MONTANE MEADOW BUTTERFLY SPECIES DISTRIBUTIONS IN THE GREATER YELLOWSTONE ECOSYSTEM

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✦ ABSTRACT

The composition of butterfly communities is a good indicator of changing environmental conditions. Butterflies have tight associations with the plant community due to their dependence on plants throughout their life history. These associations make butterfly distributions predictable based on the plant communities. Butterfly abundance data have been collected annually since 1997 within montane meadow sites characterized along a hydrologic gradient within the Greater Yellowstone Ecosystem. From this research, community composition may be predictable relative to future climatic changes and key habitat constraints. Identifying such variables is important for butterfly conservation.

✦ INTRODUCTION AND OBJECTIVES

Butterfly communities have been established in the literature as well known indicators for environmental changes (Debinski and Brussard, 1994; Gutierrez and Menendez, 1998; Simonson et al., 2001; Dennis et al., 2006; Scalercio et al., 2006). Butterfly species richness can be predicted from models using landscape variables such as elevation and topographic heterogeneity (Nally et al., 2003) and plant richness (Field et al., 2006). Butterflies have been used to predict areas that represent hotspots of biological diversity (Simonson et al., 2001) and they may serve as good indicators of climate change (Debinski et al., 2000; Debinski et al., 2006; Parmesan, 2006). They are thought to be good indicators because they play important roles within different functional groups, including herbivores, pollinators, and prey and their distribution patterns are correlated with habitat diversity (Scalercio et al., 2006). Conservation concerns have been heightened by long-term studies in Europe that have shown butterfly communities to be declining (Thomas and Albery, 1995; Grill and Cleary, 2003; and Binzenhofer et al., 2005). Understanding what is causing this decline could lead the way to uncoupling the loss of species diversity and protecting the diversity of other taxa that share the butterfly habitat.

There are many factors that have been identified to have a negative effect on butterfly communities. Loss of suitable habitat is one of the most threatening factors for butterfly species persistence (Grill and Cleary, 2003). Changes in habitat suitability due to climatic variations can also affect butterfly abundance (Ockinger et al., 2006). The pristine nature and minimal human impacts in the Greater Yellowstone Ecosystem make it an ideal location for studying the effects of climate driven variation on butterfly communities.

In this study we hope to determine whether the butterfly communities in the Greater Yellowstone Ecosystem fluctuate predictably relative to alterations of climate driven changes along a hydrologic gradient in the landscape. Climate driven variables include temperature and precipitation fluctuations, and the effects of such changes on species of forbs that serve as host plants and nectar resources for butterflies in this ecosystem. Shallow-rooted forbs are expected to be especially affected by an increase in temperature (Devalpine and Harte, 2001; and Saavedra et al., 2003; Cross and Harte, 2007) and a decrease in precipitation (Weaver, 1958) and we hypothesize that these changes will be reflected in butterfly abundance of the species that use these forbs for host plants or nectar. Stability in the butterfly community will be examined at different levels from a hierarchical perspective, including species presence and absences, abundance ranking, and absolute abundance (Pimm, 1984; Lawton and Gaston, 1989; Rahel, 1990). Groups of butterfly species using similar functional guilds of plants will be examined for correlated changes. Changes in floral resource cover and host plant percent cover will also be monitored to relate to changes in butterfly species abundance.

✦ METHODS

Study Area

The Greater Yellowstone Ecosystem was divided into two study regions for our project, which will be referred to as the Gallatin and the Teton regions. The Gallatin region includes 30 sites within the Gallatin National Forest and the northwestern portion of Yellowstone National Park in Montana. The Teton region has 25 sites within the Grand Teton National Park and Bridger Teton National Forest in Wyoming. The Gallatin and Teton regions are separated by 192 km, yet both have similar plant and butterfly communities (Su et al. 2004). The meadows selected for the surveys in both regions are approximately at the same elevation with homogenous topographic features. The average elevation for sites within the Gallatin region is 2098 m, and 2120 m in the Teton region. The meadows range from 1 – 7861 ha, with an average meadow patch of 500 ha. Six meadow types with distinct plant species were characterized, M1-M6, along a hydrologic gradient (hydric to xeric respectively) using satellite imagery (Jakubauskas et al., 1996). The Gallatin region has five replicates of each meadow type from M1-M6, and the Teton region has five replicates of each meadow type except meadows characterized as M4, which are not represented in the Teton region. The meadows were characterized as suitable for survey sites if they were within 8 km from a road or trail, a minimum of 100 m by 100 m and no more than 2 km on a side, as well as at least 500 m from another meadow site (Debinski et al., 2001).

Field Surveys

Field surveys were conducted during June through August for two week periods at each region, alternating between the two regions. Two surveys for each region were completed annually by early August. These surveys are part of a long-term study that was initiated in 1997 and continued through 2007. Sites were located in the field using written directions, topographic maps, and GPS coordinates to find the site marker stake within the meadow. In 1997, two randomly selected cardinal directions (NW, NE, etc.) were used for the placement of a 50 m x 50 m plot. This plot was annually measured and flagged so that every year the same area was sampled. Surveys were conducted on sunny days when the temperature is above 70° F with low to moderate wind. The survey lasted for twenty minutes with two people surveying butterflies within the plot. Abundance data were collected by netting butterflies, collecting them in glassine envelopes, and finally releasing them at the end of the survey after individual butterflies were identified to the species level.

At each of the 55 study sites, vegetation was surveyed once per season in the middle of the growing season (July) in 20m x 20m plots which also had one corner of two cardinal directions located at the site marker stake. Cover estimates to 1% resolution were made for ten most dominant forb species in each plot. Nectar resources were quantified by counting the number of racemes for all flowering plant species along a 1 m wide transect positioned diagonally across the 50m x 50m butterfly survey plot and they were conducted on the same days as the butterfly surveys. To obtain climatic information we used two National Climate Weather Stations (240775: BigSky, and 486440: Moran 5WNW) to represent the GYE study regions. Daily precipitation and temperature data were obtained from these locations and summarized at an annual level. To detect trends in individual species over time, we will analyze the butterfly species for responses in both abundance and distribution across the hydrological gradient. Species with adequate sample sizes will be analyzed individually by meadow type using regressions to test for temporal trends and relationships with annual climatic variables (e.g., average daily temperature, and precipitation) as well as host plant cover, and nectar resources.

✦ RESULTS

Here we provide an archive of some of these long-term data, including maps of the study sites (Figs. 1-2) with UTM locations, area, and elevation values for each site (Tables 1-2). We also include a report summarizing the overall abundance by species within each of the two study regions based upon data standardized to two surveys at each site per year across 5 years between 1997-2007 (Tables 3-4). Future reports will summarize the butterfly community trends relative to host plant, nectar, and environmental variables (temperature and precipitation).

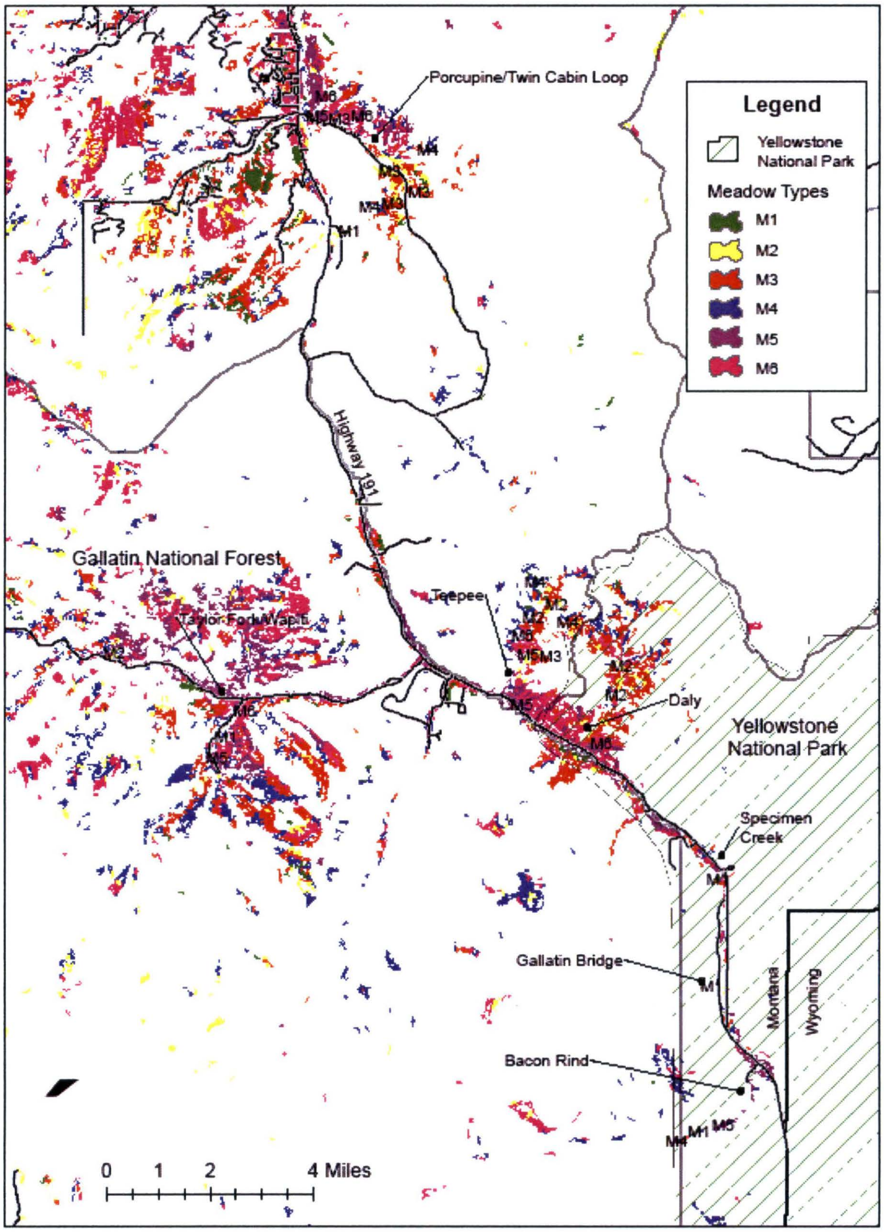

Figure 1. Gallatin Study Region including 30 long-term montane meadow survey sites. M1 meadows are hydric, M3 mesic and M6 meadows are xeric.

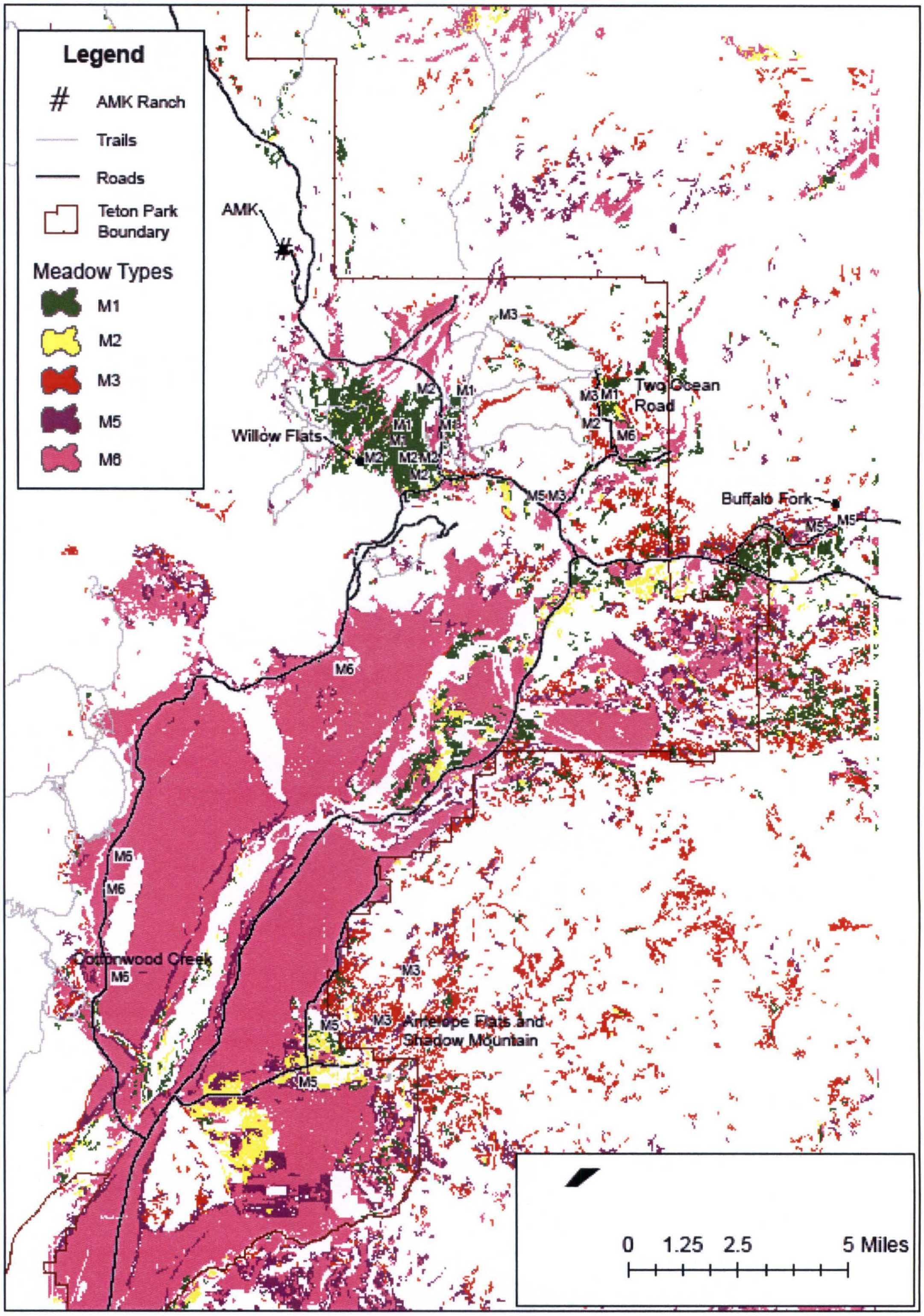

Figure 2. Teton Study Region including 25 long-term montane meadow survey sites. M1 meadows are hydric, M3 mesic and M6 meadows are xeric. M4 meadows are not present in the Teton region.

Region	Site #	Site Name	UTM Northing	UTM Easting	Elevation (ft)	Area (ha)
Gallatins	GM1A	Twin Cabin Willows	5004420	482077	6424	1.63
	GM1B	Bacon Rind	4975875	492784	7313	1.39
	GM1C	Specimen Creek	4983802	493514	6935	1.72
	GM1D	Wapiti (Taylor Fork)	4988439	478165	7050	1.05
	GM1E	Gallatin Bridge	4979476	493792	7060	~1.00**
	GM2A	Taylor Fork	4991010	474842	7080	4.00
	GM2B	Teepee Wet	4992350	488203	7152	3.97
	GM2C	Daly South	4990032	490471	7047	5.73
	GM2D	Figure 8	4992079	487750	7024	1.17
	GM2E	Daly North	4990504	490527	7109	3.02
	GM3A	Porcupine Exclosure	5007924	481627	6322	2.97
	GM3B	Black Bear Meadow	5004666	483472	7001	31.88
	GM3C	Porcupine/Twin Meadow	5005633	483988	6611	19.10
	GM3D	Porcupine Fork	5006304	483518	6400*	10.00
	GM3E	V Meadow Teepee Creek	4990795	488003	6998	15.10
	GM4A	Twin Cabin Pass	5004902	483106	6909	5.77
	GM4B	Porcupine 1.5 Creek	5006757	484573	6680	11.60
	GM4C	Teepee	4992771	487906	7237	11.65
	GM4D	Teepee East Feeder Stream	4991767	488234	7231	5.54
	GM4E	Bacon Rind	4975686	492264	7342	2.53
	GM5A	Bacon Rind M5	4976074	493441	7290	10.15
	GM5B	Porcupine M5	5007844	481033	6224	10.25
	GM5C	Wapiti Cabin	4987714	477806	7175	10.19
	GM5D	Teepee 191	4989358	487389	6722	19.11
	GM5E	Teepee Sage	4990752	487377	6883	2.48
	GM6A	Porcupine 3rd Creek	5007623	482059	6375	25.44
	GM6B	Wapiti Pond	4989242	478620	6942	55.87
	GM6C	Daly	4988125	489568	6800*	20.54
	GM6D	Teepee Burn	4991416	487553	7047	21.09
	GM6E	Gallatin Cabin	5008449	481177	6184	5.62

* Elevation taken from 7.5 min USGS map

** Estimated area value

Table 1. Study site locations and descriptions for the Gallatin region. UTM (Universal Transverse Mercator) coordinates as well as elevation and area of the meadow each site are listed for each site. Elevation and UTM data are based on readings from GPS (Magellan) during 2006 with accuracy within 20 meters.

Region	Site #	Site Name	UTM Northing	UTM Easting	Elevation (ft)	Area (ha)
Tetons	TM1A	Jackson Lodge Willow North	4859445	533499	6863	548.08*
	TM1B	Jackson Lodge Willow South	4858850	533656	6830	548.08*
	TM1C	Grand View	4859989	534803	6883	53.65
	TM1D	Two Ocean Road	4859500	540316	6909	77.85
	TM1E	Jackson Dam	4857743	532539	6811	548.08*
	TM2A	Willow Flats North	4857576	533684	6801	1.75
	TM2B	Willow Flats South	4857071	533741	6784	2.06
	TM2C	Two Ocean Road	4859177	539992	6988	5.82
	TM2D	Christian Pond	4858777	534780	6853	1.64
	TM2E	Cygnet Pond	4860372	530345	6880	1.08
	TM3A	Two Ocean Lake	4862882	536736	6958	7.74
	TM3B	Two Ocean Road	4859928	540060	6991	35.54
	TM3C	Lozier Hill	4856601	538763	6837	12.45
	TM3D	Shadow Mountain Hairpin	4838220	532801	7851	119.62
	TM3E	Sound Of Music	4839404	533446	8175	3.32
	TM5A	Lozier Hill	4856428	537905	6853	13.38
	TM5B	Buffalo Fork West	4855233	548289	7048	54.47
	TM5C	Buffalo Fork East	4855564	549366	6952	6.91
	TM5D	Antelope Flats	4835685	528705	6745	76.03
	TM5E	Shadow Mountain Base	4837479	530133	6801	23.71
	TM6A	Two Ocean Road	4858336	540888	6886	65.78
	TM6B	Cow Lake	4851603	532596	6926	2805.39
	TM6C	Timbered Island Northwest	4838381	522773	6801	4801.85**
	TM6D	Timbered Island Southwest	4841752	522279	6801	4801.85**
	TM6E	Cottonwood Creek	4838382	522770	6673	4801.85**

* One M1 meadow
** One M6 meadow

Table 2. Study site locations and descriptions for the Teton Region. UTM (Universal Transverse Mercator) coordinates as well as elevation and area of the meadow each site are listed for each site. Elevation and UTM data are based on readings from GPS (Magellan) during 2006 with accuracy within 20 meters.

Table 3. Abundance for each butterfly species observed in the Gallatin Region for the years: 1997, 1998, 2000, 2001, 2006, and 2007 totaled over all years, sites and replicates.

Species Latin Names	Species Common Names	Total Abundance
Agriades glandon	Arctic Blue	39
Anthocharis sara stella	Stella Sara Orangetip	18
*Boloria freija**	Freija Fritillary	2
Boloria frigga	Frigga Fritillary	4
Boloria kriemhild	Relict Fritillary	97
*Boloria montinus**	Purplish Fritillary	1
Boloria selene	Silver-bordered Fritillary	39
Callophrys sheridanii	Sheridan's Hairstreak	2
Cercyonis oetus	Small Wood-Nymph	592
Cercyonis sthenele	Great Basin Wood-Nymph	1
Chlosyne palla	Northern Checkerspot	36
Coenonympha haydenii	Hayden's Ringlet	1579
Coenonympha tullia inornata	Inornate Common Ringlet	93
Colias alexandra	Queen Alexandra's Sulphur	2
Colias christina	Christina's Sulphur	11
Colias eurytheme	Orange Sulphur	1
Colias gigantea	Giant Sulphur	17
Colias pelidne	Pelidne Sulphur	22
Colias philodice	Clouded Sulphur	61
Danaus plexippus	Monarch	2
Erebia epipsodea	Common Alpine	659
Euchloe ausonides	Large Marble	126
Euphilotes enoptes ancilla	Dotted Blue	27
Euphydryas chalcedona	Variable Checkerspot	20
Euphydryas editha	Edith's Checkerspot	17
Euphydryas gillettii	Gillett's Checkerspot	18
Glaucopsyche lygdamus	Silvery Blue	216
Glaucopsyche piasus	Arrowhead Blue	3
Limenitis weidemeyerii	Weidemeyer's Admiral	2
Lycaeides idas	Northern Blue	18
Lycaeides melissa	Melissa Blue	92
Lycaena cupreus	Lustrous Copper	1
*Lycaena dione**	Gray Copper	1
Lycaena editha	Edith's Copper	105
Lycaena helloides	Purplish Copper	488
Lycaena heteronea	Blue Copper	160
Lycaena hyllus	Bronze Copper	2
Lycaena mariposa	Mariposa Copper	9
Lycaena nivalis	Lilac-bordered Copper	7
Nymphalis antiopa	Mourning Cloak	4
Nymphalis californica	California Tortoiseshell	2
Nymphalis milberti	Milbert's Tortoiseshell	3
Oeneis chryxus chryxus	Brown Chryxus Arctic	29
Oeneis uhleri	Uhler's Arctic	1

Table 3. (continued)

Species Latin Names	Species Common Names	Total Abundance
Papilio eurymedon	Pale Swallowtail	1
*Papilio machaon**	Old World Swallowtail	5
Papilio rutulus	Western Tiger Swallowtail	2
Papilio zelicaon	Anise Swallowtail	21
Parnassius clodius	Clodius Parnassian	53
Parnassius phoebus smintheus	Rocky Mountan Phoebus Parnassian	121
Phyciodes campestris	Field Crescent	504
*Phyciodes mylitta**	Mylitta Crescent	107
Phyciodes selenis	Northern Crescent	27
Phyciodes tharos	Pearl Crescent	13
Pieris napi marginalis	Margined Mustard White	83
Pieris napi oleracea	Mustard White	27
Pieris rapae	Cabbage White	3
Plebejus icarioides	Boisduval's Blue	726
Plebejus lupini	Lupine Blue	40
Plebejus saepiolus	Greenish Blue	366
Plebejus shasta	Shasta Blue	13
*Polygonia faunus**	Green Comma	4
*Polygonia gracilis**	Hoary Comma	2
*Polygonia satyrus**	Satyr Comma	1
Pontia beckerii	Becker's White	9
Pontia occidentalis	Western White	7
Pontia protodice	Checkered White	19
*Satyrium titus**	Coral Hairstreak	1
Speyeria atlantis hesperis	Hesperis Atlantis Fritillary	95
Speyeria callippe	Callippe Fritillary	37
Speyeria cybele	Great Spangled Fritillary	1
Speyeria egleis	Great Basin Fritillary	15
Speyeria hydaspe	Hydaspe Fritillary	8
Speyeria mormonia	Mormon Fritillary	879
Speyeria zerene	Zerene Fritillary	21
Vanessa cardui	Painted Lady	98

* Butterfly Species only found only in Gallatin Region butterfly surveys.

Table 4. Abundance for each butterfly species observed in the Teton Region for the years: 1997, 1998, 2000, 2001, 2003-2007 totaled over all years, sites and two replicates.

Species Latin Names	Species Common Names	Total Abundance
Agriades glandon	Arctic Blue	45
Anthocharis sara stella	Stella Sara Orangetip	10
Boloria frigga	Frigga Fritillary	67
Boloria kriemhild	Relict Fritillary	74
Boloria selene	Silver-bordered Fritillary	167
*Callophrys dumetorum***	Bramble Hairstreak	18
Callophrys sheridanii	Sheridan's Hairstreak	13
Cercyonis oetus	Small Wood-Nymph	492
*Cercyonis pegala***	Common Wood-Nymph	2
Chlosyne palla	Northern Checkerspot	55
Coenonympha haydenii	Hayden's Ringlet	692
Coenonympha tullia inornata	Inornate Common Ringlet	593
Colias alexandra	Queen Alexandra's Sulphur	6
Colias christina	Christina's Sulphur	4
Colias eurytheme	Orange Sulphur	2
Colias gigantea	Giant Sulphur	69
*Colias interior***	Pink-Edged Sulphur	17
Colias pelidne	Pelidne Sulphur	26
Colias philodice	Clouded Sulphur	42
Erebia epipsodea	Common Alpine	605
Euchloe ausonides	Large Marble	80
Euphilotes enoptes ancilla	Dotted Blue	73
Euphydryas chalcedona	Variable Checkerspot	45
Euphydryas editha	Edith's Checkerspot	24
Euphydryas gillettii	Gillett's Checkerspot	6
*Euptoieta claudia**	Variegated Fritillary	1
Glaucopsyche lygdamus	Silvery Blue	101
Glaucopsyche piasus	Arrowhead Blue	29
Limenitis weidemeyerii	Weidemeyer's Admiral	12
Lycaeides idas	Northern Blue	56
Lycaeides melissa	Melissa Blue	62
Lycaena cupreus	Lustrous Copper	13
Lycaena editha	Edith's Copper	81
Lycaena helloides	Purplish Copper	239
Lycaena heteronea	Blue Copper	475
Lycaena hyllus	Bronze Copper	37
Lycaena nivalis	Lilac-bordered Copper	68
*Lycaena phlaeas***	American Copper	1
*Lycaena rubidus***	Ruddy Copper	1
Nymphalis antiopa	Mourning Cloak	7
Nymphalis californica	California Tortoiseshell	1
Nymphalis milberti	Milbert's Tortoiseshell	7
Oeneis chryxus chryxus	Brown Chryxus Arctic	12
*Oeneis jutta***	Jutta Arctic	3

Table 4. (continued)

Species Latin Names	Species Common Names	Total Abundance
Oeneis uhleri	Uhler's Arctic	1
*Papilio canadensis***	Canadian Tiger Swallowtail	7
Papilio eurymedon	Pale Swallowtail	3
Papilio rutulus	Western Tiger Swallowtail	21
Papilio zelicaon	Anise Swallowtail	27
Parnassius clodius	Clodius Parnassian	38
Parnassius phoebus smintheus	Rocky Mountan Phoebus Parnassian	9
Phyciodes campestris	Field Crescent	79
Phyciodes selenis	Northern Crescent	266
Phyciodes tharos	Pearl Crescent	5
Pieris napi marginalis	Margined Mustard White	42
Pieris napi oleracea	Mustard White	7
Pieris rapae	Cabbage White	5
Plebejus icarioides	Boisduval's Blue	1305
Plebejus lupini	Lupine Blue	202
Plebejus saepiolus	Greenish Blue	827
Plebejus shasta	Shasta Blue	21
Pontia beckerii	Becker's White	3
Pontia occidentalis	Western White	5
Pontia protodice	Checkered White	17
Satyrium sylvinus	Coral Hairstreak	1
Speyeria atlantis hesperis	Hesperis Atlantis Fritillary	6
Speyeria callippe	Callippe Fritillary	126
Speyeria cybele	Great Spangled Fritillary	41
*Speyeria edwardsii***	Edwards's Fritillary	3
Speyeria egleis	Great Basin Fritillary	10
Speyeria hydaspe	Hydaspe Fritillary	8
Speyeria mormonia	Mormon Fritillary	596
Speyeria zerene	Zerene Fritillary	28
*Vanessa annabella***	West Coast Lady	1
*Vanessa atalanta***	Red Admiral	2
Vanessa cardui	Painted Lady	74

** Butterfly Species only found only in Teton Region butterfly surveys.

✦ CONCLUSIONS

The benefits of a long-term data set increase our probability of detecting climate driven population fluctuations. Many studies on butterfly populations only observe the communities for two to three years and extrapolate trends with little assurance that their observed patterns identify community patterns (Hill et al., 1995; Spitzer et al., 1997; Gutierrez and Menendez, 1998). Previous work in the GYE system has shown that the different meadow types have distinct plant communities (Jakubauskas et al., 2001; Kindscher et al., 1998) as well as predictable butterfly communities that associate with each of these meadows established along a hydrologic gradient (Debinski et al., 2002). Recent analysis of the plant community in our study sites shows that the forb cover in many of the meadow types has decreased from 1997 to 2007 (Debinski, unpublished data), particularly in the mesic to xeric meadow types. Butterfly communities may also be showing shifts (Debinski, unpublished data). Our next steps will be to analyze butterfly trends with respect to changes in both the plant cover and abiotic data such as temperature and precipitation. Understanding climatic influences on butterfly communities will provide a window into understanding larger ecosystem responses to long-term drought in the GYE

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