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Sweet Resin Bush on the Santa Rita Experimental Range: An Eradication Effort

Abstract: Sweet resin bush (*Euryops subcarnosus* DC ssp. *vulgaris* B. Nord; or, *Euryops multifidis* (*L. f.*) *DC.*), a South African shrub introduced to Arizona in the 1930s, was discovered on the Santa Rita Experimental Range (SRER) in 1998. Due to the threat of spread of this invasive plant and its potential to cause adverse environmental and economic effects, and because it posed a threat to the Federally listed endangered Pima pineapple cactus (*Coryphantha sheerii* Muehlenph. L.D. Benson var. *robustispina* L.D. Benson), we initiated a project in early 1999 with the overall goal of eradicating about 154 acres of the shrub from SRER. Prior to initial treatments in 1999, permanent monitoring plots were randomly established within grazed and ungrazed areas that contained heavy, moderate, or no amounts of sweet resin bush. Plant cover (percent) and density (plants per 15m^2) were sampled in January and February for 4 consecutive years (1999 to 2002). Sweet resin bush was hand grubbed in 1999, 2000, and 2001. Picloram (Tordon 22K) was spot sprayed via a backpack sprayer in February 1999 to soil areas where sweet resin bush had been grubbed. Initial eradication treatments in 1999 (mechanical + chemical) greatly reduced sweet resin bush species composition and density, and apparently released soil moisture and nutrients, allowing some native plants to re-establish in 2000. Sweet resin bush seedling density increased substantially in 2001; however, the combined effects of mechanical and herbicidal treatments along with periodic drought substantially reduced sweet resin bush density and canopy cover by 2002. No new seed production occurred for sweet resin bush on SRER during this 4-year study, and we detected no encroachment of sweet resin bush into uninfested control plots (grazed or ungrazed). Although this project greatly reduced sweet resin bush on SRER, total eradication of the shrub was not accomplished. Surveys and eradication efforts for sweet resin bush are planned on SRER for at least another 10 years.

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Introduction

Sweet resin bush is a low-growing, South African shrub that was introduced into several areas of southern and central Arizona during the 1930s (Pierson and McAuliffe 1995). The shrub was selected for introduction into the arid southwest

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because it could readily propagate from seed and was extremely drought resistant. Other perceived benefits included the exotic shrub's ability to control soil erosion and provide nutritional forage for sheep. Paradoxically, some areas where sweet resin bush was introduced has experienced reduced ground cover, increased soil erosion, and decreased forage production. The shrub exhibited a remarkable ability to displace native vegetation and transform extensive landscapes into monocultures, and unfortunately proved to be unpalatable to domestic and wild herbivores. Currently, sweet resin bush infests several thousand acres in southern and central Arizona (McAuliffe 2000).

In 1998, an employee from the Natural Resource Conservation Service (NRCS) discovered a dense core infestation and several smaller "satellite" stands of sweet resin bush scattered across approximately 154 acres in and near the Gravelly Ridge Exclosure of SRER. Due to the threat of spread of this invasive plant and its potential to cause adverse environmental and economic effects, NRCS, the University of Arizona, Arizona State Lands Department, and U.S. Fish and Wildlife Service (USFWS) decided to cooperatively plan and implement a multiyear project to eradicate SRER sweet resin bush infestation. The USFWS was consulted because the Federally listed endangered Pima pineapple cactus was known to occur in the project area and was threatened by sweet resin bush expansion.

Objectives of this 4-year project were to (1) contain sweet resin bush expansion on SRER using mechanical and chemical control measures to remove plants around the infestation's perimeter, working inward to remove the core infestation; (2) evaluate effectiveness of combined mechanical and herbicidal control techniques; and (3) monitor changes in species composition and density in grazed and ungrazed plots that contained heavy, moderate, or no amounts of sweet resin bush. We monitored infested and uninfested areas, and grazed and ungrazed areas to evaluate potential influences of sweet resin bush and disturbance associated with grazing on plant community dynamics.

Methods

Pima Pineapple Cactus

In compliance with USFWS consultation, conservation measures were developed and implemented before eradication treatments were executed to locate and protect individual Pima pineapple cactus plants growing in or near areas infested by sweet resin bush. A detection team, consisting of employees from NRCS, the University of Arizona, and AmeriCorps volunteers, implemented USFWS sampling protocol. Pima pineapple cactus plant locations were recorded in a global positioning system (GPS) and flagged prior to applying treatments in 1999.

Sweet Resin Bush and Other Vegetation

In January 1999, we randomly established a total of 24 15-m^2 permanent plots in grazed (outside the Gravelly Ridge Exclosure) and ungrazed areas (inside the Gravelly Ridge Exclosure) that were ocularly estimated to contain a heavy, moderate, or no sweet resin bush cover. We collected baseline plant cover and density data for grasses, forbs, and woody plants detected in permanent plots just prior to applying treatments (table 1). Cover data were collected using the line intercept technique to determine basal (grasses) or canopy (forbs, cactus, and woody species) cover along permanent 15-m transects. Cover data were used to calculate species composition for two life form categories plus sweet resin bush (herbaceous vegetation, cactus and woody vegetation other than sweet resin bush, and sweet resin bush). For density data, we counted individual plant species rooted within permanent 15-m^2 plots. Density data were tallied by individual plant species and summarized using six life form categories plus sweet resin bush (annual grass, annual forb, perennial grass, perennial forb, woodies, cactus, and sweet resin bush).

In February 1999, nine AmeriCorps volunteers spent 2 weeks hand grubbing sweet resin bush using hoes, picks, shovels, and hand pulling. The sweet resin bush core infestation consisted of about 5 acres that were heavily infested, and a few satellite infestations that radiated outward from the core infestation to encompass a total of 154 acres. AmeriCorps volunteers were instructed to remove all sweet resin bush plants (mature and seedlings) from satellite and

Table 1—Plant species sampled in permanent sampling plots on Santa Rita Experimental Range, 1999 to 2002.

Common name	Scientific name
Grasses	
Arizona cottontop	*Digitaria californica* (Benth.) Henr.
Bush muhly	*Muhlenbergia porteri* Scribn. ex Beal
Fluffgrass	*Erioneuron pulchellum* (H.B.K.) Tateoka
Lehmann lovegrass	*Eragrostis lehmanniana* Nees
Plains bristlegrass	*Eragrostis intermedia* Hitchc.
Rothrock grama	*Bouteloua rothrockii* Vasey
Six-weeks grama	*Bouteloua aristidoides* (H.B.K.) Griseb.
Slender grama	*Bouteloua repens* (H.B.K) Scribn. & Merr.
Three awn spp.	*Aristida* spp.
Forbs	
Ayenia	*Ayenia insulicol* Cristobal
Deerweed	*Porophyllum gracile* Benth.
Desert senna	*Senna bauhinioides* (Gray) Irwin & Barneby
Ditaxis	*Argythamnia neomexicana* Muell. Arg.
Evolvulus	*Evolvulus arizonicus* Gray
Nightshade	*Solanum* spp.
Purple aster	*Machaeranthera tanacetifolia* (Kunth) Nees
Sida	*Sida abutifolia* P. Mill.
Spurge	*Chamaesyce albomarginata* (Torr. & Gray)
Woodies and cactus	
Burroweed	*Isocoma tenuisecta* Greene
Cactus spp.	*Opuntia* spp.
Desert zinnia	*Zinnia acerosa* (DC.) Gray
False mesquite	*Calliandra eriophylla* Benth.
Janusia	*Janusia gracilis* Gray
Mesquite	*Prosopis velutina* Woot.
Mormon tea	*Ephedra* spp.
Palo verde	*Cercidium* spp.
Range ratany	*Krameria grayi* Rose & Painter
Sweet resin bush	*Euryops subcarnosus* DC. ssp. *vulgaris* B. Nord
Whitethorn	*Acacia constricta* Benth.
Wolfberry	*Lycium* spp.

core infestations. As the crew removed individual sweet resin bush plants, a one-time Picloram (Tordon 22K; 1 qt ai/acre) treatment was applied via a backpack sprayer to soil areas where shrubs were grubbed to kill seedlings that might germinate near parent plants in subsequent years. No herbicide was applied within 30 m of any Pima pineapple cactus plant as directed by USFWS. Boy Scout volunteers also helped to mechanically remove sweet resin bush plants during the summer and fall of 1999 and 2000. In March of 2001, another AmeriCorps crew spent 1 week scouting the original 154-acre infestation and mechanically removing any sweet resin bush plants found growing in the formerly infested area. We collected post-treatment plant cover, species composition, and density data during January and February of 2000 to 2002 in the same manner described for pretreatment baseline data collected in 1999. Precipitation data for the Gravelly Ridge Exclosure were accessed via SRER Database.

Results and Discussion

Pima Pineapple Cactus

A total of 21 Pima pineapple cactus plants were located outside the core sweet resin bush infestation, and near "satellite" infestations. No Pima pineapple cactus plants were detected within the core infestation itself, or within any of our permanent monitoring plots.

Species Composition

Prior to treatments in 1999, sweet resin bush respectively made up 72 and 64 percent of species composition in heavily infested grazed and ungrazed plots (figs. 1A,B) and 41 and 11 percent in moderately infested grazed and ungrazed plots (figs. 2A,B). After 1999 treatments, no plot contained more than10 percent sweet resin bush from 2000 to 2002. Thus, combined mechanical and herbicidal treatments were effective in initially removing sweet resin bush cover from treated plots.

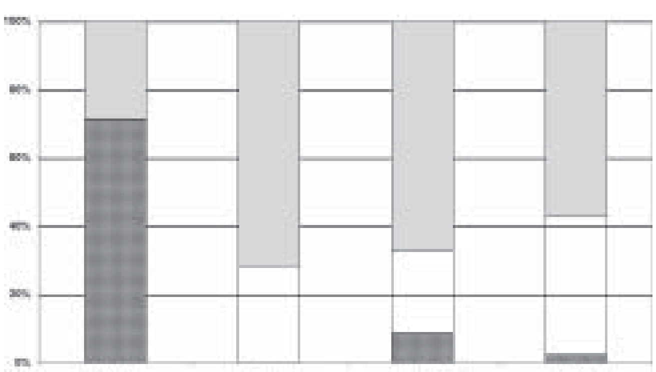

Figure 1A—Species composition (percent) in heavily infested grazed plots before (1999) and after (2000, 2001, and 2002) eradication efforts near the Gravelly Ridge Exclosure, SRER (clear bars = herbaceous vegetation; light gray bars = cactus and woody vegetation other than sweet resin bush; darkest bars = sweet resin bush).

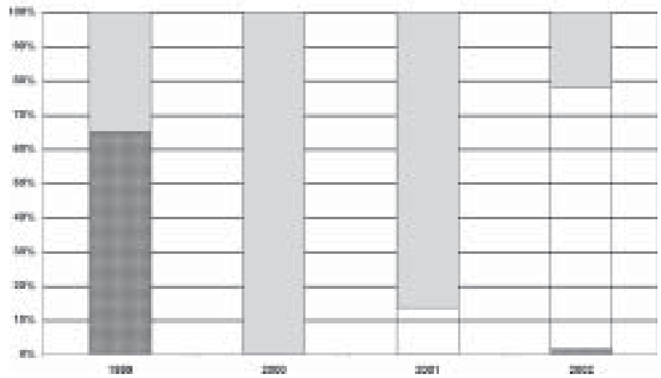

Figure 1B—Species composition (percent) in heavily infested ungrazed plots before (1999) and after (2000, 2001, and 2002) eradication efforts near the Gravelly Ridge Exclosure, SRER (clear bars = herbaceous vegetation; light gray bars = cactus and woody vegetation other than sweet resin bush; darkest bars = sweet resin bush).

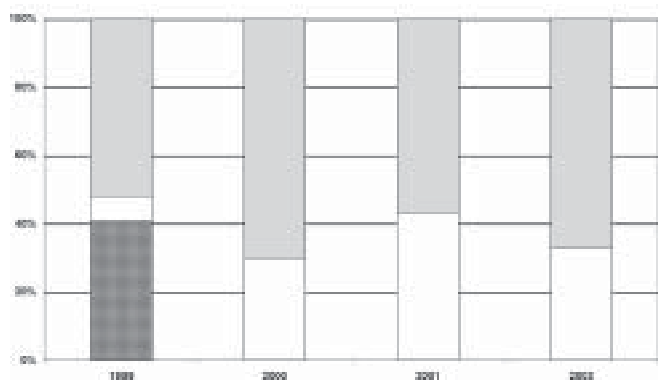

Figure 2A—Species composition (percent) in moderately infested grazed plots before (1999) and after (2000, 2001, and 2002) eradication efforts near the Gravelly Ridge Exclosure, SRER (clear bars = herbaceous vegetation; light gray bars = cactus and woody vegetation other than sweet resin bush; darkest bars = sweet resin bush).

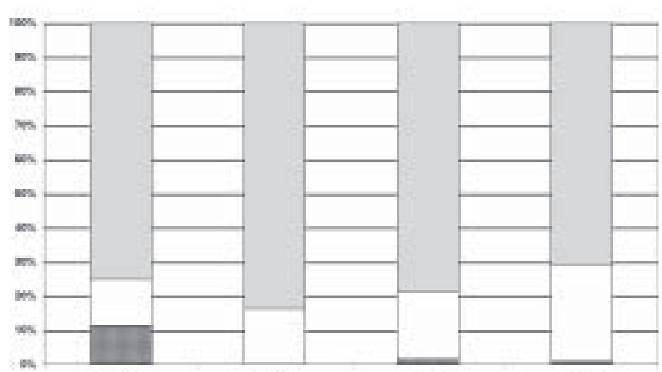

Figure 2B—Species composition (percent) in moderately infested ungrazed plots before (1999) and after (2000, 2001, and 2002) eradication efforts near the Gravelly Ridge Exclosure, SRER (clear bars = herbaceous vegetation; light gray bars = cactus and woody vegetation other than sweet resin bush; darkest bars = sweet resin bush).

Species composition remained relatively stable in control plots from 1999 to 2002, although grazed control plots contained higher relative amounts of herbaceous cover than ungrazed control plots every year of the study (figs. 3A,B). No sweet resin bush plants were detected in grazed or ungrazed control transects or plots in any year of the study.

Density

Prior to treatments in 1999, mean sweet resin bush density was respectively 167 and 67 sweet resin bush plants per 15 m^2 in heavily infested grazed and ungrazed plots (tables 2A,B), and 85 and 39 plants per 15 m^2 in moderately infested grazed and ungrazed plots (tables 3A,B). These same plots contained less than four sweet resin bush plants in 2000. Little precipitation occurred from January to May

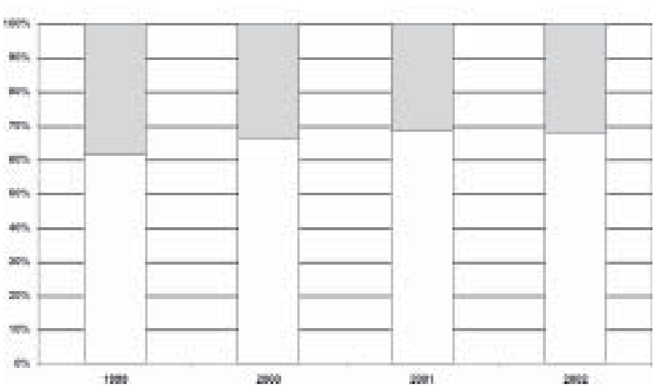

Figure 3A—Species composition (percent) in grazed plots with no sweet resin bush before (1999) and after (2000, 2001, and 2002) eradication efforts near the Gravelly Ridge Exclosure, SRER (clear bars = herbaceous vegetation; light gray bars = cactus and woody vegetation other than sweet resin bush).

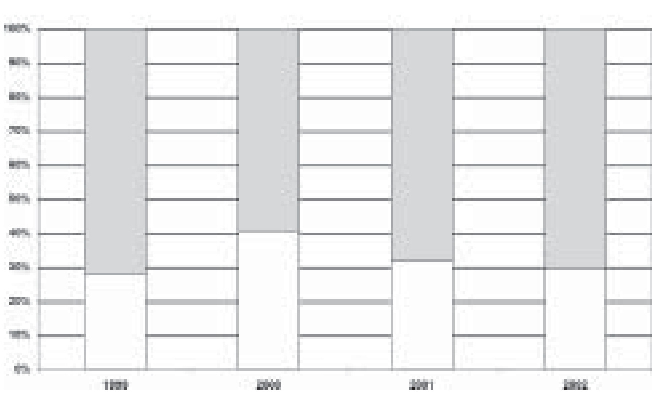

Figure 3B—Species composition (percent) in ungrazed plots with no sweet resin bush before (1999) and after (2000, 2001, and 2002) eradication efforts near the Gravelly Ridge Exclosure, SRER (clear bars = herbaceous vegetation; light gray bars = cactus and woody vegetation other than sweet resin bush).

Table 2A—Mean density (plants per 15 m^2, ± 6 SE) of sweet resin bush and other plants by life form in grazed plots that were heavily infested with sweet resin bush in 1999.

	Year			
Life form	**1999**	**2000**	**2001**	**2002**
Annual grass	0	7	154	0
Annual forb	15	13	165	179
Perennial grass	3	26	87	121
Perennial forb	0	2	10	4
Woodies	21	6	7	6
Cactus	0	0	0	0
Sweet resin bush	167	2	134	17

Table 2B—Mean density (plants per 15 m^2, ±6 SE) of sweet resin bush and other plants by life form in ungrazed plots that were heavily infested with sweet resin bush in 1999.

	Year			
Life form	**1999**	**2000**	**2001**	**2002**
Annual grass	0	1	43	40
Annual forb	8	0	312	303
Perennial grass	0	4	23	17
Perennial forb	0	0	8	2
Woodies	17	4	3	4
Cactus	1	0	1	1
Sweet resin bush	67	1	21	3

Table 3A—Mean density (plants per 15 m^2, ± 6 SE) of sweet resin bush and other plants by life form in grazed plots that were moderately infested with sweet resin bush in 1999.

	Year			
Life form	**1999**	**2000**	**2001**	**2002**
Annual grass	0	3	282	10
Annual forb	120	23	488	410
Perennial grass	28	38	26	24
Perennial forb	3	11	24	11
Woodies	12	12	11	11
Cactus	9	3	5	2
Sweet resin bush	85	2	4	2

Table 3B—Mean density (plants per 15 m^2, ± 6 SE) of sweet resin bush and other plants by life form in ungrazed plots that were moderately infested with sweet resin bush in 1999.

	Year			
Life form	**1999**	**2000**	**2001**	**2002**
Annual grass	0	9	153	6
Annual forb	86	22	680	474
Perennial grass	45	119	10	50
Perennial forb	21	9	20	1
Woodies	41	21	29	20
Cactus	5	11	6	5
Sweet resin bush	39	3	64	3

1999 (1.76 inches), which likely hindered sweet resin bush germination and the ability of Picloram to kill actively growing sweet resin bush seedlings during the first year of the study. January to May precipitation in 2000 was even more limited (1.55 inches), which apparently continued to limit sweet resin bush germination, and thus, herbicide kill of shrub seedlings.

In early 2001, sweet resin bush seedling density substantially increased in heavily infested grazed and ungrazed plots (tables 2A,B), and in moderately infested ungrazed plots (table 3B). Fall, winter, and spring (October to May) precipitation was above average in 2000 to 2001 (11.85 inches), which provided a favorable opportunity for sweet resin bush seedlings to germinate in 2001. Another Americorp crew mechanically removed these seedlings in 2001 about 1 month after plots were sampled, which helped to reduce sweet resin bush density by January and February 2002 (less than 18 plants per 15 m^2; tables 2A,B, and 3B). Moreover, data collected in early 2002 fell in the middle of another very dry fall, winter, and spring (only 1.27 inches of precipitation from October 2001 to May 2002), which likely inhibited additional sweet resin bush germination during this dry spell.

Annual grasses and annual forbs showed slight to dramatic increases in density in at least one of the years after sweet resin bush was initially treated (2000 to 2002), especially in early 2001 following the wettest year of the study (19.39 inches in 2000). The flush of annuals in early 2001 coincided with the substantial increase of sweet resin bush seedlings during the same time. Grazed and ungrazed control plots also exhibited dramatic annual plant production in 2001 (tables 4A,B).

Table 4A—Mean density (plants per 15m^2, ± 6 SE) of sweet resin bush and other plants by life form in grazed plots that contained no sweet resin bush in 1999.

Life form	Year 1999	2000	2001	2002
Annual grass	0	9	15	1
Annual forb	70	203	670	269
Perennial grass	14	25	13	14
Perennial forb	11	79	40	5
Woodies	7	7	5	5
Cactus	1	1	4	2
Sweet resin bush	0	0	0	0

Table 4B—Mean density (plants per 15 m^2, ± 6 SE) of sweet resin bush and other plants by life form in ungrazed plots that contained no sweet resin bush in 1999.

Life form	Year 1999	2000	2001	2002
Annual grass	0	9	4	4
Annual forb	90	286	1,224	879
Perennial grass	7	9	6	4
Perennial forb	26	120	81	9
Woodies	12	13	13	12
Cactus	0	0	0	0
Sweet resin bush	0	0	0	0

Mechanical and herbicidal treatments in the heavily and moderately infested plots (both grazed and ungrazed) in 1999 apparently reduced competition for soil moisture and nutrients, allowing an increase in perennial grass density by 2000 (tables 2A,B; 3A,B). Summer rainfall in 1999 (9.6 inches from June to September) was favorable for warm season perennial grass production, which was detected in our plots in early 2000.

Woody plant density declined substantially in heavily infested plots (both grazed and ungrazed) and in moderately infested plots that were ungrazed after the initial eradication treatment in 1999. Volunteers may have mistaken native, low-growing shrubs for sweet resin bush because density reductions occurred in false mesquite (*Calliandra eriophylla* Benth.), range ratany (*Krameria grayi* Rose & Painter), and desert zinnia (*Zinnia acerosa* (DC.) Gray). Picloram applied to grubbed areas could also have injured or killed native shrubs. Conversely, woody plant density remained remarkably constant in both grazed and ungrazed control plots where no mechanical or herbicidal treatments were applied (tables 4A,B).

Summary and Conclusions

Combined mechanical and chemical control measures were effective in initially removing core and satellite sweet resin bush infestations from the Gravelly Ridge area of SRER. Sweet resin bush removal in 1999 apparently released soil moisture and nutrients, allowing some components of the native plant community to begin reestablishing within 1 year. However, timing and amount of precipitation (or lack thereof) was apparently the major factor driving plant community dynamics throughout the project. Drought in early and late 1999 and throughout the first half of 2000 likely kept sweet resin bush seedling production at bay until late 2000 or early 2001; hence, there was negligible opportunity for Picloram to kill sweet resin bush seedlings during this dry period.

This field project integrated mechanical and herbicidal control measures during above and below average precipitation years and was not designed to differentiate sweet resin bush mortality due to mechanical removal, Picloram, or drought (for example, no sweet resin bush plants were left intact to monitor drought-caused mortality). Mechanical removal of sweet resin bush by volunteers in 1999, 2000, and 2001 certainly played a key role in keeping sweet resin bush in check throughout the project. In addition, both Picloram and drought likely impaired sweet resin bush seedling production during the 4-year project. However, Picloram could not override the effects of above average precipitation in late 2000, which stimulated a substantial increase in sweet resin bush seedling density in most plots by the time they were measured in early 2001. We speculate that without the one-time Picloram application in 1999, sweet resin bush seedling density may have been even more pronounced in 2001. It is noteworthy that the combined effects of mechanical and herbicidal treatments, in addition to periodic drought, prevented any **new** seed production by sweet resin bush for the entirety of our 4-year project.

Grazed plots were located immediately outside of the grazing exclosure to intentionally select a "worst case scenario" for grazing disturbance because areas near fences are typically associated with amplified disturbance associated with livestock and wildlife trailing. Sweet resin bush species composition and density were initially higher in grazed versus ungrazed plots, indicating that disturbance may have facilitated sweet resin bush establishment in heavily impacted areas. However, no sweet resin bush plants were detected in grazed or ungrazed control plots during the entire study, demonstrating that the shrub had not established and did not spread approximately 400 m north where control plots were located. Moreover, no sweet resin bush plants were detected in grazed areas outside the original 154-acre infestation where grazing disturbance was much lower than in grazed study plots located immediately outside the exclosure. Thus, light to moderate grazing apparently did not facilitate the spread of sweet resin bush on SRER.

Noxious weed invaders often exhibit the potential to explode after a long period of slow and unapparent growth (Sheley and Petroff 1999). The 154-acre sweet resin bush infestation on SRER has not expanded to the degree other sweet resin bush infestations have in Arizona (for example, about 3,000 acres on Frye Mesa in east-central Arizona). Nevertheless, several cooperating agencies and organizations justified eradicating this invasive shrub from SRER for several reasons. First, the SRER sweet resin bush infestation was small enough to justify eradication as a goal. Second, SRER sweet resin bush infestation is only 5 km from the Santa Cruz River where seeds could potentially be transported hundreds of miles during flood events. Third, the stand is only 6 km from Green Valley, a rapidly growing urban area between Tucson and Nogales. This area, with increasing traffic and large disturbed areas around construction sites, offers ideal conditions for the shrub to spread. Fourth, Interstate 19 from Tucson to Nogales is an international corridor on which nearly two-thirds of the winter produce coming into the United States is transported each year. Hence, seed from SRER could easily become a source of introduction of sweet resin bush into Mexico. Finally, USFWS views sweet resin bush as a direct threat to Pima pineapple cactus survival because SRER is the only large area of prime cactus habitat currently protected from development.

Although we did not accomplish our main goal of eradicating sweet resin bush from SRER, significant progress was made during this project. Mechanical and herbicidal treatments along with periodic drought substantially reduced sweet resin bush density and canopy cover on SRER since 1999. The fact that no new seed production occurred on SRER during this project is of paramount importance in depleting the shrub's residual seed bank, thereby reducing and eventually eliminating its capacity to reproduce in the future. Conservation measures developed during this project to identify and protect individual Pima pineapple cactus plants were successful. This project has begun to restore native plants to the previously infested area, thereby facilitating habitat recovery for the cactus, and severely limiting the potential for additional colonies of sweet resin bush to establish in uninfested endangered cactus habitat. Nevertheless, the detection of significant numbers of sweet resin bush seedlings in 2001 indicates the crucial need for follow-up monitoring when invasive plants are targeted for eradication (Sheley and Petroff 1999). Survey and eradication efforts are planned on SRER during the next 10 years.

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