

Analysis of the streamside vegetation within the Hubbell Trading Post Historic Site, Apache County, Arizona

Final Report

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Abstract

Foliage-height density (FHD) of perennial vascular plants and percent cover of annual vascular plants were estimated for the riparian vegetation along Pueblo Colorado Wash within the boundaries of the Hubbell Trading Post National Historic Site, Apache County, Arizona. Data were recorded for four years; 1998, 2001, 2002, and 2003, in a continuing assessment of changes in vegetation over time, especially with respect to areas treated for the eradication of exotic invasive shrub and tree species. Transects were measured in early summer, before monsoon rains, and, except for 2001, again in early fall, after monsoon rains. There were few apparent differences in perennial vegetation between the summer of 1998 and the summer of 2001, except where additional eradication treatments were made. Within the streamside legs of the transects, two perennials, *Eleocharis parishii* (Parish spikerush) and *Equisetum arvensis* (common horsetail) were present in 1998 and were absent in 2001. Conversely, within the floodplain legs of the transects, three native species of *Sporobolus*, *S. airoides* (alkali sacaton), *S. contractus* (spike dropseed), and *S. cryptandrus* (sand dropseed) were present in 2001, although not in 1998. In both 1998 and 2001, the native graminoid *Scirpus pungens* (common three-square) was the dominant herbaceous perennial and *Xanthium strumarium* (cocklebur) was the dominant annual. The percent cover of *S. pungens*, however, was much greater in 2001 than in 1998. Between 2001 and 2003, the native shrub *Chrysothamnus nauseosus* (rabbitbrush) and the native grass *Pascopyrum smithii* (western wheatgrass) increased in FHD along the floodplain. Along the streambed there was an increase in the FHD for *Scirpus pungens*, and shrubs, such as *Salix exigua* (coyote willow) and *S. lucida* var. *lasiandra* (pacific willow). ANOVA indicated an overall significant increase in the FHD among years for transects within treated areas.

Introduction

The primary goal of this study was to assess changes in vascular riparian vegetation along Pueblo Colorado Wash of the Hubbell Trading Post Historic Site (Figure 1). Along most of the channel, attempts were made in spring of 1998 and 2000 to eradicate the exotic shrubs *Elaeagnus angustifolius* L. (Russian-olive) and *Tamarix ramosissima* Ledeb. (salt-cedar). It is the long-term goal of the U. S. Park Service to reestablish the channel vegetation to a physiognomy similar to that which preceded the invasion of exotic species (Figure 7).

In order to estimate composition and structure of the present channel vegetation, foliage-height density or foliar-height density (FHD), by species, of perennial vascular plants, and percent cover, by species, of annual vascular plants were measured along bankside transects. Except for a single site, transects were paired; one on each side of the bank, six transects along the north bank and seven along the south bank. Both south-bank and north-bank transects were measured mid-summer 1998 and south-bank transects were remeasured early fall 1998. Thus, vegetation within the treated area was estimated before and after the period of highest average rainfall for central Arizona (Bulk 1985). Because of the lack of sufficient summer rainfall in 2001, transects were not remeasured in the fall of that year.

Methods

Vegetation sampling

Vegetation sampling along both sides of Pueblo Colorado Wash was conducted July 1998, September 1998, August 2001, June 2002, September 2002, July 2003, and September 2003. Measurements were taken along thirteen 40m transects that had initially been established along the intermittent stream channel in 1998 (Table 1, Figure 1). Foliage-height density was recorded as "hits" along vertical poles. It was calculated simply as the number of hits divided by the number sampling points along each transect. The method used herein is a modified version of the vertical-line intercept or foliage-height density of MacArthur & MacArthur (1961), MacArthur & Horn (1969) and vegetation volume of Mills et al. (1991). FHD was chosen instead of the line intercept method because the latter estimates vegetation cover only and does not account for vegetation height or structure within the canopy. Also FHD or TVV correlates closely with breeding bird densities (Mills et al. 1991), which is a primary management concern for the Park.

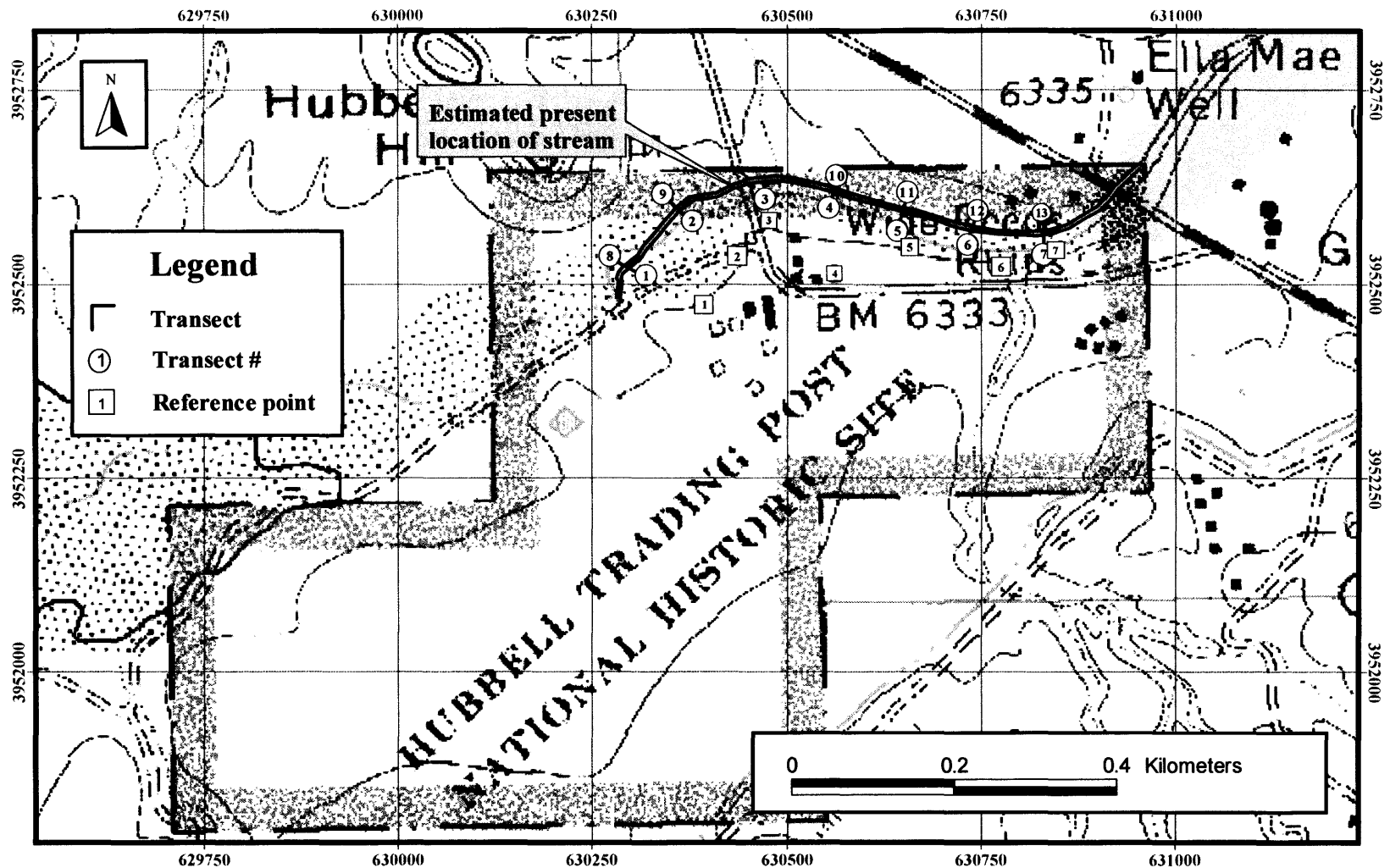


Figure 1. Hubbell Trading Post National Historic Site (Ganado USGS 7.5' topographic quadrangle), showing locations of transects, reference points, and probable present location of streambed (accuracy $\pm 8\text{m}$). UTM grid (NAD 27) shown as green lines.

Table 1. Locations of transects and reference points (N/A = not available).

transect number	UTM coordinates of transect at 00m (NAD 27, zone 12))		heading east of magnetic north of first transect leg	heading east of magnetic north from reference point	distance from reference point	reference point	UTM coordinates of reference points (NAD 27, zone 12))	
	mE	mN					mE	mN
South bank transects								
1	06 30 320	39 52 507	296°	25°	50m	1	06 30 394	39 52 470
2	06 30 382	39 52 572	309°	297°	70.1m	2	06 30 439	39 52 530
3	06 30 472	39 52 596	355°	355°	27.8m	3	06 30 471	39 52 570
4	06 30 550	39 52 588	350°	358°	67.8m	4	06 30 554	39 52 507
5	06 30 635	39 52 562	000°	321°	21.7m	5	06 30 647	39 52 541
6	06 30 720	39 52 544	000°	296°	46.0m	6	06 30 757	39 52 514
7	06 30 814	39 52 534	345°	259°	12.7m	7	06 30 825	39 52 536
North bank transects								
8	06 30 280	39 52 528	125°	N/A	N/A			
9	06 30 347	39 52 602	129°	N/A	N/A			
10	06 30 560	39 52 627	185°	N/A	N/A			
11	06 30 646	39 52 604	180°	N/A	N/A			
12	06 30 731	39 52 580	180°	N/A	N/A			
13	06 30 813	39 52 574	165°	N/A	N/A			

Seven reference points were selected within the Park boundaries (Table 1). At least one photograph was taken of each with a reference placard placed at the point.

Starting points (00m) of transects were established non-randomly at ca. 100m increments along the channel. The transects were situated at least 40m from the Park boundary in order to avoid boundary effects. Starting points were marked with 0.5in rebar at a point 20m bankside from the water's edge, or at the outer edge of obligate wetland graminoids, such as *Eleocharis parishii* Britton (Parish spikerush) and *Scirpus pungens* Vahl (common three-square). The transects were directed perpendicular to the stream channel for 20m, then to the right along the channel edge regardless of sinuosity for an additional 20m. The bearing from the starting point to the turn was recorded as degrees east of magnetic north.

Measurements were taken every two meters along the transect beginning with meter two. A nine meter collapsible pole was set vertically and living perennial vegetation within 1dm of the pole was recorded in height increments of 1m. This was done by recording the acronym of the plant species that fell within a particular meter mark on the pole. Thus for each 40m transect, vegetation volume, according to species, was sampled within twenty cylinders with a radius of 1dm.

At each 2m point along each transect a 20cm by 50cm (0.1m²) Daubenmire Grid was laid on top of the herbaceous layer. The cover of annuals was estimated by counting the number of squares occupied.

Results and Discussion

Between 1998 and 2001

The primary difference in foliage-height density (FHD) from the summer of 1998 to the summer of 2001 occurred in those areas that were treated (weed-tree removal) after the 1998 sampling (Table 2, Figure 2). There was also a marked difference in the FHD for transect three between years 1998 and 2001. The higher FHD in the 1998 data can be explained by the presence of a canopy of *Populus deltoides*, which is absent in 2001 (Figure 3). Apparently, meandering of the channel changed the position of the stream channel from under the tree canopy by 2001. Meandering was also apparent by the changes in the length of the first leg of many transects (i.e., the distance from the 00m rebar and the channel's edge).

Changes in species composition between 1998 and 2001 are less easily explained. The most conspicuous difference within the streamside legs between 1998 and 2001 is the presence of both *Equisetum arvense* and *Eleocharis parishii* in 1998 and their complete absence in 2001 (Figure 4). In 2001, there was an increase in *Scirpus pungens*, which has very similar soil moisture requirements to *E. arvensis* and *E. parishii*. Competition for space is an important factor in plant composition of high-moisture soils (Stevens 1989), and thus the generally taller, more robust-stemmed *S. pungens* may simply be displacing the other two less-robust species. Sorrell et al. (2000) have found that the root anatomy as it affects aeration may be directly correlated to the distribution of species within wetlands. Van der Valk et al. (1994) reported a decline in plant diversity associated with an increase in water level within wetlands, therefore, the decrease in diversity within the Historic Site may indicate an overall increase in average water level because of channelization or some other undocumented factor. The increase of *S. pungens* cover may also be occurring because of the lack of grazing pressure. Livestock were removed from the Historic Site in 1997 (Nancy Stone, pers. comm. 2003). Reichenbacher (1984) found a direct correlation between the occurrence of a closely related species, *S. americana*, and the absence of livestock grazing along a riparian stream in Arizona.

There is a similar trend between the bank legs of the 1998 and 2001 transects but involving different species. In 2001, three *Sporobolus*; *S. airoides*, *S. contractus*, and *S. cryptandrus*, and two *Elymus*; *E. canadensis* and *E. lanceolata*. These species were absent from the 1998 data. Unlike the stream-side transects however, there are no species that seem to be displaced by the *Sporobolus* or *Elymus*. These species may simply be increasing because of the absence of grazing. Trends of a similar nature have occurred along the Verde River, Arizona after cessation of grazing (Sue Schuhardt, pers. comm. 2003).

Table 2. Summary of vegetation type, canopy height, and foliage-height density (FHD) data for each transect by date.										
Transect number	Vegetation association	Data								
		summer 1998			fall 1998			summer 2001		
		Max. Ht. (m)	Ave. Ht* (m)	FHD (m ³ /m ²)	Max. Ht. (m)	Ave. Ht* (m)	FHD (m ³ /m ²)	Max. Ht. (m)	Ave. Ht* (m)	FHD (m ³ /m ²)
1	<i>S. cryptandrus</i> → <i>E. parishii</i>	1	0.15	0.15	1	0.50	0.6	1	0.6	0.65
2	<i>S. cryptandrus</i> → <i>S. pungens</i>	2	0.40	0.5	1	0.40	0.4	2	0.75	0.8
3	barren→ <i>S. pungens</i>	10	0.95	1.25	11	1.40	1.65	1	0.55	0.55
4	<i>P. smithii</i> → <i>S. pungens</i>	1	0.20	0.2	1	0.40	0.6	1	0.55	0.55
5	<i>P. smithii</i> → <i>C. nauseosus</i>	1	0.30	0.35	1	0.35	0.45	2	0.4	0.45
6	<i>C. nauseosus</i> → <i>S. pungens</i>	1	0.35	0.55	1	0.45	0.7	1	0.3	0.3
7	<i>C. nauseosus</i> → <i>S. pungens</i>	2	0.55	0.7	2	0.50	0.6	1	0.55	0.65
8	<i>E. angustifolia</i> → <i>S. pungens</i>	7	1.10	1.35	N/A	N/A	N/A	1	0.85	0.85
9	<i>E. angustifolia</i> → <i>S. pungens</i>	6	1.95	1.9	N/A	N/A	N/A	1	0.25	0.25
10	<i>T. ramosissima</i> → <i>S. pungens</i>	7	1.85	1.25	N/A	N/A	N/A	7	1.9	1.35
11	<i>E. angustifolia</i> → <i>S. pungens</i>	5	1.80	1.7	N/A	N/A	N/A	4	1.0	0.9
12	<i>P. deltoides</i> → <i>S. pungens</i>	12	2.25	1.8	N/A	N/A	N/A	13	2.3	1.25
13	<i>P. deltoides</i> → <i>S. pungens</i>	12	1.65	1.8	N/A	N/A	N/A	12	1.65	1.2
*average height here is the sum of the maximum heights for all transect points divided by the number of points (20)										

Table 2 (Cont.). Summary of vegetation type, canopy height, and foliage-height density (FHD) data for each transect by date.

Transect number	Vegetation association	Data								
		Summer 2002			Fall 2002			Summer 2003		
		Max. Ht. (m)	Ave. Ht* (m)	FHD (m ³ /m ²)	Max. Ht. (m)	Ave. Ht* (m)	FHD (m ³ /m ²)	Max. Ht. (m)	Ave. Ht* (m)	FHD (m ³ /m ²)
1	<i>C. nauseosus</i> → <i>S. pungens</i>	1	0.75	0.95	2	0.70	0.95	1	0.65	1.15
2	<i>C. nauseosus</i> → <i>S. pungens</i>	2	0.95	0.95	2	0.85	1.10	2	0.90	0.95
3	<i>E. canadensis</i> → <i>S. pungens</i>	1	0.70	0.95	1	0.75	0.90	1	0.65	0.90
4	<i>C. nauseosus</i> → <i>S. pungens</i>	2	0.60	0.85	2	0.95	1.10	2	0.90	1.00
5	<i>C. nauseosus</i> → <i>D. spicata</i>	1	0.45	0.55	2	0.65	0.95	2	0.90	0.85
6	<i>C. nauseosus</i> → <i>S. pungens</i>	1	0.70	0.70	1	0.70	0.70	2	0.80	0.85
7	<i>P. smithii</i> → <i>S. pungens</i>	1	0.75	0.95	1	0.85	0.95	2	0.90	1.00
8	<i>S. cryptandrus</i> → <i>M. asperifolia</i>	1	0.90	1.40	1	0.85	0.85	2	0.95	1.70
9	<i>S. cryptandrus</i> → <i>S. pungens</i>	1	0.45	0.55	1	0.40	0.50	1	0.45	0.55
10	<i>T. ramosissima</i> → <i>M. asperifolia</i>	6	1.75	1.5	6	1.60	1.70	6	1.8	1.80
11	<i>S. cryptandrus</i> → <i>S. pungens</i>	2	0.75	0.95	1	0.75	0.75	2	0.70	0.80
12	<i>P. deltoides</i> → <i>S. pungens</i>	14	2.75	2.15	12	2.35	1.95	14	2.65	2.20
13	<i>P. deltoides</i> → <i>S. pungens</i>	13	1.45	1.35	14	1.70	1.20	13	1.35	1.10
*average height here is the sum of the maximum heights for all transect points divided by the number of points (20)										

Table 2 (Cont.). Summary of vegetation type, canopy height, and foliage-height density (FHD) data for each transect by date.									
Transect number	Vegetation association	Data							
		Fall 2003							
		Max. Ht. (m)	Ave. Ht* (m)	FHD (m ³ /m ²)					
1	<i>C. nauseosus</i> → <i>S. pungens</i>	2	0.75	0.75					
2	<i>C. nauseosus</i> → <i>P. smithii</i>	2	0.80	0.80					
3	<i>E. repens</i> → <i>E. glauca</i>	1	0.70	0.75					
4	<i>C. nauseosus</i> → <i>S. pungens</i>	2	0.95	1.1					
5	<i>C. nauseosus</i> → <i>C. nauseosus</i>	2	0.75	0.85					
6	<i>C. nauseosus</i> → <i>S. pungens</i>	2	0.80	0.80					
7	<i>P. smithii</i> → <i>S. pungens</i>	2	0.90	1.00					
8	<i>M. asperifolia</i> → <i>S. exigua</i>	2	0.90	1.15					
9	<i>S. cryptandrus</i> → <i>S. pungens</i>	1	0.35	0.35					
10	<i>T. ramosissima</i> → <i>E. glauca</i>	6	1.5	1.2					
11	<i>S. fendleri</i> → <i>S. pungens</i>	2	0.60	0.75					
12	<i>P. deltooides</i> → <i>S. pungens</i>	14	2.65	2.05					
13	<i>P. deltooides</i> → <i>S. pungens</i>	13	1.2	0.85					
*average height here is the sum of the maximum heights for all transect points divided by the number of points (20)									

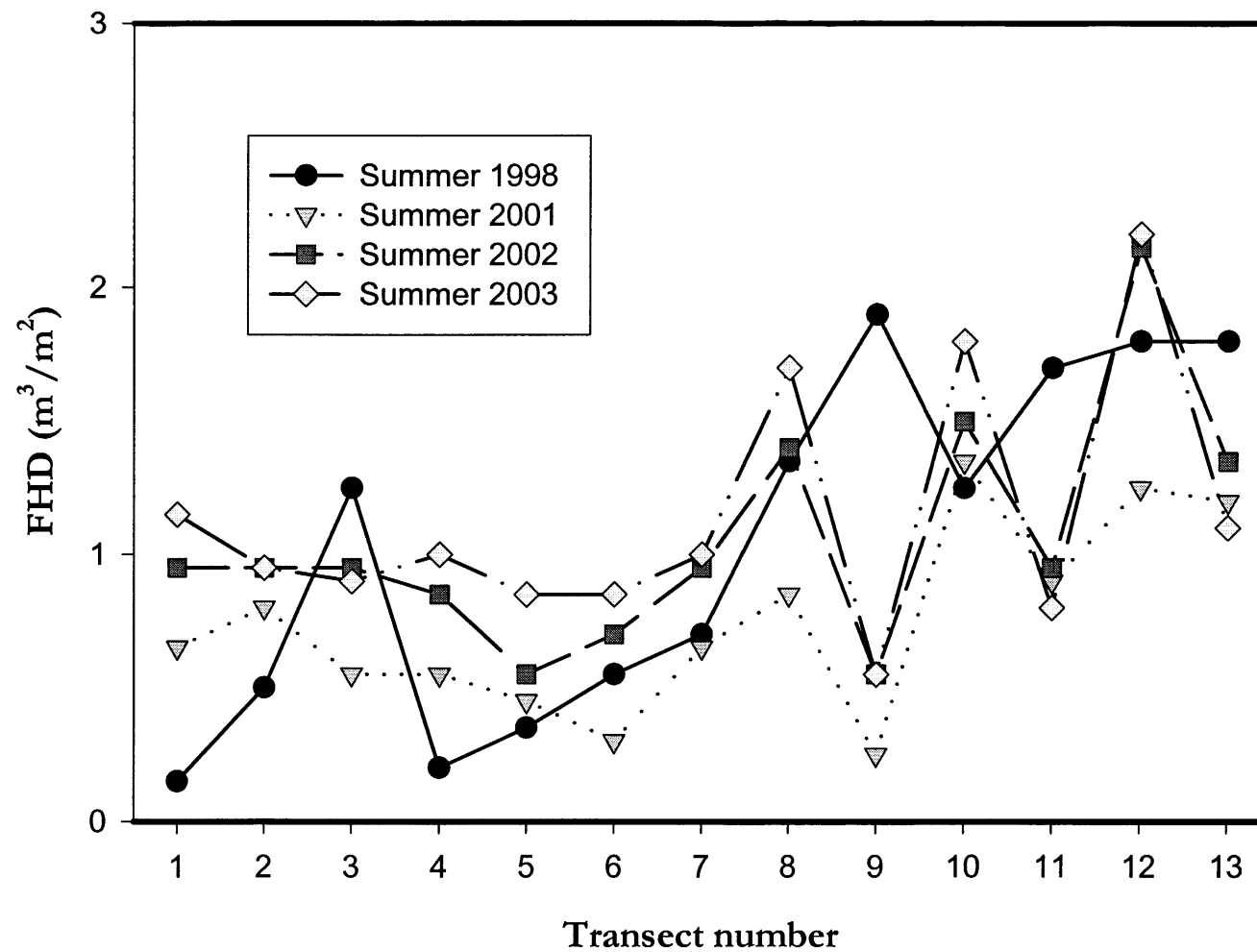


Figure 2. Composition of FHD for summer 1998, 2001, 2002, and 2003 transects.

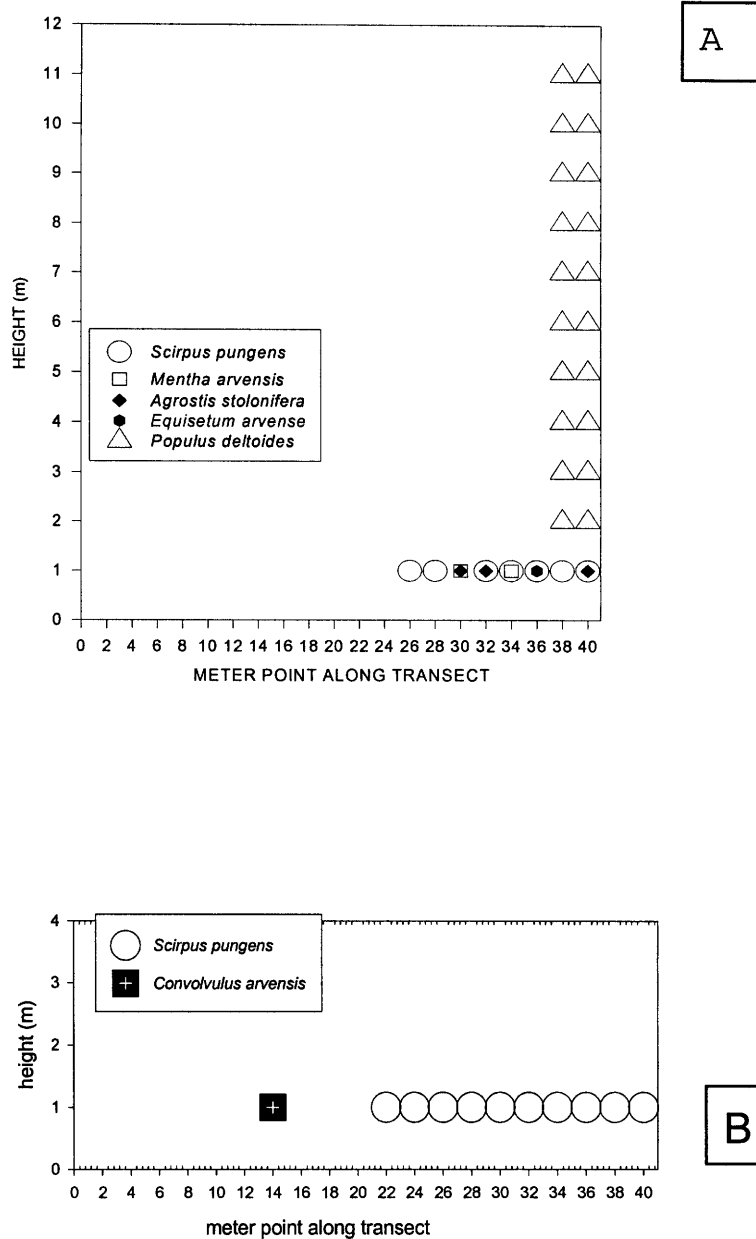


Figure 3. Comparison of foliage-height distributions (FHD) for transect three between years 1998 (A) and 2001 (B).

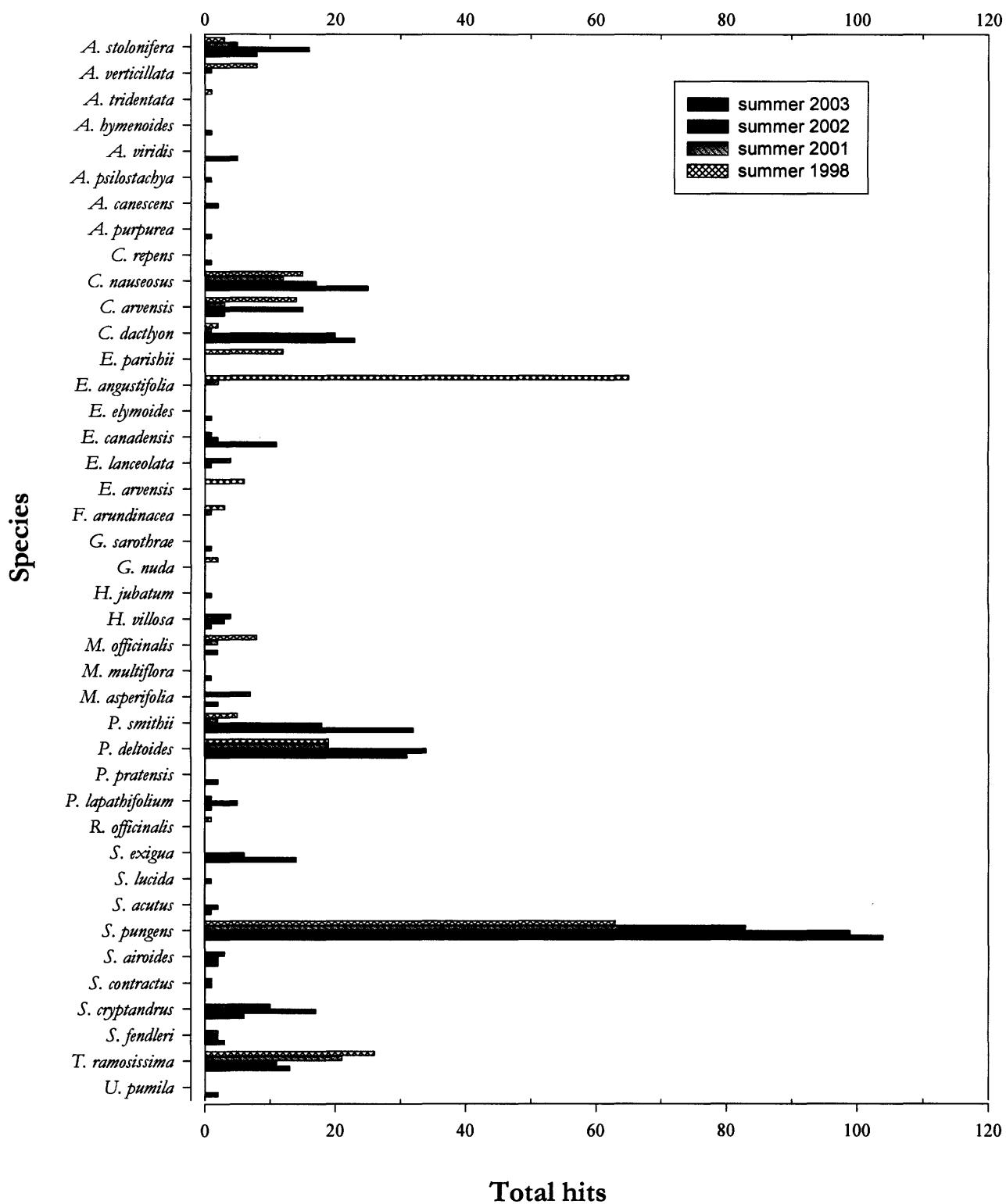


Figure 4. Total hits (FHD) of perennials for all transects, by species.

Apparently, a flush of *Populus deltoides* seedlings along the stream was lost during a flood event prior to the fall 2001 sampling (Nancy Stone and Bill Zeedyk, pers. comm. 2002). The seedlings of *P. deltoides* are well-adapted to the scouring of sandbars in the spring caused by snow-melt flooding, followed by a gradual decrease in water levels in the summer (Fenner et al. 1984). Although minor flooding may augment the establishment of *P. deltoides* seedlings (Campbell & Green 1968), major flooding deters their long-term survival. For example, Irvine and West (1979) show that the oldest trees of *P. fremontii*, a closely related species, were located beyond the zone of frequent flooding.

There was an dramatic amount of overall variation in average percent cover of annuals between summer of 1998 and summer of 2001. For each transect measured, average percent cover of annuals increased between the summer and fall sampling of 1998 (Table 3, Figure 5). This is probably correlated with late summer rainfall. Percent cover was again low in summer, 2001. The great increase in percent cover of annuals for transects eight and nine in 2001 was undoubtedly influenced by the opening of the canopy following weed-tree eradication treatments. Increase in overstory density is generally correlated with a decrease in herbaceous cover and diversity (Berger & Klaus 2000). Transect ten was not treated and transects eleven through thirteen had a canopy of either *Populus* or residual *Tamarix*. Increases in annual percent cover of annuals for 2001 along transect four and five are more difficult to explain. In both cases, a native species was on the increase. Therefore their increased presence may reflect the absence of grazing, as was postulated for the increase in percent cover of certain perennial grasses (Table 3).

Mature riparian habitat within the Historic Site is most reflected by the bankside leg of transect 13 (Figure 6), which has a tall canopy with an open understory. Such vegetation structure is typical of older riparian communities (Aber 1979).

Table 3. Comparison among transects of overall average percent cover and annuals with the greatest cover.

Transect number	Summer 1998		Fall 1998		Summer 2001	
	Annuals with greatest cover	overall ave. % cover	Annuals with greatest cover	overall ave. % cover	Annuals with greatest cover	overall ave. % cover
1	<i>Xanthium strumarium</i> , <i>Amaranthus retroflexus</i>	3.5	<i>X. strumarium</i> , <i>Portulaca oleracea</i>	24.9	<i>Helianthus annua</i>	4.0
2	<i>X. strumarium</i> , <i>Conyza canadensis</i>	4.3	<i>X. strumarium</i> , <i>Hordeum jubatum</i>	20.0	<i>X. strumarium</i> , <i>K. scoparia</i>	4.3
3	<i>X. strumarium</i>	4.0	<i>X. strumarium</i> , <i>H. jubatum</i>	8.8	<i>S. kali</i> , <i>K. scoparia</i>	6.0
4	<i>Onopordum acanthium</i>	1.4	<i>X. strumarium</i> , <i>Ambrosia acanthicarpa</i>	3.5	<i>K. scoparia</i> , <i>P. aviculare</i>	9.8
5	<i>X. strumarium</i>	1.9	<i>Bromus madritnesis</i> , <i>Plantago major</i>	5.9	<i>C. texensis</i> , <i>S. kali</i>	11.0
6	<i>X. strumarium</i> , <i>Salsola kali</i>	7.1	<i>Croton texensis</i> , <i>B. maditensis</i>	19.9	<i>S. kali</i>	2.0
7	<i>X. strumarium</i> , <i>Polygonum aviculare</i>	2.8	<i>B. maditensis</i> , <i>P. aviculare</i>	12.3	<i>X. strumarium</i> , <i>Echinochloa crus-galli</i>	6.5
8	<i>Medicago minima</i>	0.2	n/a	n/a	<i>C. canadensis</i> , <i>X. strumarium</i>	6.5
9	<i>X. strumarium</i>	0.3	n/a	n/a	<i>S. kali</i> , <i>X. strumarium</i>	9.0
10	<i>Kochia scoparia</i> , <i>X. strumarium</i>	2.9	n/a	n/a	<i>K. scoparia</i>	2.3
11	<i>X. strumarium</i>	3.3	n/a	n/a	<i>C. canadensis</i> , <i>K. scoparia</i>	3.8
12	<i>X. strumarium</i>	1.0	n/a	n/a	<i>C. texensis</i>	1.0
13	<i>X. strumarium</i>	1.5	n/a	n/a	<i>K. scoparia</i> , <i>Polypogon monspeliensis</i>	4.4

Table 3. Comparison among transects of overall average percent cover and annuals with the greatest cover.

Transect number	Summer 2002		Fall 2002		Summer 2003	
	Annuals with greatest cover	overall ave. % cover	Annuals with greatest cover	overall ave. % cover	Annuals with greatest cover	overall ave. % cover
1	<i>X. strumarium</i>	3.1	<i>X. strumarium</i>	10.9	<i>X. strumarium</i>	25.0
2	<i>K. scoparia</i>	0.8	<i>S. kali</i>	5.8	<i>X. strumarium</i>	14.5
3	<i>B. tectorum</i>	9.0	<i>S. kali</i>	19.8	<i>B. madritensis</i>	34.3
4	<i>K. scoparia</i>	1.5	<i>X. strumarium</i>	2.5	<i>C. texensis</i>	8.0
5	<i>H. jubatum</i>	3.6	<i>E. crus-galli</i>	12.5	<i>P. aviculare</i>	10.9
6	<i>X. strumarium</i>	5.0	<i>S. kali</i>	7.8	<i>B. madritensis</i>	22.3
7	<i>X. strumarium</i>	3.0	0.0	0.0	<i>B. madritensis</i>	6.2
8	<i>P. monspeliensis</i>	3.3	<i>Monroa squarrosa</i>	5.4	<i>Erodium cicutarium</i>	13.6
9	<i>B. tectorum</i>	3.2	<i>S. kali</i>	5.5	<i>S. kali</i>	30.0
10	<i>H. jubatum</i>	6.0	<i>B. tectorum</i>	8.8	<i>H. jubatum</i>	30.5
11	<i>C. canadensis</i>	1.3	<i>P. oleracea</i>	4.0	<i>E. cicutarium</i>	15.9
12	<i>Lactuca serriola</i>	1.3	<i>X. strumarium</i>	2.6	<i>Grindelia aphanactis</i>	14.6
13	<i>Aegilops cylindricus</i>	6.8	<i>K. scoparia</i>	7.8	<i>B. madritensis</i>	11.5

Table 3. Comparison among transects of overall average percent cover and annuals with the greatest cover.

Transect number	Fall 2003	overall ave. % cover
1	<i>S. kali</i>	16.3
2	<i>S. kali</i>	9.4
3	<i>X. strumarium</i>	16.3
4	<i>P. aviculare</i>	10.5
5	<i>P. aviculare</i>	9.0
6	<i>L. serriola</i>	8.3
7	<i>Gaura parviflora</i>	2.5
8	<i>Bouteloua barbata</i>	8.0
9	<i>S. kali</i>	17.8
10	<i>K. scoparia</i>	9.0
11	<i>P. oleracea</i>	13.3
12	<i>S. kali, G. aphanactis</i>	3.3
13	<i>L. serriola</i>	2.0

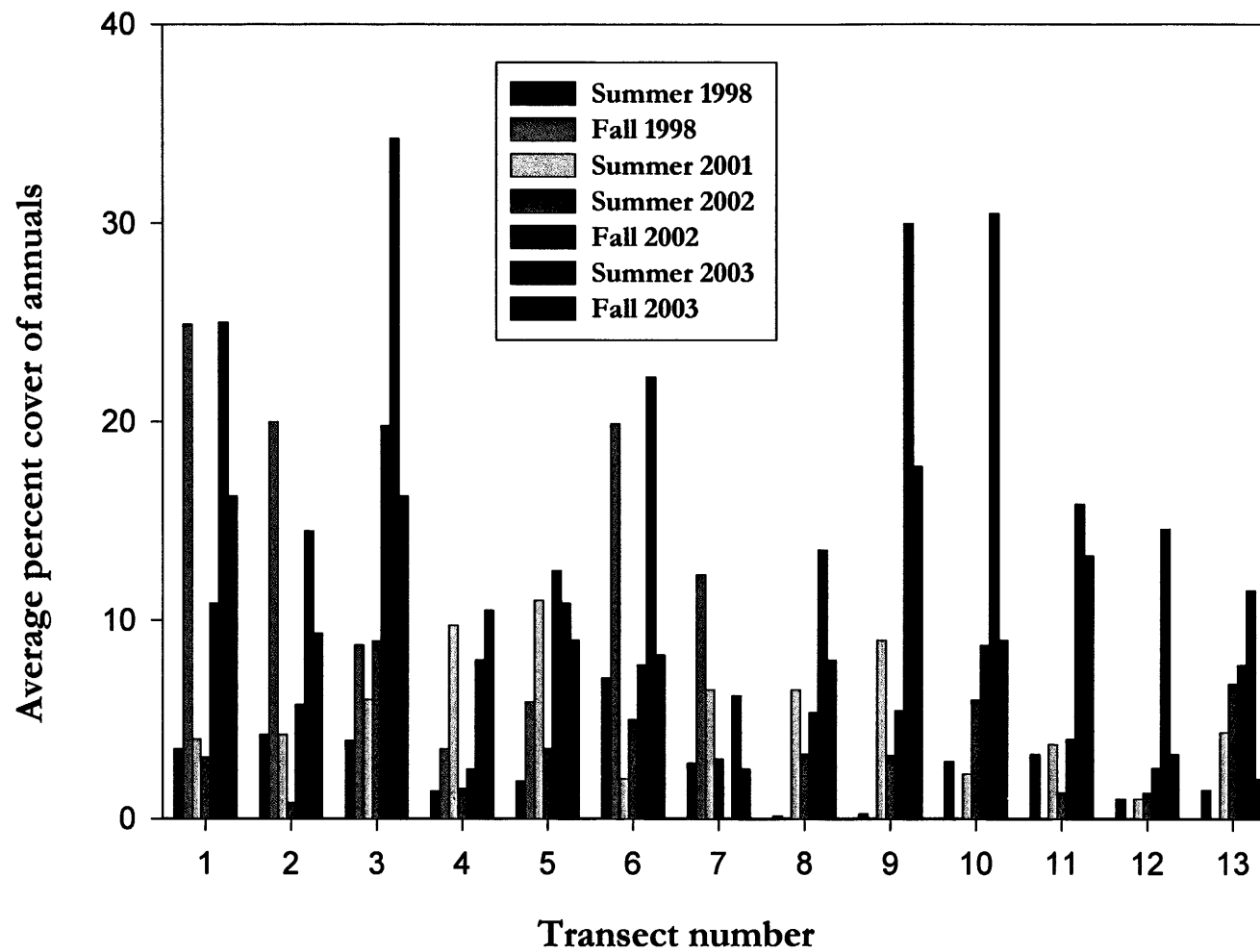


Figure 5. Average percent cover of annuals, by transect.

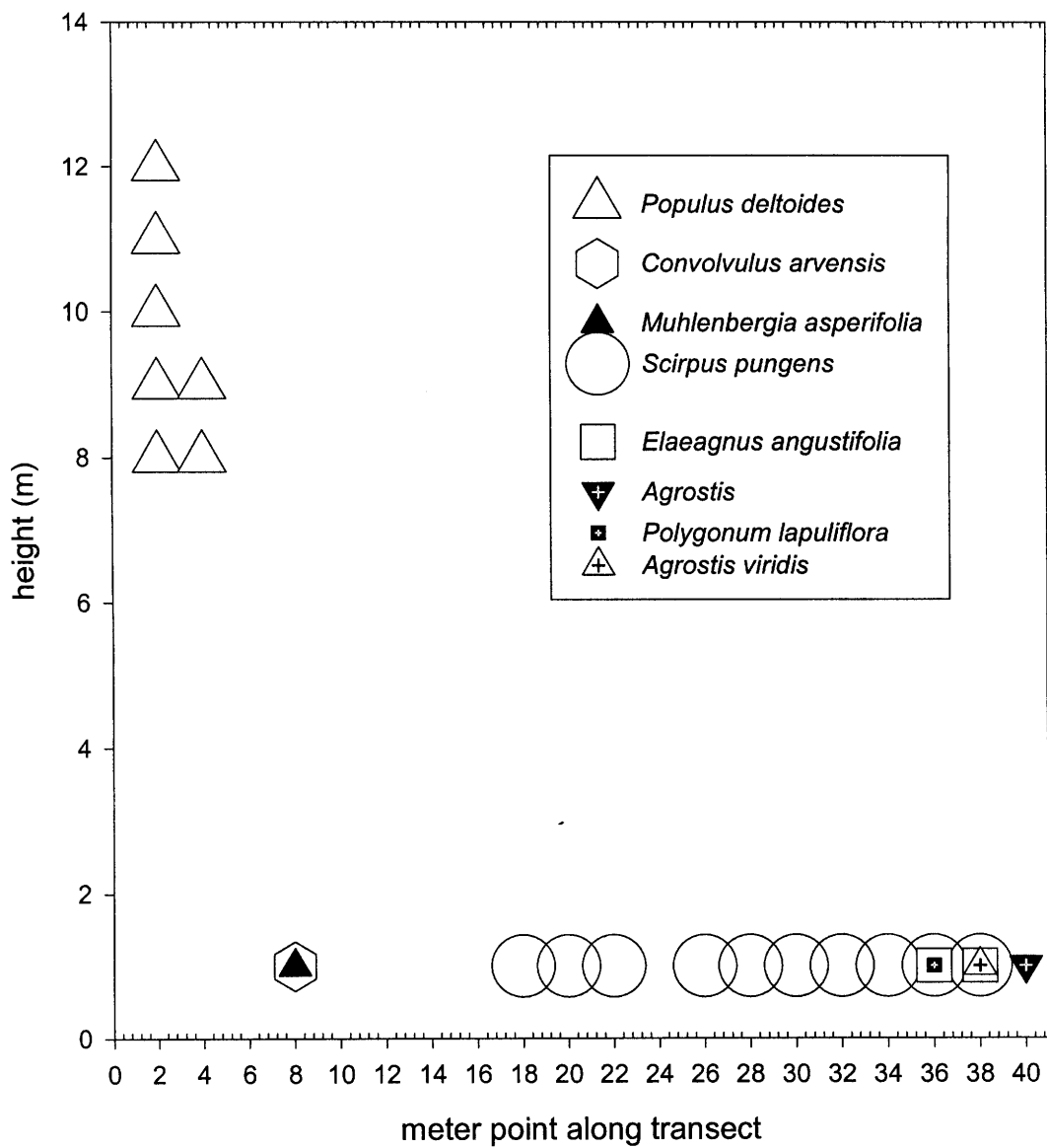


Figure 6. Graph of FHD, by species, along transect 13, 2001.

Between 2001 and 2002

There was a slight increase in FHD for nearly all transects between 2001 and 2002. (Figure 2, Table 2). Although the FHD along transect 12 decreased considerably during this period, it was simply a reflection of the change in streambed position. In 2001, the canopy of *Populus deltoides* covered three transect points, which were not covered in 2002.

There were some notable changes in perennial species composition between the summers of 2001 and 2002 (Figure 4). The most important difference was the immigration of *Salix lasiandra* (arroyo willow), *Salix exigua* (coyote willow), and *Scirpus acutus* (bulrush). All three of these species are indicators of healthy, native riparian habitat. Along the floodplain, the native species *Chrysothamnus nauseosus* (rabbitbrush) and *Pascopyrum smithii* (western wheatgrass) also increased in FHD.

Average percent cover of annuals for each transect continued to show a dramatic variation between the summer and fall samplings (Figure 5), reflecting the effects of monsoon rains.

Between 2002 and 2003

Between the sampling of summer 2002 and summer 2003, vegetation along the creek continued the trend of an overall slow and steady increase in FHD. Three transects showed a slight decrease in total FHD, while eight transects showed a slight to moderate increase in FHD (Figure 2, Table 1).

The native shrub, *Salix exigua* was a primary component for the first time along transect 8 in 2003 (Figure 7). Effort was made, starting 2001, to establish shoots (poles) of both *Populus deltoides* and *Salix exigua* along the streambed (Nancy Stone, pers. comm. 2003). *Scirpus pungens* continues a four-year trend of increasing FHD (Figure 8). The native grasses; *Elymus canadensis* (wild-rye), increased noticeably along the streambed in 2002, and *Pascopyrum smithii* continued a rather dramatic increase mostly along the floodplain. *Chrysothamnus nauseosus* also continued to increase along the floodplain.

Average percent cover for annuals showed a complete trend reversal in 2003 as compared to earlier years. All but one transect showed a greater percent cover in the early summer compared to early fall. Since fall percent cover of annuals was not noticeably lower than in previous years, the difference between pre-monsoon and post monsoon estimates was probably correlated with higher amounts of spring precipitation in 2003 in comparison to earlier sampling years. Data from the Ganado, Arizona weather station, however, gave little indication of an unusually wet spring (National Climatic Data Center 2004). Precipitation was higher than normal only in February and below normal (near 0) in April, May, and June. There were no data available for March.



Figure 7. *Salix exigua*, along transect 1, July 2003.



Figure 8. *Scirpus pungens* along transect 13, July 2003.

Overall trend, 1998-2003

ANOVA indicated that FHD of treated areas increased significantly between years 1998 and 2003 ($p = 0.008$) (Table 4). When the 1998 untreated areas were included in the analysis, the results were not significant ($p = 0.21$). Probability of significance was lower ($p = 0.23$) for fall sampling probably because of the inconsistency of sampling (not all transects were sampled in 1998 and fall sampling was not done at all in 2001).

Table 4. Comparison of FHD for all transect combined among summer samplings, by year. Significance determined by ANOVA.

YEAR	Untreated included			Untreated excluded		
	Mean	Std. Deviation	N	Mean	Std. Deviation	N
Summer 1998	1.0385	.6542	13	.5286	.3729	7
Summer 2001	.7500	.3524	13	.7500	.3524	13
Summer 2002	1.0615	.4412	13	1.0615	.4412	13
Summer 2003	1.1423	.4690	13	1.1423	.4690	13
Total	.9981	.4999	52	.9152	.4631	46
Significance	F = 1.6, $p = 0.21$			F = 4.5, $p = 0.008$		

ANOVA indicated that average height of perennial vegetation did not increase significantly for all treated transects between years 1998 and 2003 ($p = 0.14$) (Table 5). Although there was a steady increase in height over the four sampling years, there is still a considerable probability that the increase was due to change alone.

Table 5. Comparison of FHD for all transects combined for summer sampling, by year. Significance determined by ANOVA. Untreated transects of 1998 were excluded.

YEAR	Mean	Std. Deviation	N
Summer 1998	.4143	.2704	7
Summer 2001	.8962	.6485	13
Summer 2002	.9962	.6437	13
Summer 2003	1.0462	.5900	13
Total	.8935	.6089	46
Significance	F = 2.0, $p = 0.14$		

There were no apparent trends in percent cover of annual vegetation between 1998 and 2003. ANOVA indicated that cover varied significantly for summer sampling ($p = 0.00$) and did not vary significantly for fall sampling ($p = 0.08$) (Table 6). Most of the significance for summer sampling was due to the dramatic increase in cover for 2003. Summer data did not meet the assumption of homogeneity of variance regardless of attempts to transform. Untransformed fall data, however, did meet the assumption.

Table 6. Comparison of mean percent cover of all transects combined, by year. Significance determined by ANOVA.							
YEAR	Mean	Std. Deviation	N	YEAR	Mean	Std. Deviation	N
Summer 1998	2.608	1.904	13	Fall 1998	13.601	8.113	7
Summer 2001	5.412	3.082	13	Fall 2001	no data	no data	0
Summer 2002	3.673	2.419	13	Fall 2002	7.154	5.144	13
Summer 2003	18.235	9.181	13	Fall 2003	9.642	5.185	13
Total	7.482	8.038	52	Total	9.502	6.186	33
Significance	F = 26.5, p = 0.00			Significance	F = 2.7, p = 0.08		

Conclusions

Most of the changes in vegetation between the summer of 1998 and the summer of 2001 were attributable to further weed-tree treatments along the north bank. Some subtle vegetation changes may have been caused by the cessation of livestock grazing within the Historic Site. Between 2001 and 2003, a few trends were beginning to resolve. Native shrubs and grasses were on the increase along the floodplain and native graminoids and shrubs continued to increase along the streambed (Figures 7 & 8). Over the next few years, the three native willows, *Salix exigua*, *S. lasiandra*, and *S. lucida*, probably have the greatest potential for affecting the overall vegetation structure along the streambed. Thus far, data do not indicate a transition towards a community dominated by tall, deciduous trees; such as *Populus deltoides*. However, with the continued exclusion of livestock that browse on tree seedlings (Rucks 1984), the continued removal of competitive weed-tree species, and the continued efforts of diminishing stream channelization; density and height of native trees will probably increase.

Flooding events have been frequent along the stream channel and seem to have had at least some effects on the vegetation. Restoration along this small section of stream may prove difficult because of the absence of similar management upstream. In this regard, the riparian community within the Historic Site may remain in a state of perpetual succession, a fate which has been proclaimed for other stream channels in semiarid region of Arizona (Campbell & Green 1968).

Proposed monitoring

The current methodology appears to be adequate for the assessment of changes in both overall FHD and average vegetation height. Although there was no significant change, by year, in overall average vegetation height, results indicate a trend that may become statistically significant in the immediate future. With respect to percent cover and composition of annuals, the methodology has provided little more than descriptive data. Continued monitoring of transects would lead to more significant conclusions with respect to the perennial vegetation along the stream channel and would eventually provide adequate data to assess rates of change.

Future monitoring should include a second method, such as the point-quarter method, which could, with little additional effort, provide for statistical comparison with the transect method, have a much greater sample size, avoid problems associated with stream meandering, and sample additional areas of the surrounding uplands.

Sampling points for the point-quarter method would be chosen in a stratified random manner, choosing points corresponding to the channel edge, and proportioning the number of upland sample points with respect to the amount of area on either side of the channel.

Literature cited

Aber, J. D. 1979. Foliage-height profiles and succession in northern hardwood forests. *Ecology* 60:18-23.

Berger, A. L. and J. P. Klaus. 2000. Overstory composition and stand influence on herbaceous plant diversity in the mixed aspen forest of northern Minnesota. *American Midland Naturalist* 143:111-125.

Campbell, C. J. and W. Green. 1968. Perpetual succession of stream-channel vegetation in a semi-arid region. *Journal of the Arizona Academy of Sciences* 5:86-98.

Bulk, H. 1985. Useful climatic statistics for thirty-eight Arizona locations. *Climatological Publications, Climate & Energy Series #6:98*. Laboratory of Climatology, Arizona State University, Tempe, Arizona.

Fenner, P., W. W. Brady, and D. R. Patton. 1984. Observations on seeds and seedlings of Frémont cottonwood. *Desert Plants* 6:55-58.

Irvine, J. R. and N. E. West. 1979. Riparian tree species distribution and succession along the lower Escalante River, Utah.

MacArther, R. H. and J. W. MacArther. 1961. On bird species diversity. *Ecology* 42:594-598.

MacArther, R. and H. Horn. 1969. Foliage profile by vertical measurements. *Ecology* 50:802-804.

Mills, S., J. Dunning, and J. Bates. 1991. The relationship between breeding bird density and vegetation volume. *Wilson Bulletin* 103:468-479.

National Climatic Data Center. 2004. Annual climatological summary (2003) for Ganado, Arizona. Asheville, North Carolina.

Reichenbacher, F. W. 1984. Ecology and evolution of southwestern riparian plant communities. *Desert Plants* 6:15-22.

Rucks, M. G. Composition and trend of riparian vegetation on five perennial streams in southeastern Arizona. pp. 97-107, In: Warner, R. E. and K. M Hendrix (eds.), *California Riparian Systems: Ecology, conservation, and Productive Management*. University of California Press, Berkeley, California.

Sorrell, B. K., I. A. Mendelsson, K. L. McKee, and R. A. Woods. 2000. Ecophysiology of wetland plant roots: a modeling comparison of aeration in relation to species distribution. *Annals of Botany* 86:675-685.

Stevens, L. E. 1989. Mechanisms of riparian plant community organization and succession in the Grand Canyon, Arizona. Ph.D. dissertation, Northern Arizona University, Flagstaff, Arizona.

Van der Valk, A. G. , L. Squires, and C. H. Welling. 1994. Assessing the impacts of an increase in water level on wetland vegetation. *Ecological Applications* 4:525-534.

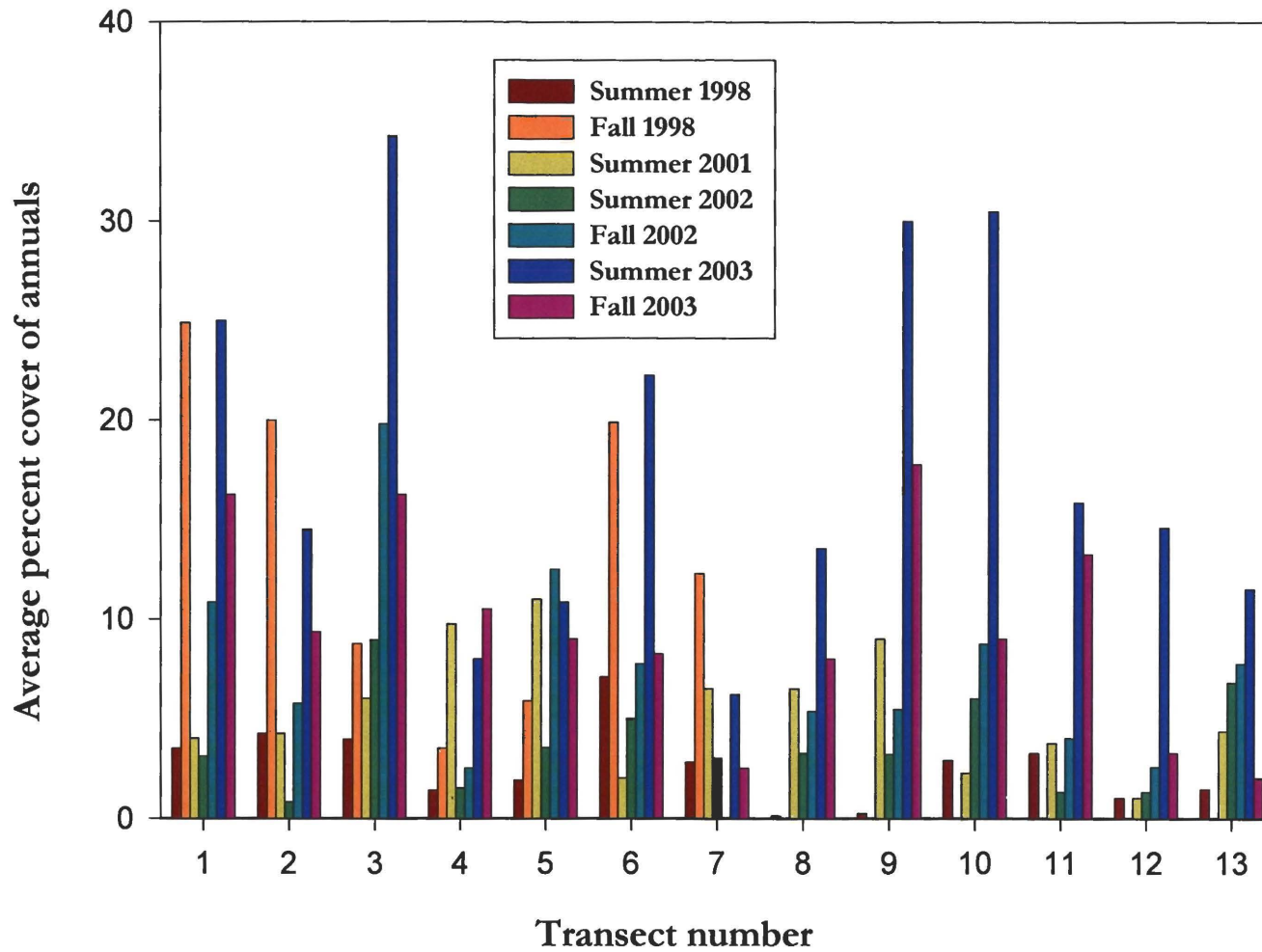


Figure 5. Average percent cover of annuals, by transect.