Analysis of Field Data for the Shawangunks Grassland and Forests Birds Habitat Study

Report #2: Grassland Management

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Prepared for

The Nature Conservancy Shawangunks Program New Paltz, NY	&	Daniel Smiley Research Center Mohonk Preserve New Paltz, NY

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Summary

We established plots and collected data at both the Mohonk Preserve and Shawangunk Grasslands National Wildlife Refuge (SGNWR) to compare management treatments for maintaining open fields at the Mohonk Preserve and grassland bird habitat at SGNWR. We chose a set of variables to measure including shrub cover, grass vs. forb cover, invasive species cover, height density, litter cover and litter depth.

The original, planned treatments included both mid-summer (July) and late summer (September) mow only and mow and burn treatments at SGNWR and the Mohonk Preserve. One field at the Mohonk Preserve was burned in the spring of 2009, but weather and other conditions prevented any other use of prescribed fire. Summer (July) mowing was completed in two of the SGNWR units and September mowing was completed in two of the Mohonk fields. The September mow at SGNWR did not occur. A spring mow was substituted and completed in one field at the Mohonk Preserve.

Total shrub abundance was generally reduced by all treatments. However, in many cases, short shrubs (< 0.5 m) remained stable or increased. Since these will enter taller height classes quickly, the effects of these treatments are temporary. One field that was burned in the spring was mowed in late summer, and the results indicated that multiple treatments in the same year can dramatically reduce shrub cover, which is an important goal both at the Preserve and SGNWR. Invasive species abundance generally increased following all treatments.

Optimal grassland bird habitat includes grass as dominating vegetative cover (70%) with forb cover of 10-30%. Management resulted in mixed changes in grass and forb abundance with most treatments increasing forb abundance. Some treatments resulted in increases in grass in one field and decreases in another at the same site. Litter depth and cover remained relatively unchanged, except for a reduction following the spring burn and increases following mowing. As would be expected, height density decreased following treatments. Annual treatments will likely be needed to reduce height density to levels preferable to most grassland nesting birds.

Management objectives should be developed for each field with a prescription or set of protocols for achieving the desired status. Managing for grassland birds requires avoiding treatments during their breeding seasons which can run from April through July with possible second broods in August. However, individual fields or subareas can be treated in the spring provided sufficient area for breeding is left. To achieve management objectives, multiple treatments within a given growing season will likely be needed to substantially reduce woody species abundance. Once this is reduced, it may be possible to manage less frequently, but annual treatments will likely be necessary.

Mowing multiple times and/or mowing before the seed set of forbs may encourage grass cover and decrease forb cover. However, it may also be necessary to completely replant fields with a high proportion of grasses to achieve the low forb cover

preferred by many grassland nesting birds. Fire can also be used if opportunities arise and resources are adequate. Invasive species control will require any of a series of methods including mechanical treatment, the use of fire in the growing season and the use of herbicides. Invasive species control will likely require annual treatments and monitoring of results to keep invasives from expanding.

Monitoring should address the specific management objectives of each field. So, using the shrub cover example, it may only be necessary to monitor shrub cover and not the other variables such as grass or forb cover as we did in this study. This will allow for an adaptive management approach based on solid information on management effectiveness while minimizing resource expenditures for monitoring.

I. Management Objectives

As part of a study of management of habitat for grassland nesting birds, field plots were established and data collected to assess changes resulting from several different treatments. This report summarizes the results and provides management recommendations. Methods are briefly summarized here, but readers should consult the protocols (Batcher 2010, adapted from Mitchell 2001) for further details.

Table 1 below lists the grassland species of conservation concern for this project at Shawangunk Grasslands National Wildlife Refuge (SGNWR) and characteristics of their habitat. These variables have typically been measured in studies of grassland bird habitat and have been identified as key factors in habitat management.

Table 1. Species of conservation concern and habitat characteristics. Source: Morgan and Burger (2008), Sample and Mossman 1997. Species are listed from low to high height-density according to Sample and Mossman (1997). Species indicated with an * are Species of Greatest Conservation Need according to NYSDEC (undated).

	Vegetation height (cm)	Vegetation density	Forb component (%)	Shrub cover (%)	Litter depth (cm)	Notes
Upland Sandpiper*	<15 and 40+	Low	10-15	1	1	Shortgrass species, preferring short-medium height grasslands (5-35 cm height-density)
Savannah Sparrow	30-40	Medium	<40	2-3	4 (+)	Midgrass species and a habitat generalist with a broad range of habitat structure; common in lush, short-medium height grasslands as found in hay pastures.
Eastern Meadowlark*	20-40	High	20-30	<1	2-6	Midgrass species and a habitat generalist found in a variety of habitats but preferring lightly grazed fields dominated by grass with some shrubs or other woody vegetation for perching. Herbaceous height 10-35 cm with dense litter layer
Bobolink*	30	Medium to low	50+	<1	3-4	Midgrass species and a habitat generalist preferring vegetation of medium to tall height-density; uses forbs and shrubs for perching

Table 2 lists management and monitoring objectives based on Table 1 and characteristics of desired habitat types described in Mitchell 2001. In addition, objectives have been established for invasive species.

Table 2. Management and monitoring objectives

Management Objective	Monitoring Objective	Shawangunk Grasslands NWR	Mohonk Preserve
Establish and maintain an average cover of 70% graminoid to 30% forb cover	The sample estimate for forb and graminoid cover should have a 90% confidence interval width of less than +/- 10%.	X	
Establish and maintain an average height-density (measured using a Robel Pole) of 25 cm	The sample estimate of average height-density should have a 90% confidence interval width of less than +/- 10 cm. (This could be wider for some species such as Upland Sandpiper).	X	
Establish and maintain woody shrub cover of less than 5%	The sample estimate of average shrub cover in each height class (<0.5 m, 0.5-1.0 m and > 1m) and for all combined should have a 90% confidence interval width of less than +/- 2%.	X	
Establish and maintain woody shrub cover of less than 20%	The sample estimate of average shrub cover in each height class (<0.5 m, 0.5-1.0 m and > 1m) and for all combined should have a 90% confidence interval width of less than +/- 10%.		X
Establish and maintain an average litter depth of 3 cm	The sample estimate of average litter depth should have a 90% confidence interval width of less than +/- 1.0 cm	X	
Establish and maintain cover of invasive species of less than 10%	The sample estimate of average cover of invasive species should have a 90% confidence interval width of less than +/- 10%.	X	X

The purpose of the above objectives is to provide a benchmark or threshold to determine if which treatments are effective in achieving them. These objectives would all apply to Shawangunk Grasslands NWR. For the Mohonk Preserve, which is managing fields for different goals, the objectives for shrub cover and invasive species would apply. Therefore, to track long-term management at the Mohonk Preserve, only those methods necessary to measure those specific management objectives would need to be implemented, though more complete surveys could be undertaken if desired.

II. Study Areas

A. Grasslands

Treatment units and plots were established at the Mohonk Preserve and at SGNWR. Both sites are in Ulster County, New York. SGNWR is an important area for grassland nesting birds and is being managed for that guild. The fields at the Mohonk Preserve are managed primarily for cultural and aesthetic purposes and are too small to support most grassland nesting birds.

1. Mohonk Fields

In 2008 a 50 x 50 m plot was established in K-24 in the Mohonk Preserve at Glory Hill. Two more plots were established with one in K-23 and the second in K-26 in 2009 (Map 1). Plot corners were marked with rebar and tagged.

2. Shawangunk Grasslands National Wildlife Refuge

Four units of approximately 4 hectares (10 acres) were established at Shawangunk Grasslands National Wildlife Refuge with one 50 x 100 m plot placed in each (Map 2). Plot corners were marked with rebar and tagged.

B. Treatments

The original idea of this study was to look at the use of both fire and mechanical treatments for managing grassland bird and field habitats and for a comparison of fall vs. spring burns for managing chestnut oak forest habitat. A rainy summer in 2009 and other logistical problems required a reduction in the number of treatments. Table 1 summarizes the completed and proposed treatments.

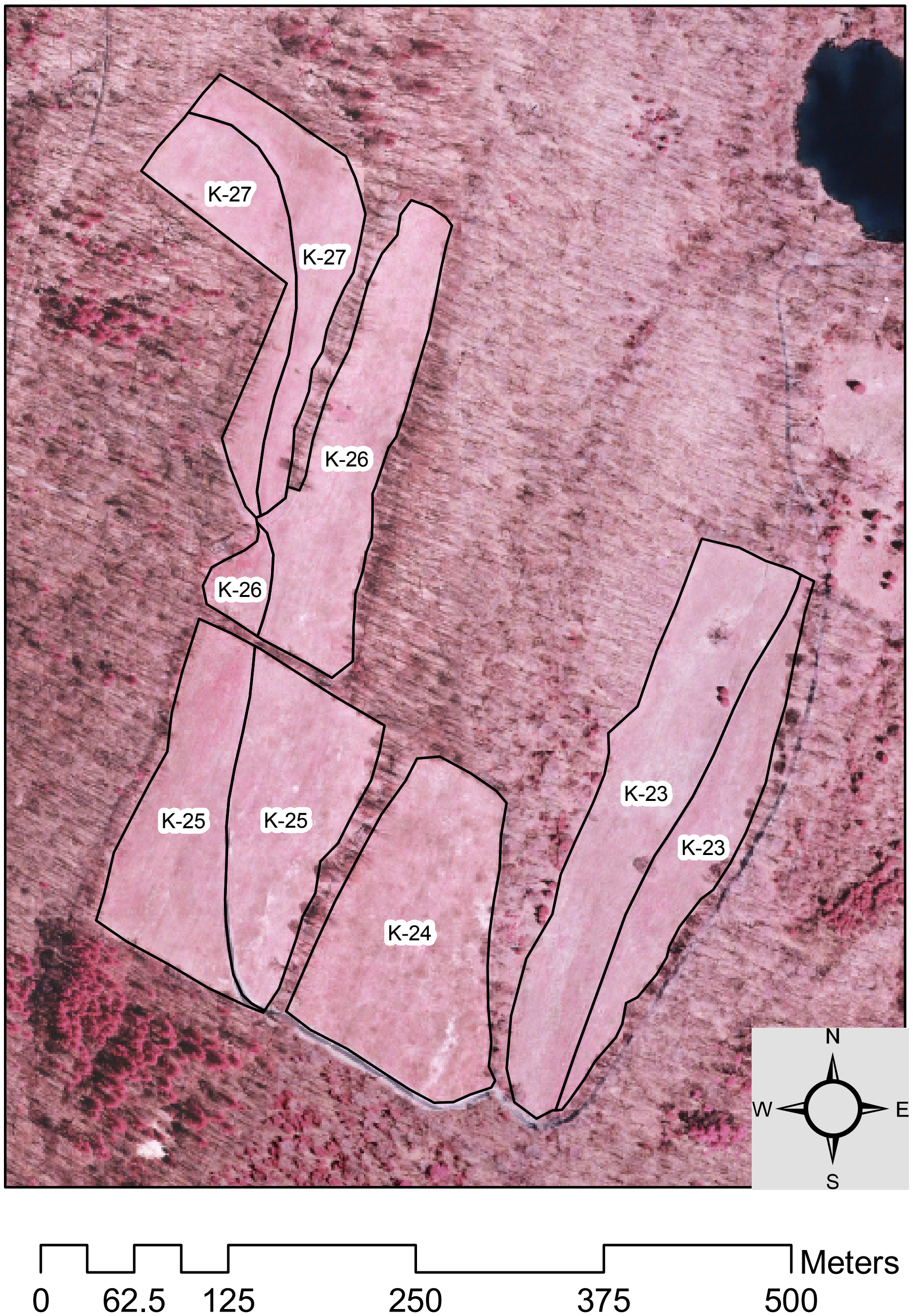
Table 3. Summary of treatments by site.

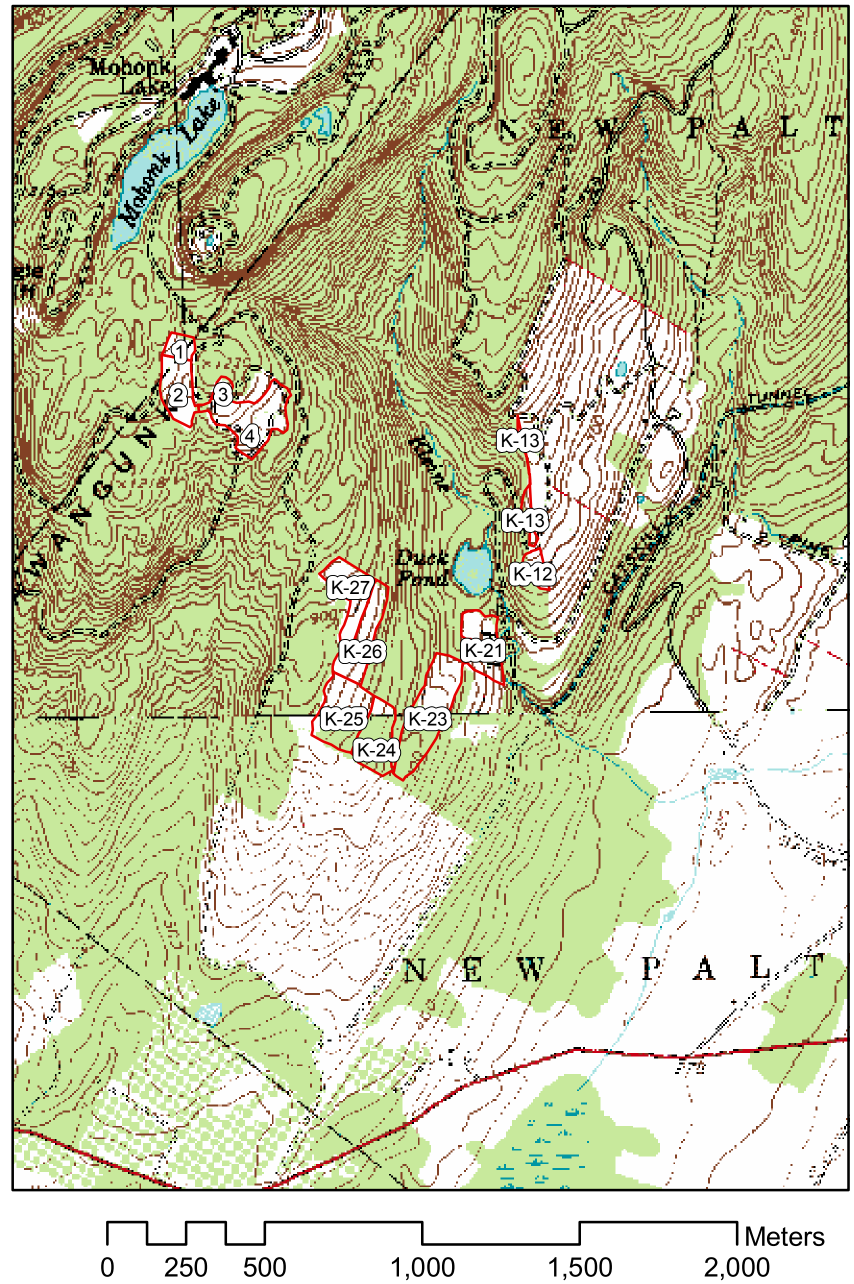
Site	Units/Subunits	Treatment
SGNWR	Units 2 and 4	Mowed between July 16 and 30, 2009
	Units 1 and 3	Mowed May 17, 2010
Mohonk Glory Hill	K-24	Burned April 16, 2009 Mowed late September 2009
	K-23	Mowed between 7 and 10 September 2009
	K-26	Mowed between April 27-28, 2010

Unfortunately, at SGNWR, the May 2010 mowing missed most area encompassing the 50 x 100 m plots, so post treatment data were not collected or analyzed for units 1 and 3.

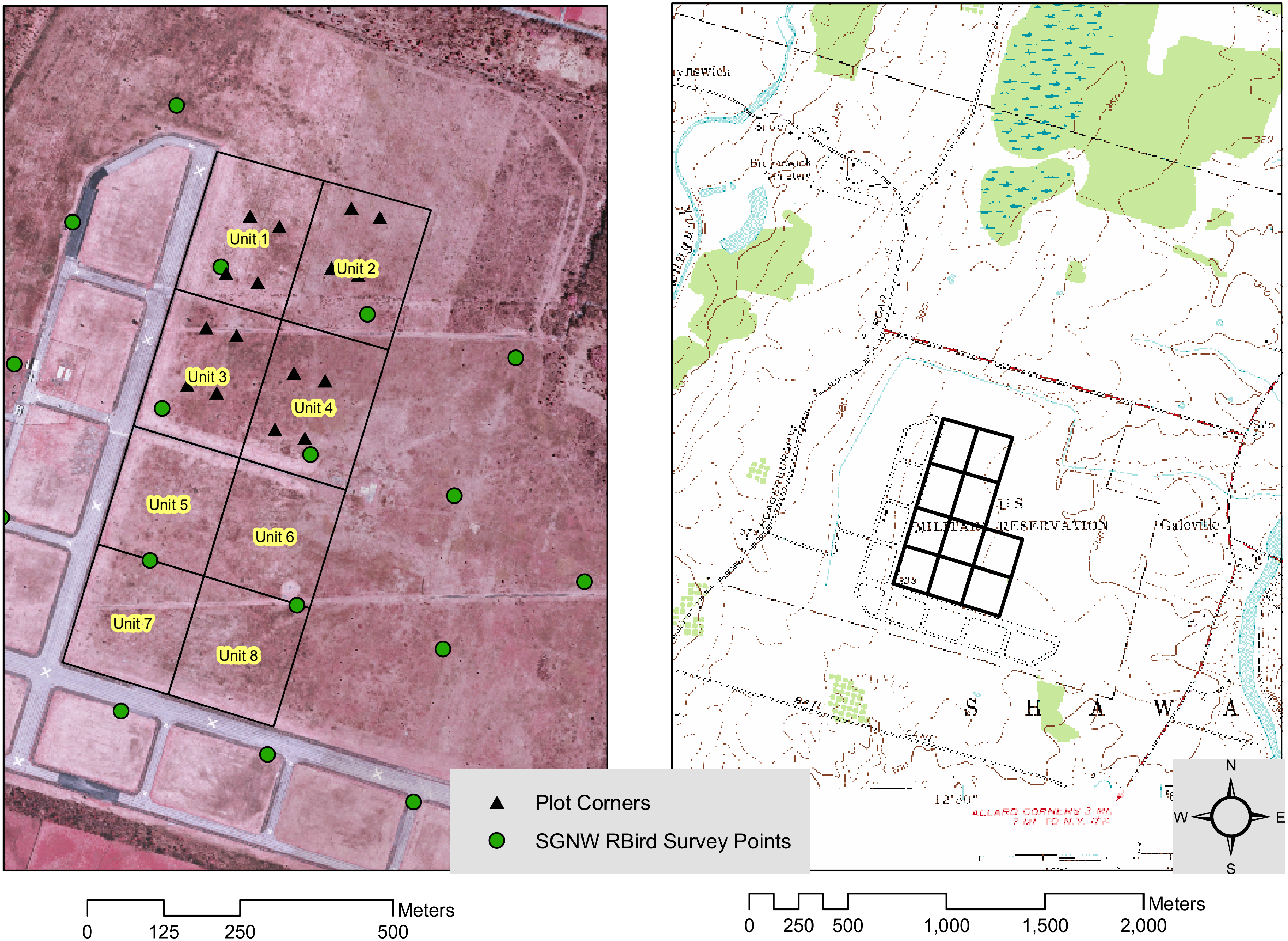
Other than at SGNWR where two units received the same treatment, none of the treatments were replicated. The comparisons here are between conditions prior to and following treatments.

Map 1. Mohonk Field Sites





Map 2. Shawangunk Grasslands NWR Treatment Units



II. Grassland Vegetation Data Analyses

A. Field Methods

Data were collected using the line-point intercept method in the fields as described above. Along each 50-meter transect, at two meter intervals, a narrow pole was held vertically with the tip on the surface. If the pole was hit by one of the following categories of vegetation, a hit was recorded:

- Graminoid (grass and sedge) vegetation
- Forb or herbaceous vegetation
- Shrub 0-50 cm tall
- Shrub 50-100 cm tall
- Shrub > 100 cm tall
- Dead vegetation
- Vine
- Invasive species including knapweed, multiflora rose, purple loosestrife and bush honeysuckle (hits were recorded by species). Shrub invasive species were counted separately, in the same height categories as for native shrubs as listed above but were not included in the shrub category.

For the surface the following were recorded if hit:

- Litter
- Bare
- Moss
- Water

At the Mohonk Preserve, the above were collected in August of 2008 in K-24, which was burned in the spring of 2009. Ten 50-meter transects were established (N=200). Data were collected for that field again in August of 2009. In 2009, fourteen 50-meter transects were established in K-23 and K-26 (N=280 for each). All three fields were surveyed again in 2010.

At Shawangunk Grasslands NWR one 50 x 100 m plot was established in each of the four treatment units described above. The same data for vegetation and surface cover were recorded along 20 50-meter transects in each plot (N=400) except for Unit 2. In 2009, we made an error in establishing transects and ended up with fewer points (376).

Litter depth to the nearest tenth of a centimeter and Robel pole measurements taken to the nearest 5 cm increment were collected at five equally spaced points along each transect (N=100), except, again in 2009 our error resulted in 94 points for litter and 93 for Robel pole measurements in Unit 2. In 2009, we missed two points in Unit 4 for a total of 98 litter depth measurements. Since the sample plot areas in Units 1 and 3 were not treated, we did not resurvey them in 2010.

B. Data Analysis Methods

Generally we can determine whether two or more samples are independent (that is, whether the null hypothesis that they are the same is true or not) using t tests for two samples, analysis of variance for three or more samples, or Chi square for binomial (yes/no; true/false) data. Since we counted whether our narrow pole hit each cover category, we collected “successes” or “failures” or 1s and 0s for hits and misses so most of our data is binomial. Binomial data has a different distribution then the data we collected on litter depth and Robel pole height-density, which are examples of continuous data.

I used Chi square analyses to determine if samples for each cover type were independent, focusing on the most important types: grass, forb, litter, counts of shrubs by height category, total shrub counts and total invasive counts. For the Robel pole and litter depth data, I used t tests. I also calculated confidence intervals, which are measures of precision of the estimated mean or proportion, using SYSTAT (2009) for the Robel pole and litter depth data and a spreadsheet developed by Sound-Science, LLC available on the web for binomial confidence intervals (Unnasch 2009). Confidence intervals represent a range considered to contain the true value (Agresti 2007). More specifically, within the fields where we collected data, if we collected similar data on counts of grass hit with our pole say, 100 times, some portion, say 90% of those data sets, would include the true number of hits of grass of all possible hits. Typical confidence intervals are between 80 and 99%, with the interval narrowing as the interval percentage increases.

Tests of significance such as Chi square use some of the same methods of calculation as confidence intervals, so the two are related. However, it is possible to have two samples with overlapping confidence intervals yet have significant differences in the means or proportions (Wolf and Hanley 2002). So, along with the Chi square and t tests, I used confidence intervals to visually compare intervals between sampling periods. If the confidence intervals of two estimated parameters overlap, then the estimate of one does not differ from the other as each could fall within an overlapping range. Where there is no overlap, we can be “confident” to the level of the interval (90%) that the estimates differ. This is a more conservative method than significance tests. Yet it also allows for easier comparisons of the degree of the effects of treatments. To focus on those variables important to bird habitat and management, I prepared confidence intervals for counts of grass, forbs, total shrubs, and total invasives at both sites, and Robel pole and litter depth measurements at SGNWR.

In addition, one can plot the threshold value of the desired state (Table 1) and compare that to the confidence interval. If the threshold value falls within the range of the confidence interval, it has not been achieved. If the goal is to increase, say grass hits to some threshold, and the confidence interval falls below the threshold value, then we can be confident to the degree of that interval (e.g., 90%), that we have achieved the threshold.

The fields at SGNWR were adjacent to each other and those at the Mohonk Preserve, either adjacent or proximate. At each site, the fields were generally similar in terms of topography, soils and vegetative characteristics. However, for many characteristics, such as pre-treatment abundance of grass or forb or shrubs, they differed. So, it may be possible to create a model of management and the degree of change, using various forms of regression or ANOVA across these sites, but those differences might reduce the accuracy and utility of such analyses.

C. SGNWR Analyses and Results

1. Vegetation Data

Table 4 below summarizes data collected in Units 2 and 4 at SGNWR in 2009 prior to the July 2009 mow and data collected in 2010. Data were collected in June of both years.

Table 4. Summary of data from SGNWR for Units 2 and 4 for 2009 and 2010. Both units were mowed in mid-July of 2009. Cover types indicated with a * had statistically significant changes (p<0.05) between 2009 and 2010.

Unit 2	2009			2010			Chi-square (df=1)		
Cover Type	# Hits	N	Proportion	# Hits	N	Proportion	Statistic	p	Power
*Grass	333	376	0.89	380	400	0.95	10.763	0.001	0.93
Forb	268	376	0.71	298	400	0.75	1.020	0.312	0.35
*Litter	333	376	0.89	378	400	0.95	8.899	0.003	0.93
Shrub <0.5m	22	376	0.06	31	400	0.08	1.098	0.295	0.29
*Shrub 0.5-1m	20	376	0.05	1	400	0.00	18.915	0.000	0.95
Shrub > 1.0m	1	376	0.00	0	400	0.00	1.065	0.302	NA
Total Shrub	43	376	0.11	32	400	0.08	1.780	0.182	0.41
Total Invasives	22	376	0.06	26	400	0.07	0.355	0.552	0.14
Unit 4	2009			2010			Statistic	p	Power
*Grass	316	400	0.79	355	400	0.89	14.057	0.000	0.98
*Forb	270	400	0.68	234	400	0.59	6.950	0.008	0.84
*Litter	368	400	0.92	395	400	0.99	20.658	0.000	0.99
Shrub <0.5m	87	400	0.22	69	400	0.17	2.580	0.108	0.55
*Shrub 0.5-1m	29	400	0.07	0	400	0.00	30.091	0.000	1.00
Shrub > 1.0m	2	400	0.01	0	400	0.00	2.005	0.157	0.64
*Total Shrub	118	400	0.30	69	400	0.17	16.756	0.000	0.99
Total Invasives	31	400	0.08	36	400	0.09	0.407	0.523	0.13

Figure 1 shows binomial confidence limits for counts of forbs and grasses (graminoid species) at the two units from 2009 to 2010. Following the 2009 mid-summer mow, counts of forbs increased in Unit 2 and decreased in Unit 4, the latter significantly. Counts of grass increased significantly in both units.

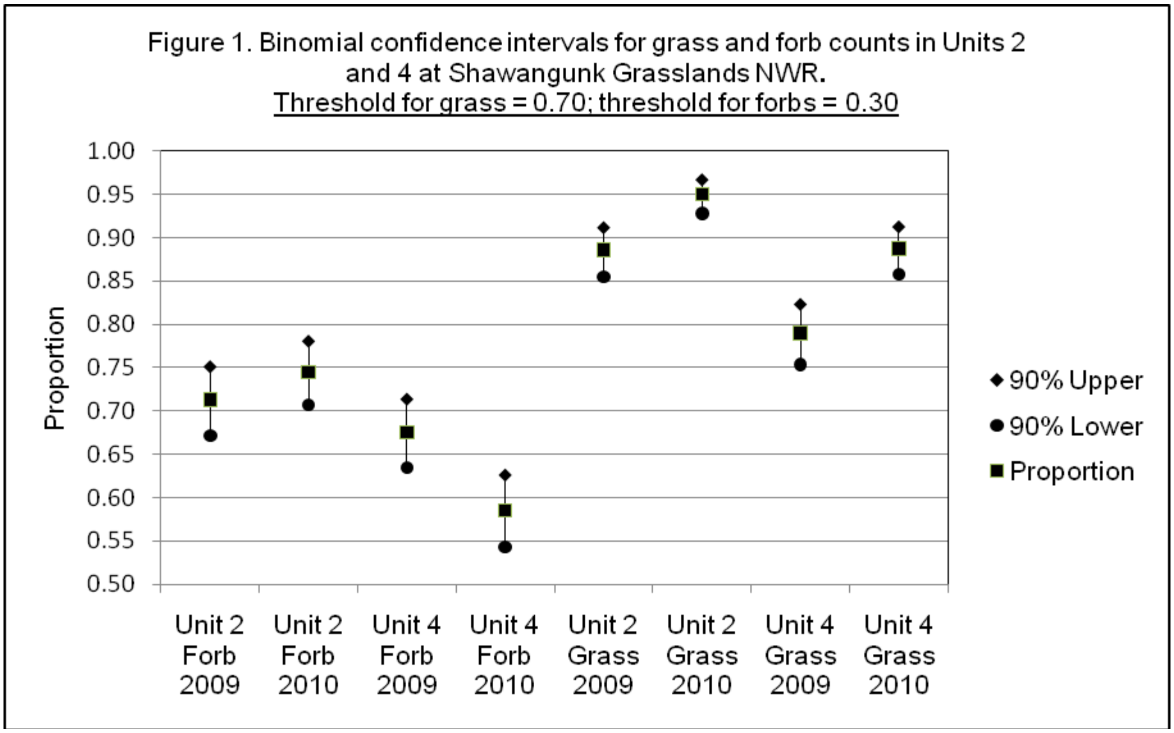
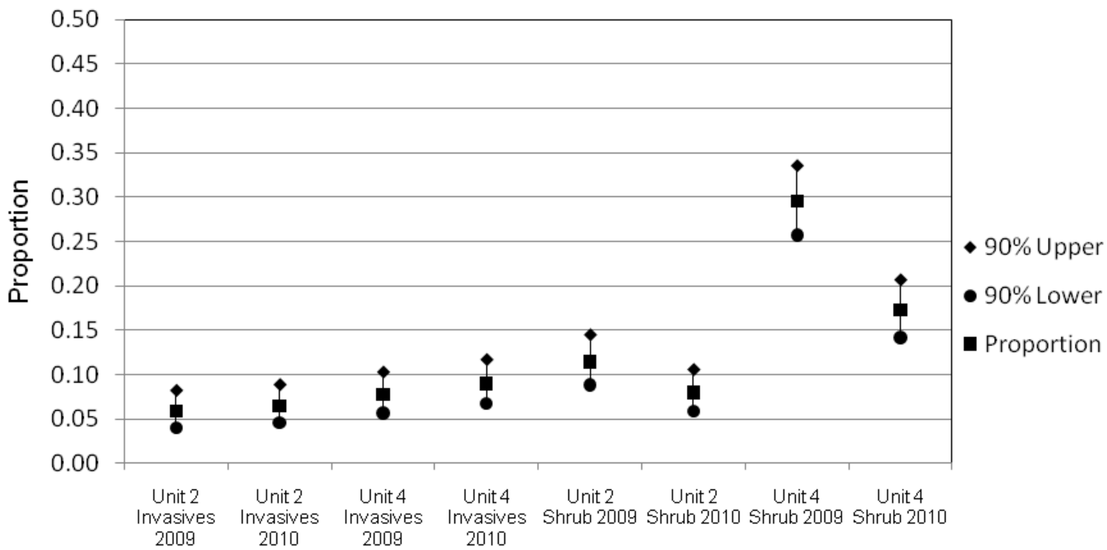


Figure 2 shows a similar comparison for total shrub counts and total invasive counts. Total shrub counts decreased following the July 2009 mowing in both units and to a signficant degree in Unit 4. In both units there was a significant reduction in shrubs in the 0.5-1.0 m height range. Looking back at Table 4, counts of shrubs in the <0.5 m range increased in Unit 2 and decreased in Unit 4. Invasive counts increased in both units, though this change was not significant.

Now if we look back at the thresholds in Table 2, the threshold for a proportion of forbs of 0.30 was not achieved. Thresholds for proportions of shrubs (0.05) or invasives (0.10) were also not achieved. For shrubs, this may be an ambitious goal, and one not likely to be achieved in a single treatment. For invasives, the threshold was achieved in Unit 2 prior to treatment and remained below the threshold level post-treatment. The threshold was not achieved before or after treatment in Unit 4.

Figure 2. Binomial confidence intervals for counts of total shrubs and total invasives in Units 2 and 4 at Shawangunk Grasslands NWR
Threshold for invasives = 0.10; threshold for shrubs = 0.05



2. Robel Pole Data

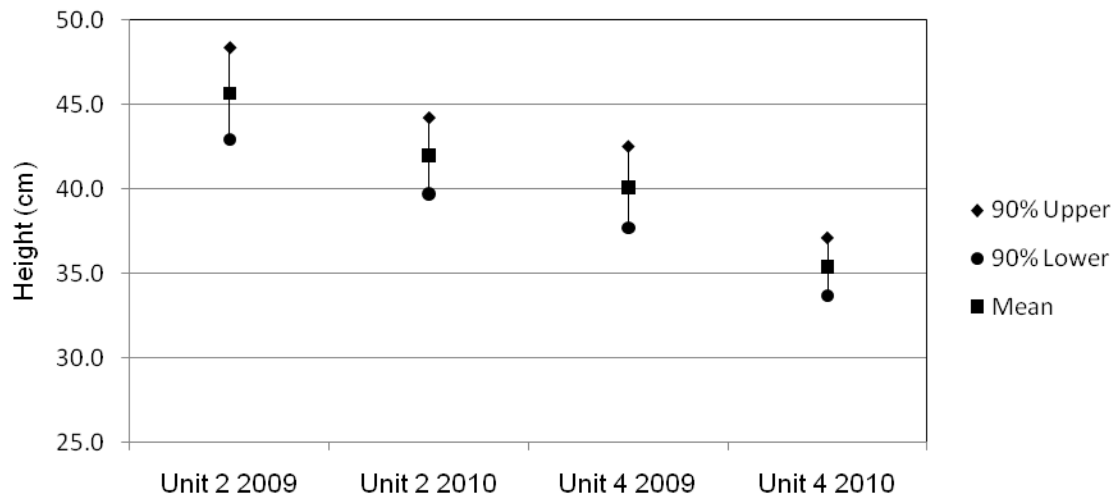
Table 5 provides a comparison of Robel pole data from Units 2 and 4 at SGNWR between 2009 and 2010. In both units, the mean declined, but in neither case was the threshold of 25 cm (Table 2) achieved. However, this may be an ambitious goal that cannot be achieved in one treatment. In addition, species are highly variable with respect to their height-density "preference" so the range may need to be expanded or areas established with different thresholds.

Table 5. Summary of Robel pole data for Units 2 and 4 at SGNWR.

Unit	N	2009	2010	t	p	Power
2	100 (93 in 2009)	45.6 (15.6)	41.9 (13.6)	1.75	0.081	0.526
4	100	40.1 (14.7)	35.40 (10.3)	2.62	0.009	0.824

Figure 3 below shows confidence intervals for mean Robel pole data for Units 2 and 4 between 2009 and 2010. The data have a bimodal distribution, and transformation did not help this problem. Basically mowing reduced the overall height of vegetation, so the readings were lower as would be expected.

Figure 3. Confidence intervals for Robel pole measurements in Units 2 and 4 at Shawangunk Grasslands NWR
Threshold for height density = 25 cm



3. Litter Depth and Cover

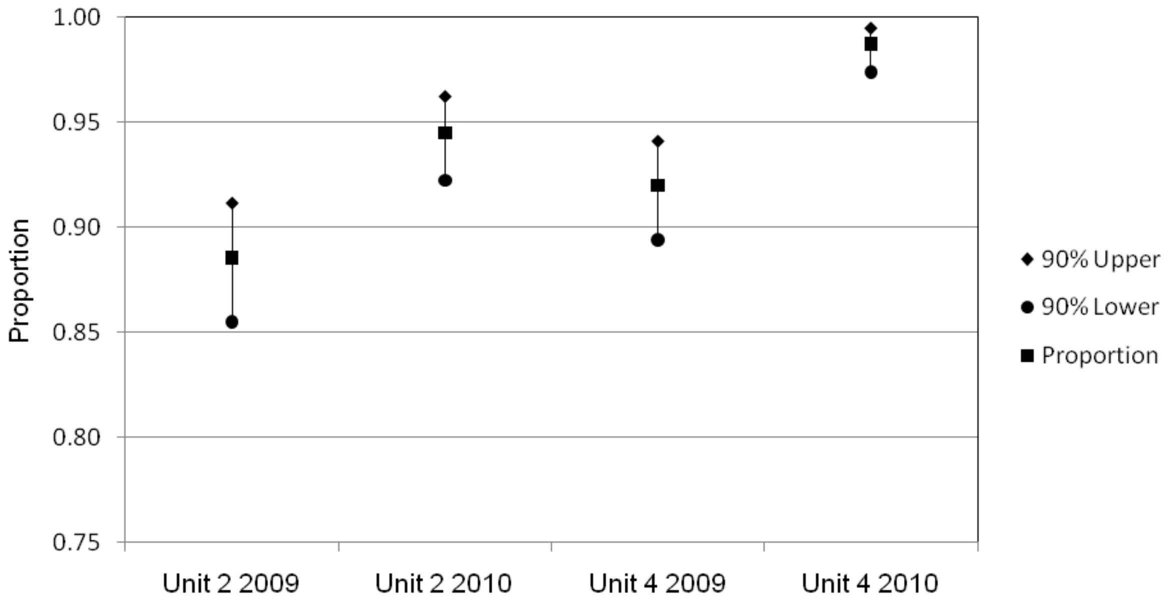
Litter depth remained relatively unchanged, though there was some increase following mowing as would be expected. These fields had not been treated for at least two years prior to mowing in 2009. The average litter depth and 90% CI encompass the threshold in Table 2.

Table 6. Comparison of litter depth in Units 2 and 4 from 2009 to 2010 at Shawangunk Grasslands NWR.

Unit	N	2009 mean depth (cm)	2010 mean depth (cm)	t	p	Power
2	100 (94 in 2009)	3.1	3.4	-0.863	0.389	0.225
4	100 (98 in 2009)	3.1	3.4	-0.912	0.363	0.243

Litter cover increased as would be expected following mowing. We did not establish thresholds for cover as bird species preferences are highly variable.

Figure 4. Binomial confidence intervals for counts of litter in Units 2 and 4 at Shawangunk Grasslands NWR



D. Mohonk Glory Hill Fields Data Analyses and Results

The primary concern of the Mohonk Preserve is reducing shrub and invasive species. I will review changes in the other measured variables, grass and forb counts as well.

1. K-24

K-24 received two treatments in 2009: a spring burn and a late summer mow. The spring burn produced significant results as total shrub cover was dramatically reduced (Figure 5). As would be expected, litter cover was also reduced and there was an increase in the area of bare soil following the burn. Counts of shrubs in the <0.5, 0.5-1.0 m and total shrubs were further reduced following the September mow, closing in on the threshold of 0.20. The count of invasive species remained relatively unchanged (Figure 5), but did not reach the threshold of 0.10. Litter depth was not measured after the mow treatment. Litter cover increased following the mow as would be expected, so litter depth probably increased as well.

Interestingly, grass counts increased following the burn and decreased following the mow, while forb counts remained unchanged following the burn and decreased following the mow (Figure 6).

Table 7. Summary of data from field K-24 and K-26 at the Mohonk Preserve for 2008 through 2010. K-24 was burned in the spring of 2009 mowed in late September of 2009. Cover types indicated with a + had statistically significant changes (p<0.05) between 2008 and 2009 and those with a * had statistically significant changes between 2009 and 2010.

K24	2008			2009			2010			Chi square 2008-2009			Chi square 2009-2010		
Cover Type	Hits	N	Prop.	Hits	N	Prop.	Hits	N	Prop.	Statistic	p	Power	Statistic	p	Power
*Grass	142	200	0.71	156	200	0.78	82	200	0.41	2.579	0.108	0.48	56.811	0.000	1.00
*Forb	144	200	0.72	141	200	0.71	100	200	0.50	0.110	0.740	0.07	17.547	0.000	0.99
*Litter	160	200	0.80	76	200	0.38	181	200	0.91	72.923	0.000	1.00	119.997	0.000	1.00
+Shrub <0.5m	31	200	0.16	48	200	0.24	36	200	0.18	4.559	0.033	0.64	2.170	0.141	0.43
*+Shrub 0.5-1m	103	200	0.52	22	200	0.11	4	200	0.02	76.346	0.000	1.00	13.328	0.000	0.98
Shrub > 1.0m	7	200	0.04	2	200	0.01	0	200	0.00	2.842	0.092	0.61	2.010	0.156	NA
*+Total Shrub	127	200	0.64	71	200	0.36	39	200	0.20	31.363	0.000	1.00	12.840	0.000	0.97
Total Invasives	56	200	0.28	62	200	0.31	50	200	0.25	0.433	0.511	0.16	1.786	0.181	0.38

Figure 5. Binomial confidence intervals for counts of total invasives and shrubs in field K-24 at the Mohonk Preserve
Threshold for invasives = 0.10; threshold for shrubs - 0.20

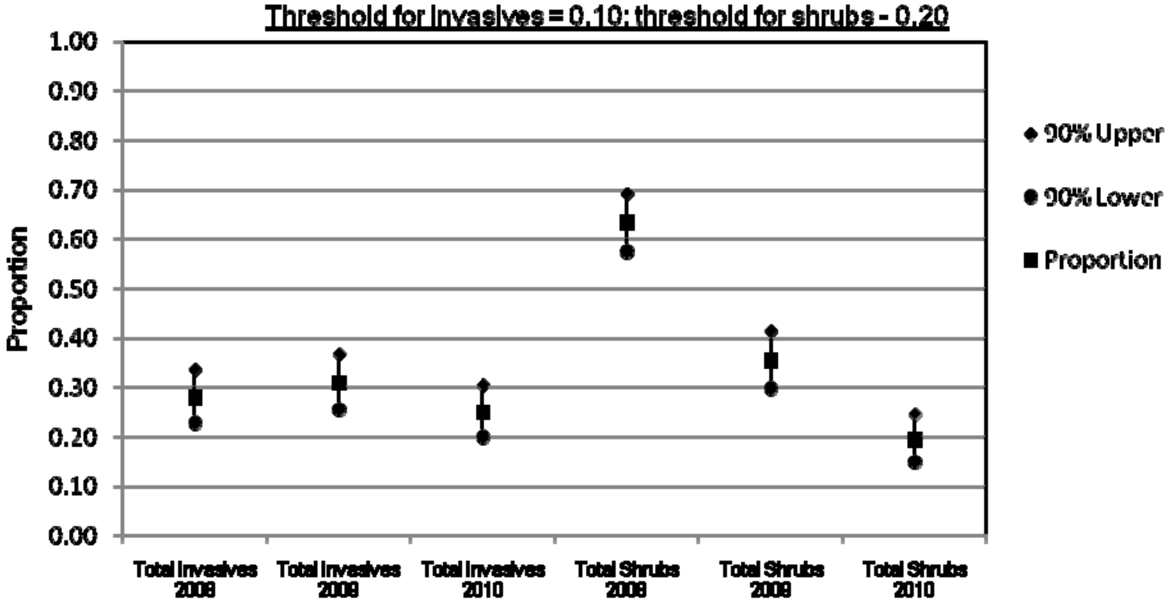
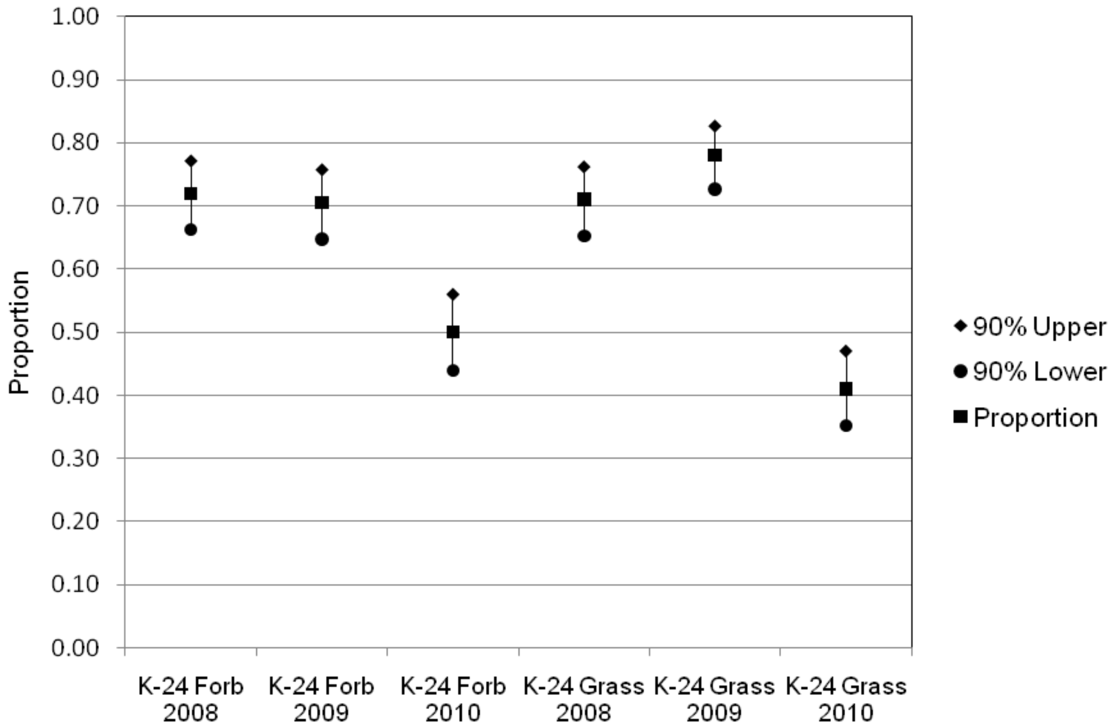


Figure 6. Binomial confidence intervals counts of forbs and grasses in field K-24 at the Mohonk Preserve
Threshold for grass = 0.70; threshold for forbs = 0.30



2. K-23 and K-26

K-23 and K-26 allow for comparing the results of late summer vs. spring mowing respectively. Total shrub counts did not decrease significantly (Figure 7, Table 8) because there were increases in shrubs <0.5 m that were far greater than the decreases in the other categories (Table 8). Total invasive counts decreased in K-26 and increased significantly in K-23. We did not achieve threshold values of 0.20 for shrubs and 0.10 for invasives.

Grass counts decreased in both fields, significantly in K-23, while forb cover increased slightly (Figure 8). Litter counts increased, most likely as they were low prior to treatment (Table 8).

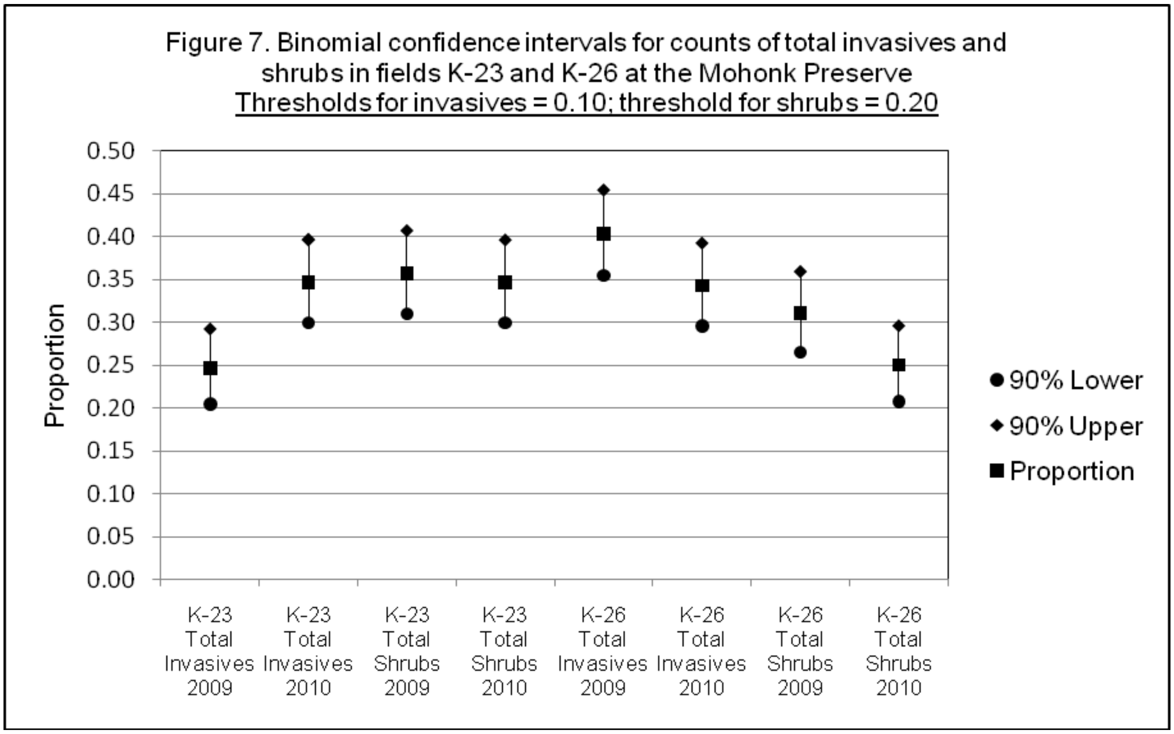
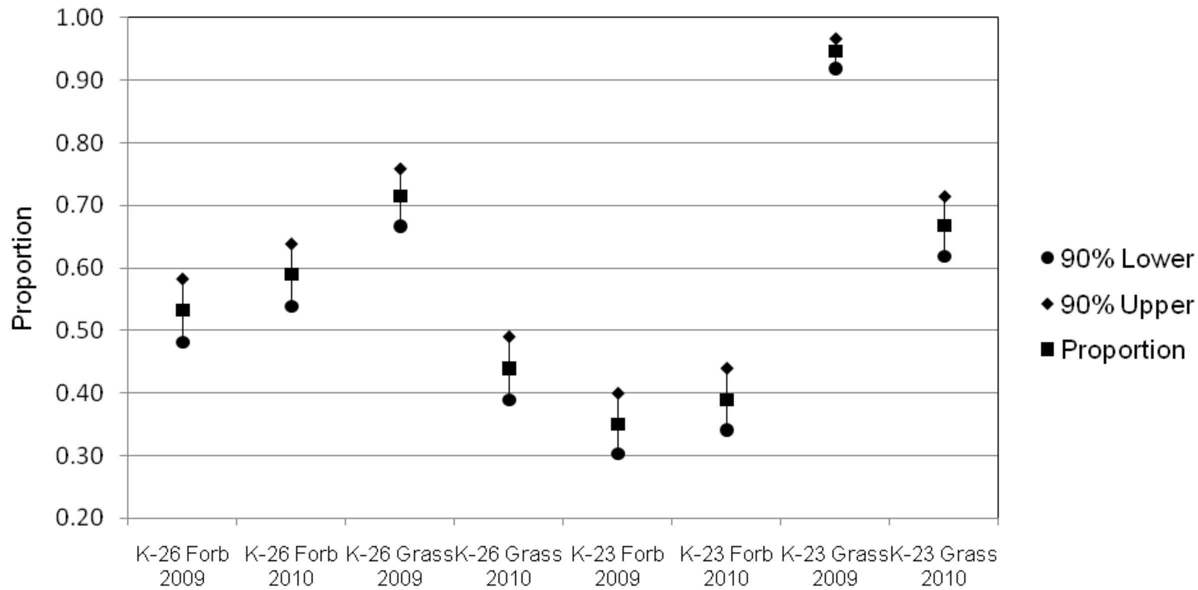


Table 8. Summary of data from fields K-23 and K-26 at the Mohonk Preserve for 2009 and 2010. K-23 was mowed in early September of 2009 and K-26 was mowed in April of 2010. Cover types indicated with a * had statistically significant changes (p<0.05) between 2009 and 2010.

K23	2009			2010			Chi square (df=1)		
Cover Type	Hits	N	Proportion	Hits	N	Proportion	Statistic	p	Power
Grass	265	280	0.95	187	280	0.67	69.794	0.000	1.00
Forb	98	280	0.35	109	280	0.39	0.927	0.336	0.25
*Litter	87	280	0.31	279	280	0.99	290.742	0.000	1.00
*Shrub <0.5m	29	280	0.10	67	280	0.24	18.154	0.000	0.99
Shrub 0.5-1m	47	280	0.17	31	280	0.11	3.813	0.051	0.66
*Shrub > 1.0m	25	280	0.09	1	280	0.00	28.232	0.000	1.99
Total Shrub	100	280	0.36	97	280	0.35	0.070	0.791	0.08
*Total Invasives	69	280	0.25	97	280	0.35	6.713	0.010	0.82
K26	2009			2010			Chi square (df=1)		
Cover Type	Hits	N	Proportion	Hits	N	Proportion	Statistic	p	Power
*Grass	200	280	0.71	123	280	0.44	43.373	0.000	1.00
Forb	149	280	0.53	165	280	0.59	1.856	0.173	0.41
*Litter	120	280	0.43	272	280	0.97	196.463	0.000	1.00
*Shrub <0.5m	11	280	0.04	65	280	0.23	44.393	0.000	1.00
*Shrub 0.5-1m	50	280	0.18	6	280	0.02	38.413	0.000	1.00
*Shrub > 1.0m	32	280	0.11	0	280	0.00	33.939	0.000	1.00
Total Shrub	87	280	0.31	70	280	0.25	2.558	0.110	0.47
Total Invasives	113	280	0.40	96	280	0.34	2.206	0.137	0.43

Figure 8. Binomial confidence intervals for counts of grass and forbs in fields K-23 and K-26 at the Mohonk Preserve
Threshold for grass = 0.70; threshold for forbs = 0.30



IV. Discussion

A. Summary of Findings

Table 9 below summarizes changes in counts of vegetation cover for the key types (grass, forb, shrubs and invasives), and, at SGNWR, height density and litter depth.

Table 9. Summary of findings for both Shawangunk Grasslands NWR and the Mohonk Preserve

Treatment	Variable	Change in Variable	Statistically Significant?	Threshold Achieved[4]	Notes
Spring burn (K-24)	Grass	Increased	No	No	
	Forb	Decreased	No	No	
	Total Shrubs	Decreased	Yes	No	Shrubs <0.5 m and 0.5 -1.0 m decreased significantly
	Total Invasives	Increased	No	No	Knapweed (*Centaurea* spp.) was the primary invasive species
Spring mow (K-26)	Grass	Decreased	Yes	No	
	Forb	Increased	No	No	
	Total Shrubs	Decreased	No	No	Short shrub (<0.5 m) counts increased significantly while 0.5-1.0 m and > 1.0 m counts decreased significantly

[4] For the Mohonk Preserve, thresholds for grass and forb cover were not established. For this table, I am using those established for SGNWR as relevant to grassland bird habitat.

Table 9. Summary of findings for both Shawangunk Grasslands NWR and the Mohonk Preserve

Treatment	Variable	Change in Variable	Statistically Significant?	Threshold Achieved[4]	Notes
	Total Invasives	Decreased	No	No	Knapweed (*Centaurea* spp.) was the primary invasive species
Mid-summer mow (SGNWR Units 2 and 4)	Grass	Decreased Unit 4 Increased Unit 2	Yes Yes	No	
	Forb	Increased Unit 2 Decreased Unit 4	Unit 2-No Unit 4-Yes	No	
	Total Shrubs	Decreased	Unit 2-No Unit 4-Yes	No	Shrubs 0.5-1 m decreased significantly in both units
	Total Invasives	Increased	No	Unit 2-Yes Unit 4-No	Purple loosestrife (*Lythrum salicaria*) was the primary invasive
	Height density	Decreased	Unit 2-No Unit 4-Yes	No	
	Litter depth	Increased	No	Yes	No change from pre-treatment depth
Late summer mow (K-23 and K-24)	Grass	Decreased	Yes	NA	
	Forb	Increased K-23 Decreased K-24	K-23-No K-24-Yes	No	
	Total Shrubs	Decreased	K-23-No K-24-Yes	No	Shrubs <0.5 m increased while those > 1.0 m decreased significantly in K-23 Shrubs 0.5-1.0 m decreased significantly in K-24
	Total Invasives	Increased K-23 Decreased K-24	K-23-Yes K-24-No	No	Knapweed (*Centaurea* spp.) was the primary invasive species followed by purple loosestrife

All of the treatments reduced shrub cover, with the combined spring burn and summer mow treatments in K-24 resulting in the greatest reductions in total shrub cover. Shrub cover was reduced in spring, mid-summer and late summer mow regimes, but statistically significant differences in shrub cover before vs. after treatment were not consistent in any of these treatments. The spring burn was most effective in reducing short shrub (<0.5 m) cover. Otherwise changes in that height category were inconsistent across mowing treatments, with some units experiencing increased abundance and others reduced abundance. Since short shrub cover was not consistently reduced, the effects of these treatments are temporary as that size class will quickly grow to a meter or more in height within one to two seasons,

Invasive species abundance generally increased. This may be caused by the ability of these species to colonize disturbed areas as reductions in other species may create more space for the invasive species.

As would be expected, height density decreased following treatments. Litter cover and depth increased following mowing, and decreased following burning. Litter tends to decompose fairly rapidly, so that repeated mowing is not likely to significantly increase litter depth.

One of the key variables important to grassland birds is dominance by grass cover. In general, grass should dominate the vegetative cover (i.e., 70%), with forb cover of 10-30%. Clearly this does not occur in any of the fields we studied. The results for changes in grass and forb abundance are mixed, with most treatments increasing forb abundance and some treatments resulting in increases in grass in one field and decreases in another at the same site.

It is possible that our methods, which involved using a narrow pole to record hits of forbs and grasses, may have resulted in a high estimate of forb counts. The wider leaves of forbs may have caused us to record more hits, though those wider leaves would increase their overall cover anyway. In addition, grasses tend to dominate early in the season with forbs such as goldenrod (*Solidago* spp.) and asters (generally *Symphyotrichum* spp.) dominating from mid to late July on. On the other hand, warm season grasses such as little bluestem (*Schizachyrium scoparium*) and big bluestem (*Andropogon gerardii*) also become dominant later in the season. Given these considerations, I believe the method did not create a bias toward forb cover.

B. Management Recommendations

Given the differences in 1) characteristics of the fields at each site and 2) the effects of similar treatments on adjacent fields, management objectives should be developed for each field with a prescription or set of protocols for achieving those. In cases where shrub cover is high, fields should be placed in a restoration rather than a management category where extensive treatment is implemented to achieve management objectives. Once those are achieved, management intensity can be reduced to maintain the desired status.

Our results show that repeated treatments (spring burn followed by summer mow) in K-24 in one growing season substantially reduced shrub cover. Therefore, to reduce woody species abundance, multiple treatments within a growing season are essential. Fire proved more effective than I anticipated. If opportunities arise for the use of fire, then fire should be used along with mechanical treatments. Fire in the growing season could be used following earlier mowing if conditions are sufficiently dry. This strategy could quickly reduce shrub cover in a field.

While the changes were statistically significant in only one case, all treatments generally resulted in an increase in invasive species abundance. Therefore it is unlikely that fire or mechanical treatments can be relied upon to reduce invasive species. Invasive species will likely require the use of herbicides as mechanical treatments are generally ineffective against species such as purple loosestrife or knapweed. Mechanical treatment of bush honeysuckle may be effective if the entire plant is removed. Dormant season cutting or burning are generally ineffective for invasive species control. However, growing season application of either or both can be applied, but may require many years of treatment (Richburg 2005). Invasive species control will likely require annual treatments and monitoring of results to keep invasives from expanding.

Managing for grassland birds requires avoiding treatments during their breeding seasons which can run from April through July with possible second broods in August (Morgan and Burger 2008). However, subareas can be treated in the spring provided sufficient area for breeding is left. So, small areas might be mowed or burned in the spring while the remaining area is treated in mid or late summer and a rotation developed so all areas are treated at least once..

Mowing multiple times may encourage grass cover and decrease forb cover. Mowing before seed set of forbs may also reduce their abundance over the long term (Morgan and Burger 2008). Zuckerberg and Vickery (2006) found higher grass abundance in mowed then burned fields. However, it may also be necessary to completely replant fields with a high proportion of grasses to achieve the low forb cover preferred by many grassland nesting birds. In addition, habitat characteristics such as litter cover and depth and height-density should also be considered in choosing management techniques, depending on the target bird species.

Monitoring should be focused to address the specific management objectives of each field. So, using the shrub cover example, it may only be necessary to monitor shrub cover and not the other variables such as grass or forb cover as we did in this study. This will allow for an adaptive management approach based on solid information on management effectiveness while minimizing resource expenditures for monitoring.

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