Pollination of Basalt Daisy (Erigeron basalticus: asteraceae)

Diedra Petrina

Central Washington University

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POLLINATION OF BASALT DAISY (*ERIGERON BASALTICUS*: ASTERACEAE)

A Thesis
Presented to
The Graduate Faculty
Central Washington University

In Partial Fulfillment
of the Requirements for the Degree
Master of Sciences

by
Diedra Petrina
May 2011
We hereby approve the thesis of

Diedra Petrina

Candidate for the degree of Master of Science

APPROVED FOR THE GRADUATE FACULTY

May 13, 2011

Dr. Tom Cottrell, Committee Chair

May 13, 2011

Dr. Kristina Ernest

May 13, 2011

Dr. Linda Raubeson

10/10/12

Dean of Graduate Studies
ABSTRACT

POLLINATION OF BASALT DAISY (ERIGERON BASALTICUS: ASTERACEAE)

by
 Diedra Petrina
 May 2011

Erigeron basalticus (basalt daisy) is a rare plant occupying a very restricted range of approximately 52 km$^2$ in only two counties (Kittitas and Yakima) in central Washington State. Growing out of the cracks and crevices of basalt columns, the population of E. basalticus is fragmented and confined to its unique niche. The entire population consists of approximately 8,000 individuals.

This study focused on the pollination system of E. basalticus, specifically self-pollination and a determination of the most frequent insect visitors. Erigeron basalticus was determined to be primarily self-incompatible, therefore, pollinators will be important for successful pollination to occur.

A total of 143 observational hours were logged in 2005 and 2006 in an effort to determine potential pollinators of E. basalticus. Only insects and no other potential pollinators were observed visiting E. basalticus flowers. At least 13 different genera of insects observed, mostly consisting of Diptera (flies) and Hymenoptera (bees and wasps). The most frequently seen visitors and probable pollinators were Geron sp., Colletes spp., Augochlora sp., and Mythicomyia sp.; however, Mythicomyia may not be a pollinator due to its small size and lack of body hair.
ACKNOWLEDGEMENTS

Dr. Tom Cottrell for his expertise in plant biology
Dr. Kristina Ernest for her expertise in ecology
Dr. Linda Raubeson for expertise in plant biology
Dr. Priya Shahani for identifying insects
My father, Norm Sash, for his patience and computer assistance
My Husband, Cedo Petrina, who has been my biggest cheerleader in life
My Mother, Terri Bogue, for all of the positive encouragement
Central Washington University for funding
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CHAPTER I

INTRODUCTION

Studying the natural history of an organism is important for understanding its life cycle; this knowledge is the foundation for many management strategies. A very important portion of an organism’s life cycle is reproduction. In plants, reproduction often includes highly evolved pollination systems. Because plants are immobile, they have successfully evolved to use different vectors to transfer and deposit pollen from other individuals or are capable of self-pollination. This paper focuses on the pollination system in *Erigeron basalticus* (Asteraceae), a rare cliff dwelling plant in Washington State, USA (Figure 1). To date no research has been published on the pollination system of *E.basalticus*. The goals of this study were to determine if *E. basalticus* is capable of self-pollination, create a list of flower visitors, and identify highly probable pollinators.

Figure 1 Image of *Erigeron basalticus* by Diedra Petrina
Modes of Pollination

Pollination is an important part of the reproductive process in plants; in general, it is the transfer of pollen from an anther to a stigma. There are three primary pollination systems: self-pollination that requires no external pollen (pollen from another plant), and abiotic pollination and biotic pollination that require transfer of pollen from another plant.

With the exception of self-pollination, flower characteristics indicate what type of vector is transferring pollen. Plants with abiotic pollination systems (wind and water) have flowers that are generally small and non-showy with no food reward, while plants with biotic pollination systems have flowers that are generally showy and/or brightly colored, scented, and offer food rewards to the vertebrate and invertebrate vectors.

Plants that are pollinated by birds are typically larger, unscented tubular flowers that are brightly colored (reds and fuchsia) while bat pollinated plants are typically larger, sour or sweet smelling belled shaped flowers that are drably colored (cream or green). Plants that are pollinated by insects have a wide range of characteristics; the flowers can be large to small, scented or unscented, brightly colored or not, tubular or non-tubular.

The flowers of *E. basalticus* are small, yellow or white, unscented tubular flowers that are clustered together in a head inflorescence (the clustering of flowers). The flower characteristics of *E. basalticus* indicate that insects are the pollinators.
Self-Pollination

More than 80% of flowering plants rely on a vector(s) (e.g. wind, insects, and birds) for successful pollination to occur (Aizen and others 2002). However, in some plant species natural selection has favored reproductive assurance through self-pollination. Self-pollinated plants do not need an external pollen source or vector for successful fertilization of the egg to occur. According to the reproductive assurance hypothesis, self-pollination is favored when pollinator activity is limited due to scarcity (Fausto and others 2001; Kalisz and Vogler 2003; Motten 1982). Self-pollination systems are thought to occur in taxa when pollinator density and visitation rates are low or flowering occurs when pollinator abundance is low. Plant density may also affect pollinator visitation rates as low plant density decreases visitation rates (Fausto and others 2001). While self-pollination may be beneficial in some cases, it can have genetic consequences, such as a reduction of allelic diversity and genetic variation. Small plant populations are more susceptible to a decrease in genetic variation than are larger populations (Les and others 1991). Some plants are not strictly self-pollinating but rather utilize a combination of selfing and out-crossing. An example of this is the plant Collinsia verna (Scrophulariaceae) (Kalisz and Vogler 2003). Strictly out-crossing plants are also susceptible to a genetic bottleneck if its population or their pollinator population suddenly decreases. These species may have a hard time recovering from a genetic bottleneck (Aizen and others 2002; Les and others 1991). These systems need special consideration for management purposes. Self-incompatibility, when fertilization is
blocked between two genetically similar gametes, promotes out-crossing and is typical of the Asteraceae, some exceptions being *Eriophyllum congonii* and *E. nubigenum* (Les and others 1991; Mooring 2002)

*Insect Pollination*

Insect pollination, also known as entomophily, is considered by some to be the most important pollination system because the majority of our food plant species rely on it (Shepherd and others 1996). A diversity of insects including Lepidoptera (butterflies and moths), Diptera (flies), Coleoptera (beetles), and Hymenoptera (bees and wasps) are important pollinators around the world. Pollination effectiveness (percentage of receptive florets setting seed following one visit by a given species) varies widely among insect species (Talavera and others 2001). Insect characteristics that influence pollination effectiveness are based on morphology, physiology, and behavior (Kendall and Solomon 1973; Olsen 1997).

The amount of hair on an insect’s body is the primary morphological characteristic used to assess how effective a pollinator is. Insects covered with hair can carry more pollen than smooth-bodied insects (Talavera and others 2001). This characteristic is used as an indicator of how much pollen can be transported at one time and how large the pollen shadow (the number of inflorescences receiving pollen after the insect gets the initial pollen load) will be. However, the behavior of the insect must also be considered when evaluating pollen shadow. Some bees, such as Apidae (e.g. bumble
bees), transfer pollen into their pollen baskets, where it is no longer available for pollination, decreasing the amount of pollen transferred (Talavera and others 2001).

Some insects that carry a small pollen load are still effective pollinators if they have a high foraging rate. For example, a smooth bodied *Erestalis* (drone fly) is just as effective as a hairy bodied bee at pollination if its foraging rate is higher (Gyan and Woodell 1987). In some insect species, temperature affects the foraging rate. For example, in yellow jackets (*Vespula germanica*) flight does not take place at temperatures below 15 degrees Celsius. A similar situation occurs in the, black bean aphid (*Aphis fabae*), where flight does not take place below 15 degrees Celsius. Black bean aphid flight increases with temperatures until 22 degrees Celsius at which point flight does not continue increasing in frequency with increasing temperature (Taylor 1963).

Many factors (morphology, physiology, and behavior) affect the efficiency of a pollinator so it is necessary to consider all flower visitors as potential pollinators unless other information is known. As a demonstration of this point, one study reporting insect visitor efficiency of the small herb, *Lithophragma parviflorum*, found that larger bees (e.g. *Osmia*) produce the largest seed set and had the longest pollen shadow when compared to Bombyliids and smaller bees (e.g. *Evylaeus* sp.). Smaller bees produced the least seed set and transferred pollen to subsequent flowers but they generally visited no more than two flowers within the defined plot (Pellmyr and Thompson 1996).
Bombyliids produced almost as much seed set per visit as the large bees but they had a shorter pollen shadow (Pellmyr and Thompson 1996).

Pollination in Asteraceae

Asteraceae (sunflower family) is one of the largest plant families with over 20,000 species distributed across the world (Hiscock 2000; Hiscock and others 2002; Hitchcock and Cronquist 2001; Walters and others 2006). This family is characterized by the clumping of individual flowers or florets on a head-like disk, producing a larger floral display than a single flower. The inflorescence is considered the functional pollination unit. Typically, flowers in the Asteraceae family mature from the periphery to the center. Even with this temporal pattern of maturation there are usually many mature flowers that are receptive to pollination at the same time (Walters and others 2006). Owing to this, and the small size of individual flowers, a single visit from a pollinator can successfully pollinate many flowers. Each flower in the head inflorescence produces a single seed with successful pollination. Most members of the Asteraceae family are self-incompatible and therefore rely on a pollen vector, often an insect, for successful pollination. However, some are self-compatible and/or wind pollinated and thus insect pollination is not as important in these family members (Berry and Calvo 1989; Cheptou and others 2001; Grashoff and Beaman 1970; Luijten and others 2002; Maki and others 1996; Olsen 1997). This highly evolved and versatile family has some species that are very abundant, adapted to a very wide range of habitat conditions, while other species are rare and occupy a narrow range of habitat.
Any plant species that occupies a narrow niche is pre-disposed to having a fragmented population and may be especially dependant on pollinator efficiency. Fragmented populations may disrupt plant-pollinator interactions, thereby increasing the risk of extinction (Colling and others 2004). In particular, self-incompatible plant species with fragmented populations may be at a higher risk of extinction and have decreased reproductive success due to a decreased visitation rate by its pollinators. This is further exacerbated by low population numbers often associated with fragmented populations.

Many believe that pollination and reproductive success decreases in sparse populations (Colling and others 2004; Kunin 1997; Roll and others 1997). Kunin (1997) has clarified this and suggested that patch size itself does not affect the pollinator species composition but the number of flowers and air temperature does affect the total number of flowers visited. Kunin found the mixture of pollinator species changes when plant density decreased; he noted that there were fewer solitary bees but an increase in syrphid flies.

*Erigeron basalticus* (basalt daisy)

*Erigeron basalticus* (Asteraceae) is a rare endemic occupying fragmented cliff habitats in central Washington State. The fragmented populations occupy an area of about 16 x 3.2 kilometers in Kittitas and Yakima Counties, near Selah Creek and north in the Yakima River Canyon. Within this 51.2 square kilometer area a population of about 8,000 individuals is divided into eight sub-populations (Conservation 2010; Hitchcock
and Cronquist 2001; WTU herbarium image collection: *Erigeron basalticus*). This fragmentation of the population is the result of the disjunct habitat the species requires. The plant is found in the cracks and crevices of basalt cliffs, because these cliffs are not continuous neither is the *E. basalticus* population.

*Erigeron basalticus* has a head inflorescence about 15 mm in diameter with approximately 25-30 ray flowers. Ray flowers are typically white although sometimes display a violet or pink color, which may be an indication of older ray flowers. Disk flowers are yellow. The wedge shaped and deeply tri-lobed leaves are about 4 cm in length and covered in stiff hairs. The normal flowering dates range from May - October (Conservation 2010; Hitchcock and Cronquist 2001; WTU herbarium image collection: *Erigeron basalticus*).

Currently there is no published information on *E. basalticus*’s reproductive system. Information about the reproductive system of *E. basalticus* may be paramount for successful management of the existing population. If it is assumed that *E. basalticus* is self-incompatible, and entomophilous (as most members of the Asteraceae family are) then we know that the plant relies on pollinators for transferring pollen. If this is the case then it is necessary that management for *E. basalticus* will include habitat management for pollinators. Currently the Washington Department of Natural Resources has no management plan for *E. basalticus* other than maintaining the current habitat and monitoring the population. According to the Washington Natural Heritage Program, the Selah Cliff *E. basalticus* sub-population is decreasing. This may be due to decreased
pollinator activity; therefore, management to maintain the current population size of *E. basalticus* may also include management of its pollinators. This study was designed to answer two questions: is *E. basalticus* self-pollinating and what daytime insects are likely to be pollinating?
CHAPTER II

METHODS

Site description

The research site was at the Selah Ridge sub-population in Yakima County, on Department of Natural Resources (DNR) land, approximately 45 kilometers south of Ellensburg along the Canyon Road State Route 182 (Figure 2).

![Image of Selah Cliff sub-population looking east. Image taken by Diedra Petrina.](image)

The research site is approximately 427 m in elevation in a predominantly shrub-steppe habitat, dominated by *Artemisia tridentata* (big sagebrush), *Ericameria nauseosa* (rabbitbrush), and *Pseudoroegneria spicata* (bluebunch wheatgrass). Basalt columns with a northern to northeastern aspect form a cliff on the west bank of the Selah Creek before it empties into the Yakima River. Irrigation runoff from an orchard at the top of the basalt
cliff flows over the cliff's west end. *Erigeron basalticus* grows out of cracks and crevices in the basalt columns. The Selah Cliff population contains approximately 2,000 individuals.

**Sample Plots**

Thirty plots were marked along the ridge, starting at the west end of the Selah sub-population and east of the irrigation runoff, were used for the self-pollination and pollinator experiments. At this location, the dominant plant species are native shrub-steppe species including big sagebrush, rabbitbrush, and *Thelypodium laciniatum* (thelypodium). From this point, plots continued eastward for approximately 805 m. Each plot was 1.5 m by 1.5 m and contained 2-5 plants. Sample locations were selected to maximize the number of plants in each plot. Because the habitat of *E. basalticus* is discontinuous, individual plants often do not cluster very close to each other. I attempted to maximize the number of plots that contained five plants though it was impossible to locate all 30 plots such that each had five plants. In the selection process I chose all possible plots having five plants, then since I had not reached 30 plots with five plants, I chose all possible plots having four plants, and so on until all 30 plots were selected. Total number of plots containing five plants was 10 while only three plots contained two plants all others contained three or four plants.

The position of these plots started at the base of the basalt columns and extended up the basalt cliff wall 1.5 m. The terrain was difficult to move quickly on and therefore
it was dangerous to follow and collect insect visitors. The plot size and position allowed for easy viewing and sample collecting without much movement (which may also disturb flower visitors).

Plots and plants were identified by attaching a standard white plastic plant identification tag (approximately 1.5 cm wide by 7.5 cm long) with a twist tie to the base of the plant. Each tag had the plot number and a unique assigned plant letter.

Self-Compatibility Test

Sixty inflorescences (2 per plot and on the same plant) were chosen for the self-pollination test between June and September 2006, prior to anthesis. One inflorescence per plot (30 inflorescences) was covered by a pollinator exclusion bag made of no-see-um netting (Figure 3). This bag was tied off approximately 1.3 cm below the inflorescence using a cotton string. These 30 bagged inflorescences were randomly assigned to either untouched (15 inflorescences) or hand-pollinated (15 inflorescences). Once the disk flowers had opened, they were hand-pollinated to simulate self-pollination, using a micro detail brush to ensure pollen transfer. The other 30 inflorescences were left under normal conditions, marked as “open.”
In 2005, a single brush was used for all of the bagged/hand selfing treatments which resulted in the potential for cross-pollination; the data collected in this year was discarded because of cross contamination. The methods for the self-incompatibility test were changed in 2006 to avoid cross-pollination. The detail brushes were used once, on a single inflorescence, and then thrown away to avoid accidental cross-pollination. The methods for the self-incompatibility test were changed in 2006 to avoid cross-pollination. Bagged and non-bagged open inflorescences on the same plant were collected approximately 1 month after the placement of the bag under the assumption that by this time seed set, indicated by presence of a visible pappus, should have occurred. Inflorescences were checked for seed set as determined by achene hardness. Achenes that
had been pollinated and contained a seed were firm, while non-pollinated achenes were soft and flexible (Berry and Calvo 1989; Messmore and Knox 1997). A count of firm vs. soft achenes were used to determine percentage of seed set. Although 30 sets of seeds were collected for the self-incompatibility test only 23 sets (46 individual inflorescences) were used for results. The remaining seven sets were invalidated by mold, seed predation, or missing.

Observations of Floral Visitors

Observations of pollinators were made from June to September in 2005 and 2006 while *E. basalticus* was in bloom. All observations were made during daylight hours (nocturnal visitors were not studied), on non-rainy days. On any single day I was unable to visit every plot because observations needed to be made during daylight hours and there was not enough time in one day to visit all plots. Using the 30 plots that were previously established, a computer generated random subset of the 30 plots was selected for each day that observations were made. The observation time at each plot was 20 minutes.

During each 20-minute observation period, each flower visitor that landed on an inflorescence within the plot was documented. A representative sample of each visitor type was collected, assigned a unique number, and later identified to genus. These unique numbers were used as a short hand in the field when identifying and tracking individual flower visitors. If a visitor sample was not collected due to inability to catch it or it was seen only once, the visitor was identified to Order. Secondary observational data were
collected on the number of plants and inflorescences that were visited; these data were documented by drawing the visitor's path within the plot until it left the plot or the 20-minute observation time ended. Data were collected on the number of inflorescences that were available to visitors, indicated by open flowers within the inflorescence.
CHAPTER III

RESULTS

Self-Compatibility Test

Only 46 of the 60 marked inflorescences (23 Open, 11 Bagged, 12 Bagged/Hand-Selfing) were used for the self-compatibility test because some of the inflorescences were destroyed by fungal infection or seed predation, or completely missing (Table 1). For all samples collected the mean number of firm achenes per inflorescence was 31.41 ± 1.56 SE with a minimum of 0.00 achenes and a maximum of 121 achenes. For both "bagged" conditions, the percentage of seed set was low, less than 12%, while the open treatment had as much as 92% seed set.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
<th>Mean Seed Set (%)± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>23</td>
<td>60.47 ± 4.90</td>
</tr>
<tr>
<td>Bagged</td>
<td>11</td>
<td>2.9 ± 1.22</td>
</tr>
<tr>
<td>Bagged/Hand-Selfing</td>
<td>12</td>
<td>1.86 ± 0.59</td>
</tr>
<tr>
<td>Total</td>
<td>46</td>
<td>31.41 ± 1.56</td>
</tr>
</tbody>
</table>

The seed set data did not meet assumptions for parametric ANOVA; the data were non-normal (Bartlett's Test) and had unequal variances (Levene's Test). Therefore, the Kruskal-Wallace ANOVA test was used to determine if there was a significant difference among treatments. This test determined that there was a significant difference (p < 0.05).
A Wilcoxon Rank-Sum Test with BonFerroni adjustment was used to determine significant differences between treatment groups. There was no significant difference between Bagged and Bagged/Hand-Selfing but there was a significant difference ($p < 0.05$) between Open and Bagged treatments as well as Open and Bagged/Hand-selfing treatments. These results indicate that *E. basalticus* is highly self-incompatible though a very minimal amount of selfing did occur.

**Observations of Floral Visitors**

Over the two summers of field study, 645 insect visitors were recorded during 143 observational hours during the months of June through September.

In 2005, 112 *E. basalticus* plants were observed a total of 60 hrs and 20 min. During this time, 189 insect visitors were recorded, averaging one visitor per 20-min observation period; however, this average does not reflect the sporadic distribution of insect visitation. There were observation periods during which insect visitors were not seen, and observation periods when several insect visitors were seen at one time.

In 2006, the same 30 plots were observed for 82 hrs and 40 min. I recorded 456 visitors, averaging 1.83 visitors per 20-min observation period. This average, like that of the previous year, is the compilation of a rather sporadic distribution of visits.

Visitors were identified to genus level rather than species because species could not be determined during field observations (Table 2). During these two years, 89% of insect visitors were small Diptera and Hymenoptera ≤10mm in length. Insect visitors
were recorded as “unknown” if a sample was not collected at some point for identification; the “unknown” categories represent multiple types of insect visitors.

Table 2 All floral visitors collected in 2005 and 2006 along with their frequencies.

<table>
<thead>
<tr>
<th>Visitor Taxon</th>
<th>2005</th>
<th>2006</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Mythicomyia</em> sp.¹</td>
<td>98</td>
<td>70</td>
<td>168</td>
</tr>
<tr>
<td><em>Colletes</em> spp.</td>
<td>15</td>
<td>148</td>
<td>163</td>
</tr>
<tr>
<td><em>Geron</em> sp.</td>
<td>38</td>
<td>123</td>
<td>161</td>
</tr>
<tr>
<td><em>Augochlora</em> spp.</td>
<td>0</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td><em>Cheilosia</em> sp.</td>
<td>17</td>
<td>9</td>
<td>26</td>
</tr>
<tr>
<td><em>Eustalamyia</em> sp.</td>
<td>0</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td><em>Osmia</em> spp.</td>
<td>2</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Unknown Hymenotera (Bee)</td>
<td>5</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td><em>Pseudopanurgas</em> spp.</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td><em>Dianthidium</em> sp.</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Unknown Coleoptera</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Unknown Diptera</td>
<td>4</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td><em>Chetostomoides</em> sp.</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><em>Eristalis</em> sp.</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Unknown Hymenoptera (Wasp)</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><em>Dioctria</em> sp.</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><em>Simulium</em> sp.</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

| N=           | 189 | 456 | 645 |

¹ Number of observations may be inaccurate due to difficulty of tracking individual flower visitors.
² Visitors combined into “other” category in subsequent references due to ≤ 10 visits each year.

The most frequent visitors recorded were *Mythicomyia*, *Geron*, and *Colletes*. These three taxa made up 76.28% of the total aggregate observed visits (Table 2). These three visitors were all small, ≤ 6mm in length. Visitors seen on average ≤ 10 times in each of the two years were combined in the “other” category and further exploration of their
behavior did not occur; this low frequency strongly indicates that they are not reliable pollinators.

The three most frequently observed insect visitors for the combined years were *Mythicomyia, Geron,* and *Colletes* (Table 2); their frequency of encounter ranged from 26% to 25% of the total number of visitors. These three flower visitors showed highly variable frequencies of occurrence in the two years. In 2005, *Mythicomyia* was the most dominant with 52% of the visits. In 2006, *Mythicomyia* sp. frequency decreased to 15% and *Colletes* became the most frequently observed visitor with 32% of all flower visitors. *Geron* frequency was similar across the years, 20% in 2005 and 27% in 2006 (Figure 4). The fourth most commonly observed insect visitor was *Augochlora* (Table 2) with a frequency of 31 total visits, however, it was only observed in 2006.
Figure 4 Frequency distribution of floral visitors by percentage comparing years and total.
In 2005, the three most frequent flower visitors made up 80% of the total visitors, while in 2006, these same three flower visitors made up 79% of the total visitors (Figure 4). In 2006, there were two additional insect visitors (exclusive of “other” category) that were not observed in 2005: Augochlora and Eustalomyia sp. Images of the three most frequent visitors: Mythicomyia, Geron, and Colletes along with Augochlora are shown in Figure 5.

Figure 5 Images of the primary visitors (taken by Diedra Petrina). Top left: Augochlora (~6 mm) Top right: Geron sp. (~4 mm) Bottom left: Colletes (~5 mm) Bottom right: Mythicomyia sp. (~1 mm)
There were no statistical tests done across years to determine if there was a significant difference in visitor frequency because the years were not equally sampled based on time, but the data were standardized by dividing the total number of observations per taxon by the total number of observation hours in each year (Table 3). This standardization shows similar results to the visitor frequency (Table 2) with the top three most frequent visitors being: *Mythicomyia*, *Colletes*, and *Geran*.

Table 3  Number of visits per hour for 2005 and 2006. *Mythicomyia* sp. and *Colletes* sp. had the most visits per hour for 2005 and 2006.

<table>
<thead>
<tr>
<th>Type of Visitor</th>
<th>Year</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Mythicomyia</em> sp.</td>
<td>1.62</td>
<td>0.85</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td><em>Colletes</em> spp.</td>
<td>0.25</td>
<td>1.80</td>
<td>1.14</td>
<td></td>
</tr>
<tr>
<td><em>Geran</em> sp.</td>
<td>0.63</td>
<td>1.49</td>
<td>1.13</td>
<td></td>
</tr>
<tr>
<td><em>Augochlora</em> spp.</td>
<td>0.00</td>
<td>0.37</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td><em>Cheilosia</em> sp.</td>
<td>0.28</td>
<td>0.11</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td><em>Eustalomyia</em> sp.</td>
<td>0.00</td>
<td>0.25</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td><em>Osmia</em> spp.</td>
<td>0.03</td>
<td>0.23</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td><em>Pseudopanurgas</em> spp.</td>
<td>0.17</td>
<td>0.00</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td><em>Dianthidium</em> sp.</td>
<td>0.00</td>
<td>0.1</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td><em>Chetostomoides</em> sp.</td>
<td>0.00</td>
<td>0.02</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td><em>Eristalis</em> sp.</td>
<td>0.00</td>
<td>0.02</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td><em>Dioctria</em> sp.</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td><em>Simulium</em> sp.</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>0.15</td>
<td>0.25</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td><strong>Total Number of Visitors</strong></td>
<td><strong>189</strong></td>
<td><strong>456</strong></td>
<td><strong>645</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total Observation Hours</strong></td>
<td><strong>60.33</strong></td>
<td><strong>82.67</strong></td>
<td><strong>143</strong></td>
<td></td>
</tr>
<tr>
<td><em>µ Visitors per Hour</em></td>
<td><strong>3.1</strong></td>
<td><strong>5.5</strong></td>
<td><strong>4.51</strong></td>
<td></td>
</tr>
</tbody>
</table>

* *Mythicomyia* sp. was very difficult to track due to its tiny size and grouping behavior, so data may not be accurate.*
Number of Plants Visited

Most flower visitors landed on one plant in each plot before leaving (Figure 6). *Geron* and *Cheilosia* were the only two taxa in which some individuals landed on three plants before leaving the plot though this was observed only once for each of these visitors. The data collected for the number of plant visitations by *Mythicomyia* were considered unreliable due to difficulty of tracking these small Diptera and were not used in further analyses.

![Graph showing the number of plants visited by different taxa](image)

Figure 6 The observed frequency distribution of number of plants visited per plot during the 2005 and 2006 seasons combined, (*Mythicomyia* excluded).
Number of Inflorescences Visited

The pattern of number of inflorescences visited is not the same across all flower visitors as it is for number of plants visited. Most *Geron*, *Colletes*, *Augochlora*, and *Eustalomyia* individuals visited only one inflorescence per plot (Figure 7). However, some individuals of all species visited multiple inflorescences per plot, and some *Geron* individuals visited as many as 14 inflorescences in one plot.

Figure 7 The observed frequency distribution of number inflorescences per plot visited by a given insect species during 2005 and 2006 seasons combined.
The Poisson Goodness of Fit spatial pattern analysis indicates that most visitors non-randomly visited a certain number of inflorescences (primarily one inflorescence) with the exception of Augochlora, which was not significant, indicating that it alone showed a random pattern of inflorescence visitation (Table 4).

Table 4 Frequency distribution of inflorescences visited per plot during 2005 and 2006, Mythicomyia excluded. All visitors show a non-random pattern for number of inflorescences visited per plot with the exception of Augochlora spp., which shows a random pattern.

<table>
<thead>
<tr>
<th>Type of visitor</th>
<th>N</th>
<th>( \mu )</th>
<th>Variance</th>
<th>Random/Non-random</th>
<th>Significance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geron sp.</td>
<td>161</td>
<td>1.82</td>
<td>1.76</td>
<td>Non-random</td>
<td>( P &lt; 0.001 )</td>
</tr>
<tr>
<td>Colletes spp.</td>
<td>163</td>
<td>1.49</td>
<td>0.71</td>
<td>Non-random</td>
<td>( P &lt; 0.001 )</td>
</tr>
<tr>
<td>Augochlora spp.</td>
<td>31</td>
<td>2.16</td>
<td>1.47</td>
<td>Random</td>
<td>( P &gt; 0.05 ) no significance</td>
</tr>
<tr>
<td>Cheilosia sp.</td>
<td>26</td>
<td>2.46</td>
<td>7.78</td>
<td>Non-random</td>
<td>( P &lt; 0.025 )</td>
</tr>
<tr>
<td>Eustalomyia sp.</td>
<td>21</td>
<td>1.81</td>
<td>2.16</td>
<td>Non-random</td>
<td>( P &lt; 0.001 )</td>
</tr>
<tr>
<td>Osmia spp.</td>
<td>21</td>
<td>3.11</td>
<td>3.61</td>
<td>Non-random</td>
<td>( P &lt; 0.001 )</td>
</tr>
</tbody>
</table>

Seasonal Patterns of Visitors

Looking at the two years combined, June had the most flower visitors per hour with an average of nine flower visitors per hour. September had the least amount of flower visitors per hour with an average of one flower visitor per hour (Figure 8).

The taxa distributions for 2005 and 2006 changed over the season (Figure 8). In June, the dominant taxon was Mythicomyia making up 62% of the flower visitors. In July, the two dominant taxa in almost equal distribution was Colletes (33%) and Geron (34%), Geron became the dominant taxon in August and comprised 54% of the visitors. In September, Cheilosia was the most dominant taxon comprising 52% of the visitors. Not only did the dominant taxa distribution percentage change over the season but the
total number of taxa during the month as well. July had the most number of taxa 13, while August had the least number of taxa, seven (Figure 9 - Error! Reference source not found.).

![Bar chart showing visitor per hour of observation by month for 2005 and 2006. June of 2005 had the most visits per hour, 12 visits. In 2006, July had the most visits per hour with 10 visits.](image)

Figure 8 Visitor per hour of observation by month for 2005 and 2006. June of 2005 had the most visits per hour, 12 visits. In 2006, July had the most visits per hour with 10 visits.
Figure 9  The 2005 and 2006 visitor distribution percentages by month.
In June, Mythicomyia made up the largest percentage of taxa at 61% and was not observed in September. In July, Colletes and Geron were nearly equal in distribution percentage 34% and 35% respectively. These two taxa individually and together made up the largest proportion of visitors. In August, Geron was observed at 54% of the visiting taxa. In September, Cheilosia was observed at 53% of the visiting taxa. Colletes was observed in almost equal proportions all four months, around 18%, with the exception of July at 34%.

The collective pollinator abundance was greatest in June (Figure 8), coinciding with the warmest recorded temperatures for both 2005 and 2006 (Table 5). September had the coldest temperatures for both years, which is also the month when pollinator abundance was the least.

Table 5 The average and maximum temperatures for each month in 2005 and 2006. Temperate data collected at each plot visited.

<table>
<thead>
<tr>
<th>Month</th>
<th>2005 N</th>
<th>2005 Avg. Temp (°C)</th>
<th>2005 Max Temp (°C)</th>
<th>2006 N</th>
<th>2006 Avg. Temp (°C)</th>
<th>2006 Max Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>127</td>
<td>25.2</td>
<td>36.7</td>
<td>112</td>
<td>30.0</td>
<td>38.1</td>
</tr>
<tr>
<td>July</td>
<td>85</td>
<td>28.1</td>
<td>35.8</td>
<td>281</td>
<td>29.1</td>
<td>34.5</td>
</tr>
<tr>
<td>August</td>
<td>46</td>
<td>25.5</td>
<td>32.5</td>
<td>106</td>
<td>27.2</td>
<td>32.3</td>
</tr>
<tr>
<td>September</td>
<td>66</td>
<td>22.9</td>
<td>28.8</td>
<td>51</td>
<td>23.6</td>
<td>30.1</td>
</tr>
</tbody>
</table>

Averge Maximum Number of Inflorescences

The average maximum number of inflorescences in bloom was calculated for two-week increments starting from June 19th and ending on September 10th for 2005 and 2006 (Figure 10). In 2005, data were not collected in the two-week period from August 14th to August 27th.
In 2005, the least number of inflorescences in bloom was during the two-week period ending on July 2\textsuperscript{nd} with two inflorescences in bloom. The largest number of inflorescences in bloom was during the two-week period ending August 13\textsuperscript{th} with eight inflorescences in bloom; during this two-week period the largest number of inflorescences in bloom recorded was 18 inflorescences on one plant.

In 2006, the least number of inflorescences in bloom was during the two-week period ending on August 27\textsuperscript{th} with 10 inflorescences in bloom (which is two more inflorescences than the largest number of inflorescences in bloom in 2005). The largest number of inflorescences in bloom was during the two week period ending September
10th with 14 inflorescences in bloom. The largest number of inflorescences recorded in bloom at one time was 50 on one plant in mid to late July.
CHAPTER IV

DISCUSSION

Self-Compatibility Test

Self-compatibility tests indicate that *E. basalticus* is highly self-incompatible. The low seed set per inflorescence in both bagged treatments (2% seed set) versus the open treatment high seed set per inflorescence (60%). This is strong evidence that *E. basalticus* is self-incompatible and indicates that *E. basalticus* is dependent on its pollinators for successful seed set. Similar results have been found in many other species of Asteraceae, for example: *Gorteria diffusa*, *Espeletia*, *Achillea ptarmica*, and *Helenium virginicum* (Andersson 1991; Berry and Calvo 1989; Cheptou and others 2001; Colling and others 2004; Johnson and Midgley 1997; Les and others 1991; Maki and others 1996; Messmore and Knox 1997).

While *E. basalticus* is primarily self-incompatible, there is evidence of some self-pollination as shown in the bagged seed set results (Table 1). However, there are other possible explanations for the results observed for the bagged seed set. It is possible that a flower visitor somehow got inside the exclusion bag and pollinated some of the flowers; although no visitors were observed inside the exclusion bags. If this occurred it is more likely that a flower visitor found an opening where the exclusion bag was tied vs. fitting through one of the holes in the no-see-um netting (Figure 3) because the holes are very
tiny (0.4mm by 0.6mm). The only flower visitor that may have fit through the holes due to its size is *Mythicomyia*.

Documentation indicates that some plants, which are primarily self-incompatible, can show signs of selfing when there is low pollinator abundance or when pollinators are absent. This attribute insures seed set (Fausto and others 2001; Kalisz and Vogler 2003; Les and others 1991; Motten 1982). It is possible that the minimal self-pollination occurring in *E. basalticus* is an indication that there are regular periods when pollinator abundance or efficiency (low pollen transfer would be similar to low abundance) is low or absent. This study did not determine if there were periods of selfing and non-selfing. If we assume that *E. basalticus* is capable of selfing when there are periods of low pollinator abundance or efficiency I suspect that June and September would show signs of self-pollination. September had the lowest pollinator abundance with an average of approximately 1 visitor per hour. In June, Mythicomyia made up approximately 65% of the visitors and I do not believe that this insect visitor is an efficient pollinator (Figure 8 & Figure 7). While this study was not designed to determine if selfing occurs when pollinators are uncommon or inefficient I suspect that this may be occurring; future research needs to be conducted to answer this question.

**Inflorescence Data**

In the first year of the study, 112 plants were identified for observation and these same plants were again observed in the second year of the study. *Erigeron basalticus* inflorescences were more prolific in 2006 than 2005 (Figure 10). The increased number
of inflorescences in 2006 may have had a positive impact on the number and frequency of taxa observed. In 2006, there were eight more insect taxa documented than in 2005 and I observed 2.4 more insects per hour in 2006 than in 2005 (Table 3).

Published literature and my observations do not explain why there was a difference in the number of inflorescences in bloom in 2005 vs. 2006; however, precipitation, temperature, age of the plant, and other factors might have been important reasons. Temperature was slightly warmer in 2006 than in 2005 (Table 5) but further investigation needs to be conducted to understand the causes and effects.

Observations of Floral Visitors

The data from two seasons of observations do not conclusively indicate the pollinating species of *E. basalticus*, they should, however, focus future research initiatives and eventually future management decisions and strategies.

There were 17 different categories of visitors observed for 2005 and 2006. In 2006, there were seven taxa observed that were not observed in 2005. In 2005, only one taxa was not observed in 2006 (Table 2). While all flower visitors collectively are important for pollination, some are more important than others in their ability to successfully pollinate *E. basalticus*. The following three variables were used to determine the important pollinators: 1) visitor frequency; 2) consistency of visitation; and 3) pollinator morphology (potential pollen load based on body hair). The visitor(s) that have all three characteristics are considered to be the most important flower visitor(s).
Visitor Frequency

Collectively the most frequent insect visitors were *Mythicomyia*, *Geron*, and *Colletes*. These three visitors comprised 76% of the total aggregate visits (492 of 645 visits) while the remaining fourteen visitors comprised less than 24% of the total aggregate visits (153 of 645 visits). *Mythicomyia*, *Geron*, and *Colletes* were observed in almost equal proportions, 25%. *Augochlora* was the fourth most frequent visitor making up 5% of the total distribution.

While the top three most frequent visitors were seen in almost equal proportion for combined years, their proportions were different between years. In 2005, *Cheilosia* is one of the top three most frequent visitors (but drops to number 6 for overall). In 2006, *Colletes* is the most frequent visitor and *Mythicomyia* drop to third. During both years, *Geron* stayed consistent as the second ranked visitor with approximately 25% of the visitors. The determination of visitor importance is different when this is accomplished for each year separately than if the combined data are used. In 2005, the most important insect visitors (based on frequency) in order are: *Mythicomyia*, *Geron*, and *Cheilosia* sp (*Colletes* is only 1% different from *Cheilosia*). In 2006, the most important insect visitors in order are *Colletes*, *Geron*, and *Mythicomyia*. It is unknown which of these years represent a more “typical” year. More research is required to understand the yearly differences.
Consistency of Visitation

If an insect is going to be considered a primary pollinator, it is important that it visits year after year. When a visitor does not show up, then pollination does not occur through that vector and we cannot consider it a primary pollinator even if it is very efficient at transferring pollen when it does visit. However, we can say that it is an important pollinator in the year that it visits.

Out of 13 different visitors (excluding the “unknown” categories) only 5 were seen both years, this includes Mythicomyia, Colletes, and Geron. In 2006, there were twice as many genera as 2005. It is uncertain which, if any, of these years are “normal.”

Seasonal Patterns of Visitors

When looking at the season as a whole, the identified primary pollinators appear to be important throughout the season, but when the season is divided into months, there is a shift in visitor distribution and these identified primary pollinators are not always available, therefore other visitors become important.

Month by month, the visitor distribution changes and so does the number of visitors per hour. Collectively, there were more visitors per hour in June, about 9 visitors per hour. The number of visitors per hour decreased each month. September had the least number of visitors per hour, about one visitor per hour (Figure 8) while it is possible that the change in number of visitors per hour can be affected by temperature, I do not believe
that the temperatures during the research period had a negative influence on insect flight. The average temperature for both 2005 and 2006 was above 22 degrees Celsius easily warm enough for maximum flight movement (Table 5) (Taylor 1963).

The number of visitors per hour is not the only difference between months as there is also a change in the dominant visitor and number taxa. In June, Mythicomycia makes up more than half of the visitors but in July, it makes up about 10% of the visitors, and is almost nonexistent by August. In July and August Geron is dominant yet in September was not observed at all. In September, Cheilosia made up more than half of the visits. Colletes made up about 25% of the visits all four months. Augochlora was mostly present in July and August (Figure 9). July had the most number of taxa.

As the visitor distribution changes throughout the season the importance of visitors changes based on their frequency. Not a single flower visitor, with the exception of Colletes, is a dominant flower visitor all four months. Colletes appears to be the most important flower visitor based on being the only flower visitor seen all four months and it was the second most frequent visitor each month. However, it is important to recognize that all visitors collectively successfully pollinate E. basalticus and should be considered important as a whole.

This study did not compare the number of achenes per month and taxa visiting, it would be interesting to see if seed set were equal all four months. This information may help determine efficiency of pollinators.
Visitor Morphology

Images of the top three most frequent visitors are shown in Figure 5 and can be examined for body hair. *Mythicomyia* does not have any visible body hair, its ability to collect and transport pollen is very questionable and pollen was never observed on the body of *Mythicomyia*. If *Mythicomyia* is incapable of collecting pollen, due to absence of body hair, then it cannot be considered a pollinator. Another limiting factor in the ability of *Mythicomyia* to transport pollen is its small body size, ~1 mm in length. While *Mythicomyia* was the most frequently observed visitor (26%) collectively, its small body size and minimal hair may reduce its pollen carrying and transferring capabilities.

*Geron* and *Colletes* both have hair on their bodies, *Geron* more than *Colletes*. Pollen was observed on the heads and proboscis of both *Geron* and *Colletes* but not in pollen baskets. These visitors were seen in both years and were in the top three most frequent visitors. Based on these observations I would conclude that *Geron* and *Colletes* are the most likely candidates for being primary pollinators.

While *Geron* and *Colletes* are most likely responsible for the majority of successful seed set and *Mythicomyia* is likely less important, there is one other flower visitor that stands out as a potentially important pollinator; *Augochlora*. *Augochlora* was observed 5% of the time, it was the fourth most frequently observed visitor after *Mythicomyia*, *Colletes*, and *Geron*. Despite its low frequency of occurrence *Augochlora* is likely important because of the visible pollen load carried in its pollen baskets (Figure 5). This pollen load may make this visitor very efficient at transferring pollen, and
therefore, a high visiting frequency may not be needed as much as for a visitor that carries a smaller pollen load. *Augochlora* was not observed in both years but data were only collected for 2 years; more data needs to be collected to determine if *Augochlora* is a regular visitor.

*Geron* and *Colletes* are most likely the primary pollinators, *Mythicomyia*, and *Augochlora* are probably important pollinators. It is still possible that the other taxa may have an important role in pollination. Combined, these taxa made up 23% of the visitors and some of the visitors are considered by others to be effective and efficient pollinators. While these flower visitors were not frequently observed, their efficiency of carrying and transferring pollen may compensate for their low visitation rate (Inouye and others 1994; Kendall and Solomon 1973; Talavera and others 2001). These visitors include *Augochlora*, *Osmia*, and *Eristalis*. According to a study done by Kendall and Solomon, *Osmia rufa* and *Eristalis tenax* carried a large amount of pollen on their bodies.

High visitation frequency, visitation observed in consecutive years, and potential pollen load based on body hair (more hair, more pollen) are the variables used to determine primary pollinators. While all visitors may be important for pollination, I conclude that the following two potential pollinators are the ones most likely responsible for the majority of successful pollination in *E. basalticus*: *Geron* and *Colletes*.

**Number of Inflorescences**

The number of visitors per hour was different between years. There was an 85% increase in visitors per hour in 2006 vs. 2005 (Figure 8). This difference may have been
influenced by weather (wind, precipitation, or temperature), pesticides from a nearby orchard, or the number of inflorescences available. In 2006, there was an average of seven more inflorescences in bloom than in 2005. It is possible that the greater number of inflorescences attracted more taxa and increased visitation frequency (Fausto and others 2001). It is unknown what caused this difference in the number of inflorescences in bloom. It could have been precipitation, nutrients, and/or pollutants in the environment. On the other hand, the bloom number may not be causal for number of visitors and instead, there may be a common environmental factor (such as severe winter temperature) that influences both factors in a similar direction. This may explain why fewer visitors and number of inflorescences were seen in 2005 than in 2006.

Number of Plants and Inflorescences Visited

The interplay among number of inflorescences and visitors may affect successful seed set. Insect behavior when visiting an inflorescence may also affect seed set and gene flow. All visitors (Geron, Colletes, Augochlora, Cheilosia, Eustalomyia, and Osmia) exhibited a "uniform" pattern when visiting plants within a plot, generally visiting one plant within the plot and then leaving. While all visitors exhibited this same behavior, Geron and Colletes typically only visited one inflorescence on a plant before leaving. Cheilosia, Eustalomyia, and Osmia which instead visited 1-5 inflorescences per plant. This behavior may be very important for genetic recombination. If the visitor went from one inflorescence to the next closest one this might result in too much near neighbor
inbreeding and increasing the chances of lower fitness. The behavior of the existing visitors may be very important for out crossing success.

_Geron_ sp.

According to Hull the genus _Geron_ is partial to composites and is attracted to yellow flowers; _E. basalticus_ has both of these attributes. _Geron_ is probably one of the two taxa that is an important pollinator responsible for the majority of successful seed set in _E. basalticus_. _Geron_ was one of the few flower visitors that met all three criteria used to determine visitor importance.

_Geron_ was the third most frequently observed flower visitor, 25% of total visits. _Geron_ was observed in almost equal proportions in both years; 20% in 2005 and 27% in 2006 and during the months of June, July, and August. _Geron_ was the most abundant taxon in August composing of 54% of the total visitors (Figure 9). I noted however, that in 2005 and 2006 _Geron_ was abundant until about the time when the rabbit brush began blooming; at which time _Geron_ was observed only on the rabbit brush.

Typically, after _Geron_ landed on an inflorescence it would probe individual flowers until (I assume) it found nectar. The visual signs that this taxon was probing was very distinctive. Because they have relatively large proboscis that they do not retract, they are required to straighten their legs out so they are taller than the proboscis. Once the proboscis is in position _Geron_ does a series of push-ups to insert its proboscis into the flower. If another _Geron_ lands on the inflorescence that another _Geron_ was feeding on both fly up off the inflorescence, hover and only one returns to the same inflorescence.
while the other goes to a different inflorescence. It was unusual to see more than one *Geron* on a single inflorescence. While observing *Geron* probe for nectar, pollen was visible on the proboscis and head area. *Geron*, when attempting to land on an inflorescence, displayed an interesting behavioral pattern that I called “yo-yoing”.

Demonstrating this behavior, the fly would come close to the inflorescence, retreat 8 - 15 centimeters away from the inflorescence, and then fly back toward the inflorescence. This “yo-yoing” pattern repeated several times before landing. This may be a behavioral trait to avoid being captured by a spider or other predator waiting on the flower.

*Colletes* spp.

*Colletes*, which is a member of the yellow-faced and Plasterer bee family, is the second flower visitor that is important in the pollination of *E. basalticus* because it meets the three criteria used to determine visitor importance. However, *Colletes* may not be as effective as *Geron* because the hair on the body is minimal and this genus is known for eating pollen and nectar that is then used to create a material that they line their nests with (Arnett 2000; Hefetz and others 1979). *Colletes* was observed in almost equal distribution all four months, July having the highest distribution percentage of 33%. *Colletes* seasonal distribution may mitigate for its low amount of body hair. Pollen was mostly seen on the face as a dusting rather than a pollen load. However, some researchers believe that smaller pollen loads actually produce more seeds than larger pollen loads once the pollen has been transferred to pollen baskets (Young and Young 1992). If this is
true then *Colletes* might be more important than *Geron* because it was a prominent visitor in both years.

*Augochlora* spp.

*Augochlora* may be an important flower visitor even though it did not meet all three requirements (it was not observed in both years) because its body was covered in hair and large amounts of pollen were frequently visible on its body. It is believed that insects with more hair will carry more pollen than insects with very little hair prior to transferring pollen to pollen baskets (Kendall and Solomon 1973). Because only two years were sampled and *Augochlora* was documented in only one of those years, I recommend collecting data for several more years to determine if *Augochlora* is a regular visitor. If *Augochlora* is documented as a regular visitor then I would consider *Augochlora* to be an important pollinator.

The year that *Augochlora* was present it was recorded as a visitor from July to the end of the study in September, becoming increasingly important in July and August.

*Mythicomyia* sp.

These were the smallest of the visitors that I observed (~1 mm in length). They often occurred in large groups flying around the plants but did necessarily land on the inflorescence of *E. basalticus*. Due to their tiny size and grouping behavior, it was difficult to track an individual’s movements and distinguish one individual from another;
data collected on this genus may be less accurate than for other species due to the difficulty of tracking them, therefore, further examination of their behavior was not conducted.

These tiny flies were not very timid and often I was able to observe them with a hand lens on the inflorescence. As I observed them on the inflorescence, it appeared that many of them were eating pollen; I did not notice any pollen attached to their bodies.

Because of their size, lack of hair on their bodies, and behavior, their pollinating abilities may be minimal. However, their great numbers require that I comment on their presence during the first part of the season (June and July). *Mythicomyia* has been reported to be active from March through September but more commonly present from April to June and then again in September (Hull 1973). According to Hull, *Mythicomyia* will visit many flowering plants but are partial to some families; Asteraceae is not on Hull’s documented list of families typically visited.
CHAPTER V

CONCLUSION

_Erigeron basalticus_ is a highly self-incompatible, and therefore, pollinators are extremely important for successful pollination. While all visitors may be important for pollination, I conclude that _Geron_ and _Colletes_ are the two key pollinators based on the three requirements: 1) frequency of visitation; 2) consistency of visitation; and 3) pollinator morphology. I do not categorize _Augochlora_ as an important pollinator because it failed criteria number one - it was not observed visiting _E. basalticus_ in both years. However, in the year that it did visit _E. basalticus_ it frequently had a large pollen load. Barring other criteria, _Mythicomyia_ may be an important pollinator because it meets two of the requirements. However, if _Mythicomyia_ cannot carry pollen due to its very small size and lack of body hair it should not be considered a pollinator at all.

Based on this study _Geron_ and _Colletes_ are most likely the primary diurnal pollinators of _E. basalticus_ but further research needs to be done to confirm this. I suggest identifying pollen on the insect visitors to verify that they are carrying pollen from _E. basalticus_.

Directions for future study of _E. basalticus_ may also include: identifying any nocturnal pollinators; determining if _E. basalticus_ does accomplish self-pollination when pollinator visitation rates are low; determining whether are all sub-populations of _E._
basalticus in the Yakima Canyon function as one population; and lastly determine whether E. basalticus is pollen limited.
REFERENCES


