POST-GRAZING CHANGES OF VEGETATION IN BIG BEND NATIONAL PARK, TEXAS: A 50-YEAR PERSPECTIVE

DANIEL J. LEAVITT,* ALLISON F. LEAVITT, AND CHRISTOPHER M. RITZI

Department of Wildlife and Fisheries Science, Texas A&M University, College Station, TX 77843 (DJL)
Raven Environmental Services, 6 Oak Bend Drive, Huntsville, TX 77320 (AFL)
Department of Biology, Sul Ross State University, Alpine, TX 79832 (CMR)
**Correspondent: dlea886@tamu.edu*

ABSTRACT—This research compared surveys of vegetation that were conducted in Big Bend National Park, Brewster County, Texas, during 1955–1960 and 1968–1969 with data collected in 2005 and 2006. Comparisons were based on percentages of cover and flora at five study sites. Results suggest some increases and decreases in certain types of vegetative cover since creation of the park, although no trend was consistent across elevations and years. Sites at lowest and highest elevations had significant increases in shrubs. Except for one, all sites had significant differences in total cover. Some species had changed in overall abundance. Lehmann lovegrass (*Eragrostis lehmanniana*) was becoming a dominant grass in foothills of the Chisos Mountains and surrounding Chihuahuan Desert. In contrast, leatherstem (*Jatropha dioica*), fragrant sumac (*Rhus trilobata*), tarbush (*Flourensia cernua*), four-wing saltbush (*Atriplex canescens*), desert hackberry (*Celtis pallida*), and Mexican mock vervain (*Glandularia bipinnatifida*) had disappeared from some, or all, locations where they were recorded previously.

RESUMEN—Esta investigación compara inventarios de vegetación que fueron realizados en el parque nacional Big Bend, condado de Brewster, Texas, durante 1955–1960 y 1968–1969 con información colectada en 2005 y 2006. Las comparaciones se basaron en porcentajes de cobertura y flora en cinco sitios. Los resultados sugieren algunos incrementos y decrementos de ciertos tipos de cobertura vegetal desde la creación del parque, aunque ninguna tendencia fue consistente entre alturas y años. Los sitios más bajos y más altos tuvieron incrementos significativos de arbustos. A excepción de uno, todos los sitios mostraron diferencias significativas en cobertura total, y algunas especies cambiaron en abundancia total. *Eragrostis lehmanniana* estuvo convirtiéndose en un pasto dominante en las laderas de las montanas Chisos y en el contiguo desierto chihuahueño. En contraste, *Jatropha dioica*, *Rhus trilobata*, *Flourensia cernua*, *Atriplex canescens*, *Celtis palida* y *Glandularia bipinnatifida* han desaparecido de algunos o todos los sitios donde habían sido reportado anteriormente.

In 1942, the state of Texas purchased many of the cattle and goat ranches that comprised much of southern Brewster County, and gave them to the federal government for creation of the first national park in Texas (Maxwell, 1985). The National Park Service manages resources with the aesthetic interests of visitors and concerns for ecological sensitivity as their highest priorities (Sellers, 1997). Thus, unlike many lands administered by the federal government, the National Park Service allows little use and manipulation of resources; this is intended to ensure an unimpaired landscape that protects ecological systems and biological diversity (Sellers, 1997). With establishment of Big Bend National Park in 1944, a unique opportunity arose in which comparisons of land-management practices could be observed in the Trans-Pecos ecoregion of Texas.

The existence of Big Bend National Park allows investigators to study effects of grazing years after it has ceased. This is of particular interest because much of the Trans-Pecos in western Texas is owned privately and either has been or is being grazed (Powell, 1998). Further, in this ecoregion, impacts have been documented on vegetative communities as a result of grazing (Wondzell, 1984).

In 1955, Degenhardt (1960, 1966) began surveys of lizards and associated vegetation in Big Bend National Park. The initial work, was part of an ecological survey of the Big Bend area conducted by the Texas Game and Fish

Commission (Wallmo et al., 1957). Among objectives of that survey was the need to determine successional trends of plant and animal communities (Wallmo et al., 1957; Degenhardt, 1960). As such, various investigators studied the flora and fauna of this biologically diverse region. Surveys of vegetation conducted by Degenhardt were continued through 1960 and repeated in 1968 and 1969 (Degenhardt, 1977).

The work by Degenhardt coincided with the early years of conservation and preservation in Big Bend National Park. Prior to his surveys, the area was subjected to a substantial drought that lasted for much of the 1950s (Degenhardt, 1960). Grazing ended in Big Bend National Park in 1947, and there have been periods of above and below average rainfall. In 2005 and 2006, we resampled study sites assessed by Degenhardt; thus, providing an opportunity to document changes in vegetation over a 50-year period. We expected to detect an increase in cover by shrubs. It also was postulated that an increase in diversity of plants would occur after cessation of grazing.

Materials and Methods—Big Bend National Park is in western Texas on the Rio Grande adjacent to the Mexican states of Coahuila and Chihuahua. Elevations range from 550 m along the Rio Grande to 2,385 m on Emory Peak in the Chisos Mountains; most of the park is below 1,000 m. Vegetation of the Big Bend region has been described by several investigators (Warnock, 1970; Powell, 1998, 2000; Wauer and Fleming, 2002; Powell and Weedin, 2004).

Study sites were along a southwest-northeast line including the Chisos Mountains and surrounding Chihuahuan Desert. Study areas were adjacent to roadsides, and most of the original rebar posts used to delineate study sites remained. The site at Tornillo Flat was 1.62 ha in size, and sites at Grapevine Hills, Burnham Flat, Green Gulch 1, and Green Gulch 2 were 0.4 ha in size. Different-sized sites were needed for studies of lizards, but that did not affect our methods. Sites were on areas that operated cattle or goat ranches prior to 1944.

The lowest-elevation site (853 m), Tornillo Flat, was the least vegetated. Soil was mostly sand with a few small rocky outcrops. The site at Grapevine Hills was at 945 m elevation at the northern base of the Grapevine Hills, a large igneous intrusion. This is the most physiographically diverse site. Soils were rocky except for a few patches of clay. The site at Burnham Flat was on a large bajada at 1,036 m elevation between the Chisos Mountains and Grapevine Hills. Soils were alluvial gravel and there was a dry creek in the northwestern corner of this site. Green Gulch 1 site was in a transitional vegetative zone at 1,280 m elevation, with the xeric desert floor downslope and mesic woodland upslope. Green Gulch is the largest drainage leaving the Chisos Mountains to the north. Upper reaches were dense forests of pinyon (*Pinus*), oak (*Quercus*), and juniper (*Juniperus*). The National Park Service conducted a prescribed burn in April 2005 in this section of Green Gulch, burning >50% of the vegetation. This fire affected our data collected in 2005 and 2006. Green Gulch 2 was the highest-elevation site (1,417 m) and it was centered between two deeply eroded washes on a small mesa.

During 28 August–14 September 2005 and 26 August–20 September 2006, line transects were assessed using the methods of Degenhardt (1966, 1977). At each site, five 30.5-m line transects (except at Tornillo Flat where 61-m lines were used) were placed in the same locations as previous line transects. The line-intercept method was used to determine percentage cover. Vegetation overhanging or shadowed by the line was recorded. Cover was recorded as a length measurement on the line to species level and later categorized as shrub or grasses and forbs as used by Degenhardt (1960, 1966, 1977). Overlapping values for cover occurred between the categories of shrubs and grasses and forbs. To determine percentage cover for each site, annual measurements from the five lines were averaged.

In addition to line transects, floristic inventories were conducted irregularly, but year-round in 2005 and 2006, to account for species that may have been overlooked because of seasonality. Plants were identified using Correll and Johnston (1970), Powell (1998, 2000), and Powell and Weedin (2004); taxonomy followed Jones et al. (1997). Photographic points established in the 1950s (Degenhardt, 1960) were re-photographed in 2006 and these were presented by Leavitt (2007). These were used for visual comparison of vegetation over time.

We had access to averages for sites in 1957–1969 from Degenhardt (1977); i.e., for these years, $n = 1$ at each site. We collected data at five transects in each site in 2005 and 2006. Comparisons among years were made using replicated data in 2005 and 2006 to estimate an error term (e.g., Steel et al., 1996). For each site, values for cover of grasses and forbs, shrubs, and all vegetation for the years were compared with a repeated-measures F-test in a mixed-model analysis of variance (transects were a random effect and years were a fixed effect) with a Bonferroni-style, LSD, multiple-comparisons test for post hoc analyses. Comparisons involving data from Degenhardt, therefore, had low power because of limited samples. Diversity of species, based on percentage cover of study areas in 2005 and 2006, was estimated with the Shannon-Weaver diversity index (Zar, 1999). A t-test was used to compare Shannon-Weaver diversity indices between 2005 and 2006 (Zar, 1999). Regression analysis was used to model diversity, density, and evenness, each as functions of elevation.

Results—Photographs from 1960 and 2006 illustrated some of the changes in vegetation that have taken place; these photographs were included in Leavitt (2007). There was no consistent trend in cover of grasses and forbs on the study sites (Table 1). We measured no

Table 1—Percentage cover at five study sites in Big Bend National Park, Brewster County, Texas, in 1958, 1968, 1969, 2005, and 2006. Data for 1957, 1958, 1968, 1969 are from Degenhardt (1977); $n = 1$ for 1958, 1968, 1969; $n = 5$ for 2005 and 2006. Means within a study area followed by the same lowercase letter are not significantly different ($P > 0.05$, protected LSD).

		Year						
Vegetation	Study site	1957	1958	1968	1969	2005	2006	$P > F$
Grasses and forbs								
	Tornillo Flat	—	0.1a	1.1a	1.7a	5.3a	3.2a	0.266
	Grapevine Hills	—	—	16.2a	16.1a	29.2a	26.8a	0.144
	Burnham Flat	—	19.0a	18.6a	18.7a	9.4a	8.0a	0.052
	Green Gulch 1	—	22.0b	62.2a	54.0a	21.5b	22.7b	0.011
	Green Gulch 2	—	23.0b	43.3b	32.7b	77.4a	48.2b	0.008
Shrub cover								
	Tornillo Flat	—	2.0b	4.6b	6.7b	12.6a	8.5b	0.008
	Grapevine Hills	—	—	25.0a	26.9a	42.8a	34.2a	0.503
	Burnham Flat	—	9.0a	19.8a	21.3a	60.2a	45.4a	0.066
	Green Gulch 1	—	4.0a	10.8a	20.7a	42.4a	42.7a	0.075
	Green Gulch 2	—	5.0b	25.7b	15.5b	77.5a	53.8a	0.041
Total cover								
	Tornillo Flat	4.0b	2.1b	5.7ab	8.5ab	15.6a	10.0ab	0.012
	Grapevine Hills	17.0d	—	41.2c	43.0bc	56.9a	53.2ab	0.004
	Burnham Flat	32.0a	28.0a	38.5a	40.0a	57.5a	44.9a	0.178
	Green Gulch 1	23.0c	26.0c	73.0a	74.7a	71.1a	56.0b	<0.001
	Green Gulch 2	21.0e	28.0de	69.0bc	48.2cd	91.6a	78.8b	0.002

significant change over time in cover of grasses and forbs at lower-elevation sites (Tornillo Flat, Grapevine Hills), while there was an insignificant decreasing trend ($P = 0.052$) at the mid-elevation site (Burnham Flat). The two upper-elevation sites were significantly different between years for cover of grasses and forbs (Green Gulch 1, $P = 0.011$; Green Gulch 2, $P = 0.008$). However, trends were not similar between these two sites; Green Gulch 1 demonstrated a parabolic trend and Green Gulch 2 exhibited a consistent increase (Table 1).

There was no apparent trend in cover of shrubs among sites (Table 1). A significant difference in shrubs was present at the lowest-elevation (Tornillo Flat, $P = 0.008$) and highest-elevation sites (Green Gulch 2, $P = 0.041$). Burnham Flat ($P = 0.066$) and Green Gulch 1 ($P = 0.075$) approached significance in increasing cover by shrubs. Further, cover by shrubs on the site at Grapevine Hills did not change significantly ($P = 0.503$). All sites, except Burnham Flat ($P = 0.178$), had significant differences in total cover (Table 1). However, this was not observed at all sites.

Numbers of species on line transects in 2005 and 2006 were 16–43 species, although number of species identified during each survey was 49–83 (Table 2). Number of species encountered on transects and during floristic inventories revealed a strong relationship with increasing elevation ($r^2 = 0.815$, $P < 0.001$; and $r^2 = 0.958$, $P <$

Table 2—Diversity, evenness, and number of species of plants on transect lines for 2005 and 2006 at five study sites in Big Bend National Park, Brewster County, Texas.

	Tornillo Flat		Grapevine Hills		Burnham Flat		Green Gulch 1		Green Gulch 2	
Biotic indices	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Diversity (H')	1.0	1.0	0.8	0.9	1.1	1.2	1.2	1.3	1.3	1.2
Evenness (J')	0.8	0.8	0.7	0.6	0.8	0.8	0.8	0.8	0.8	0.7
Number of species (k)	22	16	21	19	31	33	33	43	40	40

TABLE 3—Species encountered on line transects and their percentage of total vegetative cover in Big Bend National Park, Brewster County, Texas, during 2005 and 2006 (a zero indicates presence historically or at low density).

	Tornillo Flats		Grapevine Hills		Burnham Flat		Green Gulch 1		Green Gulch 2	
Vegetation	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Shrubs										
Agave lechuguilla	12.2	10.7	10.8	10.3	11.1	13.5	1.8	0.2	0	0
Yucca elata	0	2.0	—	—	—	—	—	—	—	—
Yucca torreyi	0	0	—	—	2.2	0	0	0	0	0
Rhus microphylla	—	—	0	0	0.8	1.6	1.7	1.6	2.3	2.4
Rhus virens	—	—	0	0	—	—	—	—	<0.1	0
Artemisia ludoviciana	—	—	—	—	—	—	—	—	<0.1	0
Chrysactinia mexicana	—	—	0	0	—	—	0.4	0	0.1	0
Flourensia cernua	—	—	—	—	7.0	8.7	—	—	0	0
Gymnosperma glutinosum	—	—	0	0	19.7	0	1.4	0.3	5.0	0
Gutierrezia sarothrae	0	0	0	0	3.1	0.2	1.1	0.8	1.1	0.2
Jefea brevifolia	—	—	0	0	0.9	1.5	0	0	—	—
Parthenium incanum	—	—	7.6	4.2	4.0	13.6	34.9	24.8	0	0
Porophyllum scoparium	3.8	0	—	—	—	—	—	—	0	0
Viguieria stenoloba	0	0	4.9	4.1	0.6	2.7	5.8	4.9	7.2	4.9
Berberis trifoliolata	—	—	—	—	—	—	0	0	0.3	1.0
Tiquilia canescens	—	—	0	0	0	0	0	0.2	—	—
Tiquilia greggii	0	0	0.7	1.1	—	—	—	—	—	—
Tiquilia hispidissima	0.3	0	0	0	—	—	—	—	—	—
Echinocereus enneacanthus	0	0	0	<0.1	0.9	0.6	0	0	0	0
Echinocereus viridiflorus	—	—	0	0	—	—	0	0.1	0.17	0.2
Mammilaria heyderi	—	—	0	0	0.1	0	0	0.1	0	0
Opuntia camanchica	0	0	3.0	4.9	0.6	0	0	0	0	0.6
Opuntia engelmannii	0	0	4.1	2.5	4.7	4.7	4.5	0.8	3.69	4.4
Opuntia leptocaulis	9.6	10.3	0	0	0	0	—	—	—	—
Opuntia parva	0	0	0	0	2.8	5.4	0	0	0	0
Opuntia schottii	0.2	0	—	—	0	0	—	—	—	—
Juniperus pinchotii	—	—	—	—	—	—	—	—	0.9	4.9
Ephedra aspera	0	0	0	0	0	0.2	0	0	4.3	2.1
Acacia angustissima	—	—	0	0	—	—	4.5	10.9	4.6	1.8
Acacia constricta	0	0	0	0	0.2	1.0	1.3	3.8	5.7	6.3
Acacia greggii	0	0	0	0	0	0.2	1.2	3.1	0.6	0.1
Acacia neovernicosa	2.4	2.9	—	—	—	—	—	—	—	—
Calliandra conferta	—	—	—	—	—	—	—	—	0.3	0.4
Dalea formosa	—	—	0	0	1.3	0.5	0	0.3	4.5	4.9
Mimosa emoryana	—	—	2.0	3.4	—	—	—	—	—	—
Prosopis glandulosa	0	0.3	2.2	1.5	3.6	10.8	4.4	4.7	0	0
Foquieria splendens	13.4	10.9	2.9	1.4	1.2	0.2	0	0	0	0
Krameria erecta	0	0	0	0	0	0	1.1	2.1	2.0	3.3
Krameria grayi	10.8	13.3	—	—	—	—	0	0	—	—
Dasylirion leiophyllum	—	—	—	—	0	0	0	2.2	11.1	9.2
Forestiera angustifolia	—	—	0	0	0	0	—	—	1.1	2.0
Menodora scabra	0.1	0	0	0	0.2	0.2	—	—	—	—
Leucophyllum frutescens	—	—	1.4	0.4	3.3	1.5	0	0	—	—
Lycium puberulum	—	—	—	—	—	—	0.4	1.9	0	0
Aloysia gratissima	—	—	—	—	—	—	0.8	0.8	0	0

Table 3—Continued.

Vegetation	Tornillo Flats 2005	Tornillo Flats 2006	Grapevine Hills 2005	Grapevine Hills 2006	Burnham Flat 2005	Burnham Flat 2006	Green Gulch 1 2005	Green Gulch 1 2006	Green Gulch 2 2005	Green Gulch 2 2006
Aloysia wrightii	—	—	0	0	2.9	1.7	0	0	—	—
Larrea tridentata	21.4	22.5	22.2	21.4	16.1	15.8	1.8	1.5	—	—
Unidentified shrub	—	—	—	—	0.8	0	—	—	—	—
Grasses and forbs										
Dychoriste linearis	—	—	—	—	—	—	—	—	0	0.2
Telosiphonia macrosiphon	—	—	0	0	—	—	0	0.4	1.3	1.5
Bahia absinthifolia	0.3	0	0.2	0	0	0.3	0.7	0.2	0	0
Erigeron modestus	—	—	—	—	—	—	—	—	14.7	0
Melampodium leucanthum	—	—	0	0	0.6	0	0.3	0	0.1	0
Porophyllum scoparium	0	0	—	—	—	—	—	—	0.1	0
Psilostrophe tagetina	—	—	0.6	0	1.2	0	0	0	0	0
Thelesperma megapotamicum	0	0	—	—	0	0.2	0	0	0	0.1
Thymophylla acerosa	0	0	0.3	0	0.7	0.9	0	0	0	0
Thymophylla pentachaeta	1.0	0	0	0	—	—	0	0	0	0
Nerisyrenia camporum	4.8	0	0	0	—	—	—	—	—	—
Drymaria pachyphyla	0	0.2	—	—	—	—	—	—	—	—
Chamaesyce cinerascens	0	5.7	0	0	0.2	0.3	<0.1	0.3	0.1	0.4
Chamaesyce serpyllifolia	0	0	0	0	0	0.2	—	—	—	—
Chamaesyce setiloba	—	—	0	1.4	—	—	—	—	—	—
Croton pottsii	—	—	0.4	0	0	0	1.3	1.8	3.0	1.5
Desmanthus velutinus	—	—	—	—	—	—	0	0.9	—	—
Abutilon fruticosum	—	—	0	0	—	—	1.0	1.1	0	0
Abutilon parvulum	—	—	—	—	—	—	0	0	2.2	0
Hibiscus coulteri	—	—	0	0.2	0	0	0	0	0	0
Hibiscus denudatus	—	—	0.4	0.8	—	—	0	0	0	0.2
Sida abutifolia	—	—	0	0	—	—	0	0.7	0	0.1
Acleisanthes longiflora	—	—	—	—	0.4	0	1.29	0.5	0	0.1
Allionia incarnata	0.1	9.6	0	0	—	—	—	—	—	—
Boerhavia intermedia	—	—	0.1	0.1	—	—	—	—	—	—
Zephyranthes longifolia	0	1.9	—	—	—	—	—	—	—	—
Aristida purpurea	0.9	0	0.2	0.8	0	0	2.8	5.4	4.6	6.6
Bothriochloa barbinoidis	0	0	—	—	—	—	0	0.8	—	—
Bouteloua aristidoides	1.0	0	—	—	—	—	—	—	—	—
Bouteloua curtipendula	—	—	0	0	0	0.8	6.5	8.8	1.6	1.5
Bouteloua eriopoda	—	—	—	—	0	0	3.4	4.1	5.0	6.7
Bouteloua gracilis	—	—	0	0	—	—	—	—	0.1	0
Bouteloua hirsuta	0	0	0	0	—	—	0	0	0	0.6
Bouteloua ramosa	—	—	35.9	41.7	8.2	9.8	0	0	—	—
Bouteloua trifida	0.4	6.1	0.1	0	0	0.4	0.3	1.6	—	—
Cathestecum erectum	0	0	0	0	—	—	0.1	0.2	—	—
Digitaria californica	4.1	1.7	0	0	0	<0.1	—	—	—	—
Digitaria cognatum	—	—	0	0	—	—	0.5	<0.1	0.7	0
Eragrostis intermedia	—	—	—	—	—	—	2.9	0.6	0	0

TABLE 3—Continued.

Vegetation	Tornillo Flats 2005	Tornillo Flats 2006	Grapevine Hills 2005	Grapevine Hills 2006	Burnham Flat 2005	Burnham Flat 2006	Green Gulch 1 2005	Green Gulch 1 2006	Green Gulch 2 2005	Green Gulch 2 2006
Eragrostis lehmanniana	9.3	0.1	—	—	0	1.5	—	—	16.2	28.0
Eragrostis pectinacea	—	—	—	—	—	—	0	0.6	0	1.8
Erioneuron pilosum	—	—	—	—	—	—	0	0	0	0.2
Leptochloa dubia	—	—	—	—	—	—	0	0	0	<0.1
Lycurus phleoides	—	—	—	—	—	—	—	—	0.5	0
Panicum hallii	0.2	0	—	—	—	—	0	0.7	0	0.1
Pleuraphis mutica	3.9	1.7	—	—	—	—	0	0.2	—	—
Setaria leucopila	—	—	—	—	0	0.3	0	0.7	0	0.3
Sporobolus cryptandrus	0	0	—	—	—	—	0.5	0	0.2	0
Tridens muticus	—	—	0	0	0	0	7.7	4.6	0	0.3
Eriogonum wrightii	—	—	—	—	—	—	0	0	0.2	0.3
Polygala alba	—	—	—	—	0.7	0.3	0	0	0.3	0
Polygala scoparioides	—	—	0	0	0.1	0.3	0	0	0	0
Astrolepis sinuata	—	—	—	—	—	—	0	0	<0.1	0.2
Ziziphus obtusifolia	0	0	0	0	0	0	2.2	0	0	0
Houstonia acerosa	—	—	—	—	—	—	0	0.6	0.3	0.4
Stenaria nigricans	—	—	—	—	—	—	—	—	0.1	0
Chamaesaracha sordida	—	—	—	—	—	—	1.5	0.6	—	—
Tetraclea coulteri	0	0	0	0	0	0	0	0	0	0.2

0.001). Shannon-Weaver diversity indices for 2005 and 2006 were 0.82–1.26 for each site. A slight, but significant increase in diversity also was noted with increasing elevation ($r^2 = 0.544$, $P = 0.015$). Evenness of sites in 2005 and 2006 showed no trend in association with elevation ($r^2 = 0.017$, $P = 0.722$). Diversity of sites were not significantly different between 2005 and 2006 (Tornillo Flat: $t = 0.357$, $P > 0.05$; Grapevine Hills: $t = 0.299$, $P > 0.05$; Burnham Flat: $t = 0.419$, $P > 0.05$; Green Gulch 1: $t = 0.895$, $P > 0.05$; Green Gulch 2: $t = 0.808$, $P > 0.05$).

In 2005 and 2006, a variety of species were not recorded at sites where they had been observed in previous years (Table 3). Fourwing saltbush (*Atriplex canescens*) was not recorded on Tornillo Flat, Grapevine Hills, or Burnham Flat, where it had been recorded in the late 1960s. Leatherstem (*Jatropha dioica*) was not encountered on Grapevine Hills, Burnham Flat, Green Gulch 1, or Green Gulch 2, where it had been recorded in the 1950s and 1960s. Fragrant sumac (*Rhus trilobata*) has not been observed on Grapevine Hills or Green Gulch 2 since it was observed in the 1960s. Common dogweed (*Dyssodia pentachaeta*), desert hackberry (*Celtis pallida*), and Mexican mock vervain (*Glandularia bipinnatifida*) also were not recorded on Green Gulch 1 or Green Gulch 2 in 2005 or 2006. Finally, tarbush (*Flourensia cernua*) was no longer present on Green Gulch 2, and tree cholla (*Opuntia imbricata*) has disappeared from Green Gulch 1.

In 2005 and 2006, least vegetative cover was at Tornillo Flat. Composition on this site was dominated by creosotebush (*Larrea tridentata*), ocotillo (*Foquieria splendens*), lechuguilla (*Agave lechuguilla*), and white ratany (*Krameria grayi*; Table 3). Grapevine Hills and Burnham Flat had intermediate percentages of vegetative cover, and in 2005 and 2006, communities were comprised of chino grama (*Bouteloua ramosa*), creosotebush, and lechuguilla. In 2005, 19.7% of Burnham Flat was covered in gumhead (*Gymnosperma glutinosum*); however, in 2006, none was recorded but many dead individuals remained from the previous year. Green Gulch 1 had a high percentage of vegetative cover, which was composed of mariola (*Parthenium incanum*), slim tridens (*Tridens muticus*), sideoats grama (*Bouteloua curtipendula*), and whiteball acacia (*Acacia angustissima*). Greatest percentages for total cover in 2005 and 2006 were on Green Gulch

2, which was comprised of Lehmann lovegrass (*Eragrostis lehmanniana*), sotol (*Dasylirion leiophyllum*), whitethorn acacia (*Acacia constricta*), and black grama (*Bouteloua eriopoda*).

Discussion—The most obvious change on sites in Big Bend National Park was a general increase in total cover since the survey began (with the exception of the site at Grapevine Hills). It is likely that this may be due in part to reduced grazing; however, there is no baseline of pre-grazing plant cover for comparison. Many abiotic and biotic influences affect structure of desert grasslands, including rainfall, soil, fire, and herbivory (Burgess, 1995; Brown et al., 1997; Van Auken, 2000). Grazing had a role in shaping structure of this plant community. However, suppression of fire has had an effect as well. Fire management has not been consistent since establishment of Big Bend National Park (Camp et al., 2006); therefore, this factor must be included when interpreting changes. Both grazing and fire may have been long-term contributors to current soil conditions; thus, affecting vegetation. Additionally, factors such as global change in climate and the southern oscillation index (Cayan and Webb, 1992; Swetnam and Betancourt, 1998) can impact moisture regimes. Thus, we are not capable of reporting the culprit of changes in the plant community and offer the aforementioned factors as potential hypotheses.

Total cover, recorded on four of the five sites was significantly different (with the exception of Burnham Flat) and trending upward since the first years of surveys. However, trends in cover of grasses and forbs and shrubs were not uniform. Specifically, Green Gulch 2 demonstrated an overall increase in both types of cover since the first surveys. We expected similar conditions on Green Gulch 1; however, trends were not the same. One potential reason for this was the recent prescribed burn.

Increases in shrubs have been recorded in Sonoran and Chihuahuan desert grasslands by various authors, many of them suggesting the increase was a result of stress caused by cessation of grazing (Leopold, 1924; McPherson, 1995; Kerley and Whitford, 2000; Van Auken, 2000). However, this theory has been challenged with an alternate hypothesis that wetter winters may result in increased cover by shrubs and that this increase is not a direct result of stress during and after grazing (Brown et al., 1997). Either way, encroachment of shrubs is obvious when compared to the previous survey.

Attention should be paid to the future status of invasive species that recently have become abundant on these study sites. Currently, three study sites have invasive grasses on them, although only two (Tornillo Flat and Green Gulch 2) presently have high enough densities of invasive plants for concern. Because all sites were near roadsides, it is likely that these areas will be at high risk for roadside invasions by plants in the future (Cleland et al., 2004). Concern remains that these invasive plants have the potential to alter natural succession. The most-threatening invasive plants currently are buffle-grass (*Pennisetum ciliare*), King Ranch bluestem (*Bothriochloa ischaemum*), Johnson grass (*Sorghum halepense*), and Lehmann lovegrass. All of these were on the site at Tornillo Flat in 2005 and 2006.

Lehmann lovegrass, not recorded in the 1950s or 1960s, was a dominant species at Green Gulch 2 (reaching 16.2 and 28.0% cover in 2005 and 2006, respectively). Lehmann lovegrass was likely introduced as a forage grass on a ranch adjacent to the park in the 1980s, and has been spreading into the park since. Implications of its advance could prove troublesome. Lehmann lovegrass increases biomass and continuity of fine fuels; thus, increasing potential for fire (Brooks and Pyke, 2001). Of equal concern, is the potential for reduced faunal diversity as a result of the infestation of Lehmann lovegrass (Brooks and Pyke, 2001). Data from Green Gulch 2 demonstrated the greatest cover by invasive plants. However, Tornillo Flat may have the greatest overall potential for replacement of native plants by exotic species. This potential is attributed to many factors, including its location near one of the busiest roads, the number of non-native plants already at the site, the available open space, and the lowest diversity of native plants, all of which are contributing factors for invasions of plants (Cleland et al., 2004).

We thank R. H. Dean, R. S. Jones, T. C. Mullet, J. Sirotnak, J. R. Skiles, D. B. Wester, and J. C. Zech for thoughtful suggestions regarding this project, our manuscript, or both. W. G. Degenhardt allowed use of data and photographs, assisted in planning, began this study, and kept precise notes, and for that we are extremely grateful. DJL thanks M. R. Flippo for providing time to conduct field work and C. G. Montaña for assisting with the resumen. Work was permitted under National Park Service permit BIBE-2005-0044 to DJL.

Literature Cited

Brooks, M. L., and D. A. Pyke. 2001. Invasive plants and fire in the deserts of North America. Pages 1–14 in Proceedings of the invasive species workshop: the role of fire in the control and spread of invasive species (K. E. M. Galley and T. P. Wilson, editors). Tall Timbers Research Station, Tallahassee, Florida.

Brown, J. H., T. J. Valone, and C. G. Curtin. 1997. Reorganization of an arid ecosystem in response to recent climate change. Proceedings of the National Academy of Sciences of the United States of America 94:9729–9733.

Burgess, T. L. 1995. Desert grassland, mixed shrub savanna, shrub steppe, or semidesert scrub? The dilemma of coexisting growth forms. Pages 31–67 in The desert grassland (M. P. McClaren and T. R. Van Devender, editors). University of Arizona Press, Tucson.

Cayan, D. R., and R. H. Webb. 1992. El Niño southern oscillation and streamflow in the western United States. Pages 29–68 in El Niño: historical and paleoclimatic aspects of the southern oscillation (H. F. Diaz and V. Markgraf, editors). Cambridge University Press, Cambridge, United Kingdom.

Cleland, E. E., M. D. Smith, S. J. Andelman, C. Bowles, K. M. Carney, M. C. Horner-Devine, J. M. Drake, S. M. Emery, J. M. Gramling, and D. B. Vandermast. 2004. Invasion in space and time: non-native species richness and relative abundance respond to interannual variation in productivity and diversity. Ecology Letters 7:947–957.

Correll, D. S., and M. C. Johnston. 1970. Manual of the vascular plants of Texas. University of Texas at Dallas, Richardson.

Degenhardt, W. G. 1960. An ecological study of the lizard genera *Holbrookia* and *Cnemidophorus* in the Big Bend National Park, with a checklist of the reptiles and amphibians. Ph.D. dissertation, Texas A&M University, College Station.

Degenhardt, W. G. 1966. A method of counting some diurnal ground lizards of the genera *Holbrookia* and *Cnemidophorus* with results from the Big Bend National Park. American Midland Naturalist 75: 61–100.

Degenhardt, W. G. 1977. A changing environment: documentation of lizards and plants over a decade. Pages 533–555 in Transactions of the symposium on the biological resources of the Chihuahuan Desert region United States and Mexico (R. H. Wauer and D. H. Riskind, editors). United States Department of the Interior, National Park Service Transactions and Proceedings Series 3:1–658.

Jones, S. D., J. K. Wipff, and P. M. Montgomery. 1997. Vascular plants of Texas. University of Texas Press, Austin.

Kerley, G. I. H., and W. G. Whitford. 2000. Impact of grazing and desertification in the Chihuahuan Desert: plant communities, granivores and granivory. American Midland Naturalist 144:78–91.

Leavitt, D. J. 2007. Reassessing a lizard survey in Big Bend National Park, Brewster County, Texas. M.S. thesis, Sul Ross State University, Alpine, Texas.

Leopold, A. 1924. Grass, brush, fire and timber in southern Arizona. Journal of Forestry 22:1–10.

Maxwell, R. A. 1985. Big Bend country. Big Bend Natural History Association, Big Bend National Park, Texas.

McPherson, G. R. 1995. The role of fire in the desert grasslands. Pages 130–151 in The desert grassland (M. P. McClaren and T. R. Van Devender, editors). University of Arizona Press, Tucson.

Powell, A. M. 1998. Trees and shrubs of the Trans-Pecos and adjacent areas. University of Texas Press, Austin.

Powell, A. M. 2000. Grasses of the Trans-Pecos and adjacent areas. Iron Mountain Press, Marathon, Texas.

Powell, A. M., and J. F. Weedin. 2004. Cacti of the Trans-Pecos and adjacent areas. Texas Tech University Press, Lubbock.

Sellers, R. W. 1997. Preserving nature in the national parks. Yale University Press, New Haven, Connecticut.

Steel, R. G. D., J. H. Torrie, and D. A. Dickey. 1996. Principles and procedures of statistics: a biometrical approach. McGraw-Hill, New York.

Swetnam, T. W., and J. L. Betancourt. 1998. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate 11:3128–3147.

Van Auken, O. W. 2000. Shrub invasions of North American semiarid grasslands. Annual Review of Ecology and Systematics 31:197–215.

Warnock, B. H. 1970. Wildflowers of the Big Bend country, Texas. Sul Ross State University, Alpine, Texas.

Wauer, R. H., and C. M. Fleming. 2002. Naturalist's Big Bend. Texas A&M University Press, College Station.

Wondzell, S. M. 1984. Recovery of desert grasslands in Big Bend National Park following 36 years of protection from grazing of domestic livestock. M.S. thesis, New Mexico State University, Las Cruces.

Zar, J. H. 1999. Biostatistical analysis. Prentice Hall, Upper Saddle River, New Jersey.

Submitted 28 March 2008. Accepted 17 October 2009.
Associate Editor was David B. Wester.