2001 Census of Colorado Butterfly Plant (*Gaura neomexicana* ssp. *coloradensis*) on F. E. Warren Air Force Base

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January 2002

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INTRODUCTION

One-quarter century after first being proposed for listing under the Endangered Species Act, the Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) was officially designated as Threatened on 18 October 2000 (US Fish and Wildlife Service 2000). This species was historically known from 26 locations in southeastern Wyoming, western Nebraska, and northeastern Colorado, of which only 14-18 are thought to be extant (Fertig 2000a). Two of the largest known 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). They are the only populations on federal land in Wyoming.

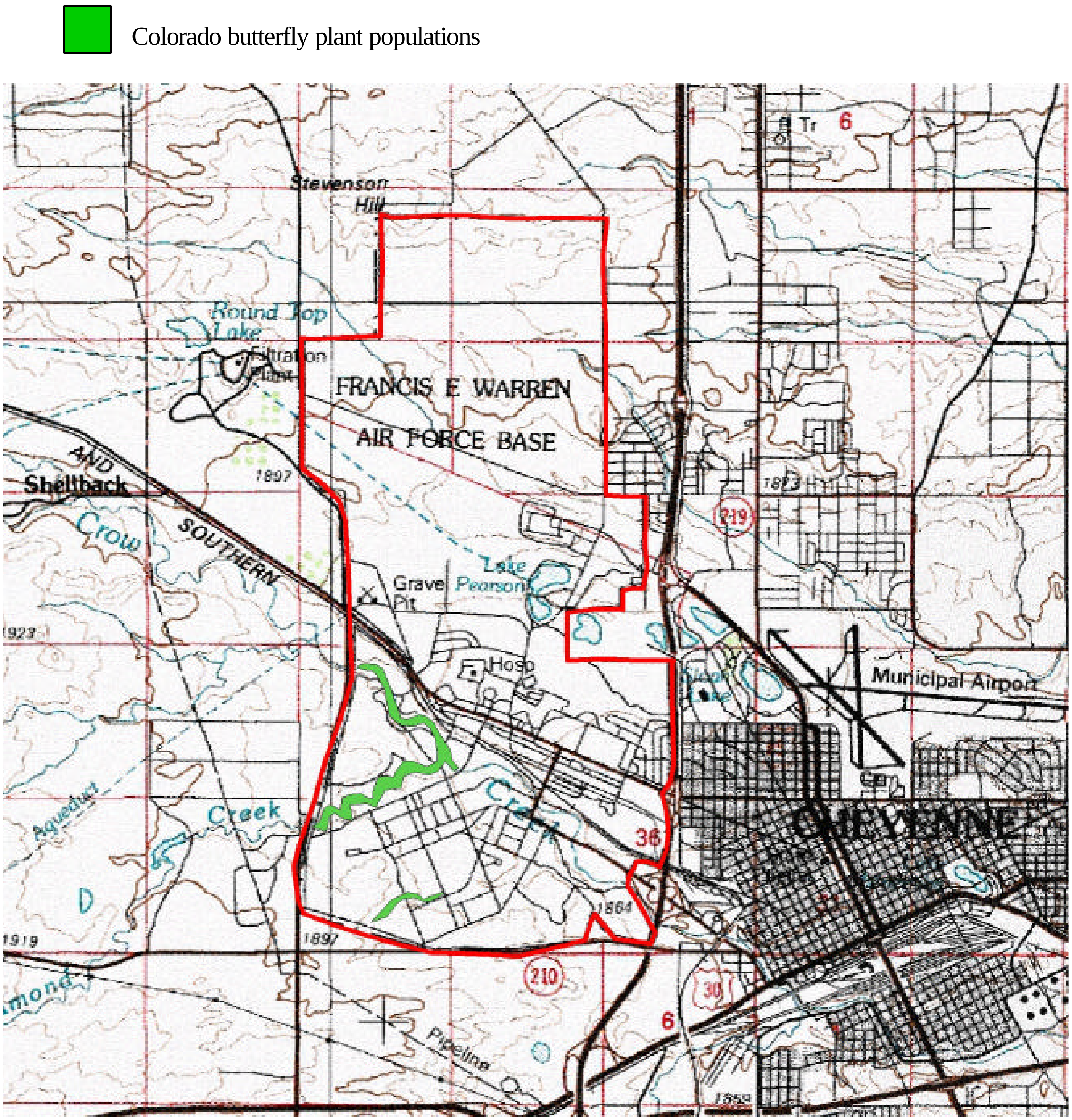
Since 1984, the US Air Force has sponsored research on Colorado butterfly plant populations at WAFB. Studies from 1984-1986 documented the distribution, abundance, habitat, and life history traits of this taxon (Mountain West Environmental Services 1985; Marriott 1989a). From 1988-2001, annual surveys have been conducted to determine population size and trends on the Base (Fertig 1993, 1995, 1996, 1997, 1998a, 1999a, 2000b, 2001; Marriott 1989a, 1989b, 1990, 1991, 1993). In recent years, other studies have addressed associated weed management issues (Floyd 1995a; Jones 1996, Hollingsworth 1996, Hiemstra and Fertig 2000; Munk 1999), plus Colorado butterfly plant population genetics (Brown 1999, 2000), and demographic structure and survivorship (Floyd 1995b; Floyd and Ranker 1998).

The following report summarizes the results of the 2001 Colorado butterfly plant census on WAFB and cross-references the concurrent weed distribution mapping (Heidel et al. 2002). It also includes a revised set of Base-wide distribution maps for butterfly plant, updates to the element occurrence records and species abstract (Appendix B, C), and a synthesis of species' life history (Appendix D), providing a framework for species' viability analysis and planning.

METHODS

Surveys were conducted by Bonnie Heidel, Scott Laursen and Walter Fertig of WYNDD along Crow and Diamond creeks and the "Unnamed Drainage" from 29 August to 6 September 2001. All flowering and fruiting plants were counted in each of 13 survey subdivisions (modified from those originally established by Marriott [1989 b]) (Appendix A). We carried annotated aerial photos of the populations for reference in the field, marked with polygons delimiting the boundaries of each colony. The location of all medium to large colonies of Colorado butterfly plant were previously mapped in the field and digitized on an arcview image of a digital orthophoto of the Base available on the internet through the University of Wyoming's Spatial Data and Visualization Center). New colonies added in the course of 2001 fieldwork were digitized and added. Field data on population size, habitat, and associated species were entered into the Element Occurrence database maintained by WYNDD (Appendix B). In addition, pilot monitoring work was conducted in a randomly selected high-density and low-density colony to examine population structure and the relationship between flowering and non-flowering plants.

Figure 1. General Location of Colorado Butterfly Plant Populations on F.E. Warren Air Force Base.



STUDY AREA

The study area includes all riparian corridor habitat occupied by Colorado butterfly plant on WAFB (Figure 1). This includes Upper Crow Creek, all of Diamond Creek (a tributary of Crow Creek with continuous colonies of Colorado butterfly plant) and the "Upper Unnamed Drainage" (an ephemeral tributary of Crow Creek with Colorado butterfly plants that are discontinuous from Crow Creek). Results for the three drainages are presented separately.

Crow Creek is a perennial stream, while Diamond Creek and Unnamed Drainage are temporary or ephemeral. Crow Creek has braided channels and shifting meanders while the other two drainages have a single meandered watercourse. Riparian areas within the floodplain are a mosaic of Coyote willow/Strapleaf willow thickets (*Salix exigua/S. eriocephala* var. *ligulifolia*), Cattail marshes (*Typha latifolia*), Nebraska sedge/Woolly sedge wetlands (*Carex nebrascensis/C. lanuginosa*), and moist meadows of Redtop (*Agrostis stolonifera*), Baltic rush (*Juncus balticus*), Kentucky bluegrass (*Poa pratensis*), Little bluestem (*Schizachyrium scoparium*), and Licorice-root (*Glycyrrhiza lepidota*) (Marriott and Jones 1988). The most extensive cover of willows are on Crow Creek, supported by the perennial water supply

There is limited vegetation management taking place in the monitoring study area over the 1986-2001 period of monitoring, apart from experimental treatments in 2 x 2 m plots by Hild students (Munz 1999, Burgess in progress). Elsewhere, mowing has been limited to heavy recreational-use areas, trails and road shoulders (Smith pers. communic.). Noxious weed control has been implemented using biocontrol agents. Sheep grazing was initiated in 2001 to control noxious weeds and included one or more areas occupied by Colorado butterfly plant (pers. observation). It appears that the spot-spraying of Canada thistle is taking place outside of the riparian corridor. The other "natural" disturbance factors in place include browsing (primarily by whitetail deer), burrowing by small mammals, and insect herbivory. In the absence of practices that remove vegetation cover and accumulation of dead plant material (thatch and litter), they increase.

The riparian corridor has other historic uses, summarized by Lichvar and Dorn (1986):

> *"Current species composition indicates that both creek bottoms have been heavily used by both man and livestock in the past. Along both streams are located old head gates and diversion systems which are probably remnants from when WAFB was a cavalry post. The terrain has also been altered from training tank drivers during World War II (Cormier, pers. commun. 1983). The switch in species composition that was observed was probably caused during the cavalry post days. Numerous weedy species which results from overgrazing are located in both drainages…"*

RESULTS

7467flowering and fruiting individuals of Colorado butterfly plant were counted on WAFB in 2001 (Table 1, Figures 2-3). This figure represents a small decrease of 2.7% (209 plants) from 2000 totals, and marks the second consecutive year of a downward trend after three straight years of population increases in the late 1990s. Despite the results, current numbers on WAFB are still 5% higher than the 15-year average, and the 2001 count is the seventh highest since annual censuses began in 1986.

Crow Creek had 878 flowering and fruiting plants in 2001, a 23.5% decline (270 plants) from 2000 (Table 2, Figures 4-5). Four of six Crow Creek subdivisions declined. The current population is 59.1% of the 15-year average of 1486 reproductive plants at the site. In 2001, the Crow Creek subpopulation accounted for less than 12% of the total Base-wide population of Colorado butterfly plant compared to 36% at the start of monitoring in 1986.

Diamond Creek had a population of 4788 reproductive individuals in 2001, a 2.1% decrease from 2000 (Table 3, Figures 6-7). The decline was most significant at the upstream end of Diamond Creek (survey subdivision 1), where the population dropped by more than one-half. Despite the ongoing decline, current numbers on Diamond Creek are still **16.6%** above the 15-year average population size of 4106 reproductive plants. The Diamond Creek population remains the largest on the Base, accounting for 64.1% of the total population.

The Unnamed drainage population contained 1801 reproductive plants in 2001, an increase of 10.0% from 2000 totals (Table 4, Figures 8-9). The west side increased significantly, while the east side decreased. Overall, the Unnamed drainage population exceeds the 15-year average of 1491 reproductive plants by 20.8%. In 2001, the Unnamed drainage accounted for 24.1% of the total base-wide population of Colorado butterfly plant compared to 9.6% at the start of monitoring in 1986.

Vegetative rosettes were not formally censused in 2001, but were sampled in a pilot monitoring study (Appendix D). Based on this and previous studies at WAFB, rosettes typically outnumber reproductive plants by a ratio of 3.2-13.2:1 (although ratios as high as 30:1 have been documented) (Fertig 2000b). Extrapolating from a conservative rosette to reproductive plant ratio of 5:1, the total number of vegetative plants is presently estimated at 37,335 individuals. The total basewide population of *Gaura neomexicana* ssp. *coloradensis* including flowering plants is estimated at 44,802 individuals, which represents 15-20% of the entire global population of the species (estimated at 283,800-301,800 individuals by Fertig [1998 b]).

The monitoring sites and results are reported separately in the life history review (Appendix D) at the end of this report.

Table 1.
Summary of Yearly Population Totals of Flowering and Fruiting Individuals of Colorado Butterfly Plant on F. E. Warren Air Force Base, 1986-2001

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
2000	7676	1148	4890	1638
2001	**7467**	**878**	**4788**	**1801**
15-yr Ave.	7082	1486	4106	1491
SD	2396	581	1727	808

* Previously reported as 2395 due to a mathematical error.

Figure 2. Colorado Butterfly Plant Census on F.E. Warren Air Force Base, 1986-2001

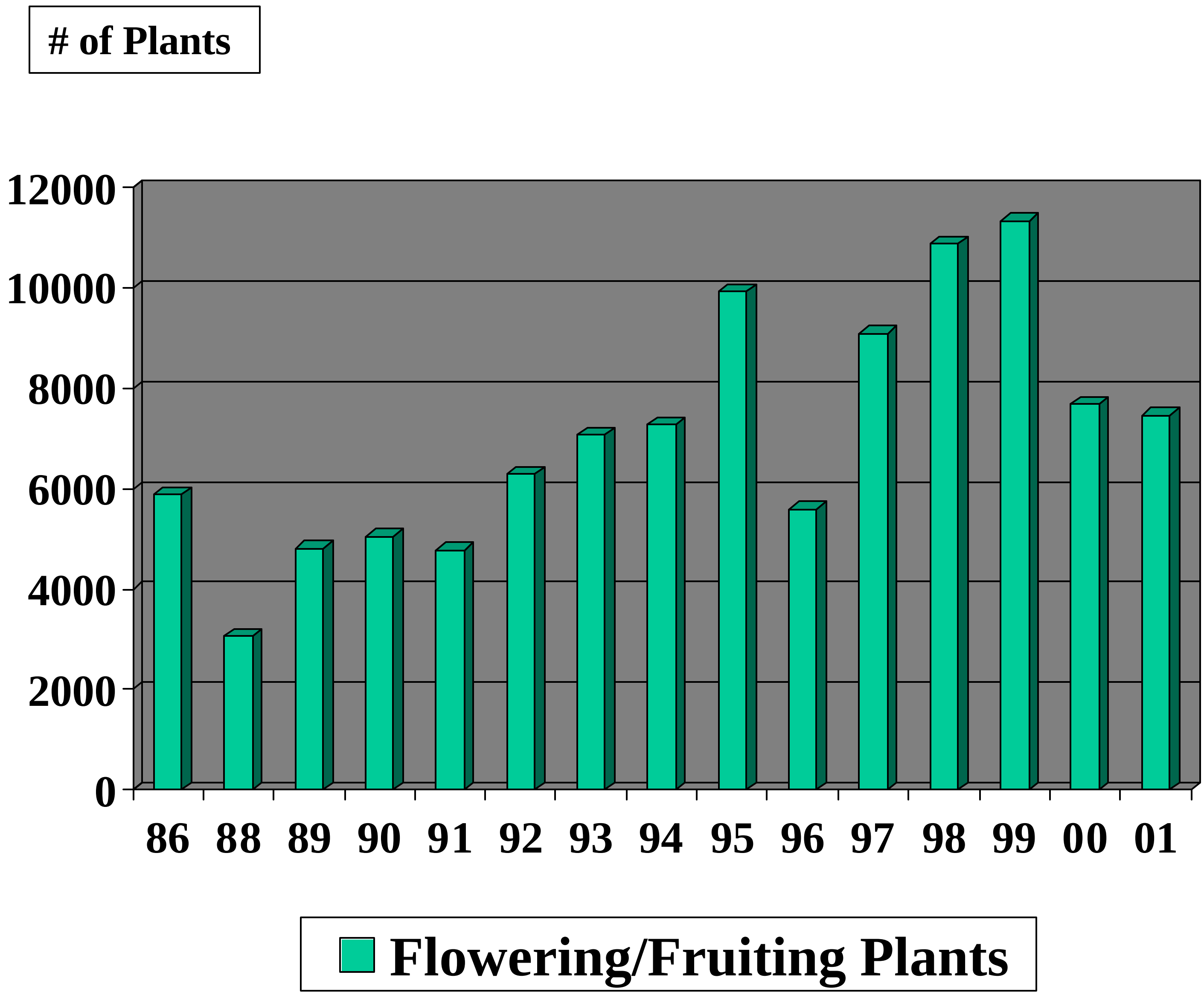
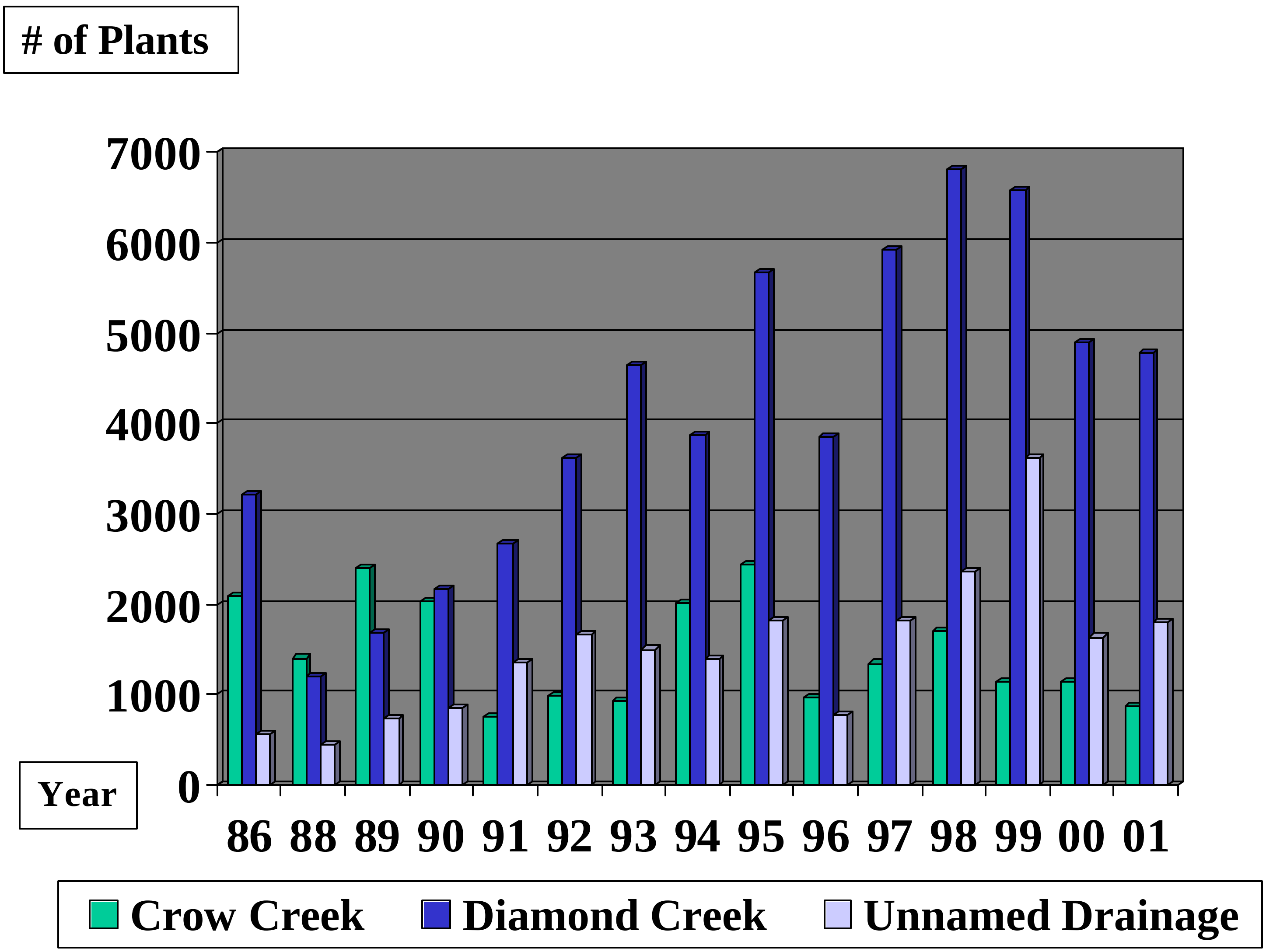


Figure 3. Colorado Butterfly Plant Census on Crow and Diamond Creeks and the Unnamed Drainage, WAFB, 1986-2001



DISCUSSION

Overview

After attaining the highest numbers in the 15-year history of census efforts on WAFB in 1999, the population of Colorado butterfly plant on the Base dropped by nearly 33% in 2000, and 2.7% in 2001. In general, the trends within monitoring subsets were not closely linked in the same drainages with exception of prevailing decline in Crow Creek. The subdivision with the highest decline, 520%, was at the head of Diamond Creek.

Are *Gaura neomexicana* ssp. *coloradensis* populations viable on WAFB? They are dynamic, and the process of answering the question depends on separating short-term fluctuations from long-term trend. The overall trends on Diamond Creek and Unnamed Creek are increasing, and the apparent trend on Crow Creek is a decreasing trend. There have not been precipitous declines (crashes) in plant numbers. At face value, it sounds encouraging if two of the three drainages are increasing. Status surveys of Colorado butterfly plant (Fertig 1998, 2000), however, suggest that Crow Creek is a rich-mesic site in which *Gaura neomexicana* ssp. *coloradensis* viability is dependent on disturbance regimes, while Diamond Creek and Unnamed Drainage are less hospitable for the species.

The distribution of plants within colonies is relatively static over time (Floyd 1995), and the distribution of separate colonies is relatively static over time (Fertig personal observation). The new practice of mapping individual Colorado butterfly plant colonies as polygons, initiated in 1999, affords new levels of detail and the opportunity to sort trends at the level of separate colonies. In 2001, there was a total of 5.2 acres of Colorado butterfly plant habitat, scattered into over 50 colonies (Heidel et al. 2002).

To set the stage for future analysis of Crow Creek trend, we reviewed the life history description and data presented in Fertig (1998) and Floyd (1995), the cumulative monitoring results through 2001, and pilot field investigation and observations in 2001 to provide a synthesis of current knowledge and a reference for further investigation (Appendix D.). The major factors affecting viability trends, as identified by Fertig (2001) and Floyd (1995), are part of the following discussion.

Climate-related interpretation and projection

Previous research (Fertig 1998, Floyd 1995, Floyd 1998) demonstrates that the processes of flowering, and recruitment of new plants [seed germination + seedling establishment] are the two pivotal stages of species' life history, and are correlated with rainfall patterns. We recommend running an analysis of variance comparison using census data and monthly precipitation factors of simultaneous and previous growing seasons to look for short-term responses in flowering as well as multi-year responses of seed germination + seedling establishment events. Such data may also help understand the effects of the 100-year flood event on Colorado butterfly plant that took place immediately prior to the start of monitoring in 1985. Is there evidence for a flush of new seed germination + seedling establishment in

1986 in the wake of flooding? Did the 100-year flood event represent a significant burst in long-distance dispersal and establishment? The body of field data collected in monitoring Colorado butterfly plant from 1984-1986 in 45 plots (Lichvar and Dorn 1986) presents a wealth of information to be re-examined in combination with climate correlation analysis to address these questions.

This earlier work is supported by census results of recent years. Significantly below-average precipitation (7.7 inches) was recorded for the Cheyenne area during the 1998 growing season (Figure 10, Table 5). Early stages of life history for *Gaura neomexicana* ssp. *coloradensis* depend on adequate moisture, as evidenced by extremely low recruitment in the dry year of a 3-year monitoring study (Floyd 1995).

Severe drought conditions continued to develop over 1998-2001, reversing a trend of above-average precipitation recorded from 1990-1997. The survival of medium and large rosettes is little-affected or enhanced in dry years (Floyd 1995), consistent with the 2-year lag in response of flowering plant numbers after the start of the dry period (Figure 10).

Flowering of mature rosettes is drought-sensitive (Floyd 1995). Even though the growing seasons of 2000 and 2001 had very similar annual precipitation totals, the 2001 season started with a relatively heavy 2.49 inches of rain in April. The spring rains may have stabilized flowering levels in 2001. An alternative explanation is that the lack of rain could have retarded vegetative growth, keeping already established plants in the rosette phase for a longer time period prior to 2001. In other words, the decline in flowering plant numbers could reflect some combination of the low recruitment, the reduced rate of plant growth, and the reduced levels of flowering.

The impacts of the drought cycle are most apparent on Diamond Creek. This may relate to the fact that its watercourse has a temporary flow, and it appears to have a steeper gradient than the other two watercourses. Crow Creek is the only perennial and unmodified stream of the three and showed the smallest proportional reduction in reproductive plant numbers over the drought interval. The drought has the least effect on the Colorado butterfly plant colonies of Crow Creek yet it shows the greatest overall decline. This would suggest that the decline is not climate-driven.

Vegetation-related interpretation

There are big differences in year-to-year trends for any given colonies of Colorado butterfly plant that are ascribed to habitat (Floyd 1995). The reasons for differences among different colonies have not been investigated. Some sites may be intrinsically poor in most years and represent chance, one-time establishment events under high-water conditions, or are only viable under uncommon climatic conditions. It is also possible that some marginal-to-poor sites are in a state of vegetation encroachment and have the potential to be excellent sites. Parallel projects to document the noxious weed extent and the willow extent were completed in 2001 and enable us to document the encroachment threats to Colorado butterfly plant in each of the locale (Heidel et al. 2002).

Competition for space and resources from expanding willow populations (particularly *Salix exigua* and *S. eriocephala* var. *ligulifolia*) appears to be a factor in reducing Colorado butterfly plant populations at several locations on WAFB. Impacts from willow expansion are probably most significant on Crow Creek, where moister soil conditions (Munk 1999) and the lack of disturbance or significant browsing pressure ultimately favors willow thickets over less densely vegetated graminoid vegetation along streambanks and adjacent floodplains. Historical photos of the Base (Barlow and Knight 1999) and more recent photos and observations clearly depict an increase in the extent and height of willow thickets along the Crow Creek Island and the main stem of the creek (Figure 11). Many areas that were formerly open meadows (including one of the demographic plots of Floyd [1995b] on the Crow Creek Island) are now dominated by willows over 2 meters tall. Being a clonal species, *Salix exigua* has been able to spread rapidly along the banks of Crow Creek, forming dense thickets that become progressively shorter in height at the leading edge of the invasion. Willow thickets are also expanding at the lower end of Diamond Creek and on the west side of the Unnamed Drainage. Butterfly plant populations are constrained by soil moisture and may be unable to expand into adjacent, drier, upland sites if their existing habitat is overtaken by willows.

Dense cover of graminoids and herbaceous plants may also limit the establishment or density of rosettes in mesic meadow sites. In the absence of grazing, mowing, flooding, or other disturbances, most riparian meadows on the Base have developed a dense thatch of dead vegetative debris that may prevent butterfly plant fruits from reaching bare soil and interfere with the establishment or growth of vegetative rosettes. Munk (1999) found that removal of all grass and forb litter in 0.5 square meter plots resulted in a significant increase in the number of vegetative rosettes the following year. Colorado butterfly plant colonies have been able to persist for over a decade in wet meadow areas that are continually mown, such as the north end of the FamCamp picnic area on the Crow Creek Island (Figure 12).

Competition from noxious weeds may be the most significant long-term threat to Colorado butterfly plant populations on WAFB. Recent weed-mapping studies by Hiemstra and Fertig 2000), Fertig and Arnett (2001), and Heidel et al. (2002) indicate that the riparian corridor occupied by Colorado butterfly plant is also occupied by Canada thistle (*Cirsium arvense*), Leafy spurge (*Euphorbia esula*), Common hounds-tongue (*Cynoglossum officinale*), and Dalmatian toadflax (*Linaria dalmatica*). These maps indicate that Colorado butterfly plant populations are negatively correlated with dense stands of Canada thistle, probably because of intense competition for light, nutrients, and space, or due to allelopathic interactions (Figure 13, Wilson 1981). Yet over 30% of all Colorado butterfly plant habitat on WAFB (30.6%), namely the polygons digitized as discrete colonies, is invaded by Canada thistle (Heidel et al. 2002.) Similarly, over 30% of the riparian corridor on Upper Crow Creek and on the Upper Unnamed Drainage (32.5% and 35.6%, respectively) is covered by Canada thistle at varying densities, while Diamond Creek has 11.0% cover of Canada thistle (Heidel et al. 2002.)

An experiment to determine the effects of herbicides on Colorado butterfly plant and on Canada thistle was identified as one of three critical study needs for WAFB weed control (Jones 1986). Such a study was pursued by Munk (1999) who concluded that herbicide removal of thistle has little to no impact on increasing *Gaura* rosette establishment one year after treatment. Munk used the herbicide Clopyralid to remove Canada thistle in her sample plots, a chemical known to persist in the soil and to be injurious to broadleaf forbs. The poor response of *Gaura neomexicana* ssp. *coloradensis* could be due to this chemical, to allelopathic compounds produced by *Cirsium arvense* litter, or by insufficient time to cause thistle mortality. Floyd (1995a) found that multiple years of thistle control were needed to achieve long-term reductions in weed density. Mechanical vegetation treatments, including different mowing and prescribed burn regimes, are being evaluated by Burgess (in progress) that may augment or work in combination with herbicide treatment of Canada thistle.

Leafy spurge is the other noxious weed, beside Canada thistle, that has the potential to invade riparian corridor habitat at densities that assume dominance (Heidel et al. 2002). Prospective biocontrol agents have been identified and critiqued by Hollingsworth (1996). Consistent with the study recommendations of Jones (1996), flea beetles have been released. We are not aware of information on the study design or results, but there were defoliated leafy spurge plants observed in low numbers and patchy patterns during the 2001 Colorado butterfly plant census (pers. obs.) The pattern of leafy spurge distribution shows a slightly lesser extent and is more uneven than that of Canada thistle, perhaps indicating a major expansion-in- progress. Leafy spurge ranges from 20.7% - 0.02% of the riparian corridors with Colorado butterfly plant in Upper Crow Creek and Upper Unnamed Drainage, respectively (Heidel et al. 2002.) Yet 20.3% of all Colorado butterfly plant habitat on WAFB, namely the polygons digitized as discrete colonies, is covered by Leafy spurge at varying densities (Heidel et al. 2002.) The weed distribution maps indicate considerable overlap with Colorado butterfly plant. It follows close behind Canada thistle as the most serious management concern. The spread of weeds in the riparian areas has become so pervasive that it is difficult to find high-quality sites that are still relatively weed-free (Figure 14).

Curtailment of past vegetation management practices on the Base may have contributed to the current situation of willow encroachment, dense native vegetation, and weedy species. In the late 1980s, the Base instituted a policy of not mowing or using herbicides within a buffer area along the 3 main watersheds of WAFB. Mowing prior to 1992 may have been a sporadic, spot-treatment of weeds rather than an annual management operation (Smith pers. communication). This has allowed both native and exotic vegetation to increase in cover, reducing the quality of many streambanks for butterfly plant. Concurrent elimination of spraying has been beneficial in reducing butterfly plant mortality. The species is extremely vulnerable to most broad-leaf herbicides, but has allowed noxious weed populations to proliferate. Some progress has been made in the establishment of biological control vectors for Canada thistle and Leafy spurge (Fertig 2000b), but success has been localized and spotty.

Munk (1999) recommended a 3-pronged strategy involving mowing, grazing, and burning to reduce vegetation cover and improve habitat quality for the Colorado butterfly plant on WAFB. Experiments by Floyd (1995a) and Munk (1999) have found that mowing and selective herbicide application by wet blade or backpack sprayers can significantly reduce thistle or graminoid cover. Such gains can be quickly lost, however, if the treatment in not continued beyond one or two years. Selection of herbicides must be done with care, as many common broadleaf pesticides are toxic to Colorado butterfly plant (Munk 1999). Timing of mowing is also important and may be most useful if done early in the growing season after the initial bolting of Canada thistle but before the reproductive maturation of butterfly plant (Fertig 2000a). Efforts to control weeds and shrubby vegetation on the Base may affect the federally Threatened Preble's meadow jumping mouse (*Zapus hudsonius preblei*) that relies on dense willow thickets for cover.

Controlled grazing by livestock may also be a management tool to reduce graminoid and forb cover. Such practices are commonly used on privately-owned rangelands harboring Colorado butterfly plant elsewhere in Laramie County (Fertig 2000a). The timing and placement of sites managed for winter grazing or stocked at low rates for summer pasture typically have shorter and less dense cover and often have fewer patches of Canada thistle or willow. Sheep were grazed and herded on Crow Creek in 2001, and the minimum requirement for evaluating their effects would be to consider timing, placement, and sheep-induced affects on Colorado butterfly plant. Although flowering or fruiting plants are commonly browsed, Colorado butterfly plant is capable of forming multiple new branches once apical dominance is removed. Due to their short stature, vegetative rosettes are rarely grazed by livestock (Fertig 2000a).

Fire has not previously been utilized to control graminoid or shrub cover in *Gaura neomexicana* ssp. *coloradensis* habitat, but could have beneficial effects through increasing light infiltration and soil temperature, improving nutrient availability, or enhancing germination with smoke. In response to the recommendations of Munk (1999) and others, Hild (2000) initiated a research project to assess the affects of controlled burning and mowing treatment on existing rosettes and the establishment of *Gaura* seedlings on WAFB. This study began in 2001 with treatments in 2 x 2 m plots with subplots (mowed in June and in August, burned in spring and in fall). Vegetation management in general offers the greatest promise in maintaining or enhancing Colorado butterfly plant on WAFB. The work of Hild and Burgess (in progress) will offer preliminary information on Colorado butterfly plant response, for broader vegetation management treatments if warranted on Crow Creek.

In the monitoring work of Lichvar and Dorn (1986), three years of vegetation composition information and other site characteristics data (1984-1986) were collected, and photographs taken. The 45 - 2 x 2 m plots were subjectively located in places of high *Gaura neomexicana* ssp. *coloradensis* density and marked by metal posts at all 4 corners. We recommend revisiting, re-reading, and re-photographing as many of the plots as are still marked. In addition, we recommend trying to relocate and reread at least 2 of the 9 Floyd (1995) plots, also 2 x 2m plots in high density locales, for which extirpation of Colorado butterfly plant was projected. The vegetation and trend information, in addition to climate correlation analyses and management response research (Hild and Burgess in progress) will provide information needed to consider management options. In the future it may be appropriate to consider weed and willow management response research at the scale of entire colonies. Any such work would include demographic monitoring and more objective sampling design.

Summary

Tentative workplans identified in this report includes the following. They are to provide pieces of information needed for a framework if the Air Force is to set recovery objectives for Colorado butterfly plant, standards, and management plans. We call for a peer-review at the stage of setting the course of future study and census work to address the most important species viability questions in the most efficient manner. Tentative workplans include:

? Continue gathering census data in 2002, and begin recording the numbers of Colorado butterfly plant within each polygon.

? Revisit the 1984-1986 monitoring sites as providing site-specific information on long-term species' trend and simultaneous vegetation trend (2002). Coordinate this work with willow monitoring.

? Review the 1984-1986 monitoring results as documentation of the 1985 flood event (2002).

? Analyze Colorado butterfly plant census results as they correlate with current-year's and previous-years' precipitation variables, and provide a potential tool for projecting population numbers (2002).

? Design a test of the correlation between Colorado butterfly plant density (each size class stage) and vegetation density

? Consult with plant monitoring experts on these tentative workplans and their experimental designs

? Evaluate the merit of weed and willow management at the scale of entire Colorado butterly plant colonies (polygons), pending results of Burgess and Hild and the preceding tasks (after 2002).

With the listing of Colorado butterfly plant as a Threatened species, management of this species is now mandated by federal law. Management actions and research undertaken on F.E. Warren Air Force Base will play a pivotal role in ensuring the long-term survival of *Gaura neomexicana* ssp. *coloradensis*, both on the Base and off.

Table 2. Colorado Butterfly Plant Census Data from Crow Creek Subdivisions, WAFB, 1986-2001.

Number of flowering and fruiting plants

Year	**NW North**	**NW South**	**NW Island**	**Camp Island**	**SE East**	**SE West**	**Total**
1986							**2095**
1988							**1406**
1989	1210	147	607	190	81	173	**2408***
1990	897	59	572	252	128	122	**2030**
1991	404	48	200	54	10	40	**756**
1992	188	67	472	145	58	67	**997**
1993	130	82	450	129	77	67	**935**
1994	637	92	906	182	40	160	**2017**
1995	1145	63	724	263	41	205	**2441**
1996	507	26	139	109	48	138	**967**
1997	589	67	254	230	31	177	**1348**
1998	458	37	235	256	124	598	**1708**
1999	275	36	157	201	31	452	**1152**
2000	467	40	126	136	6	373	**1148**
2001	**271**	**163**	**55**	**132**	**40**	**217**	**878**
1-yr Trend	- 42.0%	+ 307.5%	- 56.3%	- 2.9%	+ 566.6%	- 41.8%	**- 40.9%**
12-15 yr Ave.	552	71	377	175	55	215	**1486**
12-15 yr Trend	- 50.9%	+ 129.6%	- 85.4%	- 24.6%	- 27.3%	+ 0.009%	**- 23.5%**

2001 survey conducted on 29-31 August by Walter Fertig, Bonnie Heidel and Scott Laursen.

* Formerly reported as 2395 due to a mathematical error.

Note: Due to difficulties in relocating the original marker stakes, the Crow Creek subdivisons 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 4. Colorado Butterfly Plant Census on Crow Creek, 1986-2001.

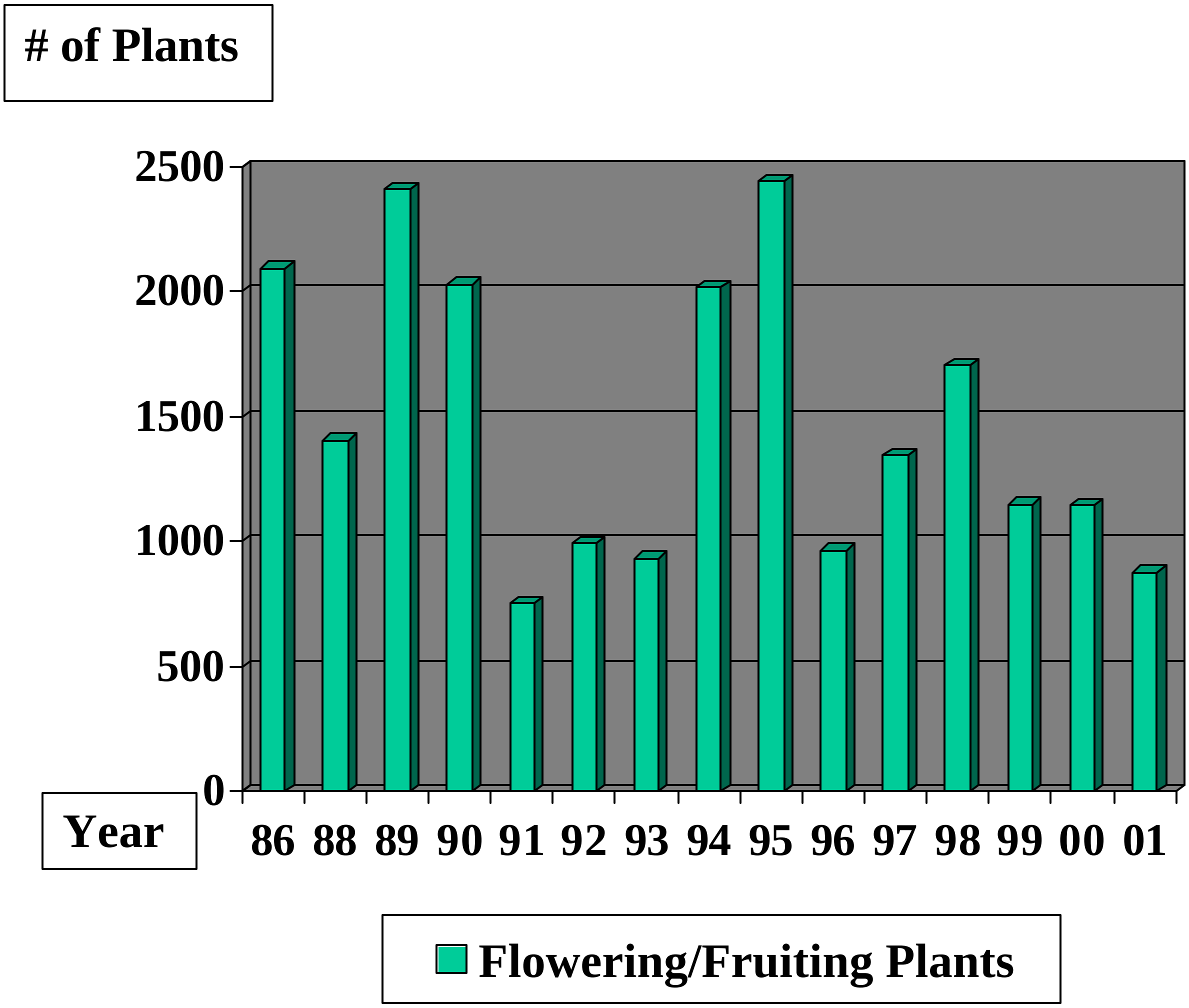


Figure 5. Colorado Butterfly Plant Populations Along Crow Creek, 2001
(Scale 1:9,000)

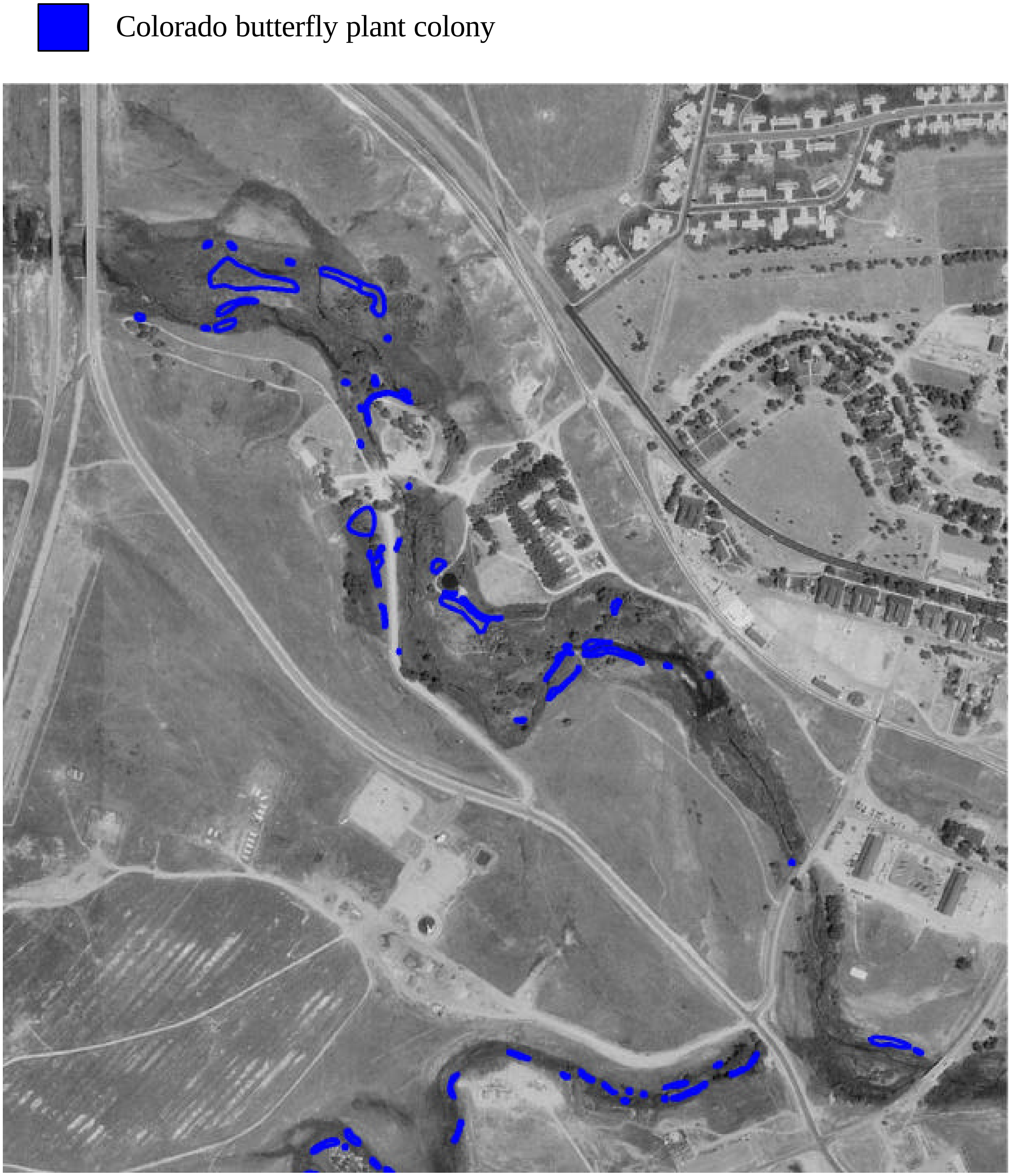


Table 3. Colorado Butterfly Plant Census Data from Diamond Creek Subdivisions, WAFB, 1986-2001.

Number of flowering and fruiting plants

Year	1	2	3	4	5	Total
1986						**3216**
1988						**1201**
1989	207	461	561	432	23	**1684**
1990	377	471	965	355	3	**2171**
1991	977	405	1016	275	*	**2673**
1992	1554	525	1055	456	37	**3627**
1993	1891	1076	1249	415	19	**4650**
1994[?]	S: 322 N: 976 Tot: 1298	S: 601 N: 145 Tot: 746	S: 263 N: 760 Tot: 1023	S: 557 N: 229 Tot: 786	S: 12 N: 0 Tot: 12	**3865**
1995	S: 406 N: 1093 Tot: 1499	S: 1058 N: 209 Tot: 1267	S: 437 N: 1922 Tot: 2359	S: 390 N:138 Tot: 528	S: 11 N: 0 Tot: 11	**5664**
1996	S: 387 N: 763 Tot: 1150	S: 484 N: 143 Tot: 627	S: 440 N: 632 Tot: 1072	S: 566 N: 396 Tot: 962	S: 39 N: 0 Tot: 39	**3850**
1997	S: 370 N: 866 Tot: 1236	S: 889 N: 181 Tot: 1070	S: 611 N: 1735 Tot: 2346	S: 890 N: 356 Tot: 1246	S: 28 N: 0 Tot: 28	**5926**
1998	S: 106 N: 1593 Tot: 1699	S: 780 N: 756 Tot: 1536	S: 632 N: 1480 Tot: 2112	S: 908 N: 507 Tot: 1415	S: 47 N: 0 Tot: 47	**6809**
1999	S: 671 N: 1340 Tot: 2011	S: 764 N: 205 Tot: 969	S: 410 N: 1682 Tot: 2092	S: 1027 N: 452 Tot: 1479	S: 20 N: 0 Tot: 20	**6571**
2000	S: 431 N: 610 Tot: 1041	S: 615 N: 152 Tot: 767	S: 485 N: 1660 Tot: 2145	S: 662 N: 268 Tot: 930	S: 7 N: 0 Tot: 7	**4890**
2001	**S: 98 N: 395 Tot: 493**	**S: 775 N: 143 Tot: 918**	**S: 367 N: 2055 Tot: 2422**	**S: 687 N: 256 Tot: 943**	**S: 12 N: 0 Tot: 12**	**4788**
1-yr Trend	- 520.6%	+ 19.7%	+ 12.9%	+ 1.4%	+ 71.4%	**- 2.1%**
12-14 yr Ave.	1187	834	1571	786	22	**4106**
12-14 yr Trend	- 58.5%	+ 10.1%	+ 54.2%	+ 20.0%	- 45.5%	**+ 16.6%**

* lumped in Crow Creek # 32 in 1991 survey

? Survey subdivisions divided into southern (S) and northern (N) segments (using the creek as the dividing line) in 1994.

2001 survey conducted on 31 August and 4-5 September by Bonnie Heidel, Scott Laursen and Walter Fertig.

Figure 6. Colorado Butterfly Plant Census on Diamond Creek, 1986-2001.

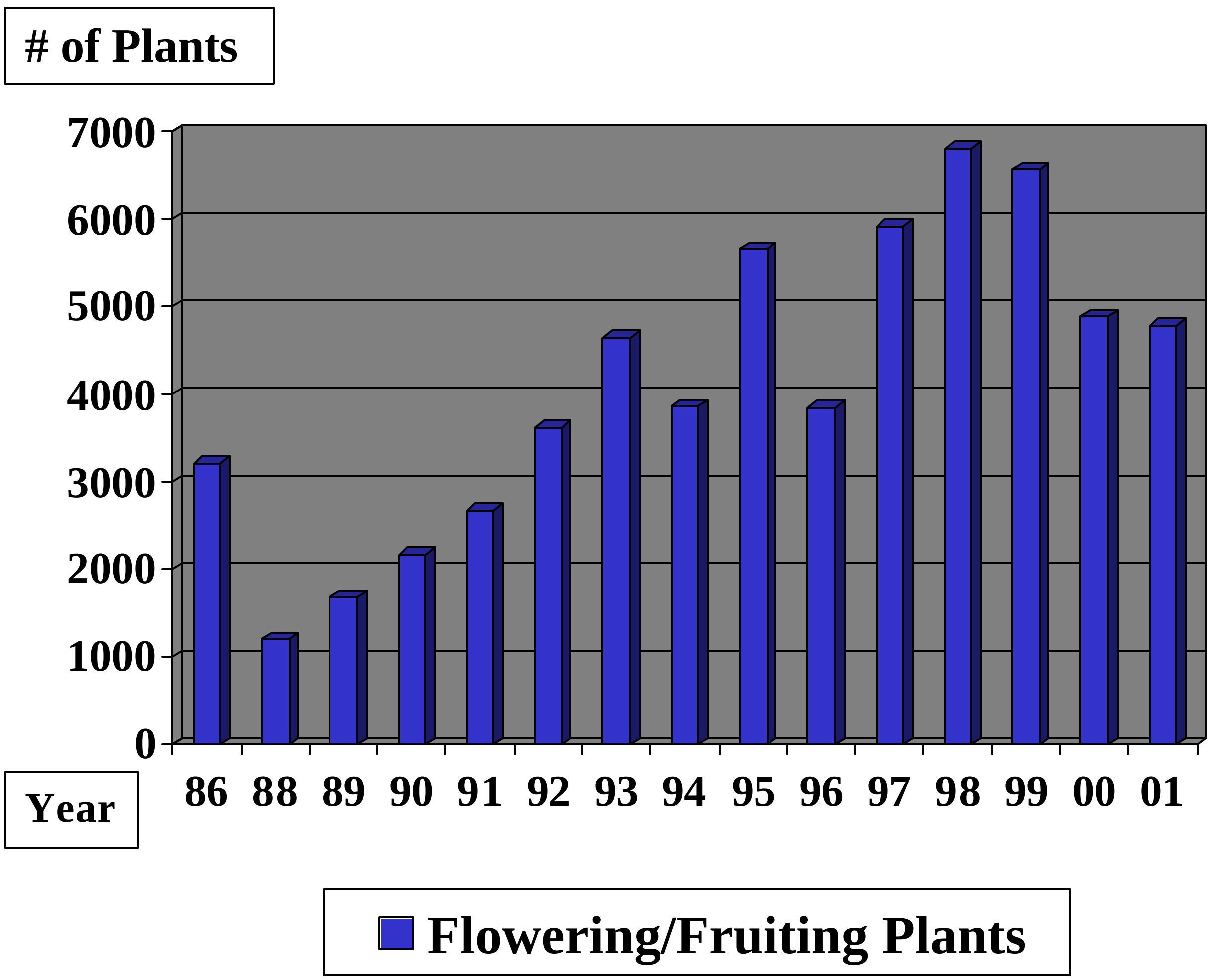


Figure 7. Colorado Butterfly Plant Populations Along Diamond Creek, 2001 (Scale 1:10,000)

Colorado butterfly plant colony

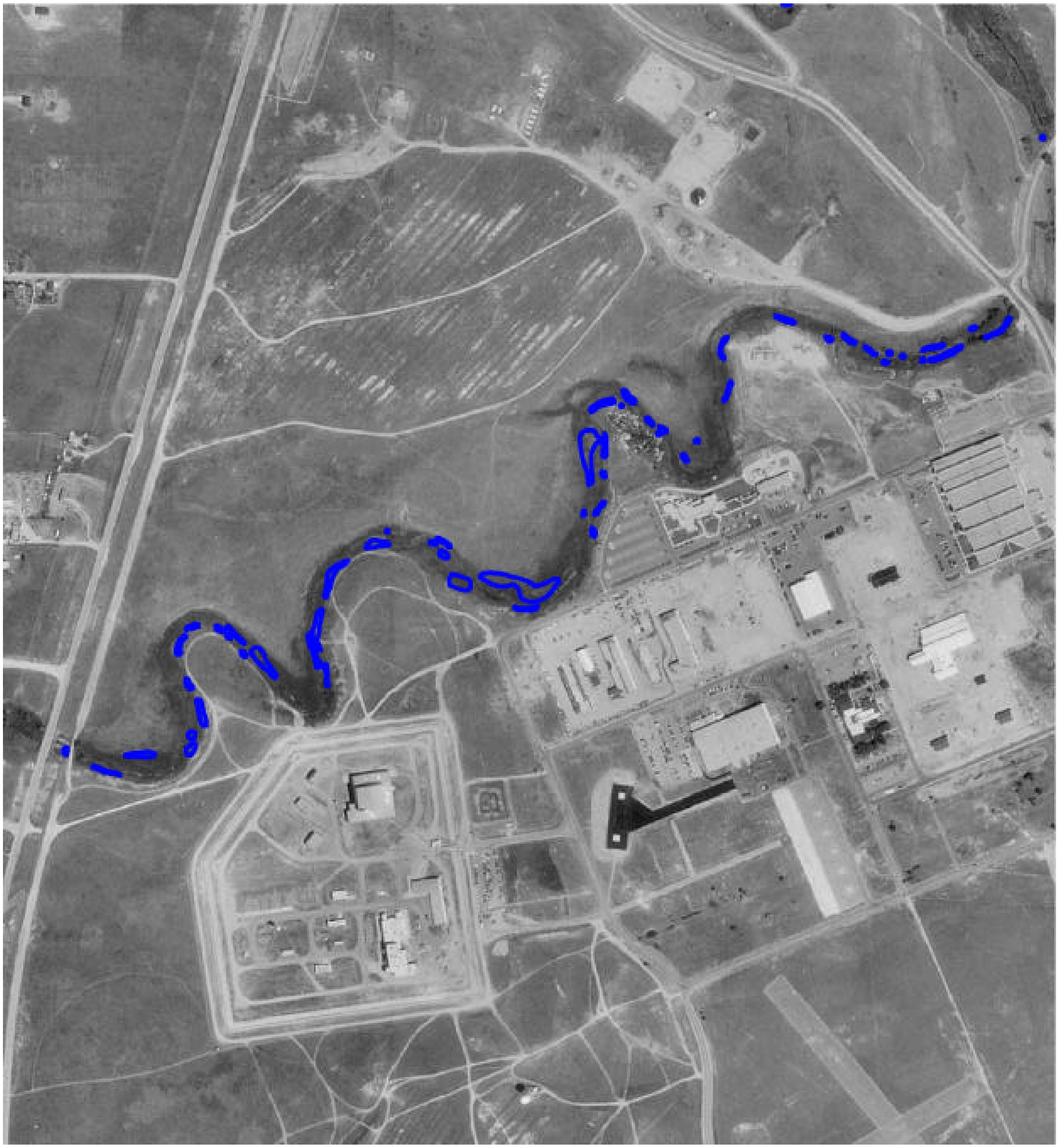


Table 4. Colorado Butterfly Plant Census Data from the Unnamed Drainage, WAFB, 1986-2001.

Number of flowering and fruiting plants

Year	1	2	Total
1986			**565**
1988			**452**
1989	84	650	**734**
1990	171	680	**851**
1991	429	925	**1354**
1992	727	942	**1669**
1993	556	947	**1503**
1994	366	1027	**1393**
1995	855	967	**1822**
1996	284	493	**777**
1997	655	1165	**1820**
1998	512	1860	**2372**
1999	1275	2346	**3621**
2000	290	1348	**1638**
2001	**S: 507** **N: 197** **Tot: 704**	**S: 539** **N: 558** **Tot: 1097**	**1801**
1-yr Trend	+ 143%	- 18.6%	**- 10.0%**
12-14 yr Ave.	531	1111	**1491**
12-14 yr Trend	+ 32.6%	- 1.3%	**+ 20.8%**

2001 survey conducted on 5-6 September by Scott Laursen, Walter Fertig and Bonnie Heidel.

Figure 8. Colorado Butterfly Plant Census on the Unnamed Drainage, 1986-2001.

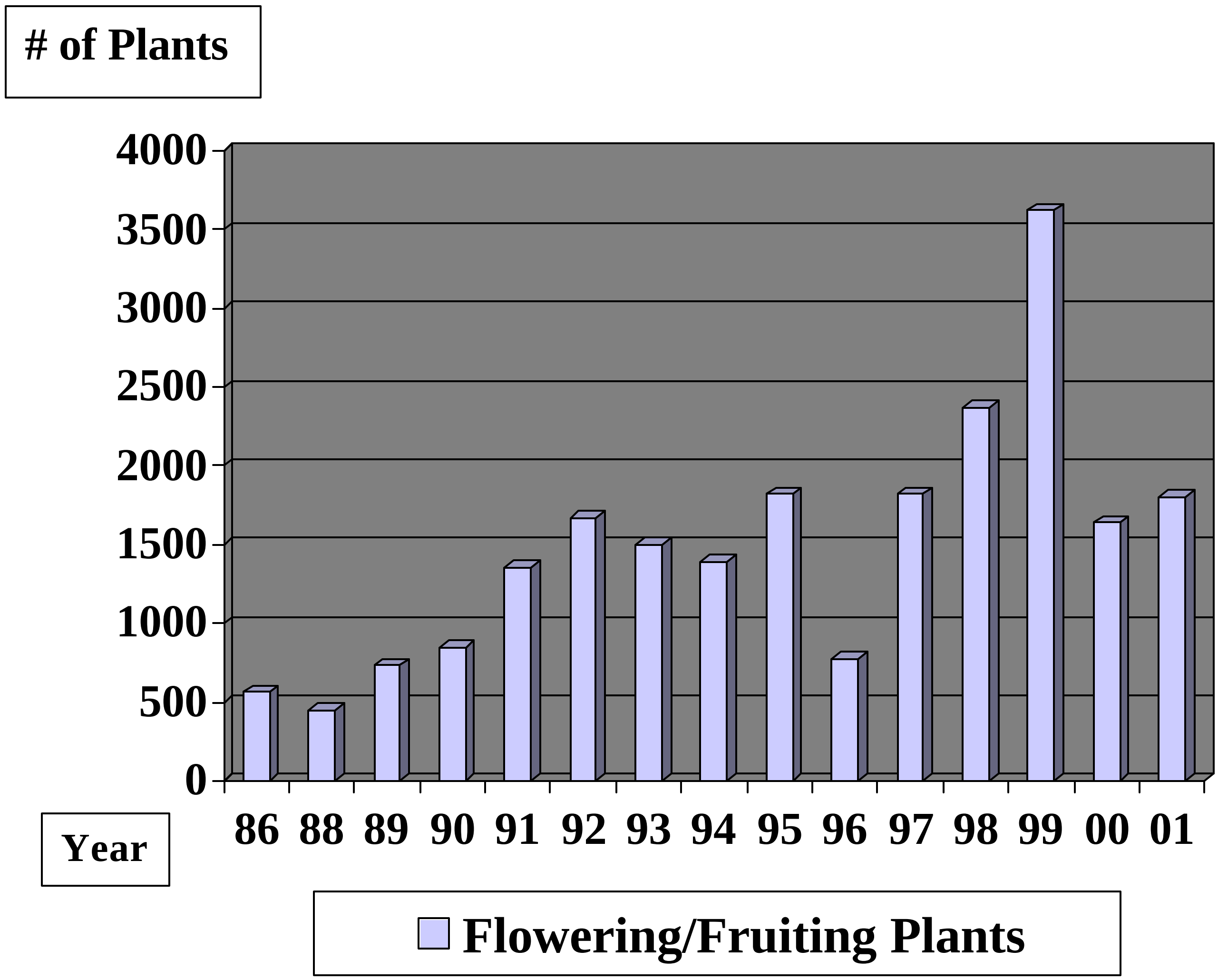


Figure 9. Colorado Butterfly Plant Populations Along the Unnamed Drainage, 2001 (Scale 1:9,000)

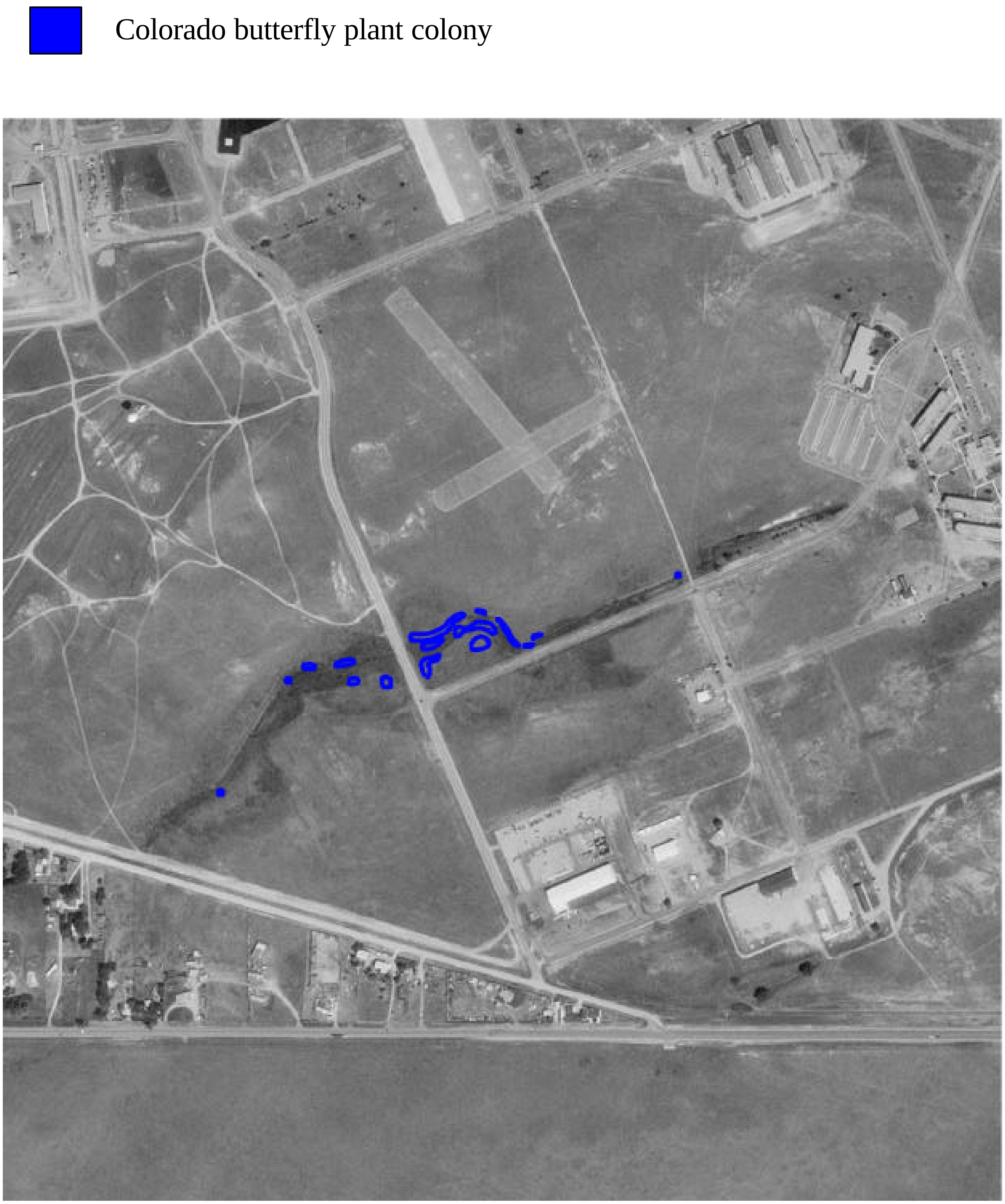


Figure 10. Yearly and Growing Season Precipitation, Cheyenne, WY, 1986-2001.

Source: National Weather Service water year precipitation data (1990-2001) (www.wrds.uwyo.edu/wrds/nws/nws.html) and USDA High Plains Research Center (1984-1993) from Fertig (1993).

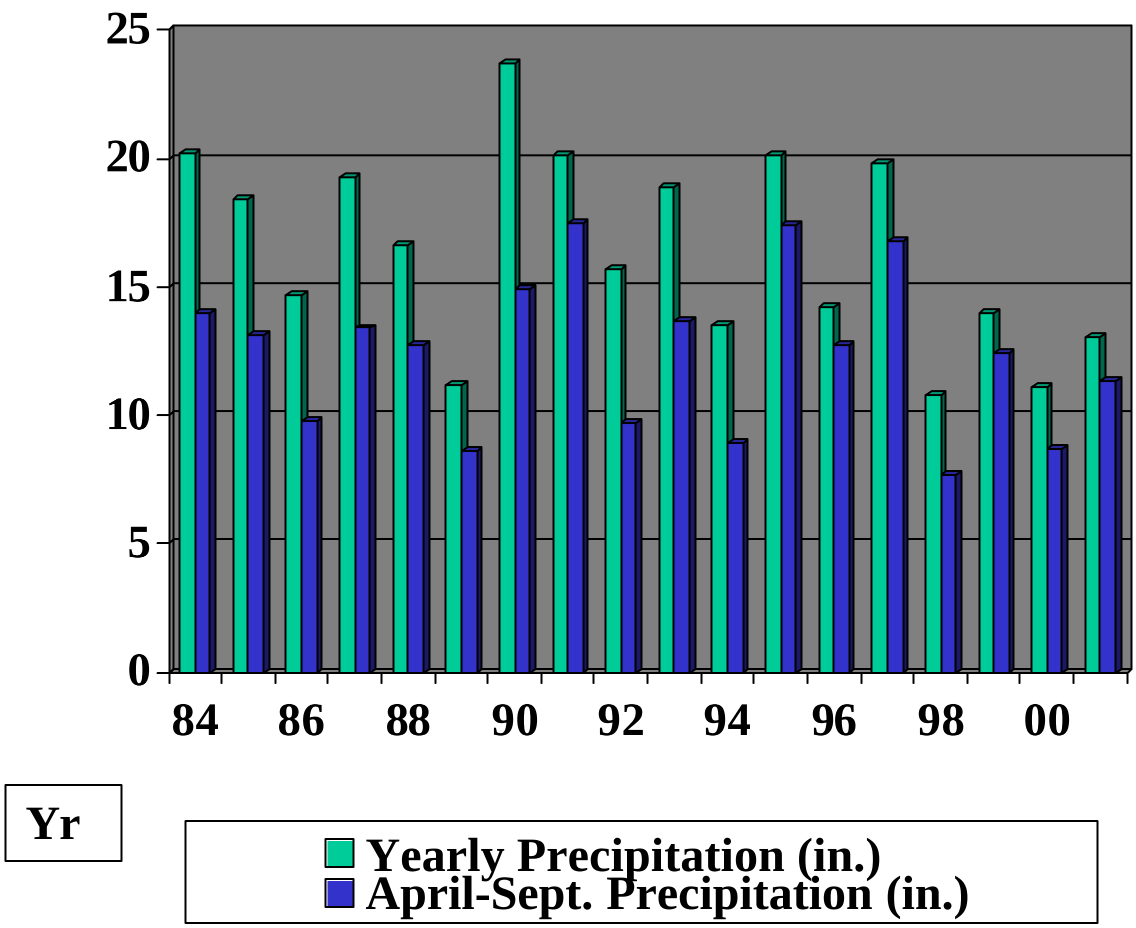


Table 5. Yearly and Growing Season Precipitation, Cheyenne, WY, 1986-2000 and Colorado Butterfly Plant Abundance

Source: National Weather Service water year precipitation data (1990-2001) (www.wrds.uwyo.edu/wrds/nws/nws.html) and USDA High Plains Research Center (1984-1993) from Fertig (1993).

Year	**Yearly Precipitation (in)**	**Growing Season (April-September) Precipitation (in)**	**# of Reproductive Colorado Butterfly Plants**
1984	20.2	14.0	
1985	18.4	13.1	
1986	14.7	9.8	5876
1987	19.3	13.4	
1988	16.6	12.7	3059
1989	11.2 ##	8.6 ##	4813
1990	23.7 #	14.9	5052
1991	20.1	17.5 #	4783
1992	15.7	9.7	6293
1993	18.9	13.7	7088
1994	13.5	8.9 ##	7275
1995	20.1	17.4 #	9927
1996	14.2	12.7	5594
1997	19.8	16.8 #	9094
1998	10.8 ##	7.7 ##	10889
1999	16.1	14.5	11344
2000	13.73	8.7 ##	7676
2001	13.07*	11.31	7467
Average	15.27	11.24	7055
Standard Deviation	3.38	3.1	

Precipitation significantly lower than average
Precipitation significantly higher than average

* Data from December 2000 was unavailable

Figure 11. Dense stand of Coyote willow (*Salix exigua*) along the northwest bank of Crow Creek on F.E. Warren Air Force Base. This area was formerly an open meadow that supported a small colony of Colorado butterfly plant. Once established, Butterfly plants may persist for a few years within these dense stands, but new rosettes are typically not recruited. WYNDD photo by W. Fertig, 1 October 2000.

Insert photo of willow stand.

Figure 12. Colorado butterfly plant habitat at the north end of the FamCamp picnic area on the Crow Creek Island. Butterfly plants (visible as a swath of light red at the middle of the photo) have been able to maintain themselves at this mown site for over a decade and the site is sometimes mown by the time of census. Without mowing, this site would probably be overtaken by dense willow thickets, found just to the north of the picnic area. WYNDD photo by W. Fertig 20 August 1988.

Insert habitat photo.

Figure 13. Dense stand of Canada thistle along a terrace bench on the north bank of Diamond Creek (at the boundary of survey subdivisions 3 and 4). This bench currently supports several small patches of Colorado butterfly plant, mostly restricted to a narrow band within 2 meters of the creek. Much additional *Gaura* habitat is available within the area dominated by thistle, but seedlings and rosettes may be unable to establish a foothold due to competition or allelopathy. WYNDD photo by W. Fertig, 1 September 1999.

Insert photo of thistle.

Figure 14. Relatively high-quality Colorado butterfly plant habitat on a floodplain terrace along the north bank of Diamond Creek (Survey Subdivision 3). In 2000, this was one of the largest populations encountered along Diamond Creek (butterfly plants can be seen as the red tinge in the middle of the photo). This site has only trace cover of noxious weeds, but high cover (over 90%) of graminoids and forbs (mostly *Solidago rigida*, *Helianthus nuttallii*, *Asclepias speciosa, Agrostis stolonifera,* and *Juncus balticus*). Some reduction in vegetation cover could be advantageous to the butterfly plant population in the future. WYNDD photo by W. Fertig, 25 August 2000.

Insert habitat photo.

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ACKNOWLEDGEMENTS

We wish to thank Cathryn Pesenti of F.E. Warren Air Force Base for her coordination of this project. George Jones, Rebekah Smith, Doug Keinath, and Robert Thurston of WYNDD provided riparian corridor information and assistance with Arc-view analysis.

Appendix A.

Maps and Descriptions of Revised Census Subdivisions

Crow Creek: The 32 survey subdivisions established by Marriott (1989 b) 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 and the streamcourses. 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.

Survey Subdivisions of Crow Creek

Colorado butterfly plant colony

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.

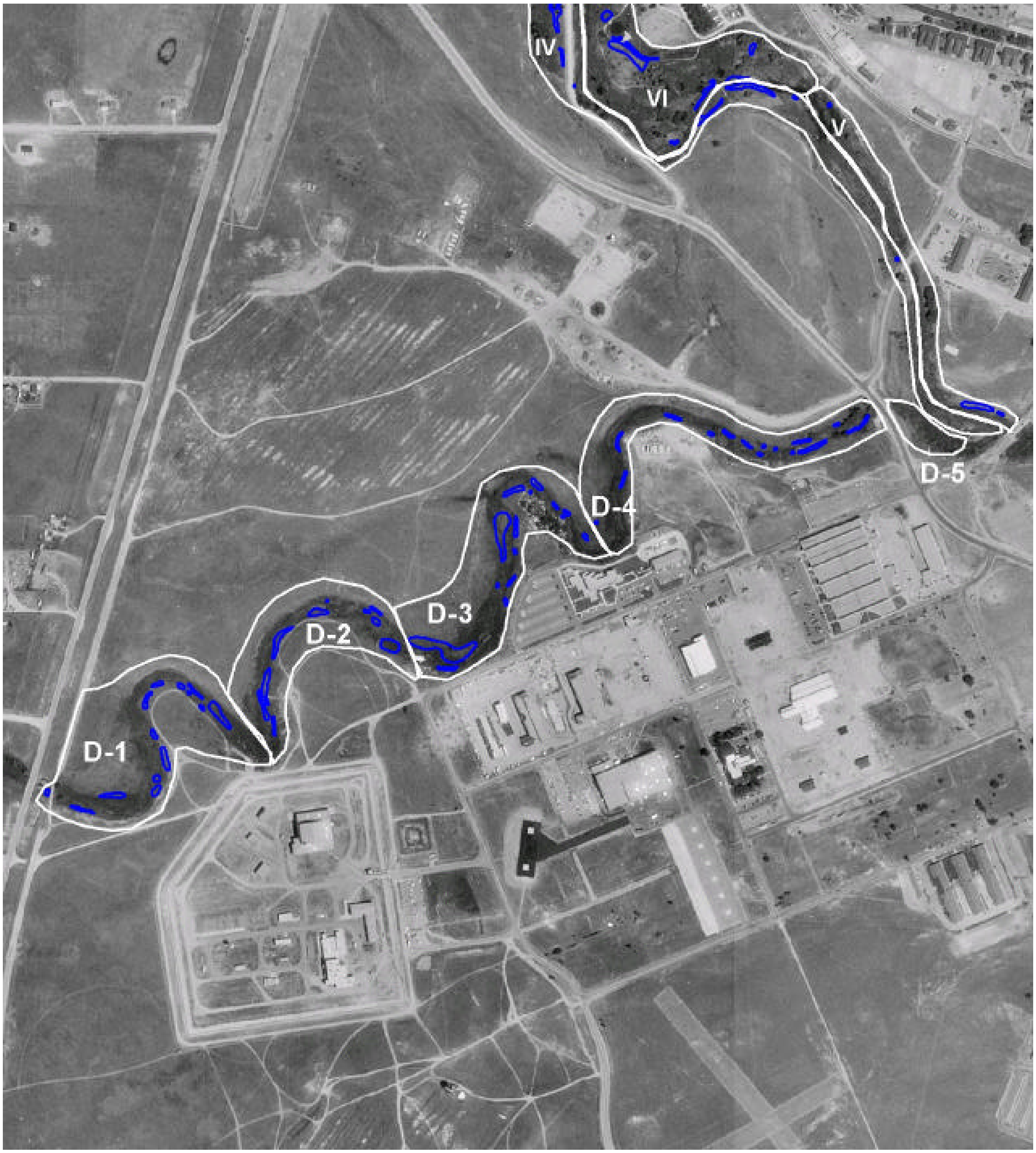
5. Area along Diamond Creek between the paved road and confluence with Crow Creek.

Unnamed Drainage

1. Base boundary northeast to Cheyenne Road.

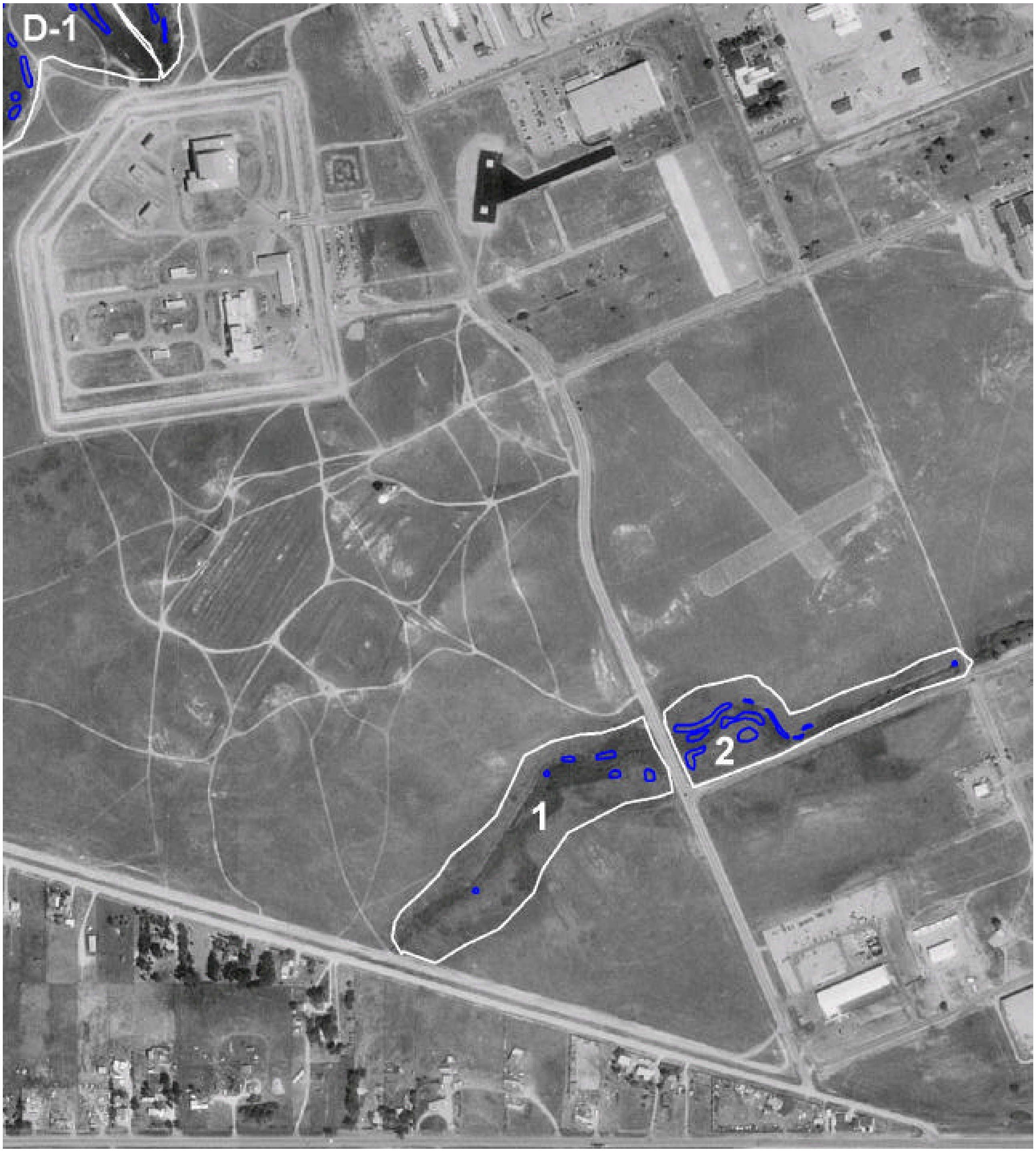
2. Cheyenne Road east to Douglas Street.

Survey Subdivisions of Diamond Creek



Survey Subdivisions of the Unnamed Drainage

Colorado butterfly plant colony



Appendix B.

Element Occurrence Records
for *Gaura neomexicana* ssp. *coloradensis*
on F.E. Warren Air Force Base

WYOMING NATURAL DIVERSITY DATABASE
-Element Occurrence Record-

GAURA NEOMEXICANA SSP. *COLORADENSIS*
COLORADO BUTTERFLY PLANT
Number: 015

Status
Data Sensitive?: No
Identification verified: Yes
TNC Global Rank: G3T2
WYNDD State Rank: S2
Federal Status: Listed Threatened
WY Distribution Note: Regional Endemic

Location
County: Laramie
USGS Quad Names: Cheyenne North and Round Top Lake
Latitude: 410900N (centrum)
South Latitude: 410835N
North Latitude: 410930N
Longitude: 1045220W (centrum)
East Longitude: 1045150W
West Longitude: 1045300W
Map Accuracy: Precise; location is within a 75 foot radius of point on USGS topo map.
Town/Range/Section: T14N R67W S26 SW4SW4; S27 E2; S34 N2NW4
Location: Southeastern Plains, Crow and Diamond Creeks on FE Warren Air Force Base from west boundary to just below confluence at Frontier Avenue.

Population Data
Last Observed: 2001-09-05
First Observed: 1978-08-19

Data: 2001-08-29/09-06: 5666 flowering and fruiting plants counted in survey by W. Fertig, B. Heidel and S. Laursen (878 on Crow Creek and 4788 on Diamond Creek).
Data: 2000-08-25/09-05: 6038 flowering and fruiting plants observed in survey by W. Fertig, L. Welp, and M. Neighbours (4890 on Diamond Creek and 1148 on Crow Creek).

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

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 pensylvanicus* near seeps.
Elevation: 6125 feet
Size: 125 acres

Comments: Monitoring has taken place at this site since 1984 and is on-going. Sandy Floyd (graduate student, Univ. Colorado) conducted demographic research and weed control studies here from 1992-95.

Managed Area: F.E. Warren Air Force Base (includes the Colorado Butterfly Plant Research Natural Area)

Mgmt Comments: Continued monitoring needed to determine long term population trends and refine management needs. An 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.

Specimens:
Dorn, R.D. (3191). 1978. RM.
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Neese, E., T. Andrews, and S. Peterson (15984). 1984. RM.
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Author: Walter Fertig
Edition Date: 01-02-12

WYOMING NATURAL DIVERSITY DATABASE
-Element Occurrence Record-

GAURA NEOMEXICANA SSP. *COLORADENSIS*
COLORADO BUTTERFLY PLANT
Number: 016

Status
Data Sensitive?: No
Identification verified: Yes
TNC Global Rank: G3T2
WYNDD State Rank: S2
Federal Status: Listed Threatened
WY Distribution Note: Regional Endemic

Location
County: Laramie
USGS Quad Name: Cheyenne North & Round Top Lake
Latitude: 410807N (centrum)
South Latitude: 410802N
North Latitude: 410812N
Longitude: 1045215W (centrum)
East Longitude: 1045200W
West Longitude: 1045230W
Map Accuracy: Precise; location is within a 75 foot radius of point on USGS topo map.
Town/Range/Section: T14N R67W S34 (S2 OF SE4)
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.

Population Data
Last Observed: 2001-09-06
First Observed: 1986-08

Data: 2001-09-06: 1801 flowering and fruiting plants counted in census by B. Heidel, S. Laursen and W. Fertig.

2000-09-01: 1638 flowering and fruiting plants counted in census by Walter Fertig and Laura Welp. Diseased plants still found on SE bank (in same area as in 1999).
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.

1995-08-30: 1822 flowering and fruiting plants observed.

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

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

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

1991-09-11: 1354 flowering plants and 2580 rosettes observed.

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

1989-08-23: 734 flowering plants and 1744 rosettes observed.

1988-08: 452 flowering plants observed.

1986-08: 565 flowering plants observed.

Habitat
Habitat: Mesic *Agrostis stolonifera-Juncus balticus* meadow along banks of stream on subirrigated, alluvial soil.
Elevation: 6175 feet
Size: 26 acres

Managed Area: F.E. Warren Air Force Base

Comments: Ongoing monitoring is needed to determine population trends and management needs. 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.

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Author: Walter Fertig
Edition Date: 00-01-12

Appendix C.

-State Species Abstract-
-Wyoming Natural Diversity Database-

GAURA NEOMEXICANA SSP
COLORADENSIS
COLORADO BUTTERFLY PLANT
Family: Onagraceae

Status:
US Fish & Wildlife Service: Threatened (October 2000)
Agency Status: USFS Region 2 Sensitive

Heritage Rank:
Global: G3T2 State: S2
WYNDD Plant List: Regional Endemic (High Conservation Priority)

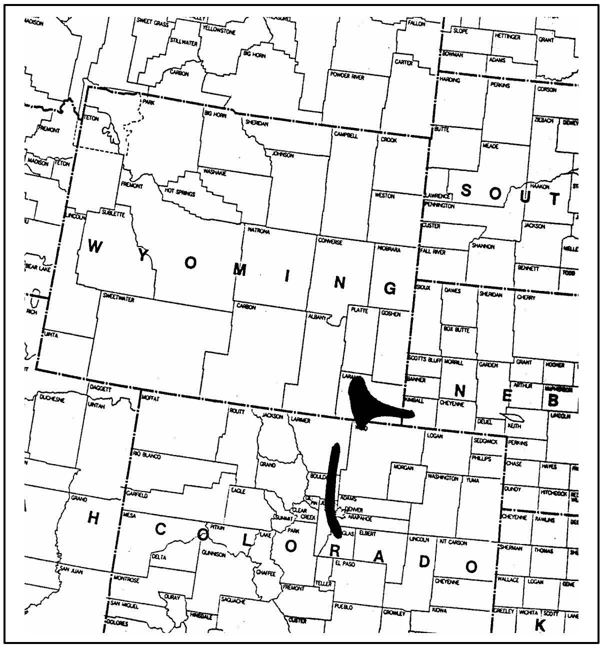
Description: Colorado butterfly plant is a short-lived perennial herb with 1-few reddish, pubescent stems 50-80 cm tall. Lower leaves are lance-shaped, with smooth or wavy-toothed margins and average 5-10 cm long, while those higher on the stem are smaller and reduced in number. The inflorescence is located above the leaves and is flat-topped when in bud. The multiple branches of the inflorescence elongate as the flowering season progresses. Usually only a few open flowers are present at any time and are located between the floral buds and the mature fruits. Flowers have 4 white petals (turning pink with age) and are 1-1.5 cm wide. The hard, nut-like fruits are 4-angled and sessile (Fertig 2000).

Similar Species: *Gaura parviflora* is an annual with a narrow, elongate inflorescence and white flowers less than 3 mm long. *G. coccinea* is a low, bushy perennial with leaves less than 3 mm long. Rosettes of

Insert photo of *G. neomexicana* spp. *coloradensis*.

Above: *Gaura neomexicana* ssp. *coloradensis* at F.E. Warren Air Force Base. Photo by Walter Fertig. Below: *G. neomexicana* ssp. *coloradensis* by Walter Fertig.

Insert drawing of *G. neomexicana* spp. *coloradensis*.



Global distribution of *Gaura neomexicana* ssp. *coloradensis*.

Cirsium flodmanii and *Oenothera* spp. are similar, but are more pubescent.

Flowering/Fruiting Period: Flowering occurs from late June or early July until the first hard frost of fall (usually mid September to early October). Fruit present from late July-early October. Reproduces only by seed. Plants are self-fertile, but also outcross. Flowers open at dusk and are pollinated by moths.

Distribution: Regional endemic of SW Nebraska, SE Wyoming, and NE Colorado. In Wyoming, known only from the Southeastern Plains in Laramie and Platte counties.

Habitat: Typically occurs on subirrigated soils on level or slightly sloping floodplains and drainage bottoms at elevations of 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, Colorado butterfly plant 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*. *Salix exigua* and *Cirsium arvense* may become locally dominant in habitats that are not periodically flooded or otherwise disturbed. Colorado butterfly plant occurs on soils derived from conglomerates, sandstones, and tuffaceous mudstones and siltstones of the Tertiary Wind River, Arikaree, and Ogalalla formations. Average annual precipitation within its range is 13-16 inches, with the majority falling as rain (Fertig 2000).

Management Considerations: Periodic disturbance events are necessary to maintain suitable habitat, control competing vegetation, and open bare ground for seedling establishment. Historically, flooding was probably the most important type of disturbance. Moderate, rotational grazing and haying may be potential management tools to create open habitat.

Occurrences in Wyoming: 19 occurrences are currently recognized in Wyoming, 12 of which have been relocated or resurveyed since 1992. [3 occurrences were combined with adjacent sites in 1997, reducing the number of recognized EOs from 21 to 18.]
Abundance: Individual colonies may be locally abundant or sparse, often depending on habitat conditions. Rangewide, the population of flowering individuals was estimated at 47,300-50,300 in 1998 (with the majority of these occurring in Wyoming). Total population size

(including non-flowering rosettes) is estimated at 283,000-300,000. Long term studies at FE Warren Air Force Base suggest that population size can vary from year to year, depending on past recruitment success and moisture conditions. Overall, the trend at the Base has been stable to slightly increasing over the past decade.

Trends: This taxon has probably declined in the past century due to loss of historically known habitat in northcentral Colorado (near Ft. Collins). Recent surveys in Wyoming suggest that extant populations are probably stable, although population sizes may vary from year to year.

Insert habitat photo.

Above: Habitat of Gaura neomexicana ssp. coloradensis along sub-irrigated banks of floodplain meadow, Laramie County, WY. Photo by Walter Fertig.

Protection status: Two occurrences on Warren Air Force Base near Cheyenne are within a designated Research Natural Area and are protected from spraying, mowing, and livestock grazing. All other occurrences are on private or state lands managed primarily for agriculture.

Threats: Haying, grazing, herbicide spraying, and urban expansion have been cited as potential threats. The primary threat, however, may be vegetative succession in the absence of periodic disturbances that makes habitat unsuitable for seedling establishment.

Managed Areas: Two occurrences are found on F.E. Warren Air Force Base. All other populations in Wyoming are on state or private lands.

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Author: Walter Fertig
Updated: 00-08-01

Appendix D. Life history of *Gaura neomexicana* var. *coloradensis* - a preliminary framework for interpreting the census of flowering plants and characterizing population biology and ecology

(This information is based on the life history description and data presented in Fertig (1998) and Floyd (1995), the cumulative monitoring results through 2001, and pilot field investigation and observations in 2001. It represents a synthesis that is needed to evaluate the direction of species' research.)

Colorado butterfly plant (*Gaura neomexicana* var. *coloradensis)* is a short-lived, semelparous perennial, i.e., it typically flowers only once at the end of its life cycle and dies. It reproduces strictly from seed. Thus, an annual census of reproductive (flowering and/or fruiting) Colorado butterfly plants provides a long-term gauge of population trend.

The census of reproductive plants does not represent the entire population but a small segment in which reproductive plants are outnumbered by nonflowering (vegetative) plants. Individual plants vary in how many years they take to flower. Thus, the census of flowering plants in any given year cannot be interpreted without understanding species' life history, knowing the census results from previous years, and the environmental conditions. The following life history discussion augments the 15 years of census data and annual precipitation data from the nearest meteorological stations as a framework to characterize overall trends.

Floyd (1995) determined that Colorado butterfly plant flowers within 2-4+ years of germination. The species was initially characterized as a biennial (Raven and Gregory 1972), but only 0.32% of the new plants that Floyd monitored at WAFB flowered in their second year. Plants grown from seed collected on WAFB were planted in a garden in Boulder, Colorado and 100% flowered in the second year (Floyd, personal observation). Possible explanations for accelerated flowering in the garden environment include the low competition and high nutrients of the garden setting, the more southern latitude of the garden, or the seed processing or planting practices that may have affected seed dormancy or imbibition to accelerate germination in the garden.

Colorado butterfly plant begins to flower in late June or early July and continues until the first hard frost of autumn (Fertig 1998). It 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 night (Floyd, personal communication to Fertig). Individual plants may produce 143-383 fruits, each containing 1-4 seeds (Mountain West Environmental Services 1985; Munz 1938; in Fertig 1998). Factors that may affect fruit production include the level of nutrient resources in the taproot, pollinator activity, and herbivory. Anecdotal information indicates that herbivory can greatly reduce fruit production if grazed or browsed in the latter half of the growing season. The number of fruits per stem may be fixed, but the number of stems can be increased if plants are grazed or browsed early in the growing season when there is adequate moisture, converting a single- or few-branched flowering stem into a multi-branched flowering stem with more fruits (presumably representing the high end of the potential fruit production numbers, mentioned previously.)

Fruit dissemination is characterized as locally concentrated around the parent plant, as shown by the pattern in which seedlings are concentrated around the point where a plant had flowered in the previous year (Floyd 1995). Flooding and transport in the mud adhered to passing wildlife may be the primary means of long-distance dispersal (Fertig 1998).

Seeds generally germinate in the spring. They appear to require after-ripening and adequate moisture. Nine-month dormancy or a 3 month moist stratification treatment are adequate for germination in cultivation (Jim Locklear, personal communication to Fertig). There is anecdotal information to indicate that bare surface substrate (low shade, low litter cover) is favorable for seed germination (Floyd 1995). Seeds can live longer than 1 year, forming a seedbank. Floyd set out germination boxes containing 100 seeds each and had 49% germination in 1993, a favorable moisture year, followed by 22.5% germination in the same two undisturbed boxes in 1994, a low moisture year (total germination = 71.5%). By contrast, only 2 seeds of 300 (0.7%) germinated in a new set of germination boxes set out by Floyd in 1994 (Floyd 1995), indicating an interaction between seed age and environmental conditions. The presence of a seedbank is supported by her monitoring plot data. Two of the nine monitoring plots produced more new plants in 1993, a favorable moisture year, than the number of fruits produced in the same plots in 1992; exceeding the previous year's fruit production by up to 266.7%. The longevity of the seedbank is unknown. Seedbanks have adaptive values for plants in dynamic environments depending on seedling establishment success, adult fecundity, and longevity (Rees 1994).

Seedlings become established over the course of the growing season to produce small rosettes. We do not have the monthly monitoring data collected by Floyd (1995) to consider the timing by which seedlings become established, but she described germination and establishment as occurring from May through September (Floyd 1995). Baseline monitoring data collected by Leah Burgess (unpublished data), comparing rosette numbers in June and in August, 2001, provides evidence of seedling establishment over the two-month span (Table 1). If these two monitoring times encompass the majority of seedling establishment during the growing season, then they indicate that seedling establishment is over a magnitude lower in the Crow Creek plot than on the Unnamed Creek plot. One possible explanation is that Burgess' monitoring plot on Crow Creek is in an exceptionally dry microhabitat that is particularly susceptible to the affects of drought.

Table 1. Changes in Colorado butterfly plant numbers within the growing season (June-Aug, 2001 by Burgess 2001)

	June tally (rosette)	**Aug tally (rosette + flowering)**	**% change (June/Aug tallies)**
Crow Creek	394	520	31
Diamond Creek	737	1601	117
Unnamed Creek	686	3012	339

Vegetative plants may live for some years as stemless "rosettes" of basal leaves arising from a taproot. Flowering plants start the growing season as rosettes, but send up a flowering stem ("bolt") usually early in the growing season (late June-early July) and the basal leaves die. Studies by Floyd (1995) and Fertig (1996) suggest that flowering occurs only after rosettes exceed a minimum basal leaf diameter. The size of basal rosettes in any given year is the most important predictor of their size the following year, or whether they will flower instead of remaining vegetative. The size classes of basal rosettes have been characterized by Floyd (1995) in small, medium, and large categories that correspond with optimum prediction values. Small rosettes include all newly-established plants (first-year plants). They are 0-5.9 cm diameter, and they do not flower in the subsequent year. Large rosettes are the vegetative plants that are most likely to flower in the subsequent year, and they are 18+ cm in diameter. Medium rosettes are 6-17.9 cm in diameter, and have low probabilities of flowering in the subsequent year. From year to year, the small and medium rosettes usually grow into a larger size class; a small fraction may remain the same size class.

The monitoring by Floyd (1995) also included a dry-year interval, providing a model for drought-cycle trends. The 1994 drought year had a high mortality level in the small rosette class compared to 1993. This might be explained by the shallower taproot depth and lesser carbohydrate reserves of small rosettes compared to medium and large rosettes. The 1994 dry year actually had lower mortality levels for medium and large rosettes compared to mortality levels in 1993, perhaps due to reduced vegetation competition in the dry year, or some secondary affects of the dry year (e.g., disturbance patterns). If we extrapolate from this dry-year data to a drought-cycle series of years, then we would expect short-term persistence (within the 1-4 year period that it usually takes a medium or large rosette to flower) and sharp decline due to low germination and low survival rates of small rosettes.

A schematic model of the Colorado butterfly plant life cycle that represents transitions between annual stage classes was developed by Floyd (1995; Figure 1, below). Her monitoring results were used to develop transition matrices and determine which life history stage(s) limit population growth. Contrary to the model, flowering plants do not transition to medium and large rosettes in one year's time.

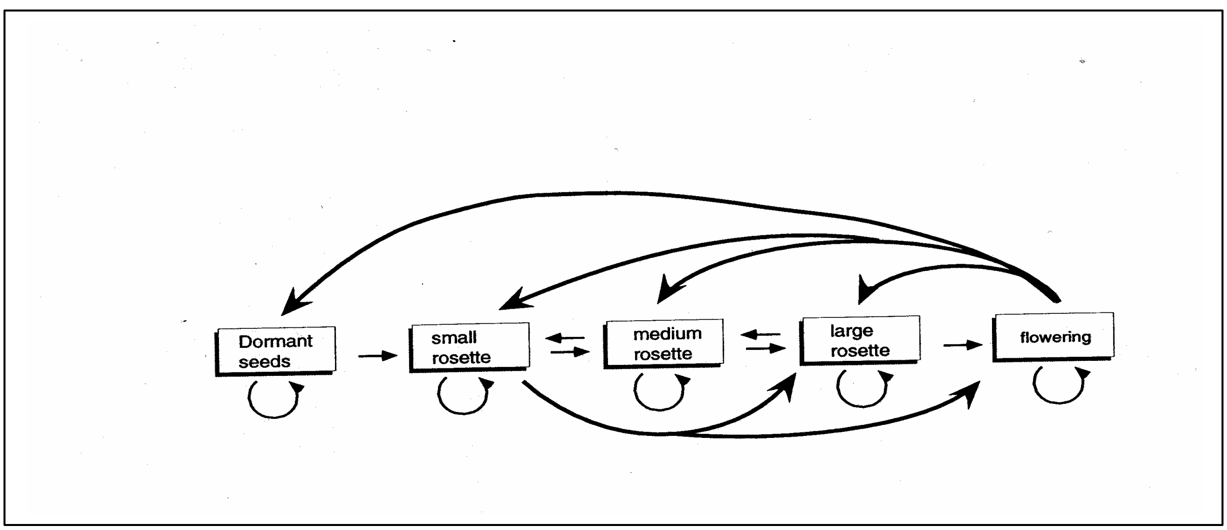

Figure 1. Life history stages of *Gaura coloradoensis* var. *neomexicana* (Floyd 1995)

It is important to note that the size classes do not equate with age classes, and that size is a better prediction of flowering than age. Almost half of the plots (4 of 9) monitored by Floyd had close correlation between size and age, i.e. first year plants were small, second year plants were medium, and third year plants were large, so that flowering was projected for 4-year old plants. Some plots were "fast" in which flowering was projected to take less than 4 years, and some plots were "slow" in which flowering was projected to take more than 4 years.

If flowering is accelerated, then the ratio of nonflowering:flowering plants might be expected to be less than 4:1. If flowering is slow, then the ratio of nonflowering: flowering plants might be expected to be more than 4:1. The mean length of time to produce flowering plants was not calculated. Fertig (1998) estimated a mean ratio of flowering to nonflowering plants as 5:1, and determined total population size by multiplying the total number of flowering plants censused in any given year by a factor of five (e.g., a census of 20 flowering plants is estimated as representing a population of 20 flowering + 100 nonflowering plants). If there were no mortality among vegetative plants, it would reflect a mean life expectancy of 6 years. Depending on mortality levels, a range of 3-5 years is more likely.

A review of four different datasets (Tables 2-5) shows a great range in the ratio of nonflowering to flowering plants, from as low as 1.7:1 to infinity (no flowering plants among vegetative plants).

Table 2. Ratios of nonflowering to flowering plants (Floyd 1995) in 2 x 2 m plots

	1994		
	Rosette	Fl+Fr	Ratio (ros/fl)
Crow 1	54	23	2.3
Crow 2	159	25	15.7
Crow 3	95	12	7.9
Unnamed 4	117	8	14.6
Unnamed 5	204	30	6.8
Unnamed 6	190	32	5.9
Diamond 7	49	29	1.7
Diamond 8	279	21	13.2
Diamond 9	270	10	27

Table 3. Ratios of nonflowering to flowering plants (Fertig 2000) in microplots within larger sample areas

	1998			1999		
	Rosette	Fl+Fr	Ratio (ros/fl)	Rosette	Fl+Fr	Ratio (ros/fl)
Crow 1	84	15	5.6			
Crow 2	35	20	1.7	63	0	Infinity (63/0)
Crow 3	35	3	11.6	63	10	6.3
Crow 4	45	5	9.0			
Diamond 1	49	5	9.8			
Diamond 2	235	26	9.0	263	12	21.9
Diamond 3	52	10	5.2			
Unnamed 1	234	54	4.3			
Unnamed 3	239	57	4.1			
Unnamed 4	40	15	2.6			
TOTAL	1048	210	4.9	398	**13**	30.6
ST Dev		19.5	4.8		6.4	20.8

Table 4. Ratios of nonflowering to flowering plants (Burgess 2001) in 2 x 2 m plots

	Rosette (veg)	**Fl+Fr (reprod)**	**Ratio (Rosette / Fl+Fr)**
Crow Creek	397	123	3.2
Diamond Creek	1361	240	5.7
Unnamed Creek	2800	212	13.2

The fourth dataset is from a pilot monitoring study that we initiated in 2001. Two polygons were randomly selected among the 30 polygons on Diamond Creek to represent high- and low-density colonies, eliminating those sites where it was not feasible to leave permanent markers. A tape measure was stretched across the length of the polygon to the nearest 5 meter interval and within 3 meters of its outer limits. Endpoints were permanently marked by rebar. A polygon GPS reading was taken near the center of each, and the compass bearing of the line across its length was determined. The placement of the transect line was across the upper limit of the polygon if a symmetrical outline existed and across the middle of the continuous occupied habitat if curvilinear in outline.

Complete census was ruled out, taking significantly more than 1 day/plot. Perpendicular transects were run off of the median transect at 1 m intervals, and microplots (Daubenmire frames) were placed at a random distance from the median belt. In the case of the curvilinear outline plot, perpendicular transects were set on either side of the median transect (i.e., at 2 m intervals on either side). We deliberately stratified the samples at even intervals across the whole polygon because the species has a patchy distribution within most polygons. A completely random placement calls for very large sample sizes, and by sampling at regular intervals across the length of the polygon, we increased the likelihood of sampling the species while covering the entire polygon.

Table 5. Ratios of nonflowering to flowering plants (Heidel and Laursen 2001) in microplots within colony polygons

	rosette	Fl/fr	Ratio
Diamond 21	26	6	4.3
Diamond 27	27	2	13.5

Possible explanations for the differences include intrinsic (genetic) differences in the colonies that they represent or unique population structure characteristics. It is also likely that the ratio differences result from extrinsic variables between sites, e.g., topography or soil water-holding capacity, vegetation, or disturbance history.

Floyd (1995) demonstrated that climate is a pivotal factor in this ratio. The stage class transitions between plants in 1992-1993 were very different than the stage class transitions in the same plots in 1993-1994 because 1994 was exceptionally dry. Sensitivity and elasticity analyses by Floyd (1995) revealed that growth from the large rosette to flowering plant stage was the single most important transition that determined population trend of Colorado butterfly plant in 1992-93 (near-normal moisture levels), and that the combined flower production, germination and establishment transitions were most important in determining population trend of Colorado butterfly plant in 1993-94 (sub-normal moisture levels). She projected that the population may face local extinctions in 2 of the 9 plots. She also determined that the mortality of small rosettes was relatively high in drought years, but the mortality of medium- and large rosettes was relatively low in drought years.

Not all monitoring plots changed in synchrony. Floyd (1995) suggested that there is one or more plot-specific attribute that explains different patterns. It can be an intrinsic factor such as the population structure in the plot, or an extrinsic factor relating to the unique environmental attributes in the plot. It is important to note that Floyd subjectively selected her monitoring plots with a population density criterion, i.e., 50-100 plants within 4 m^2, a high-density criterion that may influence population structure. She recognized microhabitat differences among plots, characterizing the habitats as good, excellent and marginal, as indicated by population growth rates. But she did not investigate the nature of the differences.

Fertig (2000) proposed that additional research be pursued on the population dynamics and abundance of Colorado butterfly plant rosettes on the Base to evaluate the affects of the drought and more accurately estimate the numbers and densities of rosettes. There was not, however, detailed monitoring in place at the onset of drought in 1998. A review of the literature and the preliminary monitoring exercise in 2001 suggests that there is as much variability between plots as for the same plots between years, i.e., population structure attributes are unique to each colony and year. What are the best means to the end? Preliminary workplans are recommended in this report (p.15) subject to further discussion and peer-review with plant monitoring experts.