

The Outlet Fire of 2000



Results from Five Years of Vegetation Monitoring, North Rim, Grand Canyon National Park

by

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Abstract

Both high severity fire and exotic plant species invasion are relatively new phenomena in America's Southwestern forests. Here, the last century of fire suppression and livestock grazing has led to high fuel loads and introductions of exotic plant species. In 2000, the Outlet fuel-reduction prescription fire on the North Rim of Grand Canyon National Park (GRCA) jumped its intended boundary and burned over 13,000 acres of Park Service and Forest Service land. Because much of the fire resulted in high-severity impact, there was concern about erosion in specific areas of the burn, namely Bright Angel Creek. In addition, there were questions regarding the impacts of fire-fighting activity on the vegetation. Within months of the fire, GRCA resource managers developed a system of point-line vegetation transects in Bright Angel Canyon as well as in a variety of areas where fire-fighting activity took place. These transects were read on several occasions each summer in the first few years following the fire, and one time per year, in late July, since 2002. Reports have been written in each year of this study (Murov, 2000; Eisenberg and others, 2001; Eisenberg and Watters, 2002; Crawford and Whitchurch, 2003). The results from the 2004 survey, along with comparisons to the surveys of previous years are the subject of this report.

While changes in floristic composition, cover, and diversity over time were statistically significant between 2000 and 2004, there were also statistically significant differences among disturbance types (burn, and the fire-fighting activities of handline and drop-point). Burn transects had the highest percentage of vegetation recovery (primarily graminoids, forbs, and tree seedlings) in the first year, and though this cover decreased in the following years, it remains high. Few exotic species were present in the burn transects, with peak cover being attained in 2001 and 2002. Handline transects had the lowest exotic and native species recovery in all years of study. There was a statistically significant difference between the vegetation of handline transects in 2000 and both other disturbance types in 2000 and in 2004. There was no statistical difference between the handline transects of 2000 and 2004, showing no significant vegetation recovery in these areas. Drop-point transects contained the highest percentage of exotic species in all years of study, but also supported a great proportion of native species.

Three main conclusions can be drawn from this report. 1) The fact that handline transects have shown little to no recovery is worrisome with regards to current fire-fighting techniques. Current methods of site rehabilitation following handline construction may need to be modified to improve vegetation recovery potential. 2) Disturbance and ruderal species in drop sites are maintained by visitor use, as many of these sites are roadside pull outs. It is difficult to ascertain how much of this disturbance was due to fire-fighting activity and how much to continued visitor use. 3) The fact that burn transects harbor few exotic plant species is positive; however, diversity in these transects has decreased following the dieback of initial ruderal invasion, and the landscapes are now relatively homogeneous. Despite the general lack of exotic species in burn transects, it should be noted that while cover of *Bromus tectorum* has remained low, its abundance has increased since 2000 and has become an indicator of burn sites in 2004.

In 2004 this study was expanded to include an additional 130 plots throughout the burn area in areas of high, moderate, and low severity fire, as well as nearby unburned forests and meadows. No additional plots were placed in areas of fire-fighting activity. These plots differ from this study in that the relevé method was employed (refer to a separate report on this study currently in preparation). Little is known about post-fire recovery in high elevation forests of northern Arizona, therefore continued monitoring of the 29 transects and 130 relevé plots is essential for enhancing our understanding of long-term changes in these landscapes. Monitoring these transects is also important in relation to future fire-suppression activities in the Park and will provide locations of exotic species infestations for control or eradication measures.

Introduction (excerpt from Crawford, 2003)

The Outlet Fire is located in northcentral Arizona, to the north and east of the developed area of GRCA's North Rim (Figure 1). The Outlet Fire began as a prescribed burn that was ignited near Outlet Canyon on April 25, 2000 and burned 465 acres (188 ha) (Figure 3, page 5). The prescribed burn spread uncontrollably and on May 9, 2000 the National Park Service classified the burn as the Outlet wildfire. The Outlet wildfire, referred to here as the Outlet Fire, began near Bright Angel Spring and burned 8,776 acres (3,552 ha) in GCNP. It spread in a northeast direction to burn 5,109 acres (2,068 ha) of Forest Service land (Figure 1). The fire continued to burn for 36 days and was contained on June 15, 2000.

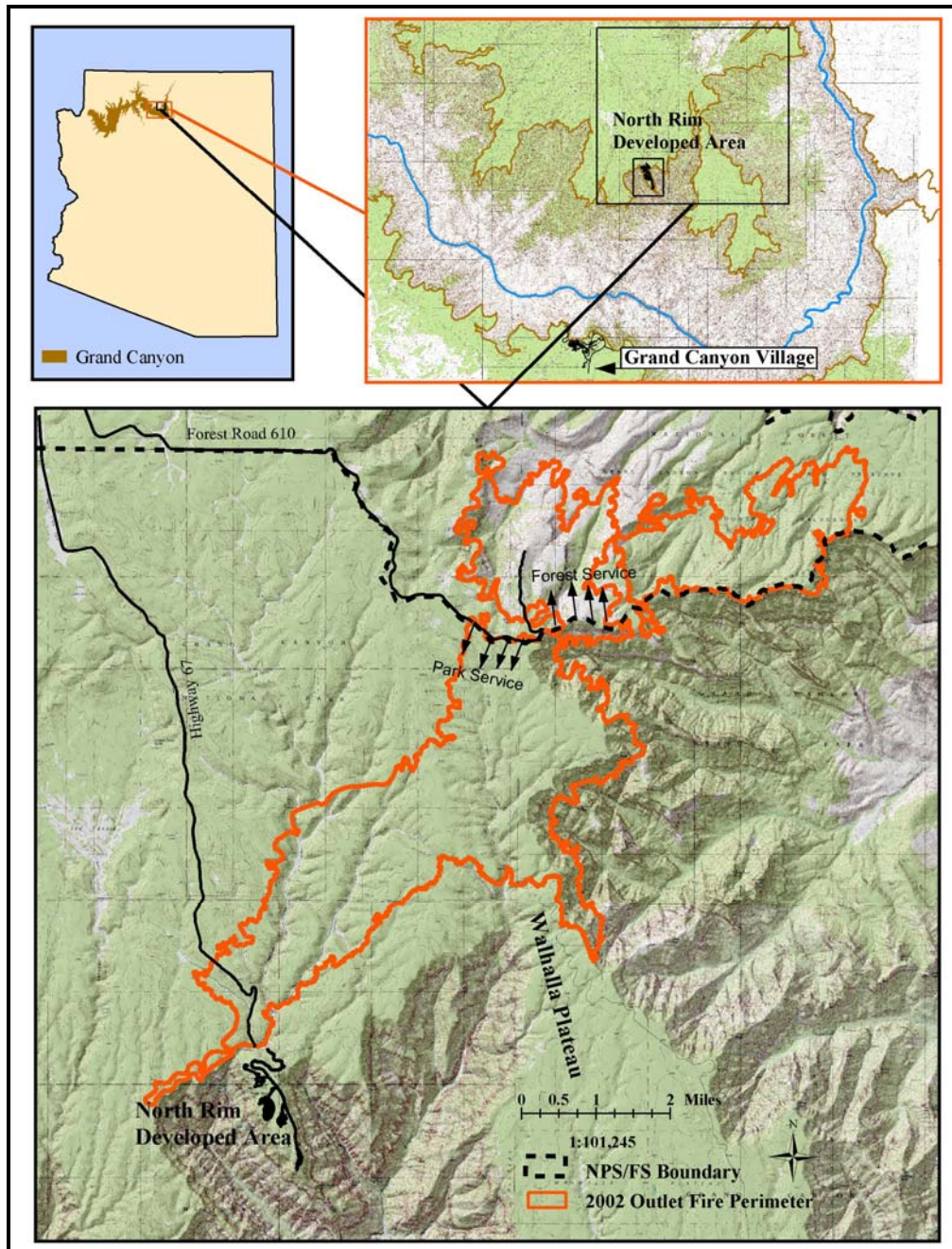


Figure 1. Location and boundaries of the 2000 Outlet fire, North Rim, GRCA. The fire began in the Outlet prescription burn and moved in a northeast direction, burning over 13,000 acres.

Of the total Outlet Fire burn area, 23% burned at high severity (tree crowns consumed), 33% at moderate severity (tree crowns scorched), 40% at low severity (understory burn only), and 4% was not burned. The fire affected stands dominated by *Picea engelmannii* (Engelmann spruce) and *Abies concolor* (white fir) (40% of the area), *Pinus ponderosa* (ponderosa pine) and other conifers (37%), *Populus tremuloides* (aspen) (10%), *Arctostaphylos patula* (green-leaf manzanita) and other shrubs (10%), grasses (2%), and *Pinus edulis* - *Juniperus* spp. (pinyon-juniper) (1%) (Figure 2).



Figure 2. The 2000 Outlet fire, North Rim, GRCA, crossed many habitat types including the mixed conifer forest (left) and *Arctostaphylos patula* shrublands (right). Photos from 2004.

This study was designed to look at vegetation response to high severity fire in the Bright Angel Drainage, an area of potential erosion, as well as to investigate the effects of fire-fighting activities a) drop-points and dip sites, and b) handlines (Figure 3). The effects of fire on vegetation are various and largely dependent upon the ecology of individual plant species, as well as the severity of the burn. The effects of fire-fighting activities on vegetation are largely unknown. The pre-fire flora was composed of a variety of plant species including re-sprouting shrubs and trees such as *Ceanothus fendleri* (buckbrush) and *P. tremuloides*, and easily killed forbs dependent on seed rain from neighboring unburned sites for re-establishment (e.g. *Antennaria* spp. [pussy toes]; *Penstemon* spp. [penstemon]; and *Lupinus* spp. [lupine]).

Several drop-points and dip sites were established during fire-fighting efforts. These sites collectively will henceforth be referred to as drop-points. Drop-points were where fire-fighting equipment was staged and fire-fighters were dropped off and picked up. Dip sites were locations where the fire team placed portable water storage tanks filled for use by helicopter dip buckets. Our transects only crossed one dip site (transect 9), and these data were combined with drop sites for analysis in 2000, 2001, and 2002. Fire-fighting efforts also included the construction and subsequent restoration of an estimated 24 miles of hand-dug fireline, referred to herein as handline. Constructing handline involved scraping the ground down to mineral soil (removing all organic and combustible materials) using hand tools. Restoration of these highly disturbed areas involved erosion control and contour resurfacing, however it did not involve the re-establishment of vegetation.

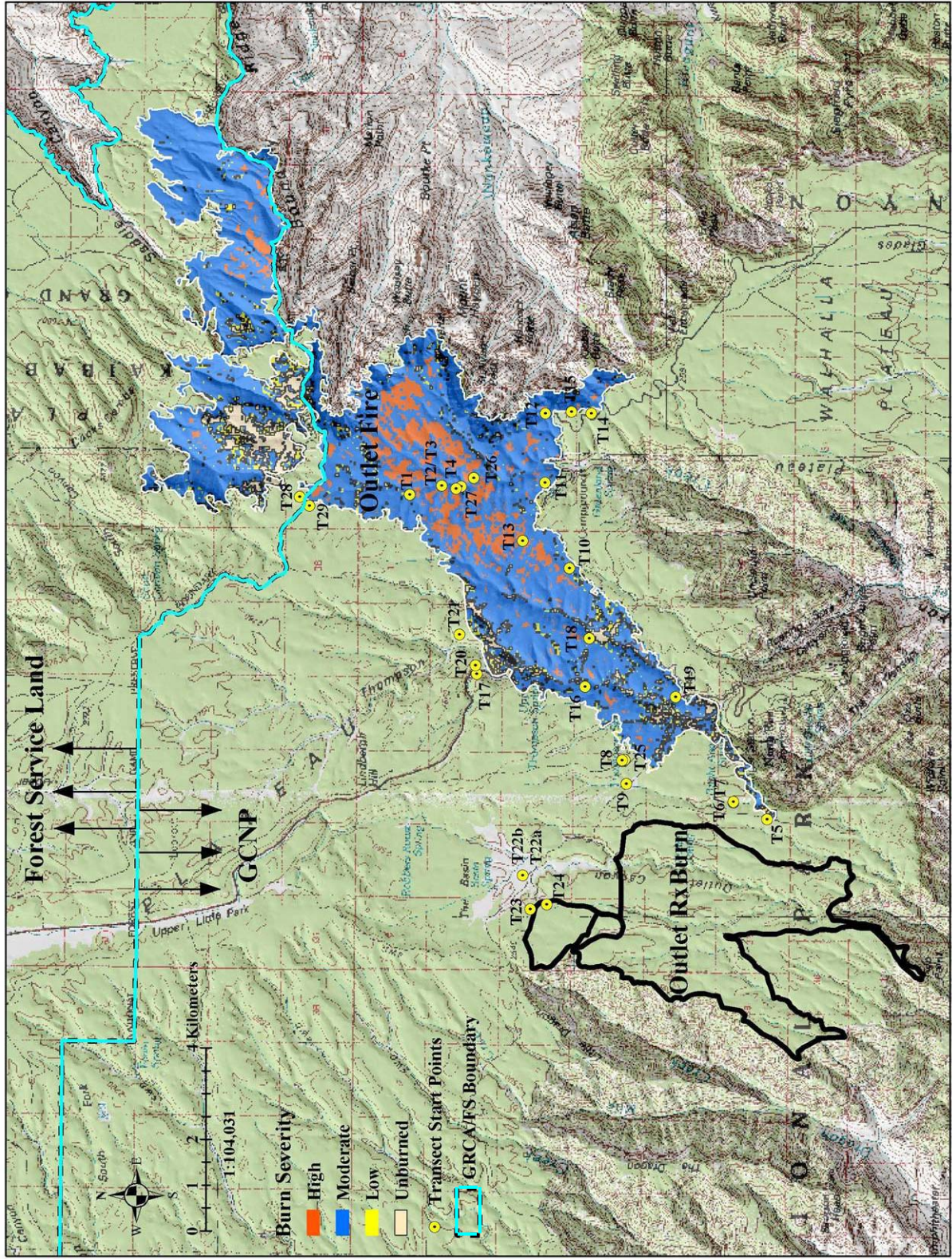


Figure 3. Map of the 2000 Outlet Fire, North Rim GRCA by severity class. Yellow dots represent transect start locations.

Of the eight exotic species found in the transects, four are considered by GRCA biologists to be a high priority for management, but with low feasibility of control (*Bromus inermis* [smooth brome], *B. tectorum*, *Poa pratensis* [Kentucky bluegrass], and *Rumex acetosella* [garden sorrel]). The remaining four species are of lower priority as they have less impact on Park resources (*Taraxacum officinale* [dandelion], *Tragopogon dubius* [goatsbeard], *Medicago lupulina* [black medic], and, *Polygonum aviculare* [knotweed]). In 2003, we reported *Chenopodium album* as an exotic; it was determined in 2004 that this species was, in fact, *Chenopodium fremontii* (Fremont's goosefoot), a native.

Methods

Field

In late July, 2004, we re-visited the twenty-nine line transects that were installed on handlines (9 transects), at drop-points (13 transects), and in burned areas (7 transects) in the fall of 2000 (Murov, 2000). In 2001 and 2002, transects were read four times from July to September in order to view phenology throughout the growing season to increase the accuracy of identification of species that flower and seed at different times (Eisenberg and others, 2001; Eisenberg and Watters, 2002). During 2003 and 2004, transects were revisited and measured in late July following the onset of monsoons when most vegetation is identifiable. Transect 9, a dip point transect, was not read in 2003 or 2004 as this transect is located in a landfill that had been graded, the markers removed, and is considered lost. In addition, in 2004 transect 16 was not read, as neither the start nor the end point was re-located. Several transects retained only one permanent marker in 2004 and were relocated using descriptions and photographs from previous surveys.

In all years following initial setup, transects were relocated using a combination of maps, photographs, written narratives, and UTM coordinates (Murov, 2000; Eisenberg and others, 2001; and Eisenberg and Watters, 2002). Since 2001, photographs were taken from both the start and end points of each transect along established compass bearings and with a 13° east declination (Appendix 3). Start and end UTM coordinates were read and recorded using Garmin GPS units (map datum NAD27). Earlier reports contain incorrect UTM coordinates; transect locations are roughly 200 meters south-east of the originally reported coordinates. Appendix 2 of this report contains correct UTM coordinates and should be used for future relocation efforts.

Each transect was 25 meters long, with the exception of transects 6 and 7, which were both 12.5 meters long; their data were combined to form one transect for analysis. A tape measure was stretched the length of each transect and secured at both ends. The point intercept method was used as it is the least biased measure of cover (Bonham 1989).

Every 0.25 meters, a $\frac{3}{4}$ inch diameter stick was placed vertically on the left side of the tape. Whatever the stick was touching at that spot was recorded as a hit (Figure 4). One hundred points were read for each transect. It was possible for more than one plant species or ground surface variable to be hit at each point, giving the possibility of greater than 100% storied cover.



Figure 4. Point-intercept transect measurement, Outlet Fire, North Rim, GRCA, 2004. Notice $\frac{3}{4}$ inch diameter stick used in recording vegetation.

During the summer of 2004 it was determined that the previous method of using a $\frac{3}{4}$ inch diameter measuring device may overestimate cover, especially of ground surface variables. In many instances the wide diameter stick touched more than one ground surface variable, leading to well over 100% cover of soil, rock, and litter. While this is acceptable for storied vegetation cover, it is less acceptable for ground surface variables. It is recommended that in future years a smaller diameter stick, such as a pin-flag, be used and a statistician consulted regarding the change.

In 2000 and 2001 litter and brush (dead plant material with a diameter larger than 3 cm) were both counted as litter. In 2002, 2003, and 2004 they were counted separately as this is more consistent with park methods and allows detection of fallen trees and brush pulled over transects during handline rehabilitation. In order to compare between years for this report, however, litter and brush (later referred to as coarse woody debris) have been combined in all years of study.

Unknown species were collected from areas near, but not on, transects and pressed for later identification. Specimens were identified in September and October in the Deaver Herbarium of Northern Arizona University and deposited both within the Deaver Herbarium and at the GRCA Museum Collections Herbarium.

Analysis

Summary statistics were calculated for each year of study across lifeform group (graminoid, forb, shrub, tree seedling, ferns and fern allies) and across disturbance type (burn, handline, drop-points): comparative graphs and charts were created. For comparison purposes, all summaries and statistics contained in this report relate to data collected in September / October 2000, and July 2001, 2002, 2003 and 2004.

Species diversity of each transect was calculated (log 10) using the Shannon index (H') (taking into account both abundance [richness] and evenness) (Magurran, 1988) and species richness (total number of species per sample) (Moore and Chapman, 1986). Differences in diversity between disturbance types were tested with two-sample t-tests using SYSTAT.

PC-Ord Indicator Species Analysis was used to calculate an importance value and associated p-value (Monte Carlo test) for each species in the first and last years of the study. These values were used to identify the

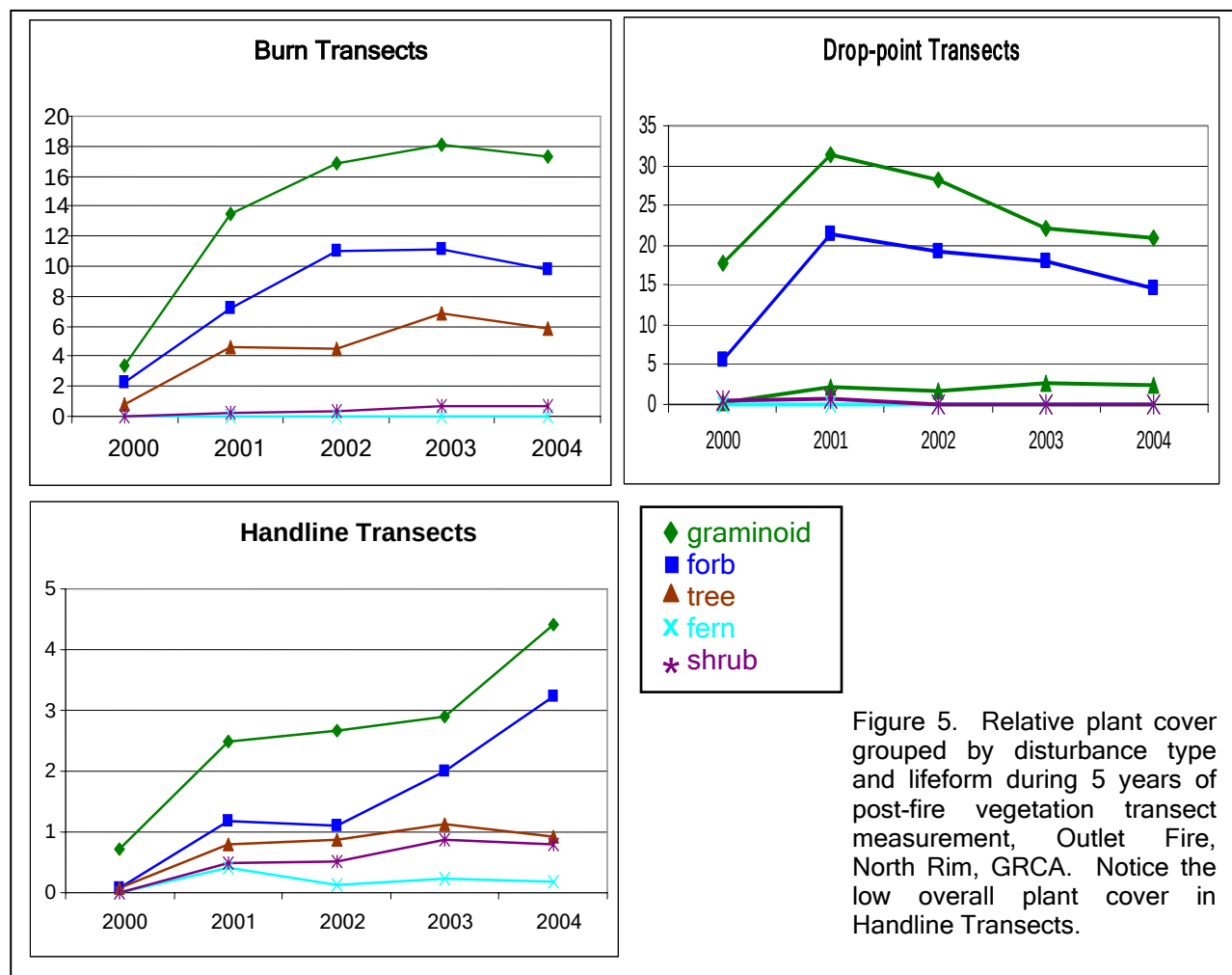
most important species that characterized the three disturbance types immediately following the fire and most recently, in 2004. Indicator values are calculated by combining relative abundance (proportional abundance of a particular species in a particular group relative to the abundance of that species in all groups) and relative frequency (proportional frequency of the species in each group) following the method of Dufrene and Legendre (1997).

Using the program PC-Ord, Nonmetric Multidimensional Scaling ordination was used to look for trends. This method created a spatial representation of species composition and cover data from our 29 transects over all years of study. The program SYSTAT was used to create 5% confidence ellipses around years and treatments. Using the software PRIMER, the non-parametric ANOSIM procedure of Clarke (1993) was used to compare floristic differences among the three disturbance types and between the years 2000 and 2004.

Results

Just over 100 species of vascular plants were recorded from transects over the 5 years of study (Appendix 1). Relative plant cover by lifeform group and disturbance type are shown in Figure 5. Transects in all three disturbance types were dominated by graminoids, with *Carex bolanderi*

(Bolander's sedge) dominant in both burn and handline areas and the exotics *P. pratensis*, *Agropyron* spp. (wheatgrass), and *B. inermis* dominant in drop-points.



In 2001, the year following the fire, percent cover of accumulated litter and coarse woody debris (CWD) increased greatly in all transects, while cover of bare ground decreased (Table 1). Since 2001, the cover of ground surface variables has been unpredictable and is likely due in part to the width of the point-intercept measuring device and variation in yearly field crew interpretation of what was hit by this device.

Disturbance Type	Year	Bare Ground	Rock	Litter CWD
Burn	2000	6.59	0.55	9.79
	2001	0.41	0.21	23.34
	2002	1.21	0.10	20.55
	2003	1.34	0.24	17.86
	2004	7.10	2.41	23.31
Drop-point	2000	5.38	2.72	14.76
	2001	0.62	0.07	43.90
	2002	2.55	0.03	38.34
	2003	5.48	0.14	22.93
	2004	13.76	7.83	33.38

Table 1. Relative cover of ground surface variables during 5 years of transect measurement, Outlet Fire, North Rim, GRCA. Cover of the additional measured variables of ash, lichen, and moss were less than 1% each in all disturbance types and years.

Disturbance Type	Year	Bare Ground	Rock	Litter CWD
Handline	2000	2.72	0.72	26.69
	2001	0.00	0.10	30.93
	2002	0.14	0.14	29.69
	2003	0.38	0.38	28.79
	2004	3.55	2.28	32.45

Table 1. continued

Species diversity was greatest in drop-point transects in 2001 (0.83), followed closely by burn transects in 2002 (0.81) (Figure 6). In burn and drop-point transects, diversity increased sharply in the first few years attesting to a spike in ruderal species presence and have decreased steadily thereafter. Trends in species richness are similar. While there was an increase in diversity and richness initially in handline transects, there has been a stabilizing trend in the last two years (Figure 6). In all years of study combined, both species diversity and richness of handline transects were significantly lower than burn ($p=0.01$, $p<0.01$) or drop-point transects ($p<0.01$, $p<0.01$).

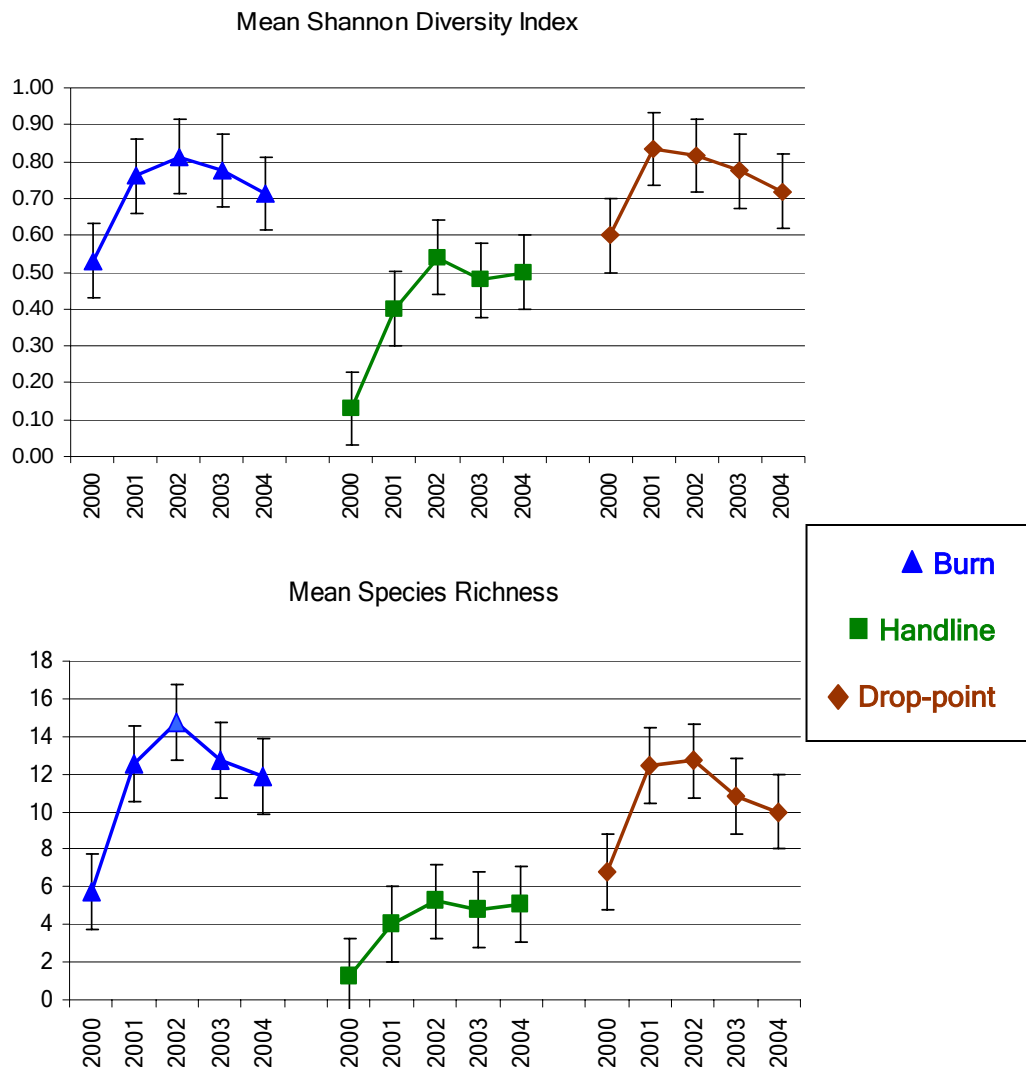


Figure 6. Mean Shannon diversity index and mean species richness by year and disturbance type.

Species composition and importance changed over time, as seen by the indicator values and significance of Table 2. Four of the top indicator species of burn transects in 2000, remain indicators in 2004 (*P. tremuloides*, *Carex* spp., *Achillea millefolium* [common yarrow], and *Fragaria virginiana* [Virginia strawberry]). The exotic *B. tectorum*, although still very low in cover, was not an indicator in 2000 and has become an indicator of the high severity burn sites in 2004. *Solidago* spp. (goldenrod) and *Geranium richardsonii* (Richardson's geranium) have decreased in importance as indicator species from 2000 to 2004. Indicator species in handlines varied between 2000 and 2004 and were not significant in either year; this is likely due to a lack of species abundance and diversity. Drop-point transects remain dominated by exotic and native weedy species such as *T. officinale* and *Erigeron* spp. (fleabane). Although not an indicator in 2000, the exotic *P. pratensis* has become the primary indicator of drop-point transects. Both *Agropyron* spp. and *B. inermis* have dropped in importance from 2000 to 2004.

2000	Plant	Burn	Handline	Drop-point	p-value
	<i>Populus tremuloides</i>	67	1	3	0.001
	<i>Carex</i> spp.	52	12	17	0.042
	<i>Solidago</i> spp.	35	0	3	0.113
	<i>Achillea millefolium</i>	32	4	3	0.156
	<i>Fragaria virginiana</i>	29	0	0	0.119
	<i>Geranium richardsonii</i>	29	0	0	0.119
	<i>Carex</i> spp.	52	12	17	0.042
	<i>Festuca ovina</i>	0	11	2	0.575
	<i>Bromus ciliatus</i>	0	6	5	0.866
	<i>Taraxacum officinale</i>	0	0	54	0.014
	<i>Agropyron</i> spp.	1	1	47	0.063
	<i>Bromus inermis</i>	0	0	38	0.059
	<i>Erigeron</i> spp.	3	0	35	0.135
2004	Plant Species	Burn	Handline	Drop-point	p-value
	<i>Carex</i> spp.	76	6	11	0.001
	<i>Populus tremuloides</i>	73	6	6	0.003
	<i>Achillea millefolium</i>	65	1	1	0.007
	<i>Fragaria virginiana</i>	57	0	0	0.002
	<i>Bromus tectorum</i>	43	0	0	0.014
	<i>Pseudostellaria jamesiana</i>	1	21	0	0.395
	<i>Poa fendleriana</i>	6	16	18	0.844
	<i>Mahonia repens</i>	4	16	0	0.397
	<i>Robinia neomexicana</i>	7	12	0	0.465
	<i>Poa pratensis</i>	0	2	52	0.017
	<i>Elymus elymoides</i>	13	1	46	0.066
	<i>Taraxacum officinale</i>	0	0	45	0.019
	<i>Erigeron</i> spp.	11	0	37	0.157

Table 2. 2000 and 2004 Indicator Species Analysis Results sorted by disturbance type. *Carex* spp. was predominantly *Carex bolanderi*, with some *C. rossii*, and *C. occidentalis*; *Erigeron* spp. consisted of *E. divergens*, *flagellaris*, *formosissimus*, and *speciosus*, and *Solidago* spp. consisted of *S. canadensis*, *S. multiradiata*, *S. nana*, *S. missouriensis*, *S. velutina*, and *Oreochrysum parryi*. Indicator values and significant p-values are in bold.

Ordination revealed a clear difference in floristic composition between the three disturbance types (Figure 7). This visual difference was verified by the ANOSIM procedure of Clark (global $R=0.274$; $p<0.001$). Ordination also revealed that the difference between the floristic composition of 2000 vs. 2001, 2002, and 2003 continued in 2004 (Figure 8). This result was also verified by the ANOSIM procedure, which found significant differences between floristic composition between 2000 and 2004 (global $R=0.12$; $p=0.01$).

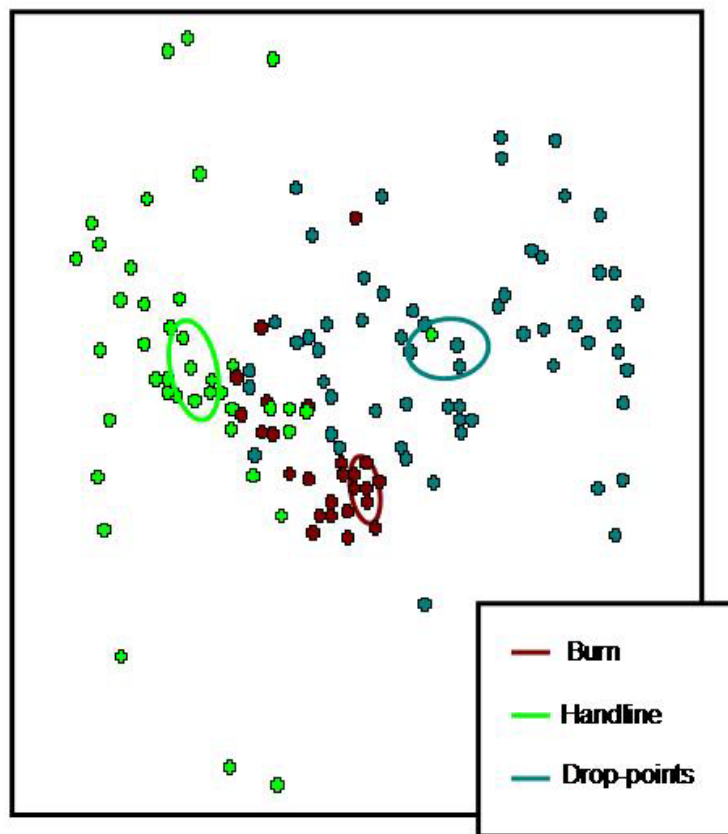
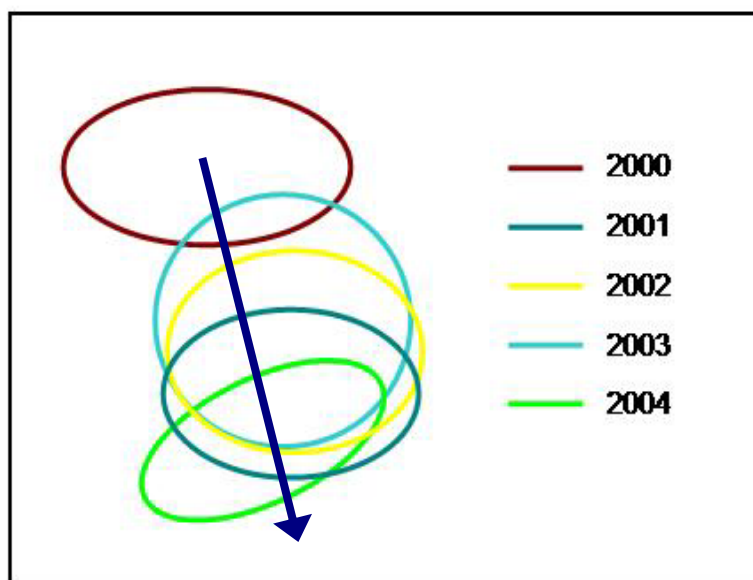


Figure 7. Non-metric Multidimensional Scaling ordination reveals a clear separation in species composition and abundance between the disturbance types of Burn, Handline, and Drop-points on the Outlet Fire, North Rim, GRCA. This ordination represents all years of data combined.

Figure 8. Results from Non-metric Multidimensional Scaling ordination by year reveal a separation in species composition and abundance between transects over time. This ordination represents all three disturbance types combined. The arrow shows the direction of the change from 2000 to 2004.



Results from ANOSIM reveal important differences between 2000 and 2004 vegetation composition and abundance in all three disturbance types (Table 3). Of particular interest is the fact that Handline transects in 2000 were significantly different from Drop-point and Burn transects in 2000 and the significant difference is maintained in 2004. There was no significant difference between Handline transects in 2000 and 2004, suggesting little to no recovery has taken place. Also of interest is the fact that burn transects are significantly different between 2000 and 2004. This is not surprising as following disturbance events such as fire, many plant species sprout from underground rhizomes and tubers, windborne seed arrives from surrounding areas, and seedbanks of early successional species spike in abundance and diversity then retreat back into the soil seedbank.

	2000 Burn	2000 Handline	2000 Drop-point	2004 Burn	2004 Handline	2004 Drop-point
2000 Burn						
2000 Handline	0.01					
2000 Drop-point	2.18	0.03				
2004 Burn	0.01	0.01	0.03			
2004 Handline	2.32	0.18	0.05	0.06		
2004 Drop-point	0.32	<0.01	1.98	0.28	0.02	

Table 3. ANOSIM p-values comparing 2000, 2004, and the three disturbance types. Significant differences are in bold type and highlighted in yellow.

Conclusions and Recommendations

Because drop-point transects are roadside pullouts and used by Park visitors, it is difficult to determine if the ruderal vegetation still dominant in these locations is a direct result of fire-fighting activity or simply a factor of the continued disturbance from visitor use. It is interesting that, similar to burn transects, a spike in both species richness and diversity followed by a decreasing trend is observed. This pattern follows well known disturbance patterns and implies a disturbance event in 2000 did occur. Perhaps the continuation of these ruderal species is perpetuated by continued disturbance from visitors. This hypothesis can not be tested without an enclosure experiment, since no pre-existing data are available and all drop points are located in areas of easy visitor access.

It is clear that handline transects have experienced little recovery even after the passing of 5 years. Not only is species diversity significantly lower than the other disturbance types, but species richness in these areas is also significantly lower. Because handline creation involves scraping down to mineral soil, it can be presumed that even with contouring the soil surface and the replacement of duff, this is not enough site preparation to allow natural regeneration, at least in the short term. This activity should be investigated and alternate methods of rehabilitation determined and employed in the future.

Following an initial post-fire ruderal vegetation pulse, diversity in the post-burn transects is steadily decreasing and becoming more homogeneous. The high severity burn transects are now dominated by *Carex bolanderi* and *Populus tremuloides* re-sprouts. While it is positive that areas of high severity disturbance were not infested with exotic species, the lack of species diversity, and hence habitat diversity in these areas is not a benefit to many species of wildlife. Vast expanses of high severity burn are therefore not a preferred management goal.

As many of the transect locations are near roadsides and visitor access, it is recommended that the current large nail markers be replaced with more permanent rebar stakes and metal tags stating "property of US government; do not remove". Because of difficulty with previous GPS coordinates and sometimes less-than-clear directions, Appendix 2 updates these items.

This study of five years of post-fire vegetation change brought to light the need to further investigate the effects of the fire on vegetation recovery. In response, the study was expanded in 2004 to include an additional 130 plots throughout the burn area (refer to a separate report on this study currently in preparation). It is important to our understanding of fire and vegetation recovery to investigate not only a larger area of the burn (outside of just the Bright Angel Creek drainage), but to also include areas of high, moderate, and low severity fire, as well as nearby unburned forests and meadows for comparison. This was accomplished with the additional 130 plots sampled in 2004; no additional plots were placed in areas of fire-fighting activity.

The additional 130 plots of 2004 differ from the line-intercept transects of the original study in that the relevé method was employed. This is a well known and accepted method of rapid assessment which allowed for a greater amount of data (including slope, aspect, canopy cover, and recorder notes) to be collected in a relatively short period of time. Continued monitoring of the 29 transects and 130 relevé plots are essential for the understanding of post-fire recovery in high elevation forests of Arizona. Monitoring these transects is also important in relation to future fire-suppression activities in the Park and will provide locations of exotic species infestations for control or eradication measures. If funding and time permit, we recommend that additional plots be placed in areas of fire-fighting activity (on this or other, more recent fires) and that exclosures be constructed in drop point areas following fire-fighter use to aid in our understanding of the effects of fire-fighting activities vs. visitor use.

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Appendix One

List of all plants found on 29 transects
of the Outlet Fire from 2000-2004

Appendix Two

Updated directions to transects and UTM coordinates

Appendix Three

Select photo comparisons from 2001 and 2004