

Census of Colorado Butterfly Plant
(*Gaura neomexicana* ssp. *coloradensis*)
on F. E. Warren Air Force Base, 1999

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TABLE OF CONTENTS

	<u>Page</u>
Introduction	4
Methods	4
Results	6
Discussion and Management Recommendations	18
Acknowledgements	21
Literature Cited	22

FIGURES, TABLES, AND APPENDICES

<u>Figure</u>	<u>Page</u>
1. Colorado butterfly plant distribution on F. E. Warren Air Force Base	5
2. <i>Gaura neomexicana</i> ssp. <i>coloradensis</i> census, F. E. Warren Air Force Base, 1986-1999	7
3. <i>Gaura neomexicana</i> ssp. <i>coloradensis</i> census, Crow Creek, 1986-1999	9
4. <i>Gaura neomexicana</i> ssp. <i>coloradensis</i> census, Diamond Creek, 1986-1999	11
5. <i>Gaura neomexicana</i> ssp. <i>coloradensis</i> census, Unnamed drainage, 1986-1999	12
6. Relative Proportions of Vegetative Rosettes to Flowering Plants of <i>Gaura</i> <i>neomexicana</i> ssp. <i>coloradensis</i> on Warren Air Force Base, 1999	14
7. Colorado butterfly plant distribution on Crow Creek	15
8. Colorado butterfly plant distribution on Diamond Creek	16
9. Colorado butterfly plant distribution on the Unnamed drainage	17
10. Photoplot on NE bank of Crow Creek (1999)	24
11. Photoplot on NE bank of Crow Creek (1985)	25
12. Photoplot on NE bank of Crow Creek (1999)	26
13. Photoplot on NE bank of Crow Creek (1984)	27
14. Photoplot on upper Diamond Creek (1999)	28
15. Photoplot on upper Diamond Creek (1984)	29
16. Photoplot on upper Diamond Creek (1999)	30
17. Photoplot on upper Diamond Creek (1984)	31

Table

1. Summary of yearly population of flowering and fruiting individuals of Colorado butterfly plant on F.E. Warren Air Force Base	6
2. <i>Gaura neomexicana</i> ssp. <i>coloradensis</i> census data from Crow Creek subdivisions, F.E. Warren Air Force Base, 1986-1999	8
3. <i>Gaura neomexicana</i> ssp. <i>coloradensis</i> census data from Diamond Creek subdivisions, F.E. Warren Air Force Base, 1986-1999	10
4. <i>Gaura neomexicana</i> ssp. <i>coloradensis</i> census data from the Unnamed Drainage, F.E. Warren Air Force Base, 1986-1999	10
5. <i>Gaura neomexicana</i> ssp. <i>coloradensis</i> rosette size class data, F.E. Warren Air Force Base, 1998-1999	13

Appendix

A. Maps and descriptions of revised census subdivisions	32
B. Element Occurrence Records	37
C. 1999 Colorado butterfly plant demographic monitoring plot data	44

INTRODUCTION

The Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) was proposed for listing as Threatened under the Endangered Species Act on 24 March 1998 (US Fish and Wildlife Service 1998)*. Historically, this taxon was known from 26 locations in southeastern Wyoming, western Nebraska, and northeastern Colorado, but currently only 18 populations are thought to be extant (Fertig 2000). Two of these populations occur on F.E. Warren Air Force Base (WAFB) in Cheyenne, Wyoming (Figure 1) and are managed within the Colorado Butterfly Plant Research Natural Area (Marriott and Jones 1988).

Since 1984, the US Air Force has contracted with The Nature Conservancy and the University of Wyoming's Natural Diversity Database (WYNDD) to conduct field studies on the Colorado butterfly plant at WAFB. Surveys from 1984-86 documented the distribution, abundance, habitat, and life history traits of this taxon (Mountain West Environmental Services 1985; Marriott 1989a). From 1988-1999, annual surveys have been conducted to determine population size and trends on the Base (Fertig 1993, 1995, 1996, 1997, 1998a, 1999a; Marriott 1989a, 1989b, 1990, 1991, 1993).

This report presents results of the 1999 census and discusses population trends on WAFB. Potential management needs are also briefly discussed, with an emphasis on improving and maintaining existing habitat on the Base. In addition, images from photo-monitoring plots established in 1985-86 and revisited in 1999 are included to show changes in vegetation cover in the past 15 years. General information on the biology and status of *Gaura neomexicana* ssp. *coloradensis* is not included, but can be found in USFWS status surveys (Marriott 1987; Fertig 1994, 1998b, 2000).

METHODS

Surveys were conducted by Walter Fertig, Laura Welp, Mary Neighbours, and Rebekah Smith of WYNDD, Stuart Markow and Amy Roderick of the University of Wyoming, and Brad Rogers, Jerry Williams, and Vicky Goodin of the US Fish and Wildlife Service along Crow and Diamond creeks and the Unnamed drainage from 31 August to 4 September 1999. All flowering and fruiting plants were counted in each of 13 survey subdivisions (modified from those originally established by Marriott [1989b]) (Appendix A). The approximate location of medium to large colonies of Colorado butterfly plant were mapped in the field and digitized on an Arcview image of a digital orthophoto of the Base (provided by the University of Wyoming's Spatial Data and Visualization Center). Field data on population size, habitat, and associated species were entered into the Element Occurrence database maintained by WYNDD (Appendix B).

Three monitoring plots were surveyed in 1999 to measure the relative proportion of reproductive plants to vegetative rosettes (Appendix C). Plots were subjectively selected to represent both dense and sparse populations of Colorado butterfly plant. Within each plot, all individuals were placed into one of 4 size classes: flowering/fruiting, small rosettes (with largest leaves under 6 cm), medium rosettes (largest leaves between 6-18 cm), and large rosettes (largest leaves over 18 cm).

* As of 29 February 2000, no decision has been made on the listing proposal.

Figure 1.

Plot photos were taken for early monitoring studies of Colorado butterfly plant colonies along Diamond and Crow creeks in 1985-86. Although the exact location of many of these plots can no longer be reliably determined, several sites were successfully relocated in 1999. New photographs were taken from similar vantage points in 1999 to allow comparisons between vegetation cover in the past and at the present time.

RESULTS

11,344 flowering and fruiting Colorado butterfly plants were counted at WAFB in 1999 (Table 1, Figure 2). This figure represents an increase of 455 plants (4.2%) from 1998 results (Fertig 1999a). Census figures from 1999 are the highest recorded for the Base, surpassing the previous record of 10889 flowering and fruiting plants in 1998. The current Base population is 61.9% higher than the 1986-1999 average of 7007 plants (Table 1).

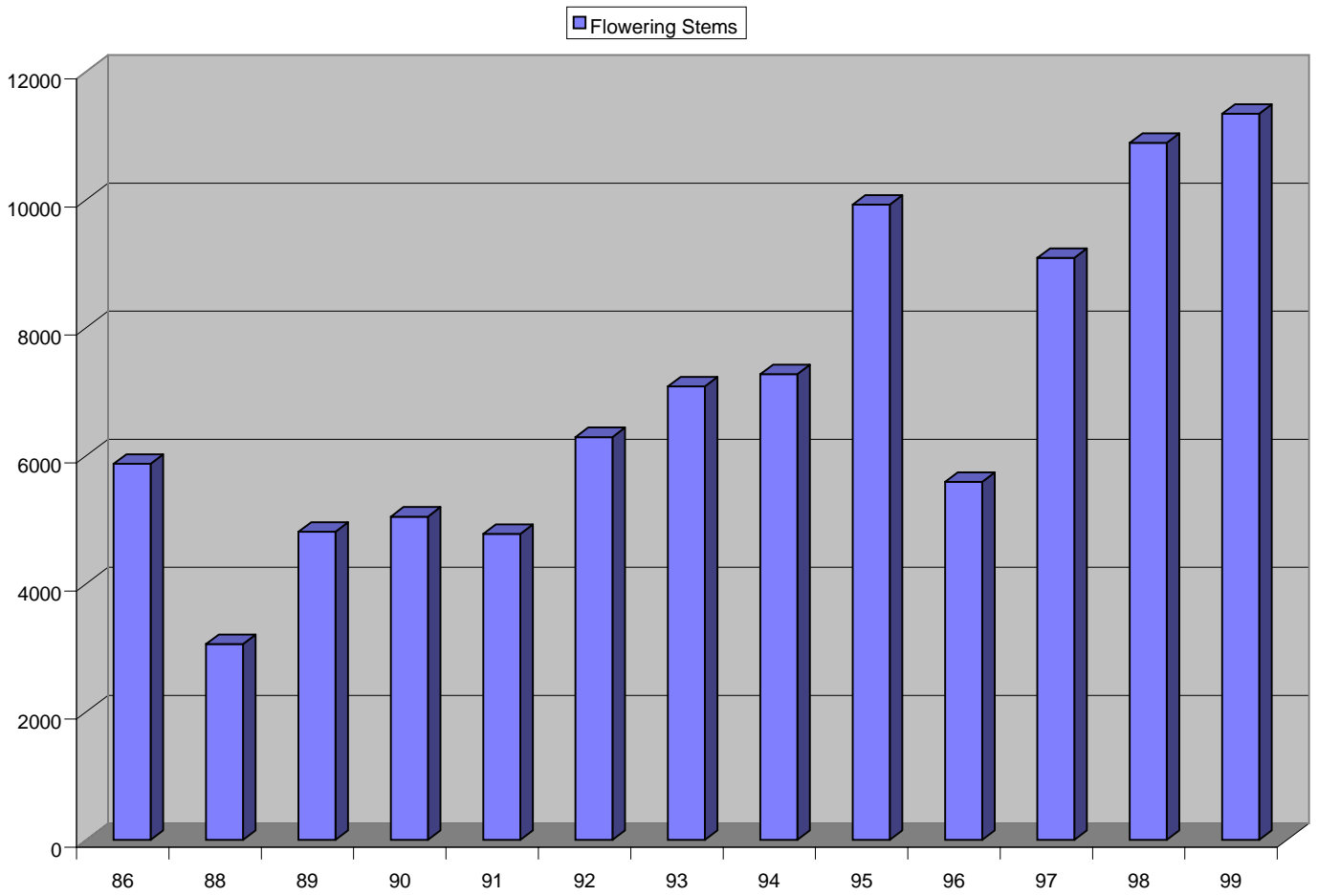
Crow Creek had 1152 flowering and fruiting plants in 1999, a decrease of 556 (32.5%) from 1998 results (Table 2, Figures 3, 7). The Crow Creek subpopulation is currently 26% below the 14-year average of 1558 plants for the area (Table 1). In 1999, the Crow Creek accounted for 10.2% of the total Base population, a decrease of 5.5% from 1998 (Fertig 1998a).

Table 1.
Summary of Yearly Population Totals of Flowering and Fruiting
Individuals of Colorado Butterfly Plant on F. E. Warren Air Force Base, 1986-1999

Year	WAFB (Total)	Crow Creek	Diamond Creek	Unnamed Drainage
1986	5876	2095	3216	565
1988	3059	1406	1201	452
1989	4813	2408*	1684	734
1990	5052	2030	2171	851
1991	4783	756	2673	1354
1992	6293	997	3627	1669
1993	7088	935	4650	1503
1994	7275	2017	3865	1393
1995	9927	2441	5664	1822
1996	5594	967	3850	777
1997	9094	1348	5926	1820
1998	10889	1708	6809	2372
1999	11344	1152	6571	3621
13-yr Ave.	7006	1558	3993	1456

* Previously reported as 2395 due to a mathematical error.

Figure 2. *Gaura neomexicana* ssp. *coloradensis* census, F. E. Warren Force Base, 1986-1999.



Diamond Creek had a 1999 population of 6571 reproductive individuals, a decrease of 238 (3.5%) from 1998 (Table 3, Figures 4, 8). Despite the decline, the 1999 count is still the second highest ever reported for Diamond Creek and marks the fourth time in the last five years that this population has exceeded 5000 individuals. The current population level is 64.6% higher than the 14-year average of 3993 plants (Table 1). Diamond Creek accounted for 57.9% of the total Base population in 1999, a drop of 4.6% from 1998 figures.

The Unnamed drainage population contained 3621 flowering and fruiting plants in 1999, an increase of 1249 plants (52.6%) since 1998 (Table 4, Figures 5, 9). These results are the highest ever reported from this site and exceed the 14-year average by 148.7% (Table 1). The Unnamed drainage occurrence now accounts for 31.9% of the total Colorado butterfly plant population on WAFB (an increase of 10.1% since 1998) and has had a larger population than Crow Creek for the last three years.

Table 2.

Gaura neomexicana ssp. coloradensis census data from Crow Creek subdivisions, F. E. Warren Air Force Base, 1986-1999.

1999 survey conducted on 31 August and 2 September by Walter Fertig, Amy Roderick, Mary Neighbours, Brad Rogers, Vicky Goodin, and Jerry Williams.

Number of flowering and fruiting plants

Sub.	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
NW North			1210	897	404	188	130	637	1145	507	589	458	275
NW South			147	59	48	67	82	92	63	26	67	37	36
NW Island			607	572	200	472	450	906	724	139	254	235	157
Camp Island			190	252	54	145	129	182	263	109	230	256	201
SE East			81	128	10	58	77	40	41	48	31	124	31
SE West			173	122	40	67	67	160	205	138	177	598	452
TOT	2095	1406	2408*	2030	756	997	935	2017	2441	967	1348	1708	1152

* Formerly reported as 2395 due to a mathematical error.

Note: Due to difficulties in relocating the original marker stakes, the Crow Creek subdivisions were reorganized in the following way in 1998: NW North = former subdivisions 1, 3, 6, 9, 12, 13, 16, and 17; NW South = former subdivisions 2, 5, 8, 11, 15, and 19; NW Island = former subdivisions 4, 7, 10, 14, and 18, Camp Island = former subdivisions 23 and 25; SE East = former subdivisions 20, 26, 27, 29, and 31; and SE West = former subdivisions 21, 22, 24, 28, 30, and 32.

Figure 3. *Gaura neomexicana* ssp. *coloradensis* census, Crow Creek, 1986-1999.

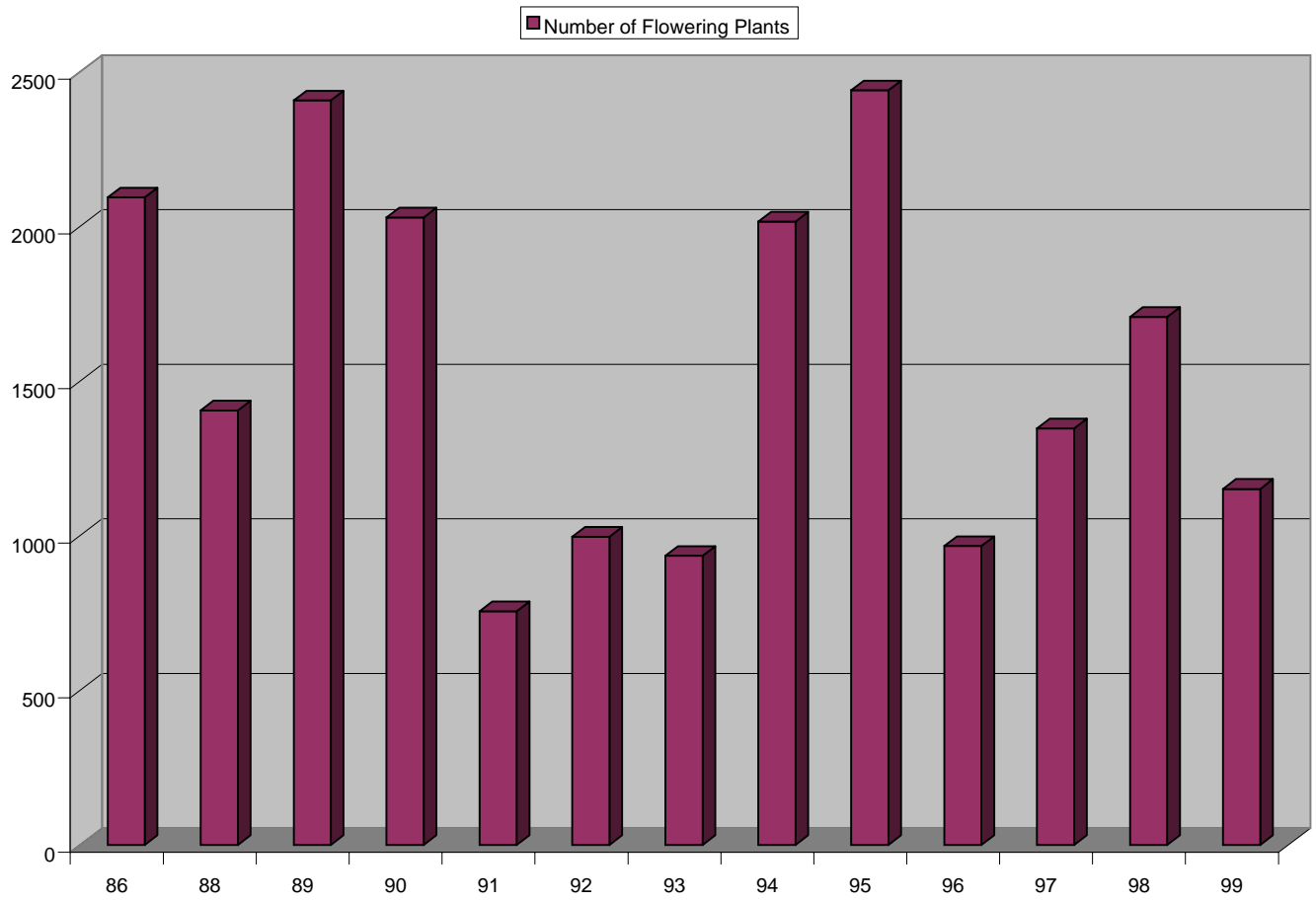


Table 3.
Gaura neomexicana ssp. *coloradensis* census data from Diamond Creek subdivisions, F. E. Warren Air Force Base, 1986-1999.

1999 survey conducted on 1-4 September by Walter Fertig, Laura Welp, Brad Rogers, Kim McGrath, Ken Allen, and Mandy Allen.

Number of flowering and fruiting plants

Sub.	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1 Total			207	377	977	1554	1891	1298	1499	1150	1236	1699	2011
1 South								322	406	387	370	106	671
1 North								976	1093	763	866	1593	1340
2 Total			461	471	405	525	1076	746	1267	627	1070	1536	969
2 South								601	1058	484	889	780	764
2 North								145	209	143	181	756	205
3 Total			561	965	1016	1055	1249	1023	2359	1072	2346	2112	2092
3 South								263	437	440	611	632	410
3 North								760	1922	632	1735	1480	1682
4 Total			432	355	275	456	415	786	528	962	1246	1415	1479
4 South								557	390	566	890	908	1027
4 North								229	138	396	356	507	452
5 Total			23	3	*	37	19	12	11	39	28	47	20
5 South								12	11	39	28	47	20
5 North								0	0	0	0	0	0
TOT	3216	1201	1684	2171	2673	3627	4650	3865	5664	3850	5926	6809	6571

* lumped in Crow Creek # 32 in 1991 survey

Table 4.
Gaura neomexicana ssp. *coloradensis* census data, Unnamed Drainage, F. E. Warren Air Force Base, 1986-1999.

1999 survey conducted on 3 September by Walter Fertig and Stuart Markow.

Number of flowering and fruiting plants

Sub.	1986	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1			84	171	429	727	556	366	855	284	655	512	1275
2			650	680	925	942	947	1027	967	493	1165	1860	2346
TOT	565	452	734	851	1354	1669	1503	1393	1822	777	1820	2372	3621

Figure 4. *Gaura neomexicana* ssp. *coloradensis* census, Diamond Creek, 1986-1999.

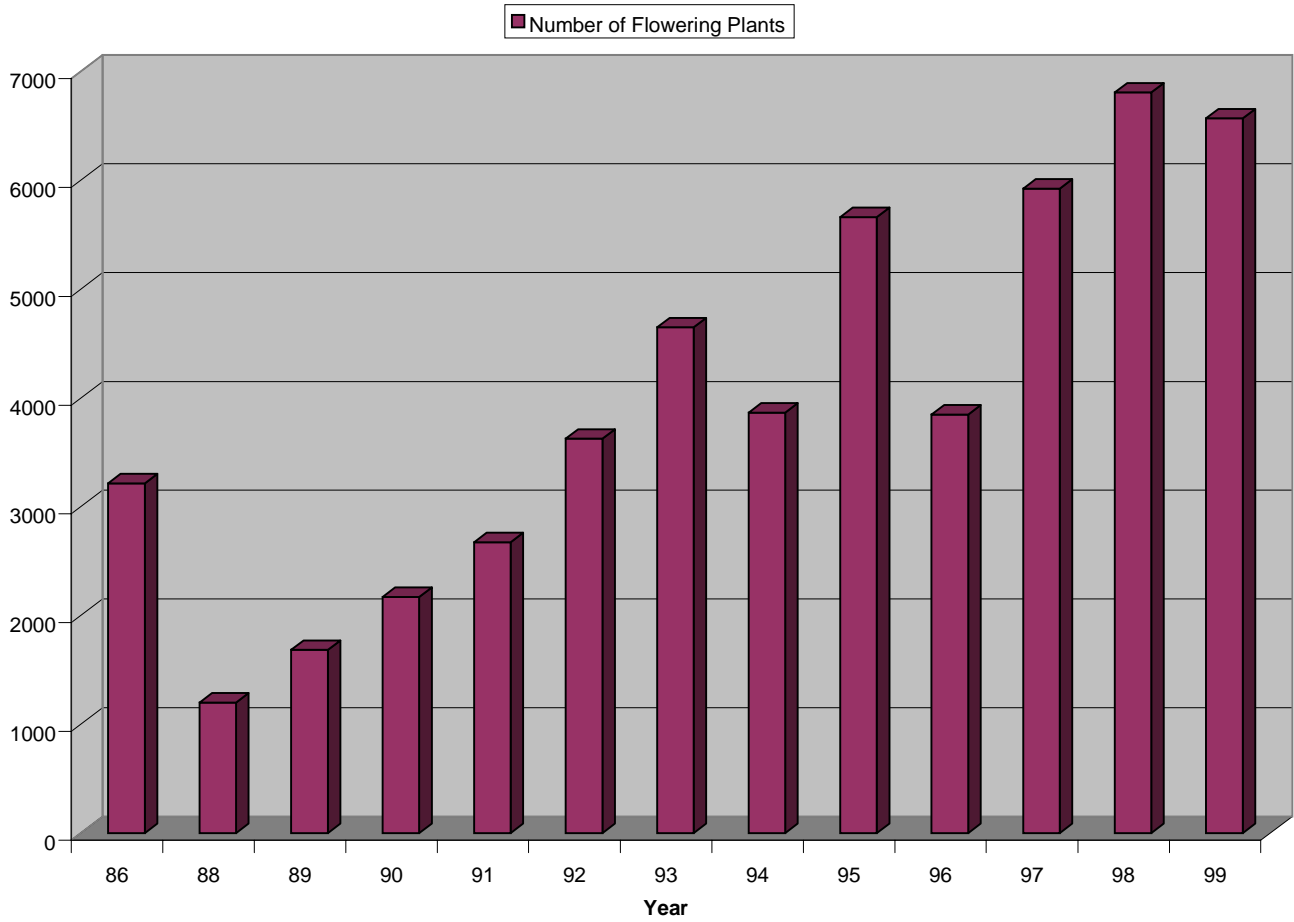
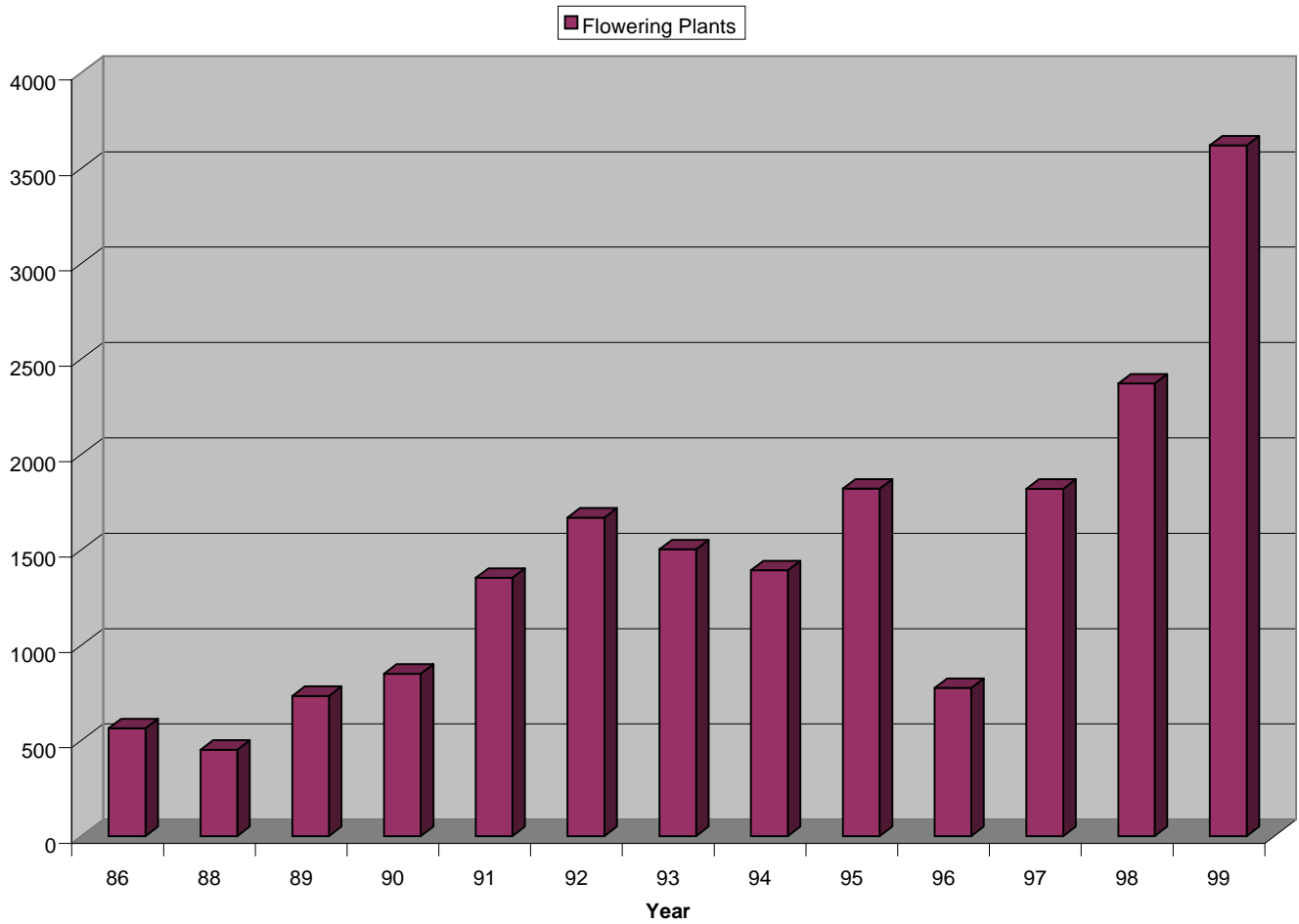


Figure 5. *Gaura neomexicana* ssp. *coloradensis* census, Unnamed Drainage, 1986-1999.



Although vegetative rosettes were not censused, data were gathered on the proportions of rosettes and reproductive plants at 3 plots on Crow and Diamond creeks (Appendix C). Based on 1999 sampling, 96.8% of the plants in these plots were rosettes and only 3.2% were reproductive (a ratio of nearly 30 rosettes to 1 flowering/fruited plant) (Table 5, Figure 6). This figure represents a major departure from past estimates of rosette to reproductive plant ratios (which have typically ranged from 13:1 to 5:1), and may be an artifact of inadequate sampling rather than a representative average across the entire Base. Using a more conservative range-wide rosette to reproductive plant ratio of 5:1 (Fertig 1998b, 2000), the number of vegetative rosettes on WAFB in 1999 is estimated at 56,720 individuals. When combined with reproductive population, the total Colorado butterfly plant population on WAFB in 1999 is estimated at 68,064 plants, an increase of about 4% from 1998 estimates.

Following the classification of Floyd (1995), vegetative rosettes in the demographic plots were divided into three size/age classes: small, medium, and large. Medium rosettes were the most numerous class, accounting for 59.6% of the total Colorado butterfly plant population in the 1999 sample plots. Small rosettes represented 14.8% of the plot population, representing a small drop from 1998. Large rosettes, by contrast, accounted for 22.4% of the butterfly plant population in 1999 plots, an increase of over 10% from 1998 averages (Figure 6, Table 5).

Table 5.
Gaura neomexicana ssp. coloradensis Rosette Size Class Data, F.E. Warren Air Force Base,
1998-1999.

Number of Reproductive and Vegetative Plants per plot

Plot	1998				1998 Tot	1999				1999 Tot
	# Fl/Fr	# SmR	#MdR	#LgR		#Fl/Fr	# SmR	#MdR	#LgR	
C1	15	17	56	11	99					
C2	20	4	29	2	55	0	8	46	9	63
C3	3	10	20	5	38	10	52	10	1	73
C4	5	2	40	3	50					
D1	5	5	40	4	54					
D2	26	71	139	25	261	12	43	147	73	275
D3	10	11	40	1	62					
U1	54	48	136	50	288					
U3	57	64	137	38	296					
U4	15	5	27	8	55					
TOT	210	237	664	147	1258	13	61	245	92	411
ST Dev	19.5	26.7	49.9	17.2	109.0	6.4	23.2	71.0	39.5	119.6

Figure 6. Relative Proportions of Vegetative Rosettes to Flowering Plants of *Gaura neomexicana ssp. coloradensis* on Warren Air Force Base, 1999.

Based on 3 demographic sampling plots on Crow and Diamond creeks in 1999.

Key: Small: largest rosette leaf < 6 cm; Medium: largest rosette leaf 6-18 cm; Large: largest rosette leaf > 18 cm.

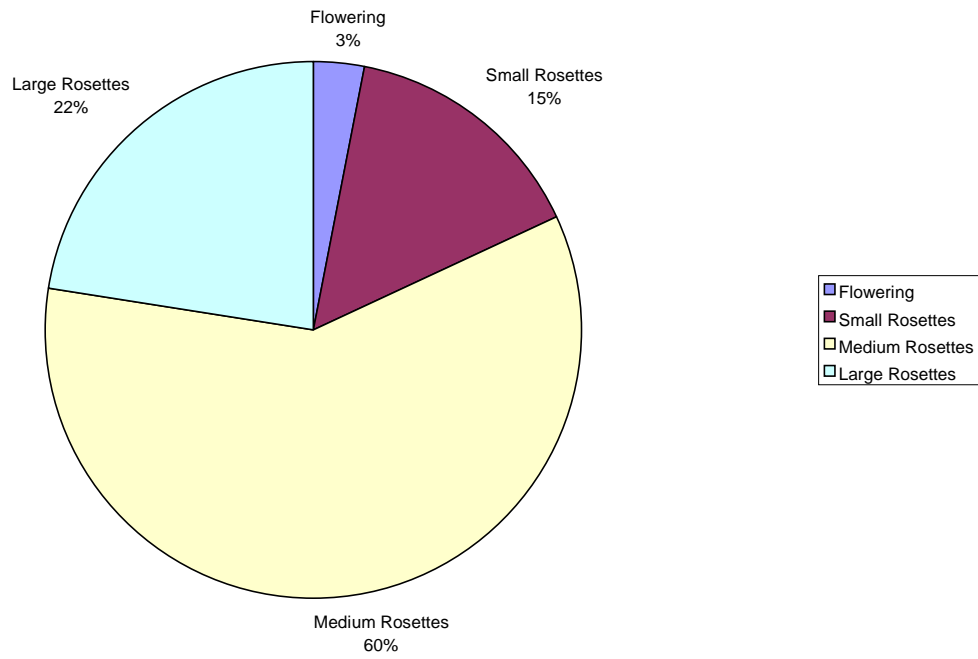


Fig 7-9

cropped wet meadow vegetation without conspicuous stands of willow. This location, near the present crossing of Crow Creek along WY Highway 210 at the south end of the Base, resembles high-quality Colorado butterfly plant habitat found elsewhere in Laramie County and could have supported this species prior to construction of the camp in 1867 (no colonies are presently known along this stretch of Crow Creek).

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

The population of Colorado butterfly plant on WAFB reached a new high in 1999, surpassing the previous 14-year record set in 1998. The current reproductive population is 61.9% greater than the Base-wide average for the period 1986-1999 (Table 1). Overall population growth has been driven by unprecedented growth in the Unnamed Drainage subpopulation, which has increased by nearly 150% since annual censuses began on the Base in 1986. Increases on the Unnamed Drainage masked a small decline on Diamond Creek and a 32% decrease on Crow Creek. Extrapolating from a range-wide rosette to reproductive plant ratio of 5:1, the vegetative rosette population on the Base is currently estimated at 56,720 individuals. The total Colorado butterfly plant population on WAFB (reproductive and vegetative plants) may be as high as 68,064 individuals, which represents 22-24% of the entire global population of the species (estimated at 283,800-301,800 individuals by Fertig [2000]).

After several years of monitoring rosette density it is apparent that a more statistically-robust sampling method is needed to better assess trends in rosette numbers. Past attempts to count all rosettes (Marriott 1993) were abandoned in 1994 because of difficulties in finding and counting rosettes amid the dense vegetation of the Base (Fertig 1995). Later efforts to count rosettes and reproductive plants within permanent plots (Floyd 1995; Fertig 1998a, 1999a) were an improvement, but the low number of macroplots and their subjective location makes extrapolations to unsampled areas of the Base statistically weak or unwise. Problems with removal of permanent markers and tags and relocation of plots in dense brush exacerbates the difficulties of monitoring rosettes.

Belt transects may offer a low cost, but statistically-meaningful alternative to traditional monitoring plots employed on the Base. Transects can be set up quickly and provide information on frequency or density of rosette and reproductive plants. Moderately sized plot frames (0.4 x 1 meter is a useful size) located in a randomly stratified manner along the transect and with adequate replication could provide baseline rosette abundance data to assess yearly changes. These transects should be located along all three watersheds and provide enough samples for meaningful extrapolation. Setting up and implementing a good monitoring design may be a more appropriate research project for a graduate student than as part of the annual census of reproductive plants.

Floyd and Ranker (1998) developed a transition matrix model to assess the population growth rate and probability of localized extinction for several Colorado butterfly plant populations on WAFB. Although there was much variability within and between sampled populations, their models predicted an overall increase in the Base population, despite some localized extirpation of smaller colonies. To date, Floyd and Ranker's predictions appear consistent with results of annual census efforts, especially on Diamond Creek and the Unnamed Drainage. Seedling

establishment rates (dictated in large part by annual fluctuations in summer precipitation) and the transition of large rosettes to flowering plants, appear to be the most important factors influencing population growth rates. Floyd and Ranker (1998) also found that the values for growth, survival, and elasticity (sensitivity of the growth rate to changes in other environmental factors) of Colorado butterfly plant populations on WAFB were comparable with other ruderal herbs that flower just once before dying.

Long-term trends on the Base remain uncertain. Populations are stable to increasing on Diamond Creek and the Unnamed Drainage, but continue to decline along Crow Creek as this area becomes increasingly dense with willow thickets. Studies by Munk (1999) indicate that the Crow Creek drainage has wetter soils at depths of 25 and 50 cm and higher soil temperatures than comparable sites along Diamond Creek and the Unnamed Drainage. While the moist conditions of Crow Creek are highly suitable for Colorado butterfly plant, these conditions may also favor greater vegetative growth of the plant's competitors. Less mesic sites along Diamond Creek and the Unnamed Drainage may be less optimal habitat for the butterfly plant, but the species thrives along these creeks because of lower competition.

Munk (1999) conducted field experiments to test the influence of exotic plants and native herbaceous/graminoid cover on the recruitment and survival of *Gaura neomexicana* ssp. *coloradensis* rosettes on WAFB. She found that rosette density increased with the reduction or removal of all vegetation, especially dense graminoid thatch. Removal of *Cirsium arvense* alone (often identified as an important threat to rosette establishment), had less influence on rosette density than removal of both *Cirsium* and graminoid cover. Munk's findings corroborate observations by Floyd (1995) and Fertig (1996, 1998b) that competition from dense vegetation is a limiting factor in butterfly plant recruitment. During the next decade, increases in vegetation cover and density may result in a base-wide decrease in Colorado butterfly plant reproduction and numbers without a program of periodic brush and vegetation reduction (Fertig 1998a; Munk 1999).

Potential management actions to enhance Colorado butterfly plant habitat on the Base may be constrained by the management needs of Preble's meadow jumping mouse (*Zapus hudsonius preblei*), a federally-listed Threatened species found along Crow Creek (Beauvais 1998). The mouse is dependent on densely vegetated willow and cottonwood stands. This type of habitat is less suited for the Colorado butterfly plant, and in the past, had been recommended for thinning to enhance *Gaura* habitat (Fertig 1995). Additional studies are needed to determine the full range and habitat usage of Preble's meadow jumping mouse on the Base and careful experimentation is needed to determine the compatibility of given management actions on populations of both species. One possible management solution would be to partition the riparian areas of the Base into different management units, with some areas dedicated to the jumping mouse and others for the Colorado butterfly plant. Based on current knowledge, Crow Creek would be more appropriate as a mouse-emphasis area, while Diamond Creek and the Unnamed drainage would be better suited for *Gaura* management. Fortunately, a number of management actions recommended for the jumping mouse should also benefit *Gaura*. These include avoidance of significant habitat alterations in riparian areas of the Base (such as new road and trail development), maintaining the hydrologic integrity of watersheds, and implementation of an integrated weed control program (Beauvais 1998).

Weeds continue to be a serious threat to Colorado butterfly plant populations on WAFB, primarily through competition for space and resources. A weed-mapping study of the upper reaches of Crow and Diamond creeks in 1999 documented extensive patches of four state noxious weed species (*Cirsium arvense*, *Cynoglossum officinale*, *Euphorbia esula*, and *Linaria dalmatica*) within butterfly plant and Preble's meadow jumping mouse habitat. Extrapolating from these mapped areas to the entire Crow and Diamond creek watersheds in the Colorado Butterfly Plant RNA, these weed species individually occupy 21-32% of the total floodplain area (Hiemstra and Fertig 2000). Some progress continues to be made in the establishment of biological control agents for Canada thistle and leafy spurge. Scattered patches of gall-infected Canada thistle were observed along all three drainages for the fourth consecutive year. Infected plants were found to be stunted, non-vigorous, and usually did not produce viable fruit. Small patches of leafy spurge with grub-bearing, inrolled leaf tips and reduced vigor were also observed along Crow Creek, suggesting that populations of flea beetle (*Apthona*) may be locally established. Despite these successes, other weeds such as yellow sweet-clover (*Melilotus officinalis*) and purple loosestrife (*Lythrum salicaria*) are becoming established in wetland areas. A small population of the latter is present just upstream of the Crow Creek Reservoir, and if left unchecked could become a serious threat to all *Gaura* populations, as well as the Preble's meadow jumping mouse, and other wetland animals (Fertig 1999b).

One final management concern regarding Colorado butterfly plant on WAFB is the species' apparent genetic homogeneity. Brown (1999) used Randomly Polymorphic DNA (RAPDs) to assess the genetic diversity between the three main butterfly plant subpopulations on WAFB and found minimal differentiation. The Base populations also differed little from a *Gaura* population sampled on Lodgepole Creek, near Burns, Wyoming, located nearly 42 km (26 miles) northwest of WAFB. Brown's study was hampered somewhat by difficulties in extracting *Gaura* DNA from associated mucilaginous compounds in the plant's leaves. Additional sampling is recommended to confirm these preliminary genetic patterns. Low levels of genetic diversity suggest that butterfly plant populations on the Base and in southeast Wyoming in general may have relatively few barriers to gene flow. Conversely, these populations may be genetically homogeneous due to founder effects or genetic bottlenecks when the population was more restricted in the past.

Elsewhere in its range, Colorado butterfly plant continues to thrive in many agricultural areas, despite a number of persistent threats. The most serious of these threats are competition from non-native plants or replacement of early successional vegetation, mortality from broadleaf herbicides, and conversion of rangelands for crop agriculture or urban expansion (Fertig 1998b; 2000; Munk 1999). Because it contains the only native populations under any formal protection, WAFB plays a pivotal role in the conservation of this species. Fertig (2000) recommended the following five conservation actions to ensure the long-term survival of the Colorado butterfly plant:

1. Maintain current, compatible land uses on private lands. Such uses include early season mowing for hay, winter or short-rotational livestock grazing, and weed control without chemical pesticides. To ensure beneficial management over the long term, better financial incentives and other rewards are needed for private landowners.

2. Continue management efforts and weed control programs on F.E. Warren Air Force Base.

Past management actions, such as the prohibition of indiscriminate use of chemical herbicides in riparian habitats, establishment of the Colorado Butterfly Plant Research Natural Area, initiation of biological weed control, ongoing monitoring of butterfly plant populations, and funding of population genetic research, needs to continue. The Memorandum of Agreement between the Air Force and other interested parties should be renewed to facilitate interagency cooperation.

3. Establish additional populations within the species' historic range.

Studies at the University of Wyoming greenhouse, Nebraska Statewide Arboretum, and National Resources Conservation Service (NRCS) plant lab in Montana have shown that Colorado butterfly is easy to propagate and has excellent potential for reintroduction to suitable habitats within its range (Fertig 1998b). Pawnee National Grassland in northeastern Colorado is one of the sites being proposed for reintroduction. A major factor limiting restoration has been the poor availability of seed or transplant stock. WAFB could play an important role in providing seeds for reintroduction efforts.

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 the NRCS plant lab, and experimental populations are also present at the University of Colorado and University of Wyoming. Additional seed banks should be established at other local or regional arboreta and botanical gardens, such as the Cheyenne and Denver botanical gardens. WAFB could be an important source of seed for these efforts.

5. Develop management techniques to maintain or improve Colorado butterfly plant habitat.

Studies at WAFB 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.

Thanks in large part to past efforts by the Air Force, the Colorado butterfly plant population on WAFB appears to be secure at present. Good stewardship needs to continue, however, to ensure that this species remains plentiful and does not require future listing as Threatened under the Endangered Species Act.

ACKNOWLEDGEMENTS

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Figs 10-17

Appendix A.

Maps and Descriptions of Revised Census Subdivisions

Crow Creek: The 32 survey subdivisions established by Marriott (1989b) were combined into 6 subdivisions in 1998 to facilitate census efforts (most of the old marker posts established by Marriott have either been removed or obliterated from ready view due to growth in vegetation). These new subdivisions are marked by permanent roads or are islands. They include:

I. NW North (former subdivisions 1, 3, 6, 9, 12, 13, 16, 17). Area extends from the boundary of the Base (along the Roundtop Road) downstream on the north and east bank of Crow Creek south to the FamCamp Road.

II. NW South (former subdivisions 2, 5, 8, 11, 15, 19). Area extends from the boundary of the Base (along the Roundtop Road) downstream on the south and west bank of Crow Creek south to the Pavilion and sharp bend in the FamCamp Road.

III. NW Island (former subdivisions 4, 7, 10, 14, 18). Includes all of the “island” between the two branches of Crow Creek and the north side of the FamCamp Road (including the picnic area east of the Pavilion).

IV. Camp Island (former subdivisions 23, 25). Area extends from south of the FamCamp Road through the “Nature Area” along the west side of the FamCamp to the north end of the Crow Creek Reservoir.

V. SE East (former subdivisions 20, 26, 27, 29, 31). Area along the east bank of Crow Creek from the FamCamp along the dirt road paralleling Crow Creek to its confluence with Diamond Creek.

VI. SE West (former subdivisions 21, 22, 24, 28, 30, 32). Area along the west bank of Crow Creek, from just south of the Pavilion (along both sides of the FamCamp Road) south along the creek to the confluence with Diamond Creek.

Diamond Creek

1. From the western Base boundary downstream to the midpoint of the north side of the second meander.
2. Midpoint on north side of the second meander east to a line formed by the extension of South Dakota Avenue.
3. South Dakota Avenue line east to drainage outlet on bluff south of creek and below office buildings (boundary line bisects the north side of the meander).
4. Drainage outlet east to paved road.
5. Area along Diamond Creek between the paved road and confluence with Crow Creek.

Unnamed Drainage

1. Base boundary northeast to Cheyenne Road.
2. Cheyenne Road east to Douglas Street.

Appendix B.

Element Occurrence Records

for *Gaura neomexicana* ssp. *coloradensis*

on Warren Air Force Base

Element Occurrence Record
GAURA NEOMEXICANA SSP *COLORADENSIS*
COLORADO BUTTERFLY PLANT
Occurrence # 015

IDENT: Y

ELEMENT RANK: G3T2/S2

COUNTY: Laramie

LOCATION: Southeastern Plains, Crow and Diamond Creeks on FE Warren Air Force Base
from west boundary to just below confluence at Frontier Avenue.

QUADNAMES Cheyenne North and Round Top Lake PRECISION: S

LATITUDE: 410900N (centrum)

Southernmost Latitude: 410835N

Northernmost Latitude: 410930N

LONGITUDE: 1045220W (centrum)

Easternmost Longitude: 1045150W

Westernmost Longitude: 1045300W

TOWN/RANGE/SECTION: T14N R67W S26 (SW4SW4); S27 (E2); S34 (N2NW4)

WATERSHED: 10190009

LASTOBS: 1999-09-02 FIRSOBS: 1978-08-19

POPULATION DATA:

- 1999-08-31/09-02: 7723 flowering and fruiting plants observed in survey by Fertig, A. Roderick, M. Neighbours, J. Williams, V. Goodin, B. Rogers, L. Welp, and R. Smith (6571 on Diamond Creek and 1152 on Crow Creek).
- 1998-08-25/09-03: 8517 flowering and fruiting plants observed in survey by W. Fertig, L. Welp, B. Rodgers, K. McGrath, K. Allen, and M. Allen (6809 on Diamond Creek and 1708 on Crow Creek).
- 1997-09-12: 7274 flowering and fruiting plants observed in survey by Fertig and Welp (5926 on Diamond Creek and 1348 on Crow Creek). Unusual "mutant" plants observed along Diamond Creek (Sec 34 N2NW4) with flower buds replaced by

vegetative shoots and many flowers with leaf-like parts in place of petals and stamens.

- 1996-09-05/12: 4817 flowering and fruiting plants observed in survey by Fertig, Marriott, Struttmann, and Neighbours (3850 on Diamond Creek and 967 on Crow Creek).
- 1995-09-11: 8105 flowering and fruiting plants observed in survey by Fertig, Mills, and Neighbours (5664 on Diamond Creek and 2441 on Crow Creek).
- 1994-09-14: 5882 flowering and fruiting plants observed in survey by Fertig, Walford, and Peterson (3865 on Diamond Creek and 2017 on Crow Creek).
- 1993-08-20: 5585 flowering and fruiting plants and 11666 rosettes observed by Fertig, Walford, and Neighbours (4650 flowering plants and 8346 rosettes on Diamond Creek and 935 flowering plants and 3320 rosettes).
- 1992-09-03: 4624 flowering plants and 16324 rosettes observed in survey by Marriott and Floyd (3627 flowering plants and 13656 rosettes on Diamond Creek and 997 flowering plants and 2668 rosettes on Crow Creek).
- 1991-09-10: 3429 flowering plants and 6352 rosettes observed in survey by Marriott and Horning (2673 flowering plants and 5301 rosettes on Diamond Creek and 756 flowering plants and 1231 rosettes on Crow Creek).
- 1990-08-20: 4201 flowering and fruiting plants and 5993 rosettes observed in survey by Marriott, Patton, and Neighbours (2171 flowering plants and 3121 rosettes on Diamond Creek and 2030 flowering plants and 2872 rosettes on Crow Creek).
- 1989-08-23: 4079 flowering plants and 8435 rosettes observed (1684 flowering plants on Diamond Creek [5560 rosettes] and 2395 flowering plants on Crow Creek [2875 rosettes]).
- 1988-08: 2607 flowering plants observed in survey by Marriott. Crow Creek subpopulation down 33% from previous year and Diamond Creek subpopulation down 63%.
- 1986-08: 5311 flowering plants (plus numerous rosettes) observed in survey by Marriott.
- 1985-08: Significant decline observed in numbers of rosettes and flowering in 2 of 3 main sites.
- 1984-08: 45 plots established at 3 sites on Crow and Diamond creeks.
- 1981-08-10: In flower and fruit. With *Agrostis*, *Salix*, *Glyceria*, and *Cirsium*.
- 1978-08-19: In flower and fruit, petals pink. With *Carex* and *Glycyrrhiza*.

HABITAT: Occurs in 2 main habitats: (1) Moist, subirrigated or streamside meadows dominated by *Poa pratensis* and *Agrostis stolonifera* along stream meanders and low banks. These sites may also be dominated by dense stands of *Cirsium arvense* and *Euphorbia esula*. (2) *Salix exigua*/*S. bebbiana* and *Populus angustifolia* thickets in riparian bottoms along perennial or intermittent streams. Soils mostly moist, sandy loam on Diamond Creek and better drained sandy gravels along Crow Creek. Also occasionally found at the edge of semi-open savannas of *Fraxinus pennsylvanicus* near seeps.

ELEVATION: 6125

SIZE: 125 acres

MANAGED AREA: Colorado Butterfly Plant Research Natural Area; F.E. Warren Air Force Base

MANAGEMENT COMMENTS: Occurrence is within the Colorado Butterfly Plant Research Natural Area. Experimental weed control program is being developed for Canada thistle and leafy spurge. Evidence of the establishment of biological control agents has been observed since 1996. Canada thistle plants have been observed with large galls, reduced vigor, and no flowers and leafy spurge plants have been observed with dead, inrolled leaf tips. Continued monitoring is needed to determine long term population trends and refine management needs.

SOURCES:

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- Fertig, W. 1999. Census of Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) on F.E. Warren Air Force Base, 1998. Report prepared for the US Air Force by the Wyoming Natural Diversity Database, Laramie, WY.
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- Floyd, S.K. and T. Ranker. 1998. Analysis of a transition matrix model for *Gaura neomexicana* ssp. *coloradensis* (Onagraceae) reveals spatial and temporal demographic variability. *International Journal of Plant Sciences* 159 (5): 853-863.
- Marriott, H. 1987. Status report for *Gaura neomexicana* ssp. *coloradensis*. Report prepared for the US Fish and Wildlife Service by the Wyoming Natural Diversity Database, Laramie, WY.
- Marriott, H. 1989. Monitoring of Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) on F. E. Warren Air Force Base, 1984-1988. Report prepared for the US Air Force by the Wyoming Natural Diversity Database, Laramie, WY.
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- on F. E. Warren Air Force Base, 1989. Report prepared for the US Air Force by the Wyoming Natural Diversity Database, Laramie, WY.
- Marriott, H. 1990. Census of Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) on F. E. Warren Air Force Base, 1990. Report prepared for the US Air Force by the Wyoming Natural Diversity Database, Laramie, WY.
- Marriott, H. 1991. Census of Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) on F. E. Warren Air Force Base, 1991. Report prepared for the US Air Force by the Wyoming Natural Diversity Database, Laramie, WY.
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SPECIMENS: Dorn, R.D. (3191). 1978. RM.
Lichvar, R.W. (4725, 4729, 4730). 1981. RM.
Neese, E., T. Andrews, and S. Peterson (15984). 1984. RM.
Fertig, W., L. Welp, and I. Thien (18054). 1997. RM.

EDITION: 00-01-12 EDAUTHOR: Walter Fertig

Element Occurrence Record
GAURA NEOMEXICANA SSP *COLORADENSIS*
COLORADO BUTTERFLY PLANT
Occurrence # 016

IDENT: Y

ELEMENT RANK: G3T2/S2

COUNTY: Laramie

LOCATION: Southeastern plains, east of Cheyenne on FE Warren Air Force Base, "Unnamed Drainage", first drainage south of high security area compound, from southwest boundary of the Base east-northeast across Cheyenne Road to Douglas Street.

QUADNAMES: Cheyenne North and Round Top Lake PRECISION: S

LATITUDE: 410807N (centrum)

Southernmost Latitude: 410802N

Northernmost Latitude: 410812N

LONGITUDE: 1045215W (centrum)

Easternmost Longitude: 1045200W

Westernmost Longitude: 1045230W

TOWN/RANGE/SECTION: T14N R67W S34 (S2 OF SE4)

WATERSHED: 10190009

LASTOBS: 1999-09-03 FIRSTOBS: 1986-08

POPULATION DATA:

1999-09-03: 3621 flowering and fruiting plants observed in survey by Fertig and S.

Markow. Patch of diseased plants observed on SE bank - axils of leaves on lower branches were covered with tiny red, bud-like structures and plants atypically leafy, but fruits appear normal.

1998-08-25: 2372 flowering and fruiting plants observed in survey by W. Fertig. Plants found in 6 main subpopulations, with the largest colonies on the east side of the Cheyenne Road from the road to the first large bend in the drainage.

1997-09-09: 1820 flowering and fruiting stems observed in survey by W. Fertig and L. Welp. Occurs with *Poa pratensis*, *Glycyrrhiza lepidota*, *Solidago canadensis*, *Helianthus nuttallii*, *Salix exigua*, *Agrostis stolonifera*, *Cirsium arvense*, and *C. flodmanii*.

1996-09-09: 777 flowering and fruiting plants observed by W. Fertig.

1995-08-30: 1822 flowering and fruiting plants observed by W. Fertig and S. Mills.

1994-09-12: 1393 flowering and fruiting plants observed by W. Fertig.

1993-08-31: 1503 flowering plants and 3656 rosettes observed by W. Fertig.

1992-09-03: 1669 flowering plants and 4228 rosettes observed by H. Marriott.

1991-09-11: 1354 flowering plants and 2580 rosettes observed by H. Marriott and D. Horning.

1990-08-30: 851 flowering plants and 1891 rosettes observed by M. Neighbours.

1989-08-23: 734 flowering plants and 1744 rosettes observed by H. Marriott and D. Culver.

1988-08: 452 flowering plants observed by H. Marriott.

1986-08: 565 flowering plants observed by H. Marriott.

HABITAT: Mesic *Agrostis stolonifera*-*Juncus balticus* meadow along banks of stream on subirrigated, alluvial soil.

ELEVATION: 6175 ft

SIZE: 26 acres

MANAGED AREA: F.E. Warren Air Force

MANAGEMENT COMMENTS: High density of willow and Canada thistle are present on the west side of the Cheyenne Road in potential *Gaura* habitat. Linda Munk, a graduate student at the University of Wyoming, has established treatment plots in this area to assess the response of vegetation to different management treatments. Ongoing monitoring is needed to determine population trends and management needs.

SOURCES:

- Fertig, W. 1993. Census of Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) on F. E. Warren Air Force Base, 1993. Report prepared by the Wyoming Natural Diversity Database, Laramie, WY.
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SPECIMENS: Fertig, W. and S. Mills (16368). 1995. RM.

EDITION: 00-01-12 EDAUTHOR: Walter Fertig

Appendix C.

1999 Colorado butterfly plant Demographic Monitoring Plot Data

Due to time constraints, only 3 demographic plots were resampled in 1999. Of these, 2 had to be relocated because of loss or removal of previous markers. Each macroplot was enlarged to 8 x 20 m and sample plots within the macroplot were chosen randomly. The goal of monitoring in 1999 was to assess ratios of flowering and fruiting plants to different rosette size classes. Suggestions for improving monitoring in 2000 are provided on page 18.

Key: S = small rosette; M = medium rosette, L = large rosette, Fl = Flowering or fruiting, D = dead.

Crow Creek # C2

Location: N 41° 09.492; W104° 52.501

Northeast side of Crow Creek in open meadow ca 200 feet north of creek just east of the large bend in the creek and opposite the last large cutbanks of the railroad track.

Origin: 290° west from origin.

50 0.4 x 1 meter plots within a 8 m x 20 m macroplot . Open moist meadow with willows ca 3-5 feet tall and dense growth of leafy spurge and yarrow. Plot is being invaded by willow saplings.

Date: 1 October 1999

Surveyors: Laura Welp and Stuart Markow

Year	# Flowering/ Fruiting Plts	# Small Rosettes [largest leaf < 6 cm]	# Medium Rosettes [largest lf 6-18 cm]	# Large Rosettes [largest lf > 18 cm]
1999 count	0	8	46	9
1999 frequency	0%	12%	32%	14%

Notes: A smaller area was sampled in 1999 (20 m²) compared to 1998 (36 m²), but plots in 1999 were sampled randomly within a larger macroplot. Because of differences in methodology, statistical comparisons between 1998 and 1999 are not relevant. Frequency values are probably too low to serve as a good baseline for detecting significant downward trends, although they would be adequate to detect population increases.

Crow Creek # C3

Location: N 41° 09.250; W104° 52.516

West side of FamCamp Road south of the Pavilion between the bend in the road and the last ash trees. Origin: 175° south from origin.

50 0.4 x 1 meter plots within a 8 m x 20 m macroplot. Grassy meadow at edge of clump of willows and grove of ash trees. Canada thistles are locally abundant. Plot is being invaded by willow saplings.

Date: 1 October 1999

Surveyors: Laura Welp and Stuart Markow

Year	# Flowering/ Fruiting Plts	# Small Rosettes [largest leaf < 6 cm]	# Medium Rosettes [largest lf 6-18 cm]	# Large Rosettes [largest lf > 18 cm]
1999 count	1	10	52	10
1999 frequency	2%	10%	22%	10%

Notes: A larger macroplot was used in 1999 and sample plots within the plot were randomly selected, making statistical inferences more meaningful.

Diamond Creek # D-2

Location: N41° 08.668; W104° 52.917

North side of first bend downstream from Base boundary (ca 150 feet from metal “box” on far bank near large *Typha* patch).

50 0.4 x 1 meter plots within a 8 m x 20 m macroplot. Community of *Agrostis stolonifera*, *Juncus balticus*, and *Cirsium arvense* on floodplain.

Date: 21 September 1999

Surveyor: Walter Fertig

Year	# Flowering/ Fruiting Plts	# Small Rosettes [largest leaf < 6 cm]	# Medium Rosettes [largest lf 6-18 cm]	# Large Rosettes [largest lf > 18 cm]
1999 count	12	43	147	73
1999 frequency	22%	38%	62%	46%

Notes: Original plot stakes were removed in 1999, making the plot impossible to relocate. A new, larger macroplot was established and sample plots within were randomly located. 55 reproductive plants were counted in the entire macroplot, but only 12 were found within the 50 randomly placed sample plots (24%).
