Annual Report Vol. 39 (2016)

Flowering phenology and bumblebee activity in early summer in Grand Teton National Park

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Abstract From late May through late June we monitored flowering phenology of all plants in four transects in Grand Teton National Park. We identified and collected blooming data on 25 species. In addition, we assessed both bumblebee species composition and foraging activity in the same transects. We captured queens from five different bumblebee species in vane traps. Observations of transects for forager activity yielded little data, and we recommend future studies employ walking transects.

Introduction

Understanding the biological impacts of climate change is a pressing issue in ecology. In recent years a surge in work investigating the phenological shifts of flowering plants (Inouye, 2008; Kudo and Hirao, 2006) has led to an emerging concern that climate change is driving mismatches between plant flowering and the emergence of insect pollinators (Hegland et al., 2009; Memmott et al., 2010; Kudo, 2014; Liu et al., 2011; Solga et al., 2014); such mismatches could have significant negative impacts on the fitness of both plants and their pollinators. Mismatches are likely to occur if phenological shifts across pollinators and flowers are not operating at the same temporal and spatial scales (Figure 1). Given that upwards of 85% of angiosperms rely on insect pollination (Ollerton et al., 2011), disruption of these interactions could have profound consequences for ecosystem health. This issue is likely exacerbated in alpine systems, which have shorter growing and foraging seasons. However, investigating the existence and impact of phenological mismatches is a difficult task in many geographic locations, as we are experiencing a world-wide crash in pollinator populations (Potts et al., 2010). Population declines are likely driven by multiple factors, including habitat loss, anthropogenic pollution, agrochemicals, and climate change (reviewed by Potts et al. 2010). In many study sites, local pollinator populations likely experience two or more of these stressors (McFrederick et al., 2008; Whitehorn et al., 2012; Henry et al., 2012). Grand Teton National Park presents a unique opportunity, in that much of the park experiences relatively little anthropogenic disturbance, allowing for the study of the impacts of climate change (the primary driver of phenological shifts) in isolation from other factors. In addition, previous park investigations have provided some baseline data on flowering phenology (Scogin, 1996) and pollinator communities (Dillon, 2011). Our study built upon past work, surveying phenology and pollinator foraging activity in alpine meadows within GTNP.

We focused on bumblebees, critical pollinators in alpine communities that can serve as important indicators of ecosystem health (Sepp et al., 2004). Bumblebee life history could make them particularly vulnerable to changes in flowering phenology: fertilized queens overwinter, then must forage by themselves after emerging to rear their first brood. Once mature, the first brood takes over foraging and rearing duties as the queen continues to lay eggs and grow the colony (Wilson, 1971; Goulson, 2010). During these early stages, resource scarcity may kill colonies directly or slow their growth such that they may ultimately die out, given that only the largest colonies successfully produce reproductives (Owen et al., 1980; Müller and Schmid-Hempel, 1992). Our project had four objectives aimed at exploring whether or not there have been shifts in flowering phenology in GTNP, potentially limiting forage for bumblebee pollinators. These four objectives were:

1. Measure the flowering phenology of common plant species in alpine meadows during the late spring to early summer bloom transition.
2. Track foraging activity of bumblebees in alpine meadows during the late spring to early summer bloom transition.
3. Characterize bumblebee community composition in alpine meadows during the late spring to early summer bloom transition.
4. Determine if bumblebee activity at monitored artificial feeding sites can serve as an assay for how much natural forage is available.

Methodology

Field sites

Four 4mx4m transects were established in alpine meadows near the UW-NPS research station in Grand Teton National Park. Each transect was comprised of sixteen 1mx1m quadrats. Both flowering phenology and pollinator observations were performed at these sites.

Flowering phenology

Plants in each quadrat were mapped and labeled with a plant ID by species and number. Phenology of plants in each quadrat was observed at a minimum once per week from early May through late June by recording the number of buds, open flowers, and senescing flowers. On an observation day, 8 quadrats were randomly selected within a transect. In 4 cases, plant species had tiny, numerous flowers atop small individual stems, a morphology that prohibited reliable tracking of individual flowers. These species, *Collinsia parviflora*, *Cryptantha sp.*, *Galium aparine*, and one unidentified species were tracked in a single randomly selected quadrat per transect.

Pollinator observations

Quadrats

Quadrats randomly selected for plant observation were also observed for 3 minutes for bumblebee activity. Observers classified bumblebee activity as either “fly by”, “approach”, or “landing”. No approaches were observed throughout the study. In cases of landing the relevant plant ID was recorded. Relevant environmental variables (time and temperature) were also recorded for each observation session.

Walking transects

Due to the paucity of bumblebees observed in quadrats, towards the end of the study we also did walking observations. Observers walked for 15 minutes, recording bumblebees seen within 2 meters on either side of the path. Bumblebee caste and species was recorded when possible. Bees were recorded the same way as in the quadrats. When bees investigated or landed on a flower, the species was recorded.

Pollinator capture and species identification

Once per week a blue vane trap was placed alongside each transect and left for 12 hours. Collected bumblebees were washed, pinned, and identified to species.

Bumblebee monitoring stations

Monitoring stations were comprised of a feeder, a motion-activated camera, a temperature probe, and a light sensor. Feeders were outfitted with three 3-D

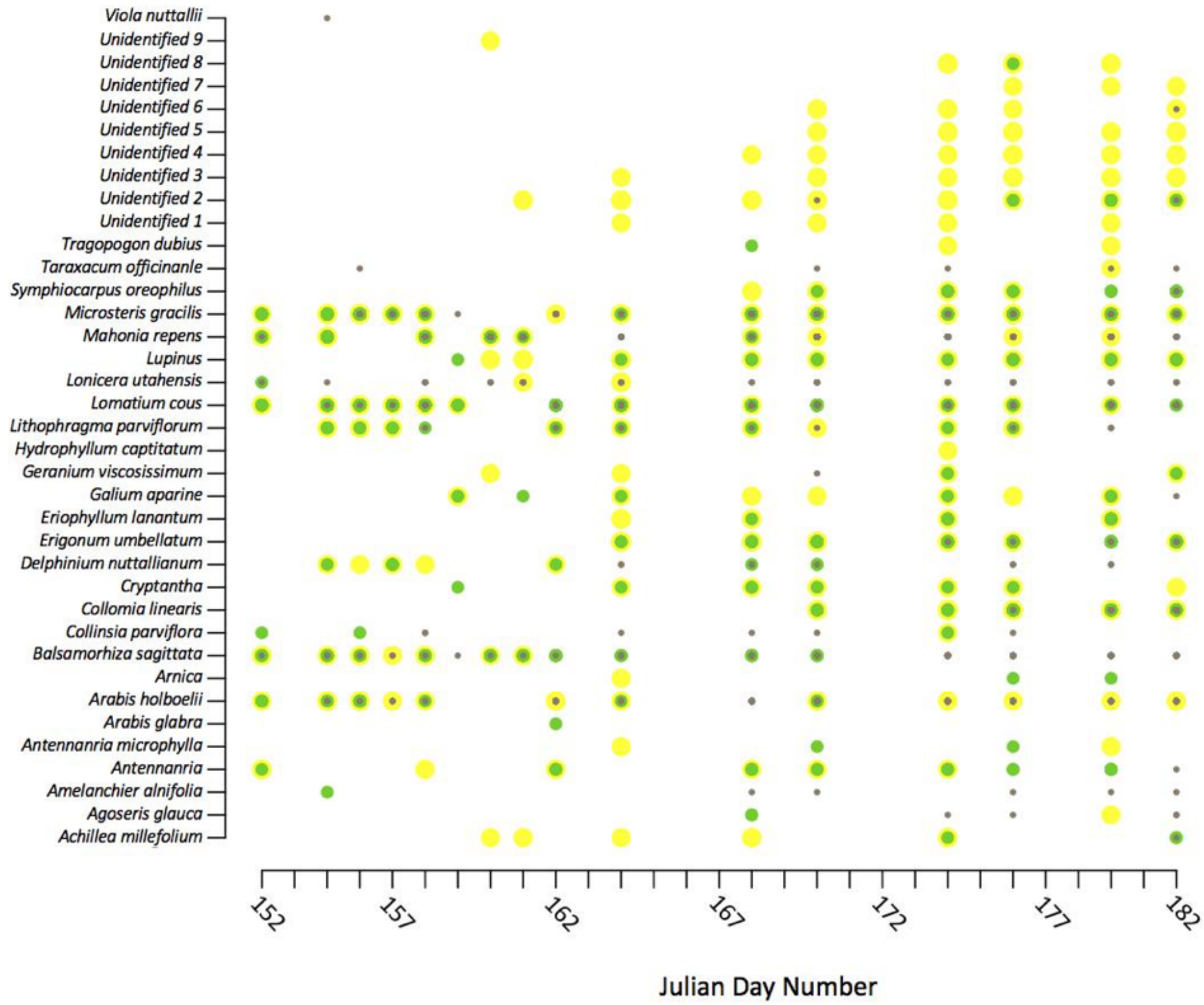

Figure 1. Phenology of observed flowers at the UW-NPS research station at Grand Teton National Park. Plants in budding phase are represented with a large-yellow dot; those in blooming phase are represented with a medium-green dot; and those moving into senescence are represented with a small-brown dot. Budding phase is determined by plants having more buds than open or senescing flowers; blooming phase by having more open flowers than buds or senescing, and senescent by having more dying than budding or open flowers. The number of individuals across transects is represented by the histogram on the right y-axis.

printed flowers which resembled *Balsamorhiza sagittata* flowers often visited by local bumblebees. Flowers were painted different colors: one white, one yellow and one blue. The inflorescences housed stainless steel wicks pulling 'nectar' from a large reservoir containing 8% sucrose solution. This feeder is a larger scale version of a proven design currently being used in behavioral experiments (Krall, Wechsler, and Sprayberry in prep). The feeder was monitored by a motion activated camera, which took a picture whenever an insect entered the field of view. The triggering mechanism was sensitive enough that a quick fly by, or walking ants would result in image capture. Picture quality facilitated identification of bumblebees to the genus, rather than species, level. One monitoring station was continuously maintained by the Director's cabin at the UW-NPS research station. A second station was placed for 12 hours by sites AMK1, AMK2, and AMK4 at least once per week.

	Transects:			
	AMK1	AMK2	AMK3	AMK4
Fly-by sightings	7	13	12	12
Lonicera landing	3	n/a	n/a	n/a
Balsamarhiza landing	1	n/a	0	0
Lupinus landing	0	n/a	n/a	1

Table 1. Transect observations of bumblebee activity

Results and Discussion

Flowering phenology

We tracked flowering phenology of 34 species across the four transects, 25 of which were able to be identified (Figure 1). Five representative species were selected for statistical analysis: *Balsamorhiza sagittata*, *Lupinus*, *Symphiocarpus oreophilus*, *Lomatium cous*, and *Lithophragma parviflorum*. These were chosen for their wide distribution between sites and/or their observed preference by bees. ANOVAs (plus Tukey HSD post-hoc) looked for both observer and interactive observer-date effects, as not all observers were present for the entire study. While two species (*Lupinus sp.*, p=0.04, and *Lomatium cous*, p=0.004) returned a significant observer effect, there were no interactive date-observer effects, indicating that the "observer effects" are likely an artifact. Further statistical analysis on transects and quadrats showed that plants were non-homogenously distributed through the landscape.

Comparisons with historical phenology data

Our data set contains 18 species in common with Scogin's 1996 survey of GTNP phenology. Included in this 18 are three species identified to genus level compared to *Lupinus argenteus*, *Cryptatha torreyana*, and *Arnica cordifolia* from Scogin's data. Comparing Scogin's observed first open flowers with the first incidence of blooming phase (Figure 1, green dot) we found that 13 of 18 species exhibited blooming an average of 7.58±4.37 days earlier. Of the species that bloomed earlier, 5 also senesced earlier at an average of 12.8±5.0 days. This is a conservative comparison, as flowers in "budding phase" have more buds than flowers, but can still have open flowers.

Transect observations were less effective than walking observations

The majority of bumblebees observed during this study were queens, indicating that large worker populations were not yet available for foraging. As such, there were relatively few bumblebee sightings. The limited foraging observations were, however, focused on a small number of plant species: *Lonicera utahensis*, *Balsamorhiza sagittata*, and *Lupinus* (Table 1). Walking pollinator observations through AMK field sites also showed *Bombus spp* foraging on *Lupinus*. These walking observations were performed at the end of the study, to determine if they were a more effective method of sampling bumblebee activity. On June 27th we compared quadrat to walking observations in Death Canyon, and on June 29th we performed the same comparison at AMK. We observed numerous queens in Death Canyon (6633 ft elevation), indicating that queen emergence was running a little later than the AMK sites at UW-NPS research center (6800 ft elevation). Quadrat observations resulted in 5 bee sightings over 48 observer minutes (ratio=0.1) while walking observations yielded 30 ob-

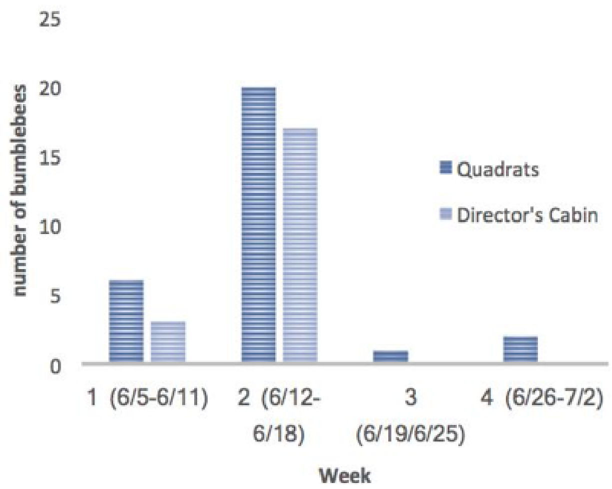

Figure 2. Number of bumblebees photographed at automatic-monitoring stations.

servations over 135 observer minutes (ratio=0.22). Likewise, at AMK there were 0 bee observations over 93 observer minutes (ratio=0) and 13 bee observations over 180 observer minutes (ratio=0.07). Walking observations cover a larger area, leading to a greater likelihood of encountering foraging bumblebees.

Automated monitoring stations indicate bumblebees were more prolific at AMK in early rather than late June

Automated feeder station images were used to successfully identify bumblebee activity (Figure 2). Data from the director's cabin and from quadrat stations indicated higher bumblebee activity in early versus late June. This coincides with our observations of queen bumblebees early in the month and no observations of workers in the remaining weeks. Because of the delayed emergence of worker bumblebees we were unable to test for a correlation between activity at the automated feeding sites and activity on natural forage.

What types of bumblebees were foraging during this study?

Vane traps near the phenology sites captured 13 bumblebee queens representing 5 species: *Bombus rufocinctus* (3), *B. fervidus* (1), *B mixtus* (3), *B. appositus* (1), and *B. bifarius* (2). This was not completely representative of the diversity of species we casually netted (which also included *B. nevadensis*).

Summary

This study provides a baseline of late spring-early summer flowering forage available to bumblebees near the UW-NPS research station in Grand Teton National Park. The paucity of worker-bumblebee activity indicates a longer (and later) field season is required in future years. Likewise, preliminary data indicate that walking forager observations are more efficacious than static quadrat observations. Future work can provide the type of multi-year data-set necessary to test for phenological mismatch.

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