A Butterfly Monitoring Program for Assessing the Composition and Distribution of Butterfly Communities in the City of Boulder Open Space and Mountain Parks

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Abstract

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A Butterfly Monitoring Program for Assessing the Composition and Distribution of Butterfly Communities in the City of Boulder Open Space and Mountain Parks

Thesis directed by Professor M. Deane Bowers

During the summers of 2001 and 2002 I developed monitoring protocols and recorded butterfly community composition and abundance results for six habitats across open space lands managed by the City of Boulder, Colorado. A preliminary survey of eight sites representing five of the six habitats was assessed in 2001. Using 1,000 meter standardized transects, the sites were surveyed to test protocols, improve researcher field identification, and provide a preliminary assessment of butterfly populations in these areas. The 2001 field season occurred in a year of plentiful spring moisture following a mild winter. Butterflies were abundant with 2381 individuals observed representing 50 different species. A foothills canyon site yielded the greatest number of species and a foothills grassland site resulted in the greatest abundance. In 2002, the study sampled three sites within each of the six habitats with 500 meter walking transects. A mild winter and a dry spring resulted in very different butterfly abundance results. Only 995 individuals were documented, however, 53 species were observed. This study provides an initial view of Open Space and Mountain Parks butterfly diversity, and presents a system and recommendations for a long-term monitoring program.

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This effort would not have been possible without the encouragement and support of my major adviser M. Deane Bowers. Her advice and guidance kept me motivated and challenged. Additionally, Robert Guralnick and Paula Cushing as my committee were generous with their time and assistance. The City of Boulder Open Space and Mountain Parks department provided both funding for this study, assistance by its staff, and access to its wonderful lands. In particular, Cary Richardson and Chris Wanner provided research guidance and GIS support. Virginia Scott provided insight and access to the butterfly collections in the University of Colorado Museum. I could not have succeeded without the patience and encouragement of Ruth McMillen, Lauren Armstead Bracchi, and my many friends, co-workers, and family members.

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Introduction and Background

Butterflies are excellent invertebrates to include in monitoring programs. They are well studied, easily observed, and can be sensitive to changes in vegetation and management practices (Murphy and Wilcox 1986, New 1997). Patterns in butterfly distribution and abundance are known to respond in the short-term to variations in weather, while longer-term effects are commonly attributed to alterations and disturbances in habitat quality and availability (Kocher and Williams 2000). Consistent methods for surveying butterflies have been developed and applied in many different settings and are often based on samples collected during standardized walking transects (Pollard 1993, Fleishman et al. 1999, Ries et al. 2001, Caldas and Robbins 2003). The City of Boulder manages a large open space system with many different habitats including short grass and tallgrass prairies, foothills grasslands, woodlands, and stream riparian corridors. This mix of habitats and previous surveys of butterflies in the Boulder area indicate that there are many areas suitable for diverse butterfly populations including some rare and sensitive species (Pineda and Ellingson 1998).

The combination of a rich butterfly fauna in the Boulder area, a community dedicated to preserving and protecting critical wildlife resources and habitats, and inconsistent past efforts to survey and monitor local butterfly populations motivated me to initiate this study. Due to the variability of butterfly populations with their mobility and response to changing weather conditions, only long-term standardized monitoring can provide an accurate picture of the distribution and abundance of the butterflies dependent on the City of Boulder's natural areas. This study provides the foundation for implementing a long-term butterfly monitoring program on Boulder's open space lands.

City of Boulder Open Space and Mountain Parks

Since 1898 the City of Boulder has continuously acquired lands around and within its city limits for natural area protection, passive recreation, and other open space purposes. This community was one of the first to tax itself to be able to acquire lands that protected the scenic and natural resources that define the Boulder area. The current Open Space and Mountain Parks (OSMP) system includes 43,000 acres of land protecting the montane foothills backdrop, short and mixed-grass mesas and valleys, remnant tallgrass prairie patches and the riparian zones of the Boulder area. The Boulder community and land managers responsible for protecting the natural systems of OSMP are challenged by the expansion of neighboring urban development, recreation, and yet providing for agricultural needs. Reliable, long-term information about the floral and faunal resources of OSMP is imperative to assist the community and OSMP managers in assessing and managing the complex issues affecting Open Space and Mountain Parks.

Butterflies of Open Space and Mountain Parks

The Colorado Front Range is well-known and well-documented for its biological diversity including numerous species of butterflies (Opler 1994). Approximately 176 resident or regular colonist skippers and butterflies have been documented in this region, representing the fourth richest butterfly region in the United States (Opler 1994, Pineda and Ellingson 1998). The butterfly fauna of

Boulder County is perhaps the best sampled part of the Front Range. Its butterfly fauna is a mix of northern artic, boreal, Rocky Mountain, southwestern desert, Great Plains, and eastern species, as well as regional endemics that reside or wander into the the Boulder area (Rodeck 1964, Pineda and Ellingson 1998). Some of the butterflies present on Open Space and Mountain Parks lands are rare and sensitive species, including several local endemics and species at the periphery of their range. A two year systematic survey for rare and imperiled butterflies on OSMP by the Colorado Natural Heritage Program targeted 14 priority species for conservation and documented 10 of the 14 and a total of 97 species overall (Pineda and Ellingson 1998). It is possible that as many as 150 butterfly species may occur on OSMP lands. Butterflies of highest conservation interest occurring on OSMP include the hops blue (*Celestrina humulus)* family Lycaenidae, Ottoe skipper (*Hesperia ottoe)* and arogos skipper (*Atrytone arogos*) family Hesperiidae, and the regal fritillary (*Speyeria idalia*) family Nymphalidae.

Invertebrate Monitoring

Long-term ecological monitoring makes it possible to provide information about changes in the biota of a particular region and provides a tool to identify future research needs and management responses. Rather than attempting to sample an entire invertebrate community, certain species or assemblages of species are identified and used as surrogates for the entire community, so-called indicator species. Indicator species and assemblages provide a focus for monitoring efforts so that resource managers can evaluate the success of their policies (Sparrow et al. 1994). Historical and legal requirements for federal agencies to assess habitat quality and resident animal and plant populations emphasize the value of utilizing biological indicators in natural resource management (Landres et al. 1988). Additional benefits of using biological indicators to monitor habitat conditions include alleviating the expense, inconvenience, and difficulty required of more complex monitoring efforts.

The concept and application of indicator species (also called umbrella species) to natural resource management and conservation is controversial at best (Landres et al. 1988, Oliver et al. 1997). The primary concern is that one species or assemblage of species cannot be extrapolated to include others (Wilcove 1986, Landres et al. 1988, Kremen 1992). In addition, by condensing the requirements and relationships of many species and variables into a simple index species or indicator species, the contribution of each component and represented species may be obscured (Landres et al. 1988, Morrison et al. 1992). Additional complications result when the relationships between indicator taxa and other biotic elements are not well understood, making extrapolation to other members of the community difficult, if not impossible. For example, if vertebrates are solely used in monitoring programs, there is little basis for assessing whether or not invertebrates are adequately protected by wildlife management programs (Murphy and Wilcox 1986). A more appropriate approach is to study indicators encompassing different functional groups and life-history strategies (Noss 1990, New 1991). Including an invertebrate monitoring component in wildlife management programs insures the opportunity to protect invertebrates and provides additional data and criteria to discern changes in biological conditions.

Butterflies as Indicator Species

Butterflies are excellent invertebrates to use in monitoring programs. They are relatively convenient to observe, taxonomically well described, ecologically well studied, and representative of other invertebrate habitat requirements (Murphy and Wilcox 1986, New 1997). Changes in butterfly populations are often correlated with habitat deterioration, extreme weather events and changes in plant community composition affecting the quality and abundance of larval host plants and nectar sources (Murphy, et al. 1990). This association of butterflies with plant community composition and their sensitivity to habitat change is the foundation for including butterflies in monitoring programs (Blair and Launer 1997). Transect surveys are an efficient means of monitoring butterfly distributions and relative densities among sites and years (Pollard 1977, Morton 1984, Pollard and Yates 1993, Swengel 1996, Brown and Boyce 1998). Adult butterflies can be observed and counted during transect walks which are standardized for habitat, season, time of day, and weather (New et al. 1995). Relative species abundance can be compared between sites and provide considerable conservation value (Kitahara and Fujii 1994).

Related Studies and OSMP Monitoring Needs

In 1996 and 1997 the Colorado Natural Heritage Program (CNHP) conducted a survey of rare and imperiled butterflies for the City of Boulder Open Space and Mountain Parks (Pineda and Ellingson 1998). The CNHP survey updated baseline inventory knowledge and recommended further research and monitoring, however, to date, no follow-up has occurred. In addition, patterns of plant and animal diversity in a grassland urban context have been studied on OSMP using standardized plots (Bock and Bock 1994). These biodiversity plots were later sampled to assess the effects of habitat characteristics and landscape context on butterfly diversity. The results showed that grassland quality and type (shortgrass, mixed grass, tallgrass, hayfield), and not urban context, strongly influenced butterfly diversity (Collinge et al. 2003).

The City of Boulder Open Space and Mountain Parks has implemented a Forest Ecosystem Management Program (FEMP). Management objectives outlined in FEMP recommend monitoring butterfly populations in addition to other wildlife monitoring (City of Boulder 1999). In coming years, OSMP also plans to initiate a grassland management program that will benefit from this monitoring effort. Having current butterfly community information available and standardized monitoring sites in grasslands throughout the OSMP system will be of considerable value.

Study Objectives

The purpose of this project is to develop a butterfly monitoring program that is compatible with overall OSMP monitoring needs. This project provides standardized protocols, baseline data, and analysis guidance that will be useful for a long-term butterfly monitoring program. Additionally this project helps update the 1997 CNHP survey of butterfly populations of high conservation concern. The study was designed to be in line with OSMP resources currently available and has the potential for expansion as volunteers and additional resources become available and are incorporated.

This study established preliminary transect routes in the summer of 2001 to test the transect sampling method for butterflies and to establish the suitability of particular sites and habitats. Eight pilot transects were located representing a mix of locations and prairie and foothills habitats including mixed grass prairie, tallgrass prairie, foothills grassland, montane woodland, and foothills riparian. Some of the pilot transects sampled a single habitat while others transitioned through different habitats. As an example, the Big Bluestem transect started in a tallgrass habitat and after 200 meters rose out of a stream floodplain to a low mesa that was dominated by mixed grass prairie. Transition points between habitats were marked on individual transects and butterflies were recorded relative to their position along transects to distinguish the habitat in which they were observed. Each transect was sampled monthly from June through August using a consistent walking pace. The results of the pilot transect surveys guided modifications helpful in establishing final sites and protocols. Problems such as accurately establishing transition points between habitats along transects, providing enough representative sites across the system, and uneven sampling effort between habitats indicated that modifications were needed.

The study sites and transect lengths were modified in 2002 so that each transect would sample a single habitat. Reducing transect lengths to 500 meters improved the ability to locate transects within a single habitat and increased the number of potential sites. This economy of effort also made it possible to survey plains riparian sites which were not surveyed during the pilot year. The total length of transects in the pilot year was 8000 meters, in 2002 the total length of transects was 9000 meters. Additionally, greater replication and consistency of sampling effort per habitat were accomplished.

During the surveys, butterfly abundance and composition in six distinct habitats on OSMP were sampled for comparison across habitats and over time. The six habitats identified for sampling include plains riparian, foothills riparian, plains grassland, tallgrass, foothills grassland, and montane woodland (Appendix A). Species presence and absence within and between habitats were tracked, total richness and abundance and relative abundances were calculated. To track how each site compared with others in a similar habitat, species diversity indices for each habitat were calculated, as were similarity indices. The cumulative addition of new species per sampling effort for each habitat was assessed and accumulation curves created to determine how well a particular habitat was sampled.

The objectives of this project were to test walking transects as a method for sampling butterfly distribution and composition in specific habitats associated with Open Space and Mountain Parks, refine the transect method for effectiveness and replication, and establish and provide a baseline sample to initiate a long-term program. Additionally, I wanted to determine if a stratification of common OSMP vegetation associations into six broad habitats was associated with different butterfly communities. The outcome of the two year study has resulted in: 1) establishment of 18 mapped and described sampling sites representing six different habitats; 2) collection of baseline data on butterfly abundance and presence/absence at each site for the months of May through August; 3) development of transect protocols and field observation forms and data capture databases; 4) production of educational and field identification photos and notes to assist future staff and volunteer training for participation in yearly monitoring; 5) survey updates for rare and conservation concern butterfly species; 6) management recommendations for improving butterfly habitat and future management and research needs. The products of this study establish the initial protocols for what will be an ongoing and continuous effort to document and monitor the butterflies occurring on the City of Boulder Open Space and Mountain Parks properties.

Methods

Study Area

The Open Space and Mountain Parks system is located on lands adjacent to the City of Boulder (40°00' 54''N, 105°16'12''W) and includes grasslands, wetlands, agricultural lands and the mountain backdrop adjacent to the City (Figure 1). Elevations range from 1600m (5200 ft) to 2468m (8100 ft). The areas of OSMP with the greatest potential for highly diverse butterfly communities were delineated into six broad habitats (Table 1). These particular habitats were also selected because they historically contain many of the butterfly species of greater conservation concern. Plains riparian are stream corridors dominated by deciduous trees and shrubs with an abundant and diverse forb understory. Foothills riparian consist of foothills canyons with permanent or ephemeral streams with some deciduous overstory and a thick shrub layer. Plains grasslands are short and mixed grass sites with occasional cattle grazing. Tallgrass are irrigated or flood plain lowlands containing remnant tallgrass species. Foothills grasslands are mesas and foothill hogback ridges dominated by mixed grasses and low forbs. Montane woodlands are forested mesas with a mixed grass and forb understory.

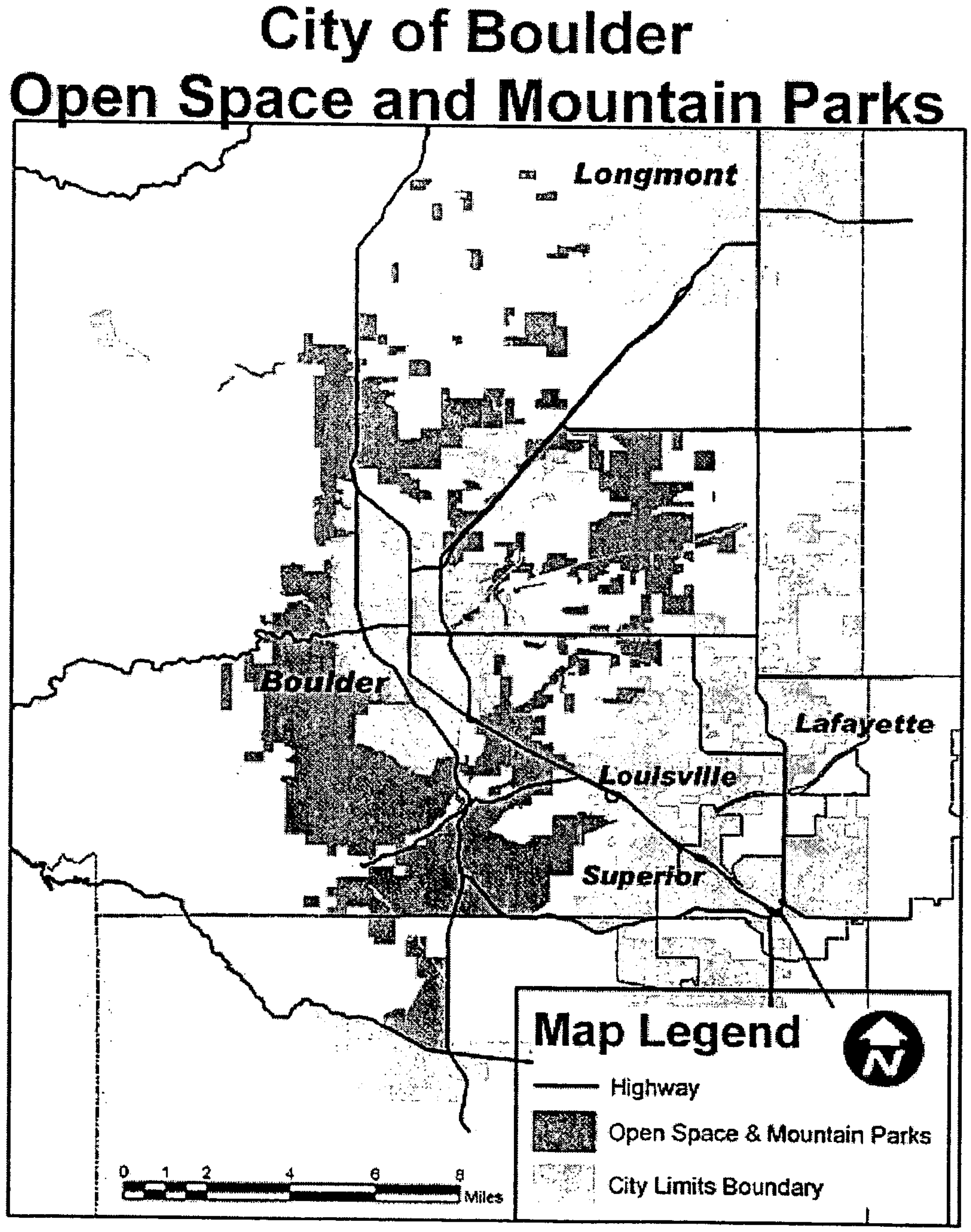


Figure 1: Map of the City of Boulder Open Space and Mountain Parks Lands

Table 1: Butterfly monitoring habitats and common plant species.

Habitat Type	Common Plant Species	
	family	**genus species**
Grassland	Poaceae	*Agropyron smithii* (western wheatgrass) *Bouteloua gracilis* (blue grama) *Bouteloua curtipendula* (side-oats grama) *Buchloe dactyloides* (buffalo grass) *Schizachyrium scoparium* (little bluestem) *Bromus tectorum* (cheat grass)
	Asteraceae	*Artemesia ludoviciana* (prairie sage)
	Cyperaceae	*Carex pensylvanica* (sun sedge)
	Brassiceae	*Allyssum minus*
Foothills Grassland	Poaceae	*Bromopsis inermis* (smooth brome) *Bromus tectorum* (cheat grass) *Koeleria macrantha* (June grass) *Stipa comata* (needle and thread grass) *Agropyron smithii* (western wheatgrass) *Andropogon gerardii* (big bluestem) *Poa pratensis* (bluegrass) *Poa compressa* (Canada bluegrass)
	Asteraceae	*Artemesia ludoviciana* (sage)
		Liatris punctata (blazing star)
		Eriogonum brevicaule (buckwheat)
Tallgrass	Poaceae	*Andropogon gerardii* (big bluestem) *Panicum virgatum* (switchgrass) *Sorghastrum nutans* (Indian-grass) *Spartina pectinata* (prairie cordgrass) *Bromopsis inermis* (smooth brome) *Agrostis gigantean* (redtop)
	Plantaginaceae	*Plantago lanceolata* (plantain)
	Juncaceae	*Juncus arcticus* (arctic rush)
	Cyperaceae	*Carex nebrascensis* (Nebraska sedge)
	Fabaceae	*Glycyrrhiza lepidota* (wild licorice)

Table 1(continued):

Riparian *(not surveyed in 2001)*	Salicaceae	*Populus deltoides*, (plains cottonwood) *Salix* exigua (coyote willow) *Salix amygdaloides* (peach-leaved willow) *Salix fragilis* (crack willow)
	Oleaceae	*Fraxinus pensylvanica* (green ash)
	Ulmaceae	*Ulmus pumila* (Chinese elm)
	Caprifoliaceae	*Symphoricarpus occidentalis* (snowberry)
	Poaceae	*Bromopsis inermis* (smooth brome)
	Rosaceae	*Padus virginiana* (chokecherry) *Prunus americana* (plum) *Crataegus* spp. (hawthorne)
Montane	Pinaceae	*Pinus ponderosa* (ponderosa pine) *Pseudotsuga menziesii* (Douglas-fir)
	Poaceae	*Poa agassizensis* (bluegrass) *Poa compressa* (Canada bluegrass) *Koeleria macrantha* (Junegrass) Achnatherum nelsonii (needlegrass)
	Berberidaceae	*Mahonia repens* (holly-grape)
	Grossulariaceae	*Ribes cereum* (wax currant)
	Rosaceae	*Rosa woodsii* (wild rose)
	Cyperaceae	*Carex pensylvanica* (sun sedge)
	Cupressaceae	*Sabina scopulorum* (Rocky Mountain Juniper)
	Apiaceae	*Harbouria trachypleura* (whiskbroom parsley)
	Asteraceae	*Artemisia ludoviciana* (prairie sage) *Achillea lanulosa* (western yarrow) *Liatris punctata* (blazing star)
Foothills Riparian	Betulaceae	Corylus cornuta (hazelnut)
	Rosaceae	*Padus virginiana*, (choke cherry) *Prunus* americana (wild plum) *Crataegus* spp. (hawthorne)
	Aceraceae	*Negundo aceroides* (boxelder)
	Ulmaceae	*Celtis occidentalis* (hackberry)
	Anacardiaceae	*Rhus trilobata* (skunkbrush)
	Salicaceae	*Populus agustifolia*, (narrow leaf cottonwood)

Transect Placement

Walking transects, as developed by Pollard and refined as part of the British Butterfly Monitoring Scheme, are frequently applied to sample butterfly populations (Pollard 1977, Pollard and Yates 1993). During the pilot field season in 2001, eight one kilometer transects were established in sites across OSMP that contained representative sites of five of the six habitats (Table 2). Originally, plains riparian was not included as a habitat. Transitions between dominant vegetation types were marked along transects and butterfly observations recorded for each habitat segment. Transects were started from a location that could be mapped, described and relocated easily. The direction of each transect was randomly selected and limited only when necessary so that transects would stay within a particular habitat and not occur along the edge of two adjacent habitats. The order in which transects were surveyed each month was randomly selected.

Table 2: 2001 butterfly survey sites and their habitat types.

	Habitat Type				
Site Name	Grassland	Foothills Grassland	Tallgrass	Montane Woodland	Foothills Riparian
North Foothills		X			
Gregory Canyon		X			X
Enchanted Mesa		X		X	
Lower Skunk Canyon		X			X
Big Bluestem		X	X		
Doudy Draw		X			
South Boulder Creek			X		
Church	X		X		

Problems identified during the initial pilot transect surveys of 2001 determined how routes should be modified for 2002. Transects were shortened to 500 meters in length to better sample only a single habitat (Figure 2). One kilometer long transects were too long to find routes that stayed in only a single habitat. All sites used in 2001 were included in the 2002 survey but only half the length of the 2001 pilot transects were surveyed. Foothills riparian sites were modified to more uniformly keep transects within the band of riparian vegetation in the canyon bottom.

The final layout of transects resulted in eighteen 500 meter transects placed in the six habitat types (Table 3). To the extent possible, transects were sited in locales that overlap with FEMP implementation sites, the Colorado Tallgrass Prairie Management Plan, and other long-term monitoring programs established by the Open Space and Mountain Parks department. Transect routes were not placed within 200 meters of another transect and remained 50 meters from an ecotone or area receiving a significantly different management practice (e.g. weed management, grazing, mowing). Stream riparian areas occur as narrow ribbons of habitat and in some locales were not wide enough to meet the 50 meter ecotone criterion, but the transects remained in the riparian extent. The complexity of riparian vegetation and structure, the movement of butterflies along stream corridors, and the presence of water could be confounding factors, but I considered sampling these sites to be important.

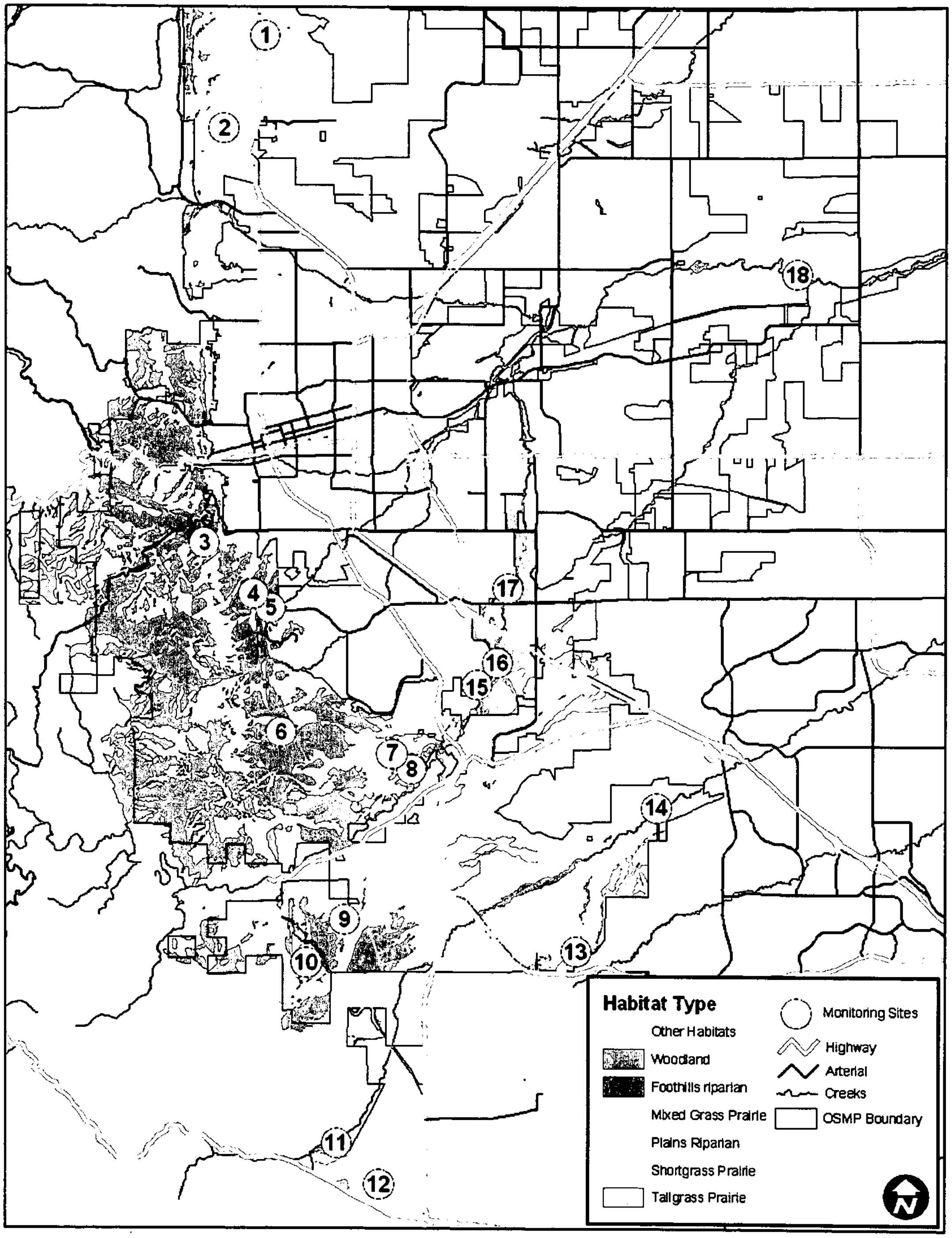


Figure 2: Map of transect locations and habitats sampled on Open Space and Mountain Parks.

Table 3: 2002 butterfly survey sites and their habitat types.

		Habitat Type					
#	Site Name	Grassland	Foothills Grassland	Tallgrass	Montane Woodland	Plains Riparian	Foothills Riparian
1	East Beech	X					
2	North Foothills		X				
3	Gregory Canyon						X
4	Enchanted Mesa				X		
5	Lower Skunk						X
6	Shanahan				X		
7	Big Bluestem		X				
8	Big Bluestem Tallgrass			X			
9	Doudy Draw		X				
10	Lindsay				X		
11	Coal Creek Foothills						X
12	Jewel Mountain	X					
13	Superior	X					
14	Coal Creek Plains					X	
15	S. Boulder Creek Tallgrass			X			
16	Church			X			
17	S. Boulder Creek					X	
18	White Rocks					X	

Transect Surveys

Each transect was surveyed once per month from May through August, starting no earlier than 9:00 A.M. and ending before 3:00 P.M., in a randomly assigned order. For each transect survey, weather conditions and sun exposure were documented to detail weather-related effects that could alter butterfly activity. Routes were only surveyed on days that met the following weather requirements:

- Less than 30% cloud cover
- Less than 15 mph winds
- Temperatures above 75 degrees Fahrenheit (24° C), and below 100 degrees Fahrenheit (38° C)

If weather conditions changed while a survey was in progress and conditions no longer met weather criteria, the transect was halted and run again in its entirety on the next available sampling day. Transects were walked at a slow and consistent pace and any butterflies within a five meter sampling space around the observer were recorded. Observations of butterflies outside the five meter boundary were recorded only if the species was not otherwise observed within the sample space and was recorded as occurring off of the transect. Butterflies recorded as "off transect" contribute to site and system-wide species lists and distribution. Butterflies observed within the five meter sampling space were identified to species or the lowest taxonomic level possible. Some skipper species are difficult to field identify to species and were classified in a genus complex. Species unable to be readily identified were caught with a standard butterfly net to aid identification. Specimens were held temporarily for digital photo documentation, and then promptly released.

Some of the netted butterflies were collected for later identification and to develop a voucher and synoptic collection for OSMP. Collected butterflies were placed into glassine envelopes, frozen and stored in the University of Colorado Museum's entomology collection. Specimens will be spread, labeled and placed into protective drawers containing only butterflies sampled from this monitoring effort. Developing a voucher and synoptic collection of OSMP butterflies will aid in verification of species identification and the training of volunteers and OSMP staff to assist with future transect sampling. The collections will be housed in the University of Colorado Museum of Natural History

Analysis

Butterfly occurrence, distribution, and diversity patterns were determined through the sampling of eight sites representing five habitats in 2001 and 18 sites representing six habitats in 2002. In each year, the butterfly survey efforts are summarized by assessing the butterfly abundance (total number of individuals), relative abundance (abundance per 100 meters of transect sampled), richness (number of species), and the number of unique species encountered. For the 2002 baseline year nested ANOVA analysis was used with SPSS statistical software to determine which habitats differed significantly in mean number of species and individuals per transect. The cumulative changes in abundance and richness from monthly sampling were assessed to determine peak butterfly sampling periods. The addition of sites and modifications to transects in 2002 only allow qualitative comparisons between 2001 and 2002. The relative abundances among habitat types can be compared to relate differences between the years. Similarities and differences in dominant and rare species are also compared.

Using the data collected, species accumulation curves for each habitat were plotted to show whether the baseline sampling effort adequately described the potential species richness of each habitat. Non-parametric estimates of species richness were generated using EstimateS 6: Richness Estimator program version 6 (Colwell 2001). These estimators incorporate the total observed species, total individuals, singletons, doubletons, uniques, and duplicates to generate an estimate of total species richness (Colwell 2001). The species richness estimators selected for use are ICE, Chao 2, and firstorder jackknife. All are incidence-based coverage estimators that are less sensitive to sample size and patchiness. The ICE estimator is a sample coverage based estimator using the proportion of rare species observed that are not unique to derive estimates of total species richness (Lambshead et. al. 2003). The Chao 2 estimator is based on using uniques and duplicates encountered in sampling and thus rely on rarity of incidence and the distribution of individuals to estimate richness (Toti et. al. 2000). The Chao 2 estimator performs well with inventories of very diverse groups where there is a preponderance of relatively rare species (Colwell and Coddington 1994). The first order jackknife estimator is based on the number of species found to be in only one sample, the 'unique species' (Colwell and Coddington 1994). Formulas for each of the species richness estimators used in this study are as follows with details available in Appendix B:

$$S_{Chao\,2} = S_{obs} + \frac{Q_1^2}{2(Q_2 + 1)} - \frac{Q_1 Q_2}{2(Q_2 + 1)^2}$$

$$S_{ice} = S_{freq} + \frac{S_{inf\_r}}{C_{ice}} + \frac{Q_1}{C_{ice}} \gamma^2_{ice}$$

$$S_{jack1} = S_{obs} + Q_1\left((m-1)/m\right)$$

The three selected estimators were jointly plotted with the observed species accumulation and a Coleman curve which is a reliable alternative to a rarefaction estimate of species accumulation (Colwell and Coddington 1994). A Coleman curve estimates sample species richness using species actually surveyed and the pooled total species richness after all randomizations are complete (Colwell 2001).

The data on species occurrence and abundance from the baseline year were used to calculate several measures of species diversity and evenness. To aid in the graphic interpretation of diversity patterns, rank abundance graphs were plotted. Species richness is a commonly used measure of diversity, however without looking for patterns in evenness, rarity, and dominance, the use of only species richness to reflect diversity may overlook more subtle differences in diversity patterns (Magurran 1988). To complement species richness, three diversity indices were calculated to enhance the assessment of species diversity patterns: Shannon index (H'), Simpson index (D), and Fisher's alpha index (α). These were selected based on their widespread use in ecological studies and their calculation by the software EstimateS (Colwell 1997). Each of the indices calculates an index of species diversity, placing a different emphasis on species richness and abundance data. The Shannon index prioritizes species richness and dominant species. The Simpson index is influenced by the relative abundance of the most abundant species. The Alpha index is influenced by species of median abundance and less responsive to rare and very abundant species (Longino 2000).

The similarity, or conversely the dissimilarity, of habitats is important in understanding species diversity. Two sites with greater overlap in species contribute less to overall diversity than two very different sites. Colwell and Coddington (1994) recommend the term "complementarity" as the best terminology for the dissimilarity between two sites. Jaccard's coefficient (J) measures species overlap between two species lists. The index, calculated as $J=A/(A+B+C)$, is based on a ratio of the jointly occurring species (A) and the sum of joint occurrences (A) and unique occurrences in each of the two samples (B) and (C). A value of 1 indicates two lists that contain identical species. The converse therefore is a measure of complementarity $(1 - J)$ which correlates to greater differences between two lists (Longino 2000). The species overlap between each of the habitats is compared to determine which habitats provide greater contribution to overall species diversity on OSMP.

A list of which butterfly species occur in each of the habitats and which habitats contain species unique to them is important for conservation planning. A preliminary species list and a phenology for OSMP butterflies was made and will be updated with future field data to provide a complete view of when species are on the wing and to document a list of butterflies occurring on OSMP. (Appendix C)

For yearly comparison of butterflies identified as indicator and conservation concern species an index of abundance, as suggested by Thomas (1983) and applied by Arenz (1995), are calculated. The index is calculated as follows:

$$I = [(100)(N)(A)] / L \quad \textit{or} \quad I = [(100)(N)(.25)]/500$$

where

I = index of abundance
N = number of butterflies observed standardized to 100 meters
A = area in hectares (.25) since each transect samples an equivalent standardized area
L = length (500 meters) all transects are equal length

The index of abundance can then be compared over time for each site to establish trends in abundance of conservation concern butterflies. To compare changes in relative abundance, the percent change can be determined by dividing the difference between the base year index (BI) and the current year index (CI) by the base year index (Crawford 1991, Arenz 1995).

$$P = [100(CI-BI)] / BI$$

Where

P = percent change
CI = current year index
BI = base year index

A summary of the questions investigated, methods used in analysis and results are available in Table 4.

Table 4: Summary of analysis questions, methods and results.

Question	Method	Summary Result
Is there a difference between habitats in their mean number of species and individuals per transect?	Use nested ANOVA analysis to test for difference between habitats.	The foothills riparian habitat had a significantly higher number of species compared to the other habitats. The montane habitat had a lower abundance than foothills riparian and grassland and riparian habitats.
What is the expected species richness of each of the habitats? Which estimator provides the best estimate with the sampling effort undertaken?	Calculate nonparametric species estimators; Chao2, ICE and Jackknife 1.	The Chao2 estimator worked best for the montane, tallgrass, and foothills riparian habitats. Further sampling is required to continue to assess estimator usefulness.
Is the sampling effort adequate to estimate species richness?	Calculate a Coleman Curve for each habitat (alternative to rarefaction estimate of species accumulation).	The level of sampling of each of the habitats appears to be adequate for estimating species richness.
What are the species diversity patterns for the habitats?	Calculate three diversity indices for each habitat; Shannon index (H'), Simpson index (D), Fisher's Alpha index (α).	The foothills riparian habitat is the most diverse followed by montane and tallgrass. Plains riparian was the least diverse habitat.
Which habitats are similar and which are not in the species they share?	Complementarity measures between habitats based on the converse of the Jaccard similarity coefficient.	Riparian and montane habitats shared the fewest species while grassland and foothills riparian also had relatively few shared species. Foothills grassland and grasslands shared the most species.
For butterflies limited to a particular habitat or considered conservation priorities, how does abundance vary over time?	Calculate an abundance index for each butterfly species and compare to base year results and over time.	Abundance indices were determined for two species of conservation concern: *Hesperia ottoe* *Erynnis martialis*

Results

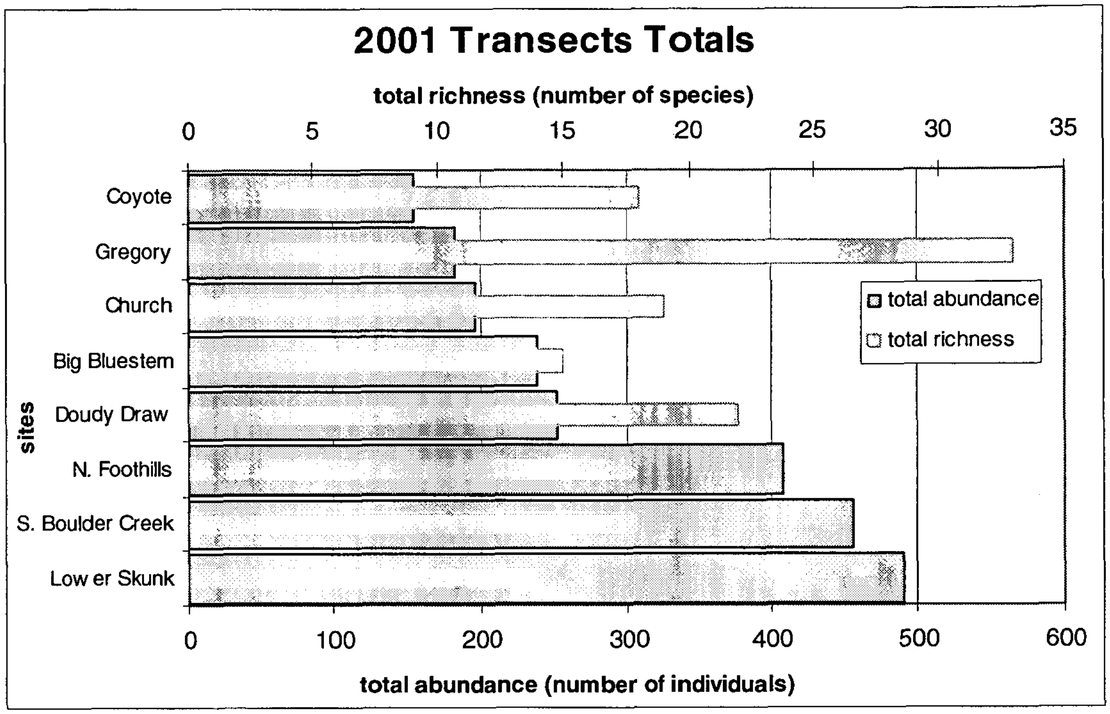
2001 Pilot Season

The summer of 2001 followed a mild winter with above normal temperatures and below normal snowfall. A wet spring and the fifth wettest July on record resulted in above normal precipitation totals for the year at 16.55 inches and average monthly temperatures from May to August slightly above normal (NOAA www.crh.noaa.gov/den/cli). Mean summer temperatures and precipitation records are provided in Appendix D.

Surveys along transects established in 2001 resulted in a total of 50 butterfly species being documented out of a total of 2381 individuals (Appendix E). Three additional species were documented "off transect" but still within the habitat being sampled. The month of June had both a greater abundance of butterflies (1155 individuals) and number of species (39) than the other months sampled.

Cosmopolitan butterfly species taking advantage of the mild winter and higher spring and summer precipitation experienced rapid extensions of their ranges and high abundances throughout the summer. Butterflies such as the variegated fritillary (*Euptoieta claudia)* and the painted lady (*Vanessa cardui)* (family Nymphalidae), orange sulfur (*Colias eurytheme)*, cabbage white (*Peries rapae)*, checkered white (*Pontia protodice)*, and western white *(Pontia occidentalis)* (family Pieridae), were particularly abundant and common at most sites. Of the total number of individual butterflies observed, 1896, or 80%, were comprised of the above six species.

Comparisons among sites for total species richness and abundance showed that Gregory Canyon had the highest species richness but the second lowest number of individuals while Skunk Canyon had the lowest richness but greatest abundance (Figure 3). The high number of individuals encountered on several transects was greatly influenced by the cosmopolitan species described in the text.



Habitats included for each site:

Coyote: montane	North Foothills: foothills grassland
Gregory: foothills riparian	S. Boulder Creek: tallgrass
Church: tallgrass/grassland	Lower Skunk: foothills grassland
Big Bluestem: tallgrass/foothills grassland	

Figure 3: Comparison of species abundance and richness at each of the eight sites surveyed in 2001.

Summary results broken out by habitat types are summarized in Table 5. The sampling effort was held constant for each transect but habitats were not equally distributed among transects. Habitat comparisons for total numbers reflect a dissimilar sampling effort. The relative abundance of butterflies is the most appropriate measure to compare across habitats. Tallgrass habitats had the highest relative abundance closely followed by foothills grasslands, while butterflies in montane habitats were considerably less abundant.

Table 5: Number of species, number of individuals, and relative abundance per 100 meters of transect and number of unique species for each of the five habitats surveyed in 2001.

Habitat	number of species	number of individuals	relative abundance/100 m	number of unique species
Tallgrass	23	572	11.9	2
Grassland	14	127	7.1	0
Foothills Grassland	39	1498	11.3	6
Foothills Riparian	27	133	7.4	5
Montane	7	51	2.1	1
Total of all sites	**50**	**2381**	**9.9**	**14**

Unique species, those occurring in only a single habitat type, represent 14 of the 50 species observed. Foothills grassland and foothills riparian habitats were where a majority of the unique species occurred. One of the species of special concern, the hop-feeding blue *(Celestrina humulus)*, was documented off transect in Skunk Canyon during its June and early July flight period. The hop-feeding blue is ranked by the Colorado Natural Heritage Program (CNHP) as a globally and state-wide imperiled species due to its likelihood of being endemic to the Front Range of Colorado (Pineda and Ellingson 1998). A single butterfly was observed at a location consistent with previous surveys by the CNHP. The host plant, wild hops (*Humulus lupulus)*, grows nearby supporting the potential of a persistent population.

2002 Baseline Field Season

The winter and spring leading into the 2002 field season were mild, with slightly below normal snow fall. As the spring and summer progressed, the region experienced drought conditions. Each of the 12 months of 2002 had below normal precipitation and by the end of the year, the region finished with the lowest amount of annual precipitation in 130 years of weather records (NOAA www.crh.noaa.gov/den/cli) (Appendix D).

As a result of the hot and dry summer, there was reduced abundance of butterflies. Some of the species that were very abundant in the 2001surveys were greatly reduced in numbers in 2002. For example, comparison between years for the painted lady (*Vanessa cardui)* saw a reduction from 135 to 2 individuals; orange sulfur (*Colias eurytheme)* 218 to 11 individuals; and the western white *(Pontia occidentalis*) 354 to 13 individuals. In total for the 2002 field season, 995 butterflies were observed, comprised of 53 different species (Appendix F). An additional six species were documented off transect within the habitat being sampled (Appendix G). The number of species recorded in a particular habitat ranged from a high of 36 in foothills riparian to a low of 13 in montane woodlands. The abundance of individuals ranged from a high of 244 and 241 in plains riparian and foothills grassland, respectively, to a low of 38 in montane woodlands (Figure 4). Twenty-three of the 53 butterfly species surveyed were recorded only in a single habitat type of which foothills riparian habitats had the most unique species, with 13. All other sites had substantially fewer unique species (Table 6).

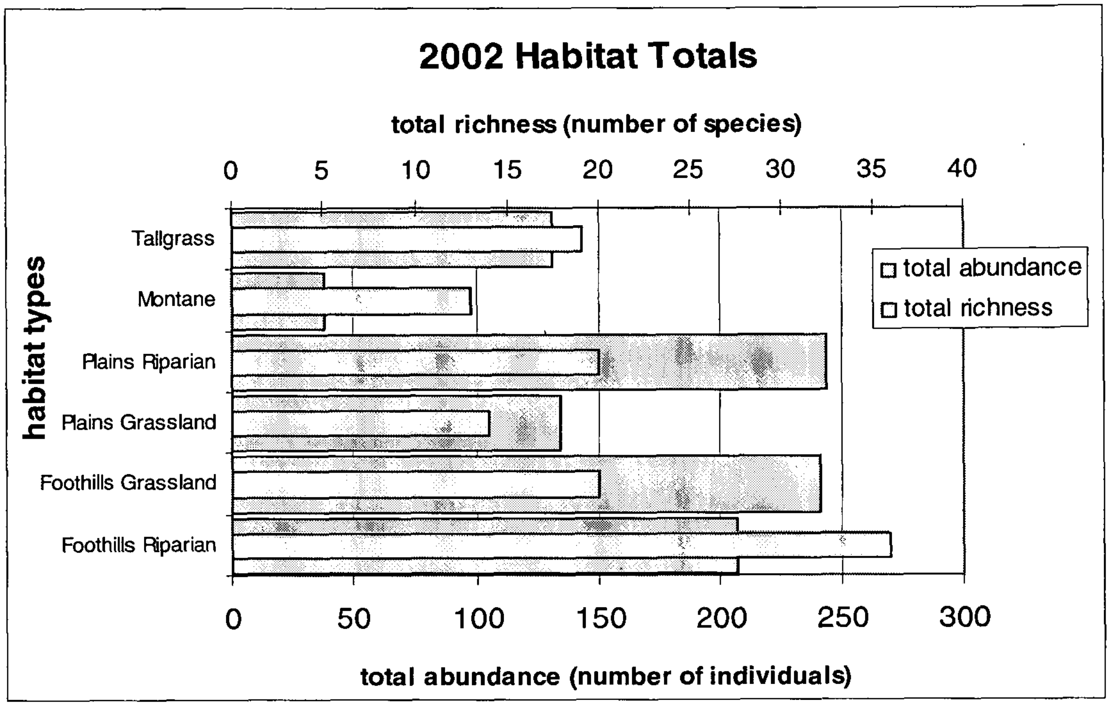


Figure 4: Comparison of species abundance and richness at each of the six habitats surveyed in 2002.

Table 6: Number of species, number of individuals, relative abundance per 100 meters of transect, and number of unique species for each of the six habitats surveyed in 2002.

Habitat	number of species	number of individuals	relative abundance /100m	number of unique species
Tallgrass	19	131	2.2	3
Grassland	14	134	2.2	2
Foothills Grassland	20	241	4.0	2
Riparian	20	244	4.1	2
Foothills Riparian	36	207	3.5	13
Ponderosa Woodland	13	38	0.6	1
Total of all sites	**53**	**995**	**2.8**	**23**

The mean number of species per transect for each of the habitats ranged from a high in foothills riparian of 6.5 ± 0.98 SE (n=12) to a low in montane 2.0 ± 0.46 SE (n=12) and grassland 2.25 ± 0.55 SE (n=12). The remaining three habitats were clumped together: riparian 3.50 ± 0.48 SE (n=12), tallgrass 3.58 ± 0.51 SE (n=12), and foothills grassland 4.0 ± 0.84 SE (n=12). A nested analysis of variance comparing the number of species in each of the habitats using SPSS 11.5 with a post-hoc test (Tukey HSD) showed that habitats differed significantly in the number of species observed (Table 7). The foothills riparian habitat was significantly higher in number of species ($p<.05$) than riparian, montane, grassland, and tallgrass habitats.

Table 7: Nested ANOVA comparing the number of species for each of the habitats.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	953.389	1	953.389	219.310	.000
	Error	52.167	12	4.347(a)		
HABITAT	Hypothesis	155.444	5	31.089	7.151	.003
	Error	52.167	12	4.347(a)		
SITE(HABITAT)	Hypothesis	52.167	12	4.347	.775	.673
	Error	303.000	54	5.611(b)		

a MS(SITE(HABITAT))
b MS(Error)

Based on the nested ANOVA analysis, 27.3% of the variation was due to differences among habitats, while surveyed sites for each habitat accounted for only 3.9% of the variation. The remaining variation in species richness was due to other factors and error.

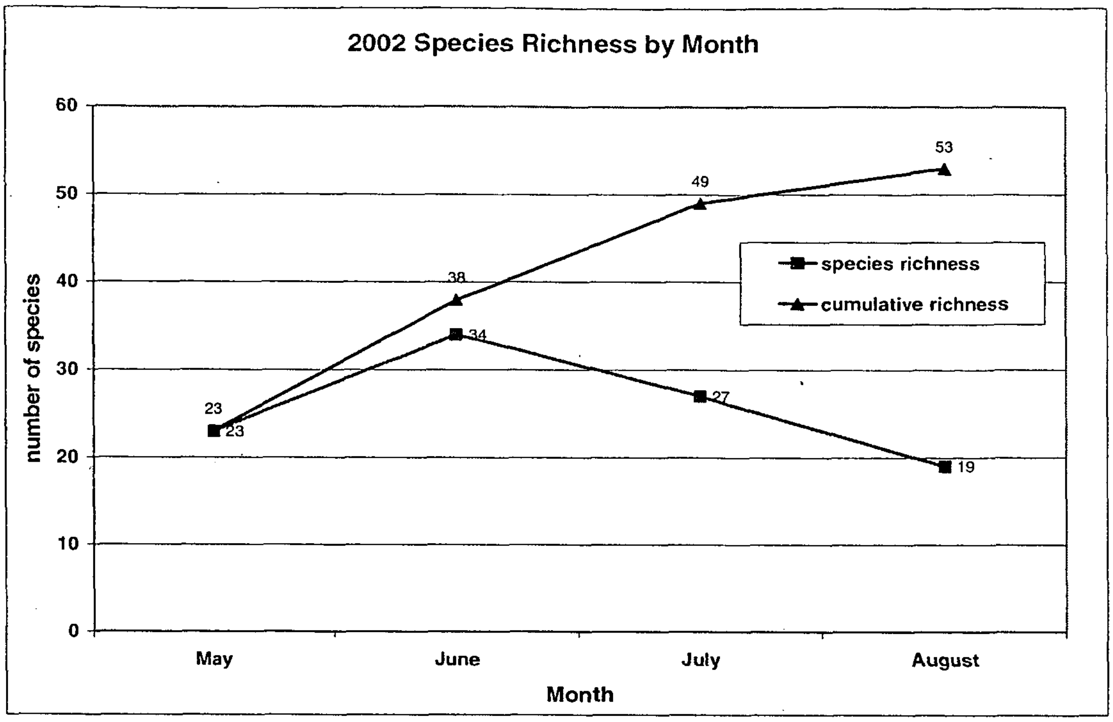
The mean number of individuals per transect for each of the habitats ranged from a high in riparian 20.33 ± 5.68 SE (n=12) and foothills grassland 20.17 ± 5.37 SE (n=12) to a low in montane 3.17 ± 0.81 SE (n=12). The other habitats were intermediate: foothills riparian 17.25 ± 3.62 SE (n=12); grassland 11.17 ± 4.64 SE (n=12); and tallgrass 10.92 ± 2.54 SE (n=12). Nested analysis of variance of butterfly abundance for the habitats indicated that there was a significant difference ($p<.05$) among habitats (Table 8). Although montane abundance numbers were much lower than the other habitats, a post-hoc test comparison (Tukey HSD) indicated that montane was not significantly different from the other habitats at a ($p<.05$) significance. 12.2% of the variation was due to differences among habitats and 9.9 % was a result of the differences among sites selected to represent each of the habitats.

Table 8: Nested ANOVA comparing the number of individuals for each of the habitats.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Hypothesis	13778.000	1	13778.000	123.677	.000
	Error	1336.833	12	111.403(a)		
HABITAT	Hypothesis	2681.167	5	536.233	4.813	.012
	Error	1336.833	12	111.403(a)		
SITE(HABITAT)	Hypothesis	1336.833	12	111.403	.491	.911
	Error	12244.000	54	226.741(b)		

a MS(SITE(HABITAT))
b MS(Error)

The month of June had a greater abundance of butterflies (411 individuals) and number of species (34) than any other month sampled (Figure 5). The early summer months normally correspond with greater butterfly abundance and richness, as there are ample larval and adult food sources, combined with an overlap of late spring and early summer butterfly flight periods. As the summer progressed in 2002, drought conditions resulted in a noticeable decrease in diversity and abundance of butterflies. Several transect runs in August resulted in no observable butterflies which was unprecedented in earlier transect runs. New species were documented in August as late summer butterflies emerged, but the abundance data show that numbers were low and there were few of the normally abundant cosmopolitan species.



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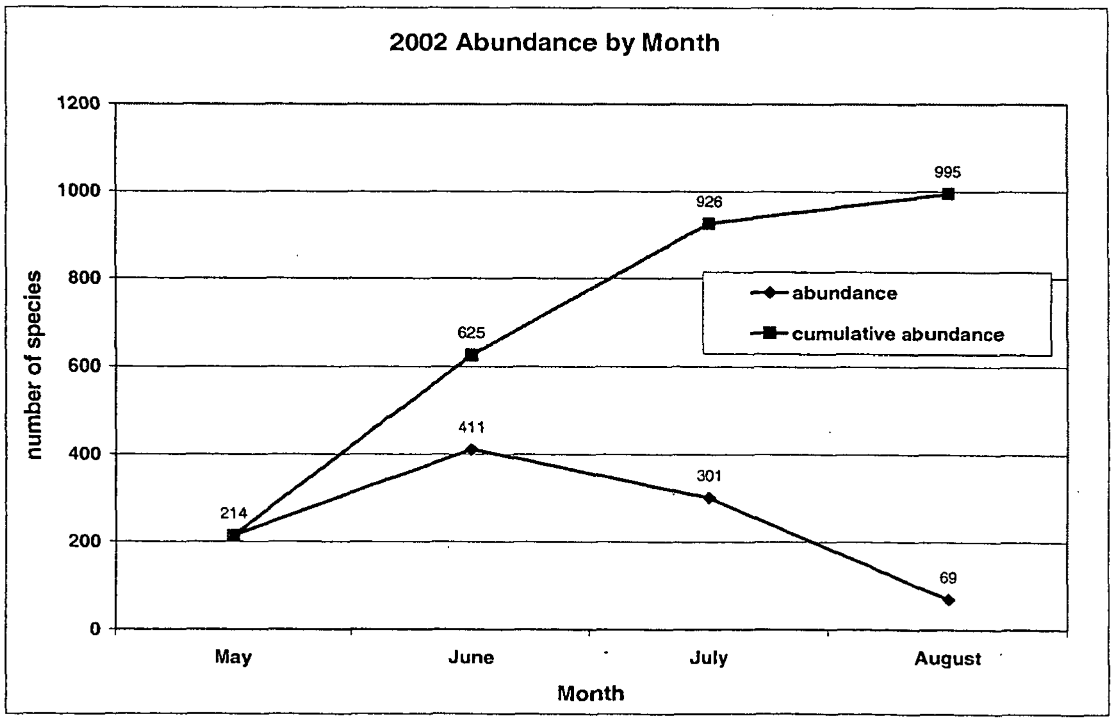


(b)

Figure 5: 2002 baseline year monthly and cumulative results for (a) species richness and (b) abundance.

Two rare and CNHP-ranked butterflies were observed during systematic transect monitoring: the mottled dusky wing (*Erynnis martialis*) and the ottoe skipper (*Hesperia ottoe*). The mottled duskywing is usually found in shrubby foothill stands of *Cercocarpus* and *Ceanothus*, both of which are present in Skunk Canyon (Ferris and Brown 1981). The ottoe skipper, a grassland specialist, was recorded at the Jewel site which contains several of the butterfly's potential host plants including big bluestem (*Andropogon gerardii*) and side oats grama (*Bouteloua curtipendula*) (Scott 1986). A third butterfly species, the indra swallowtail (*Papilio indra*), while not ranked as a conservation concern by the CHNP, is an uncommon resident butterfly and was observed puddling on the bank of a ditch neighboring the Doudy Draw transect (Appendix I).

2001 and 2002 Comparison

Direct comparisons between the pilot season 2001 and the baseline year 2002 must be made with caution due to sampling effort inconsistencies among habitats. Some qualitative comparisons can, however, show a range of differences that were observed during the two years. Comparing the total abundance observed, the pilot year (2381 individuals) and the baseline year (995 individuals), illustrates the large potential for year to year variation. The six most abundant species in 2001 accounted for 80% of the individuals observed and in contrast, only 44% of the individuals in 2002. Although not abundant, several butterflies were observed in particular habitats in 2001 that were not observed in those habitats in 2002. For example, the bronze skipper (*Lycaena hyllus)* was observed in tallgrass habitats on several occasions in 2001 but not in 2002. Likewise, the Sara orange-tip (*Anthocharis julia)* was observed during its early summer flight period in 2001, but not at all in 2002. In 2001, buckeyes (*Junonia coenia)*; painted ladies (*Vanessa cardui);* monarchs (*Danaus plexippus);* and dainty sulfurs (*Nathalis iole),* were recorded on multiple occasions from different sites, but either not at all or infrequently observed in 2002. The drought conditions likely contributed to the lack of these normally non-overwintering species in 2002 and a mild winter and moist spring in 2001 accounted for more favorable conditions.

A quantitative comparison of the number of individual butterflies surveyed between the two years is possible by comparing relative abundances. In 2001 the relative abundance of butterflies per 100 meters surveyed was nearly three times higher than what was observed in 2002 (Table 9). Tallgrass habitats showed the largest drop in relative abundance between years with a decrease from 11.9 to 2.2.

Table 9: Comparison of the relative abundance of butterflies surveyed in each habitat between the 2001 pilot year and the 2002 baseline monitoring year. Relative abundance is based on surveyed butterflies per 100 meters of transect covered in each habitat.

Habitat Type	2001 relative abundance/100 m	2002 relative abundance/100 m
Tallgrass	11.9	2.2
Grassland	7.1	2.2
Foothills Grassland	11.3	4.0
Foothills Riparian	7.4	3.5
Montane	2.1	0.6
Riparian	na	4.1
Total of all sites	**8.0**	**2.8**

Accumulation Curves (sampling effort)

The Chao 2, ICE, and Jackknife 1 species richness estimators and species-accumulation curves derived from the estimators, as well as observed species accumulation and the rarefaction substitute Coleman curve for the six habitats are displayed in Figure 6 a-f. Fifty randomizations of sample order were used in the calculation of the species richness estimators to assist in "smoothing" the curves by reducing the effect of sample sequence. The shape of accumulation curves is dependent on the ordering of sample sequence and how many new species are added with each subsequent sample. Randomizing the sampling sequence produces a generalized curve. The slope of the curves for all habitats indicates that additional sampling increases the number of new species detected but with marginally less success as sampling increases. Curves which taper off and approach their asymptote indicate that the sampling effort is nearly adequate to describe the butterfly community of that particular habitat. A horizontal line lacking any slope indicates adequate sampling has been reached.

The Chao 2 estimator of species richness rises quickly and reaches its asymptote with less sampling than the other estimators. The ICE estimator also rises quickly and levels out but is more erratic. The Jacknife 1 estimator tends to consistently have an increasing slope and not level out. Overall the Chao 2 estimator appears to work best for predicting species richness. It performs the best in the montane, tallgrass, foothills grassland, grassland and foothills riparian habitats. The accumulation curve levels as sampling increases and after twelve samples appears to approach the asymptote and thus may be adequate to describe the butterfly community. The riparian habitat curve maintains a more consistent increase in slope suggesting that greater sampling is appropriate.

All three estimators converge after twelve samples in the montane and grassland habitats showing some consistency between the estimators in their species richness estimates for these particular habitats. For foothills riparian and tallgrass, the Chao 2 and Jackknife converge while the ICE estimator results in a higher estimate. For the grassland habitat, ICE and Chao 2 converge while the Jackknife 1 has a lower estimate. Riparian habitats resulted in each of the estimators resulting in distinctly different values. The ICE estimator curve in several habitats rose quickly forming peaks showing more potential of greater overestimates with limited sampling. All of the estimators overestimated species richness compared to actual observed species richness. Future sampling and estimator calculations will allow additional evaluation and assessment of which estimators offer the best predictive value.

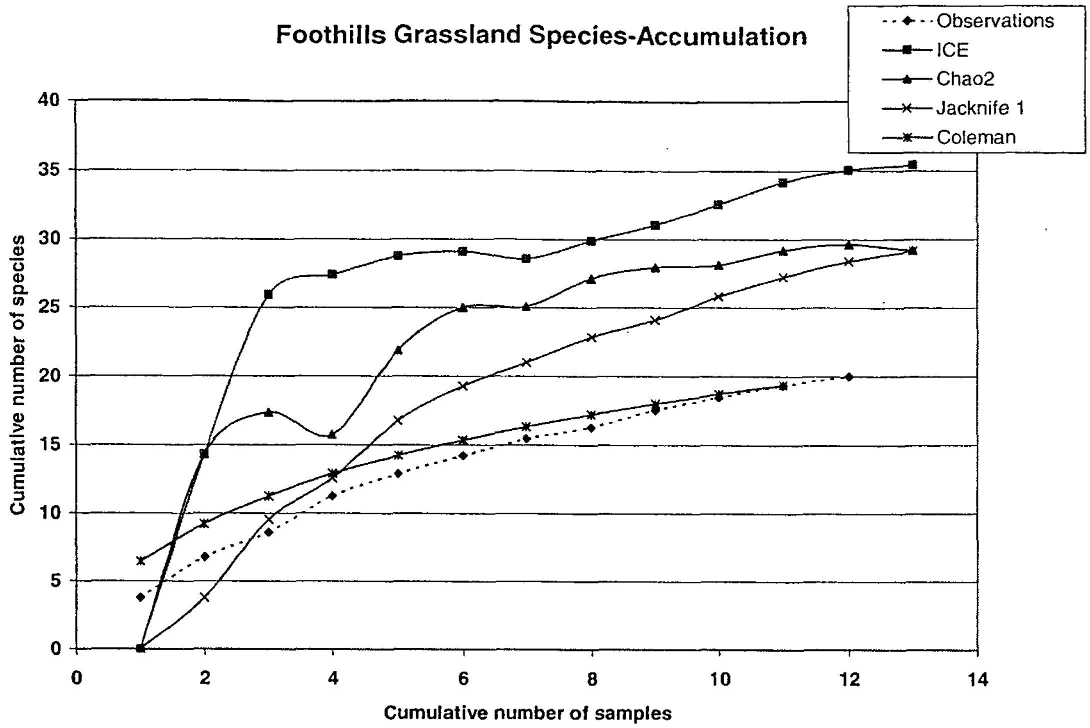


Figure 6a

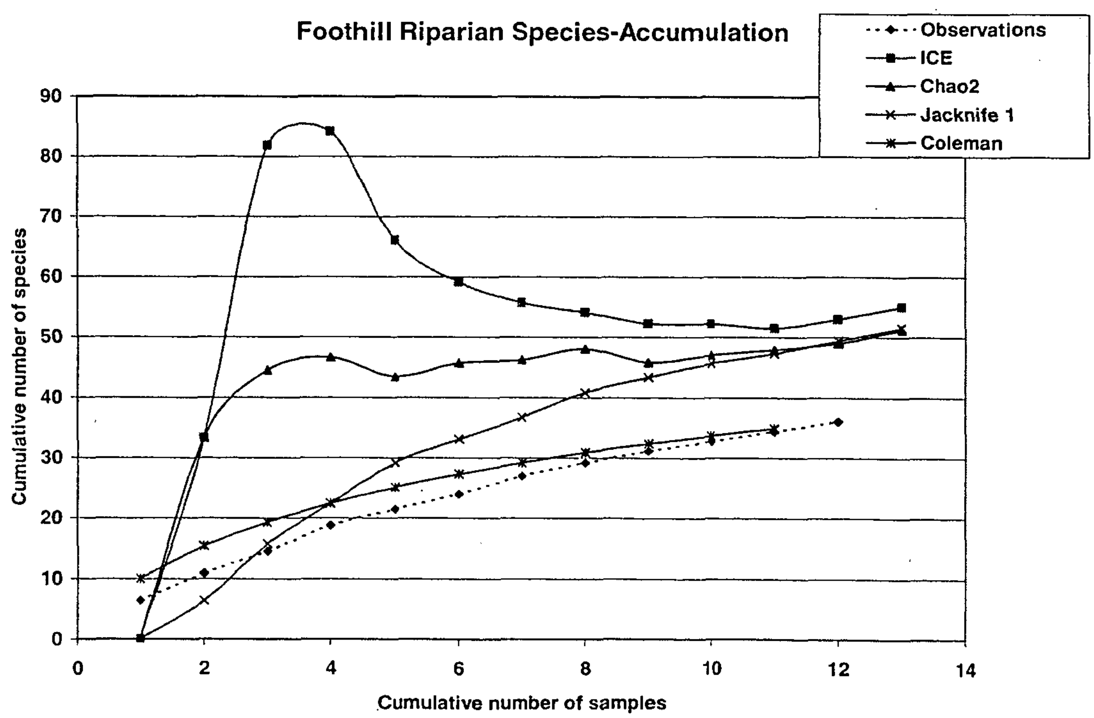


Figure 6b

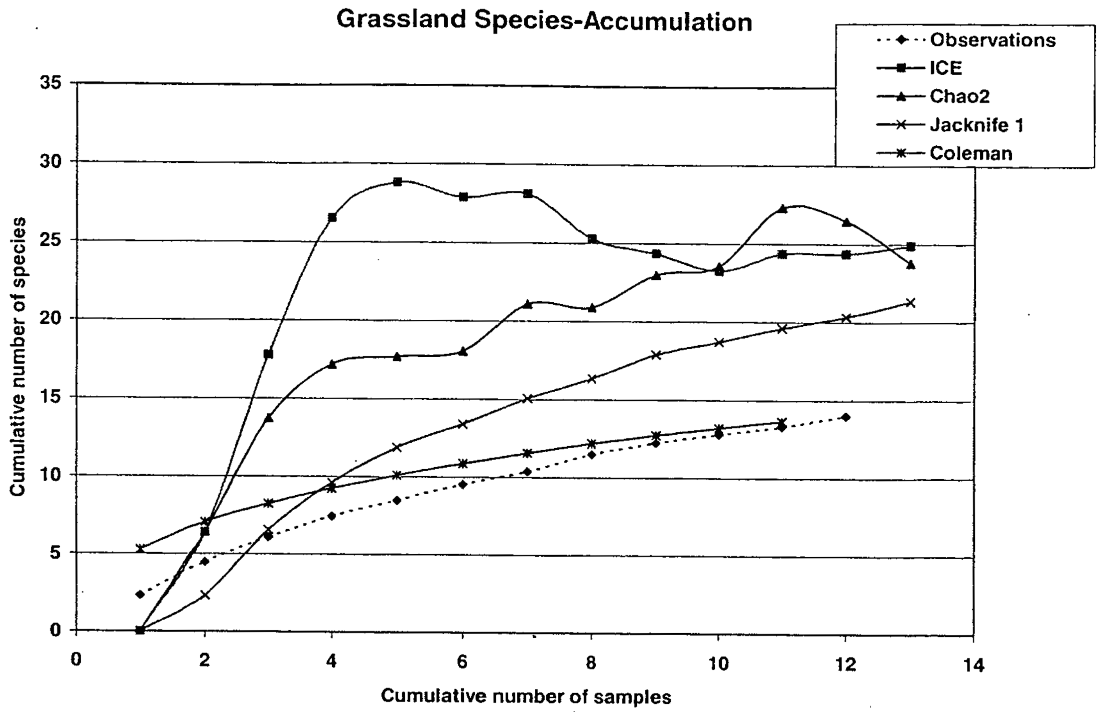


Figure 6c

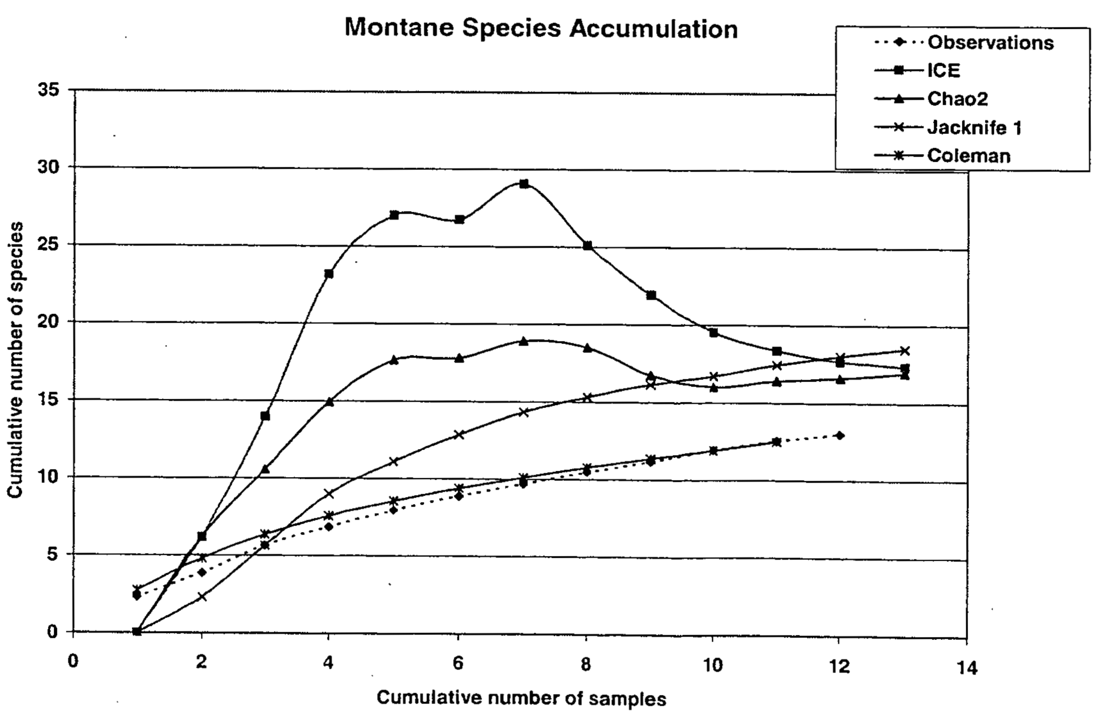


Figure 6d

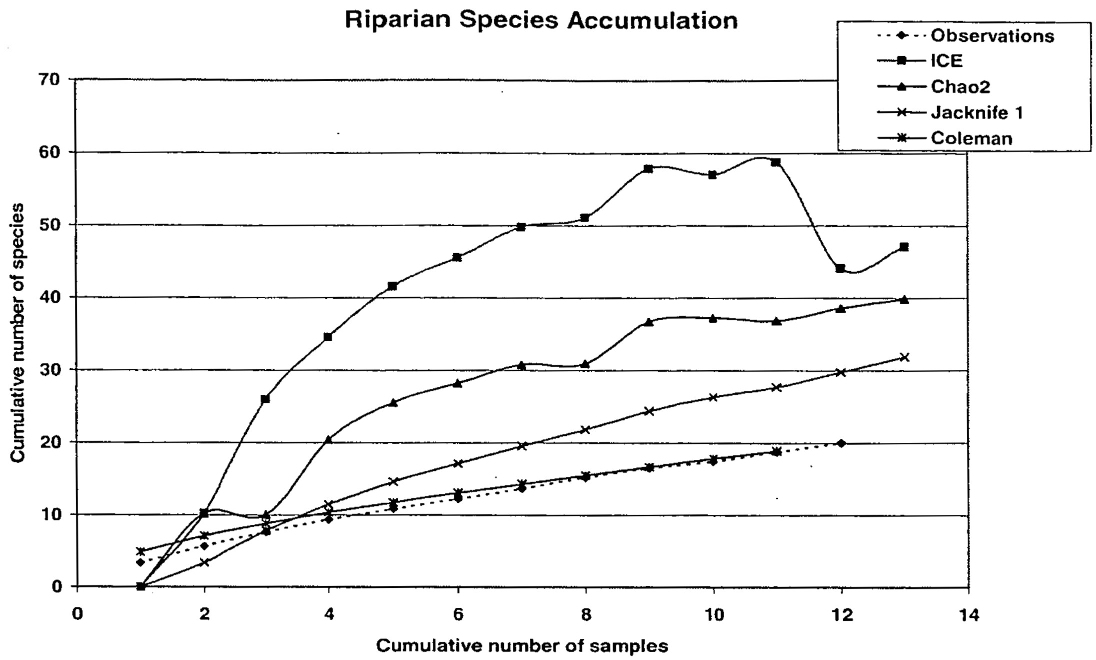


Figure 6e

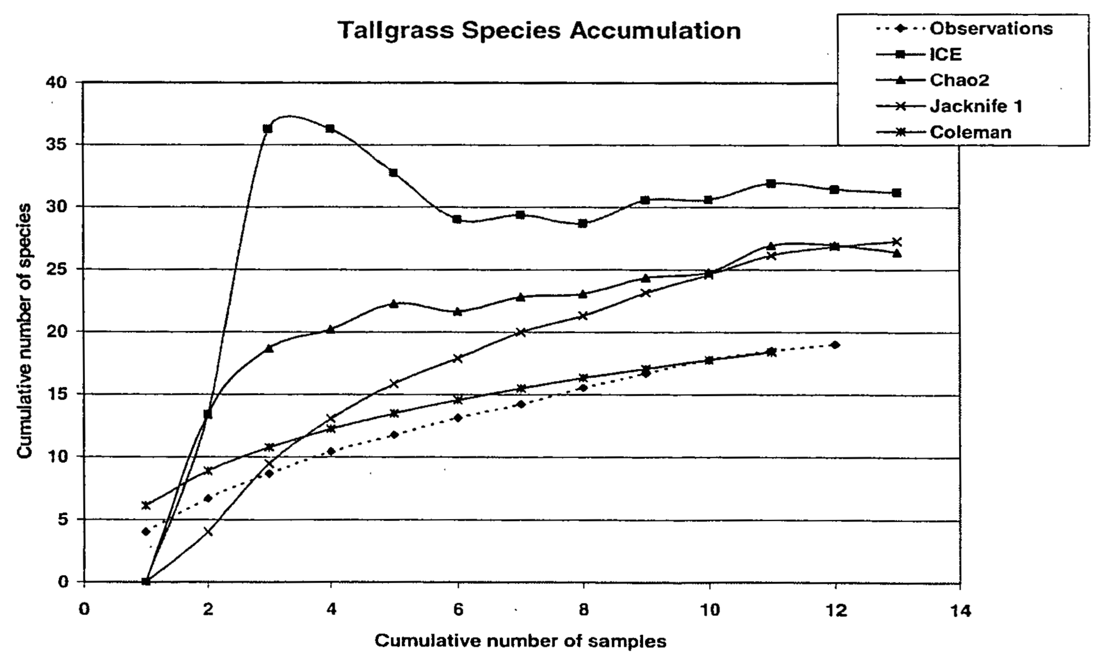
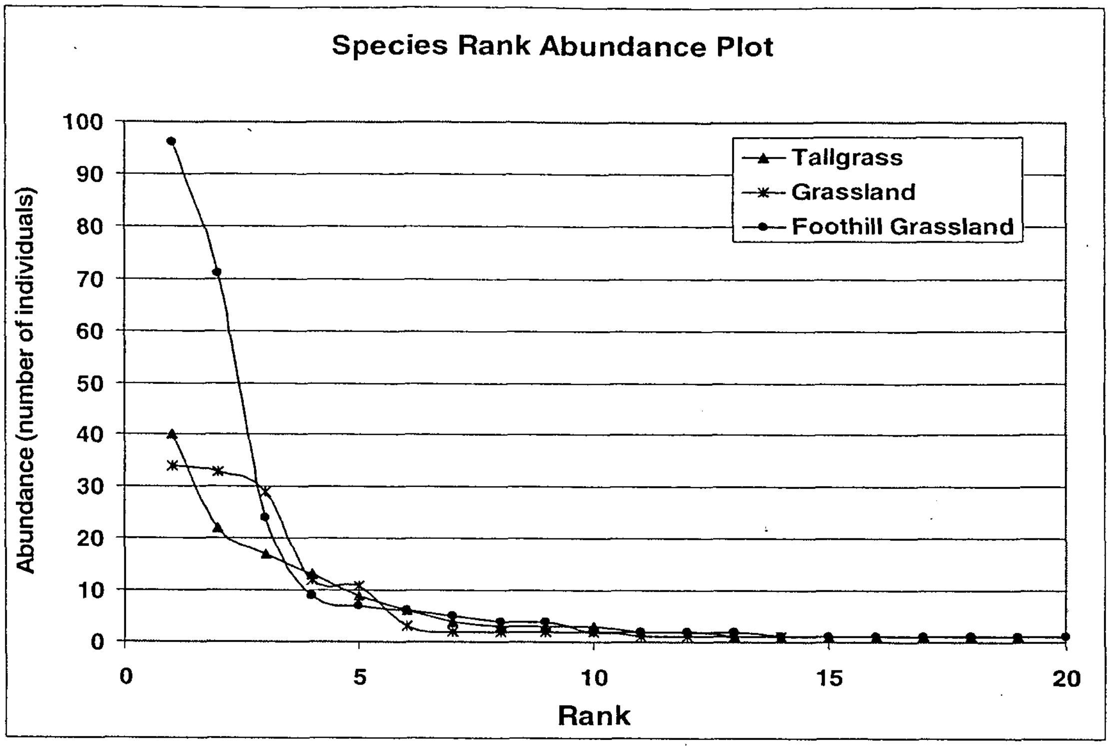


Figure 6f

Figure 6: Accumulation curves for butterfly species richness for each habitat. Estimators of species richness are compared with observed species richness and Coleman curves (rarefaction substitute) for (a) foothills grassland, (b) foothill riparian, (c) grassland, (d) montane, (e) riparian, (f) tallgrass.

Population Description and Diversity

Assessing which of the habitats is more diverse in butterflies is an important question for conservation management, but also difficult to determine. Two important components of diversity are the number of species and the evenness of their numbers. Many ecologists define even distributions of species as being more diverse (Longino 2000). A rank abundance plot graphically depicts the diversity by ranking species by their abundance (Figures 7a and 7b). The general steepness of the slope represents evenness and length is representative of the number of species. Thus, habitats with greater species diversity graph with a uniform slope and abundant species. A steep and short line is interpreted as a less diverse butterfly community. Transect results for all three sites representing a habitat are pooled. The foothills riparian habitat resulted in a long line with a moderately gentle slope as compared to other sites. The length and relatively mild slope indicate that the foothills riparian habitat is more diverse than other habitats with the exception of montane habitats. The montane habitat, due to the gentle slope, appears to have a high diversity based on evenness; however the shortness of the line reflects the low species richness and a lower overall contribution to total species richness. In contrast, the steep drop and short length of riparian habitats indicate relatively low overall species diversity.



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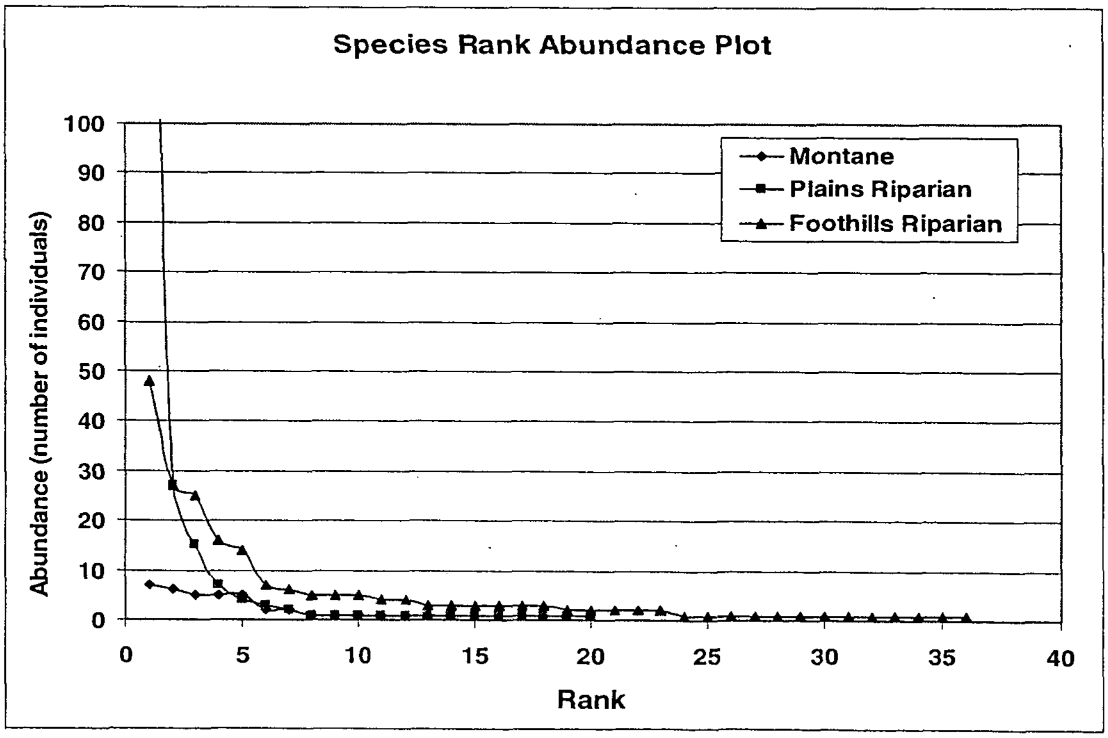
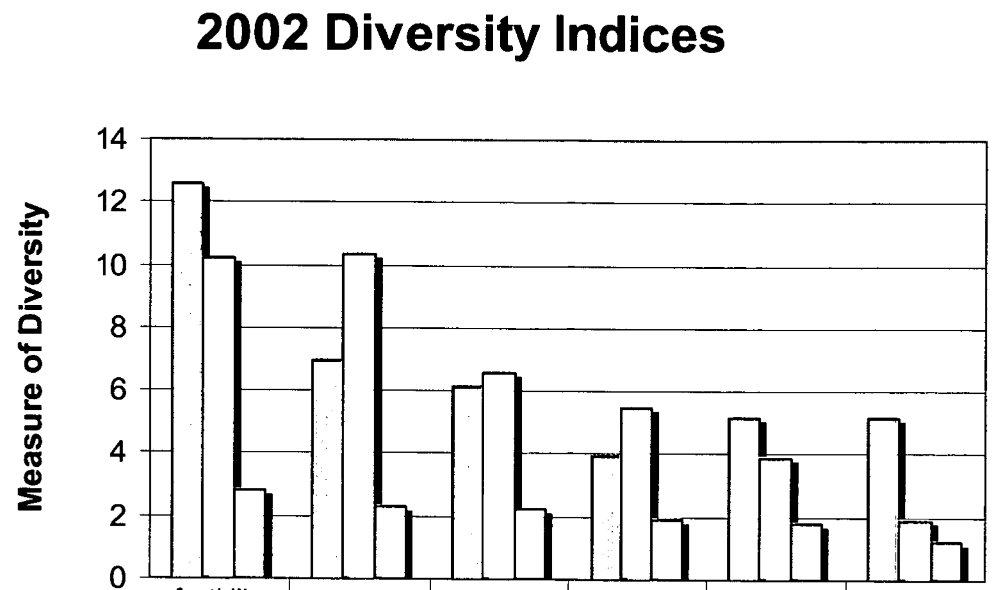


(b)

Figure 7: Butterfly species rank-abundance curves for each habitat type (a) tallgrass, grassland, foothills grassland, and (b) montane, riparian, foothills riparian.

Diversity indices are useful for further interpretation and assessment of diversity patterns between habitats. Three diversity indices, Shannon index, Simpson, and Fisher's alpha were calculated for each of the habitats (Figure 8). The results confirm what the rank abundance curves indicate: three indices show that the foothills riparian habitat is the most diverse, followed by montane and tallgrass with less consistent results for determining the relative position of grasslands and foothills grasslands. The other consistent result was that plains riparian habitat resulted in the least diverse habitat for butterflies.



	foothills riparian	Montane	tallgrass	plains grassland	Foothills grassland	plains riparian
Alpha	12.59	6.98	6.11	3.94	5.18	5.16
Simpson	10.2	10.34	6.59	5.49	3.9	1.93
Shannon	2.81	2.29	2.24	1.93	1.81	1.21

Habitat Type

Figure 8: Comparison of the Fisher's Alpha diversity, Simpson diversity, and Shannon diversity indices for each of the habitats surveyed in the 2002 baseline year. Habitat diversity results are ordered from highest diversity to lowest.

Complementarity

A comparison of the complementarity indices of the six habitats shows that riparian and montane habitats contain the fewest shared species, 18%, and grassland and foothills riparian habitats only shared 19% (Table 10). Foothills grassland and grasslands habitats share 48% of the species observed, indicating considerable overlap in species. Foothills grassland and montane also shared many species with a 43% overlap. However, montane and grassland only share 29%, so many of the species sharing foothills grasslands and grasslands are not the same as those sharing foothills grasslands and montane. Foothills grasslands are potentially a blending area with species mixing from other habitats. Foothills riparian followed closely by montane habitats had the least similarity with other habitats and thus contributed the most complementarity to species diversity.

Table 10: Complementarity index and percent overlap of species compared across habitats. An index of 1.0 represents no overlap in species, and 0 represents complete overlap.

Habitat	foothills grassland		grassland		tallgrass		foothills riparian		riparian	
	Index	shared	Index	shared	Index	shared	Index	shared	Index	shared
grassland	0.52	48%								
tallgrass	0.66	34%	0.68	32%						
foothills riparian	0.73	27%	0.81	19%	0.75	25%				
riparian	0.67	33%	0.69	31%	0.66	34%	0.67	33%		
montane	0.57	43%	0.71	29%	0.77	23%	0.71	29%	0.82	18%

Each habitat was sampled using three different sites that represent some of the range of potential habitat patch treatments including past land management practices, neighboring land context and the intrusion of weedy non-native plants. The similarity of species sampled from each of the three replicate sites indicates the overlap of species between the sites. The montane habitat had the highest overlap between site replicates with 41% ± 9% SE (n=3) followed by foothills grassland (34% ± 5%), foothills riparian (33% ± 11%), riparian (26% ± 3%), tallgrass (22% ± 6 %), and grassland (14% ± 3%). The low overlap in grassland sites is likely attributed to the low number of species observed at two of the sites, Beech (4 species observed) and Jewel (3 species observed) in contrast to the third site Superior (10 species observed). The montane habitat had a low number of species compared to other habitats, however the three sites had relatively even species numbers: Enchanted Mesa (7 species observed); Lindsay (8 species observed); and Shanahan (8 species observed). The generally low overlap between sites indicates there is a lot of variability in butterflies between the sites and that other environmental parameters besides habitat are potentially contributing to the occurrences of particular butterfly species.

Discussion

Sampling Effort and Community Species Richness Estimation

Community species richness is one of many ways to determine the relative conservation value of areas of interest and is often used as a conservation indicator (Debinski and Brussard 1994, Longino 2000). Species richness estimators and accumulation curves provide a method for extrapolating species richness from sampling results. It is important to obtain dependable estimators of species richness to assist in determining the effectiveness of sampling and to help determine what level of sampling effort may be necessary to adequately describe a community's species richness (Longino 2000). Species accumulation curves based on sampling results and species richness predictions using estimators allow the comparison of current rates of detection and predictions of the effects of additional sampling. The reporting or comparison of species richness for sites is less meaningful without some basis for understanding how close to completion a list of species is (Soberon and Llorentė 1993). Species accumulation curves and estimator results help provide a method of establishing how complete species lists are relative to the sampling efforts undertaken.

Estimator models of species accumulation use the approach that species accumulation reaches an asymptote as continued sampling results in marginally fewer new species. The estimator pattern of species accumulation may be based on parametric or nonparametric models of estimation. Species accumulation curves that climb steeply indicate that the species richness is under sampled and not well described. If the curve approaches its asymptote above a specific sample size, then that level of sampling effort is adequate for describing community species richness (Longino 2000). The pooled sampling results for each habitat show that the level of sampling undertaken is adequate to determine species richness for all but one of the habitats surveyed, that one habitat being plains riparian.

OSMP, with a variety of habitats and previously well documented resident and transitory butterfly species, has the potential for a very rich butterfly community. The prediction of habitat species richness from pooled samples from the three sites resulted in the following species richness estimates: 24 species for the grassland habitat, 17 species for the montane habitat, 26 species for the tallgrass habitat, 51 species for the foothills riparian habitat, and 29 species for the foothills grassland habitat. The species richness of plains riparian habitats is predicted by the three estimators to be between 31 and 47 species. Transect observations in 2003 should use the same three estimators to determine the precision of the estimates. The continuation of drought conditions might confirm 2002 results or higher precipitation may provide a very different estimation of species richness based on more favorable conditions for butterflies.

Butterfly Distribution and Diversity

Monitoring the distribution and compositional changes of any group of organisms is a difficult endeavor fraught with complexity. It is difficult to tease out the natural changes from sampling bias. Sampling across time and space, though, provides the clearest picture. Although this butterfly survey only presents the preliminary stages of a long term monitoring effort of butterfly species diversity on Open Space and Mountain Parks, definitive patterns are apparent. Even with a fairly coarse stratification of vegetation into six habitats, butterfly distribution was not evenly distributed across the OSMP landscape. The results support what other researchers have found in that butterfly species abundance and richness tend to be influenced and respond to local vegetation characteristics (Simonson et al. 2001, Collinge et al. 2003). Different habitats on OSMP contribute more to butterfly species diversity than others.

Foothills riparian sites in both the pilot field season and the baseline monitoring year contributed the greatest number of butterfly species. The relatively high number of observed species and the number of unique species documented is not surprising. The rich diversity of vegetation in canyon riparian stretches and the collection of highly mobile butterflies patrolling for mates or moving through these zones contribute to the observed species richness and abundance. The extensive edges along narrow riparian corridors results in butterflies wandering in from neighboring habitats and mixing with more predictable riparian species. The presence of water also enhances the potential for greater butterfly diversity through its positive effects on associated vegetation and provides a collection point for puddling butterflies (Murphy and Wilcox 1986). In all three foothill riparian sites, congregations of puddling butterflies were observed at open water holes. The high species richness, uniqueness, and abundance of butterflies in foothills riparian habitats is reflected by trends of other wildlife and plants being very diverse in foothills canyons as well (Hogan 1993). The attraction of water, in addition to the rich vegetation, contributed to the higher numbers of individuals and species observed.

Consistent with high species richness and abundance, both the alpha and Shannon diversity indices ranked foothills riparian as the most diverse habitat, while the Simpson index only rated the montane index higher. The Simpson index result was most likely due to the greater butterfly evenness in montane habitats in spite of overall lower species richness. Species richness for foothills riparian was significantly higher than the species richness of montane, grassland, tallgrass, and plains riparian habitats. Observations of a greater number of unique species also contributed to greater species diversity. Butterflies such as the pale swallowtail (*Papilio eurymedon)* (family Papilonidae), dun skipper (*Euphyes vestris)* (family Hesperiidae), western elfin (*Callophrys eryphon*) (family Lycaenidae), and Weidemeyer's admiral, (*Limenitis weidemeyerii*) (family Nymphalidae), were several of the unique species documented in foothills riparian sites. The documentation of *C. humulus* nearby the Lower Skunk transect suggests that future sampling of this transect may result in recording this butterfly on this transect as a species of conservation concern and as a unique species. The high species richness, abundance, uniqueness, and diversity of foothills riparian sites reinforce the importance of the inclusion and continued monitoring of this habitat.

In stark contrast to the foothills riparian habitat is the montane habitat. The montane habitat contributed the lowest numbers of butterfly species and the lowest abundance of butterflies in not only the baseline year, but also in the limited sampling of the pilot season. Woodland shade conditions affect the distribution of butterflies perhaps by influencing flight temperatures and the presence of flowers for adult nectaring (Pollard and Yates 1993, Simonson et al. 2001). These conditions are less ideal for butterflies in general and thus may reduce butterfly abundance and richness, yet create an opportunity for the presence of species that can tolerate such conditions and contribute in a small but important way to the overall butterfly distribution and diversity. The overlap of sites sampled in the montane habitat also was the highest of all habitats, showing a consistency between sites but again a lower contribution to overall diversity. Only one specie, the common sooty wing (*Pholisora catullus*) (family Hesperiidae), was unique to montane habitats. This result will likely change with continued surveys as its life history predicts it will likely show up in other habitats.

Montane habitat species diversity, as measured using the three indices, ranked second only to foothills riparian and was rated highest with the Simpson index. The low species richness, abundance, and number of unique species contrasts with the high ratings of diversity. The distribution of species surveyed in the montane is more uniform and even than for most of the other habitats, thus the resulting higher measure of diversity.

The plains riparian habitat was intermediate in the number of species and during the baseline year had the highest number of individuals. This high abundance was primarily due to the abundance of the cabbage white (*Peris rapae)* which accounted for 71% of the individual butterflies observed. The common occurrence of the cabbage white was likely a result of adjacent agricultural lands and weedy pastures. The cabbage white thrives in cultivated and agricultural areas and as a mobile butterfly was also particularly abundant in riparian habitats. Although agricultural lands were not surveyed in this effort, approaches to riparian sites went through adjacent lands where an increased occurrence of cabbage white butterflies was readily observed. The dominance of the cabbage white butterfly is important in understanding why riparian habitats ranked the lowest in all three diversity indices. The low butterfly diversity of riparian habitats is opposite to common ecological expectations that riparian areas contain high species diversity. The influence of poor quality riparian sites and adjacent land conditions and management practices probably had the most effect on which species were observed in riparian habitats.

Grassland habitats had a lower butterfly abundance and species richness than the other habitats. Only 14 species were documented yet the number of individuals was much higher, in part due to the presence of some common species such as the variegated fritillary (*Euptoieta claudia)*, field crescent *(Phyciodes campestris)*, and the checkered white (*Pontia protodice)*. The ranking of diversity indices consistently placed grasslands in both years as the second lowest with the exception of 2002 where the alpha diversity rated it last. These results were rather unexpected given the potential for some of the higher quality and more native grasslands to host grassland specialist butterflies. Observation of grassland specialist butterflies like the Ottoe skipper (*Hesperia ottoe*), Leonard's skipper (*Hesperia leonardus pawnee*), and the white-lined skipper (*Hesperia uncas*), show that these grassland habitats support species likely to be found only in grasslands. The presence of these butterflies underline the important contributions of grasslands to overall regional butterfly diversity, but the relative species diversity and abundance compared to other habitats is reduced.

Tallgrass habitat results were the most surprising in that they were intermediate in the number of butterfly species documented and in abundance. Tallgrass patches on OSMP are remnants from the last glacial period when cooler and wetter conditions prevailed (Livingston 1952). The sites are often aided with wetter conditions by irrigation or being located in flood zones neighboring local creeks. The drought conditions of 2002 probably greatly affected the butterflies of tallgrass habitats. Research on habitat characteristics and their effects on grassland butterflies on OSMP found that tallgrass plots had the highest species richness when compared with three other types of grasslands and had several butterfly species only associated with this habitat type (Collinge et al. 2003). In the 2001 pilot season, tallgrass was sampled to have 23 species and the highest relative abundance. In 2002, with the drastic change in precipitation, tallgrass habitat was similar to foothills grasslands in species richness and only above montane habitats in relative abundance. The reduced vigor of plants, lack of blooming flowers, and dry conditions most certainly contributed to a reduction in species diversity in tallgrass areas as compared to what was expected. In 2001 the bronze copper, *Lycaena hyllus,* was observed on several occasions but not one observation occurred in 2002. Only one unique butterfly was associated with the tallgrass in 2002, the acadian hairstreak (*Satyrium acadica).* The South Boulder tallgrass site which was sampled in both years had 18 species observed in 2001 and only 11 in 2002, of which seven species were the same in both years. Butterflies which were extremely abundant in the pilot season such as the cabbage white (*Pieris rapae*), checkered white (*Pontia protodice*), and orange sulfur (*Colias eurytheme*) were still the dominant species in 2002 but their total numbers were greatly reduced. Butterflies like the monarch, (*Danaus plexippus*), viceroy (*Limenitis archippus*), and buckeye (*Junonia coenia*) were frequently observed in 2001 but not in 2002.

Diversity indices for both years showed tallgrass to be intermediate when compared to the other habitats. With future surveys of the tallgrass sites, I expect the species diversity and unique grassland species that have previously been associated with this special type of prairie to be documented, and more frequent, and thus increase the relative diversity of tallgrass habitats.

The last habitat to be considered is foothills grassland. These mixed grass sites on the slopes of mesas and hogback ridges were abundant with butterflies and relatively high in species richness. The habitat is a bridging zone between the grasslands on the lower prairies and the montane woodlands of ridges and mesas. As an intermediate habitat between plains grassland and montane woodland, it was expected there would be some overlap between foothills grasslands butterfly species and the montane and grassland species. The analysis of species overlap showed that there was considerable overlap between foothills grasslands and plains grasslands and montane woodlands, but that the overlap was of different shared species. The butterflies common between grasslands and foothills grassland were not the same as those shared between foothills grassland and montane habitats. Only three unique species were encountered in foothills grasslands, another indication of the high species overlap with adjacent habitats. These findings indicate that foothills grasslands as an independent habitat may not have butterflies unique compared to other habitats. However, the butterfly community composition may be a distinct mix of butterflies and thus deserve continued monitoring.

Several butterflies of conservation concern have been documented in the foothill grasslands of Boulder including the arogos skipper (*Atrytone arogos*) and the cross-line skipper (*Polites origenes*) as well as the uncommon indra swallowtail (*Papilio indra*) (Pineda and Ellingson 1998). Further butterfly surveys and habitat comparisons will offer continued analysis and insight into determining the contribution of foothills grassland to the overall OSMP butterfly diversity and continued justification to keep it stratified as a primary habitat for butterflies.

Comparing 2001 to 2002

Butterfly populations can experience diurnal, seasonal, and annual temporal variability which can influence measured diversity (Shapiro 1975). The value of long-term monitoring and, coincidently, the challenges of establishing monitoring criteria, are affected by such temporal variation. The differences between the 2001 pilot season and the 2002 baseline year are a good example of this variability. Most striking is the significant reduction in numbers of individuals surveyed between the two years, 2381 in 2001 to 995 in 2002. The substantial drop in abundance is most likely due to drought conditions experienced in 2002. Flowers providing nectar resources were scarce and the overall vigor of plants appeared reduced. The cumulative relative abundance of butterflies at all sites in 2002 was approximately a third of the cumulative relative abundance of 2001. In addition, the drought conditions resulted in far fewer migrant and non-over wintering butterflies being surveyed which also contributed to the lower butterfly abundances. Minimal precipitation and arid weather patterns may shift not only the number of butterflies but what butterflies utilize OSMP. The difference between 2001 and 2002 underscores the need for long term population assessments of butterfly populations to understand variation patterns. The baseline monitoring year in 2002 will lend to interesting comparisons with future years.

Indicator Candidates (rare, local and habitat predictive species)

Monitoring changes in butterfly species diversity provides some insight into ecosystem health. Additional attention to subgroups of butterflies or specific species that have greater host plant specificity or depend on specific habitats provide even better means of assessing ecosystem changes. Variation in the abundance and presence of butterflies can be influenced by regional weather patterns, local physiological conditions, a species' mobility and colonizing ability, and the ability for researchers to detect a species by its behaviors or flight patterns. Cosmopolitan and migratory butterflies can affect assessments of habitats strictly from species richness and abundance metrics and diversity patterns through either being very abundant or widespread in distribution or by not being very responsive to improving or degrading local habitat conditions. For example, the high numbers documented of the cabbage white butterfly, *P. rapae,* greatly increased abundance results for sites where it was recorded. Similarly, the orange sulfur, *C. eurytheme,* as an opportunistic generalist and very mobile butterfly, was observed in most habitats with less apparent affinity for specific locales. These opportunistic generalist species may be more resilient to environmental changes and add to butterfly diversity but provide little indicator value.

Species that are dependent on local plant associations, and therefore more likely to be sensitive to ecosystem degradation or change, provide the greatest value as indicators. Rare and imperiled butterfly species may be the most sensitive to disturbance and change, but because of their low numbers and specialized life requirements, may be too inconsistent in presence and ease of observation to provide consistent monitoring value if they are relied upon solely. Species that have an affinity to a particular ecosystem and are encountered frequently enough to assess population trends between sites or different management treatments offer the best indicator abilities. All observations of butterflies of conservation concern deserve great care and rigor in documenting their occurrence, noting behaviors and observing habitat considerations that may provide better understanding of life history requirements. These observations may be of considerable value when determining the conditions of habitats that remain favorable for the continued survival of such conservationally important butterflies. However, other slightly more common yet habitat-specific butterflies included with the rare species provide the best indicator potential. A list of resident species from 2001 and 2002 that were found in either a single or limited habitats is listed in Appendix G.

A subgroup of the butterflies observed, consisting of more sensitive butterflies that are less resilient to vegetation changes and environmental perturbations are potentially the best indicators (Nelson and Andersen 1994). The foothills riparian habitat has the most candidate species with potentially 23 species showing a preference for this habitat. However, some of these species are dependent on host plants not strictly associated with riparian habitats and future survey results may determine that they are not appropriate indicators. The remaining habitats have much less specificity in species. The tallgrass habitat had two species that were unique, but both depend on specific tree host plants most likely associated with adjacent stream riparian sites. A list of initial habitat indicator species is provided in Appendix H. The analysis of two additional years of survey results will provide a better basis for determining the most appropriate list of habitat indicator butterflies. The species listed in Appendix H should be viewed as tentative as it is not clear which butterfly species or collective groups are habitat specialist for OSMP lands and therefore the best indicator species.

Management implications and Cautions

Butterflies, as phytophagous invertebrates, are dependent on plants and, in some specific cases, dependent on specific plants. The type of grassland, and more importantly, the grassland quality have been shown to strongly influence butterfly richness, abundance and composition (Collinge et al. 2003). The occurrence and intensity of grazing with associated effects on vegetation height also can affect butterfly species abundance and richness (Kruess and Tscharntke 2002). While the surrounding urbanization of a grassland habitat may not affect butterfly species composition (Collinge et al. 2003), the increasing intensity of urbanization or human modifications to a landscape does affect butterfly composition (Blair and Launer 1997, Kitahara and Fujii 2001). Butterflies are more sensitive to patch and alterations in site specific habitat conditions than broader landscape characteristics. Butterfly communities on OSMP are most likely more resilient to surrounding landscape changes. Neighboring land disturbance through urban development, intensive recreation use, and even agricultural practices may have less effect on the butterfly community of a specific habitat than changes in, or modifications to, the vegetation of the habitat. Thus land management activities that affect specific high diversity areas or areas where conservation concern species occur are the greatest threat to butterfly conservation for OSMP. Locations where the greatest diversity occurs and conservation concern species continually appear should be prioritized for minimal disturbance in vegetation quality.

Foothill riparian canyons are "diversity hot spots" and loss of the conditions and types of plants in these areas can have serious impacts on butterfly communities on OSMP. The spread of exotic plants and the degradation of these sites from high recreational use pose the greatest risk. The occurrence of two butterflies of conservation concern on OSMP land validates the importance of emphasizing protective measures for such habitats.

Grassland habitats were not diversity hot spots, but did contain species of conservation concern and have many potential grass-feeding butterflies that require high quality grasslands. The spread of exotic plants, changes in vegetation resulting from the expansion of prairie dog colonies, and grazing of high quality grasslands potentially has the most serious impacts to grassland butterflies. The grassland habitat contains documented conservation concern butterfly species which are of greatest risk from these threats. The Jewel grassland site, while having very low butterfly diversity, does potentially support a population of *Hesperia ottoe* and was actively being grazed during part of the summer. The Superior grassland site likewise had a less diverse butterfly community but abundant observations of *Hesperia uncas*, another grassland specialist butterfly that prefers less disturbed grassland habitats. The Superior grassland site also was grazed and contains an expanding prairie dog colony, so that these potential conditions must be carefully monitored so as to not degrade the grassland quality of this site and jeopardize the butterfly community.

Future needs

Continued surveys of each habitat and site will be important to determine the variability of butterfly communities with more focused attention placed on the habitat-specialist butterflies and species of conservation concern. Butterfly diversity and community composition have the potential to be considerably different year after year, exemplified by the considerable change in butterfly numbers between the pilot (2001) and baseline (2002) years. At least two more years of butterfly surveys will be needed to provide a better understanding of the variability of butterfly richness and abundance so that criteria can be established to guide tolerances for changes in the butterfly habitat specialist guilds that would indicate potential changes in habitat conditions and the need for a management response.

When a rare butterfly of conservation concern is documented during the transect survey, the specific transect should be run two additional times within a seven day time frame. These additional surveys will only be focused on surveying the particular species of conservation concern to develop an index of abundance for each site based on multiple transect runs (Pollard 1977, Thomas 1983, Caldas and Robbins 2003). This will ensure a replicated effort to document the abundance of a potential population and do so in a timely way for more accurate assessment of the species abundance during its flight period. A list of conservation concern butterflies that should be tracked with replicate surveys and an index of abundance are listed in Appendix I and Appendix J.

Vegetation structure and composition analysis for each of the monitoring sites would be of considerable value in analyzing potential relationships between butterfly occurrences and distributions with vegetation patterns. Several of the butterfly survey sites have long-term vegetation monitoring points nearby to assist in describing vegetation patterns, but the methods, frequency and purposes of the monitoring varies. A consistent vegetation monitoring program connected with butterfly monitoring would provide analysis of habitat conditions that affect butterfly occurrence. A more refined vegetation monitoring component would also assist in refining the analysis of habitat stratification to insure they reflect stratifications in butterfly communities.

High quality native grasslands on OSMP are important for butterfly conservation and unfortunately also happen to be threatened by many past and present land management decisions and actions Management practices that impact the quality of native grasslands should be studied with regard to resulting changes in occurrences and distributions of grassland specialist butterflies. Increased exotic plant incursions, grazing practices, mowing practices, fire management, and prairie dog expansion are all important factors that likely affect vegetation structure and composition and therefore butterfly conservation on OSMP.

Finally, expansion of monitored habitats to include mountain grasslands in locations such as the west sides of Flagstaff Mountain and South Boulder Peak would be important. These sites have previously been surveyed as likely hot spots for butterfly diversity and were found to contain butterflies of conservation concern and may potentially contain habitat-specialists. The grasses of higher elevations are different from lower elevation grasslands and the surrounding woodland and forest habitats might hinder the movement of less mobile butterflies in and out of the small mountain grassland patches.

Products

The intent of this study is to establish a program and tools for the City of Boulder Open Space and Mountain Parks to continue to survey butterfly communities. The collection and analysis of initial data was important, but developing and testing the methods, sites and tools to promote continuation of the monitoring are also import outcomes. The following products are either complete or in progress to facilitate the future success and continuity of this monitoring program.

- Eighteen mapped and described transects representing six habitat types (Appendix A)
- Baseline year abundance indices for conservation concern butterflies. (Appendix J)
- Detailed monitoring protocols (including suitable weather conditions and forms for recording observations) (Appendix K)
- Educational and field identification tools for staff and volunteers to assist in identification of butterflies, flight periods, habitat preferences, and behavioral norms (Appendix L)
- Microsoft Access database for storing data and Excel spreadsheets for data preparation for analysis. (Appendix M and N)
- Pilot year survey of eight sites representing five habitats and baseline year data for all eighteen transects
- Initial synoptic and voucher collections housed in the entomology collection at the University of Colorado Museum of Natural History

References

Arenz, C. L. 1995. Initiation of a buttefly monitoring program at the Tallgrass Prairie Preserve, Osage County, Oklahoma. Proceedings of the Oklahoma Academy of Science 75: 25-29.

Bock, C. and J. Bock. 1994. A field guide to City of Boulder Open Space grassland biodiversity plots. Unpublished report. EPO Biology, University of Colorado.

Blair, R.B. and A.E. Launer. 1997. Butterfly diversity and human land use: species assemblages along an urban gradient. Biological Conservation 8 : 113-125.

Brown, J. A. and M. S. Boyce. 1998. Line transect sampling of Karner blue butterflies (*Lycaeides melissa samuelis*). Environmental and Ecological Statistics 5:81-91.

Caldas, A. and R. Robbins. 2003. Modified Pollard transects for assessing tropical butterfly abundance and diversity. Biological Conservation 110:211-219.

Collinge, S.K., K.L. Prudic and J.C. Oliver. 2003. Effect of local habitat characteristics and landscape context on grassland butterfly diversity. Conservation Biology 17: 178-187.

Colwell, R.K. and J.A. Coddington. 1994. Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society (Series B) 345:101-118.

Colwell, R. K. 1997. EstimateS: Statistical estimation of species richness and shared species from samples. Version 6.0b1. User's Guide and application published at: http://viceroy.eeb.uconn.edu/estimates.

Crawford, T. J. 1991. The calculation of index numbers from wildlife monitoring Data. Pages 225-248 in B. Goldsmith editor. Monitoring for Conservation and Ecology, Chapman and Hall, New York.

Debinski, D.M. and P. F. Brussard. 1994. Using biodiversity data to assess species-habitat relationships in Glacier National Park, Montana. Ecological Applications 4: 833-843.

City of Boulder. 1999. City of Boulder Forest Ecosystem Management Plan Part I. Unpublished report, City of Boulder, Colorado.

Ferris, C. and F. M. Brown. 1981. Butterflies of the Rocky Mountain States. University of Oklahoma Press, Norman Oklahoma.

Fleishman, E., Murphy, D.D., Austin, G.T. 1999. Butterflies of the Toquima Range, Nevada: distribution, natural history, and comparison to the Toiyabe Range. Great Basin Naturalist 59: 50-62.

Hogan, T. 1993. A floristic survey of the Boulder Mountain Park Boulder, Colorado. Natural History Inventory of Colorado, No. 13. Boulder, CO. University of Colorado Museum

Kitahara, M. and F. Fujii. 1994. Biodiversity and community structure of temperate butterfly species within a gradient of human disturbance: an analysis based on the concept of generalist vs. specialist strategies. Research and Population Ecology 36:187-199.

Kocher, S.D. and E.H. Williams. 2000. The diversity and abundance of North American butterflies vary with habitat disturbance and geography. Journal of Biogeography 27:785-794.

Kremen, C. 1992 Assessing the indicator properties of species assemblages for natural areas monitoring. Ecological Applications 2:203-217.

Kruess A. and T. Tscharntke. 2002. Grazing intensity and the diversity of grasshoppers, butterflies, and trap-nesting bees and wasps. Conservation Biology 16:1570-1580.

Lambshead, J.D., C. J. Brown, T. J. Ferreor, L. E. Hawkins, C. R. Smith and N. J. Mitchell. 2003. Biodiversity of nematode assemblages from the region of the Clarion-Clipperton Fracture Zone, an area of commercial mining interest. BMC Ecology 3:1. http://www.biomedcentral.com/1472-6785/3/1.

Landres, P.B., J. Verner, and J. W. Thomas. 1988. Ecological uses of vertebrate indicator species: a critique. Conservation Biology 2:316-328.

Livingston, R. B. 1952. Relict true prairie communities in central Colorado. Ecology 33:72-86.

Longino, J. T. 2000. What to do with the data. Pages 186-203 in D. Agosti, J. Majer, L. Alonso, and T. Schultz, editors. Ants: Standard Methods for Measuring and Monitoring Biodiversity. Smithsonian Institute Press, Washington and London.

Magurran, A.E. 1988. Ecological Diversity and its Measurement. Princeton University Press, Princeton, NJ. 179pp.

Morrison, M. L., B. G. Marcot, and R. W. Mannan. 1992. Wildlife-Habitat Relationships Concepts and Applications. University of Wisconsin Press, Madison, Wisconsin.

Morton, A. C. 1984. The effects of marking and handling on recapture frequencies of butterflies. Pages 55-58 in R. I. Vane-Wright, and P. R. Ackery, editors. The biology of butterflies. Princeton University Press, Princeton, NJ.

Murphy, D.D., and B. A. Wilcox. 1986. Butterfly diversity in natural habitat fragments: A test of the validity of vertebrate-based management. Pages 287-292 in J. Verner, M. L. Morrison, and C. J. Ralph, editors. Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. University of Wisconsin Press, Madison, Wisconsin.

Murphy, D. D., K. E. Freas, and S. B. Weiss. 1990. An environment-metapopulation approach to population viability analysis for a threatened invertebrate. Conservation Biology 4:41-51.

Nelson, S.M., and D.C. Andersen. 1994. An assessment of riparian environmental quality by using butterflies and disturbance susceptibility scores. The Southwestern Naturalist 39:137-142.

New, T. R. 1991. Butterfly Conservation. Oxford University Press, Australia, Melbourne.

New, T. R. 1997. Are Lepidoptera an effective 'umbrella group' for biodiversity conservation? Journal of Insect Conservation 1:5-12.

New T.R., R. M. Pyle, J. A. Thomas, C. D. Thomas, P. C. Hammond. 1995. Butterfly conservation management. Annual Review of Entomology 40:57-83.

Noss, R. F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

Oliver, I., A. J. Beattie, and A. York. 1997. Spatial fidelity of plant, vertebrate, and invertebrate assemblages in multiple-use forest in eastern Australia. Conservation Biology 12:822-835.

Opler, P. A. 1994. Conservation and management of butterfly diversity in the United States. Office of Information Transfer. U. S. Fish and Wildlife Service, Fort Collins, Colorado.

Pineda, P. M. and A. R. Ellingson. 1998. A Systematic Inventory of Rare and Imperiled Butterflies on the city of Boulder Open Space and Mountain Parks. February 1998. A report by the Colorado Natural Heritage Foundation. Fort Collins, Colorado.

Pollard, E. 1977. A method for assessing changes in abundance of butterflies. Biological Conservation 12:115-133.

Pollard, E. and T. J. Yates. 1993. Monitoring Butterflies for Ecology and Conservation. Chapman and Hall, London.

Ries, L., D. Bebinski, and M. Wieland. 2001. Conservation value of roadside prairie restoration to butterfly communities. Conservation Biology 15:401-411.

Rodeck, H. G., editor. 1964. Natural History of the Boulder Area. The University of Colorado Museum, Boulder.

Scott, J. A. 1986. The Butterflies of North America A Natural History and Field Guide. Stanford University Press, Stanford, California.

Shapiro, A.M. 1975. The temporal component of butterfly species diversity. In Ecology and Evolution of Communities. Pp 181-195. Edited by M.L. Cody and J.L. Diamond. Harvard University Press, Cambridge, MA.

Simonson, S. E., P. A. Opler, T. J. Stohlgren and F. W. Chong. 2001. Rapid assessment of butterfly diversity in a montane landscape. Biodiversity and Conservation 10:1369-1386.

Soberon, J.M. and J.B. Llorente. 1993. The use of species accumulation functions for the prediction of species richness. Conservation Biology 7:480-488.

Sparrow, H. R., T. D. Hisk, P. R. Ehrlich, and D. D. Murphy. 1994. Techniques and guidelines for monitoring neotropical butterflies. Conservation Biology 8:800-809.

Swengel A. B. 1996. Effects of fire and hay management on abundance of prairie butterflies. Biological Conservation 76:73-85.

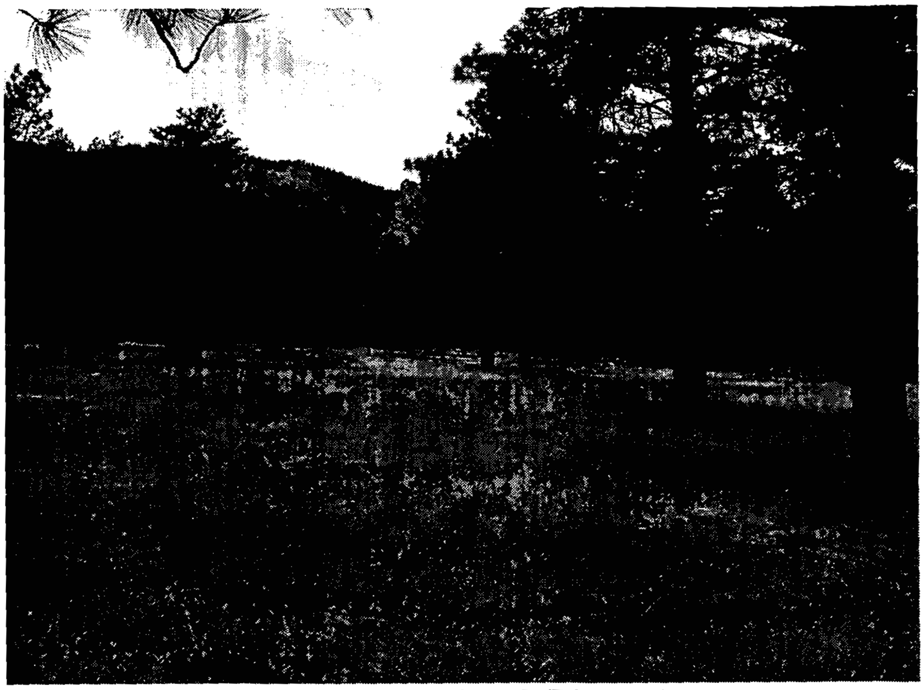
Thomas, J. A. 1983. A quick method for estimating butterfly numbers during surveys. Biological Conservation 27:195-211.

Toti, D. S., F.A. Coyle, J.A. Miller. 2000. A structured inventory of Appalachian grass bald and heath bald spider assemblages and a test of species richness estimator performance. The Journal of Arachnology 28:329-345.

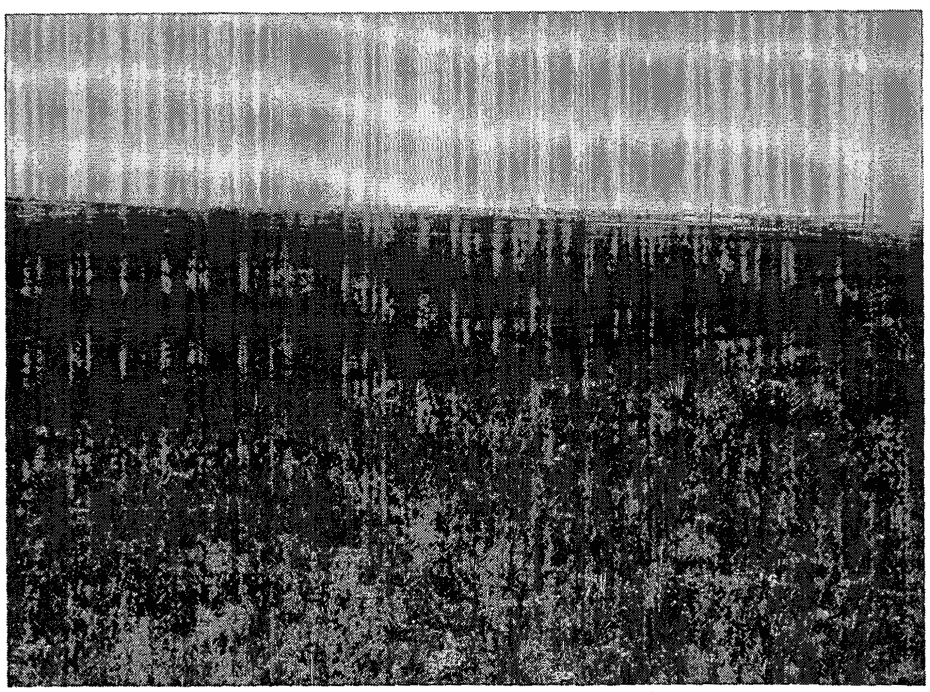
Wilcove, D. S. 1986. From fragmentation to extinction. Natural Areas Journal 7: 23-27.

Appendix A

Habitat Photos



Montane Woodland (Lindsay)



Plains Grassland (Superior)

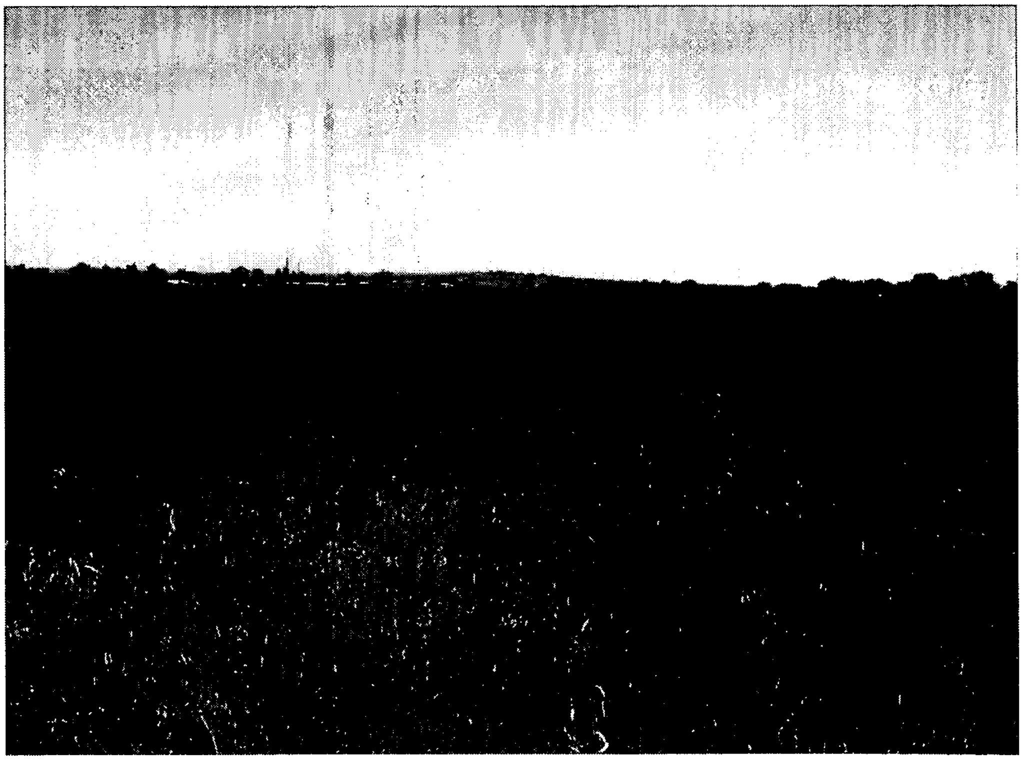
Appendix A

Foothills Grassland (North Foothills)

Foothills Riparian (Coal Creek)

Appendix A

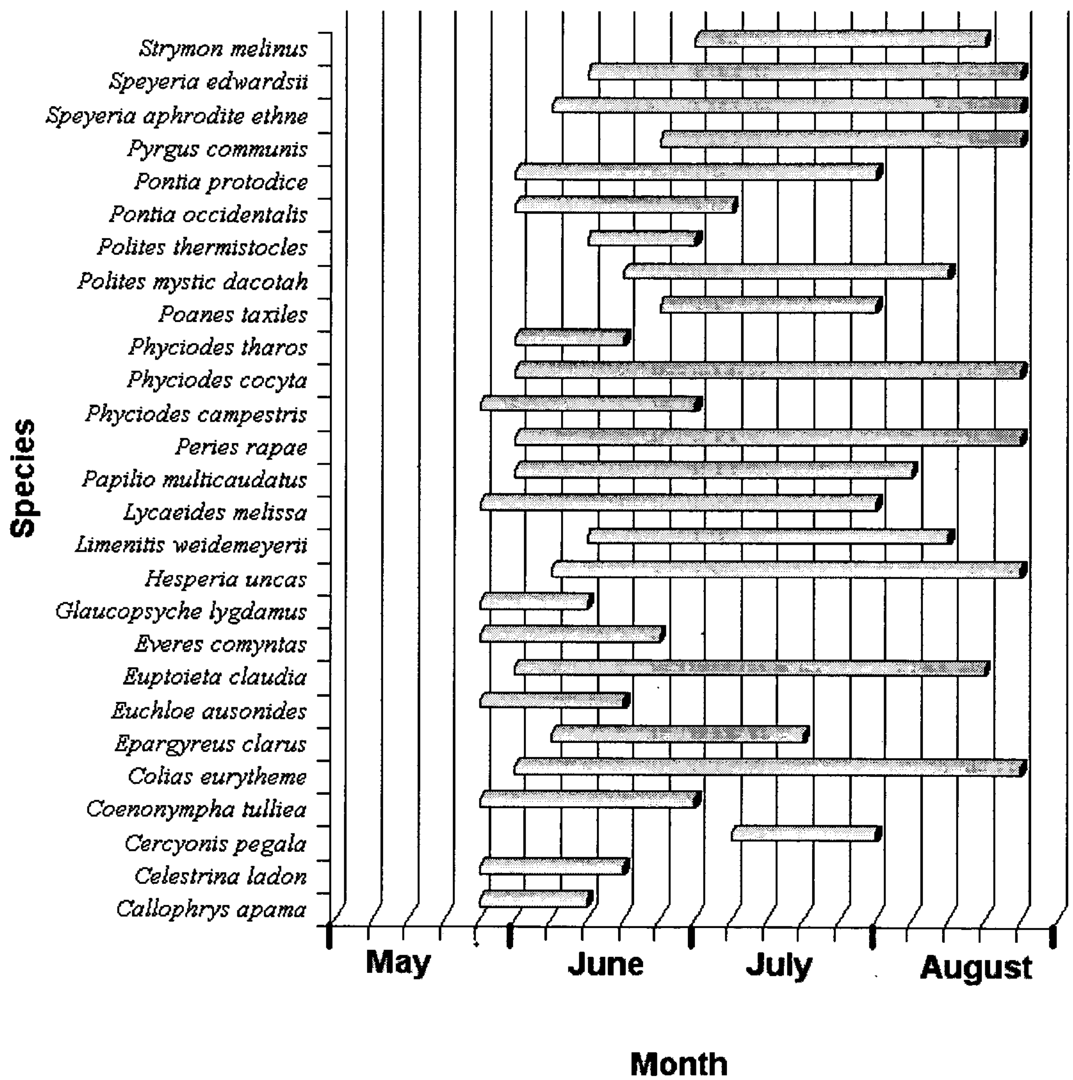
Plains Riparian (South Boulder Creek)



Tallgrass (Church)

Appendix B

Phenology of Common Butterflies for the year 2002



Appendix C

Species Richness Estimator Formulas

Chao 2: $$S_{Chao\,2} = S_{obs} + \frac{Q^2_1}{2(Q_2 + 1)} - \frac{Q_1 Q_2}{2(Q_2 + 1)^2}$$

ICE: $$S_{ice} = S_{freq} + \frac{S_{inf\_r}}{C_{ice}} + \frac{Q_1}{C_{ice}} \gamma^2_{ice}$$

$$C_{ice} = 1 - Q1/ N_{infr}$$

Jackknife 1: $$S_{jack1} = S_{obs} + Q_1\big((m-1)/m\big)$$

S_{obs}	=	Total number of species observed in all samples pooled
S_{freq}	=	Number of frequent species (each found in more than 10 samples)
S_{infr}	=	Number of infrequent species (each found in 10 or fewer samples)
Q_j	=	Number of species that occur in exactly j samples (Q_1 is the frequency of uniques, Q_2 the frequency of duplicates)
m	=	number of samples
S_{infr}	=	Number of infrequent species (each found in 10 or fewer samples)
C_{ice}	=	Sample incidence coverage estimator
N_{infr}	=	Total number of incidence (occurrences of infrequent species.

Source: (Colwell 1997)

Appendix D

Annual Weather Statistics for the Denver Region

Month/ Year	Ave. Max Temp °F	Ave. Monthly Temp °F	Monthly Norm °F	Extreme High Temp °F	Precipitation in inches	Precipitation (norm) in inches
May- 01	69.7	57.1	55.9	85	3.74	16.55 (16.11)
Jun- 01	84.2	69.4	67.0	98	1.53	
Jul- 01	90.7	76.7	72.1	101	4.75	
Aug- 01	87.2	73.3	69.8	95	0.71	
4 month mean		**69.1**	**66.2**			
May- 02	70.6	56.2	57.2	93	0.94	7.48 (15.81)
Jun- 02	87.2	71.1	67.6	97	1.45	
Jul- 02	91.5	76.3	73.4	99	1.39	
Aug- 02	87.1	71.5	71.7	100	0.78	
4 month mean		**68.8**	**67.5**			

Appendix E

2001 Butterfly Observations by Habitat

Scientific Name	grassland plains	foothills grassland	tallgrass	montane	foothills riparian	Total
Papilio multicaudatus		3			5	**8**
Papilio polyxenes		2				**2**
Papilio rutulus		1			1	**2**
Danaus plexippus	1	6	2			**9**
Euptoieta claudia	8	544	14		1	**567**
Chlosyne gorgone					1	**1**
Junonia coenia	2	1	3			**6**
Limenitis archippus			9			**9**
Limenitis weidemeyerii		1			8	**9**
Nymphalis antiopa			1		2	**3**
Phyciodes campestris camilla	1	49	3			**53**
Speyeria aphrodite ethne		63			39	**102**
Speyeria edwardsii		1				**1**
Vanessa atalanta		5			2	**7**
Vanessa cardui	1	80	31	9	14	**135**
Anthocharis julia					5	**5**
Colias eurytheme	18	126	64	4	6	**218**
Colias philodice	5	67	10	4		**86**
Euchloe ausonides		3			3	**6**
Nathalis iole		8	1			**9**
Peries rapae	3	8	310		1	**322**
Pontia occidentalis	65	245	17	23	4	**354**
Pontia protodice	17	130	49		2	**198**
Celestrina ladon		1	2		3	**6**
Everes comyntas					2	**2**
Glaucopsyche lygdamus		2			2	**4**
Glaucopsyche piasus					3	**3**
Hemiargus isola		3	11			**14**
Lycaeides melissa	1	14				**15**
Plebejus acmon		2			2	**4**
Plebejus icarioides		1				**1**
Lycaena hyllus			8			**8**
Callophrys apama		7			1	**8**
Callophrys eryphon					2	**2**
Satyrium saepium		1				**1**
Strymon melinus	2	11	4			**17**
Cercyonis pegala	2	58	17	1	5	**83**
Coenonympha tulliea		19	1	9		**29**
Oeneis chryxus		3			2	**5**
Epargyreus clarus			1		2	**3**

Scientific Name	grassland plains	foothills grassland	tallgrass	montane	foothills riparian	Total
Erynnis persius complex		1				**1**
Hesperia comma complex		1				**1**
Hesperia leonardus pawnee		6				**6**
Hesperia uncas	1	1				**2**
Oarisma garita		1	9			**10**
Ochlodes sylvanoides		1			14	**15**
Pholisora catullus				1		**1**
Polites mystic dacotah		1	4			**5**
Pyrgus communis		21	1			**22**
Euphyes vestris					1	**1**
Total number of butterflies	**127**	**1498**	**572**	**51**	**133**	**2381**
Total number species	**14**	**39**	**23**	**7**	**27**	**50**

Appendix F

2002 Butterfly Observations by Habitat

Scientific Name	Tallgrass	plains grassland	Foothills grassland	Plains Riparian	Foothills Riparian	Montane	Totals
Papilio eurymedon					1		**1**
Papilio multicaudatus			1	1	6	2	**10**
Papilio polyxenes			1				**1**
Papilio rutulus					1		**1**
Parnassius smintheus					2		**2**
Euptoieta claudia		34	9	1			**44**
Limenitis archippus				1			**1**
Limenitis weidemeyerii					5		**5**
Nymphalis antiopa					3		**3**
Phyciodes campestris camilla	17	33	96	4	27		**177**
Phyciodes cocyta	1				5		**6**
Phyciodes tharos				2	3		**5**
Speyeria aphrodite ethne	3	2	6		48	5	**64**
Speyeria edwardsii		1	4		1	1	**7**
Vanessa cardui	1			1			**2**
Colias eurytheme	9				1	1	**11**
Colias philodice	3						**3**
Euchloe ausonides					3	6	**9**
Peries rapae	13		2	173	7		**195**
Pontia occidentalis	4	2	7				**13**
Pontia protodice	40	29	71	27	4	5	**176**
Celestrina ladon					3		**3**
Everes comyntas		1	5	1	14	1	**22**
Euphilotes ancilla	3				1		**4**
Glaucopsyche lygdamus			1		2	2	**5**
Hemiargus isola	1						**1**
Leptotes marina				1			**1**
Lycaeides melissa	1	3	1	1			**6**
Plebejus acmon			1		1		**2**
Lycaena heteronea					1		**1**
Callophrys apama					3		**3**
Callophrys eryphon					3		**3**
Satyrium acadica	1						**1**
Satyrium saepium					1		**1**
Strymon melinus	1		1	1			**3**
Cercyonis pegala	22	1	2	7	16	7	**55**
Coenonympha tulliea	6	12	24	3	25	5	**75**
Oeneis chryxus					1		**1**
Polygonia gracilis				1	1		**2**
Epargyreus clarus				1	2		**3**
Erynnis martialis					1		**1**

Scientific Name	Tallgrass	plains grassland	Foothills grassland	Plains Riparian	Foothills Riparian	Montane	Totals
Euphyes vestris					2		**2**
Hesperia comma complex						1	**1**
Hesperia leonardus pawnee		1					**1**
Hesperia ottoe		2					**2**
Hesperia uncas		11	2				**13**
Oarisma garita	2		4			1	**7**
Ochlodes sylvanoides				1	2		**3**
Pholisora catullus			1				**1**
Poanes taxiles				15	5		**20**
Polites mystic dacotah	1			1	4		**6**
Polites thermistocles			2		1	1	**4**
Pyrgus communis	2	2		1	1		**6**
Total number of butterflies	**131**	**134**	**241**	**244**	**207**	**38**	***995***
Total number species	**19**	**14**	**20**	**20**	**36**	**13**	**53**

Appendix G

Single Habitat and Potential Habitat Resident Predictive Butterflies

Scientific Name	Species Code	Tallgrass	Grassland	Foothills Grassland	Riparian	Foothills Riparian	Montane
Unique Habitats							
Papilio eurymedon	paeu					1	
Papilio indra	pain			1*			
Parnassius smintheus	pasm					2	
Limenitis archippus	liar				1		
Limenitis weidemeyerii	liwe					5	
Nymphalis antiopa	nyan					3	
Celestrina ladon	cela					3	
Lycaena heteronea	lyhe					1	
Callophrys apama	caap					3	
Callophrys eryphon	caer					3 (2)	
Satyrium acadica	saac	1					
Satyrium saepium	sasa					1 (1)	
Oeneis chryxus	oech					1	
Erynnis martialis	erma					1	
Euphyes vestris	euve					2 (1)	
Hesperia comma complex	heco						1
Hesperia leonardus pawnee	hele		1				
Hesperia ottoe	heot		2				
Pholisora catullus	pcat			1			
Lycaena hyllus	lyhy	(8)					
Plebejus icarioides	plic			(1)			
Chlosyne gorgone	chgo					(1)	
Anthocharis Julia	anju					(5)	
Glaucopsyche piasus	glpi					(3)	
Celestrina humulus	celu					(1) *	
Limited Habitats							
Ochlodes sylvanoides	ocsy				1	2	
Hesperia uncas	heun		11	2			
Epargyreus clarus	epcl				1	2	
Polygonia gracilis	pogr				1	1	
Euphilotes ancilla	euan	3				1	
Euchloe ausonides	euau					3	6
Phyciodes tharos	phth				2	3	
Poanes taxiles	pota				15	5	

Butterflies with their name in **Bold** require an abundance index
* observed off transect
(#) 2001 pilot season observation

Appendix H

Potential Habitat Indicator Butterflies

Habitat	Species	Host Plants
Foothills Riparian	*Glaucopsyche piasus*	*Lupinus spp., Astragalus spp.*
	Anthocharis julia	Cruciferae
	Euphyes vestris	*Carex spp.*
	Callophrys eryphon	*Pinus ponderosa*
	Papilio eurymedon	*Prunus spp., Malus spp., Crataegus spp., Ceanothus spp. and Rhamnus spp.*
	Limenitis weidemeyerii	*Salix spp., Populus spp., Prunus spp., Amelanchier spp., and Holodiscus spp.*
	Satyrium saepium	*Salix spp.*
	Celestrina humulus	*Humulus lupulus*
	Erynnis martialis	*Ceanothus fendleri*
Tallgrass	*Lycaena hyllus*	*Polygonum coccineum, Rumex spp.*
	Satyrium acadica	
Grassland	*Hesperia ottoe*	*Andropon gerardii., Bouteloua spp.*
	Hesperia uncas	*Andropon gerardii.*
	Hesperia leonardus pawnee	*Bouteloua spp., Andropogon gerardii., Stipa spp., Sporobous spp. and Poa spp.*
Foothills Grassland	*Papilio indra*	Umbelliferae: *Cymopterus spp. Aletes spp. Lomatium spp. and Harbouria spp.*
	Plebejus icarioides	*Lupinus spp.*
Riparian	*Limenitis archippus*	
	Poanes taxiles	
Montane	*Euchloe ausonides*	Cruciferae

Appendix I

Conservation Concern Butterflies For Abundance Index Monitoring

Species	Common Name	CNHP Rank	Federal Status
Celestrina humulus	Hops-feeding azure	G2S2	
Speyeria idalia	Regal fritillary	G3S1	C
Hesperia ottoe	Ottoe skipper	G3G4S2	
Atrytone arogos	Arogos skipper	G3G4S2	
Euphyes bimacula	Two-spotted skipper	G4S2	
Erynnis martialis	Mottled dusky wing	G4S2S3	
Stinga morrisoni	Morrison's skipper	G4S3S4	
Polites origenes	Crossline skipper	G5S3	
Callophrys mossii schryveri	Schryver's elfin	G4T3S2S3	
Paratrytone snowi	Snow's skipper	G4S3	
Polites rhesus	Rhesus skipper	G4S2S3	
Atrytonopsis hianna	Dusted skipper	G4G5	
Euphilotes rita coloradensis	Colorado blue	G4T2T3S2	
Amblyscirtes simius	Simius roadside skipper	G4S3	

Source: Colorado Natural Heritage Program (CNHP), 1998.

<u>CNHP Ranks</u>
G: Global **S:** State **T:** used for subspecies

Numbers represent rank on a five-point scale (1 = extremely rare/imperiled, 5 = abundant/secure)

When two ranking numbers exist (e.g.,S2S3), the rank of the butterfly falls between the two ranks

<u>Federal Status</u>
C: Candidate listing as endangered or threatened under Endangered Species Act

Appendix J

2002 Abundance Indices

Species	Habitat	Site	Date	Number	Abundance Index (I)
Hesperia ottoe	Grassland	Jewel	July	2	.1
Erynnis martialis	Foothills Riparian	Lower Skunk	May	1	.05

(calculated in 2002 using only a single transect survey)

I = [(100)(N)(A)] / L

I = index of abundance
N = number of butterflies observed standardized to 100 meters
A = area in hectares (.25 hectares or 2500 sq meters since each transect samples an equivalent standardized area)
L = length (all transects are an equal length of 500 meters)

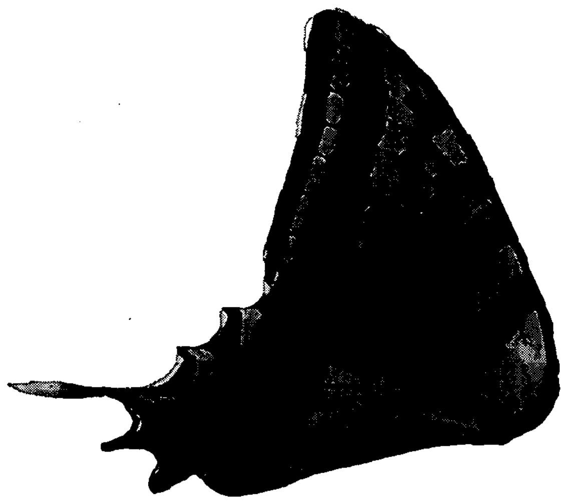
Alternatively:

I= [(100) (N) (.25)]/500

Appendix K

Protocol Manual

Open Space and Mountain Parks Butterfly Monitoring Program Protocols



January 16, 2004

Contents

Overview

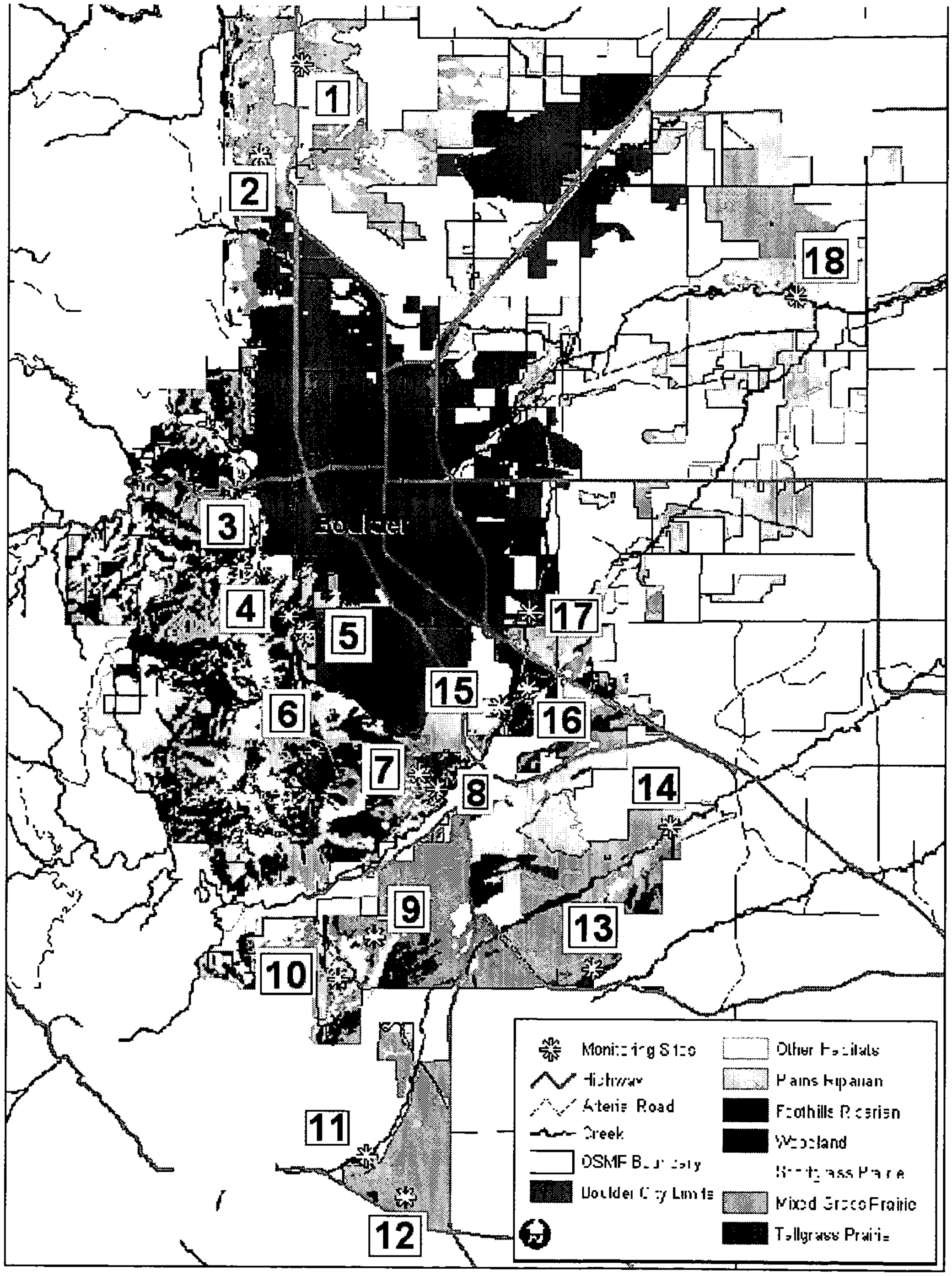
Land managers responsible for the conservation of natural areas require information about the animals that inhabit and more importantly are dependent upon the areas under their stewardship. Butterflies are excellent organisms to survey and include in monitoring programs. They are well studied, easily observed and recognized, and can be sensitive to changes in vegetation and management practices. Patterns in butterfly distribution and abundance respond in the short-term to variations in weather, while longer-term may they may respond to alterations and disturbances in habitat availability and quality. Consistent methods for surveying butterflies have been developed and applied in many settings and are often based on samples collected during standardized walking transects. The City of Boulder manages a large open space system with many different habitats including short grass and tallgrass prairies, foothills grasslands, woodlands, and stream riparian corridors. These mixes of habitats along with previous surveys of butterflies in the Boulder area suggest that there are many areas suitable on Open Space and Mountain Parks for diverse butterfly populations.

The Colorado Front Range is well-known and well-documented for its biological diversity of invertebrates, especially the butterflies. Approximately 176 resident or regular colonist butterflies have been documented in this region, representing one of the richest butterfly regions in the United States. The butterfly fauna of Boulder County is perhaps the best sampled part of the Front Range. Its butterfly fauna is a mix of northern artic, boreal, Rocky Mountain, southwestern desert, Great Plains, and eastern species, as well as regional endemics that reside or wander into the Boulder area. Some of the butterflies present on Open Space and Mountain Parks (OSMP) lands are rare and sensitive species, including several local endemics and species at the periphery of their range. It is possible that as many as 150 butterfly species may occur on OSMP lands. Butterflies of highest conservation interest occurring on OSMP include the hops blue (*Celestrina humulus)* family Lycaenidae, Ottoe skipper (*Hesperia ottoe)* and arogos skipper (*Atrytone arogos*) family Hesperiidae, and the regal fritillary (*Speyeria idalia*) family Nymphalidae. Any walk along hiking trails on a sunny spring or summer day will be filled with butterflies seeking nectar, perches, and mates and this incredible butterfly richness is important to document and understand.

Due to the variability of butterfly populations with their mobility and response to changing weather conditions, only long-term standardized monitoring can provide an accurate picture of the distribution and abundance of the butterflies dependent on the City of Boulder's Open Space and Mountain Parks natural areas. This long-term monitoring program provides the foundation for improved understanding of what butterflies occur on Open Space and Mountain Parks lands and provides relative butterfly density information that can assist managers understand how changes in the system either favorable or not might affect the quality of habitats for butterfly populations.

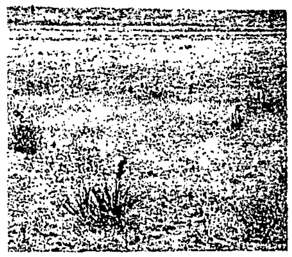
Transect Locations

		Habitat Type					
#	Site Name	Grassland	Foothills Grassland	Tallgrass	Montane Woodland	Plains Riparian	Foothills Riparian
1	East Beech	X					
2	North Foothills		X				
3	Gregory Canyon						X
4	Enchanted Mesa				X		
5	Lower Skunk						X
6	Shanahan				X		
7	Big Bluestem		X				
8	Big Bluestem Tallgrass			X			
9	Doudy Draw		X				
10	Lindsay				X		
11	Coal Creek Foothills						X
12	Jewel Mountain	X					
13	Superior	X					
14	Coal Creek Plains					X	
15	S. Boulder Creek Tallgrass			X			
16	Church			X			
17	S. Boulder Creek					X	
18	White Rocks					X	


1
2
18
3
4
5
17
15
16
6
7
8
14
9
13
10
11
12
Road

Transect Descriptions

East Beech



Site Access
Site is accessed by parking on highway 36 across from Beech Business Park and walking two track east to starting point. Small shrub on south side of two track marks the starting point.

Site Description
Transect runs parallel to highway 36 across field with a narrow gully cutting across the transect. Dominant plants include yucca, cheat grass, and western wheatgrass.

North Foothills

Site Access
Site is accessed by parking at North Foothills Trailhead off of highway 36. Walk Foothills Trail west to an old railroad grade and then follow railroad grade north to start point. Start point is on slope above railroad grade west of fence and northwest of very large rock.

Site Description
Transect runs at an angle down slope across east facing aspect of foothill hogback crossing over old railroad grade. Dominant plants consist of cheat grass, big bluestem, yucca, and needle and thread grass.

Gregory Canyon

Site Access
Site is accessed by parking at the Gregory Canyon Trailhead at the west end of Baseline Road. Hike Gregory Canyon Trail to the junction of Saddlerock Trail which is the start point.

Site Description
Transect runs up the Gregory Canyon Trail to a small trail that cuts down to the creek and continues west up the creek winding through the vegetation. Dominant plants include choke cherry, wild plum, cottonwood, poison ivy, horse mint, and willow.

Enchanted Mesa

Site Access
Site is accessed by parking at the Enchanted Mesa Trailhead out of Chautuaqua and hiking up Enchanted Mesa trail to the starting point. The starting point is on the west side of the trail by a large rock adjacent to the trail.

Site Description
Transect runs south through pine woodland crossing over Enchanted Mesa Trail as it curves west. Dominant plants include ponderosa pine, smooth brome, bluegrass, holly-grape and sun sedge.

Lower Skunk

Site Access
Site is accessed by parking at the junction of Deer Valley and Holly Berry drives and walking along the access road to the fenced pump station. On the west side of the fenced pump station is a utility clearing angling up slope. Start point is on the west side of clearing along the south side of thick shrub vegetation near cement man hole.

Site Description
Transect runs west up the south side of the stream crossing over to the north side along an old trail. Dominant plants include hawthorne, choke cherry, skunkbrush, cottonwood and boxelder.

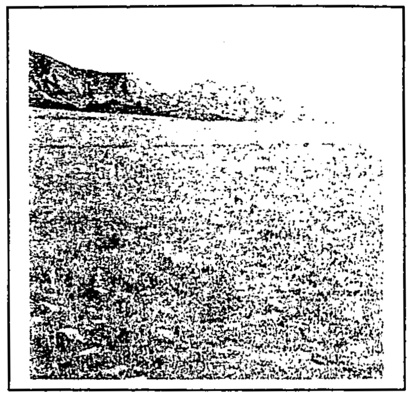
Shanahan

Site Access
Site is accessed by parking on Cragmore Drive and hiking trail to North Shannahan Trail going west to the junction of Mesa Trail. Follow Mesa Trail south to the start point on the east side of trail.

Site Description
Transect runs east down slope through the ponderosa woodland. Transect crosses through a small meadow over South Shannahan Trail. Dominant plants include ponderosa pine, smooth brome, orchard grass, holly grape, wild rose and blazing star.

Big Bluestem

Site Access
Site is accessed by parking in the South Boulder Creek trailhead on the west side of highway 93. Hike Big Bluestem Trail to corral area for cattle and follow fence line that runs south from the corral. Start point is at the next fence junction with a west oriented fence line.



Site Description
Transect runs west toward livestock water tank in the distance. Dominant plants include blue grama, bluegrass, blazing star, and June grass.

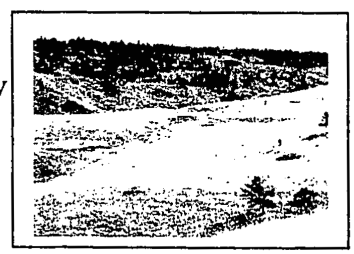
Big Bluestem Tallgrass

Site Access
Site is accessed by parking in the South Boulder Creek trailhead on the west side of highway 93. Hike South Boulder Creek trail through trailhead gate and a second gate. At the junction of a west fence with the fence line paralleling the trail, hike west along the west oriented fence to broken fence stay which is the start point.

Site Description
Transect runs southwest through tallgrass protection area.
Dominant plants include big bluestem, prairie chord grass, switchgrass, and plantain.

Doudy Draw

Site Access
Site is accessed by parking in the Doudy Draw trailhead on highway 170 west of highway 93. Hike Doudy Draw trail south up draw going to the north west corner of the private property with a house. Cross over fence to large spread out skunkbrush shrub that sits low to the ground. Start point is on the south side of bush.



Site Description
Transect runs south up ridge and through small drainage concluding at narrow foot trail. Dominant plants include cheat grass, smooth brome, skunk brush, blazing star, and prairie sage.

Lindsay

Site Access

Site is accessed by parking at the gate off of County Road 67 south of Highway 170. Hike the access roadway to a junction going south (left) along the ditch road. After road crosses over ditch on wooden bridge, follow two-track to the west (right) to start point.

Site Description

Transect runs west towards Mickey Mouse rock through woodland. Dominant plants include ponderosa pine, blue grass, blazing star, arnica, and sun sedge.

Coal Creek Foothills

Site Access

Site is accessed from Plainsview Road off of Highway 72. Park on the south side of the road Near the bridge over Coal Creek to access start point. Follow stream down to the fence line where it crosses over the stream. Start point is on the south side of the stream.

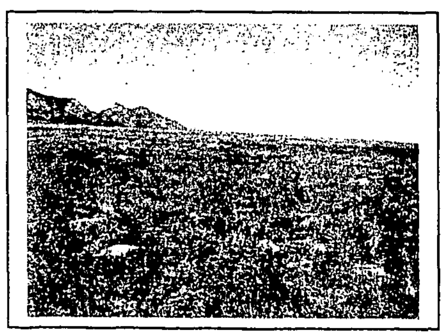
Site Description

Transect runs west up the stream crossing over the stream several times. Dominant plants include cottonwood, hawthorne, choke cherry, willow, skunkbrush, and smooth brome.

Jewel Mountain

Site Access

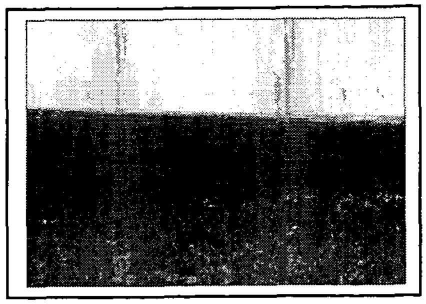
Site is accessed directly off of Highway 72 one half mile west of Highway 93. Hike north to start point which is at the base of the utility pole.



Site Description

Transect runs north toward the Third Flatiron ending on a faint two track. Dominant plants include blue grama, buffalo grass, little bluestem, sulfur flower and blazing star.

Superior



Site Access
Access site off of Highway 128 east of Highway 93. Park at the entry into Coalton Trail and hike northeast to start point at the edge of the mesa on the north side of large clump of yucca.

Site Description
Transect runs northeast down slope and ends near power poles and developing prairie dog colony. Dominant plants include yucca, blue gramma, cheat grass, blazing star, and wavy leaf thistle.

Coal Creek Plains

Site Access
Site is accessed by parking on Coalton Road where cemented irrigation ditch goes beneath the roadway. On the east side of the bridge, south side of the roadway is a gate and a two track. Proceed southeast through a prairie dog colony. Follow two-track to its end and hike to east fence line. Start point is where fence line crosses creek.

Site Description
Transect runs west upstream crossing over several times and ending at large bend near big willow tree. Dominant plants include willow, cottonwood, hawthorne, choke cherry, snowberry, and smooth brome

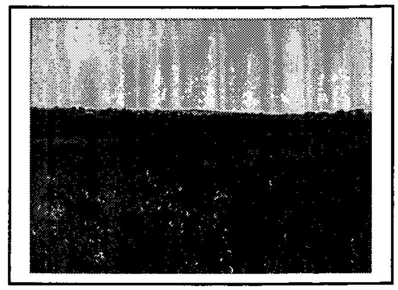
S. Boulder Creek Tallgrass

Site Access
Site is accessed by parking on Marshall Road at the West end of South Boulder Creek trail as it ends at Marshall Road. Hike east on South Boulder Creek trail to a long wooden boardwalk. The northwest corner of the boardwalk is the start point.

Site Description
Transect runs northeast toward very large cottonwood. Dominant plants include big bluestem, prairie cord grass, Canadian thistle, smooth brome and redtop.

Church

Site Access



Access site by parking on side of Cherryvale Road and hiking two track west over cement bridge crossing irrigation ditch to start point. Start point is the crooked fence post on fence south side of the two-track.

Site Description

Transect runs north toward large red barn in the distance. Dominant plants include big bluestem, smooth brome, wild licorice, thistle, and switchgrass.

S. Boulder Creek

Site Access

Access site by parking at the East Boulder Recreation center and hiking along South Boulder Creek Trail over bridge and follow south (right) to start point where irrigation culvert crosses over creek.

Site Description

Transect runs north along the east bank of the creek. Dominant plants include willow, cotton wood, smooth brome, bluegrass and

White Rocks

Site Access

Access site only with permission. Access is from Teller Farm North Trailhead and hiking the East Boulder Trail towards White Rocks. After crossing the bridge over Boulder Creek, start point can be found following north bank of river west.

Site Description

Transect runs west along north bank of creek ending shortly after stream turns north. Dominant plants include willow, cottonwood, smooth brome, thistle and milk weed.

Monitoring Protocols

Transect Run Criteria

Each transect should be surveyed once per month from May through August. Surveys should begin no earlier than 9:00 A.M. and end before 3:00 P.M. to insure butterfly observations occur during peak activity periods. The order for running the transects should be randomly determined.

Weather conditions and sun exposure are to be documented to detail weather-related effects which might alter butterfly activity. Weather characteristics including temperature, wind, cloud cover, and barometric pressure are recorded both at the beginning and at the end of transect surveys. Routes are only to be surveyed on days that meet the following weather requirements:

- Less than 30% cloud cover
- Less than 15 mph winds
- Temperatures above 75 degrees Fahrenheit (24° C), and below 100 degrees Fahrenheit (38° C)

If weather conditions changed while a survey is in progress and conditions no longer meet weather criteria, the transect is to be halted and run again in its entirety on the next available day.

Transect Run Procedures

Each transect should begin at the designate start point as determined by a silver survey cap placed in the ground located with the assistance of GPS coordinates and available maps and site descriptions. Transects are walked at a slow and steady pace by the observer who records all butterflies within a five meter space around the observer as they proceed along the transect. Only one observer should record butterfly observations, but other individuals can follow observer so long as they do not alert the observer to any missed butterflies. Any additional butterflies noted not by the observer, but someone assisting should be documented in the comments section for presence information, but not included as occurring on the transect survey. The observer can stop and look with binoculars, photograph, or net unknown butterflies that are in the transect sampling space to identify the butterfly. During the pauses incurred when attempting to identify a butterfly, all other butterflies observed can only be recorded as occurring off transect. Butterflies requiring chase and capture and requiring the observer to leave the transect area (more than 10 meters) should not be followed. After the capture, identification, and release of butterflies, the survey resumes with butterflies being recorded as occurring on transect. Observations of butterflies outside the five meter boundary are recorded as occurring off transect and need documented only if the species is not otherwise observed on the transect. Butterflies observed within the five meter sampling space are identified to species or the lowest taxonomic level possible. Some skippers are difficult to field identify to species and may be only classified to a genus complex.

Documentation Forms

Observation forms are available for documenting weather and sunlight conditions and field observations. The first side of the form is to document transect location, comments about blooming plants, conditions of the habitat (i.e.water in ditches, recent precipitation, cattle presence, site disturbances), and the start and end time weather conditions. The other side of the form is for recording butterfly observations. Each species observed is documented by its butterfly code, the number observed, the butterfly's behavior (nectaring, perching/basking, chasing, mating, flying), on/off transect, and any plants associated to the butterfly's activity.

side one

Transect Name ____________________ Number ______

Date ______________

Start	End
Temp ______________	Temp ______________
Wind ______________	Wind ______________
Sun ______________	Sun ______________
time ______________	time ______________
Pressure ______________	Pressure ______________

Comments ____ *side two*

Transect: **Date:** **Page ____of _____**

Species Code	Number Observed	**Behavior** *(nectaring, perch/basking, chasing, mating, flying)*	Off transect	Associated Plants

Butterfly List and Species Code

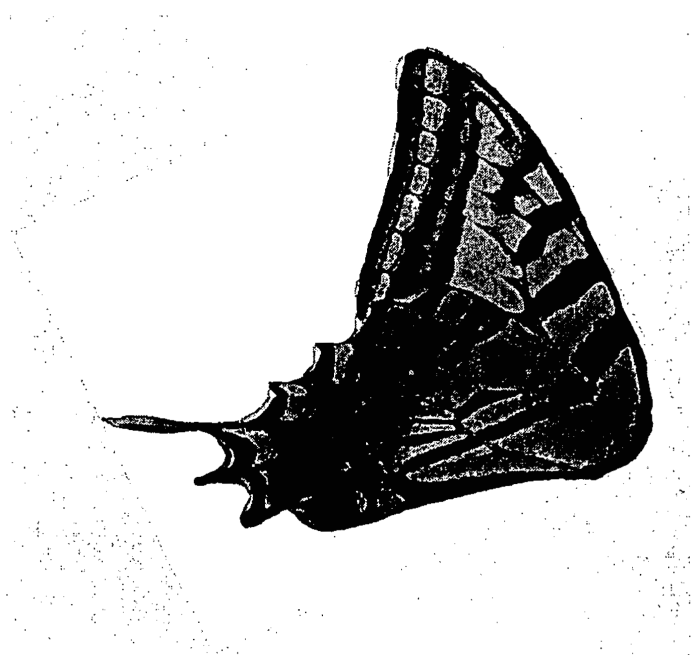
Common Name	Scientific Name	Species Code
Bronze Roadside Skipper	*Amblyscirtes aenus*	*amae*
Orange-headed Roadside Skipper	*Amblyscirtes phylace*	*amph*
Common Roadside Skipper	*Amblyscirtes vialis*	*amvi*
Rocky Mountain Orangetip	*Anthocharis julia*	*anju*
Hackberry Emperor	*Asterocampa celtis*	*asce*
Sachem	*atalopedes campestris*	*atca*
Arogos Skipper	*Atrytone arogos*	*atca*
Green Hairstreak	*Callophrys apama*	*caap*
Western Pine Elfin	*Callophrys eryphon*	*caer*
Hops Blue	*Celestrina humulus*	*cehu*
Spring Azure	*Celestrina ladon*	*cela*
Small Wood Nymph	*Cercyonis oetus*	*ceoe*
Wood Nymph	*Cercyonis pegala*	*cepe*
Gorgone Checkerspot	*Chlosyne gorgone*	*chgo*
Ringlet	*Coenonympha tulliea*	*cotu*
Orange Sulfur	*Colias eurytheme*	*coeu*
Common Sulfur	*Colias philodice*	*coph*
Monarch	*Danaus plexippus*	*dapl*
Silver-Spotted Skipper	*Epargyreus clarus*	*epcl*
Afranius Duskywing	*Erynnis afranius*	*eraf*
Sleepy Duskywing	*Erynnis brizo*	*erbr*
Funereal Duskywing	*Erynnis funeralis*	*erfu*
Mottled Duskywing	*Erynnis martialis*	*erma*
Pacuvius Duskywing	*Erynnis pacuvius*	*erpa*
Persius Duskywing	*Erynnis persius complex*	*erpe*
Large Marble	*Euchloe ausonides*	*euau*
Dotted Blue	*Euphilotes ancilla*	*euan*
Two-Spotted Skipper	*Euphyes bimacula*	*eubi*
Dun Skipper	*Euphyes vestris*	*euve*
Variegated Fritillary	*Euptoieta claudia*	*eucl*
Tailed Blue	*Everes comyntas*	*evco*
Silvery Blue	*Glaucopsyche lygdamus*	*glly*
Arrowhead Blue	*Glaucopsyche piasus*	*glpi*
Reakirt's Blue	*Hemiargus isola*	*heis*
Western Branded Skipper	*Hesperia Comma complex*	*heco*
Juba Skipper	*Hesperia juba*	*heju*
Blazing-Star Skipper	*Hesperia leonardus pawnee*	*hele*
Nevada Skipper	*Hesperia nevada*	*hene*
Ottoe Skipper	*Hesperia ottoe*	*heot*
Uncas Skipper	*Hesperia uncas*	*heun*
Green Skipper	*Hesperia viridis*	*hevi*
Buckeye	*Junonia coenia*	*juco*
Marine Blue	*Leptotes marina*	*leme*
Viceroy	*Limenitis archippus*	*liar*
Weidemeyer's Admiral	*Limenitis weidemeyerii*	*liwe*
Orange-Margined Blue	*Lycaeides melissa*	*lyme*

Blue Copper	*Lycaena heteronea*	*lyhe*
Bronze Copper	*Lycaena hyllus*	*lyhy*
Dainty Sulfur	*Nathalis iole*	*naio*
Mourning Cloak	*Nymphalis antiopa*	*nyan*
Western Skipperling	*Oarisma garita*	*oaga*
Woodland Skipper	*Ochlodes sylvanoides*	*ocsy*
Chryxus Arctic	*Oeneis chryxus*	*oech*
Pale Swallowtail	*Papilio eurymedon*	*paeu*
Indra Swallowtail	*Papilio indra*	*pain*
Two-Tailed Swallowtail	*Papilio multicaudatus*	*pamu*
Black Swallowtail	*Papilio polyxenes*	*papo*
Tiger Swallowtail	*Papilio rutulus*	*paru*
Anise Swallowtail	*Papilio zelicon*	*paze*
Snow's Skipper	*Paratrytone snowi*	*pasn*
Rocky Mountain Parnassian	*Parnassius smintheus*	*pasm*
Cabbage White	*Peries rapae*	*pera*
Common Sootywing	*Pholisora catullus*	*pcat*
Field Crescent	*Phyciodes campestris camilla*	*phca*
Nothern Crescent	*Phyciodes cocyta*	*phco*
Pearl Crescent	*Phyciodes tharos*	*phth*
Russet Skipperling	*Piruna pirus*	*pipi*
Silver-Studded Blue	*Plebejus acmon*	*plac*
Boisduval's Blue	*Plebejus icarioides*	*plic*
Lupine Blue	*Plebejus lupini*	*pllu*
Taxiles Skipper	*Poanes taxiles*	*pota*
Draco Skipper	*Polites draco*	*podr*
Long Dash	*Polites mystic dacotah*	*pomy*
Peck's Skipper	*Polites peckius*	*pope*
Rhesus Skipper	*Polites rhesus*	*porh*
Tawney Edged Skipper	*Polites thermistocles*	*poth*
Hoary Comma	*Polygonia gracilis*	*pogr*
Western White	*Pontia occidentalis*	*pooc*
Checkered White	*Pontia protodice*	*popr*
Spring White	*Pontia sisymbrii*	*posi*
Checkered Skipper	*Pyrgus communis*	*pyco*
Two-banded Checkered Skipper	*Pyrgus ruralis*	*pyru*
Acadian Hairstreak	*Satyrium acadica*	*saac*
Hedgerow Hairstreak	*Satyrium saepium*	*sasa*
Aphrodite Fritillary	*Speyeria aphrodite ethne*	*spap*
Atlantis Fritillary	*Speyeria atlanta*	*spat*
Callippe Fritillary	*Speyeria callippe*	*spca*
Edward's Fritillary	*Speyeria edwardsii*	*sped*
Gray Hairstreak	*Strymon melinus*	*stme*
Mexican Cloudywing	*Thorybes mexicana*	*thme*
Northern Cloudywing	*Thorybes pylades*	*thpy*
Red Admiral	*Vanessa atalanta*	*vaat*
Painted Lady	*Vanessa cardui*	*vaca*

Appendix L

Example Field Identification Guide

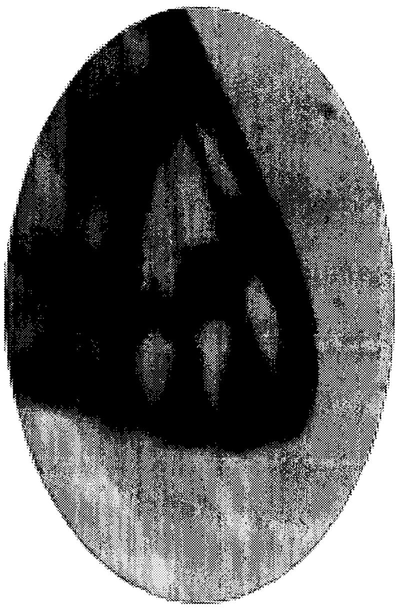
Open Space and Mountain Parks Butterfly Monitoring Field Identification Guide



Pierids

Western white
(*Pontia occidentalis*)

- Above marginal spots tend to be gray with black submarginal band
- Males have 5-6 marginal spots
- Hindwing below strong gray-green veining

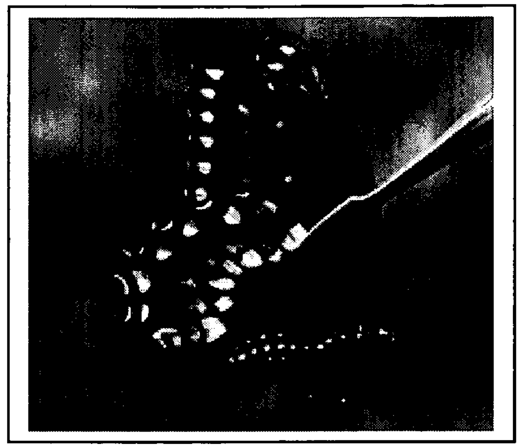


Flight Period
February to November, three possible generations.

Papilios

Black Swallowtail
(Papilio polyxenes)

- abdomen with rows of yellow spots
- long tails on hind wing



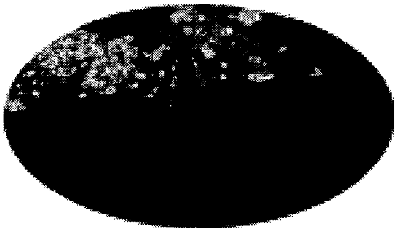
Flight Period

February to November, two possible generations

Papilios

Indra Swallowtail
(Papilio indra)

- thorax near head with yellow line of spots
- tails on hind wing are short



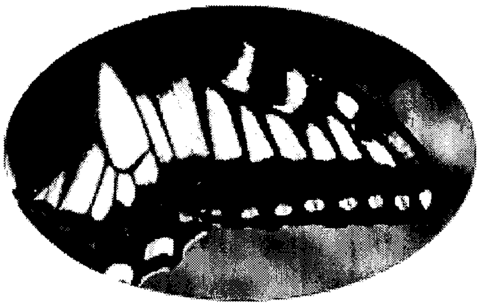
Flight Period

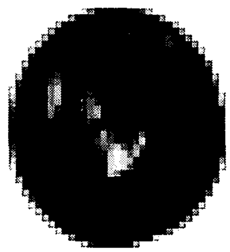
May to early July, usually on one generation

Papilios

Anise Swallowtail
(Papilio zelicaon)

- broad yellow submarginal band
- eyespot on hindwing has centered black spot
- yellow marginal spots flatten towards wing tip





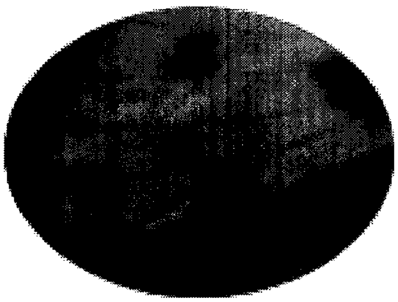
Flight Period

April to early August, usually only one generation.

Pierids

Checkered white
(*Pontia protodice*)

- Above marginal spots tend to be similar color
- Males have 2-3 marginal spots
- Females have a break in the submarginal spot
- Hindwing below with yellow-brown veining



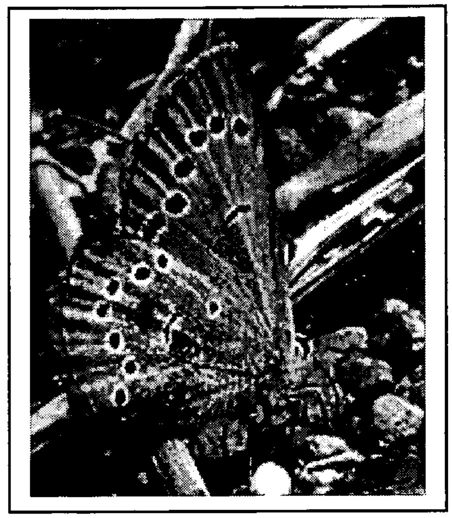
Flight Period

February to November, two generations normally

Lycaenids

Silvery Blue
(Glaucopsyche lygdamus)

- Postmedian line of black spots
- No marginal spots
- Male above bright blue



Flight Period

April to June, one generation.

Lycaenids

Rocky Mountain Dotted-Blue
(*Euphilotes ancilla*)

•

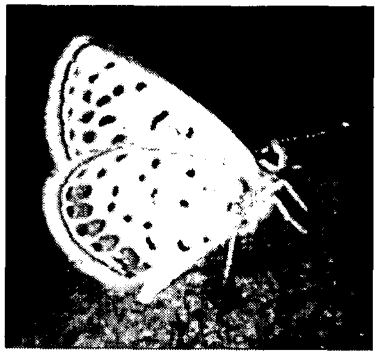
Flight Period

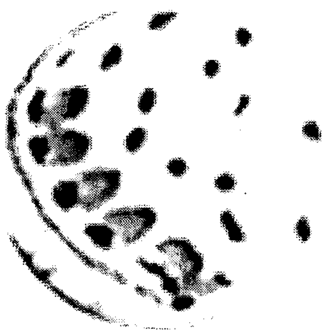
Late April to early August, one generation.

Lycaenids

Acmon Blue
(*Plebejus acmon*)

- orange hindwing band capped with metallic blue spots
- orange band on dorsal view as well
- fringes uncheckered
- veins

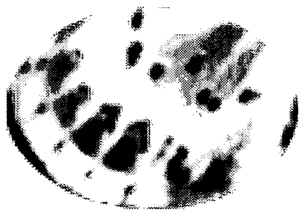




Lycaenids

Arrowhead Blue
(*Glaucopsyche piasus*)

- postmedian band on hindwing of arrowheads pointed inward
- fringe checkered



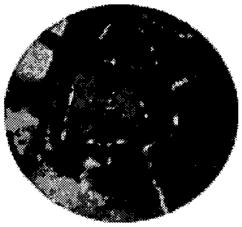
Flight Period

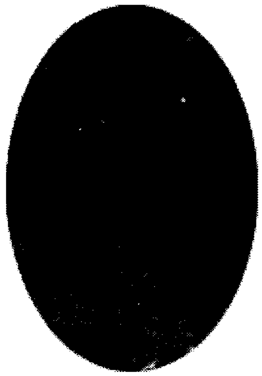
March to early July, normally one generation.

Lycaenids

Hedgerow Hairstreak
(Satyrium saepium)

- underside without orange spots
- strong postmedian line
- pale cell-end bars





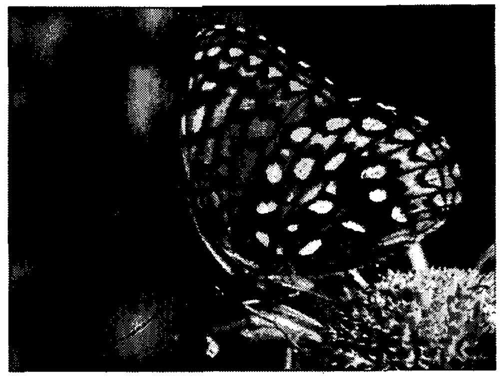
Flight Period

July to August with one generation.

Nymphalids

Atlantis Fritillary
(Speyeria atlantis)

- disc brown to reddish brown
- eyes blue-gray
- narrow pale submarginal band



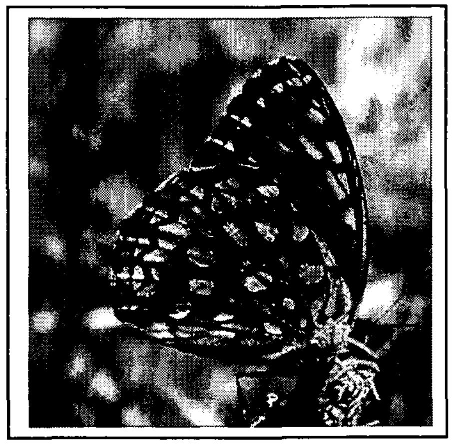
Flight Period

June to early September, normally one generation.

Nymphalids

Aphrodite Fritillary
(Speyeria aphrodite)

- yellow-green eyes
- brown to reddish-brown extending beyond the postmedian silver spots
- dorsal view on males do not have swollen black on forewing veins
- dorsal view, black spot in forewing cell



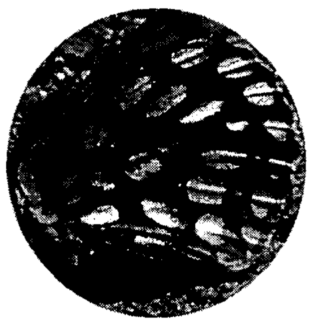
Flight Period

June to October, normally one generation.

Nymphalids

Edwards's Fritillary
(Speyeria edwardsi)

- forewing pointed and indented below tip
- pronounced silvering of discs
- olive-green underside
- large marginal silver spots, rounded inward
- dorsal view, third black bar away from head does not touch second black bar
- bold black border on dorsal view



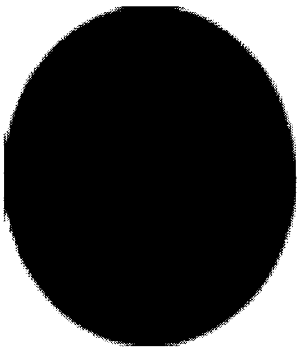
Flight Period

May to early September, normally one generation.

Hesperia

Woodland Skipper
(Ochlodes sylvanoides)

- spotband of yellow or cream squarish spots.
- Spotband straight with top spot inset
- Male has prominent black stigma
- Dorsal wing with jagged dark borders



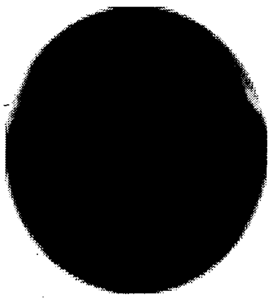
Flight Period

July to October, normally one generation.

Hesperia

Common Branded Skipper
(Hesperia comma)

- Basal spots often form the shape of a "C"
- Outer spot band also curved enclosing basal spot
- Variable



Flight Period

Early June to mid September, one generation.

Hesperia

Long Dash
(Polites mystic)

- Hindwing orange/brown with broad yellow spotband
- Short basal spot

Flight Period

Late May to early August, one generation.

Hesperia

Peck's Skipper
(*Polites peckius)*

- Hindwing brown and tan
- Postmedian band has center spot jutting outward
- Two bands, may be connected
- Broad bands

Flight Period

May to September, may have two generations.

Appendix M

Example Database Forms and Fields

Record #	1
Butterfly Code	PYCO
Family	Hesperiidae
Sub Family	Pyrginae
Genus	Pyrgrus
Species	communis
Sub Species	
Common Name	Common Checkered Skipper
Conservation Status	None
Habitat Association	Generalist
Flight Period	
Elevation Limits	
Dorsal Key Id Feature	
Ventral Key Id Feature	
Known Locals	Many
Host Plants	
Nectar Plants	
Collected	☑
Collected ID	
Photo Take	☑
Photographs	

ID	3
Date	
Start Temp	0
End Temp	0
Start Percent Clouds	0
End Percent Clouds	0
Start Wind Code	0
End Wind Code	0
Start Time	
End Time	
Run #	1
Comments	
Observer	

Appendix N

Example Data Management Spreadsheets

Transect Run Data

Scientific Name	Species Code	North Foothills				Doudy Draw			
		1	2	3	4	1	2	3	4
Papilio eurymedon	*paeu*	0	0	0	0	0	0	0	0
Papilio indra	*pain*	0	0	0	0	0	0	0	0
Papilio multicaudatus	*pamu*	0	0	0	0	0	1	0	0
Papilio polyxenes	*papo*	0	1	0	0	0	0	0	0
Papilio rutulus	*paru*	0	0	0	0	0	0	0	0
Papilio zelicon	*paze*	0	0	0	0	0	0	0	0
Parnassius smintheus	*pasm*	0	0	0	0	0	0	0	0
Asterocampa celtis	*asce*	0	0	0	0	0	0	0	0
Danaus plexippus	*dapl*	0	0	0	0	0	0	0	0
Euptoieta claudia	*eucl*	1	0	1	0	0	4	1	0
Chlosyne gorgone	*chgo*	0	0	0	0	0	0	0	0
Junonia coenia	*juco*	0	0	0	0	0	0	0	0
Limenitis archippus	*liar*	0	0	0	0	0	0	0	0
Limenitis weidemeyerii	*liwe*	0	0	0	0	0	0	0	0
Nymphalis antiopa	*nyan*	0	0	0	0	0	0	0	0
Phyciodes campestris camilla	*phca*	16	17	0	0	8	1	0	0
Phyciodes cocyta	*phco*	0	0	0	0	0	0	0	0
Phyciodes tharos	*phth*	0	0	0	0	0	0	0	0
Speyeria aphrodite ethne	*spap*	0	1	0	0	0	4	0	0
Speyeria atlanta	*spat*	0	0	0	0	0	0	0	0
Speyeria callippe	*spca*	0	0	0	0	0	0	0	0
Speyeria edwardsii	*sped*	0	1	0	0	0	0	3	0
Vanessa atalanta	*vaat*	0	0	0	0	0	0	0	0
Vanessa cardui	*vaca*	0	0	0	0	0	0	0	0
Anthocharis julia	*anju*	0	0	0	0	0	0	0	0
Colias eurytheme	*coeu*	0	0	0	0	0	0	0	0
Colias philodice	*coph*	0	0	0	0	0	0	0	0
Euchloe ausonides	*euau*	0	0	0	0	0	0	0	0
Nathalis iole	*naio*	0	0	0	0	0	0	0	0
Peries rapae	*pera*	0	0	0	0	0	2	0	0
Pontia occidentalis	*pooc*	0	0	0	0	1	0	0	0
Pontia protodice	*popr*	9	10	0	0	6	8	2	0
Pontia sisymbrii	*posi*	0	0	0	0	0	0	0	0
Celestrina humulus	*cehu*	0	0	0	0	0	0	0	0
Celestrina ladon	*cela*	0	0	0	0	0	0	0	0
Everes comyntas	*evco*	0	0	0	0	4	1	0	0
Euphilotes ancilla	*euan*	0	0	0	0	0	0	0	0
Glaucopsyche lygdamus	*glly*	0	0	0	0	1	0	0	0
Glaucopsyche piasus	*glpi*	0	0	0	0	0	0	0	0
Totals		*27*	*31*	*2*	*0*	*43*	*25*	*8*	*0*

Appendix N

Example Spreadsheets for Data Management

Butterfly Behavior Data Spreadsheet

Scientific Name	Code	North Foothills								
		N	P	B	C	M	F	O	T	O
Papilio eurymedon	paeu								0	
Papilio indra	pain								0	
Papilio multicaudatus	pamu								0	
Papilio polyxenes	papo								0	
Papilio rutulus	paru								0	
Papilio zelicon	paze								0	
Parnassius smintheus	pasm								0	
Asterocampa celtis	asce								0	
Danaus plexippus	dapl								0	
Euptoieta claudia	eucl						1		1	
Chlosyne gorgone	chgo								0	
Junonia coenia	juco								0	
Limenitis archippus	liar								0	
Limenitis weidemeyerii	liwe								0	
Nymphalis antiopa	nyan								0	
Phyciodes campestris camilla	phca						16		16	
Phyciodes cocyta	phco								0	
Phyciodes tharos	phth								0	
Speyeria aphrodite ethne	spap								0	
Speyeria atlanta	spat								0	
Speyeria callippe	spca								0	
Speyeria edwardsii	sped								0	
Vanessa atalanta	vaat								0	
Vanessa cardui	vaca								0	
Anthocharis julia	anju								0	
Colias eurytheme	coeu								0	
Colias philodice	coph								0	
Euchloe ausonides	euau								0	
Nathalis iole	naio								0	
Peries rapae	pera								0	
Pontia occidentalis	pooc								0	
Pontia protodice	popr						9		9	

N: nectaring	M: mating	T: total number
P: perching	F: flying	O: off Transect
B: basking	O: other	
C: chasing		