

Status Review of the
Colorado Butterfly Plant
(*Gaura neomexicana* ssp. *coloradensis*)

Prepared for the
Wyoming Cooperative Fish and Wildlife Research Unit,
US Fish and Wildlife Service, and Wyoming Game and Fish Department

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INTRODUCTION

The Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) was first recognized as a distinct taxon by Rydberg (1904), based on a specimen collected near Fort Collins, Colorado in 1895. From 1899-1964, the plant was observed at only three other sites in northeast Colorado and along the Wyoming/Nebraska state line. Due to its apparent rarity, the Colorado butterfly plant was identified as a potential candidate for listing as Endangered under the Endangered Species Act by the Smithsonian Institution in 1975 (Ayensu and DeFillips 1978). Although it was not listed at that time, the Colorado butterfly plant remained a Category 1 Candidate for listing from 1980 to 1998.

Since 1977, surveys in Colorado, Wyoming, and Nebraska have resulted in the discovery or relocation of over 20 *Gaura neomexicana* ssp. *coloradensis* populations. Early studies identified a number of potentially serious threats to the survival of this taxon, including small population size, herbicides, grazing, mowing, competition from exotic plants, urban expansion, and lack of adequate protection (Clark and Dorn 1979; Marriott 1987; Mountain West Environmental Services 1985; Rocky Mountain Heritage Task Force 1987). More recent surveys have found many populations to be relatively stable and some perceived threats to be less significant than previously reported (Fertig 1994, 1998 b, 1998 c).

In March 1998 the US Fish and Wildlife Service proposed *Gaura neomexicana* ssp. *coloradensis* for listing as Threatened under the Endangered Species Act (US Fish and Wildlife Service 1998). In order to better assess the merits of listing, the USFWS contracted with the Wyoming Natural Diversity Database (WYNDD) in 1998 to conduct follow-up surveys of known *Gaura neomexicana* ssp. *coloradensis* sites to determine population trends, response to management, and potential conservation needs. These results were summarized by Fertig (1998 c).

As part of an ongoing effort to develop a community-based Habitat Conservation Plan for listed, proposed, and candidate plant and animal species in Laramie County, Wyoming, the USFWS solicited a follow-up report from WYNDD in 1999 that includes new information on the Colorado butterfly plant compiled since 1998. These data are summarized in this report.

METHODS

Information on the taxonomy, distribution, habitat, population size, and life history of *Gaura neomexicana* ssp. *coloradensis* was obtained from scientific literature, specimens from the Rocky Mountain Herbarium (RM), reports from the Wyoming, Colorado, and Nebraska natural heritage programs, and field surveys conducted by WYNDD staff and others in 1998-1999.

SPECIES INFORMATION

Classification:

Scientific Name: *Gaura neomexicana* Woot. ssp. *coloradensis* (Munz) Raven and Gregory
[Raven and Gregory 1972].

Common Name: Colorado butterfly plant.

Family: Onagraceae (Evening primrose family).

Synonyms: *Gaura coloradensis* Rydb. (Rydberg 1904); *G. neomexicana* Woot. var. *coloradensis* (Rydb.) Munz [Munz 1938].

Phylogenetic Relationships: Raven and Gregory (1972) recognize 21 species in the genus *Gaura*, all restricted to the United States and Mexico. Colorado butterfly plant belongs to section *Gaura*, a group of six annual to short-lived perennials with four-angled fruits. Carr *et al.* (1986) have shown that all taxa within the section are potentially interfertile, but are maintained as separate species in nature due to geographic isolation and other pre-mating barriers to hybridization.

Legal Status: Colorado butterfly plant was proposed for listing as Threatened under the Endangered Species Act by the US Fish and Wildlife Service in March 1998 (US Fish and Wildlife Service 1998). As of 31 December, 1999, a final rule has not yet been published. From 1980-1998, *Gaura neomexicana* ssp. *coloradensis* was a “Category 1” Candidate for listing (US Fish and Wildlife Service 1996). This taxon is also designated as “Sensitive” by US Forest Service Region 2 (Estill 1993). It is not currently protected under any state statutes within its range (Fertig 1994), although it has been proposed for listing under Nebraska’s state endangered species program (Gerry Steinauer, pers. comm).

Natural Heritage Rank: The Nature Conservancy’s network of natural heritage programs gives *Gaura neomexicana* a rank of G3, indicating that the full species is rare or local throughout its range or found locally in a restricted range with 21-100 extant occurrences (Fertig 1997 a). Subspecies *coloradensis* is ranked T2, indicating that it is imperiled throughout its range because of rarity or factors demonstrably making the taxon vulnerable to extinction. At the state level, ssp. *coloradensis* is ranked S2 in Wyoming and S1 in Colorado and Nebraska (Colorado Natural Heritage Program 1997; Nebraska Natural Heritage Program 1996; Fertig 1997 a). Subspecies *neomexicana* is ranked T3 and is not considered a high priority taxon for conservation attention at the present time (Ellen DeBruin, formerly of the New Mexico Natural Heritage Program, personal communication).

Description: The Colorado butterfly plant is a short-lived perennial herb with 1-several reddish, pubescent stems 50-80 cm tall that branch primarily from below the middle of the plant (Figure 1). The lance-shaped stem leaves average 5-10 cm long and have smooth or wavy-toothed margins. The inflorescence is located above the leaves and consists of numerous branches that continue to grow throughout the flowering season. Only a few flowers are open at any one time and are located below the rounded buds and above maturing fruits on each flowering branch. Individual flowers are 1-1.5 cm long with 4 reddish sepals and 4 white petals that turn pink or red with age. The flowers have a slightly irregular symmetry due to the downward curve of the 8 stamens. The hard, nut-like fruits are 4-angled and sessile. Non-flowering plants consist of a prostrate rosette of oblong, mostly glabrous, entire or toothed leaves 4-18 cm long (Clark and Dorn 1979; Fertig 1994, 1995 b, 1998 b; Fertig *et al.* 1994; Marriott 1987; Munz 1938).

Figure 1. Line drawing of *Gaura neomexicana* ssp. *coloradensis* from Fertig (1994).



Similar Species: *Gaura parviflora* is an annual with slender inflorescences of small flowers (each less than 3 mm long), smooth fruits, and stems that typically branch above the middle of the plant. *G. coccinea* is a low, bushy perennial with leaves less than 3 mm long. *Mirabilis hirsuta* superficially resembles Colorado butterfly plant in having red stems, reddish flowers, and ovate leaves, but differs in having fused involucre bracts and fruits enclosed within a calyx. Rosettes of *Cirsium flodmanii* and *Oenothera villosa* are notably hairy (especially below), while those of *Taraxacum* spp. differ in exuding white milky juice when broken (Dorn 1992; Fertig 1994).

The two subspecies of *Gaura neomexicana* differ in stem pubescence, fruit size, and geographic range. Subspecies *neomexicana*, restricted to southwest Colorado and central New Mexico, has long spreading hairs on the lower stems and fruits 8.5-11 mm long. Subspecies *coloradensis* of southeastern Wyoming and adjacent Colorado and Nebraska has short, appressed hairs on the stems and smaller fruits (Fertig 1994). Populations from southern Colorado appear to be intermediate between the two taxa (Raven and Gregory 1972).

Geographic Range: *Gaura neomexicana* ssp. *coloradensis* is a regional endemic restricted to approximately 1700 acres of habitat in Laramie County, Wyoming, western Kimball County, Nebraska, and Weld County, Colorado (Figure 2) (Jennings *et al.* 1997). Historically, native populations were also known from Boulder, Douglas, and Larimer counties in Colorado, but these populations are believed to be extirpated (Fertig 1994; O’Kane 1988; Spackman *et al.* 1997). Extant populations are restricted to Bear, Crow, Horse, Lodgepole, and Spring creeks, all within the North and South Platte River watershed. An introduced population occurs in Boulder County, Colorado at the Chambers Preserve (Fertig 1994).

Habitat: Colorado butterfly plant typically occurs on subirrigated, alluvial soils on level or slightly sloping floodplains and drainage bottoms at elevations of 1524-1950 meters (5000-6400 feet). Colonies are often found in low depressions or along bends in wide, meandering stream channels. Most populations are found a short distance from the actual channel and may even occur at the base of low, alluvial ridges at the interface between riparian meadows and drier grasslands. On wet sites, *Gaura neomexicana* ssp. *coloradensis* is often associated with communities of *Agrostis stolonifera* and *Poa pratensis*, while in drier habitats it may occur in stands of *Glycyrrhiza lepidota*, *Cirsium flodmanii*, *Grindelia squarrosa*, and *Equisetum laevigatum* (Fertig 1994; 1998 b). *Salix exigua* and *Cirsium arvense* may become locally dominant in Colorado butterfly plant habitats that are not periodically flooded or otherwise disturbed (Fertig 1994; Jennings *et al.* 1997; Marriott 1987). *Gaura neomexicana* ssp. *coloradensis* occurs on soils derived from conglomerates, sandstones, and tuffaceous mudstones and siltstones of the Tertiary White River, Arikaree, and Ogalalla formations (Love and Christiansen 1985). Average annual precipitation for Colorado butterfly plant habitat ranges from 13-16 inches, with the majority occurring as rain. Peak rainfall occurs in May at the west edge of its range and July in the eastern edge (Martner 1986).

Figure 2. Rangewide distribution of *Gaura neomexicana* ssp. *coloradensis*.



Population Size and Trends: Since 1895, *Gaura neomexicana* ssp. *coloradensis* has been documented from 26 main locations in southeastern Wyoming, western Nebraska, and northeastern Colorado (Table 1) (Fertig 1998 c). Eighteen of these populations have been discovered or relocated since 1992 (including 15 in 1998-1999). Four populations in Colorado and four in Wyoming have not been relocated since 1986 and may be extirpated. One additional, introduced population has been established at the Chambers Preserve near Boulder, Colorado.

Surveys in 1998 documented 41,518 flowering and fruiting plants at 14 occurrences in Wyoming, Colorado, and Nebraska (Table 2). An additional 807 reproductive plants have been reported for 3 other extant populations in Nebraska and Colorado surveyed from 1989-1992. Unsurveyed potential habitat in Wyoming may account for an additional 5,000-8,000 flowering and fruiting individuals, bringing the entire estimated reproductive population of Colorado butterfly plants to 47,300-50,300 individuals (Fertig 1998 c).

Vegetative rosettes are often difficult to observe and census in dense cover. Studies of demographic transects on F.E. Warren Air Force Base have documented ratios of rosettes to flowering plants as high as 10:1 (Floyd 1995 a) or 12.7:1 (Fertig 1998 a). These studies, however, were conducted in atypically dense subpopulations and may not reflect average conditions (Fertig 1998 a). Random rosette sampling on the Base in 1998 found the average ratio of rosettes to reproductive plants to be 5:1 (Fertig 1999). Floyd (1995 b) reported a similar ratio (3.67:1) for a population in northern Colorado. Based on a 5:1 ratio, the current rosette population is estimated at 236,500-251,500 individuals. If combined with the estimated number of reproductive plants, the total current population of Colorado butterfly plant is projected to be 283,800-301,800 (Fertig 1998 c).

Surveys from 1986-1997 estimated the total population of Colorado butterfly plant at 20,000-26,000 reproductive individuals (Marriott 1987; Fertig 1994; Jennings *et al.* 1997). 1998 census data indicate a population increase of 14,500-20,500 reproductive plants (if raw data are used) to 21,000-30,000 (if estimated numbers are used). If current rosette to flowering plant ratios are comparable over time, the entire population of this taxon may have increased by 105,000-150,000 individuals. Of the 14 occurrences surveyed in 1998, 8 showed moderate to large population increases compared to previous surveys, 4 had decreased, and 2 were approximately stable. These data should be interpreted with some caution, however, as changes in abundance could be artifacts of differences in sampling intensity (Fertig 1998 c).

Three Wyoming populations were resurveyed in 1999 (a fourth was relocated, but not censused). Populations on F.E. Warren Air Force Base showed a large increase along the “unnamed drainage” on the south side of the Base, but a decrease along Crow and Diamond creeks. WEST Inc. conducted a partial survey of a population on private lands north of Cheyenne, and found that numbers were stable compared to 1998 totals (David Young, pers. comm.).

Table 1.
Abundance and trend information for known populations of
Gaura neomexicana ssp. *coloradensis*

Note: Unless otherwise noted, all population counts are based on numbers of flowering and fruiting plants. Vegetative rosettes typically outnumber reproductive plants by a minimum of 5:1.

Native Populations

Occ. #	Location*	Population Size	Trend
WY-001	WY: Laramie Co: South Fork Bear Creek.	1986-08-07: 3 (incomplete survey by H. Marriott). 1985-08-20: 601 (survey by R. Lichvar).	Not known
WY-002	WY: Laramie Co: unnamed south tributary of North Bear Creek.	1998-08-14: 1950 (survey by W. Fertig & L. Welp). 1993-09-03: 3952 (survey by W. Fertig & S. Markow). 8000 + rosettes estimated. 1986-09-19: 1447 (survey by H. Marriott).	Short-term: Down Long-term: Stable
WY-003	WY: Laramie Co: North Fork of South Fork Bear Creek.	1998-08-14: 187 (partial survey by W. Fertig & L. Welp). 1993-09-03: 1156 (survey by W. Fertig & S. Markow). 1986-09-19: 674 (survey by H. Marriott).	Short-term: Down Long-term: Down
WY-004	WY: Laramie Co: South Fork Bear Creek.	1998-08-17: 800 (survey by W. Fertig). 1993-09-03: 543 (survey by W. Fertig & S. Markow). 1986-09-19: 28 (partial survey by H. Marriott).	Short-term: Up Long-term: Up
WY-005 (incl WY-006)	WY: Laramie Co: Little Bear Creek.	1998-08-11: 1323 (survey by W. Fertig in W half of area). 1993-09-09: 164 (survey by W. Fertig, M. Neighbours, & S. Floyd in E half of area). 1992-09-02: 646 (survey by W. Fertig in W half of area). 1986-09-03/18: 908 (survey by M. Neighbours).	Short-term: Up Long-term: Up
WY-007	WY: Laramie Co: Horse Creek and tributaries east of Interstate 25.	1999-08-24: Observed by B.E. Nelson 1984-09-15: < 35 (survey by R. Dorn).	Not known
WY-008	WY: Laramie Co: Horse Creek west of Interstate 25.	1999-07: 250+ individuals (partial survey by D. Young). 1998-08-13: 112 (partial survey by W. Fertig). 1997-08-29: 50-60 (partial survey by T. Hildebrand). 1993-09-09: 243 (partial survey by W. Fertig). 1992-09-01: 17 (partial survey by W. Fertig). 1985-08-16: 648 (survey by R. Lichvar).	Short-term: Down Long-term: Down?
WY-009 (incl NE 001-003)	WY: Laramie Co: and NE: Kimball Co: Lodgepole Creek along the WY/NE border north and northeast of Pine Bluffs.	1998-08-27: 1005 (partial survey by W. Fertig & R. Gullion in NE). 1992-08-09: 2520 (partial survey by M. Fritz in NE). 1985-07-10: 2065 (1235 in NE & 830 in WY in survey by R. Dorn & R. Lichvar).	Short-term: Not known Long-term: Stable?
WY-010	WY: Laramie Co: Lodgepole Creek north of Burns.	1998-09-10/11: 3489 (survey by W. Fertig, R. Gullion, L. Welp, & G. Brown). Area larger than previously reported.	Long-term: Down to stable

		1997-08-28: ca 50 (partial survey by T. Hildebrand). 1985-07-26: 4528 (partial survey by R. Lichvar).	
WY-011 (incl WY-012)	WY: Laramie Co: Lodgepole Creek north of Hillsdale.	1998-08-26/27: 1304 (survey by W. Fertig, R. Gullion, S. Leistriz, & M. Hicks). Area larger than previously reported. 1996-08-16: 20-30 (partial survey by D. Hazlett). 1985-07-11/26: 469 (partial survey by R. Lichvar & R. Dorn).	Long-term: Up
WY-014 (incl 013)	WY: Laramie Co: Upper Lodgepole Creek west and east of Interstate 25.	1998-09-16: 4878 (partial survey by L. Welp, B. Rodgers, K. Allen, & M. Allen). 1998-08-03: 13 (partial survey on roadside by J. Carroll & D. Hazlett). Former EO 013. 1997-08-30: 50-60 (partial survey by T. Hildebrand & B. Steinauer). 1993-09-08: 848 (partial survey by W. Fertig). 1986-09-18: 1292 (partial survey by H. Marriott & M. Neighbours). Includes census of 30 plants in former EO 013. 1985-07-03: 125 (partial survey by R. Lichvar). Former EO 013. 1984-09-14: 100 (partial survey by R. Dorn). Former EO 013.	Short-term: Up Long-term: Up
WY-015	WY: Laramie Co: Crow and Diamond creeks on FE Warren Air Force Base, Cheyenne,	1999-08-31/09-02: 7723 (survey by W. Fertig, L. Welp, R. Smith, A. Roderick, B. Rogers, M. Neighbours, J. Williams, & V. Goodin). 1998-08-25/09-03: 8517 (survey by W. Fertig, L. Welp, B. Rogers, K. McGrath, K. Allen, & M. Allen). 1997-09-12: 7274 (survey by Fertig, Welp, & Thien). 1996-09-12: 4817 (survey by Fertig, Marriott, Struttman, & Neighbours). 1995-09-11: 8105 (survey by Fertig, Mills, & Neighbours). 1994-09-14: 5882 (survey by Fertig, Walford, & Peterson). 1993-08-20: 5585 (survey by Fertig, Walford, & Neighbours). 1992-09-03: 4624 (survey by Marriott & Floyd). 1991-09-10: 3429 (survey by Marriott & Horning). 1990-08-20: 4201 (survey by Marriott, Patton, & Neighbours). 1989-08-23: 4079 (survey by Marriott, Culver, & Neighbours). 1988-08: 2607 (survey by Marriott). 1986-08: 5311 (survey by Marriott). 1978-08-19: observed by Dorn, not censused.	Short-term: Up Long-term: Up
WY-016	WY: Laramie Co: "Unnamed Drainage" on FE Warren Air Force	1999-09-03: 3621 (survey by W. Fertig & S. Markow).	Short-term: Up

	Base, Cheyenne.	1998-08-25: 2372 (survey by Fertig). 1997-09-09: 1820 (survey by Fertig & Welp). 1996-09-09: 777 (survey by Fertig). 1995-08-30: 1822 (survey by Fertig & Mills). 1994-09-12: 1393 (survey by Fertig). 1993-08-31: 1503 (survey by Fertig). 1992-09-03: 1669 (survey by Marriott). 1991-09-11: 1354 (survey by Marriott & Horning). 1990-08-30: 851 (survey by Neighbours). 1989-08-23: 734 (survey by Marriott & Culver). 1988-08: 452 (survey by Marriott). 1986-08: 565 (survey by Marriott).	Long-term: Up
WY-017	WY: Laramie Co: Upper Diamond Creek and tributaries, southwest of FE Warren Air Force Base.	1998-08-26/09-04: 8050 observed in partial survey of 2 locations (708 in one site and 7342 in other). Total population estimated at 10,000-12,000. (survey by W. Fertig, R. Gullion, S. Leistriz, M. Hicks, & L. Welp). 1993-09-08: 567 (partial survey by W. Fertig). 1988: 500-600 (partial survey by H. Marriott). 1985-07-05: 930 (partial survey by R. Lichvar). 1978-07-18: Discovered by Dorn, but no population estimate made.	Short-term: Up Long-term: Up
WY-018	WY: Laramie Co: near Spring Creek west of Cheyenne.	1986-09-11: 6 fruiting plants and 2 rosettes (survey by M. Neighbours).	Not known, may be extirpated
WY-019	WY: Laramie Co: Lone Tree Creek, southwest of Borie.	1977-08-13: < 100 (survey by R. Dorn).	Not known; may be extirpated.
WY-020	WY: Laramie Co: Duck Creek, ca 2 air miles north of the Wyoming-Colorado border.	1984-09: 42 (survey by R. Dorn).	Not known, may be extirpated
WY-021	WY: Laramie Co: Brunyansky Draw, 1-1.5 miles south of Horse Creek, 0.5-1 mile west of Interstate 25.	1998-09-14: 6518 (survey by L. Welp). 1992-09-01: 1040 (survey by W. Fertig).	Short-term: Up Long-term: Not known.
CO-002	CO: Larimer Co: "meadow east of Poudre".	1984-08: 0 (unsuccessful search by E. Neese). 1895-07-08: Observed by J. Cowen.	Long-term: Presumed extirpated
CO-003 (incl CO-001)	CO: Weld Co: Lonetree Creek, 3.3-3.7 miles south of the Wyoming border along Interstate 25 south of the Natural Fort Rest Area.	1992-09: 0 (unsuccessful partial search by W. Fertig). 1989-08: 240 (survey by D. Culver & M. Neighbours) 1988: 0 (unsuccessful search by H. Marriott and B. Brown). 1984-08-20: 202 (survey by H. Marriott, E. Neese, J. Peterson, & T. Andrews). 1979: 1 plant observed by B. Carr. 1964: Collected 3 times by C.L. Porter, P. Raven, & D. Gregory.	Long-term: Not known
CO-005	CO: Weld Co: Lone Tree Creek east of Interstate 25, ca 0.5 miles south of the WY state line.	1989-08: 0 (unsuccessful search by D. Culver). 1984-08-20: 30 (survey by E. Neese & T. Andrews).	Not known, Presumed extirpated

CO-006	CO: Larimer Co: "30 miles north of Fort Collins". Exact location unknown	1944-08-04: Collected by H. Harrington.	Presumed Extirpated
CO-007	CO; Boulder Co. Lee Hill Road, 0.6 miles west of junction with foothills highway just north of Boulder.	1984-09-22: 1 plant observed by W. Weber and J. Phipps.	Not known, Presumed extirpated
CO-011	CO: Weld Co.: Meadow Springs Ranch, ca 0.5 miles south of Carr exit (#293) on east frontage road off Interstate 25.	1998-08-08: Population estimated at about 1000 flowering plants by S. Floyd. 1996-08: Population reported to be in decline by S. Floyd. 1995-07-31/08-04: 977 (survey by S. Floyd) Rosette population estimated at 3908. 1994-09-10: "Hundreds of rosettes & only tens [of flowering plants]"(survey by S. Spackman). 1994-08-21: 200 + flowering plants & 500 + rosettes (survey by E. Wheeling).	Short-term: Stable Long-term: Not known
NE-004 (incl NE 005-006)	NE: Kimball Co: Lodgepole Creek near Highway 30, near Bushnell.	1992-08-10: 547 plants observed in 3 main subpopulations by M. Fritz.	Not known
NE-007 (incl. NE-008)	NE: Kimball Co: Oliver Reservoir east of Bushnell..	1992-08-09: 43 fl plants and 14 rosettes observed at 2 sites by M. Fritz.	Not known

Introduced Populations

Occ. #	Location	Population Size	Trend
CO	CO: Boulder Co: Chambers Preserve south of Boulder.	1992-09: 12 fl plants and 35 rosettes observed by S. Floyd.	Stable?

Census data based on Fertig 1993, 1994, 1995 a, 1996, 1997, 1998 a, 1998 c, 1999; Floyd 1995 b; Marriott 1987, 1989 a, 1989 b, 1990, 1991, 1993; Mountain West Environmental Services 1985; Rocky Mountain Heritage Task Force 1987 and unpublished data from B. Ernie Nelson, Dave Young, Sandy Floyd and the Colorado and Nebraska Natural Heritage Programs.

1998 *Gaura neomexicana* ssp. *coloradensis* Survey Results
(see Fertig 1998 c)

Census data	Count
1998 observed number of flowering and fruiting plants (based on census of 14 occurrences in Wyoming, Colorado, and Nebraska)	41,518
1998 estimated number of flowering and fruiting plants (based on amount of unsurveyed potential habitat in Wyoming and 1989-92 population estimates for additional extant sites in Colorado and Nebraska)	47,300-50,300
1998 estimated number of vegetative rosettes (based on conservative rosette: reproductive plant ratio of 5:1)	236,500-251,500
1998 total estimated Colorado butterfly plant population (sum of estimated flowering/fruiting plant and vegetative rosette counts)	283,800-301,800

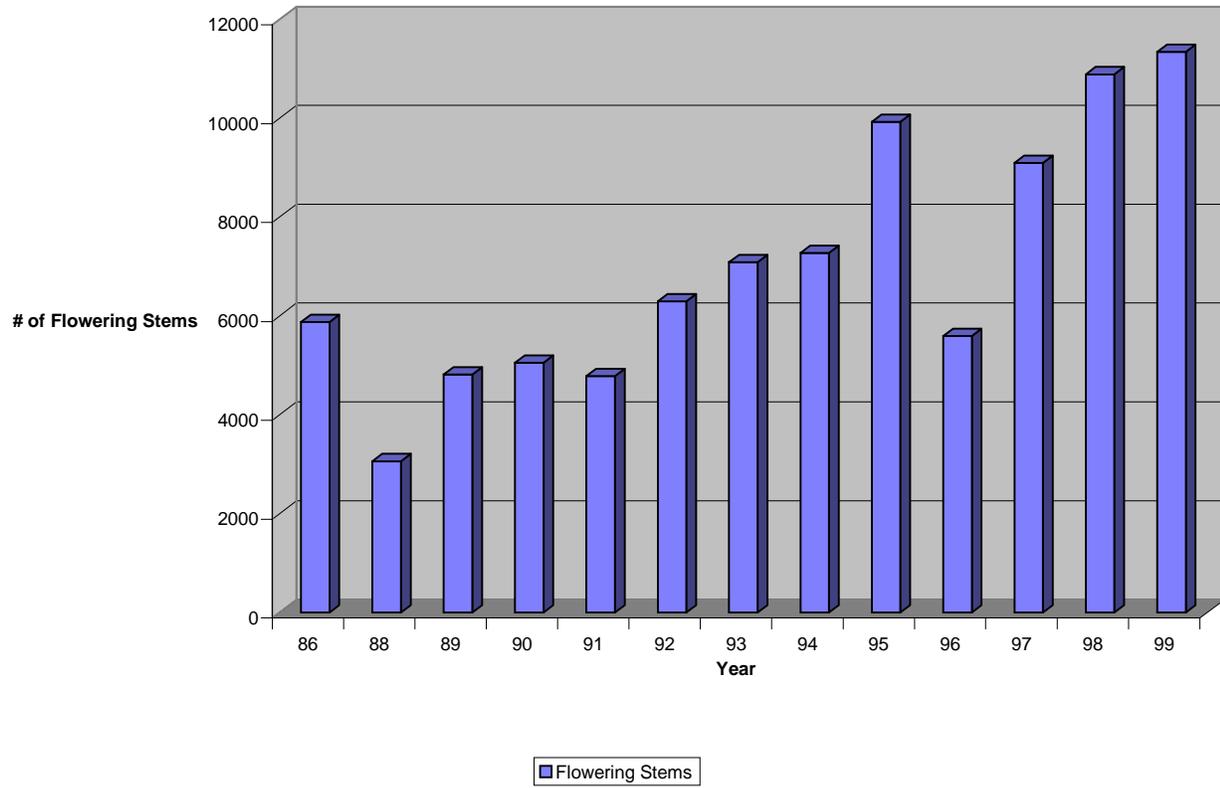
* Under state law WYNDL is not allowed to divulge information on the exact location of plant and animal populations on private lands without landowner consent.

Thirteen-year trend data from F.E. Warren Air Force indicate that the number of flowering individuals of *Gaura neomexicana* ssp. *coloradensis* fluctuates annually (Figure 3) (Fertig 1998 c). Oscillations in population size may reflect past rates of seedling establishment, which in turn may be strongly influenced by adequate summer precipitation (Fertig 1996, 1998 a, 1998 b; Floyd 1995 a; Floyd and Ranker 1998). During the drought of 1994, Floyd measured 47% less seedling recruitment at sample plots on the Base than in the wet summer of 1993 (Floyd and Ranker 1998). Differences in soil moisture and vegetative cover may also influence recruitment success. Munk (1999) found that Crow Creek had significantly moister soils than Diamond Creek or the unnamed drainage, but had lower Colorado butterfly plant rosette densities (and presumably lower recruitment success) due to greater competition from forbs and shrubs. Once established, vegetative rosette populations may be relatively stable and capable of surviving adverse climatic years when new seedling establishment is low. Episodic establishment of large seedling recruitment classes may be important for the long-term growth, replenishment, and survival of populations of this species (Floyd and Ranker 1998).

Individual populations of *Gaura neomexicana* ssp. *coloradensis* may range in size from less than 35 to over 8500 reproductive plants. Populations typically consist of numerous subpopulations, each with dozens to hundreds of flowering stems and rosettes. These subpopulations are often widely scattered and may be isolated by gaps of seemingly suitable habitat. It is not uncommon for subpopulations to be scattered along 2-10 miles of stream channels, with gaps of 1-4 miles between neighboring colonies. These gaps are probably too small to prevent the dispersal of pollinators or fruits between adjacent subpopulations, and thus colonies within the same stream reach should be considered part of the same breeding population. Preliminary studies by Brown (1999) indicate that populations on Diamond and Crow creeks and the unnamed drainage on F.E. Warren Air Force Base do not differ substantially in their genetic composition, suggesting there have been few barriers to past gene exchange. The Base populations also show little genetic differentiation from a population on Lodgepole Creek near Burns, located nearly 42 km (26 miles) to the northwest and in a separate drainage (Brown 1999).

Population Biology and Ecology: *Gaura neomexicana* ssp. *coloradensis* begins to flower in late June or early July and continues until the first hard frost of Autumn (usually late September to early October). Fruits begin to mature in late July and will continue to develop through September (Fertig 1994). Colorado butterfly plant reproduces entirely by seed. Carr *et al.* (1986) report that this species is self-compatible, but usually outcrosses in nature. Moths are thought to be the primary pollinators, with pollination occurring in late evening or during the night (S. Floyd, pers. comm.). Individual plants may produce 143-383 fruits, each containing 1-4 seeds (Mountain West Environmental Services 1985; Munz 1938).

Figure 3. Long term trend data for *Gaura neomexicana* ssp. *coloradensis* on F.E. Warren Air Force Base.



Fruit dissemination is poorly understood, although flooding and transport by muddy animals may be important mechanisms. Average dispersal distances may be quite short, as suggested by the clumped pattern of reproductive and vegetative plants in most colonies (Fertig 1994). Long-distance dispersal (possibly by muddy waterfowl), may occur frequently enough to account for the relatively homogeneous genetic structure across widely spaced populations observed in preliminary studies by Brown (1999). In cultivation, the seeds of *Gaura neomexicana* ssp. *coloradensis* have over 50% germination when they are allowed to lie dormant for approximately 9 months (S. Floyd, pers. comm.). A three-month moist stratification treatment may also be adequate for germination (Jim Locklear, Nebraska Statewide Arboretum, pers. comm.). Seeds seem to require a period of after-ripening and adequate moisture for germination in the field. Sample plots on F.E. Warren Air Force Base have lower seedling establishment rates on dry sites than in more mesic areas (Floyd 1995 a).

Individual Colorado butterfly plants may live for 1-5 years as stemless, vegetative rosettes before flowering once and dying. Studies by Floyd (1995 a) and Fertig (1996) suggest that flowering occurs only after rosettes exceed a minimum basal leaf diameter. Demographic plot data from F.E. Warren Air Force Base indicate that nearly 33% of all large rosettes (with a basal leaf diameter over 18 cm) flower each summer, while essentially no medium (6-18 cm) or small (under 6 cm) rosettes flower. Floyd (1995 a) identified the transition from large rosettes to flowering plants as one of the most critical stages in the life cycle of this species. Seedling establishment and survival is an equally critical phase, and may be negatively impacted by cold winter temperatures, foliar herbivory, and competition for space and resources from dense native vegetation and exotic plants (Fertig 1996; Floyd and Ranker 1998; Marriott 1987).

Gaura neomexicana ssp. *coloradensis* is a naturally rare taxon with a restricted geographic range and high habitat specificity. Studies in Wyoming suggest that the long-term survival of populations or the establishment of new colonies may be dependent on periodic disturbances that maintain short vegetative cover or early seral conditions (Fertig 1994; Marriott 1987; Munk 1999). In the absence of such disturbances, habitats may become overgrown with exotic plants or dense, brushy, late successional vegetation. Prior to European settlement, flooding, fire, and bison grazing probably maintained the habitat conditions favored by this species. Some agricultural practices, such as winter or short-rotational grazing, and early or late season mowing, appear to compensate for these processes at many sites in Wyoming (Fertig 1994). Reintroduction of natural disturbance processes (fire, flooding, and grazing) or development of management strategies involving mowing, brush removal, and integrated pest management for weed control have been recommended to maintain and improve Colorado butterfly plant habitat on F.E. Warren Air Force Base in Cheyenne, Wyoming (Fertig 1997, 1998 a, 1998 b. Munk 1999).

ASSESSMENT AND MANAGEMENT RECOMMENDATIONS

Current Management: Two populations of Colorado butterfly plant are currently protected on F.E. Warren Air Force Base near Cheyenne, WY. The Air Force has entered into cooperative agreements with the US Fish and Wildlife Service and The Nature Conservancy to develop management plans and conduct annual monitoring of butterfly plant populations on the Base. Habitat along Crow and Diamond creeks has been designated as the Colorado butterfly plant Research Natural Area by the Air Force (Marriott and Jones 1988). Current management on the Base includes restrictions on application of herbicides and mowing near stream areas and the introduction of biocontrol insects.

Small populations of Colorado butterfly plant are also found in special management areas at the Chambers Preserve, (near Boulder, Colorado) and Oliver Reservoir State Recreation Area (east of Bushnell, Nebraska). These sites are managed primarily for open space and recreation values. At least three other populations in Wyoming are found partly or entirely on state school trust lands managed mostly for agricultural use. The Meadow Springs Ranch population in northern Colorado is owned by the City of Fort Collins and managed for municipal sewage treatment (Floyd 1995 b). All other known occurrences of *Gaura neomexicana* ssp. *coloradensis* are found on private lands managed primarily for hay production or livestock pasture. None of these private lands are formally “protected” through conservation easements or comparable designation.

Existing and Potential Threats: On agricultural lands, herbicide spraying, grazing by cattle and horses, haying and mowing, water development, conversion of rangeland to cultivation, competition from exotic plants, and loss of habitat to urban expansion have been cited as the main potential threats to the Colorado butterfly plant (Fertig 1994; Jennings *et al.* 1997; Marriott 1987). Within protected areas (F.E. Warren Air Force Base, WY, Oliver Reservoir State Recreation Area, NE, and the Chambers Preserve, CO) replacement of early successional vegetation by late seral species and high recreation use are the primary threats (Jennings *et al.* 1997).

The most serious threat on agricultural lands is probably the application of broadleaf herbicides for the control of Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), and other non-native plants (Marriott 1987). Although competition from weedy species may have negative impacts on *Gaura* populations, observations have indicated that the Colorado butterfly plant is highly susceptible to commonly used herbicides (especially if no special precautions are taken during application). Alternative (and presumably more *Gaura*-friendly) methods of weed control involving the release of biocontrol insects, mowing, and new chemical application techniques, are currently being investigated on F.E. Warren Air Force Base (Hollingsworth 1996).

Grazing by cattle may be a threat at some sites, especially if animals are not periodically rotated or if use is concentrated in small areas during the summer flowering period. Studies have shown that the Colorado butterfly plant may persist and thrive in habitats that are winter grazed or managed on a short-term rotation cycle (Fertig 1994; Mountain West

Environmental Services 1985). Although reproductive individuals of *Gaura neomexicana* ssp. *coloradensis* may be grazed (the plant is quite palatable to a wide range of herbivores), the establishment and survival of seedlings and rosettes is enhanced by the reduction of competing vegetative cover (Fertig 1994, 1996; Munk 1999). Due to their low stature, rosettes do not appear to be regularly grazed (Mountain West Environmental Services 1985). Grazing by horses also occurs in many privately owned Colorado butterfly plant sites, but does not appear to negatively impact this species under normal stocking rates.

Observations in 1998 suggest that mowing an area for hay production is rarely a threat to Colorado butterfly plant populations unless cutting is done before fruits are able to mature. Once fruits have ripened they are protected by a hard, woody fruit wall that is not readily damaged by machinery. Mowing in mid-summer may actually stimulate extra flower and fruit production through increased branching from the release of apical dominance in cut stems. Colorado butterfly plants may also benefit from decreased competition and enhanced moisture availability in mowed environments (Munk 1999). Late summer and fall mowing may facilitate seed dispersal, provided that fruits have already ripened (Jennings *et al.* 1997). The three largest private land populations of *G. neomexicana* ssp. *coloradensis* observed in 1998 were all found in areas that had been mowed in mid summer or late fall.

Construction of stock ponds and reservoirs, conversion of rangeland to crop cultivation, and the loss of habitat to residential and urban development are also important threats in agricultural areas. The cities of Cheyenne, WY and Fort Collins, CO contain areas of formerly suitable Colorado butterfly plant habitat that have been lost to urbanization. The protection or continued agricultural management of suitable private land habitat may be critical to the long-term survival of the species.

In non-agricultural settings, the main threat to *Gaura neomexicana* ssp. *coloradensis* may be changes in habitat suitability resulting from natural succession. Without periodic disturbances, the semi-open habitats preferred by this species may become choked by tall and dense growth of willows, graminoids, and exotic weeds (Fertig 1994). Munk (1999) observed an increase in the number and density of butterfly plant rosettes on sample plots at F.E. Warren Air Force Base where competing forb, grass, and weed cover was eliminated. Natural disturbance events, such as flooding, fire, and ungulate grazing, may have been sufficient in the past to create favorable habitat conditions. In the absence of such events today, managed disturbance may be necessary to maintain and create areas of habitat (Fertig 1994; 1996, 1998 b; Munk 1999).

Management Recommendations:

1. Maintain Current, Compatible Land Uses on Private Lands: Although two populations on F.E. Warren Air Force Base are protected, the long-term survival of the Colorado butterfly plant will depend on the persistence of populations on private lands. Most of these populations occur in areas managed for hay production or livestock forage. These activities can be compatible with the survival of *Gaura neomexicana* ssp. *coloradensis* if haying takes place early in the growing season or after fruits have hardened and if livestock grazing is

done on a rotational basis or in winter. Changes in current agricultural practices or conversion of rangelands and hay meadows to subdivisions are significant threats to the survival of this taxon.

Programs need to be developed and implemented to provide incentives for private land owners to manage populations of the Colorado butterfly plant. Financial compensation would help defray costs incurred by private individuals to manage this species and would ensure greater cooperation between landowners, federal agencies, and private conservation groups. Monetary awards could come from existing agricultural support programs (such as those administered by the Natural Resources Conservation Service), income or estate tax relief (through conservation easements), or compensation from private conservation organizations. Incentives could also come through public recognition and rewards for good stewardship. The creation of a Habitat Conservation Plan for listed and candidate Threatened and Endangered species in Laramie County, Wyoming, may provide some tangible incentives for private land owners to conserve Colorado butterfly plant populations in the county.

2. Continue Management Efforts and Weed Control Programs on F.E. Warren Air Force Base: F.E. Warren Air Force Base has been cooperating with the USFWS and The Nature Conservancy to manage and protect critical Colorado butterfly plant habitat on the Base since the early 1980s. Conservation efforts have included prohibiting herbicide spraying and mowing in wetland areas, establishment of the Colorado butterfly plant Research Natural Area, initiation of biological control programs for weeds, and annual monitoring of *Gaura* populations. The current Memorandum of Agreement between the Air Force and other interested parties has lapsed and renewal may be dependent on continued federal protection of this species (Tom Smith, F.E. Warren Air Force Base, personal communication).

3. Establish Additional Populations Within the Species' Historic Range: Colorado butterfly plant has excellent potential for restoration into suitable habitat within its historical range (Fertig 1998 b). Studies at the University of Wyoming greenhouse and the Nebraska Statewide Arboretum have demonstrated that *Gaura neomexicana* ssp. *coloradensis* is easy to propagate from seed, and can also be transplanted as a rosette if kept sufficiently moist (S. Floyd, pers. comm). The major limiting factor to the establishment of new populations may be the availability of seed or transplant stock and the need for site preparation (removal of brush or other disturbance) (Fertig 1998 b). The Pawnee National Grassland in northeast Colorado has been proposed as a potential reintroduction site for this species (Hazlett 1994).

4. Establish Off-Site Seed Banks and Populations in Arboreta: Seed banks for *Gaura neomexicana* ssp. *coloradensis* are currently being maintained by the Nebraska Statewide Arboretum and NRCS Plant Materials Center (Bridger, MT) and experimental populations have been established at the University of Colorado and University of Wyoming. Additional seed banks should be established in local and regional arboreta, botanical gardens, and seed banks, including the Denver Botanical Garden and Cheyenne Botanical Gardens.

5. Develop Management Techniques to Maintain or Improve Colorado Butterfly Plant Habitat: Studies at F.E. Warren Air Force Base have shown that reduction of grass, forb, and weed cover can stimulate recruitment and rosette establishment of *Gaura neomexicana* ssp. *coloradensis* (Munk 1999). Management plans for this species need to be developed that incorporate various cover-reducing habitat treatments, including mowing, brush removal, fire, grazing, and herbicide application. Practical techniques are also needed for weed control at several Colorado butterfly plant sites. Several biocontrol insects have shown promise for reducing the vigor of Canada thistle and leafy spurge infestations and may be suitable for release on F.E. Warren Air Force Base and other weedy *Gaura* populations (Hollingsworth 1996; Jones 1996).

Potential actions to enhance *Gaura neomexicana* ssp. *coloradensis* habitat may be constrained by the management needs of Preble's meadow jumping mouse (*Zapus hudsonius preblei*), a listed Threatened species that can co-occur with the Colorado butterfly plant. Brush-thinning, mowing, or weed control efforts that might benefit *Gaura* could have negative consequences for the jumping mouse (Beauvais 1998). Partitioning of riparian habitats into different management units (with some units dedicated to jumping mice, and others emphasizing butterfly plants) is one possible means of integrating management of these two taxa (Fertig 1998 a).

SUMMARY

The US Fish and Wildlife Service uses five biological criteria (threats to a species range or habitat, overutilization, susceptibility to disease or predation, inadequacy of existing regulatory mechanisms, and other natural or man-made factors) to assess the merits of listing a taxon under the Endangered Species Act. Long-term census studies suggest that the habitat of Colorado butterfly plant may be less threatened than originally suspected. Such agricultural practices as mowing, short-term or rotational cattle grazing, and horse grazing do not appear to jeopardize known populations. Herbicide spraying remains a legitimate concern, although alternatives to traditional spraying programs (such as biological control and new application techniques) offer much promise. Loss of habitat to urban expansion or subdivision is also a continuing threat, especially for populations near the city of Cheyenne. Overutilization and susceptibility to disease or predation have never been concerns for this taxon, nor have any other natural or man-made factors affecting this species been identified.

Inadequacy of existing regulatory mechanisms may be the main impediment to long-term conservation of *Gaura neomexicana* ssp. *coloradensis*. Only two natural populations are currently provided full protection, both of which are on F.E. Warren Air Force Base. To date, the Air Force has been cooperating with the US Fish and Wildlife Service to protect the habitat of this species and conduct ongoing research. This management could change, however, if the Colorado butterfly plant is no longer a candidate for federal listing or is not listed under the Endangered Species Act (Tom Smith, personal communication). Even if conservation efforts continue unchanged on the Base, these two protected populations may be insufficient to ensure the survival of the species if other populations are lost. At present, no private or state-owned natural populations (the Chambers Preserve contains an introduced colony) are protected by conservation easements or other formal

programs aimed at integrating Colorado butterfly plant management with compatible land uses. This is in part due to the lack of incentives to participate in conservation of this species and mistrust with governmental protection edicts.

Listing the Colorado butterfly plant as Threatened under the Endangered Species Act appears to be less imperative today than in the recent past when initial census data and observations suggested that the taxon existed at low population densities and in highly threatened environments. Although population numbers are now known to be higher, and many (but not all) threats are less severe, the taxon remains at some risk of extinction due to its small geographic range, specialized habitat, and inadequate rangewide protection. Listing this taxon would ensure that populations on public and government-owned lands would be protected under the Endangered Species Act and could result in increased funding being available for management. It would do relatively little, however, to protect populations of *Gaura neomexicana* ssp. *coloradensis* on private lands. Under the Endangered Species Act, listed plants receive far less protection than animals. Restrictions under the act include prohibitions on collecting plant parts without a permit, engaging in interstate or international trade in plant products, and use of some regulated herbicides. Private landowners are not prohibited under the Act from harming listed plants or destroying habitat on their property, unless they are receiving federal funds for a development project. Listing the Colorado butterfly plant could actually be counter-productive by increasing landowner hostility towards the species and its conservation.

If *Gaura neomexicana* ssp. *coloradensis* is listed under the Act, the immediate goal of the recovery effort should be to derive and implement management objectives that integrate the biological needs of this species with compatible land uses on private lands. Delisting should be considered when an adequate percentage of public and private land sites are covered by formal, cooperative management plans. Whether or not this species is listed, its long-term survival will probably depend on active land management that promotes episodic disturbances needed for seedling establishment.

The case of the Colorado butterfly plant is representative of many of the problems of implementing the Endangered Species Act to protect rare plants found primarily on private lands. The best solution to this problem would be to amend the Act to provide better monetary incentives for landowner cooperation and a greater participatory role in management decisions. If such incentives were already in place, private land issues would not be so contentious, and the outlook for this species would be brighter.

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