Dutchwoman Butte Revisited

Examining paradigms for livestock grazing exclusion

By Jim Sprinkle, Mick Holder, Chas Erickson, Al Medina, Dan Robinett, George Ruyle, Jim Maynard, Sabrina Tuttle, John Hays, Jr., Walt Meyer, Scott Stratton, Alix Rogstad, Kevin Eldredge, Joe Harris, Larry Howery, and Wesley Sprinkle

In 2000, a collaborative range-monitoring program, "Reading the Range," was established with the University of Arizona Cooperative Extension in Gila County, the Gila County Cattle Growers, and the Tonto National Forest with the assistance of the US Department of Agriculture Renewable Resources Extension Act grant program. Funding for Reading the Range has continued with the assistance of the Gila County Board of Supervisors, the Natural Resources Conservation Service (NRCS), and the Tonto Natural Resources Conservation District. This monitoring program uses standardized monitoring techniques to assess rangelands and the information is used to assist in management decisions. The Dutchwoman Allotment was selected as one of 4 ranches in Gila County to participate in the monitoring program. Located on the allotment is a 100-acre isolated landform (Photo 1) supporting relict vegetation, Dutchwoman Butte (DWB). Chas Erickson and Mick Holder, permittees of the Dutchwoman Allotment, suggested that one of the key areas selected for the allotment should be located on DWB (4,844 feet) and be paired with a grazed companion site (4,214 feet) immediately across the canyon (Fig. 1; Photo 2). Over geologic time, it is assumed that DWB separated from the companion site across the canyon.

Photo 1. Dutchwoman Butte, a 100-acre isolated landform protected from livestock grazing, December 2000.

In 2000, Ambos and others[1] published an article in *Rangelands* comparing DWB to a grazed area located 25 miles away. Briefly, they described that DWB had 1) very high soil organic carbon (4.7%); 2) limited snakeweed (present in trace amounts on DWB but not encountered in any transects); 3) much greater diversity (12 species) and canopy cover (35%–40%) of perennial grasses than the grazed

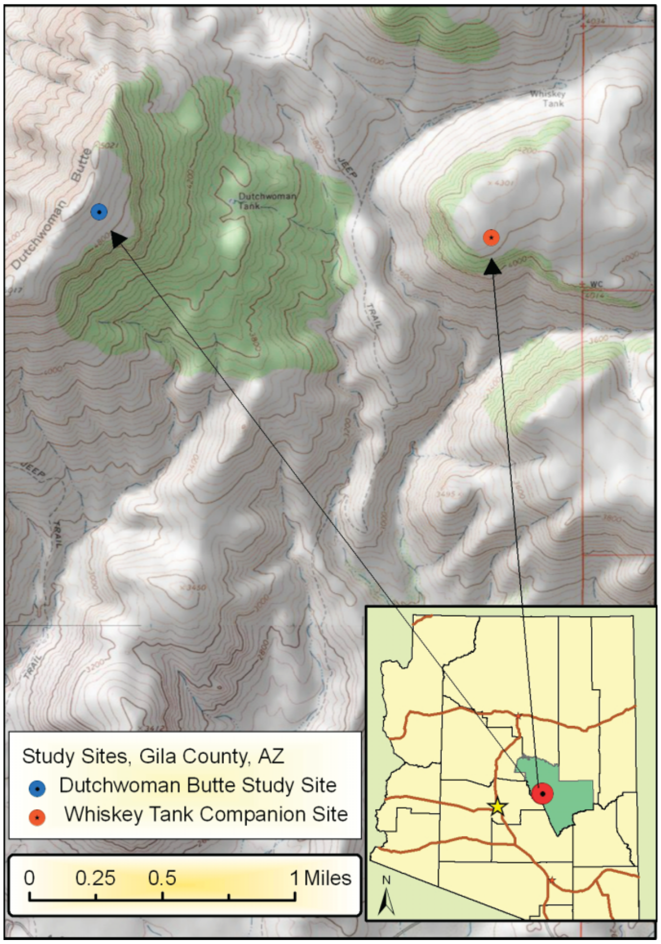

Figure 1. Map of the study sites in Gila County, Arizona.

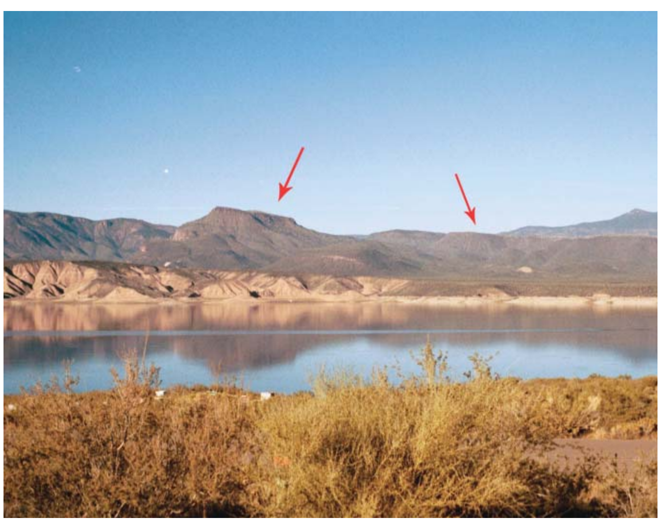

Photo 2. Dutchwoman Butte to the left, grazed Whiskey Tank companion site to the right.

comparison site (2 species; 15.9% canopy cover); and 4) soil bulk density at $0.93\ g \cdot cm^{-3}$ compared to the grazed comparison site at $1.22\ g \cdot cm^{-3}$. They described the grazed comparison site as having compacted soils with poor root development. They further stated that "Dutchwoman Butte offers a valuable comparison area to demonstrate that soils impacted from livestock grazing are not functioning at an optimum level and can be improved." Our desire was to compare DWB to a closely located site as similar as possible on a ranch with a long-term management plan.

Description and History of Dutchwoman Butte

The geology of DWB consists of Precambrian Apache Group with layers or strata of limestone, shale, conglomerate, and quartzite; quartzite (arkose) is dominant at the top of the butte. As reported previously[1], elevations at the top of DWB range from approximately 4,720 feet at lower levels to just over 5,000 feet at the extremity, tilting to the southeast on a 20% slope. The top of the butte has never been grazed by domestic livestock, though deer and bear ascend its heights periodically. No fires have burned on DWB in recent history, but burned juniper stumps occur on the north, northeast, and east sides of the butte.

DWB is located in Major Land Resource Area[2] 38, the Mogollon Transition Area in central Arizona, as described by NRCS. It is within the 16–20 inch precipitation zone (38-2) of this region. The US Forest Service describes the area similarly, as being in the Central Highlands (Transition Zone) between the Colorado Plateau to the north and the Basin and Range to the south. The butte is located at the southern extremity of the Sierra Ancha Mountains just north of Roosevelt Lake in central Gila County, Arizona.

Oral history accounts suggest that the butte was named in honor of a female captive recovered after a military engagement with the Tonto Apache on the slopes of DWB (M. Holder, personal communication related to J. Sprinkle, April 6, 2006). A former military map for the area had designated the mountain as Island Butte because of a creek passing on both sides of a limestone monolith as it merged with the Salt River. The civilian employees accompanying the military expedition requested the name change to honor the survival of the woman captive. The name she was able to impart was Sally Mae but unfortunately the spelling for the nearby creek was corrupted to Salome. However, DWB was retained for the next military map and all subsequent maps. At that time in our nation's history, people from Europe, and especially Germany, were often referred to as "Dutch." This can be traced to German immigrants referring to themselves as "Deutsch."

Description and Grazing History for the Nearby Grazed Whiskey Tank Companion Site

The Whiskey Tank companion site (WT) is situated approximately 630 feet lower than DWB (Photo 3) on a mesa with a 10% slope and a similar southeastern aspect. The parent material for soils at both locations was an unnamed shale in the Apache Group. Bedrock at the

Photo 3. Dutchwoman Butte in the background, grazed Whiskey Tank companion site in the foreground.

bottom of both soil pits described below was hard unweathered quartzite. The clayey soil materials above this bedrock did not weather from the bedrock but from the shale above and associated shale within the soil profile. The principal soil erosion for both sites is from sheet flow and an aridic soil moisture regime prevails at these elevations.

The Dutchwoman Allotment has been under the same management since 1979. At that time perennial grasses were not prevalent at WT and other upper elevation areas of the ranch. Mr Holder requested and was able to change the season of grazing for this section of the ranch to dormant-season grazing. Dormancy for perennial grasses was defined as being prior to the advent of summer monsoon rains that ordinarily begin in July and continue through September. Grazing was curtailed until fall, allowing warm season grasses to set seed.

The recent fire history on the grazing allotment included a low-intensity controlled burn that burned through WT in June 1993. The objectives of the burn in the pasture containing the WT monitoring site were to prevent further encroachment of prickly pear and juniper and to allow more recruitment of perennial grasses. The fire did not appear to be hot enough to effectively reduce prickly pear and juniper but it did benefit perennial grasses. As a result of the controlled burn, the most notable recruitment was for cane beardgrass and Arizona cottontop. Recruitment of broom snakeweed also occurred.

Long-term stocking rates from 1979 to present in the 1,794-acre pasture that includes WT have fluctuated from 60 cows to 175 cows, but have averaged 140 cows, grazing from approximately September 15 to April 1 each year from 1979 to 1993 and every other year from 1994 to 2005. The pasture enclosing WT was grazed lightly (less than 40%) from September 15, 2000, to May 1, 2001, by 116 cows and calves (58% of the permitted livestock numbers). This was the first year of data collection. A severe drought occurred in 2002 and all cattle were removed from the allotment in July 2002. Cattle did not return to the allotment until May 2004. Lower cattle numbers (60 cows; 30% of permitted numbers) entered the Whiskey Pasture on September 15, 2005, and grazed this pasture until April 1, 2006. At the time of monitoring in the fall of 2005, utilization at WT was 15%.

Range Monitoring Data Collection

Range monitoring data reported here were collected from 2001 to 2005, excluding 2002. Data were not collected in 2002 because of drought and livestock removal. Range monitoring data were collected annually in October or November, except for 2001, when data were collected in February. Data collection on the top of DWB consisted of 6 paced transects encompassing 300 0.16-m^2 quadrats for plant frequency[3] and dry-weight rank[3] for plant species composition. Cover point data for gravel (2 mm to 3/4 inch), rock (> 3/4 inch), live perennial basal vegetation, litter, persistent litter (> 0.5 inch deep and persistent), and bare ground were collected at 2 points identified by screws on each quadrat. From the center point of the quadrat frame in a 360° arc, the distance to the nearest perennial plant base (fetch) was measured for each quadrat. Landscape photos were also obtained for monitoring transects at each monitoring site.

Data collection at WT was identical to that conducted on DWB, except that we only collected frequency, cover, fetch, and dry-weight rank data from 200 quadrats placed along 4 transects. Fewer transects were used because of space limitations. Additionally, forage utilization for all perennial grasses encountered from 100 pace-points in 2 transects was estimated using height–weight forage curves generated by the Rocky Mountain Research Station Forage Utilization Gauge,[4] with the exception of 2001, when utilization was estimated ocularly.

Soils Data Collection

A soil pit was dug at each site and soils were classified following NRCS field procedures.[5–7] Particle size analyses[8] were used to verify field soil texture classes. Duplicate soil texture assays for the 2 soil pits were conducted in 2 independent labs by hydrometer.[9] Percentage of organic carbon[10] was determined for the A horizon of each pit plus 5 additional random samples from the site to assess relative site differences in surface organic matter. Soil organic matter of the A horizon was obtained by multiplying organic carbon by 1.7.

Results and Discussion

Climate During the Study

Precipitation in central Arizona typically occurs in a bimodal fashion, with a very dry May and June. Winter moisture is influenced by Pacific oceanic temperatures and airstreams; summer moisture is influenced by the North American

Scientific names for plant species encountered	
Plant species	**Scientific name**
Perennial grasses	
Green sprangletop	*Leptochloa dubia* (Kunth) Nees
Curly mesquite	*Hilaria belangeri* (Steud.) Nash
Sideoats grama	*Bouteloua curtipendula* (Michx.) Torr.
Hairy grama	*Bouteloua hirsuta* Lag.
Hook threeawn	*Aristida ternipes* Cav. var. *gentilis* (Henr.) Allred
Threeawn	*Aristida* spp.
Cane beardgrass	*Bothriochloa barbinodis* (Lag.) Herter
Plains lovegrass	*Eragrostis intermedia* A. S. Hitchc.
Bottlebrush squirreltail	*Eymus elymoides* (Raf.) Swezy spp. *elymoides*
Arizona cottontop	*Digitaria californica* (Benth.) Henr.
Tanglehead	*Heteropogon contortus* (L.) Beauv. Ex Roem. & J. A. Schult.
Half-shrubs	
Shrubby buckwheat	*Eriogonum wrightii* Torr. ex Benth.
White-ball or fern acacia	*Acacia angustissima* (P. Mill.) Kuntze
Snakeweed	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby
Yerba de pasmo	*Baccharis pteronioides* DC.
Ayenia	*Ayenia filiformis* S. Wats.
White sage	*Artemisia ludoviciana* Nutt.
Agave/cacti	
Parry's agave	*Agave parryi* Engelm.
Beargrass	*Nolina microcarpa* S. Wats.
Sotol	*Dasylirion wheeleri* S. Wats.
Banana yucca or Spanish dagger	*Yucca baccata* Torr.
Engelmann prickly pear	*Opuntia phaeacantha* var. *discata*
Hedgehog cactus	*Echinocereus* spp.

Plant species	Scientific name
Shrubs	
Catclaw acacia	*Acacia greggii* Gray
Honey mesquite	*Prosopis glandulosa* Torr.
Turbinella oak	*Quercus turbinella* Greene
Desert hackberry	*Celtis ehrenbergiana* (Klotzsch) Liebm.
Trees	
Redberry juniper	*Juniperus coahuilensis* (Martiñez) Gaussen ex R. P. Adams
Perennial forbs	
Globemallow	*Sphaeralcea* spp.
Spurge or rattlesnake weed	*Chamaesyce albomarginata* (Torr. & Gray) Small
Wild onion	*Allium* spp.
New Mexico thistle	*Cirsium neomexicanum* Gray
Weakleaf burr ragweed	*Ambrosia confertiflora* DC.
Silverleaf nightshade	*Solanum elaeagnifolium* Cav.
Guara	*Gaura coccinea*
Verbena	*Verbena* L.
Evolvulus	*Evolvulus* spp.
Navajo fleabane	*Erigeron concinnus*
White prairie aster	*Symphyotrichum falcatum* (Lindl.) Nesom
Antelope horns	*Asclepias asperula*
Sida	*Sida filicaulis*
Scurf pea or twin leaf senna	*Senna covesii* (Gray) Irwin & Barneby
Spiny cliff brake	*Pellaea truncata*
Annual forbs and grasses	
Indian wheat	*Plantago ovata* Forrsk.
Aster	*Aster* spp.
Goldeneye	*Viguiera* Kunth
Filaree	*Erodium cicutarium* (L.) L'Her. ex Ait.
Desert lupine	*Lupinus sparsiflorus*
Red brome	*Bromus rubens* L.

monsoon. Summer moisture generally occurs from July through September. It should be recognized that summer rainstorms exhibit considerable variability in their location and intensity. For the purpose of this study, winter moisture is defined as that occurring from November through June and summer moisture from July through October. There was 0.50 inches of moisture received in May 2001 at the Roosevelt weather station[11] (located 8 aerial miles away from the study site at 2,200 feet elevation), but no other rainfall in May or June was recorded for any of the other years of this study. Moisture in October was classified as summer precipitation because of the ability of warm season grasses to continue growing when the nighttime air temperature is 50°F or warmer.

Winter and summer precipitation at the Roosevelt weather station[11] is shown in Table 1. Preceding data collection in this study, below-average precipitation occurred in 1996 (10.0 inches), 1997 (10.4 inches), and 2000 (11.7 inches), with most of the deficit occurring during the winter. Average annual precipitation is 15.88 inches. Precipitation recorded in 2002 was the lowest in Arizona recorded history (since 1905), though more severe cumulative drought may have occurred over the last 1,000 years, particularly in the epic megadrought of the 1500s.[12] However, the *total* 2002 precipitation was less than Southwestern tree-ring-estimated[13] *cool season* (November to April) precipitation for all years since AD 1000 except possibly 1904, 1773, 1685, 1664, and 1150.

Rainfall gauges were placed at the 2 key areas in October 2003 and rainfall data are presented in Table 1.

Soils

In the field, soil pits dug on both sites were within the same soils classification and soils series. Both soils were tentatively classified as moderately deep, clayey-skeletal smectitic, thermic, Aridic Argiustolls. At this time, NRCS does not have an established soil series for this soil type in this area of Arizona. Both soils were well drained, with moderate to slow permeability.

Contrasts by individual soil horizons are presented in Table 2. One major difference between the 2 soils was the thickness of the surface horizon (7 inches for DWB and 1 inch for WT). This could indicate historical surface soil loss on the WT companion site. It could also account for different soil moisture relationships between the 2 sites. Another difference was in soil depth. The depth of the soil pit on DWB was 36 inches to hard bedrock and at WT was 26 inches to bedrock. Fine plant roots grew onto the bedrock at WT but not at DWB, perhaps indicating that the normal depth of wetting in clayey soils in this area is about 30 inches. Differences in hydrometer clay content were observed for the second and third horizons between sites.

Table 1. Precipitation data, inches

Year	Winter (November–June)	Summer (July–October)	Total
Roosevelt weather station			
November 2000 to November 2001	8.40	7.06	15.46
November 2001 to November 2002	1.97	1.88	3.85
November 2002 to November 2003	8.37	5.61	13.98
November 2003 to November 2004	7.66	4.25	11.91
November 2004 to November 2005	17.85	4.47	22.32
Long-term average	10.03	5.85	15.88
Dutchwoman Butte			
October 2003 to November 2004	7.50	5.50	13.00
November 2004 to November 2005	19.50	4.25	23.75
Whiskey Tank companion site			
October 2003 to November 2004	7.00	6.00	13.00
November 2004 to November 2005	17.00	3.50	20.50

The Roosevelt weather station is located approximately 8 aerial miles away from the study sites at 2,200 feet elevation. The study sites were at 4,844-feet elevation on Dutchwoman Butte and at 4,214-feet elevation at the Whiskey Tank companion site.
Source for Roosevelt weather station data: Arizona Climate Summaries, Western Regional Climate Center, 2006.

Table 2. Soil characteristics

Horizon	Depth, inches	Clay, %	Silt, %	Sand, %	Texture	pH	Organic carbon, %	Organic matter, %
Dutchwoman Butte relict area, Lab 1								
A	0–2	18	34	48	Loam	6.0		
AB	2–7	22	34	44	Loam	6.2		
Bt1	7–17	36	32	32	Clay Loam	6.0		
Bt2	17–26	58	26	16	Clay	6.0		
Bt3	26–36	64	18	18	Clay	6.0		
Dutchwoman Butte relict area, Lab 2								
A	0–2	17	39	44	Loam	6.0	1.907	3.24
AB	2–7	21	37.5	41.5	Loam	6.2	2.885	4.90
Bt1	7–17	36	30.5	33.5	Clay Loam	6.0	1.782	3.03
Bt2	17–26	53.5	30.5	16	Clay	6.0	2.404	4.09
Bt3	26–36					6.0	1.959	3.33
Whiskey Tank grazed companion site, Lab 1								
A	0–1	26	34	40	Loam	6.0		
Bt1	1–10	46	34	20	Clay	6.0		
Bt2	10–13	58	26	16	Clay	6.0		
Bt3	13–21	60	26	14	Clay	6.0		
Bt4	21–26	68	22	10	Clay	6.2		
Whiskey Tank grazed companion site, Lab 2								
A	0–1	23.5	58	18.5	Silty Loam	6.0	2.355	4.00
Bt1	1–10	43.75	33.25	23	Clay	6.0	1.897	3.22
Bt2	10–13	48.5	33	18.5	Clay	6.0	1.787	3.04
Bt3	13–21	56	28	16	Clay	6.0	2.396	4.07
Bt4	21–26					6.2	1.499	2.55

The pH of soil horizons was determined in the field. Bedrock for both sites was arkose (quartzite high in feldspar) in the Apache Group, Precambrian, although it is felt that the clayey soils weathered from shale on top of the quartzite.

These differences may classify WT as an Aridic Paleustoll instead of an Argiustoll. One of the soil labs also identified a soil texture difference between the A horizons at the 2 sites, classifying DWB as loam and WT as silt loam. With the exception of the A horizon, results from the 2 labs concurred for all the other soil horizon texture analyses.

Neither organic carbon nor soil organic matter differed statistically (via *t* tests) between sites for the replicate A horizon samples (not shown in Table 2). Average organic carbon was 1.41% (2.4% organic matter) at DWB and 1.64% (2.79% organic matter) at WT. This is a stark contrast to organic carbon results reported in Ambos and others[1] of 4.7% for the A horizon of DWB. Ambos and others[1] compared organic carbon values for other Mollisol soils in Arizona and noted that the organic carbon for DWB was exceptionally (3×) higher than expected. The values reported here for both sites are within the range reported by Ambos and others[1] for Arizona Mollisols. Differences between studies could be attributed to an increased sample size for this study ($n = 6$) or laboratory analytical variability as was demonstrated for texture determinations between labs in the study reported here.

Examination of soils' physical attributes did not reveal any plausible explanation for the changes we observed over time in plant attributes (see below) unless the greater depth to clay at DWB influenced vegetation. However, the thinner-soil-surface site (WT) should have resulted in a more severe site for perennial grasses and the thicker soil surface site (DWB) would have produced better infiltration and would have been more effective in capturing summer rain. The DWB soil would have had higher water holding capacity because of greater depth and should have been the more favorable site for perennial grasses. One grass species, curly mesquite, seems to favor soils with clayey horizons close to the surface and this may be the reason it was more common at the WT site than at DWB (see frequency data below). Curly mesquite is also considered an "increaser" with grazing pressure and this may have been another reason it was more common at WT than at DWB. Until further sampling is done, we are not sure what the range in variability of soil surface thickness or soil depth is on either site.

Species Composition

Due to the onset of severe drought in 2002, the perennial grasses on DWB were mostly replaced by annuals (Photos 1 and 4). Though perennial grasses dropped precipitously at WT, they were not reduced to the same levels as they were on DWB (Photos 5 and 6). Partial recovery

Photo 4. Dutchwoman Butte, November 2005.

Photo 5. Grazed Whiskey Tank companion site, December 2000.

Photo 6. Grazed Whiskey Tank companion site, November 2005.

of perennial grasses following the brief respite from the ongoing drought occurred at WT in 2004, but this was not the case at DWB. Figure 2 shows the total composition of perennial grasses at each site preceding and through the drought. At DWB, all perennial grass species declined to 3% or less frequency in 2003 (see frequency data below) and remained below 5% throughout the study. At the conclusion of the study, all perennial grass species at DWB were observed to have plant frequencies of 3.1% (green sprangletop) or less. At WT, all perennial grass species except curly mesquite declined to 6% or less plant frequency in 2003. Conversely to what was observed at DWB, most perennial grasses at WT recovered in subsequent years with 4 species having 5% or greater frequency in 2005. A shift in plant populations occurred at DWB after 2001 with a major portion of the total production being contributed by annuals instead of perennial grasses. This was not the case for WT.

Cover Data

Table 3 displays the cover data for the 2 key areas preceding and following the brief respite from drought. Because of

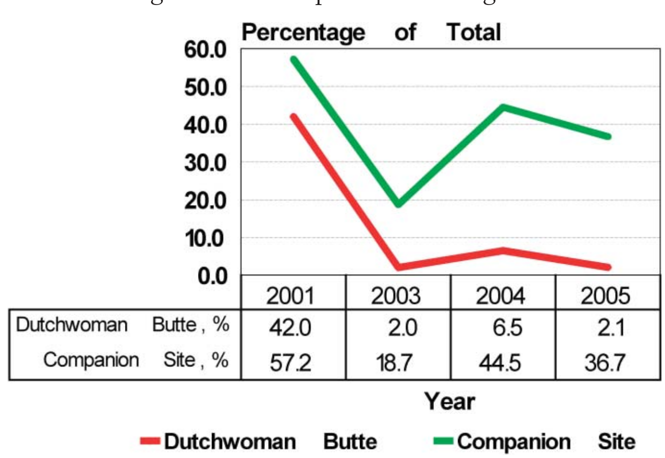

Figure 2. Percentage of total production from perennial grasses as estimated by dry-weight rank. Grasses included in totals are listed in Table 4 or in text.

Table 3. Cover data

Type of data	Year	Dutchwoman Butte	Whiskey Tank companion site
Distance to closest perennial plant, inches	2005	10.5 a*	6.8 c*
	2004	12.0 a*	5.3 a*
	2003	14.4 b*	11.1 b*
	2001	4.3 c*	5.1 a*
Bare ground, %	2005	14.3 a	14.7 a
	2004	17.6 a	16.0 a
	2003	25.9 a	21.5 a
	2001	11.6 a	16.1 a
Live basal perennial vegetation, %	2005	6.7 a	12.4 a
	2004	13.4 a	18.0 a
	2003	9.4 a	8.9 a

Live basal vegetation cover in 2001 included annuals, so those data are not included here. Within key area, by cover classification, reported values with differing letters following them are statistically different. The probability is less than 5% that the reported difference is due only to chance or inadequate sampling. Reported values for Dutchwoman Butte vs Whiskey Tank followed by * are statistically different for that year within the cover classification at the same 95% degree of confidence. Statistical tests used to compare reported values were paired *t* tests with pooled variance.

the much larger sample size for the fetch data compared to the bare ground and live vegetation cover data (200 to 300 individual measurements vs 4 to 6 transects), only the fetch data changed in a statistically significant way during the study. At the beginning of the study, plants were closer together on the top of DWB. Throughout the drought, plants were closer together at WT. By the fall of 2004, WT had recovered sufficiently to have plant spacings comparable to what was observed at the onset of the study. However, because of the poor monsoon moisture received at WT in 2005, plant spacings increased again in 2005. They were still closer than the spacing observed on DWB, although DWB simultaneously experienced 0.75 inches more summer precipitation in 2005 and a nonsignificant decrease in fetch lengths.

Frequency Data

Perennial grass frequency varied prior to and through the drought at both monitoring sites (Table 4). Perennial grass species encountered infrequently or in trace amounts at DWB not listed in Table 4 included plains lovegrass and bottlebrush squirreltail. Perennial grasses observed in trace amounts at WT not included in Table 4 included plains lovegrass, Arizona cottontop, and tanglehead. Prior to the drought, DWB had a much greater abundance of green sprangletop but curly mesquite was more abundant at WT. The sites were comparable with respect to sideoats grama, hairy grama, and threeawn. The WT site also had a greater frequency of cane beardgrass than did DWB at the beginning of the trial.

Surprisingly, one of the grass species most impacted on both sites was sideoats grama. At the end of the study, sideoats grama had not recovered on either site. It would have been expected that the shallower-rooted hairy grama species would suffer more plant mortality during the drought, but on WT this species had recovered to predrought levels (2001) by the end of the study. Curly mesquite, a shallow-rooted, sod-forming grass, also rebounded fairly quickly from the effects of the drought on WT. Given the proper moisture and temperature, curly mesquite has the ability to anchor new plants from stolons.

Many managers have discussed the influence of livestock grazing upon the increased presence of grazing-resistant plants such as curly mesquite in the Southwest. Although it is true that livestock grazing may increase the competitive advantage of curly mesquite in relation to bunchgrasses, in this study the presence of curly mesquite may have actually aided in the drought recovery for WT. Almost without exception, among the approximately 120 key areas monitored in Gila County in the Reading the Range program, sites dominated by sod-forming grasses such as curly mesquite have closer spacings of perennial plants (fetch) when compared to bunchgrass-dominated plant communities. At the beginning of this study, plant spacing on the top of DWB was closer (Table 3) and estimated dry-weight composition contributed by hairy grama was 7.3% and by curly mesquite, 2.8%. On WT in 2001, the estimated dry-weight composition contributed by hairy grama was 8.7% and by curly mesquite, 26.8%. The composition of curly mesquite at WT varied from a low of 9.7% in 2003 to a high of 27.3% in 2004. At the conclusion of this study in 2005, the dry-weight species composition of curly mesquite at WT was 20.9%. It is our opinion that the closer spacing of the plants on WT was influenced by the presence of curly mesquite, which may have increased shading and rainfall infiltration during the drought, making what little rainfall that fell more effective. Curly mesquite in the desert Southwest may be undervalued for its resiliency to drought.

Table 4 also compares the frequency of half-shrubs and cacti. Woody plant species and cacti not included in Table 4 that were encountered infrequently or in trace amounts at both WT and DWB included sotol, banana yucca or Spanish dagger, ayenia, redberry juniper, catclaw acacia, and desert hackberry. Other woody plant species and cacti encountered in trace amounts at DWB only and not included in Table 4 included Parry's agave, turbinella oak, white sage, yerba-de-pasmo, and beargrass. Woody plants encountered in trace amounts at WT only and not included in Table 4 were honey mesquite. Prior to the drought, the 2 monitoring sites were quite different in the species composition of half-shrubs (Table 4). DWB had a much greater abundance of shrubby buckwheat than did WT. DWB also had 15% fern acacia whereas WT had none. The WT site had 19% snakeweed compared to only 1% at DWB.

A surprising consequence of the drought was the extensive mortality of shrubby buckwheat on DWB, dropping from 43% frequency in 2001 to 3% in 2003. Because it is a woody species, we would have expected shrubby buckwheat to manifest more drought tolerance. Following the 2002 drought, Arizona experienced extensive die-off of some trees, notably ponderosa pine, pinyon pine, Arizona cypress, and juniper. Winter moisture is very important to the health of woody species.[14] With improved conditions and an abnormally wet winter in 2005, shrubby buckwheat on DWB increased again to 8%. Conversely, snakeweed declined on both DWB and WT in 2005. Snakeweed has been shown to exhibit cyclicity in its population trends.[15]

Compared to WT, there was a greater frequency of prickly pear at DWB at the beginning and throughout the study, possibly due to less fire frequency in recent years. With the loss of ground cover of perennial grasses on DWB, it appears that the frequency of prickly pear was able to increase during this study.

Hedgehog cactus frequency on DWB remained greater than on WT throughout the study, except in 2004. Possibly this was influenced by the increased elevational gradient at DWB or at WT by the greater access by javelina, which are locally reported to consume hedgehog cactus.

With the 2002 drought and the accompanying loss of ground cover by perennial grasses on DWB, considerable recruitment of the perennial forbs globemallow and silverleaf nightshade and the annual forb goldeneye occurred (Table 5). The high frequency of goldeneye on DWB in 2003 could have made less summer moisture available for warm season perennial grass recovery.

The 2 sites differed in the frequency of globemallow after 2001. Spurge was present in greater amounts at WT after 2001. Because of the late occurrence of data collection in 2001 (February) and the propensity for spurge to die back to the root in late winter, no spurge was detected on either site in 2001. On WT, wild onion was greater after 2003. Silverleaf nightshade was not documented at WT but it increased to 14% by 2005 at DWB. On DWB, ragweed was never present in any appreciable frequency, whereas it ranged from 4% to 14% at WT.

Among annual forbs, aster, goldeneye, and filaree were greater on DWB. From 2004 onward, Indian wheat was identified separately from other cool-season annual forbs in data collection. This species was more prevalent in 2004 and 2005 on WT. In 2005, because of concern over invasive species and their contribution to fires that occurred in Arizona following the wet winter, red brome was separated from other cool-season annual grasses in data collection (data not shown). On DWB, there was an 87% frequency of occurrence of red brome, whereas on WT there was a 40% frequency of red brome. On DWB, the dry-weight composition contributed by red brome was 16.8% whereas on WT it was 1.5%. Cattle were absent from May 1, 2001, until September 15, 2005, on WT, so little opportunity for grazing to reduce red brome existed following the wet winter and spring of 2005. Less perennial grass cover on DWB likely allowed for a greater abundance of annual forbs and grasses at that site. When plant communities are allowed to simplify and lose cover for whatever reasons, they may be set up for more rapid colonization by invasive species.

Why Was There a Difference?

Why did the perennial grass population decline on DWB and not on WT? Both study sites were as similar as we could make them with the exception of grazing. The absence of grazing on DWB did not make the vegetation more resistant to drought nor were perennial grasses species on DWB more resilient. Grazing exclusion on DWB also did not make the vegetation more resistant to invasion by exotic annuals. Adaptive plant responses in grazed systems may include the following: 1) the same mechanisms or genetic mutations that make plants resistant to grazing may also make them more resistant to drought;[16–18] 2) grazing may result in a more diverse age classification of plants due to seed dispersal and seed implantation by grazing herbivores, thus making grazed plant communities more resistant to environmental stress than more even-aged plant communities;[19] and/or 3) grazing removes senescent plant material, and if not extreme, helps open up the plant basal area to increase photosynthesis and rainfall harvesting (via reducing rainfall interception by the aerial canopy).[19]

Additional possibilities in comparing grazed vs excluded sites are suggested by Holechek and others[20] in the February

Table 4. Frequency data—perennial grasses/half-shrubs/cacti

Plant species	Growth habit	Year	Dutchwoman Butte	Whiskey Tank companion site
Green sprangletop	Perennial grass	2005	3.1 a	0.5 b
		2004	4.4 a*	0.0 b*
		2003	1.3 a	0.0 b
		2001	23.5 b*	0.5 b*
Curly mesquite	Perennial grass	2005	0.7 c*	40.0 c*
		2004	5.0 ab*	48.3 a*
		2003	2.0 b*	29.8 b*
		2001	6.5 a*	36.7 bc*
Sideoats grama	Perennial grass	2005	2.1 a	3.5 a
		2004	5.0 a	5.2 a
		2003	2.7 a	5.7 a
		2001	21.5 b	20.3 b
Hairy grama	Perennial grass	2005	1.0 a*	9.9 c*
		2004	0.3 a*	18.7 b*
		2003	1.7 a	3.6 a
		2001	14.3 b	12.9 c
Hook threeawn	Perennial grass	2005	0.7 b*	4.9 b*
		2004	1.0 b*	14.0 a*
		2003	0.0 b*	4.6 b*
Threeawn	Perennial grass	2005	0.3 a*	7.4 b*
		2004	1.0 a	3.6 ab
		2003	0.3 a	0.5 a
		2001	7.5 b	7.4 b
Cane beardgrass	Perennial grass	2005	0.3 a	1.5 a
		2004	0.3 a	3.1 a
		2003	0.0 a	2.1 a
		2001	0.7 a*	6.9 b*
Shrubby buckwheat	Half-shrub	2005	7.6 c*	3.0 b*
		2004	3.7 bc	4.7 b
		2003	2.7 b	4.1 b
		2001	42.7 a*	5.5 b*
White-ball or fern acacia	Half-shrub	2005	18.6 a*	0.0 a*
		2004	11.7 b*	0.0 a*
		2003	17.3 ab*	0.5 a*
		2001	14.7 ab*	0.0 a*

Table 4. Continued				
Plant species	**Growth habit**	**Year**	**Dutchwoman Butte**	**Whiskey Tank companion site**
Snakeweed	Half-shrub	2005	1.7 a*	20.9 a*
		2004	5.4 b*	30.1 b*
		2003	3.0 ab*	19.5 a*
		2001	1.3 a*	18.9 a*
Engelmann prickly pear	Cactus	2005	13.4 a*	3.0 a*
		2004	9.4 ab*	2.1 a*
		2003	7.7 ab*	1.5 a*
		2001	6.5 b*	1.5 a*
Hedgehog cactus	Cactus	2005	12.7 a*	3.0 ab*
		2004	9.0 a	5.7 a
		2003	9.7 a*	3.6 ab*
		2001	11.7 a*	2.0 b*

Within key area, by species, reported values with differing letters following them are statistically different. The probability is less than 5% that the reported difference is due only to chance or inadequate sampling. Reported values for Dutchwoman Butte vs Whiskey Tank followed by * are statistically different for that year within the species at the same 95% degree of confidence.
Source: Statistical tests for 95% confidence intervals are from a binomial statistics table (as described by Owen 1962) in Ruyle et al. 1999.

2006 issue of *Rangelands*. In their study, they reported that livestock grazing at light to moderate intensities can have positive impacts on rangelands in the Southwest (Arizona and New Mexico). Loeser and others[21] reported that moderate grazing was superior to both grazing exclusion and high-impact grazing in maintaining plant diversity and in reducing exotic plant recruitment in a semiarid Arizona grassland. Courtois and others[22] found similar results between grazed and excluded sites in Nevada and concluded, "Few changes in species composition, cover, density, and production inside and outside exclosures have occurred in 65 years, indicating that recovery rates since pre-Taylor Grazing Act conditions were similar under moderate grazing and grazing exclusion on these exclosure sites." The results of our study substantiate the research of Holechek and others.[20]

Rainfall in Arizona is highly variable in both time and space and different plant communities exploit various permutations of temperature and moisture that occur from year to year. Range sites with more diversity of both lower and higher successional species within a particular state (such as WT) may be better able to recover after severe drought or disturbance than are sites with fewer disturbance-induced communities. Disturbance such as grazing, drought, and fire often help open up plant communities and create new niches for different plant species within the plant community when followed by favorable environmental conditions.

Management Implications

Two paradigms that have become dogma need to be reexamined. First, the presence of grazing-tolerant native grasses should not be viewed only as an indication of degraded ecological systems. They may in fact be described as a stable vegetation community within the state-and-transition dynamics of a particular ecological site that is functioning effectively and contributing to a healthy ecosystem.[23] The second paradigm that needs to be reevaluated is that removing livestock from ecological systems will always lead us to "Nirvana," or at least that livestock removal is always a management alternative that moves an ecosystem to a more desirable potential plant community. In the 2002 book entitled *Welfare Ranching: The Subsidized Destruction of the American West*,[24] DWB is used as an ideal example of a pristine ecosystem that we should all strive for as "livestock-free." Would that still be the case? Probably not, because the current plant community on DWB is more indicative of what is commonly thought to be an overgrazed community. Our data add to the complexity of interpreting the array of consequences regarding the impacts of range livestock grazing. In this case, climate was the biggest influence on current vegetation conditions, followed distantly by

Table 5. Frequency data—forbs			
Plant species	**Year**	**Dutchwoman Butte**	**Whiskey Tank companion site**
Perennial forbs			
Globemallow	2005	14.1 a*	0.5 a*
	2004	9.0 ab*	0.5 a*
	2003	8.3 b*	1.0 a*
	2001	3.6 c	0.5 a
Spurge or rattlesnake weed	2005	0.0 a*	7.0 a*
	2004	0.3 a*	9.9 a*
	2003	0.3 a*	16.5 b*
	2001	0.0 a	0.0 c
Wild onion	2005	0.3 a*	17.8 a*
	2004	1.7 a*	39.0 b*
	2003	0.0 a	3.1 c
Silverleaf nightshade	2005	13.7 a*	0.0 a*
	2004	9.0 a*	0.0 a*
	2003	9.0 a*	0.0 a*
	2001	0.0 b	0.0 a
New Mexico thistle	2005	2.4 a	0.5 a
	2004	5.7 a*	0.0 a*
	2003	2.0 a	1.0 a
	2001	0.0 a	0.0 a
Weakleaf burr ragweed	2005	0.0 a*	9.9 ac*
	2004	0.0 a*	13.5 a*
	2003	0.7 a*	6.2 bc*
	2001	0.0 a*	4.0 b*
Annual forbs			
Indian wheat	2005	55.7 a*	69.6 a*
	2004	42.5 b*	53.5 b*
Aster	2005	46.7 a*	34.1 a*
	2004	36.5 b*	28.6 a*
	2003	18.3 c*	9.3 b*
Goldeneye	2005	27.8 a*	18.3 a*
	2004	26.8 a*	4.2 b*
	2003	56.2 b*	21.6 a*

Table 5. Continued			
Plant species	**Year**	**Dutchwoman Butte**	**Whiskey Tank companion site**
Filaree	2005	25.4 a*	3.0 a*
	2004	66.7 b*	20.3 b*
	2003	32.6 c*	24.2 b*

Within key area, by species, reported values with differing letters following them are statistically different. The probability is less than 5% that the reported difference is due only to chance or inadequate sampling. Reported values for Dutchwoman Butte vs Whiskey Tank followed by * are statistically different for that year within the species at the same 95% degree of confidence. Other species observed infrequently at both Dutchwoman Butte and Whiskey Tank included sida, scurf pea or twin leaf senna, desert lupine, and various cool-season and warm-season annual forbs; at Dutchwoman Butte only were spiny cliff brake, antelope horns, white prairie aster, Navajo fleabane, verbena, and gaura; at Whiskey Tank only evolvulus.
Source: Statistical tests for 95% confidence intervals are from a binomial statistics table (as described by Owen 1962) in Ruyle et al. 1999.

management. Poor management can exacerbate the effects of drought, whereas effective management can help temper and ease drought recovery. On WT, effective management has been practiced for over 25 years.

The timing of this study was especially fortuitous because it preceded and followed the 2002 drought, which was an epic dry year in the midst of a longer-term drought. This study only intended to document the variation between a grazed and ungrazed relict area on a well-managed ranch. Instead, we not only collected data related to our original design, we also captured ecological changes that may only occur once in a millennium. Will DWB recover? The authors of this study are divided on this question. Some feel that Arizona may be entering an extended period of drought and when moisture comes to DWB, it may be exploited by the presence of invasive and native annuals, preventing extensive reestablishment of perennial grasses. Some research further indicates that *Bromus* species present in large quantities may alter nitrogen dynamics of rangelands.[25,26] Others feel that the seed source is present on the butte and if several seasons of favorable summer moisture and temperatures occur in succession, perennial grasses could begin to reestablish. Our intention is to continue data collection at the 2 sites into the future. With continued monitoring, we will be able to determine if DWB recovers.

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Authors are Area Extension Agent, Animal Science, University of Arizona Cooperative Extension, PO Box 2844, Payson, AZ 85547, sprinkle@ag.arizona.edu (J. Sprinkle); Rancher, Tonto Basin, AZ 85553 (Holder); Rancher, Paradise Valley, AZ 85253 (Erickson); Research Ecologist, USDA–Forest Service Rocky Mountain Research Station, Flagstaff, AZ 86001 (Medina); Rangeland Management Specialist, Retired, Natural Resources Conservation Service, Plant Materials Center, Tucson, AZ 85705-9223 (Robinett); Professors and Range Management Extension Specialists, School of Natural Resources, University of Arizona, Tucson, AZ 85721 (Ruyle and Howery); Range Consultant, Southwest Resource Consultants, LLC, Las Cruces, NM 88007 (Maynard); Extension Agent, San Carlos Apache Reservation, San Carlos, AZ 85550 (Tuttle); Senior Research Specialist, School of Natural Resources, University of Arizona, Tucson, AZ 85721 (Hays); Lecturer, School of Natural Resources, University of Arizona, Tucson, AZ 85721 (Meyer); Rangeland Management Specialist, Natural Resources Conservation Service, Chandler, AZ 85225 (Stratton); Science Program Coordinator, Arizona–Sonora Desert Museum, Tucson, AZ 85743 (Rogstad); Rangeland Management Specialist, Fairfield Ranger District, Fairfield, ID 83327 (Eldredge); Rangeland Management Specialist, Douglas Ranger District, Douglas, AZ 85607 (Harris); and Undergraduate Researcher, Northern Arizona University School of Forestry, Flagstaff, AZ 86011 (W. Sprinkle).