

**Syrphid fly distributions along an elevation gradient in and around the Rocky
Mountain Biological Laboratory (RMBL)**

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Abstract

Much is known about bee pollination, but there is little information concerning pollination by syrphid flies. Syrphid flies are also important to study because they are the most significant flower visiting Dipteran insects, which are the second most important order among flower-visiting and flower-pollinating insects. Describing abundance and diversity along an elevation allows for the exploration of abiotic and biotic drivers of distribution. Our knowledge of syrphids needs to be enhanced concerning (i) How does syrphid abundance change over an elevation gradient, (ii) How does the number of syrphid morphospecies change over an elevation gradient, and (iii) What biotic and abiotic factors are associated with syrphid fly abundance and diversity? A five-week observational study was carried out at five weather stations in and around RMBL, covering an elevation range of 561m. Flower abundance was recorded at each site, followed by sampling of syrphids. Linear regression analysis revealed that day of year correlated to the number of individuals as well as number of morphospecies. Percent cloud cover also correlated to the number of individual syrphids. This could possibly be because fly detection increased as time went on and/or there are more flies later in the season. Elevation is correlated to number of flowers and number of flower species. This could possibly reflect the year, in that there was a lot of frost damage at lower elevations. It is important to continue this study to see if this is a common trend or unique to this drought year.

Introduction

Pollination is an integral process in which pollen is transferred from the stamen to the stigma of angiosperms leading to fertilization and sexual reproduction in plants. Much is known about bee pollination, (Kearns, 1992) but there is little information concerning pollination by syrphid flies. Despite the fact Diptera are the second most important order among flower-visiting and flower pollinating insects (Larson *et al.*, 2001), and syrphids are the most significant flower visiting Diptera (Larson *et al.*, 2001), an information gap exists. They are especially abundant at high altitudes, thus high altitudes are a good place to start studying them, because they are likely to play a large role in pollination in these ecosystems. It has been suggested that flies are major pollinators in montane, alpine, and Arctic environments (Kearns, 1992). High altitude habitats are expected to warm rapidly under continued climate change and there is concern about how climate warming affects plant-pollinator interactions, such as how warming temperatures will affect the phenology of plant-pollinator interactions. Hegland *et al.* (2009) reported that there is a need to elucidate the possible effect climate change has had on altered phenologies, abundance and distribution of plants and animal species, as well as the disturbance of flower-pollinator interactions. If temperature continues to increase there is the potential of affecting the phenologies of both plants and animals, due to alterations in metabolism, growth, maturation, and timing of behavior (Hegland *et al.*,

2009). Plant and animal phenology has taken an important role as an indicator of a species' response to the changing climate (Graham-Taylor *et al.*, 2009). In some cases the onset of flowering in plants and first appearance dates of pollinators appear to advance linearly in response to recent temperature increases (Hegland *et al.*, 2009). Studies have indicated that the distribution and phenology of plants and animals have followed predicted global warming changes; spring events have advanced at a rate of 2.3 days per decade, and species' ranges have shifted by 6.1km per decade towards the North and South poles over the last few decades (Parmesan and Yohe 2003).

It is therefore important to develop an understanding of how climate change might affect plant-pollinator interactions because these interactions could influence population persistence. Increased temperatures might also affect flower abundance as well as plant and pollinator interactions. Observational studies by Inouye and others (2003) provide evidence that increased spring temperatures may decrease flower abundance. Decreased flower abundance might have a negative effect on both the plant and other animals (Vrieling *et al.*, 1999 in Hegland *et al.*, 2009). Increased temperatures might also affect the abundance and distribution of pollinators. Flies appear to be more abundant in colder and wetter habitats, whereas bees appear to be more abundant in warmer and drier habitats (Arroyo *et al.* 1982; McCall and Primack 1992; Totland 1993; Lazaro *et al.* 2008 in Hegland *et al.*, 2009). This suggests that there could be variation in abundance and distribution of pollinators as a result of variation in temperature and water availability across habitats.

To determine if there is variation in abundance and distribution of pollinators elevation gradients are helpful. Elevation gradients are useful because they serve as a proxy for climate change. It is expected to be warmer at lower elevations and colder at higher elevations. They are valuable because climate warming has been shown to affect plant and animal phenology, local abundance of plant and animal fauna, and large-scale distribution of plants and pollinators (Hegland *et al.*, 2009, Dunne *et al.*, 2004).

This project will serve as baseline data for Syrphidae abundance and distribution for future projects at RMBL and it will also serve as a proxy for climate change, associated with the phenologies of plants and syrphids in a sub-alpine environment. Specific questions to be addressed by this project include:

1. How does syrphid abundance change over an elevation gradient?
2. How does the number of syrphid morphospecies change over an elevation gradient?
3. How many syrphid fly morphospecies are found across the elevation gradient established at RMBL?
4. What biotic and abiotic factors are associated with syrphid fly abundance and diversity?

Methods

Study site and data collection

The Rocky Mountain Biological Laboratory (RMBL) is located in the West Elk Range of the Colorado Rocky Mountains (2,900m (a.s.l)). The station consists of over 122 hectares, at a minimum altitude of 2,895 meters. The area experiences hundreds of centimeters (up to 350 cm) of snow during the winter, typical mountain thunderstorms, and temperatures reaching 23 degrees Celsius in the summer (Rocky Mountain Biological Laboratory 2012). RMBL is home to one of the largest collections of long term data, making it an ideal location to study. RMBL has installed six weather stations along an elevation gradient from 8,000ft to just over 11,000ft. Each of these stations tracks temperature, moisture, wind speed, and soil conditions. This information allows for a greater understanding of how climate factors such as temperature affect ecological characteristics such as when plants flower and when animals emerge.

Syrphids were sampled at five weather stations (Kettle Ponds, Research Meadow, Judd Falls, Billy Barr, and Mexican Cut) in and around RMBL. The stations are located along an elevation gradient ranging from 2,860m to 3,421m. One 50m x 1m transect was established at each weather station. The number of flower species and the density of each species was recorded in each transect on a weekly basis for five weeks. Insects were netted for 30 minutes inside each transect once in the morning and once in the afternoon, on a weekly basis for five weeks. The flower species from which each syrphid was netted was recorded. Syrphids were then placed into kill jars containing cyanide. A reference collection of morphospecies was made of the Syrphidae sampled. Each fly was assigned a number that correlated to its specific morphospecies. The collection will be used for future experiments and for reference.

Analysis

Linear regression was used to explore the effect of elevation independently of other potential drivers of diversity and abundance. Linear regression was also used to determine the effect of day of year of sampling. Multiple linear regression analysis was used to look for factors that were associated with fly and flower abundance and diversity.



Fig. 1 Map of observational sites ranging from 3,421m (top left) to 2,860m (bottom middle)

Results

A total of 67 flies were netted, representing a total of nine morphospecies. The greatest flower abundance and flower diversity was at the highest site, Mexican Cut and the lowest flower abundance and flower diversity was at the lowest site, Kettle Ponds (Table 1).

A species accumulation curve, using morphospecies, shows that thorough sampling was carried out (Table2; Fig2). The graph shows that as the number of individuals increases the number of fly morphospecies starts to slow down, suggesting that increased sampling effort would not lead to large increases in the number of morphospecies represented.

Multiple linear regression analysis was used to determine if elevation and day of year correlated with number of flowers and number of flower species. Elevation correlated with number of flowers and number of flower species ($R^2 = 0.85$, $F_{1,23} = 129.21$, $P < 0.0001$; $R^2 = 0.78$, $F_{1,23} = 87.22$, $P < 0.0001$; Fig 3 a,b), but day of year did not correlate with either of the two (Table 3). Fig. 3 also illustrates that elevation did not correlate to number of fly morphospecies or total number of flies ($R^2 = 0.11$, $F_{1,23} = 2.84$, $P = 0.11$; $R^2 = 0.025$, $F_{1,23} = 0.6$, $P = 0.45$; Fig 3 c,d). Day of year also did not correlate with either fly diversity or abundance (Table 3).

Multiple linear regression analysis was also used to determine if day of year, elevation, percent cloud coverage, number of flowers, and number of flower species correlated to the total number of flies and the number of fly morphospecies. Day of the year is correlated to both total number of flies and number of fly morphospecies ($R^2=0.4$, $F_{5,19}=2.85$, $P=0.03$; $R^2=0.30$, $F_{5,19}=1.60$, $P=0.04$). While percent cloud coverage is correlated to total number of flies ($R^2=0.43$, $F_{5,19}=2.85$, $P=0.03$). Although when total number of flies was fit by day of year and percent cloud coverage independently the correlation was not considered significant ($R^2=0.10$, $F_{1,23}=2.70$, $P=0.11$; $R^2=0.08$, $F_{1,23}=2.09$, $P=0.16$ Fig 4 a,b). The same occurrence was observed when number of morphospecies was fit by day of year ($R^2=0.13$, $F_{1,23}=3.53$, $P=0.07$ Fig 5).

Table 1 Summary data showing floral and syrphid fly abundance and diversity across an elevation gradient at the Rocky Mountain Biological Laboratory (RMBL).

Site	Elevation (m)	Flower Species	# Flowers	Fly Morphospecies	# Fly Individuals
Kettle Ponds	2860	12	349	7	19
Research Meadow	2917	16	395	3	8
Billy Barr	2917	14	1032	5	7
Judd Falls	3003	17	1290	4	9
Mexican Cut	3421	24	3956	4	24

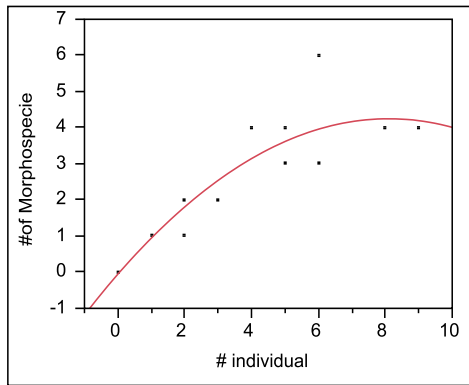


Fig. 2 Morphospecies accumulation curve of syrphid flies caught over five weeks at five sites in the East River Valley near the RMBL.

Table 2 Polynomial fit of the number of morphospecies represented as the sampling effort in terms of number of individuals increased (Fig. 2).

Response Variable	Predictor Variable	Slope	SE	t	P	R^2	F
# Morphospecies	# Individuals	0.72	0.07	10.66	<0.0001	0.87	$F_{2,22}=71.12$
# Morphospecies	# Individuals ²	-0.07	0.02	-3.54	0.002	0.87	$F_{2,22}=71.12$

Table 3 Linear fit data from multiple regression analysis showing elevation correlates to total number of flowers and number of flower species.

Response Variable	Predictor Variable	Slope	SE	<i>t</i>	<i>P</i>	<i>R</i> ²	<i>F</i>
Total # of Flowers	Day of Year	0.43	2.51	0.17	0.87	0.85	$F_{2,22} = 61.89$
	Elevation	1.31	0.12	11.12	<0.0001		$F_{2,22} = 61.89$
# of Flower Species	Day of Year	-0.06	0.04	-1.66	0.11	0.81	$F_{2,22} = 45.61$
	Elevation	0.02	0.002	9.44	<0.0001		$F_{2,22} = 45.61$
Total # of Flies	Day of Year	0.08	0.05	1.67	0.11	0.21	$F_{2,22} = 2.93$
	Elevation	0.004	0.002	1.71	0.10		$F_{2,22} = 2.93$
# of Fly Morphospecies	Day of Year	0.06	0.03	1.84	0.08	0.16	$F_{2,22} = 2.03$
	Elevation	0.001	0.001	0.76	0.45		$F_{2,22} = 2.03$

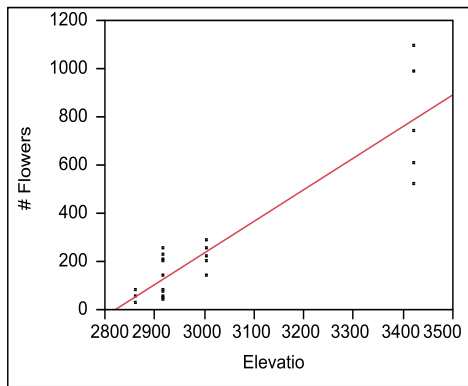


Fig. 3a Linear fit of the total number of flowers counted at five different elevations over five weeks in the East River Valley.

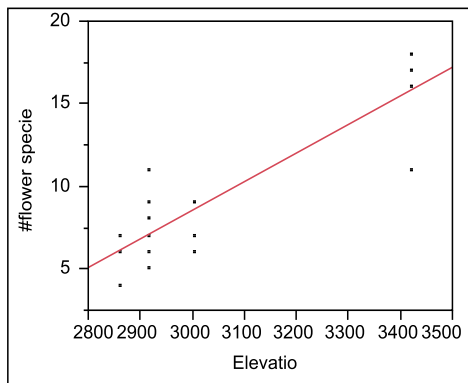


Fig. 3b Linear fit of the total number of flower species counted during weekly censuses at five different elevations over five weeks in the East River Valley

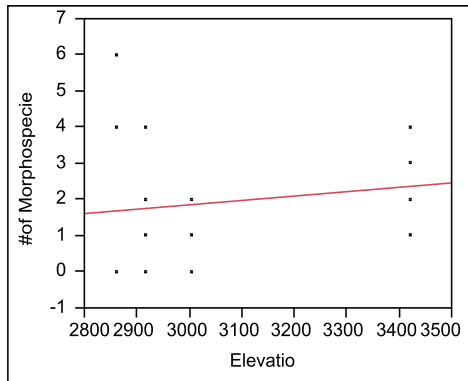


Fig. 3c Linear fit of the total number of syrphid morphospecies collected at five different elevations over five weeks in the East River Valley.

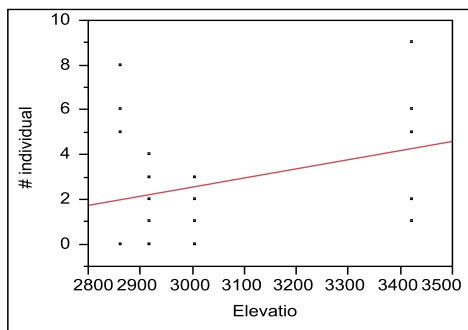


Fig. 3d Linear fit of the total number of syrphid flies collected during weekly samples at five different elevations over five weeks in the East River Valley.

Table 4 Linear fit data from multiple linear regression analysis showing percent cloud coverage and day of year are correlated to total number of flies.

Response Variable	Predictor Variable	Slope	SE	t	P	R ²	F
Total # of Flies	% Clouds	-0.06	0.03	-2.31	0.03	0.43	F _{5,19} = 2.85
	# Flowers	-0.002	0.005	-0.30	0.77		F _{5,19} = 2.85
	# Flower Species	0.34	0.32	1.07	0.30		F _{5,19} = 2.85
	Elevation	0.002	0.006	0.25	0.80		F _{5,19} = 2.85
	Day of Year	0.12	0.05	2.29	0.03		F _{5,19} = 2.85

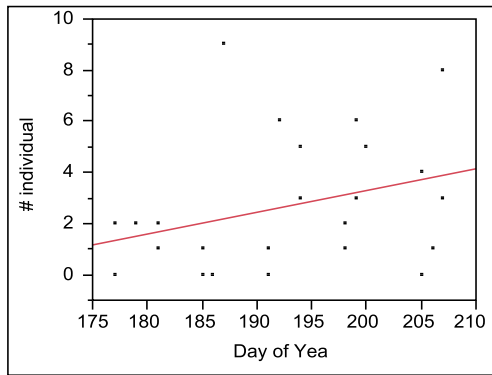


Fig. 4a The number of syrphid flies collected during weekly samples on different days of the year.

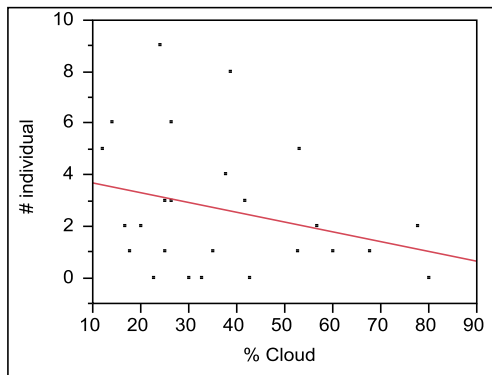


Fig. 4b The number of syrphid flies collected during weekly samples as a function of variation in different percent cloud coverage.

Table 5 Data from multiple linear regression showing day of year is correlated to number of morphospecies

Response Variable	Predictor Variable	Slope	SE	<i>t</i>	<i>P</i>	<i>R</i> ²	<i>F</i>
# Morphospecies	% Clouds	-0.03	0.02	-1.70	0.11	0.30	<i>F</i> _{5,19} =1.60
	# Flowers	-0.001	0.004	-0.35	0.73		<i>F</i> _{5,19} =1.60
	# Flower Species	0.19	0.22	0.86	0.40		<i>F</i> _{5,19} =1.60
	Elevation	0.0002	0.004	0.05	0.96		<i>F</i> _{5,19} =1.60
	Day of Year	0.08	0.04	2.19	0.04		<i>F</i> _{5,19} =1.60

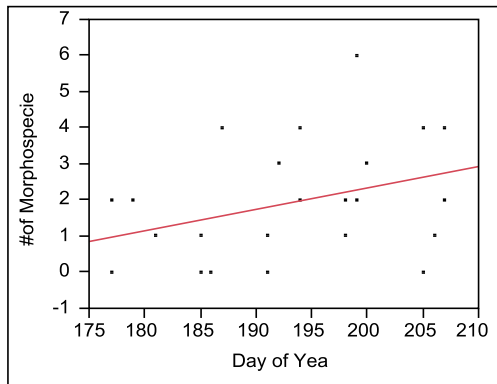


Fig. 5 The number of syrphid fly morphospecies collected during weekly samples on different days of the year.

Discussion

There seems to be abiotic factors that are associated with abundance and diversity of syrphid flies. Elevation, percent cloud coverage, and day of the year all seemed to have some correlation to syrphid fly abundance. These conclusions could possibly be because detection increased at later sampling dates and/or because there were more flies later in the season.

We can only conclude so much about these data for several reasons. The time that was allotted to carry out the sample was only five weeks, perhaps a longer study would allow us to conclude differently. If sampling could be carried out longer syrphid fly abundance and diversity is likely to increase. Possibly a greater range in elevation would conclude different results. Because we are already sampling at a relatively high altitude sampling at even lower altitudes might reveal that syrphid fly abundance and diversity is correlated to elevation. Also this year was different than most years. Phenology was ahead of schedule by approximately four to six weeks (Inouye, unpublished data). There was a lot of frost damage at lower elevations (S. Bruce personal observation) which may have contributed to the pattern of lower floral abundance at lower elevations. It is important to continue this work to determine if this pattern in floral abundance was unique to this year or is a reoccurring trend. It was also interesting that floral abundance and diversity were poor predictors of fly abundance and diversity given the importance of pollen to the reproductive cycle of syrphids (Larson *et al.* 2001). Because syrphid abundance from Malaise trap records was similar to other years, despite low floral abundance, (Inouye, unpublished data) suggests that abiotic factors may be important in explaining syrphid abundance and diversity.

We have learned that syrphid flies are relatively constant across the elevation gradient, but that a slight trend of more individuals is observed at higher elevations. Until we can conclude that elevation is in fact correlated to the total number of syrphid flies it is hard to say that pollination by syrphid flies is greater at higher elevations.

Kearns (1992) found that most fly species (67%) were collected from only one of the three elevation zones (low, mid, and high), but only eight percent of the species, including syrphids, were collected in all elevation zones. This is consistent with the result of this study that found that the number of fly morphospecies remained constant over the elevation gradient. Kearns (1992) also concluded that the mid and high elevation zones shared the most species (Kearns, 1992). This might have been the case in this study if the elevation range was greater so that it could be determined if the number of species does change across elevations. It seems that our results are similar to Kearns (1992), but further sampling needs to be carried out to see if this in fact is the case. Kearns (1992) also determined if thorough sampling was carried out, and found that sampling was not as thorough at the lower elevation zone, which could explain why there were fewer species in the lower zone. Maybe if sampling was carried out again Kearns would experience a relatively constant number of species among the three elevation zones, somewhat like the results of this study that were observed across the five elevations in and around RMBL.

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