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Broom Snakeweed (*Gutierrezia sarothrae*): Toxicology, Ecology, Control, and Management

Michael H. Ralphs and Kirk C. McDaniel*

Broom snakeweed is a native weed widely distributed on rangelands of western North America. It often increases to near monocultures following disturbance from overgrazing, fire, or drought. This paper presents an up-to-date review of broom snakeweed toxicology, seed ecology, population cycles, succession, and management. The greatest ecological concern is that broom snakeweed displaces desirable forage for livestock or wildlife and greatly reduces biodiversity. It also is toxic and can cause abortions in all species of livestock. Propagation usually is pulse-driven in wet years, allowing large expanses of even-aged stands to establish and dominate plant communities. Snakeweed can be controlled by prescribed burning or spraying with herbicides. A weed-resistant plant community dominated by competitive grasses can prevent or minimize its reinvasion.

Nomenclature: Broom snakeweed, *Gutierrezia sarothrae* (Pursh) Britton & Rusby GUESA.

Key words: Invasive weed; poisonous plant; seed ecology; population cycles; state-and-transition model.

Broom snakeweed [*Gutierrezia sarothrae* (Pursh) Britton & Rusby] is widely distributed across western North America, from Canada south through the plains to west Texas and northern Mexico, and west through the Intermountain region and into California (Figure 1). It ranges in elevation between 50 and 2,900 m (160 and 9,500 ft) and commonly inhabits dry, well-drained, sandy, gravely, or clayey loam soils (Lane 1985).

Broom snakeweed is a suffrutescent subshrub, with many unbranched woody stems growing upwards from a basal crown, giving it a broom-shaped appearance. These stems die back each winter and new growth is initiated from the crown in early spring. It often is confused with two similar plants. Douglas rabbitbrush [*Chrysothamnus viscidiflorus* (Hook.) Nutt.] is similar in appearance, but is distinguished by its multibranched woody stems and linear twisted leaves. The closely related threadleaf snakeweed [*G. microcephala* (DC.) A. Gray] is similar in growth form and appearance, but differs in that it has only one to two florets per flowering head, compared to three to five in broom snakeweed. Most of this review pertains to broom snakeweed.

Broom snakeweed is a native plant that can increase in density when other more desirable plants are reduced or removed by disturbance, such as overgrazing, fire, or drought. It can dominate many of the plant communities on western rangelands, including: salt desert shrub, sagebrush, and pinyon–juniper plant communities of the Intermountain region; short- and mixed-grass prairies of the plains; and mesquite, creosotebush, and desert grassland communities of the southwestern deserts (U.S. Forest Service 1937). In addition to its invasive nature, it contains toxins that can cause abortions in livestock (Dollahite and Anthony 1957). Platt (1959) ranked it one of the most undesirable plants on western rangelands.

Interpretive Summary

Broom snakeweed is an invasive native subshrub that is distributed widely across rangelands of western North America. In addition to its invasive nature, it contains toxins that can cause death and abortions in livestock. It establishes in years of above-average precipitation following disturbance by fire, drought, or overgrazing. This allows widespread, even-aged stands to develop that can dominate plant communities. Although its populations cycle with climatic patterns, it can be a major factor impeding succession of plant communities. Snakeweed can be controlled with prescribed burning and herbicides; however, a weed-resistant plant community should be established and/or maintained to prevent its reinvasion. Proper grazing management to maintain competitive grasses is essential for suppression of this invasive weed.

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* Rangeland Scientist, USDA/ARS Poisonous Plant Lab, Logan UT 84341; Professor, Animal and Range Science Department, New Mexico State University, Las Cruces NM 88003. Corresponding author's E-mail: Michael.Ralphs@ars.usda.gov

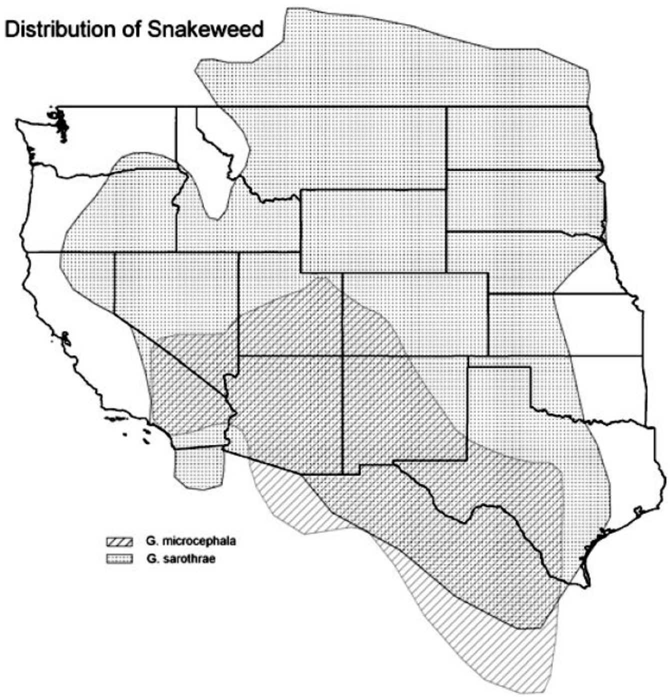

Figure 1. Distribution of broom snakeweed (dots) and threadleaf snakeweed (hatched).

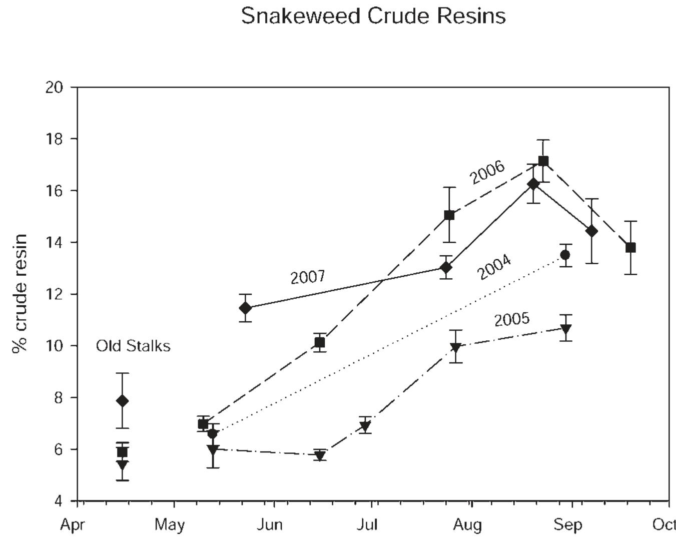

Figure 2. Crude resin concentration in aboveground foliage of broom snakeweed over the growing season and among years.

Previous reviews have discussed the ecology and control of snakeweeds (Huddleston and Pieper 1989; McDaniel and Ross 2002; McDaniel and Sosebee 1988; McDaniel and Torell 1987; Sterling et al. 1999). This paper briefly reviews broom snakeweed toxicology, and presents recent information on its seed ecology, population cycles, succession, and management.

Chemistry. The toxic and abortifacient compounds in snakeweeds have not been identified clearly. Dollahite et al. (1962) extracted a crude saponin fraction that was demonstrated to induce abortions and death in cows, goats, and rabbits. However, saponins are a very broad and poorly defined complex of compounds that foam when agitated. Roitman et al. (1994) found specific furanoditerpene acids in broom snakeweed that structurally are similar to isocupressic acid, the abortifacient compound in ponderosa pine needles. Gardner et al. (1999) speculated that whether a cow aborts or is poisoned depends on the concentration of specific diterpene acids.

Crude resin includes most of the terpenes and other nonpolar carbon-based secondary compounds in broom snakeweed. It has been used as an index of palatability and potential toxicity (Ralphs et al. 2007). Crude resin concentration in the old dry stalks from the previous year ranged between 6 to 8% of the dry weight of the plants (Figure 2). Resins in the new growth increased over the growing season, peaked during flowering (16%), then declined slightly as seeds shattered. They accumulate over the growing season, similar to other Asteraceae species, big sagebrush (*Artemisia tridentata* subsp. *tridentata* Nutt.) (14 to 25%; Cedarleaf et al. 1983; Kelsey et al. 1982) and rabbitbrush [*Chrysothamnus nauseosus* (Pall. ex Pursh) Briton subsp. *turbinatus* (M. E. Jones) H. M. Hall and Clem.] (36%; Hegerhorst et al. 1988). As in sagebrush and rabbitbrush, the high concentration of crude resins renders snakeweed unpalatable to livestock and wildlife.

Toxicology. If animals eat snakeweed, they can be poisoned or pregnant animals can abort. Clinical signs of poisoning include anorexia, nasal discharge, loss of appetite and listlessness, diarrhea followed by constipation, and rumen stasis, which can lead to death (Mathews 1936). Clinical signs of the abortion include weak uterine contractions, occasional incomplete cervical dilation, and excessive mucus discharge (Dollahite and Anthony 1957). The abortion often results in stillbirth or the birth of small weak calves, depending on the period of gestation. Cows that have aborted can retain the placenta, which can lead to uterine infection and death.

Low nutrition exacerbates fertility problems caused by broom snakeweed. Smith et al. (1991, 1994) reported that increasing amounts of snakeweed in rat diets reduced intake of food, which led to malnutrition and contributed to diminished fertility and increased fetal mortality. Edrington et al. (1993) confirmed that increasing amounts of snakeweed in rat diets reduced intake, but it directly impaired hormonal balance and disrupted blood flow to the uterus and developing embryos, leading to fetal death. Ewes fed low-quality blue grama hay [*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths] (11% crude protein) refused to consume rations containing more than 10% snakeweed, and 43% of these ewes did not show estrus and did not breed (Oetting et al. 1990). In contrast, ewes on high-quality alfalfa (18% crude protein) readily consumed the ration mixed with up to 25% snakeweed, and showed no adverse effects on estrus. Heifers fed snakeweed as 15% of a balanced diet before breeding and during early gestation showed no effect on progesterone levels or conception rates (Williams et al. 1992). Snakeweed added up to 30% of this same diet during the last trimester of gestation, did not cause abortion or lower calf birth weight (Martinez et al. 1993).

Supplemental protein and energy might enhance degradation and elimination of terpenes. Strickland et al. (1998) reported that a protein supplement improved tolerance to snakeweed toxicosis in cows in low body condition. Cows receiving protein had greater elimination of bromosulphthalein (BSP), indicating an increased capacity of the liver to conjugate and eliminate xenobiotics in Phase II biotransformation. They also had lower bilirubin and alkaline phosphatase levels, indicating less liver damage. In contrast, Ralphs et al. (2007) reported no effect of a special supplement formulated to provide bypass protein high in sulfur-containing and glucogenic amino acids and additional energy for detoxification of terpenes. It remains unclear whether protein or energy supplements will prevent snakeweed poisoning or abortions.

Seed Ecology. Snakeweed is a short-lived perennial shrub, typically surviving 4 to 7 yr (Dittberner 1971). It is a prolific seed producer with 2,036 to 3,928 seeds plant^{-1} (Wood et al. 1997). Seeds held in dried flower heads gradually are dispersed over winter, mainly during high wind and snowfall events. They have no specialized structures such as wings to aid in long-range dispersal, thus they usually drop directly beneath or close to the parent plant. Seed remain viable over winter and into spring, but rapidly disintegrate if they remain exposed on the soil surface (Wood et al. 1997). Optimum germination occurs in spring with alternating night and day temperatures between 10 and 20 C (50 and 68 F) (Mayeux and Leotta 1981). Germination is light-stimulated (Mayeaux 1983); therefore, seeds must remain partially exposed on the soil surface (Mayeux and Leotta 1981). The soil surface also must remain near saturation for at least 4 d for the seeds to imbibe and germinate successfully (Wood et al. 1997). Buried seeds remain viable for several years and germinate when moved to the soil surface by disturbance (Mayeux 1989).

Pulse Establishment. The fluctuating resource availability theory of invasibility (Davis et al. 2000) suggests that plant communities are more susceptible to weed invasion whenever there are unused resources. This occurs when there is either an increase in resource supply or a decrease in resource use. Snakeweed populations often establish in years with above-average precipitation following disturbance that reduces competition from other vegetation. McDaniel et al. (2000) monitored snakeweed germination and establishment in permanent plots from 1990 to 1998 following burning and herbicide treatments applied on shortgrass prairies in central New Mexico. The majority of the 394 snakeweed seedlings $\cdot$ m^{-2} established in the wet years of 1991 and 1992. Few seedlings were noted in other years when spring precipitation was below normal. Most seedlings established the first or second yr after burning events (92%), which exposed soil and reduced grass cover, compared to herbicide spraying (4%). The majority of the seedlings (64%) germinated in spring of 1992 when precipitation was 224% above average, and most establishment occurred in open spaces (71%) between grass plants.

Ralphs and Banks (2009) reported a new crop of snakeweed plants (30 $\cdot$ m^{-2}) established in a crested wheatgrass seeding [*Agropyron cristatum* (L.) Gaertner] after an intensive spring grazing trial when spring precipitation was 65% above average. A heavy late-spring snow storm occurred during the study and saturated the soil for several days. Intense grazing reduced the grass standing crop (which reduced use of soil moisture by crested wheatgrass) and trampling disturbed the soil surface, thus providing ideal soil and environmental conditions for snakeweed establishment.

In a companion defoliation study (Ralphs 2009), density of snakeweed seedlings was higher in clipped plots in both the crested wheatgrass seeding and in a native bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh) A. Löve] stand. Clipping reduced competition for soil moisture from grass and mature snakeweed plants, allowing new snakeweed seedlings to establish (57 m^{-2}) in the clipped treatment vs. 16 m^{-2} in the unclipped control plot in the crested wheatgrass seeding, and 7.9 m^{-2} vs. 1.5 m^{-2}, respectively, in the bluebunch wheatgrass stand. This study showed that in wet years, snakeweed can establish even in healthy stands of native bluebunch wheatgrass or seeded crested wheatgrass, when heavy defoliation of the grasses reduces competition for soil moisture.

Population Cycles. Pulse establishment allows massive even-aged stands of snakeweed to establish. There is little intraspecific competition among snakeweed seedlings (Thacker et al. 2009a), thus large expanses of even-aged stands establish in wet years. As these stands mature, they become susceptible to die-off, mainly from insect damage or drought stress. Although snakeweed is highly competitive for soil moisture, it is not particularly drought-tolerant (Pieper and McDaniel 1989; Wan et al. 1993b). In southern New Mexico, broom snakeweed populations died out during droughts in 1970 to 1971, 1978, 1982, and 1994, but rapidly reestablished in subsequent wet winters or springs (Beck et al. 1996, 1999; McDaniel 1989a;

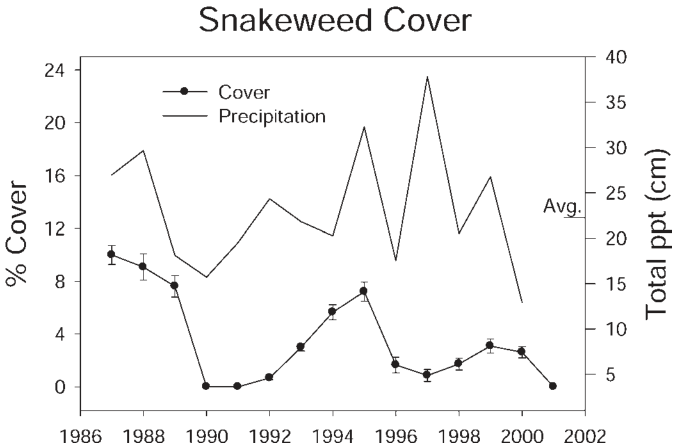

Figure 3. Population cycle of broom snakeweed and annual precipitation (Ralphs and Sanders 2002).

McDaniel et al. 2000; Pieper and McDaniel 1989). The buried seed must have been exposed by the heavy precipitation, and the saturated soil conditions enabled germination. In central New Mexico, most mature snakeweed plants died in 1994 from drought stress and thereafter only occurred at minimal levels for the next 15 yr because spring precipitation remained below normal (Torell et al. 2011). Ralphs and Sanders (2002) reported snakeweed populations in a salt desert shrub community on the Colorado Plateau died out in 1990, re-established in 1994, declined in 1996, completely died out in 2001 (Figure 3), and have not re-established during the current region-wide drought. In a crested wheatgrass seeding on the Snake River plain, snakeweed established during the wet years of 1983 to 1986, died back in the drought of 1992, and completely died out in 2000 (Ralphs and Sanders 2002), and has not reestablished since. It appears that the short-term increase in populations might have come from seeds in the seed bank germinating in favorable years, but the extended void in the populations could require the slow reinvasion process of a few plants establishing, setting seed, and gradually increasing the seed source.

Competition. Once established, snakeweed is very competitive with other vegetation. McDaniel et al. (1993) reported a negative exponential relationship between snakeweed overstory and grass understory that implies snakeweed's presence, even in minor amounts, suppresses grass growth. Partial removal of snakeweed allowed remaining plants to increase in size and continue to dominate the plant community (Ueckert 1979). Total removal allowed grass production to increase > 400% on blue grama grasslands (McDaniel and Duncan 1987; McDaniel et al. 1982). Control strategies should strive for total snakeweed control.

Snakeweed's root structure and depth provide a competitive advantage over associated grasses for soil moisture (Torell et al. 2011). In the southwest, its deeper roots enable it to extract soil water at greater depths (30 to 60 cm [12 to 24 in]), compared to the shallow-rooted sand dropseed [*Sporobolus cryptandrus* (Torr.) A. Gray] (Wan et al. 1993c). Snakeweed populations in the northern Great Basin have shallower roots of smaller diameter than plants growing on southern plains and prairie (Wan et al. 1995). In its northern range, snakeweed is acclimated to a saturated soil profile from snowmelt and spring rains to sustain rapid growth. When soil water stress increases seasonally or during drought, leaf stomata do not close completely (DePuitt and Caldwell 1975; Wan et al. 1993a); this allows snakeweed to continue transpiring. This depletes soil moisture to the detriment of associated grasses. If drought persists, leaf growth declines and leaves are eventually shed to cope with water stress, but stems continue photosynthesis to enable it to complete flowering and seed production (DePuitt and Caldwell 1975). However, as drought stress increases, tissues dehydrate and mortality occurs rapidly (< 10 d) when soil water potential drops below −7.5 MPa and leaf water content declines to 50% (Wan et al. 1993b).

Succession Patterns. Early researchers suggested broom snakeweed originally was found on rocky ridges, gravelly slopes, and infertile soils (Parker 1939). Overgrazing disturbed grass communities and allowed snakeweed to increase or invade deeper, more fertile soils, which resulted in a decline in the successional status of many plant communities (Campbell and Bomberger 1934; Costello and Turner 1941; Dayton 1931; Green 1951; Talbot 1926; Wooton 1915). Snakeweed commonly was considered an indicator of poor range condition (reviewed by McDaniel and Torrell 1987). However, Jameson (1970) showed its populations fluctuated with wet and dry periods, and concluded it was not a reliable indicator of range condition. It even has increased in good condition plant communities (high seral stage of succession) in the absence of grazing (Chew 1982; Hennessy et al. 1983).

In sagebrush/bunchgrass plant communities of the Intermountain region, snakeweed was a minor component, averaging 1.9% foliar cover on undisturbed sites (Christensen 1964a). It increased to 5.9% cover (which amounted to 31% of the perennial plant cover) following overgrazing and when fire removed the sagebrush overstory (Christensen 1964b; Pickford 1932). Snakeweed also increased following fire in the sagebrush steppe in Idaho (Pechanec and Blaisdell 1954), and the pinyon–juniper type in Arizona (Arnold et al. 1964). Once established, snakeweed often dominates for several years until sagebrush or juniper reestablish. The successional pattern begins with a few snakeweed plants that survive or establish rapidly after a fire; they produce abundant seed, and increase rapidly in the open niches. Snakeweed increased in varyingaged burns in the pinyon–juniper type of west-central Utah from 11% frequency 3 yr after burning, to a maximum frequency of 46 to 52% from 11 to 22 yr following a fire. After 22 yr, sagebrush increased and suppressed snakeweed, and finally juniper dominated the community at about 70 yr (Barney and Frischknecht 1974).

Healthy sagebrush/bunchgrass communities can suppress snakeweed. Thacker et al. (2008) described a fenceline contrast between a Wyoming big sagebrush/ bluebunch wheatgrass community and a degraded sagebrush/Sandberg bluegrass (*Poa secunda* J. Presl.) community in northern Utah. A 2001 wildfire removed the sagebrush in both communities. Snakeweed established on the degraded side of the fence and increased to 30% cover and dominated the site by 2005. Bunchgrasses on the other side of the fence prevented establishment of snakeweed.

Thacker et al. (2008) proposed a new broom snakeweed phase in the state-and-transition model of the Upland Gravelly Loam (Wyoming big sagebrush) ecological site (Figure 4). Two "triggers" (Briske et al. 2008) were identified that lead to snakeweed invasion. Heavy spring grazing over decades eliminated most of the bunchgrass in the plant community, putting the community "at risk" and eventually transitioning from the Current Potential State (2.2) over a threshold (T2b) to a dense Wyoming Sagebrush State (4). The lack of competition from bunchgrasses allowed snakeweed to establish in the understory. Fire then removed the sagebrush, and snakeweed was the first plant to germinate, establish, and rapidly increase and dominate the Snakeweed /Sandberg bluegrass phase (4.2). Subsequent fires will remove snakeweed and the site will likely transition over another threshold (T4b) to a cheatgrass (*Bromus tectorum* L.) community in the Invasive Plant State (5). Thacker et al. (2008) suggests that if robust perennial bunchgrasses can be maintained in the community, they will provide "resilience" (Briske et al. 2008) to resist snakeweed invasion or expansion, recover from fire or drought, and produce more forage for wildlife and livestock.

Management. Grazing systems designed to improve range condition can reduce snakeweed populations. Allison (1989) reported both four-pasture-one-herd, and short-duration grazing systems tend to have lower snakeweed populations over time. Increased grass cover provides competition with snakeweed, and increased grazing pressure in rotational grazing systems can force some consumption of snakeweed. Pieper (1989) reported that cattle will select some snakeweed early in spring before warm season grasses begin growth. Allison (1989) emphasized that nonuse does not reduce or prevent snakeweed infestations.

Targeted grazing has been investigated as a means of biological control, to force cattle to graze snakeweed. One group of cattle was positively conditioned to accept snakeweed (Ralphs and Wiedmeier 2004), and another group was forced to graze snakeweed using extremely high grazing pressure in narrow grazing lanes (Ralphs et al. 2007). The cows depleted the herbaceous forage in the mornings then turned to snakeweed in the evenings. The cows were moved to new lanes each day and were allotted sufficient herbaceous forage to maintain body condition. Over 4 yr, cattle consumed 50 to 85% of the snakeweed biomass and reduced snakeweed density from 2.1 to 0.31 plants m^{-2}. Even though the associated vegetation also was heavily grazed, crested wheatgrass cover was maintained in spring grazing trials, and actually increased in late summer grazing trials (Ralphs and Banks 2009). Although this study showed snakeweed could be controlled by grazing, the high stock density and time control of livestock might not be practical in a large-scale operation.

Snakeweed can be controlled by herbicides and prescribed burning. McDaniel and Ross (2002) recommended prescribed burning during the early stages of a snakeweed infestation or when mature plants are sparse and there is sufficient grass to carry a fire. Summer fires are more intense than at other seasons and kill most mature snakeweed plants (Dwyer 1967). However, weather conditions to conduct a safe and successful burn are difficult to come by in summer, thus spring burning (which also results in less grass damage) is the preferred time to burn in the southwest (McDaniel et al. 1997).

Herbicide control is recommended on dense snakeweed stands, particularly where fine fuels are not sufficient to carry a fire. Picloram at 0.28 kg ae ha^{-1} (0.25 lb ac^{-1}) or metsulfuron at 0.03 kg ai ha^{-1} (0.43 oz ac^{-1}) applied in the fall provided consistent control in New Mexico (McDaniel 1989b; McDaniel and Duncan 1987). Sosebee et al. (1982) suggested that fall applications were more effective than spring in the southwest because carbohydrate translocation was going down to the crown and roots, thus carrying the herbicide down to the perennating structures. Whitson and Freeburn (1989) recommended picloram at 0.56 kg ae ha^{-1} and metsulfuron at 0.04 kg ai ha^{-1} applied in the spring on shortgrass rangelands in Wyoming. In big sagebrush sites in Utah, the new herbicide aminopyralid at 0.12 kg ae ha^{-1} was effective when applied during the flower stage in fall, as was metsulfuron 0.042 kg ai ha^{-1} and picloram + 2,4-D 1.42 kg ae ha^{-1} (Keyes et al. 2011). Picloram by itself at 0.56 kg ae ha^{-1} was most effective and eliminated snakeweed when applied in either spring or fall. Residual control was obtained with tebuthiuron (80% wettable powder) at 1.1 to 1.7 kg ai ha^{-1} on mixed grass prairies in west Texas (Sosebee et al. 1979).

After snakeweed control, a weed-resistant plant community should be established to prevent reinvasion of snakeweed, cheatgrass, and other invasive weeds. Thacker et al. (2009a) reported competition from cool season

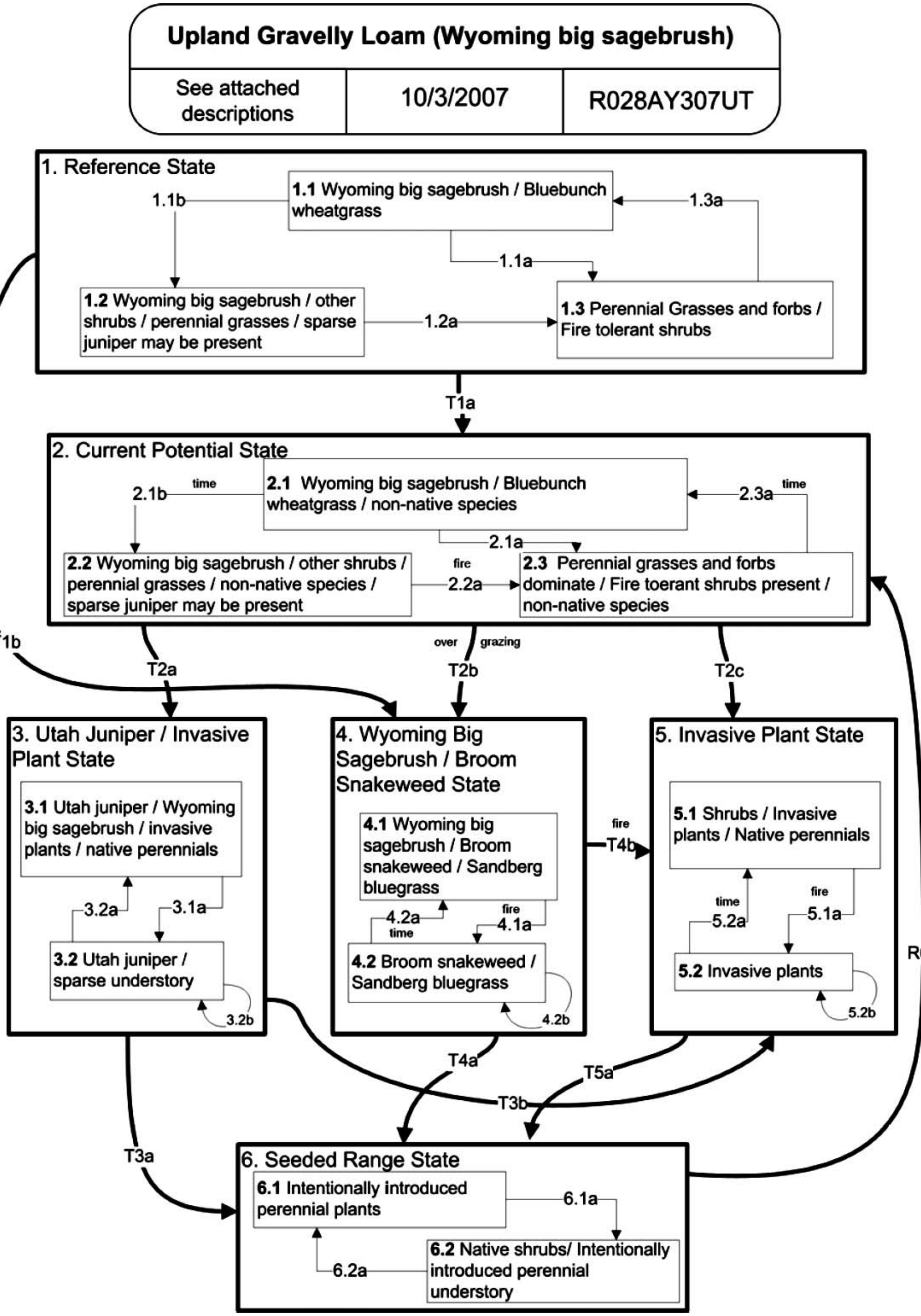

Figure 4. Upland Gravelly Loam (Wyoming big sagebrush) Ecological Site state-and- transition model. USDA/NRCS Ecological Site Description. at ftp://ftp-fc.sc.egov.usda.gov/UT/Range/D28AY/28AY307UT.pdf. Accessed: November 17, 2007.

grasses prevented establishment of snakeweed seedlings in both potted-plant and field studies. Snakeweed seedlings appear to be sensitive to competition from all established vegetation, including cheatgrass. Thus, disturbance appears necessary for it to establish. Hycrest crested wheatgrass [*Agropyron cristatum* (L.) Gaertner × *A. desertorum* (Fisch. Ex Link) Schultes] was the most reliable grass to establish on semiarid rangelands; thus, it was most effective in suppressing snakeweed establishment and growth (Thacker et al. 2009b). There appears to be a window of opportunity for grasses to suppress snakeweed in its seedling stage, if the grasses can be rapidly established. However, once established, snakeweed is very competitive and likely will remain and dominate the plant community.

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