

Title/Keywords:

The Effect of Climate Change on Two Primitively Eusocial Bees

Keywords: Solitary bees, primitive eusociality, phenology, climate change, RMBL

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Abstract:

High altitude regions are likely to be highly affected by climate change. Pollinators such as bees in these regions may have to change life history traits to survive. Because eusociality is associated with reduced mortality and increased resilience to resource variation, primitively eusocial bees may become increasingly social. Using data from 2010-2017 in the Irwin bees dataset, I evaluated the hypothesis that a warming climate will increase the probability of sociality in primitively eusocial bees. Social bees form two broods: one of workers, and one of breeders. Solitary bees typically have one brood. Measuring the difference in male and female emergence over time will allow me to assess sociality, that can be used to draw conclusions about the social status of bees known to be primitively eusocial. I would expect that bees that are eusocial will only produce males near the end of the female flight season, whereas bees that are solitary will produce males and females throughout their flight season. I found no significant effects, suggesting that *Halictus virgatellus* and *Halictus rubicundus* are not changing in sociality. A lack of male abundance data may also be influencing these trends. By better understanding changes in social strategies, it is possible to evaluate how a changing climate may affect the expression of life history traits which could buffer bees from the effects of climate warming.

Introduction:

As more research on climate change is conducted, further evidence suggests that climate change can have serious effects on life history traits. In birds, climate change is suggested to have effects on distribution, reproduction, and population size of many birds (Rodenhouse 2007). Group behaviors of breeding are also common in birds as a way to reduce mortality (Kingma 2010) and may be affected by climate change. Direct and indirect effects of climate change also heavily impact insects (Kiritani 2013), which exhibit social behaviors in certain groups. Hymenoptera, including bees, are especially noted as model systems for the study of social behavior in insects (Jandt 2014, Packer 1991, Eickwort 1996, etc).

Solitary bees make up 75% of bee species. However, not all of these species are strictly solitary. Instead, some solitary species vary in their degree of sociality within a species, from solitary to primitively eusocial. For example, species are often categorized with labels such as social, semisocial, and eusocial. However, some species exhibit

certain traits of sociality and are known as primitively eusocial. Primitively eusocial bees typically have multiple broods per year, cooperative breeding, and castes. Primitively eusocial species can also have generational overlap. However, the castes in these bee species usually have small differences in morphology compared to those that are considered fully eusocial (Gibbs et al. 2012).

Many bees in the genera *Lasioglossum* and *Halictus* have expression of alternative social behaviors that are generally correlated with environmental factors such as altitude (Kocher et al. 2014). Despite genetic explanations for social and solitary behaviors, sociality is also correlated with mean snowfall (Soucy and Danforth 2002). As mean snowfall continues to decrease and become more variable due to the effects of climate change (Benniston and Fox 1996), social behaviors may begin to change. For example, bees in the *Halictus* genus were found to be more social under harsher weather conditions (Packer 1986a). In addition, if mean foraging days become long enough, bees with social plasticity that are typically solitary at high altitudes may become social. Growth time may constrain sociality at high altitudes (Kocher et al. 2014) and thus as growing seasons increase with increased temperature, they will have enough growth time to produce two broods: one mostly of a working caste, and one of a breeding caste as is typical in social bees (Michener 1974).

Social bees tend to have lower brood mortality from parasitism which increases with temperature (Forrest and Chrisholm 2016) and increased adaptability to variable foraging conditions (Rehan et al. 2011). This may result in changing ecological interactions with the subalpine environment present at RMBL and may suggest changes in sociality at other similar sites. Changes in sociality may result in changes in foraging behavior and pollination, which could have ripples throughout the ecosystem and result in niche restructuring. Although the effects of elevation on sociality and the sociality of some solitary bees at RMBL have been previously measured (Eickwort et al. 1996), they have not been examined in the context of climate change which is now possible with the Irwin long-term dataset.

The degree to which populations of bees are social vs. solitary can be estimated through the later emergence dates of males in relation to females with increasing warming, because breeding males are mostly in the second brood of social bees (Yanega 1993). Thus, shifts in male emergence compared to females can be used to show the change in breeding strategies of primitively eusocial bees. *Halictus* bees are especially relevant for this research because species such as *Halictus rubicundus* have been shown to have varying social behaviors at different altitudes (Eickwort et al. 1996), and thus have some degree of social plasticity.

Hypothesis:

As climate change hastens snowmelt, the growing season of primitively eusocial bees will become longer and will result in higher levels of sociality in these bees, which is measurable through later emergence timing and flight season of males compared to females because of the development of multiple broods of offspring.

Predictions:

1. As snowmelt becomes earlier, primitively social bees will increase in sociality at high altitudes.
2. Male emergence will become later in and correlate negatively with earlier snowmelt date.

Methods:**Field Sampling:**

At 16 sites, data are collected along two 42m transects that are approximately perpendicular in orientation. Data collection involves three phases: netting, bee bowls, and plant evaluation. Netting involves walking along the transects and catching all bees in sight for one hour each in the morning and afternoon. Bees that are caught are placed in ethanol vials for pinning at the lab, and date, survey time (AM or PM), surveyor, and plant caught on are all recorded. Bumble bees are field identified and marked to avoid recaptures. Bumble bees are classified according to caste, species, and plant caught on.

Bee bowls are placed upon arrival at the study site approximately 3m apart, with a total of 15 per transect. The time bee bowls are placed and picked up is recorded. Bee bowls are painted white, fluorescent yellow, and fluorescent blue to avoid bias in bee preference. The bowls passively sample the bees. Bees in bee bowls are placed in vials according to the color bowl they are found in and taken back to the lab.

Plant evaluation is done at 3 by 2x2 m plots along each transect. Only blooming plants are counted. The number of flowers on the first ten blooming plants in the transect are counted, as well as the number of total blooming plants. Plants blooming outside of the transects are also recorded. All plants are also ranked 1-3 according to relative abundance at the site (1 equals less than 10 blooming plants, 2 equals 10-50 blooming plants, and 3 equals greater than 50 blooming plants).

Lab work:

Specimens taken back to the lab are labeled, pinned, and shipped to researchers for identification. After identification, specimens are uploaded to the Irwin bees long term dataset. Data sheets containing information about plant transects and *Bombus* field data are also uploaded.

Data analysis:

To analyze the sociality of *Halictus* species, the emergence timing of males was examined using the Irwin bees dataset ranging from 2009- 2017. Data from 2009 was

excluded because of the small number of bees recorded that year. Species included in the analysis were those listed by Danforth (2002) as primitively eusocial and with sample sizes of greater than 20 per year, which include *Halictus rubicundus* and *H. virgatellus*. The focus of this study was on variation among years rather than sites. To obtain enough data on males and females within years, data were pooled across sites within years. Because sociality can be measured based on the emergence date of males compared to females, I used a generalized linear mixed model with female and male phenology as the response variable. The predictor variable was snowmelt day of year, with sex as a factor. Snowmelt day of year was obtained from billy barr's long-term snowmelt data. Dates were converted to numeric day of calendar year. Interactions with sex and snowmelt day of year were also used. I analyzed the following phenophases: emergence (the date 5% of bees emerged by), timing of peak abundance (the day with the highest number of bees), senescence (the date 95% of bees emerged by), and flight period (emergence – senescence). All calculations were performed in R-studio.

Results:

None of the interactions between snowmelt day of year and sex were significant for the emergence (fig. 1 and 2), senescence (fig. 3 and 4), flight period (fig. 5 and 6), or peak abundance timing (fig. 7 and 8), suggesting that variation in snowmelt timing did not differentially alter female compared to male phenophases. Snowmelt day of year was marginally significant for timing of peak abundance of *H. rubicundus* ($p = .073$, fig. 8). Snowmelt day of year had a positive relationship with both the males and females of *H. rubicundus* and *H. virgatellus* for emergence, peak abundance, and senescence. *H. virgatellus* had a weak positive relationship with snowmelt day of year and sex for flight period. *H. rubicundus* had a slight negative correlation for male flight period and a positive relationship with female flight period.

Discussion:

None of the interactions between snowmelt day of year and sex were significant, suggesting that sexes did not differentially respond to variation in snowmelt timing. Most phenophases for both species followed a positive association with snowmelt timing for both sexes. Because male phenophases were not negatively correlated with snowmelt day of year, this suggests that sociality is not increasing in earlier snowmelt years within these two species. However, the slight divergence in *H. rubicundus* flight period (fig. 6) may suggest that some slight changes in males are occurring. This is because divergence illustrates different trends in male and female flight period compared to snowmelt. As divergence increases, this may suggest the development of a second brood of bees, which supports the hypothesis of increased sociality. Future research could focus on a comparison of more species to see if this trend is supported more generally.

Because male abundance was low overall, the data were skewed and followed a non-normal distribution. A follow-up study with more species is recommended. The lack of male abundance was also frequent in the Irwin database, but further research is

needed on male abundance because it is not known if low male abundance is a function of sampling method or if it represents actual low male abundance in the ecosystem.

Conclusion:

Further research is needed to confirm if male-female divergence is occurring in other species. As climate change continues to alter the floral and other resources of bees, changes in sociality may occur in bees with social plasticity. Increased parasitism and other climate change related pressures may accelerate these changes.

Figures:

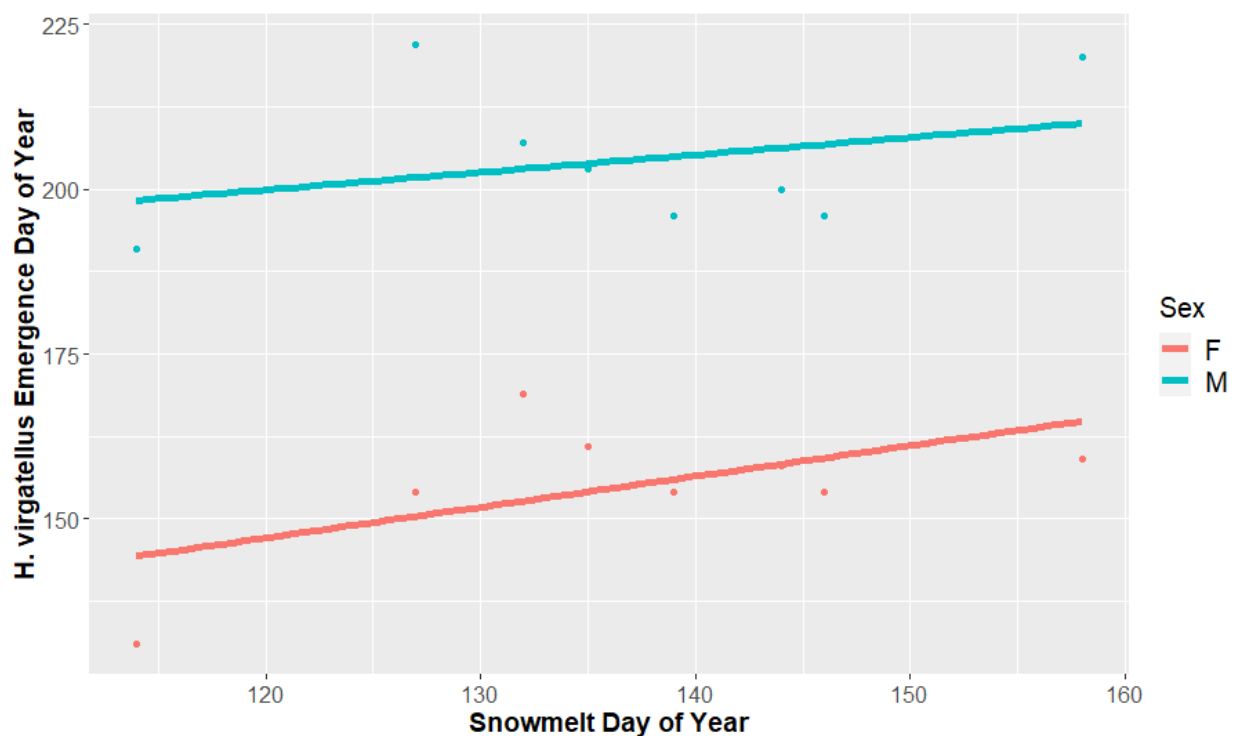


Fig. 1 illustrates the emergence date of *H. virgatellus* compared to snowmelt day of year. A general positive relationship exists between emergence date for both males and females. All effects from the linear model were non-significant.

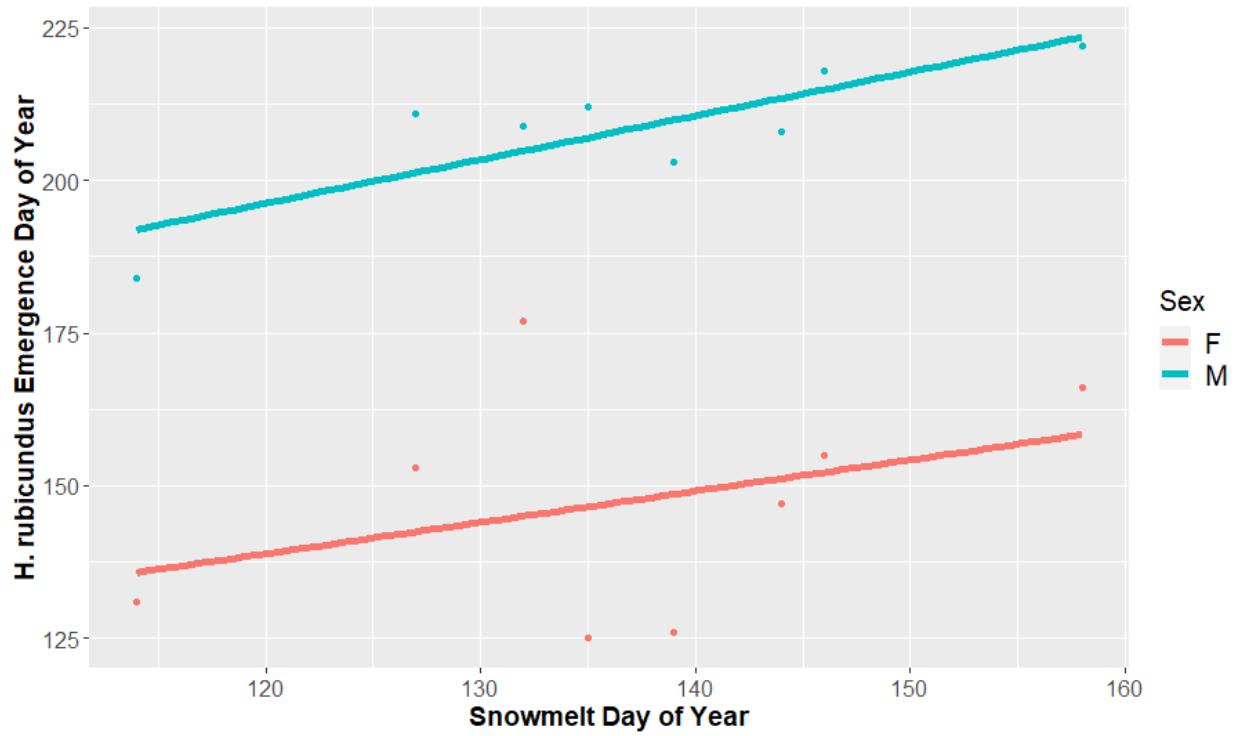


Fig. 2 illustrates the emergence date of *H. rubicundus* compared to snowmelt day of year. A general positive relationship exists between emergence date for both males and females. All effects from the linear model were non-significant.

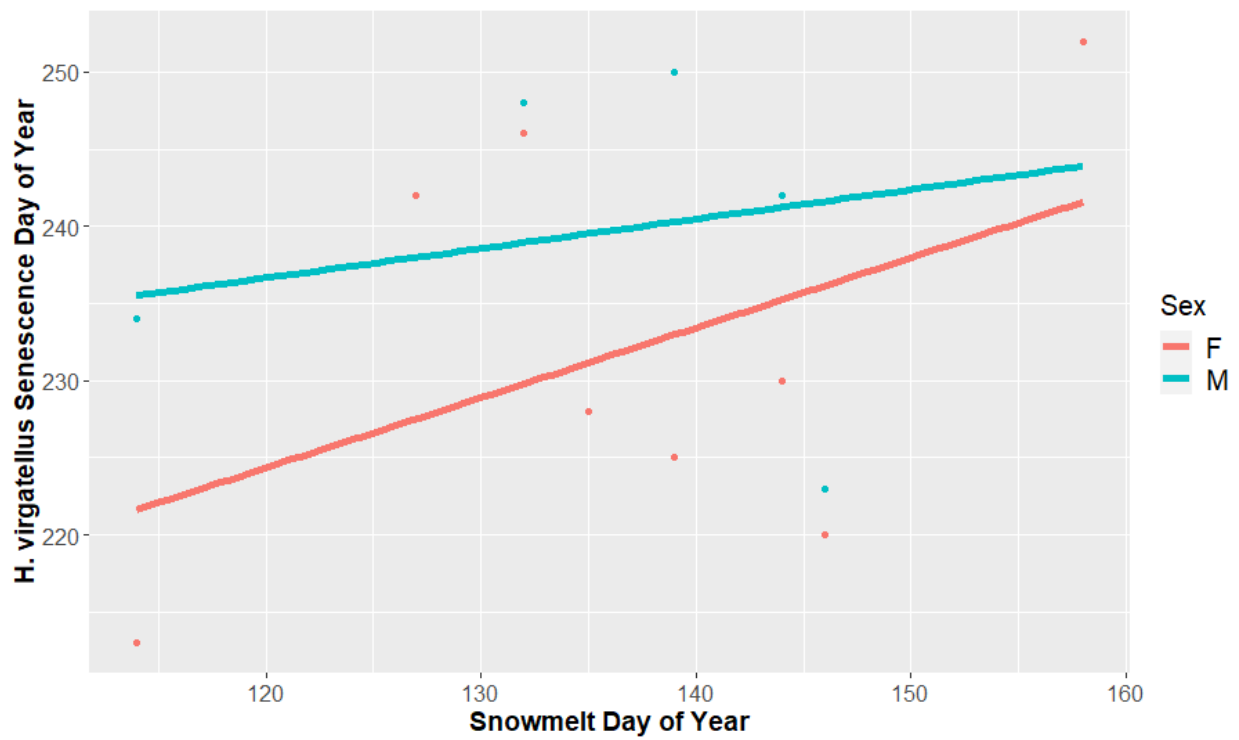


Fig. 3 illustrates the senescence date of *H. virgatellus* compared to snowmelt day of year. A general positive relationship exists between emergence date for both males and females. All effects from the linear model were non-significant.

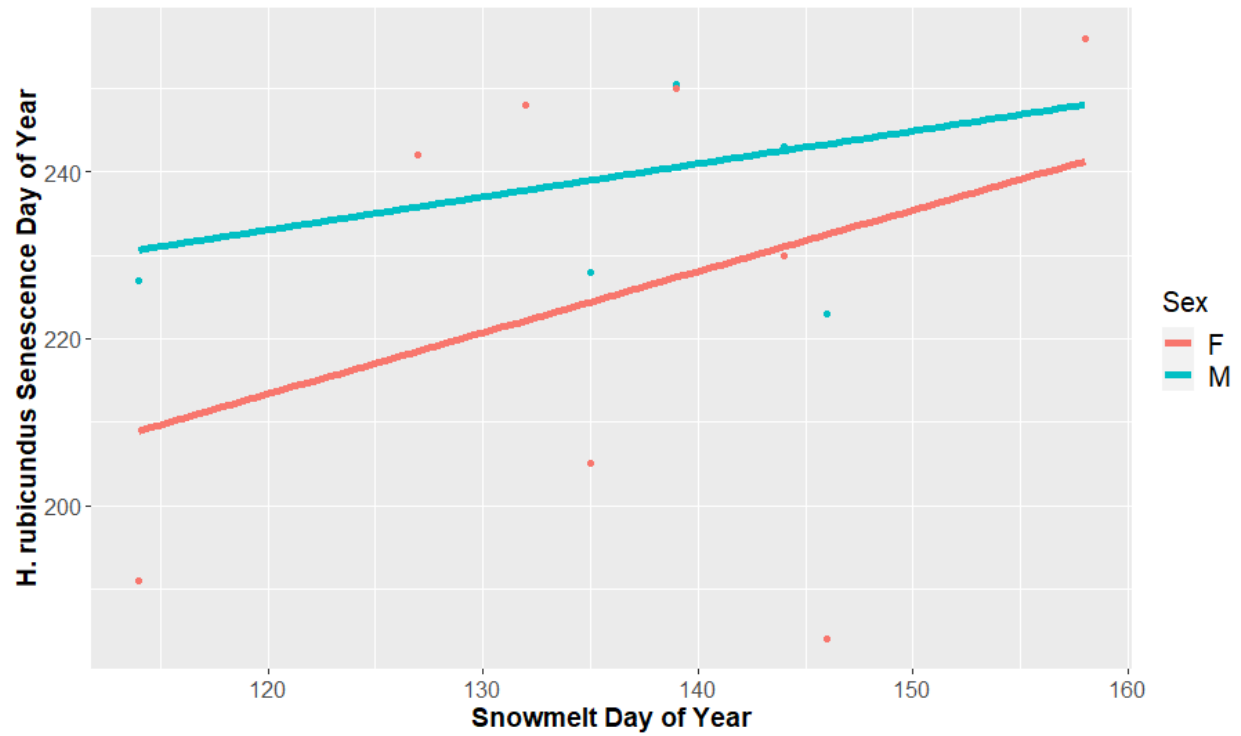


Fig. 4 illustrates the senescence date of *H. rubicundus* compared to snowmelt day of year. A general positive relationship exists between emergence date for both males and females. All effects from the linear model were non-significant.

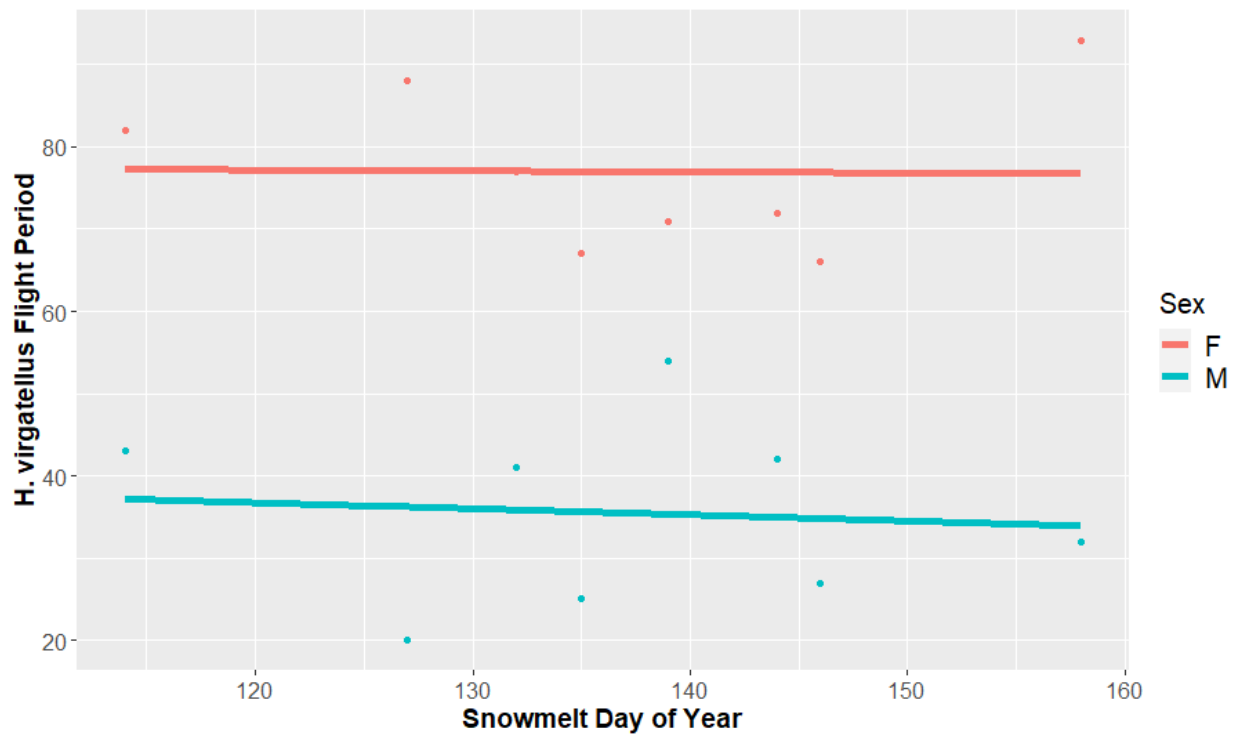


Fig. 5 illustrates the flight period of *H. virgatellus* compared to snowmelt day of year. Slope was nearly 0 for both males and females. All effects from the linear model were non-significant.

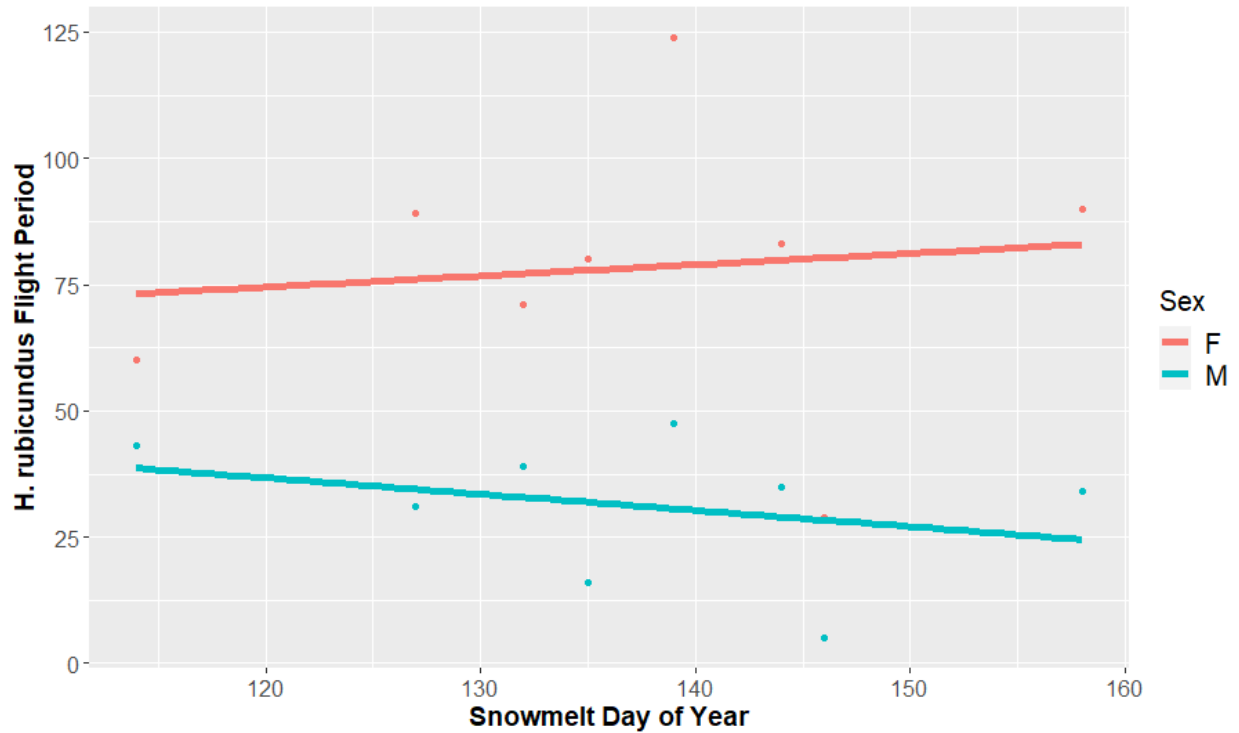


Fig. 6 illustrates the flight period of *H. rubicundus* compared to snowmelt day of year. A general positive relationship exists between emergence date for females. Males had a slight negative relationship between snowmelt date and flight period. All effects from the linear model were non-significant.

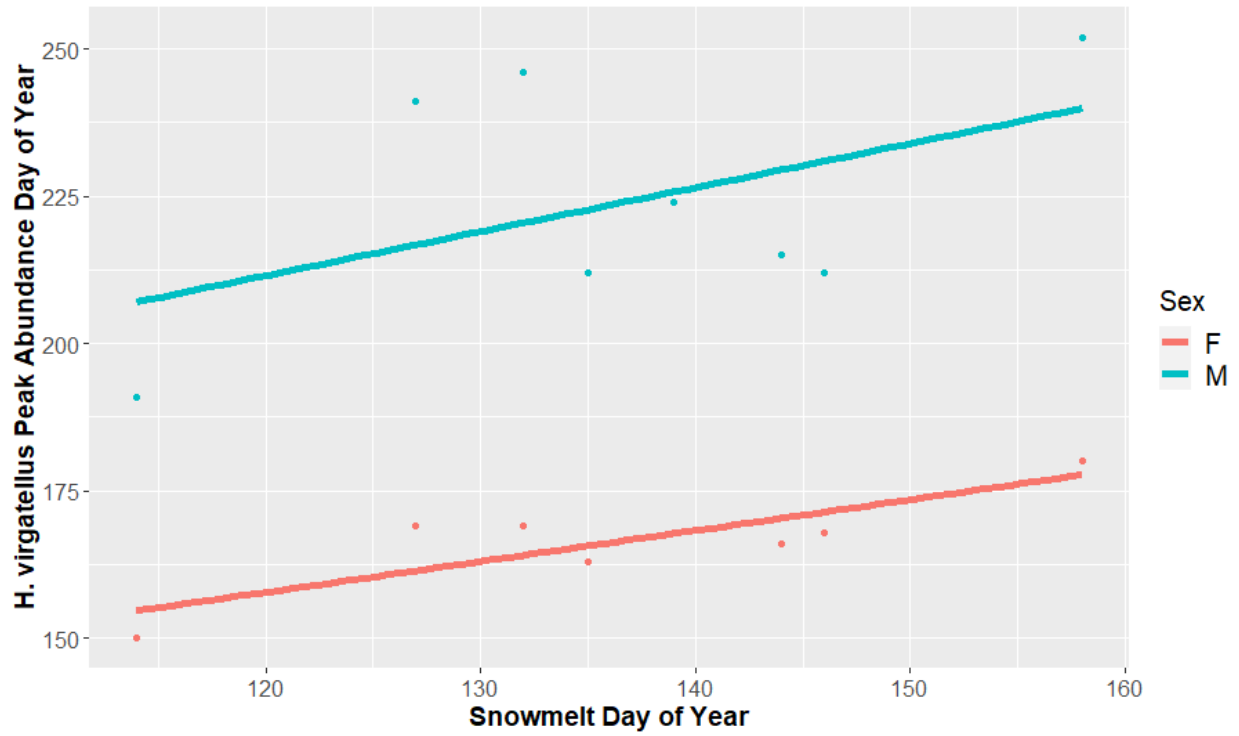


Fig. 7 illustrates the peak abundance of *H. virgatellus* compared to snowmelt date. A general positive relationship exists between emergence date for both males and females. All effects from the linear model were non-significant.

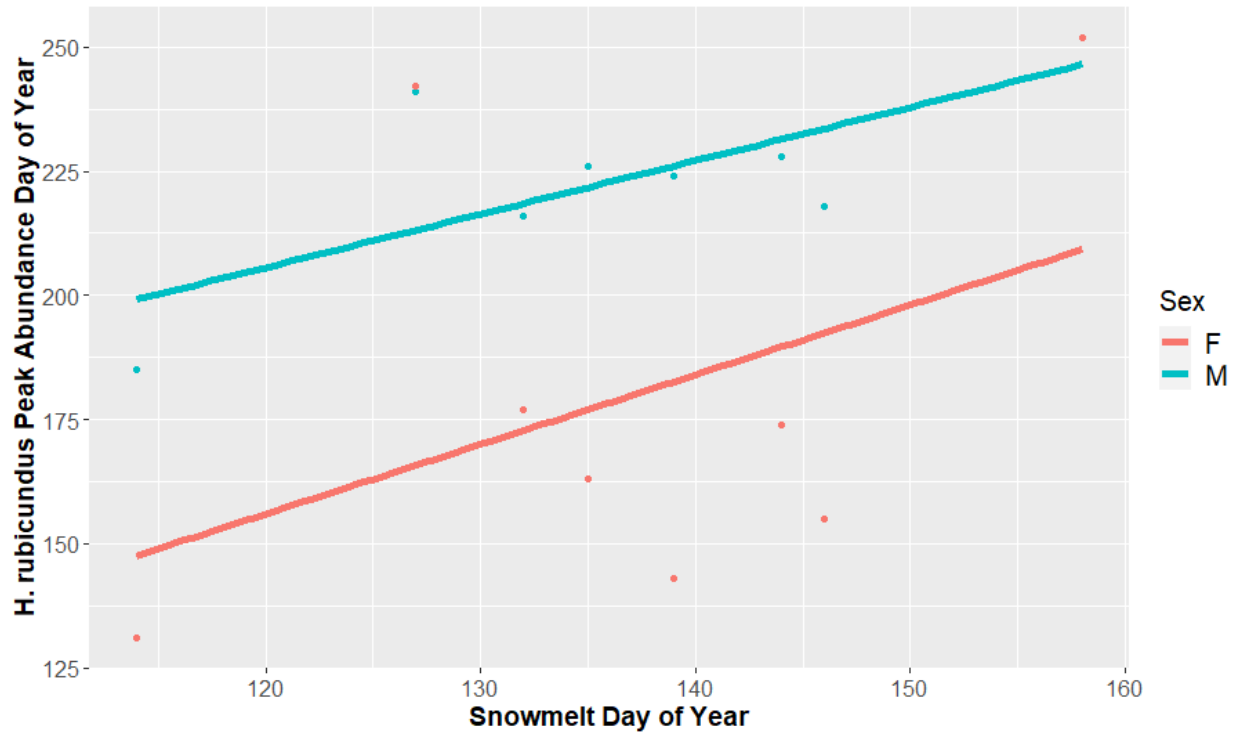


Fig. 8 illustrates the peak abundance of *H. rubicundus* compared to snowmelt day of year. A general positive relationship exists between emergence date for both males and females. Snowmelt date was marginally significant ($p = .073$). Sex was not significant.

Study Sites



Fig. 9 shows the study sites known as Almont and Almont Curve. These sites are transects marked by GPS markers on the ESRI satellite basemap.

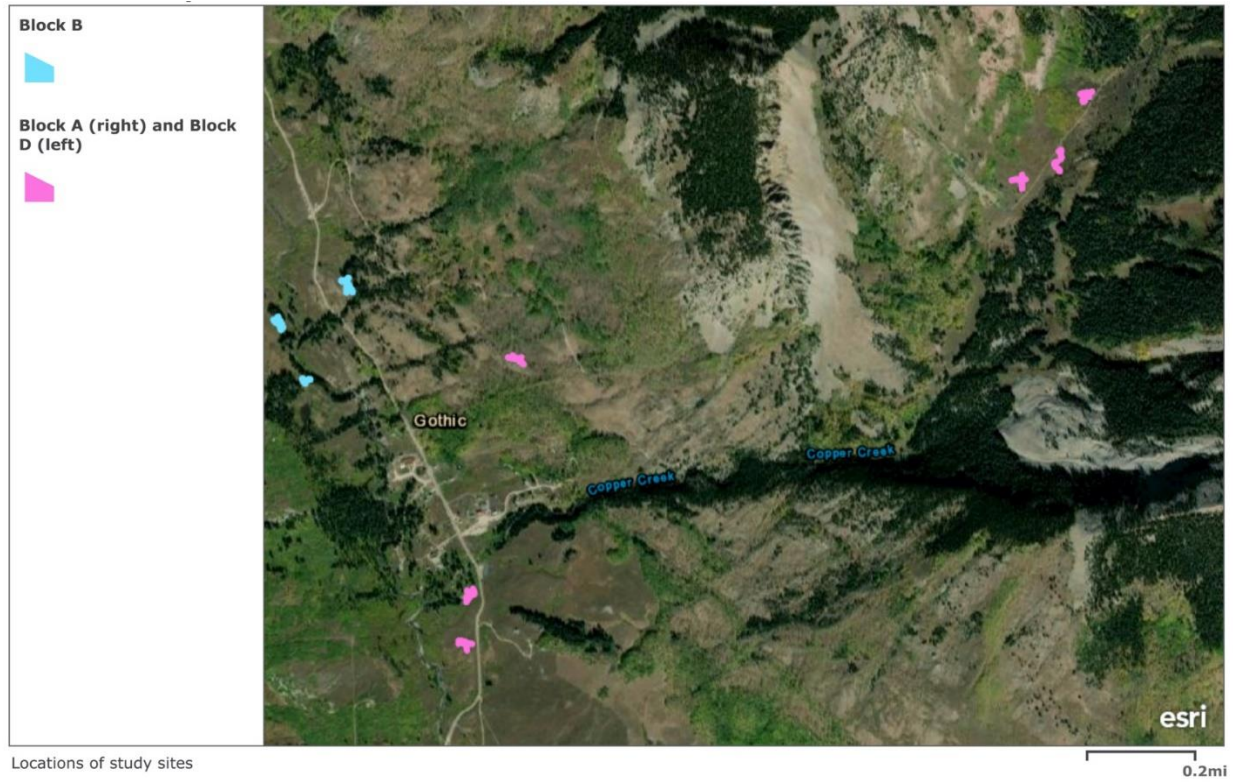


Fig. 10 shows the study sites in blocks A, B, and D. Block A consists of sites Tuttle, Willey, and Davids. Block B consists of sites Beaver, Gothic, and Sean's. Block D consists of sites Hill, Little, and Copper. These sites are transects marked by GPS markers on the ESRI satellite basemap.



Fig. 11 shows the study sites known as Lypps and CDOT. These sites are transects marked by GPS markers on the ESRI satellite basemap.

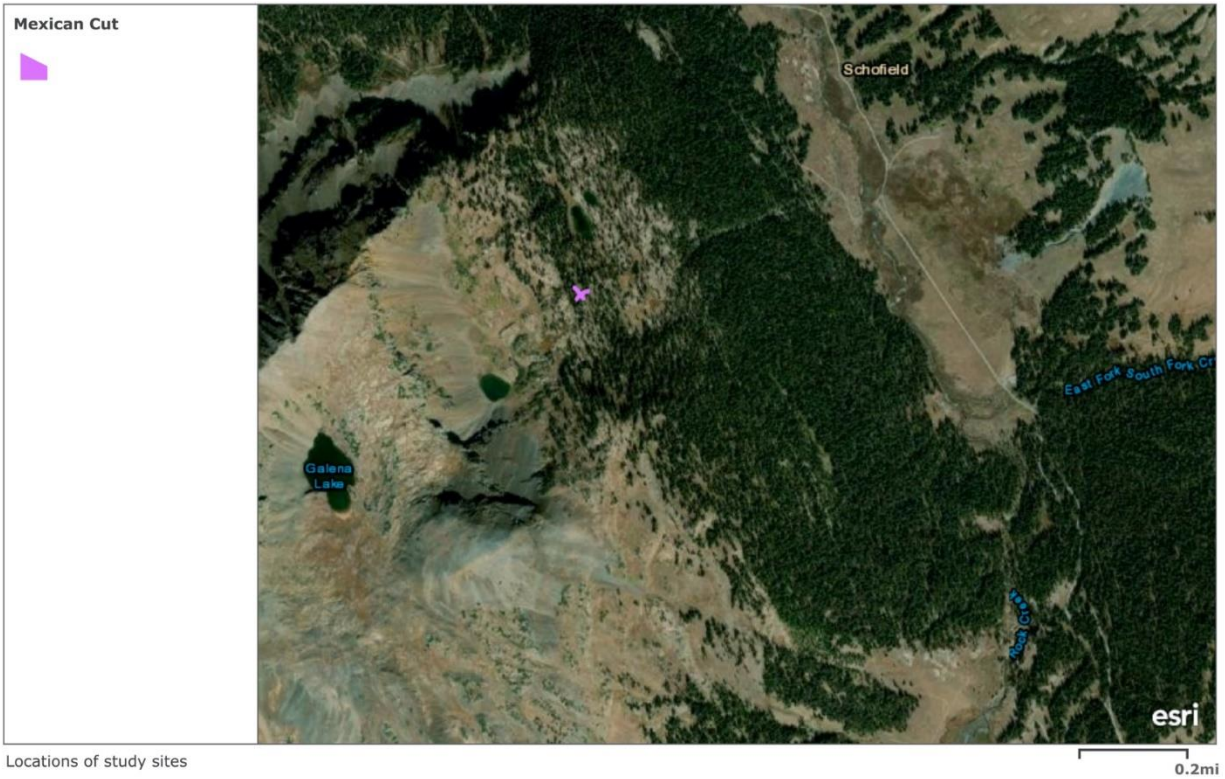


Fig. 12 shows the study site known as Mexican Cut. These sites are transects marked by GPS markers on the ESRI satellite basemap.



Fig. 13 shows the study site known as Rustlers. This sites are transects marked by GPS markers on the ESRI satellite basemap.

The North Elko site was not included since no data were used from that site in this paper.

Land Acknowledgement:

The land RMBL research is conducted on is traditional Uncompaghre Ute lands. The Ute nation was continually subdivided by land treaties in Colorado, including the Treaty of 1849, Treaty of 1868, and Dawes Act in 1887. With our place-based research, it is important to recognize how we have benefited from these seized lands and the hardships we have created for Indigenous Peoples through our oppressive history.

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