

The effects of elevation and climate on butterfly (*Lepidoptera*) abundance and activity

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Abstract

Numerous factors, including climate, resource availability, and habitat diversity, act as determinants of global species diversity. I collected baseline species richness data at three sites along an elevation gradient. Discovery curves indicated that I recorded all species at a site. Interestingly, the most types of butterflies were observed at the middle elevation site. In addition, I investigated the direct effects of the climate variables temperature, wind speed, relative humidity, and solar radiation on butterfly activity at three sites. Increased temperature and solar radiation resulted in increased butterfly activity; no relationship between relative humidity or wind and butterfly activity was observed. These abiotic factors are important determinants of butterfly activity, however, the effect of temperature was only observed at 2 of the 3 sites.

Introduction

Over the past 100 years, the global average temperature has increased by approximately 0.6° and is projected to continue to rise at an unprecedented rate. The current warming trend is of particular significance, for it is heavily influenced by human activity, and is proceeding at a rate unparalleled in the past 1,300 years (Church et al. 2007). Observations of range shifts in relationship with climate change have been predominantly rich in northern European countries, where observational records for many birds, butterflies, herbs, and trees date back to the mid-1700's (Parmesan, 2003). Since the early part of the twentieth century, researchers have documented the sensitivity of insects to spring and summer temperatures (Bale et al. 2002, Dennis 1993, Uvarov 1931). Ford (1945) described northward range shifts of several butterflies

in England, attributing these shifts to a summer warming trend that began around 1915 in Britain (Parmesan, 2003).

Although species have responded to climatic changes throughout their evolutionary history, a primary concern for species and their ecosystems is this rapid rate of change. Quaternary responses of butterfly species indicate that most species have extended their distribution polewards (Hill et al. 1996b; Parmesan et al. 1999; Thomas and Lennon 1999; Warner et al. 2001) or to higher altitudes (Grabherr et al. 1994; Parmesan 1996) during recent twentieth century climate warming. Responses to climate change are also likely to vary in relation to species' range; low-altitude species may benefit and have the potential to expand their ranges, although high-altitude and/or high-altitude species may have little opportunity to shift their ranges and may decline or become extinct (Huntley et al. 1995; Saetersdal et al. 1998; Pounds et al. 1999).

In this study, I focused on four climate variables and their affect on high-altitude butterflies (*Lepidoptera*) along an elevation gradient. Butterflies are an ideal group for studying because their life-cycle, activity, distribution, and abundance are influenced by temperature. Most butterfly species require one or at most a few plant species as larval hosts and require an array of adult nectar sources (Menendez et al. 2007). This dependence on plants usually makes butterflies highly habitat specific (Menendez et al. 2007). For this reason, butterflies as a group are sensitive to thermal conditions and often show immediate dramatic responses to climate fluctuations (Menendez, et al. 2007).

One goal of this study was to create a butterfly species list at the three weather station sites; Judd Falls, Kettle Ponds, and Almont and generate a discovery curve. These species lists are good baseline data to see if species presence or absence changes over time. I also addressed

the following questions. (1) Does butterfly abundance change with elevation? (2) Does butterfly abundance change over the observation period (July)? (3) If so, what explains the pattern? (4) Are temperature, wind speed, relative humidity, and solar radiation correlated with butterfly activity?

Methods

Location

I obtained butterfly data at three different sites located in Gunnison County, Colorado. The first study site was the Kettle Ponds Weather Station (2,860 meters). The second study site was Judd Falls Weather Station (3,003 meters). The third study site was the Almont Weather Station (2,469 meters). I obtained a total of 480 observation minutes at the Kettle Ponds Weather Station and did observations on 7/5/2011, 7/15/2011, 7/21/2011, and 7/31/2011. I obtained a total of 300 observation minutes at the Judd Falls Weather Station and did observations on 7/6/2011, 7/13/2011, 7/19/2011, and 7/27/2011. I obtained a total of 400 observation minutes at the Almont Weather Station and did observations on 7/7/2011, 7/14/2011, 7/22/2011, and 7/28/2011.

Data Collection

At each site, there were two 50 meter transects within 500 meters of each weather station. I visited each weather station 4 times over a 4 week period to observe butterflies. During the observation period, I walked one 50 meter transect for 10 minutes, spending one minute collecting data every 5 meters. During observations I noted the date and time I started and ended

walking the transect, the time I observed a butterfly within the transect, butterfly description, notes, weather, and if a picture was taken or not. After the 10 minute transect, I spent 5 minutes walking to my second 50 meter transect and repeated the same process. After observations, I obtained the climate data specific to the site and observation times.

Data Analysis

I present species lists for each of three sites; Almont Weather Station, Kettle Ponds Weather Station, and Judd Falls Weather Station. I also present Discovery Curves for each site.

I calculated butterfly abundance by dividing the total number of butterflies observed for a given date by the total observation time at each site for a given date. I used ANCOVA to test the effect of site (Almont Weather Station, Kettle Ponds Weather Station, Judd Falls Weather Station) and Julian date on butterfly abundance. In addition, I calculated butterfly activity during hour-long time periods. Butterfly activity was the number of butterflies observed during a given hour (e.g. 10am to 11am) divided by the amount of time spent observing butterflies during the same time period (e.g. 10am to 11am). I used ANCOVA to test the effect of site and the abiotic variables temperature, wind speed, relative humidity, and solar radiation on butterfly activity.

Results

I observed the most species at the Kettle Ponds site (Table 1). The other two sites had an equal number of species. The butterflies I observed in the Pieridae family included *Colias eriphyle*, *Colias eurytheme*, *Colias alexandra*, *Colias scudderii*, *Pieris napi*, *Pontia protodice*, *Pontia occidentalis*, and *Plebejus saepiolus* *Euchloe ausonides*. The butterflies I observed in the

Lycaenidae family included *Glaucopsyche lygdamus*, *Plebejus aquilo*, *Plebejus melissa*, , *Lycaena heteronea*, *Plebeius [Icaricia] icarioides*, and *Agriades rustica*. I observed *Speyeria atlantis* and *Speyeria mormonia* at the Kettle Ponds site. The Swallowtails observed included *Papilio zelicaon* and *Papilio rutulus*.

Table 1: Morph type list observed at each weather station shows variation in abundance of butterflies at Almont, Kettle Ponds, and Judd Falls weather stations.

Judd Falls Weather Station	Kettle Ponds Weather Station	Almont Weather Station
COENONYMPHA OCHRACEA	COENONYMPHA OCHRACEA	EREBIG EPIPSODEA
PIERIDAE	PIERIDAE	PIERIDAE
LYCAENIDAE	LYCAENIDAE	SWALLOWTAIL
SWALLOWTAIL	SWALLOWTAIL	NYMPHALIS ANTIOPA
	EREBIG EPIPSODEA	
	SPEYERIA SP	
	NYMPHALIS ANTIOPA	

I measured the total number of butterfly morphs at each site and generated a discovery curve for each site. (Figure 1, 2, 3) A discovery curve is a graph recording the cumulative number of species of living things (butterflies) recorded in a particular environment as a function of the cumulative effort (observation hours) expended searching for them. At the Kettle Ponds site, it took me 10 hours of observation time until I observed all butterfly morphs at the site. At Almont it took me 2 hours of observation time until I observed all butterfly morphs at the site, and at Judd Falls it took me 5 hours of observation time until I observed all butterfly morphs at the site.

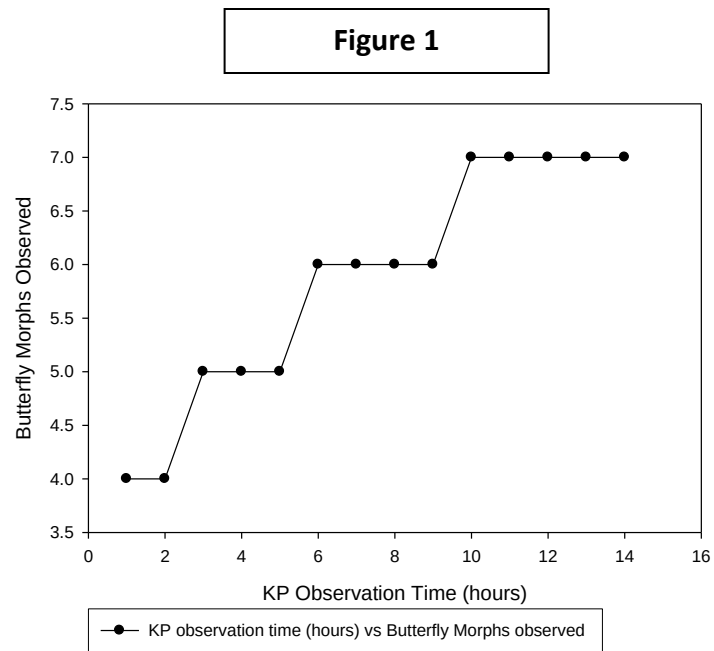


Figure 1: Kettle Ponds Discovery Curve

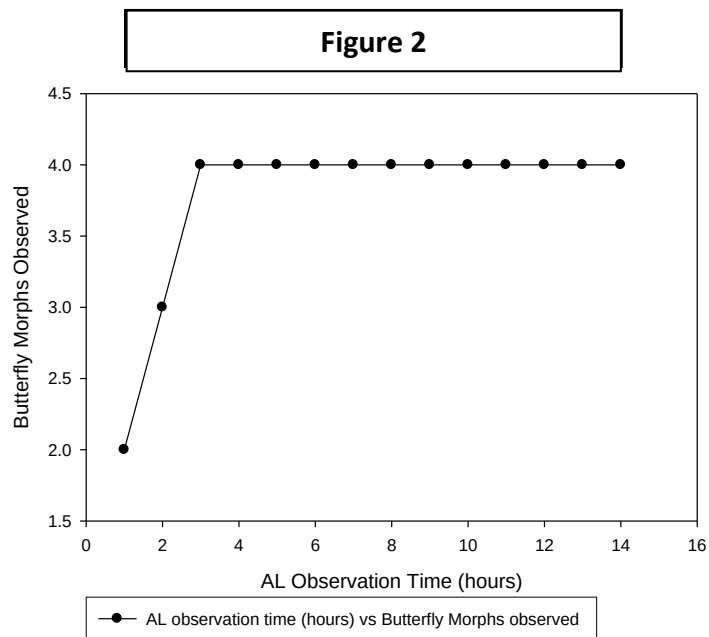


Figure 2: Almont Discovery Curve

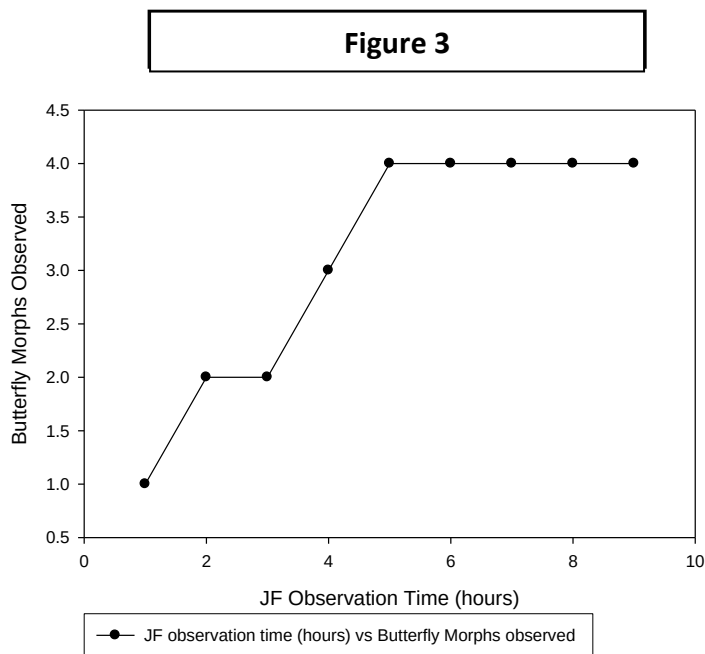


Figure 3: Judd Falls Discovery Curve

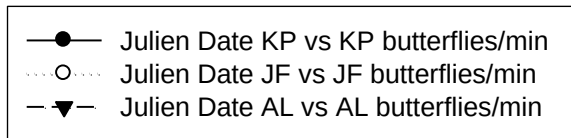
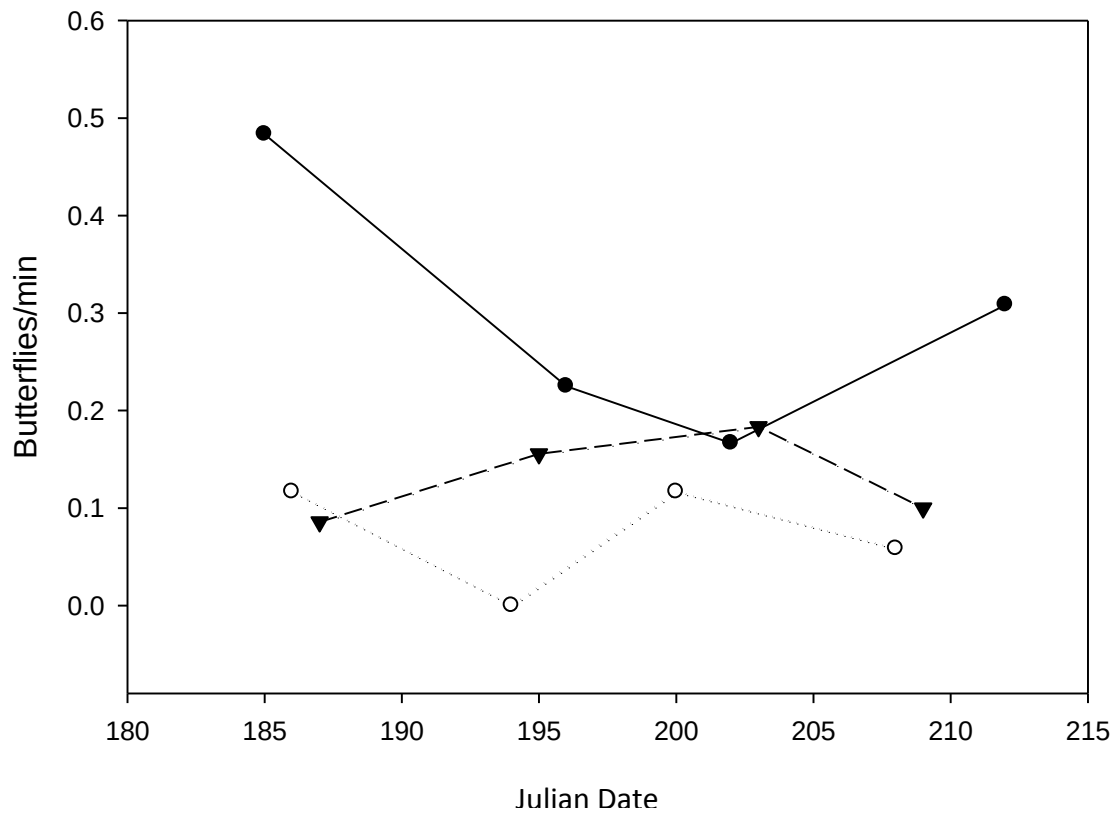
I graphed butterfly abundance at each site over the 4 week observation period. Butterfly abundance didn't change much over summer, and I saw no major effect of Julian date on butterfly abundance (table 2). There was also no strong phenological change over the observation period. However, there was a strong site effect on butterfly abundance. Kettle ponds had the most butterflies (figure 4) with an average of 0.2958 butterflies/minute compared with Judd Fall's average of 0.0729 butterflies/minute and Almont's average of 0.1311 butterflies/minute. There was no strong elevational pattern in butterfly abundance since the site with the highest abundance (Kettle Ponds) was at the middle elevation point.

Table 2: Results of ANCOVA for butterfly abundance at each site.

Sources	df	SS	F	P
Site	2	0.1118	6.2380	0.0342*
Julien Date	1	0.0045	0.5053	0.5039
Julien Date X Site	2	0.0116	0.6501	0.5552
Error	31	0.4335		

Butterfly Abundance over time

Figure 4



Because butterfly activity changed so much during the day, I looked at the effect of four climatic variables on butterfly activity during one hour time blocks. I found the following results for each abiotic factor. Wind did not have an effect on butterfly activity (table 3 figure 5). However, there was a significant Site x Temperature interaction. As temperature increased at Kettle Ponds and Judd Falls, butterfly activity increased. However, at Almont, there was no effect of temperature on butterfly activity (table 4 figure 6). As relative humidity increased, butterfly activity decreased (table 5 figure 7). There was a significant Site x Solar Radiation interaction at Judd Falls and Almont. As solar radiation increased, butterfly activity increased (table 6 figure 8). Solar radiation data was not available for the Kettle Ponds weather station.

Table 3. Results of ANCOVA for site, wind, and interaction on butterflies per minute.

Sources	df	SS	F	P
Site	2	0.151	5.110	0.0121*
Max Hourly Wind	1	0.0008	0.054	0.8176
Max Hourly Wind X Site	2	0.0101	0.344	0.7117
Error	31	0.459		

Figure 5

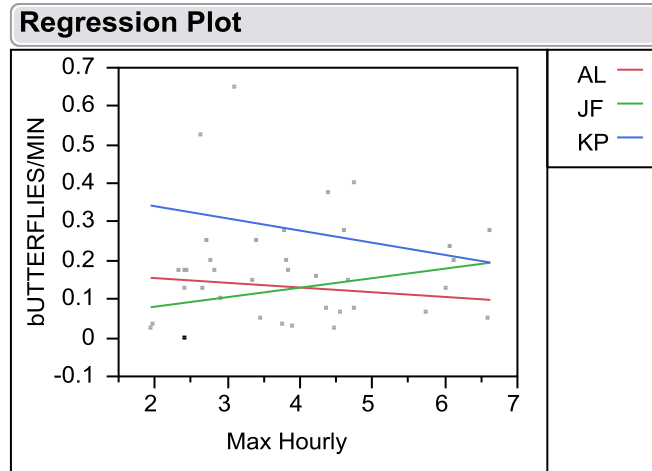


Figure 5. Effect of maximum hourly wind speed on butterfly abundance at Kettle Ponds (KP), Almont (AL), Judd Falls (JF).

Table 4. Results of ANCOVA for site, temperature, and interaction on butterflies per minute.

Sources	df	SS	F	P
Site	2	0.080	3.654	0.0376*
Temperature	1	0.129	11.828	0.0017*
Temperature X Site	2	0.123	5.635	0.0082*
Error	31	0.0339		

Figure 6

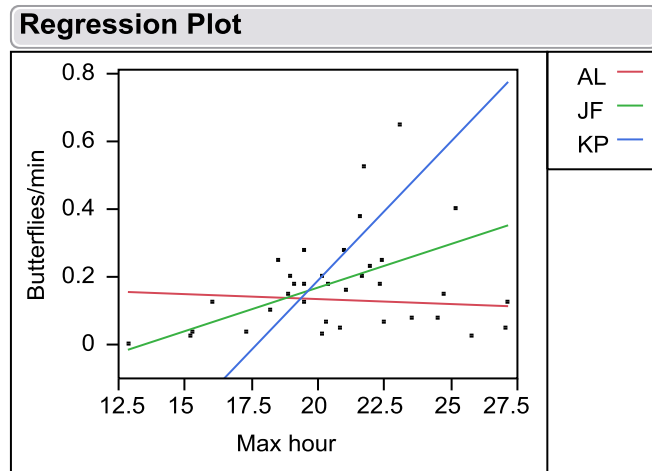


Figure 6. Effect of maximum hourly temperature on butterfly abundance at Kettle Ponds (KP), Almont (AL), Judd Falls (JF).

Table 5. Results of ANCOVA for site, relative humidity, and interaction on butterflies per minute.

Sources	df	SS	F	P
Site	2	0.088	3.238	0.0528
Relative Humidity	1	0.066	4.955	0.0334*
Relative Humidity X Site	2	0.029	1.081	0.3517
Error	31	0.415		

Figure 7

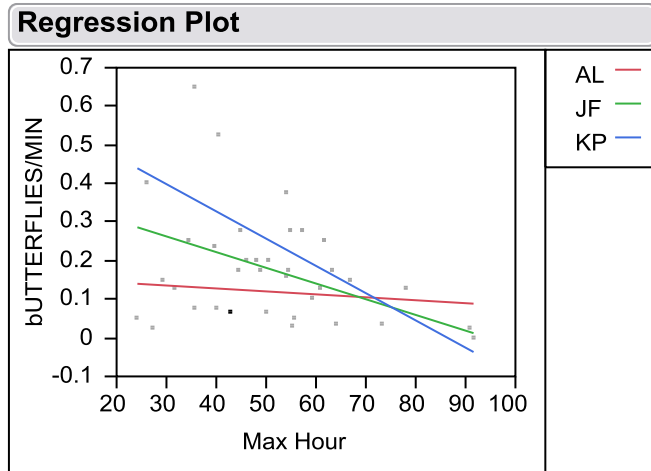


Figure 7. Effect of maximum hourly relative humidity on butterfly abundance at Kettle Ponds (KP), Almont (AL), Judd Falls (JF).

Table 6. Results of ANCOVA for site, solar radiation, and interaction on butterflies per minute.

Sources	df	SS	F	P
Site	1	0.0215	13.8243	0.0205*
Solar Radiation	1	0.0032	2.0592	0.2246
Solar Radiation X Site	1	0.0007	2.0592	0.5186
Error	4	0.0062		

Figure 8

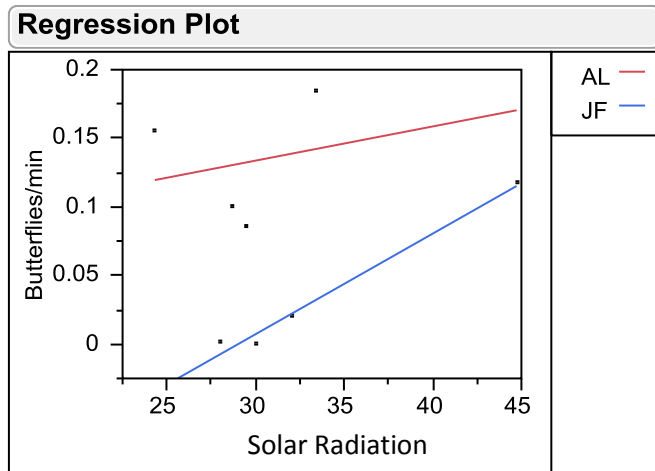


Figure 8. Effect of average hourly solar radiation on butterfly abundance at Kettle Ponds (KP), Almont (AL), Judd Falls (JF).

Discussion

There are many possible explanations for the greater abundance of butterflies observed at the Kettle Ponds site than at the Judd Falls and Almont sites. One possibility is host plant abundance. The host plants were more plentiful and started to bloom earlier at Kettle Ponds than at the Judd Falls sites. I think plants probably bloomed earlier at Almont than at Kettle Ponds. It could be that there are more “butterfly host plants”, such as lupines at the Kettle Ponds than at the other two sites. Also, the distance from the Kettle Ponds site to water was closer than Almont and Judd Falls which could potentially influence butterfly activity and promote increased reproduction.

A complete species list was generated at all three sites. These species lists and discovery curves are useful for future studies. Two species (*Erebia epipsodae* and *Nymphalis antiopa*) were observed at the two lower elevation sites (Almont and Kettle Ponds), but not at Judd Falls,

the highest elevation site. These discovery curves and species lists provide baseline data for future butterfly abundance and range shift studies. With a warming climate, we might observe these species moving up in elevation. Also, species intolerant to warming temperatures might be forced to higher elevations and/or eventually go extinct.

The butterfly abundance I measured over the observation period (July) showed no strong phenological change. There was also no strong elevational pattern in butterfly abundance. This was unexpected, and could be caused by a compression of the summer season. The majority of the high-elevation butterflies I observed might be most active in July. If this is true, low-elevation butterflies could potentially show a stronger phenological change over time.

Butterfly activity was variable over short periods of time (one observation day). A combination of the abiotic factors temperature, relative humidity, and solar radiation are explanations for this variation, however, wind did not significantly effect butterfly activity. Though, the trend was in the direction I expected- decreased butterfly activity as wind increased.

Butterfly activity increased during warmer temperatures and stronger solar radiation, and decreased during cooler temperatures. Since butterflies are ectotherms, they warm their bodies and gain heat from external sources such as sunlight energy. They also become more active at warmer temperatures because of the energy needed for fitness. Butterfly species at higher altitudes have a broad thermal tolerance and are living in climates that are currently cooler than their physiological optima, so warming temperatures may enhance their fitness (Deutsch et al. 2008).

I expected butterfly activity to increase with increased relative humidity, but the opposite held true. Further research is necessary to determine the correlation between relative humidity

and butterfly activity, and wind and butterfly activity. Environmental factors not included in this study may be influencing the measured negative effect of relative humidity.

Conclusion

In the short term, an increase in temperature due to climate change might cause an increase in butterfly abundance in high elevations as species from lower elevations shift their ranges. But, in the long term, a changing climate proves to have negative effects on butterfly host plants. Increased warming could change the dominant vegetation of a widespread meadow habitat (Harte and Shaw, 1995). During a warming experiment in 1995, Dr. Harte and Dr. Shaw found that above ground biomass of forbs decreased and above ground biomass of shrubs increased. The decreased forbs serve as larval host plants and adult nectar sources, as they become scarce, butterfly abundance could decrease. The impact of increasing atmospheric temperature on the abundance and range shifts of butterflies is an important and direct biological consequence of climate change and can be evaluated on a global scale. Since butterflies are so sensitive to climate fluctuations, they could be great indicators of climate change.

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