that wetland. However, muskrat pressure has been much greater in Wetland 2 in recent years (Higgins and Mitsch, 2001), primarily because macrophyte productivity was much higher in Wetland 2. Muskrat grazing may have actually reduced the large difference in tree productivity between the two wetlands, not increased it.

Several explanations for the greater tree productivity in the unplanted versus planted wetland have been discussed, and are consistent with the conclusion that it was the increased competition with planted macrophte species that resulted in the lower tree productivity adjacent to the planted wetland. Competition is an important factor driving willow and cottonwood establishment patterns in riparian forests.

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Appendix 1. Species, diameter, and story by transect for all stems in wetlands 1 and 2

Wetland	Transect	Story[a]	Species[b]	Diameter[c]	Wetland	Transect	Story[a]	Species[b]	Diameter[c]
1	1	U	BE	0.4	2	1	O	CW	2.4
1	1	U	BE	0.3	2	1	O	CW	3.7
1	1	U	BE	0.3	2	1	O	CW	5.9
1	1	O	CW	3.9	2	1	O	CW	2.9
1	1	O	CW	3.1	2	1	U	CW	1.6
1	1	O	CW	0.8	2	1	O	CW	3.1
1	1	O	CW	5	2	1	U	CW	1.2
1	1	O	CW	5	2	2	U	RM	0.2
1	2	O	CW	2.9	2	2	U	RM	0.2
1	2	U	W	0.8	2	2	U	RM	0.2
1	2	U	W	0.6	2	2	U	RM	0.2
1	2	U	W	0.5	2	2	U	RM	0.2
1	2	U	CW	0.6	2	2	O	W	2.2
1	2	O	CW	0.7	2	2	O	W	7.3
1	2	U	CW	0.6	2	2	U	CW	1.0
1	3	O	CW	0.8	2	2	O	W	4.8
1	3	O	CW	1.1	2	2	U	CW	1.3
1	3	U	CW	0.6	2	2	O	W	1.8
1	3	U	CW	0.6	2	2	O	CW	1.4
1	3	U	CW	0.9	2	2	O	CW	3.2
1	3	U	CW	0.4	2	2	U	CW	1.2
1	3	O	CW	2.4	2	2	U	CW	0.8
1	3	O	CW	2.1	2	2	U	CW	1.5
1	3	O	CW	1.9	2	2	O	CW	2.3
1	3	U	CW	1	2	2	O	W	17.8
1	3	U	RM	0.2	2	2	O	W	10.5
1	3	U	CW	0.9	2	2	O	W	4.1
1	3	U	CW	0.8	2	2	O	CW	2.8
1	3	U	CW	0.8	2	2	O	CW	4.3
1	3	U	CW	0.4	2	2	O	W	14.3
1	3	U	CW	1	2	3	U	RM	0.2
1	3	U	CW	0.6	2	3	U	RM	1.3
1	3	O	CW	1.5	2	3	U	W	1.1
1	3	O	CW	1.6	2	3	U	W	0.6
1	3	O	CW	0.9	2	3	U	W	1.0
1	3	O	CW	0.5	2	3	U	W	1.3
1	3	U	S	0.6	2	3	U	W	0.8
1	3	O	SM	1.2	2	3	U	CW	0.6
1	3	O	SM	1.5	2	3	U	W	1.0
1	3	O	SM	1.3	2	3	O	W	0.8
1	3	O	SM	0.8	2	3	U	W	1.3
1	3	O	M	0.4	2	3	U	W	0.2
1	3	U	SM	1.5	2	3	U	W	0.2
1	4	U	W	0.3	2	3	U	CW	0.7
1	4	O	W	0.4	2	3	O	W	1.8
1	4	O	CW	3.1	2	3	U	CW	1.1
1	4	O	W	1.3	2	3	U	W	0.2
1	4	U	W	0.6	2	3	U	W	0.2
1	4	O	W	0.7	2	3	U	W	0.5
1	4	O	W	2.4	2	3	U	W	0.7
1	4	O	W	1.2	2	3	U	CW	1.9
1	4	O	W	0.5	2	3	O	CW	0.0
1	4	O	CW	3	2	3	U	CW	1.1
1	4	O	W	0.7	2	3	U	RM	0.2
1	4	O	CW	0.9	2	3	O	CW	1.7
1	4	O	W	0.5	2	3	O	CW	1.8
1	4	O	W	0.5	2	3	U	CW	0.6
1	4	O	W	1.5	2	3	U	W	0.6
1	4	U	SM	0.2	2	3	U	W	1.2
1	4	U	BE	0.2	2	3	U	CW	0.8
1	4	O	W	1.1	2	3	O	CW	2.2
1	4	O	W	1.4	2	3	O	CW	4.9
1	4	U	BE	1.4	2	3	U	W	0.9
1	4	U	RM	0.2	2	3	O	CW	1.8
1	4	U	BE	0.6	2	3	O	CW	1.8
1	4	U	BE	0.8	2	3	U	W	1.1
1	5	O	W	0.6	2	3	O	W	2.2

1	5	O	W	0.7	2	3	O	W	4.4
1	5	O	W	0.9	2	3	O	W	2.0
1	5	O	W	0.4	2	3	U	W	2.2
1	5	O	BE	0.3	2	3	U	W	2.3
1	5	O	CW	1.7	2	3	U	W	1.9
1	5	O	W	1.6	2	3	U	W	2.0
1	5	O	W	0.4	2	3	U	W	1.5
1	5	O	W	0.6	2	3	U	W	1.8
1	5	O	W	0.3	2	3	U	W	1.3
1	5	O	W	0.9	2	3	O	W	2.6
1	5	O	W	0.7	2	3	O	W	3.6
1	5	O	CW	0.8	2	3	O	W	4.8
1	5	O	CW	0.6	2	3	U	W	5.4
1	5	O	W	4.1	2	3	O	W	3.5
1	5	O	CW	0.7	2	3	O	W	2.7
1	5	O	W	0.6	2	3	O	W	4.8
1	5	O	W	0.6	2	3	U	W	1.0
1	5	O	CW	0.4	2	3	U	W	1.7
1	5	O	W	3.8	2	3	U	W	1.6
1	5	O	CW	0.5	2	3	U	W	1.1
1	5	U	CW	0.4	2	3	U	W	1.3
1	5	U	W	0.3	2	3	U	W	2.8
1	5	U	W	0.2	2	3	U	W	1.9
1	5	O	CW	2	2	3	U	W	3.2
1	5	O	CW	1.4	2	3	U	W	3.1
1	5	O	W	0.8	2	3	U	W	0.9
1	5	O	CW	0.6	2	3	U	W	1.0
1	5	O	CW	0.9	2	3	O	W	0.9
1	5	U	CW	0.8	2	3	U	W	1.0
1	5	U	CW	0.5	2	3	U	W	5.5
1	5	U	CW	1	2	3	U	W	5.4
1	5	U	CW	1.2	2	3	U	W	1.7
1	5	U	CW	0.7	2	3	O	W	5.5
1	5	O	CW	3	2	3	O	W	5.0
1	5	O	CW	2	2	3	U	W	1.2
1	5	O	CW	1.3	2	3	U	W	0.6
1	5	O	CW	0.5	2	3	U	W	1.3
1	5	O	CW	0.4	2	3	U	W	1.0
1	5	O	CW	0.3	2	3	U	W	1.3
1	5	O	CW	0.5	2	4	U	W	0.2
1	5	O	CW	2.6	2	4	U	W	0.2
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1	5	O	CW	1.8	2	4	O	CW	4.0
1	5	U	W	0.6	2	4	O	CW	4.3
1	5	U	W	0.6	2	4	O	CW	2.2
1	5	U	W	1	2	4	U	W	0.2
1	5	U	W	0.5	2	4	U	W	0.2
1	5	U	W	0.7	2	4	O	CW	1.7
1	5	U	W	0.4	2	4	O	CW	2.5
1	5	U	W	1.3	2	4	U	W	0.8
1	5	U	W	0.3	2	4	O	CW	2.4
1	5	U	W	0.3	2	4	O	CW	7.3
1	5	U	W	0.5	2	4	U	CW	1.1
1	5	U	W	0.7	2	4	U	CW	1.8
1	5	U	W	0.3	2	4	U	CW	1.5
1	5	U	W	0.2	2	4	O	CW	2.4
1	5	U	RM	0.5	2	4	O	CW	3.4
1	5	U	BE	0.4	2	4	O	CW	5.3
1	5	U	RM	0.5	2	4	U	M	1.5
1	5	U	SM	1.1	2	4	U	CW	1.8
1	5	U	E	0.2	2	4	U	CW	0.9
1	5	U	SM	0.6	2	4	U	CW	1.0
1	5	U	RM	0.9	2	4	O	CW	5.0
1	6	O	W	1.2	2	4	O	CW	2.6
1	6	O	W	1.1	2	4	U	CW	1.1
1	6	O	W	0.5	2	4	O	CW	2.6
1	6	O	W	1.2	2	4	U	W	3.2
1	6	U	CW	0.7	2	4	U	RM	1.0
1	6	U	SM	1.1	2	4	U	CW	5.0
1	6	O	W	1.4	2	4	U	CW	2.1
1	6	O	W	0.2	2	4	O	CW	2.6

1	6	O	W	0.3	2	4	O	CW	3.2
1	6	O	W	0.4	2	4	O	CW	1.5
1	6	O	W	2.4	2	4	U	CW	1.8
1	6	O	CW	2.6	2	4	O	CW	3.4
1	6	O	W	2.7	2	5	O	S	3.0
1	6	U	W	0.5	2	5	U	CW	0.8
1	6	O	CW	0.9	2	5	U	W	0.2
1	6	U	W	0.5	2	5	U	RM	1.8
1	6	U	CW	0.6	2	5	U	W	0.2
1	6	U	BE	0.5	2	5	U	W	0.2
1	6	U	BE	0.4	2	5	O	CW	6.6
1	6	U	E	0.2	2	5	U	W	0.4
1	6	U	E	0.1	2	5	O	S	3.8
1	6	U	RM	0.2	2	5	U	CW	1.0
1	6	U	RM	0.1	2	5	U	W	0.3
1	6	U	RM	0.2	2	5	U	CW	1.7
1	6	U	SM	0.8	2	5	O	CW	2.4
1	6	U	SM	0.6	2	5	O	CW	3.8
1	6	U	RM	0.2	2	5	O	CW	7.9
1	6	U	RM	0.3	2	5	U	BE	0.1
1	6	U	RM	0.8	2	5	O	CW	6.0
1	6	U	BE	0.2	2	5	O	CW	4.3
1	7	O	W	0.2	2	5	U	CW	1.3
1	7	U	W	1.5	2	5	O	CW	5.2
1	7	O	W	0.2	2	5	O	CW	2.5
1	7	O	W	0.2	2	5	O	CW	4.1
1	7	U	W	1.5	2	5	O	CW	1.6
1	7	U	W	0.5	2	5	O	CW	5.6
1	7	O	W	0.4	2	5	O	CW	2.6
1	7	O	W	0.6	2	5	O	CW	1.4
1	7	O	W	0.2	2	5	O	CW	6.1
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1	7	O	W	0.5	2	5	O	RM	2.3
1	7	O	W	0.6	2	5	O	CW	2.2
1	7	O	W	0.6	2	5	O	CW	2.4
1	7	O	CW	1	2	5	O	CW	2.2
1	7	U	W	0.2	2	5	U	BE	1.3
1	7	U	W	0.4	2	5	O	CW	1.3
1	7	O	W	0.3	2	5	O	CW	2.9
1	7	O	W	0.4	2	5	O	CW	1.6
1	7	O	W	0.6	2	5	O	CW	1.5
1	7	O	W	0.4	2	5	U	CW	1.0
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1	7	U	W	0.3	2	5	U	CW	1.8
1	7	U	W	0.3	2	5	U	CW	5.4
1	7	O	W	0.4	2	5	U	BE	1.5
1	7	O	W	0.3	2	5	U	W	1.8
1	7	O	W	0.3	2	5	O	W	6.0
1	7	O	W	0.3	2	5	O	W	3.7
1	7	O	W	0.4	2	5	U	W	1.8
1	7	O	CW	0.6	2	5	U	W	1.6
1	7	U	W	0.2	2	5	O	W	3.2
1	7	O	W	0.4	2	6	U	RM	0.2
1	7	O	CW	0.6	2	6	U	W	0.2
1	7	O	W	0.5	2	6	U	W	0.2
1	7	O	CW	0.6	2	6	U	W	0.2
1	7	O	W	1.4	2	6	O	W	3.2
1	7	O	W	0.6	2	6	O	W	1.7
1	7	O	W	0.6	2	6	U	RM	0.2
1	7	O	CW	0.6	2	6	U	W	0.5
1	7	O	W	0.8	2	6	U	W	0.2
1	7	U	CW	0.5	2	6	U	W	0.2
1	7	O	CW	0.4	2	6	U	W	0.2
1	7	O	CW	0.9	2	6	U	W	0.2
1	7	O	CW	0.6	2	6	O	CW	4.1
1	7	O	CW	0.3	2	6	U	W	0.2
1	7	O	CW	0.5	2	6	U	W	0.2
1	7	O	CW	0.6	2	6	U	W	0.2
1	7	O	CW	0.5	2	6	O	CW	4.0
1	7	O	CW	0.7	2	6	O	CW	1.7

1	7	O	W	1.3	2	6	O	CW	5.1
1	7	U	CW	0.6	2	6	O	CW	1.6
1	7	U	W	0.2	2	6	O	CW	2.4
1	7	U	W	0.2	2	6	U	CW	1.5
1	7	O	CW	0.2	2	6	O	CW	1.4
1	7	O	CW	0.5	2	6	U	CW	1.3
1	7	O	CW	1.6	2	6	O	CW	1.8
1	7	O	CW	0.5	2	6	U	CW	1.0
1	7	O	CW	1.1	2	6	U	CW	1.8
1	7	O	W	1.5	2	6	O	CW	2.0
1	7	O	W	0.9	2	6	O	CW	1.9
1	7	U	CW	1.2	2	6	O	CW	7.8
1	7	O	CW	0.9	2	6	U	CW	1.5
1	7	O	CW	0.9	2	6	U	W	1.3
1	7	O	CW	0.8	2	6	O	CW	3.5
1	7	O	W	0.3	2	6	O	CW	2.0
1	7	O	W	1.4	2	6	O	CW	1.8
1	7	O	W	1.7	2	6	O	CW	2.2
1	7	O	CW	1	2	6	O	CW	1.7
1	7	O	CW	0.8	2	6	O	CW	1.8
1	7	U	W	0.2	2	6	O	CW	2.0
1	7	U	W	0.7	2	6	U	W	1.2
1	7	O	CW	0.7	2	6	U	W	1.3
1	7	O	CW	0.6	2	6	U	W	1.1
1	7	O	CW	0.8	2	6	U	W	0.8
1	7	O	W	1	2	6	U	CW	1.7
1	7	O	CW	0.8	2	6	O	CW	3.2
1	7	U	CW	0.7	2	6	O	CW	2.2
1	7	U	CW	0.6	2	6	O	W	5.9
1	7	U	CW	1.2	2	6	O	CW	4.2
1	7	O	CW	1	2	6	O	W	7.1
1	7	O	CW	0.3	2	6	O	W	10.8
1	7	O	CW	0.4	2	6	U	W	1.2
1	7	U	CW	1	2	6	U	W	1.1
1	7	O	W	0.3	2	6	U	W	1.2
1	7	U	W	0.4	2	6	U	W	1.7
1	7	U	CW	1.1	2	6	U	CW	1.3
1	7	U	CW	0.9	2	6	U	CW	1.3
1	7	O	CW	0.4	2	6	U	CW	2.0
1	7	O	CW	0.4	2	6	O	W	4.3
1	7	U	CW	1.1	2	7	U	M	7.1
1	7	O	CW	0.5	2	7	U	W	0.3
1	7	O	CW	1	2	7	U	W	0.3
1	7	O	CW	0.5	2	7	U	W	0.2
1	7	O	W	1.7	2	7	O	CW	3.6
1	7	O	CW	0.2	2	7	O	S	6.4
1	7	O	CW	0.6	2	7	U	W	0.4
1	7	O	W	0.2	2	7	U	S	0.7
1	7	U	CW	1.1	2	7	O	CW	8.2
1	7	U	CW	1	2	7	O	W	1.3
1	7	U	W	0.4	2	7	O	CW	1.6
1	7	U	W	0.4	2	7	O	CW	2.0
1	7	U	W	0.4	2	7	O	W	2.9
1	7	U	W	0.2	2	7	U	W	1.0
1	7	U	W	0.4	2	7	O	CW	2.7
1	7	U	W	0.4	2	7	U	CW	1.3
1	7	U	W	0.1	2	7	O	CW	2.4
1	7	U	W	0.4	2	7	O	W	2.1
1	7	U	RM	0.2	2	7	O	CW	1.5
1	7	U	W	0.2	2	7	O	CW	1.5
1	7	U	RM	0.1	2	7	U	CW	1.5
1	7	U	RM	0.4	2	7	O	CW	3.1
1	8	O	W	1	2	7	U	CW	0.9
1	8	O	W	2.8	2	7	O	CW	1.3
1	8	O	W	1.8	2	7	U	CW	0.6
1	8	O	CW	0.3	2	7	U	CW	1.5
1	8	O	W	0.4	2	7	O	W	3.2
1	8	O	CW	1.1	2	7	U	CW	0.9
1	8	U	CW	1	2	7	U	CW	1.1
1	8	O	W	1.2	2	7	U	CW	1.1
1	8	O	W	1.4	2	7	O	W	2.1

1	8	U	W	0.6	2	7	O	W	2.6
1	8	O	W	1.7	2	7	O	CW	3.2
1	8	O	W	2.4	2	7	O	CW	3.2
1	8	O	CW	1.3	2	7	U	CW	0.2
1	8	O	W	1.8	2	7	O	CW	1.5
1	8	O	CW	0.3	2	7	U	CW	1.0
1	8	O	W	1	2	7	U	CW	1.2
1	8	O	CW	0.5	2	7	O	W	9.6
1	8	U	CW	0.8	2	7	O	W	2.9
1	8	O	CW	0.5	2	7	O	CW	1.4
1	8	O	W	1.5	2	7	U	W	1.7
1	8	O	CW	0.5	2	7	O	CW	2.1
1	8	O	CW	0.2	2	7	O	CW	2.8
1	8	O	W	0.7	2	7	U	RM	0.7
1	8	O	CW	0.5	2	7	U	RM	0.8
1	8	O	CW	0.7	2	7	U	CW	1.5
1	8	O	CW	0.5	2	7	O	W	1.4
1	8	O	W	1.1	2	7	O	CW	1.8
1	8	U	RM	0.2	2	7	O	CW	1.8
1	8	O	CW	1.2	2	7	U	RM	0.0
1	8	U	SM	0.3	2	7	O	CW	11.6
1	8	U	E	0.1	2	7	U	W	1.5
1	8	U	E	0.1	2	7	U	CW	1.3
1	8	U	RM	0.1	2	7	O	W	1.5
1	8	U	RM	0.2	2	7	O	W	4.6
1	8	U	RM	0.1	2	7	O	W	3.2
1	9	U	W	0.4	2	7	O	W	2.5
1	9	U	W	0.4	2	7	O	W	4.5
1	9	U	W	0.5	2	8	O	BE	3.6
1	9	U	W	0.6	2	8	U	BE	1.6
1	9	U	W	1	2	8	O	BE	5.3
1	9	O	W	0.4	2	8	O	CW	5.1
1	9	O	W	0.9	2	8	U	CW	0.3
1	9	O	W	0.9	2	8	U	CW	0.9
1	9	O	W	0.7	2	8	O	CW	1.5
1	9	U	W	0.9	2	8	U	W	0.0
1	9	O	CW	0.4	2	8	O	CW	5.0
1	9	U	CW	0.9	2	8	U	W	0.4
1	9	O	W	4.5	2	8	U	W	0.4
1	9	U	W	0.6	2	8	U	W	0.2
1	9	U	W	0.2	2	8	U	W	0.4
1	9	U	W	0.2	2	8	O	CW	7.3
1	9	U	CW	1	2	8	O	CW	2.1
1	9	U	CW	1.2	2	8	O	CW	8.3
1	9	U	CW	0.6	2	8	U	CW	1.9
1	9	O	W	4.3	2	8	U	W	2.1
1	9	U	W	0.8	2	8	U	CW	1.5
1	9	U	W	0.7	2	8	U	CW	1.0
1	9	U	CW	0.9	2	8	O	CW	4.1
1	9	O	CW	1.2	2	8	U	CW	3.3
1	9	O	CW	0.5	2	8	O	CW	2.8
1	9	O	CW	0.4	2	8	U	W	2.6
1	9	O	CW	0.4	2	8	O	CW	1.2
1	9	U	CW	0.5	2	8	U	RM	1.1
1	9	U	CW	0.4	2	8	O	CW	2.7
1	9	U	CW	1.4	2	8	O	CW	2.6
1	9	O	CW	0.5	2	8	U	CW	9.7
1	9	O	CW	1.6	2	8	U	CW	1.1
1	9	O	CW	3	2	8	U	W	1.1
1	9	O	CW	0.7	2	8	U	W	1.1
1	9	U	W	0.7	2	8	O	CW	3.2
1	9	U	CW	0.7	2	8	O	CW	4.5
1	9	U	CW	0.6	2	8	O	CW	2.6
1	9	U	W	0.8	2	8	U	CW	1.3
1	9	U	CW	0.4	2	9	U	CW	1.9
1	9	O	W	0.5	2	9	U	W	0.2
1	9	O	CW	0.5	2	9	O	CW	2.7
1	9	O	CW	0.4	2	9	U	W	1.3
1	9	U	RM	0.1	2	9	U	W	0.5
1	9	U	RM	0.2	2	9	U	CW	0.5
1	9	O	CW	0.6	2	9	U	W	0.8

1	9	U	CW	0.8
1	9	U	CW	0.7
1	9	U	CW	0.5
1	9	O	W	1.8
1	9	U	CW	0.8
1	9	U	W	0.7
1	9	O	CW	0.5
1	9	U	W	0.8
1	9	O	W	0.2
1	9	O	CW	2
1	9	O	W	0.7
1	9	O	CW	0.4
1	9	U	E	0.3
1	9	U	E	0.2
1	10	O	W	1.1
1	10	U	CW	0.5
1	10	O	W	1.1
1	10	U	W	1.3
1	10	U	CW	1.7
1	10	U	CW	1.2
1	10	O	CW	0.8
1	10	O	CW	2.8
1	10	O	CW	0.8
1	10	O	CW	0.4
1	10	O	CW	0.5
1	10	U	W	0.6
1	10	U	W	0.5
1	10	U	W	0.6
1	11	U	W	1.3
1	11	U	W	0.8
1	11	O	W	0.5
1	11	U	RM	0.3
1	11	O	W	0.4
1	11	O	W	1.6
1	11	U	W	1
1	11	O	CW	0.4
1	11	O	CW	1.3
1	11	O	CW	0.5
1	11	U	CW	0.5
1	11	U	CW	1.3
1	11	U	CW	0.3
1	11	U	CW	0.7
1	11	O	W	0.6
1	11	O	W	0.8
1	11	O	W	1.2
1	11	O	W	1.6
1	11	U	W	0.4
1	11	U	W	0.4
1	11	O	W	0.2
1	11	O	W	2.5
1	11	O	W	0.6
1	11	O	W	0.9
1	11	O	CW	1.9
1	11	O	CW	1.5
1	11	O	W	1
1	11	O	W	0.9
1	11	O	W	0.6
1	12	O	CW	0.9
1	12	U	S	0.8
1	12	O	W	1.6
1	12	O	CW	0.7
1	12	O	CW	0.6
1	12	O	W	1.4
1	12	O	W	1.1
1	12	O	CW	1
1	12	O	CW	0.5
1	12	U	W	0.3
2	9	U	CW	1.5
2	9	O	CW	3.9
2	9	U	W	0.6
2	9	O	CW	2.2
2	9	U	CW	3.1
2	9	U	CW	1.3
2	9	U	CW	0.7
2	9	O	CW	2.3
2	9	U	CW	1.3
2	9	O	CW	2.9
2	9	O	CW	2.5
2	9	O	W	3.8
2	9	U	CW	1.0
2	9	U	CW	0.7
2	9	O	CW	2.3
2	9	O	W	3.1
2	9	U	CW	1.6
2	9	U	CW	1.8
2	9	U	CW	1.0
2	9	O	CW	2.9
2	9	O	CW	4.8
2	9	O	CW	1.6
2	9	U	CW	0.8
2	9	U	GA	1.4
2	9	O	CW	2.9
2	9	U	CW	1.2
2	9	U	CW	2.2
2	9	O	W	2.4
2	9	U	CW	1.5
2	9	U	CW	1.3
2	9	O	W	5.6
2	9	O	CW	3.4
2	9	O	CW	5.1
2	9	O	CW	3.0
2	9	U	CW	1.1
2	9	U	CW	1.5
2	9	O	CW	8.1
2	9	O	CW	2.9
2	9	U	W	0.7
2	9	U	W	0.7
2	9	O	CW	1.7
2	9	O	W	1.4
2	10	U	W	0.7
2	10	U	W	0.6
2	10	U	W	0.7
2	10	U	W	0.6
2	10	U	W	0.7
2	10	U	W	0.6
2	10	U	W	0.7
2	10	U	W	0.6
2	10	U	W	0.7
2	10	U	W	0.7
2	10	U	W	0.9
2	10	U	W	1.2
2	10	U	CW	0.8
2	10	U	W	0.7
2	10	U	W	1.2
2	10	O	CW	2.5
2	10	O	W	1.3
2	10	U	CW	1.4
2	10	U	CW	1.3
2	10	O	CW	2.1
2	10	O	CW	1.6
2	10	O	CW	1.9
2	10	O	CW	1.5
2	10	O	CW	2.1
2	10	O	CW	1.2
2	10	O	CW	2.8
2	10	U	W	0.9
2	10	O	CW	2.5
2	10	O	CW	1.9

2	10	O	CW	1.2
2	10	O	CW	2.0
2	10	O	CW	2.4
2	10	U	W	0.9
2	10	O	CW	2.7
2	10	O	CW	2.7
2	10	O	CW	2.9
2	10	O	CW	2.0
2	10	U	CW	1.8
2	10	O	CW	3.2
2	10	U	CW	2.0
2	10	U	W	0.3
2	10	U	W	0.7
2	10	U	W	0.7
2	10	U	W	0.6
2	10	U	W	0.8
2	10	U	W	0.7
2	10	O	CW	1.5
2	10	O	CW	1.7
2	10	O	CW	2.2
2	10	O	CW	1.2
2	10	U	CW	1.3
2	10	O	CW	1.8
2	10	O	CW	1.5
2	10	O	CW	2.9
2	10	O	CW	2.8
2	10	O	CW	4.2
2	10	O	CW	5.3
2	10	U	CW	1.8
2	10	U	CW	1.0
2	10	U	CW	1.0
2	10	U	CW	0.9
2	10	O	CW	1.4
2	10	O	CW	1.6
2	10	O	CW	3.6
2	10	O	CW	3.5
2	10	O	CW	1.4
2	10	O	CW	3.5
2	10	O	CW	1.6
2	10	O	CW	2.5
2	10	O	CW	2.4
2	10	O	CW	2.6
2	10	O	CW	2.1
2	10	U	CW	1.5
2	10	O	CW	9.2
2	10	U	CW	1.3
2	10	U	CW	2.1
2	10	O	CW	4.8
2	10	O	CW	7.8
2	10	U	CW	1.7
2	10	U	CW	1.8
2	10	U	W	2.7
2	10	U	W	2.2
2	10	U	W	2.0
2	10	U	W	1.3
2	10	U	W	1.4
2	10	O	W	2.4
2	10	O	W	2.3
2	10	U	W	2.0
2	10	U	W	0.6
2	10	U	W	0.7
2	10	U	W	0.8
2	10	U	W	0.8
2	10	U	W	0.7
2	10	U	W	0.9
2	11	U	W	0.3
2	11	U	W	0.3
2	11	U	W	0.6
2	11	U	W	0.7
2	11	O	E	3.9
2	11	U	W	1.0

2	11	U	W	1.1
2	11	O	CW	2.3
2	11	O	CW	1.9
2	11	U	W	0.3
2	11	U	W	0.7
2	11	U	W	0.3
2	11	U	W	0.3
2	11	O	W	1.2
2	11	O	W	1.3
2	11	U	W	1.6
2	11	O	W	3.5
2	11	U	W	1.1
2	11	U	W	0.8
2	11	O	CW	3.8
2	11	O	CW	3.2
2	11	U	W	1.0
2	11	U	CW	1.3
2	11	O	CW	1.7
2	11	O	CW	2.2
2	11	O	CW	3.4
2	11	U	CW	2.0
2	11	U	CW	1.6
2	11	O	CW	2.6
2	11	O	CW	2.0
2	11	O	CW	2.7
2	11	O	CW	1.9
2	11	U	CW	1.3
2	11	O	W	2.3
2	11	O	CW	2.1
2	11	O	CW	0.9
2	11	O	W	1.2
2	11	O	W	1.4
2	11	O	CW	2.9
2	11	O	CW	2.4
2	11	O	CW	2.2
2	11	U	W	1.8
2	11	O	W	1.7
2	11	O	CW	1.7
2	11	O	CW	1.8
2	11	O	CW	2.0
2	11	U	W	0.3
2	11	U	W	0.7
2	11	U	RM	0.3
2	11	O	CW	1.1
2	11	U	CW	1.0
2	11	O	W	19.1
2	11	O	CW	1.6
2	11	O	W	2.9
2	11	O	W	1.7
2	11	U	W	1.0
2	11	U	W	1.2
2	11	O	W	2.2
2	11	U	W	1.3
2	11	U	W	1.7
2	11	U	W	1.0
2	11	U	W	0.9
2	12	U	W	0.3
2	12	O	E	2.4
2	12	O	E	2.2
2	12	U	W	0.3
2	12	O	E	3.3
2	12	U	W	2.4
2	12	U	E	0.7
2	12	U	E	1.0
2	12	U	E	1.2
2	12	U	E	0.3
2	12	U	E	0.3
2	12	U	W	1.1
2	12	U	E	1.3
2	12	U	E	1.0
2	12	O	W	1.7

2	12	O	W	1.8
2	12	U	W	0.8
2	12	U	W	1.0
2	12	U	W	1.9
2	12	U	W	1.3
2	12	U	W	0.9
2	12	U	W	0.3
2	12	O	CW	1.2
2	12	U	CW	1.2
2	12	U	CW	1.2
2	12	U	CW	2.6
2	12	O	CW	2.0
2	12	O	CW	3.2
2	12	O	CW	3.0
2	12	O	W	1.9
2	12	O	W	1.8
2	12	O	W	2.0
2	12	U	W	0.7
2	12	U	CW	1.2
2	12	O	CW	2.1
2	12	O	CW	1.9
2	12	O	CW	1.3
2	12	O	CW	1.8
2	12	U	CW	1.0
2	12	O	W	1.2
2	12	O	CW	1.2
2	12	O	CW	1.9
2	12	O	CW	2.6
2	12	O	CW	2.7
2	12	O	W	1.7
2	12	O	W	1.2
2	12	U	CW	0.8
2	12	U	CW	1.0
2	12	O	CW	2.0
2	12	U	W	0.8
2	12	U	CW	1.0
2	12	O	CW	1.2
2	12	U	W	1.0
2	12	U	W	1.9
2	12	U	W	2.1
2	12	U	RM	0.9
2	12	U	CW	1.3
2	12	U	CW	1.6
2	12	O	W	1.5
2	12	O	W	3.6
2	12	O	W	2.7
2	12	U	W	0.3
2	12	O	CW	3.2
2	12	U	RM	0.3
2	12	U	W	0.7
2	12	U	W	1.1
2	12	O	CW	3.2
2	12	U	CW	1.3
2	12	U	CW	1.3
2	12	O	W	1.4
2	12	O	CW	6.3
2	12	U	W	0.8
2	12	O	W	2.1
2	12	O	CW	1.6
2	12	O	W	1.5
2	12	O	W	2.0
2	12	O	W	2.1
2	12	O	W	2.6
2	12	U	W	1.6
2	12	U	W	1.5

a. O = overstory; U= understory
b. W = willow; CW = cottonwood; E = elm; RM = red maple; SM = silver maple; BE = boxelder; S = sycamore; M = mulberry; GA = green ash
*c.*diameter in cm