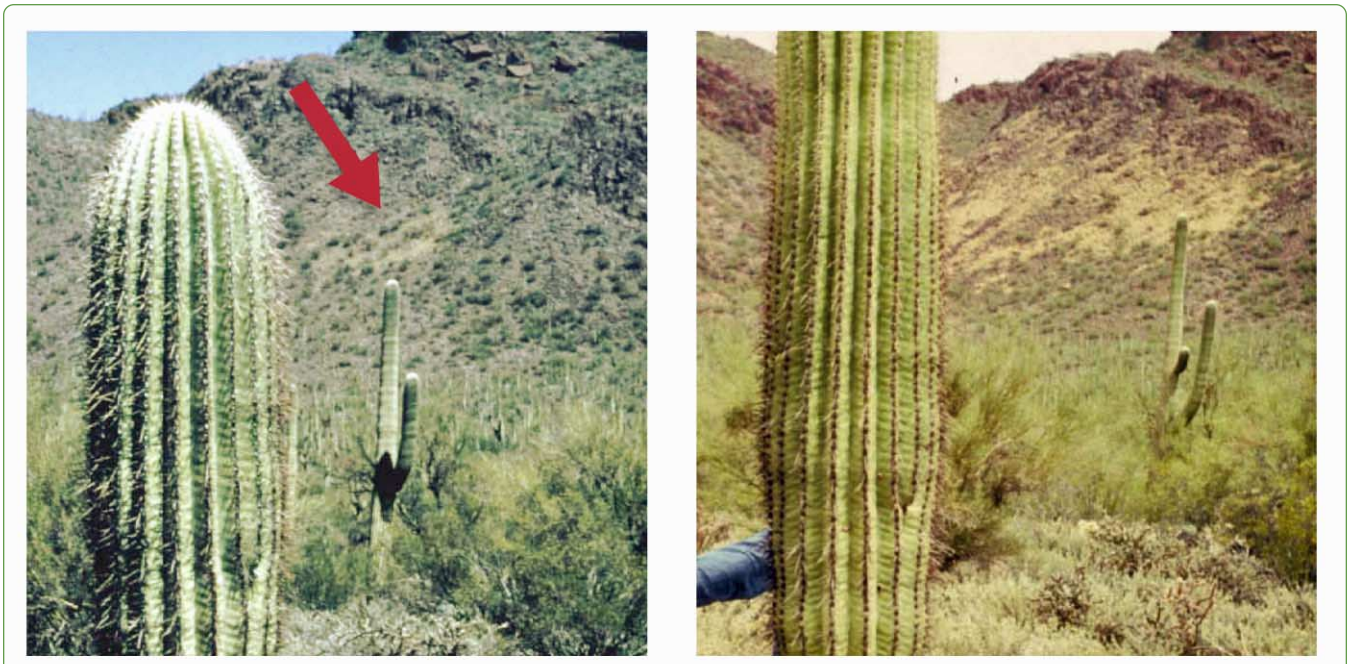

Buffelgrass on Panther Peak 1989 (left) and 2000 (right). *Photos courtesy Dale Turner*

The Long Journey from Buffelgrass Introduction, Spread and Latency, to an Eruptive Explosion in Arizona

by John Scheuring[1] and Kim Franklin[2]

Buffelgrass (*Pennisetum ciliare*) has become the most notorious noxious weed in southern Arizona. With a distribution spanning nine counties, buffelgrass is equally at home in our cities and our wildlands. Buffelgrass lines roadsides, overruns vacant lots, and fills urban washes. It climbs desert hillsides, displacing native grasses and perennial dicots. Buffelgrass can engulf entire desert landscapes, transforming rich biodiverse desert scrub communities into depauperate grasslands. A long-lived perennial, it accumulates fuel loads much greater than our native grasses, burning hot and furious through desert ecosystems not adapted to fire.

Buffelgrass is a drought-tolerant perennial bunchgrass native to Africa where it is well adapted to arid and semi-arid regions, providing fodder for wild and domestic animals. Buffelgrass thrives on fire, and pastures are often burned during the dry season to stimulate new growth.

Between 1880 and 1930, recurrent droughts in North America and elsewhere decimated cattle herds and impoverished soils. In an attempt to stabilize cattle populations, a worldwide effort was made to find a drought-resistant "miracle grass." Grass species were collected in drought prone areas of North America and Africa and tested in the U.S., Mexico, Australia, and Africa. One of those species was buffelgrass. Another was Lehmann's lovegrass (*Eragrostis lehmannii*). Both were found to be well suited for their ease of establishment, persistence, and fodder production (Cox et al. 1984, 1988). Buffelgrass was also found to be an excellent species to stabilize copper mine tailings.

Although it arrived in Arizona 82 years ago it has become aggressively invasive in only the last 35 years. In this paper we trace the introduction, slow spread, and sudden eruption of this grass. Since there is little information in the literature describing the details of the initial spread and timing patterns, we have interviewed a number of "old timers" who have memories of their initial buffelgrass sightings.

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Arizona Introductions

In the early 1930s, Franklin J. Crider, director of the newly established Boyce Thompson Arboretum, led the introduction and testing of exotic grasses in southern Arizona. In 1934 Crider established and became the director of the Soil Conservation Service (SCS) Plant Materials Center in Tucson (Heather Dial, Tucson Plant Materials Center, USDA, personal communication). There he continued his work with exotic grasses, selecting several species, including buffelgrass, for their suitability to the heat and aridity of southern Arizona.

In the 1940s through the 1980s, the Soil Conservation Service, which later became the Natural Resources Conservation Service (NRCS), made numerous plantings on reservations and federal lands with the hope that buffelgrass would spread on its own naturally. Not all plantings were successful. Several experimental plantings were done beginning in 1941 at Aguila near Phoenix. Most did not do well. In the early 1980s, buffelgrass was planted on Bureau of Land Management (BLM) land near Cerro de Represo, west of Tucson. Although the buffelgrass, planted on flat ground, died out, ten years later the slopes of the adjacent 45-acre Cerro de Represo has been engulfed in buffelgrass, the seed undoubtedly originating from the original planting (T.R. Van Devender, Greater Good Charities, personal communication). Evaluation of buffelgrass at the Tucson Plant Materials center ceased in 1991 (Munda 1995).

Also in the early 1980s, buffelgrass was seeded on the flood control structures at White Tanks by the Maricopa County Flood Control District and as part of road construction projects by the Indian Highways Department of the Bureau of Indian Affairs. (Dan James, professional roadside hydroseeder and owner of Desert Seeders, Gila Bend, AZ, personal communication). The Arizona Department of Transportation (ADOT) never used buffelgrass in its roadside seed mixes, preferring instead another exotic grass, Lehmann's lovegrass, for right-of-way stabilization (LeRoy Brady, Chief Landscape Architect, AZDOT, personal communication).

Buffelgrass and Lehmann's lovegrass were seeded to stabilize the tailings of copper mines south of Tucson in the 1960s and 1970s. Both species were found to establish easily and grow as "pioneer plants." At that time, seed supply of these exotic species was abundant, whereas native grass seed was unavailable (Stuart Bengson, Copper Operations, ASARCO Inc., personal communication).

The first herbarium records of buffelgrass in Arizona are from 1938 from the Plant Materials Center in Tucson (https://swbiodiversity.org/seinet/index.php). The number of buffelgrass records has grown each decade since the 1930s. The data reflect slow spread through 1980, rapid increase in the 1980s, and explosion between 1990 and 2020. From the time of first introduction for a period of approximately 40 years, buffelgrass spread slowly, remaining in a state of latency until sudden population upsurge in the 1980s. John Brock (*The Plant Press*, this issue) describes that typical slow spread and lag time in which newly introduced plants become adapted to their new home.

Table 1: Buffelgrass records in herbaria 1930–2020. Data available from SEINet (SEINet images 1938–1982, 1983–2020); https://swbiodiversity.org/seinet/index.php.

Years	Total Plant Specimens	Total Arizona Counties	Arizona Counties
1930–1960	1	1	Pima
1961–1970	6	2	+ Maricopa
1971–1980	10	4	+Yuma, La Paz
1981–1990	23	5	+Yavapai
1991–2000	35	6	+Pinal
2001–2010	75	8	+ Santa Cruz, Cochise
2011–2020	97	9	+Gila

Botanists on Tumamoc Hill, a 364-hectare desert preserve near the heart of Tucson and home of The Desert Laboratory, have been monitoring its flora since 1903. Buffelgrass was first recorded there in 1968. A survey of exotic plants on the Hill in 1983 found only 6 buffelgrass plants growing near the road (Bowers et al. 2006). In 2005 the Hill was surveyed again. Those 6 buffelgrass plants had turned into 485 plants, an increase far larger than that of any of the 34 exotic species recorded in 1983. Buffelgrass had spread to all exposures of the Hill and formed several continuous stands the largest of which was approximately 50 hectares (Bowers et al. 2006). Tony Burgess, a botanist stationed at the Desert Laboratory from the late 1970s through the early 1990s, reported a sudden increase and spread of buffelgrass following above-average rainfall in 1983 and 1984 (Burgess et al. 1991).

In the same period, Sue Rutman noted a similar pattern of buffelgrass spread in Organ Pipe Cactus National Monument. In the 1970s and 1980s, sightings of buffelgrass were relatively rare but significantly increased between 1984 and 1987. By 1994 buffelgrass had spread to up to 25 square miles within the monument (Rutman and Dickson 2002). Similarly, an incipient buffelgrass patch on Panther Peak in Saguaro National Park in 1989 had grown into to a massive infestation

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by 2000 as revealed by repeat photography (D.S.Turner and C.S. Funicelli 2000).

Buffelgrass Spread Patterns

With the sustained intentional plantings of buffelgrass on public and reservation lands in southern Arizona, buffelgrass slowly spread to wildlands and increased in abundance in urban areas through the 1980s.

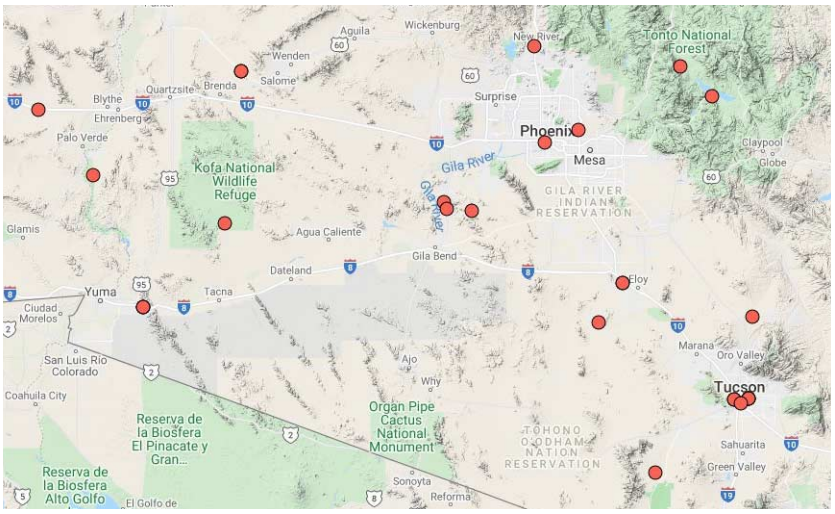

Figure 2. Buffelgrass collection locations 1938 to 1982.

In the late 1980s and through the early 2000s buffelgrass rapidly spread along roadways. Three of the first initial plants detected on Tumamoc Hill were along the main road. In Western Pima County, Rutman noted the heaviest initial infestations along the Mexican border (Mexican Highway 2) and the north-south Arizona Highway 85 (Rutman and Dickson 2002). Van Devender and Dimmit made an extensive buffelgrass survey from the mid-1990s to 2005 and concluded that, at that time (2006), buffelgrass in southern Arizona was found mostly along roadsides and roadside infestations appeared to be the seed source for further infestations into desert wildlands (Van Devender and Dimmit 2006).

Several botanists have noted that the roadside infestation of the early 1990s preceded the later infestations of drainages and hillsides that occurred extensively after 1995 (Tom Van Devender, Greater Good Charities, and James Brock, Professor Emeritus, College of Integrative Sciences and Arts, Arizona State University, Mesa, AZ, personal communications). Windblown buffelgrass seed quickly spreads up the slopes, especially favoring saguaro-palo verde bajadas. David Bertelsen, renowned for his work documenting long-term trends in the flora of the Santa Catalina Mountains, noted the first appearance of buffelgrass in Finger Rock Canyon in the Santa Catalinas in 1990 (Bertelsen 2018). Buffelgrass moved up the slopes of Tucson's Sentinel Peak following the July 4, 1994, fire that was fueled by another invasive grass, red brome grass (*Bromus rubens*) (Diane Hadley, homeowner at the base of Sentinel Peak, AZ and Tony Burgess, botanist and plant ecologist based at the Desert Laboratory on Tumamoc Hill from the 1970s to 1990, personal communications).

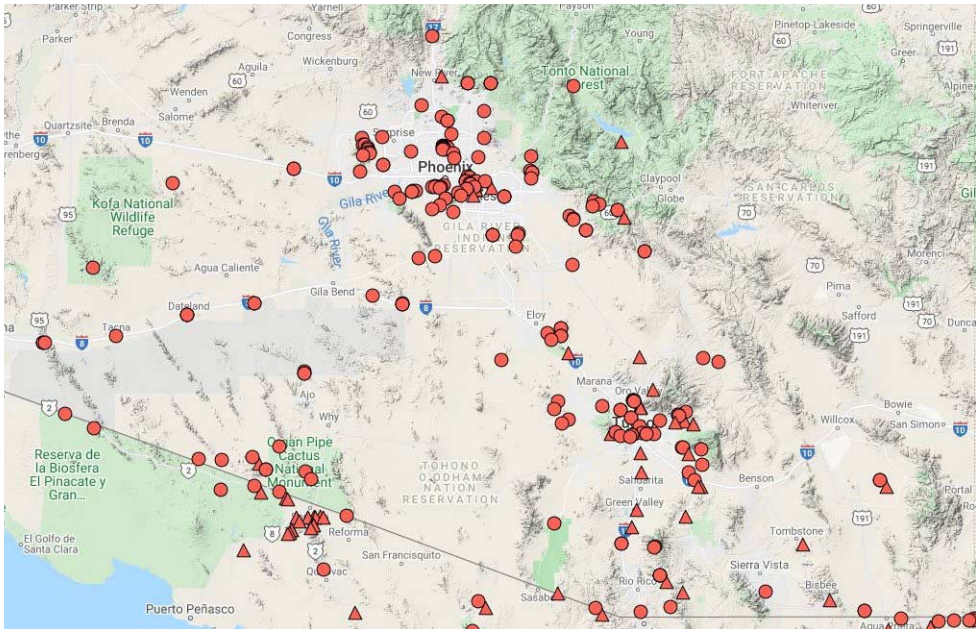

Figure 3. Buffelgrass collection locations 1983 to 2000.

Buffelgrass infestations in the Phoenix area quickly followed those of Tucson with the first sightings along the I-10 frontage road in 1990 and the south end of Indian Bend Wash in Tempe in the mid-1990s. By the late 1990s, buffelgrass was moving up desert slopes at the Spur Cross Park. By the early 2000s buffelgrass was climbing desert hills and infesting state and county roads throughout Maricopa County (John Brock, Professor Emeritus, College of Integrative Sciences and Arts, Arizona State University, Mesa, AZ, personal communication).

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Roadside buffelgrass.

The Long Journey from Buffelgrass Introduction

continued

Table 2: Phoenix and Tucson airport deviations from average in monsoon rainfall (June 1 to September 30) and winter rainfall (Oct 1 to May 31) between 1981 and 1990 (Crimmins 2020a and 2020b).

	Tucson		Phoenix	
Year	Winter (inches +/- average of 5.0")	Monsoon (inches +/- average of 6.1")	Winter (inches +/- average of 4.6")	Monsoon (inches +/- average of 2.6")
1981	+0.2	+2.1	-1.5	-1.4
1982	-0.9	+1.4	+1.0	-0.1
1983	+2.0	+4.4	+4.8	+2.7
1984	+3.3	+3.9	-0.9	+7.0
1985	+3.0	+0.2	+1.1	+0.2
1986	+2.0	-0.4	+3.6	+0.4
1987	+1.8	-0.6	+0.4	-0.5
1988	-0.2	+0.2	+0.9	-1.1
1989	-0.2	-3.7	+1.1	-0.9
1990	-0.7	+3.9	-1.9	+2.2

Buffelgrass Eruption in the 1980s and 1990s

1983 through 1986 were wet years in both Tucson and Phoenix. This period was punctuated by historic flooding in October 1983 and followed by two years with above average rainfall in both winter and summer monsoon seasons. (Crimmins 2020 a and b). This continuous wet period from 1983 to 1986 was the trigger that set off the massive outbreak of buffelgrass in Arizona in the 1990s.

Buffelgrass in Arizona emerges and grows with enough warmth (above 70°F daytime temperature) and sufficient soil moisture regardless of season. In contrast, perennial native grasses and forbs generally grow during one season and remain dormant or "rest" in the following season. With no requirement for a period of rest and provided adequate moisture, buffelgrass can take advantage of those rest periods to outcompete native species, including brittlebush (*Encelia farinosa*), triangleleaf bursage (*Ambrosia deltoidea*), native grasses, and even foothill palo verde (*Parkinsonia microphylla*).

In addition, buffelgrass quickly germinates and grows in disturbed soil caused by roadside scraping, road widenings, and construction disturbances. Between 1990 and 2020 there were extensive interstate widenings that caused right-of-way soil disturbances resulting in considerable invasive weed infestations which included buffelgrass.

Potential Natural Limits on Buffelgrass

One advantage that buffelgrass has over native grasses is a lack of natural enemies. Few Sonoran Desert animals consume buffelgrass enthusiastically, with the single exception of a native spittle bug, *Aeneolamia albofasciata*. First reported from buffelgrass pastures in Sonora in 1981, this spittlebug was causing declines in pasture productivity just a few years later (Martin et al. 1995). The damage inflicted by this insect on buffelgrass pastures in both northeastern and northwestern Mexico has stimulated a line of research on its control (Martin et al. 1999).

Recent reports of this spittlebug from Santa Cruz and Pima counties in southern Arizona suggest that its range may be moving northward (iNaturalist 2020, available from https://www.inaturalist.org). With enough time, these insects may discover the massive stands of buffelgrass in the mountains surrounding the Tucson Basin, a literal spittlebug all-you-can eat buffet, and perhaps provide some assistance to land managers whose current repertoire of tools does not include biological controls.

Much effort has been directed towards developing a bioherbicide for buffelgrass control. In contrast to a true biocontrol agent, a bioherbicide is not a living organism released into the environment, but rather an herbicide derived from pathogens that attack a target invasive species. Masi et al. (2019) successfully isolated phytotoxic metabolites from two fungal pathogens commonly found in buffelgrass populations in North America. Moreover one of these metabolites, radicinin, has been shown to have a high toxicity on buffelgrass and a low toxicity on native plant species. Much more research is needed to better assess the potential application of radicinin and other phytotoxic metabolites as bioherbicides for buffelgrass.

Extreme weather events might bring new opportunities for the suppression of buffelgrass and other noxious weeds.

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The Long Journey from Buffelgrass Introduction *continued*

Excessively wet winters might favor the growth of pathogens, a phenomenon observed in buffelgrass populations lying in moist areas along roadsides in Tucson in February 2020 (Scheuring, unpublished data). A deep freeze might cause dieback near the upper elevational range limit of a species limited by freezing. Severe drought can result in drastically reduced growth and seed production and even mortality. For example, during a 2003 buffelgrass survey of Ironwood Forest National Monument, Dimmitt and Wiens (2010) recorded a large, healthy stand of buffelgrass that subsequently died due to a chronic, multi-year drought. Given limited resources, the ability to take advantage of opportunities afforded by climate variability may prove to be a key component of successful invasive species control efforts.

Lessons Learned

Governmental, academic, and non-profit organizations have gradually recognized the dangers of exotic plant introductions. As early as 1977 the U.S. federal government recognized the risk of exotic species dispersal and banned the use of species not locally native in mine waste restoration through the Federal Surface Mining and Reclamation Act (Bengson 1988). Since then, many other federal, state, and local laws have been passed attempting to improve the prevention, control, and management of invasive species, but these laws and regulations are often reactive, rather than proactive. Too often they are species-specific responses to emerging crises, and as such they fail to address potential future invaders.

In Arizona, the only limitation to the introduction of an exotic species through nurseries is appearance on the Arizona Noxious Weed List, but listing requires evidence that the species is economically or ecologically harmful to agricultural or horticultural crops, natural habitats or ecosystems, humans or livestock. As the case of buffelgrass demonstrates, the potential for a species to cause massive economic and ecological harm may not become apparent for decades. With a changing climate, and more frequent extreme weather events, we should be monitoring populations of the scores of exotic species already naturalized and lying in latency in urban and wild landscapes throughout Arizona. Moreover, we ought to address the lack of scrutiny of exotic plant introductions through the nursery industry and narrow this potential invasion pathway.

Early control of roadside infestations is imperative to staunch the spread of new weeds from incipient localities. Roadside rights-of-ways jump-started the rapid initial spread of buffelgrass throughout the Sonoran Desert. Its light, airborne seeds readily cling to dust on fast-moving vehicles. Effective and timely roadside weed control is essential to stopping not only the constant flow of buffelgrass seed, but many other invasive plants as well. Roadside weed control is inconsistent across ADOT districts and county and municipal jurisdictions.

Buffelgrass was already recognized as an explosive weed by the early 1990s, but it was not added to the Arizona Noxious Weed list until 2005. This delayed the awareness level of buffelgrass and the focus and release of control funding by federal and state agencies. Following the 2005 update, there was a 15-year delay before the noxious weed list was allowed to be updated again in 2020. Timely response to the pressing issues of emerging noxious weeds requires governmental cooperation and support.

The well-intentioned efforts to rebuild cattle herds and to stabilize berms and mine tailings in the 20th century resulted in the establishment of small buffelgrass populations through many parts of the Sonoran Desert of Arizona. But buffelgrass remained a benign exotic until its population explosion the 1980s. Many other exotic species are now lying in wait for the right conditions to potentially spark their own population explosions. Let us apply the lessons learned from the case of buffelgrass to anticipate the future and already mitigate the consequences of inaction.

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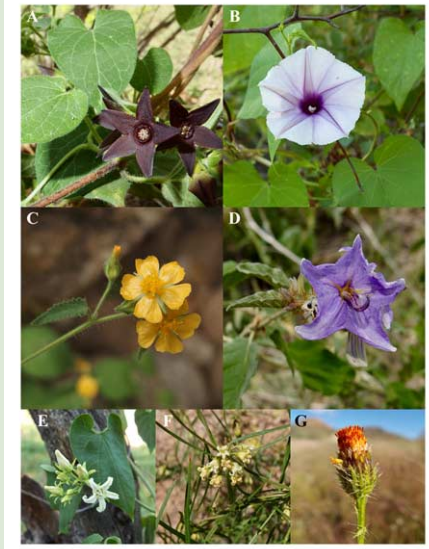

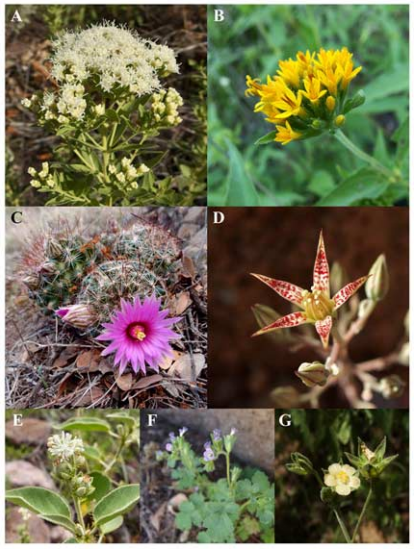

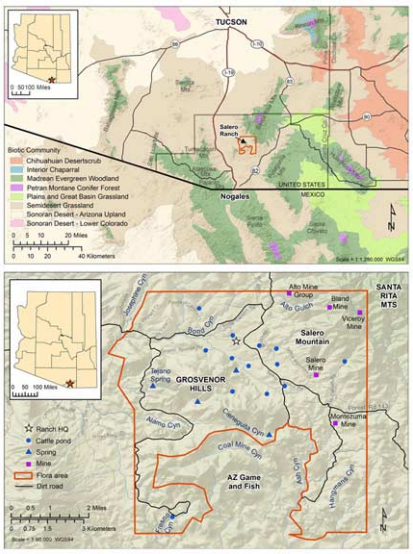

BOOK REVIEW Diversity in a Grassland: Flora of the Salero Ranch, Santa Cruz County, Arizona *continued*

Short-lived Natal grass has become so prevalent in recent years on south-facing slopes that it creates a fire hazard when it is dry. Other exotic grasses have also become established on the ranch, and pose issues for the native environment in their totality, if not to individual species.

Putting aside the discussion of exotic grasses and human impacts, it is hard to read this flora and not feel a little optimistic. The documentary photos of the land are beautiful landscapes, and the plant photos are an independent work unto themselves. This is Arizona at its best, and science writing at its finest. The Salero flora is scientific documentation concerning a plant study, but it reads like entertainment. The flora touches all the bases necessary for a complete and very useful science document, but offers all the interest of botany for a diversity of plant lovers. It would fit well on anyone's bookshelf right there between Janice Bowers and Kathryn Mauz.

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