THE PAN-PACIFIC ENTOMOLOGIST
87(3):161–171, (2011)

Bumble bee (Hymenoptera: Apidae) community structure on two sagebrush steppe sites in southern Idaho

STEPHEN P. COOK[1,2], SARA M. BIRCH[3], FRANK W. MERICKEL[1],
CARRIE CASELTON LOWE[4], & DEBORAH PAGE-DUMROESE[5]

[1]Department of Plant, Soils and Entomological Sciences, University of Idaho, Moscow, Idaho
[3]Department of Forest Resources, University of Idaho, Moscow, Idaho
[4]Environmental Science Program, University of Idaho, Moscow, Idaho
[5]USDA-Forest Service, Rocky Mountain Research Station, Moscow, Idaho

Abstract. Although sagebrush, *Artemisia* spp., does not require an insect pollinator, there are several native species of bumble bees, *Bombus* spp. (Hymenoptera: Apidae), that are present in sagebrush steppe ecosystems where they act as pollinators for various forbs and shrubs. These native pollinators contribute to plant productivity and reproduction. We captured 12 species of bumble bees (437 individuals) at two sites during this study. The three most commonly captured species of *Bombus* at the first site (Red Mountain in the Targhee-Caribou National Forest) were *B. rufocinctus* Cresson, *B. fervidus* and *B. melanopygus* Nylander. *Bombus fervidus* dominated the trap catch at the second site (Lave Lake Land and Livestock) followed by *B. rufocinctus* and *B. californicus consanguineus* Smith. When numerous species of bumble bees co-occur on a given site, the community must have some mechanism for partitioning the available resources for the coexistence to occur. Along with temporal separation that was demonstrated by monthly differences in the capture of several of the individual species of bumble bees at both study sites, differences in capture of individual species of bumble bees was influenced by trap color. The differences observed among the species of *Bombus* we captured at the two sites may serve to limit competitive interactions among some of the species. Further, more bumble bees were captured in traps placed in the plots with the lowest percentage of sagebrush in the canopy. The results suggest that sagebrush steppe habitats can harbor a diverse community of native bumble bees and that multiple *Bombus* species can coexist on these sites. To maintain these diverse bumble bee communities, some portion of the sites should be managed to have little to no sagebrush in the canopy.

Key Words. Bombus, *Artemesia*, pollination, biodiversity, species richness.

INTRODUCTION

Sagebrush steppe ecosystems occupy 48 million ha and are found in fourteen states and two Canadian provinces where they provide a vital resource for wildlife habitat, watershed management, livestock production, recreation, and esthetics (Blaisdell et al. 1982). Sagebrush steppe systems are characterized by the presence of one or more *Artemesia* species present within the overstory and with an understory of annual and perennial, herbaceous forbs, cheatgrass and bunchgrasses. Further, sagebrush steppe systems experience temperature extremes and have low amounts of precipitation. Although widespread across the west, the ecological integrity of sagebrush steppe is threatened by livestock grazing, invasive species, altered fire regimes, climate change, land management objectives and human presence (Bunting et al. 2003).

Insects are widespread in most terrestrial habitats where they provide a number of ecosystem services such as pollination and nutrient cycling (Samways 1994). In general, insects can also serve as important indicators of ecosystem health or change

[2] Corresponding author

(Rosenberg et al. 1986). However, minimal information has been published on the roles played by insect communities in sagebrush steppe ecosystems (Hampton 2005). Therefore, improved knowledge of the diversity and roles of insects within these systems should improve monitoring and assessment programs to restore the health and integrity of sagebrush steppe sites (Karr & Kimberling 2003).

There are several species of bumble bees, *Bombus* spp. (Hymenoptera: Apidae), that are present in sagebrush steppe ecosystems (Stephen 1957) but their diversity may not be represented in large numbers within general surveys of insects occurring on any particular site. For example, there were only two species of *Bombus* (*B. fervidus* (Fabricius) and *B. huntii* Greene) listed in a compilation of 1240 insect species captured on the 570,000 acre site of the Idaho National Laboratory in the south-central part of the state over a period of 35 years (Hampton 2005).

Although sagebrush does not require an insect pollinator, many of the native bumble bee species act as pollinators for the various forb and shrub species present within sagebrush steppe ecosystems where they contribute to plant productivity and reproduction. If numerous species of bumble bees co-occur on a given site, the community must have some mechanism for partitioning the available resources for the coexistence to occur. Three possibilities for partitioning the flower resource have been suggested (Schoener 1974): 1) partitioned in time (i.e., differences in seasonal abundance/occurrence of various bumble bee species), 2) partitioned by food source (i.e., differential attraction based on some trait, such as flower color) or 3) partitioning by preferred habitat (i.e., differences in where they forage). Further, different species within the genus may have different nesting requirements or use different life history strategies, thus allowing the co-occurrence of multiple species within the genus.

Because of their roles and potential diversity, we have hypothesized that the structure of the bumble bee community may provide information useful in determining the overall health and resilience of individual sagebrush steppe sites. The first step in investigating the role of the bumble bee community in determining system health or resilience is to determine the structure of the community on various sites. Therefore, the overall objective of the current study was to determine the species composition of the bumble bee communities occurring on two sagebrush steppe sites in southeastern Idaho. In addition to determining species occurrence, the specific objectives of the study were to: 1) compare the monthly capture of the different bumble bees species occurring on the sites and 2) determine if the individual members of the bumble bee community may be preferentially attracted to different traps based upon color (yellow versus blue) or the amount of sagebrush in the overstory.

Materials and Methods

Study Sites. The study was conducted on two sites in southern Idaho. One of the sites was located on Red Mountain in the Targhee-Caribou National Forest located approximately 25 km northeast of Montpellier, ID in Bear Lake County. The second site was located on land owned by Lava Lake Land and Livestock and consisted of two areas located within the Fish Creek and West Fork drainages in the Pioneer Mountains, approximately 20 km northeast of Carey, ID in Blaine County. Sites were selected in part because both are grazed on an annual basis and upon overall similarities in factors such as plant community structure. The data reported were part of a larger project that examined the impact of disturbance on local insect community structure. Grazing occurred throughout the Red Mountain site and the investigated disturbance was the occurrence of small (< 1.0 ha) prescribed burns that were used in an attempt to enhance wildlife habitat. Disturbance at the Lava Lake site was defined as various levels of grazing intensity.

Trapping locations at the Red Mountain site ranged from 2100–2200 m in elevation while the elevation of the Lava Lake site is approximately 1900 m. Plant cover at both locations was similar and included some combination of mountain big sagebrush (*Artemisia tridentata* var. *pauciflora* Winward & Goodrich), bluebunch wheatgrass (*Agropyron spicatum* (Pursh.) A. Löve), rabbitbrush (*Chrysothamnus viscidiflorus linifolius* Greene), Idaho fescue (*Festuca idahoensis* Elmer, only at the Lava Lake site), and a mixture of additional forb species such as lesser rushy milkvetch (*Astragalus convallarius* Greene) and lupine (*Lupinus sericeus* var. *asotinensis* (Phillips) Hitchcock).

Bumble Bee Sampling. There were a total of 768 trapping days at the Red Mountain site. A trapping day was defined as the additive number of days individual traps were deployed at a site (e.g., 8 traps deployed for 5 days = 40 trapping days total). Sampling occurred periodically during four consecutive summers (two 5-day sample periods (11–15 July and 8–12 August) during 2006, three 5-day sample periods (16–20 May, 16–20 June and 13–17 July) during 2007, one 5-day sample period (28 June–2 July) during 2008 and two 4-day sample periods (9–12 June and 18–21 August) during 2009. During 2006 and 2007, eight plots were sampled using a combination of traps (pitfall traps, standard yellow Japanese beetle traps and Lindgren funnel traps) but all of the *Bombus* were captured in the Japanese beetle traps (Great Lakes IPM, Inc.). During 2008 and 2009 only Japanese beetle traps were deployed, one blue trap (Rust-Oleum®, harbor blue) and one standard, yellow trap per plot (27 total plots in 2008 and 18 plots in 2009). During 2009, the percentage of canopy cover comprised of mountain big sagebrush was estimated at the Red Mountain site and traps were placed in six areas in which individual plots were located in areas that had 0–10% sagebrush canopy, 10–25% sagebrush canopy or > 25% sagebrush canopy. Within a sample area, plots of differing canopy cover were contiguous with one another and traps were separated by a minimum distance of 100 m. Traps were not baited, but had an insecticide strip (Hercon Vaportape II) placed in them.

There were a total of 720 trapping days at the Lava Lake site (48 traps deployed over a total of 15 days). Sampling was conducted during three 5-day periods (17–22 May, 15–19 June and14–18 July of 2007), using pairs of blue and yellow Japanese beetle traps placed in 24 sample plots. As at Red Mountain, traps were not baited, but had an insecticide strip placed in them.

All of the collected bumble bees were sorted and identified to species (Stephen 1957, Stephen et al. 1969). The total number of individuals per trap during each sampling period was recorded for each species of bumble bee captured.

Data Analysis. For each site, data from all of the collection periods were combined to produce a list of *Bombus* species richness captured by site during this project. Monthly data were also combined across years at the Red Mountain site and plots were generated to examine the seasonal capture (total individuals per trap day) of the 3 most commonly caught species of *Bombus* at each of the study sites. Data from 2007 at the Lava Lake site and from 2008 and 2009 at the Red Mountain site were

Table 1. Total number of individual species of *Bombus* captured at two sagebrush steppe sites from 2006 through 2009. There were a total of 38 trapping days at the Red Mountain site and 15 trapping days at the Lava Lakes site.

	Study site	
Bombus sp.	Red Mountain	Lava Lake
B. appositus Cresson	4	1
B. bifarius Cresson	22	
B. californicus consanguineus Smith	15	15
B. centralis Cresson	7	9
B. fervidus (Fabricius)	42	142
B. griseocollis (DeGeer)	1	3
B. huntii Greene	12	
B. insularis Friese	20	6
B. melanopygus Nylander	38	
B. nevadensis Cresson	13	4
B. occidentalis Greene	7	
B. rufocinctus Cresson	52	24
Total	233	204

used to compare the capture of individuals within a species at the two colors of traps using paired *t*-tests for the entire season. Only species with > 10 individuals captured during these periods were used in the analysis. The 2009 data from the Red Mountain site were used to compare the capture of individuals within a species at traps placed within the plots with varying percentages of sagebrush canopy cover (analysis of variance test with a complete block design). All statistical comparisons were made using SAS 9.1 (Statistical Analysis Software 2003).

Results

There were 12 species and 437 individual bumble bees captured at the two sites during this study (12 species and 233 individuals were captured at Red Mountain while 8 species and 204 individuals were captured at Lava Lake) (Table 1). The three most commonly captured species of *Bombus* at the Red Mountain site were *B. rufocinctus* Cresson ($n = 52$), *B. fervidus* ($n = 42$) and *B. melanopygus* Nylander ($n = 38$). *Bombus fervidus* dominated the trap catch at Lava Lake ($n = 142$) followed by *B. rufocinctus* ($n = 24$) and *B. californicus consanguineus* Smith ($n = 15$).

There were apparent differences in the number of individuals for the three most commonly captured *Bombus* species by month at both study sites. At the Red Mountain site (Figure 1), both *B. rufocinctus* and *B. fervidus* were captured more frequently during June than in other months while *B. melanopygus* was captured almost exclusively during the August sample periods. At the Lava Lake site (Figure 2), *B. rufocinctus* was captured at equal frequencies during June and July but decreased in August while the *B. fervidus* and *B. californicus consanguineus* were captured more frequently during July, with lower numbers captured in June and August. Also of note is that the social parasite *B. insularus* Friese was predominantly captured in May and June compared with July and August (19 of 26 individuals were captured during either May or June), when many of the other species would have been initiating colonies and producing brood. Further, all of the specimens of *B. occidentalis* Greene that were captured were collected late in the summer (six of the

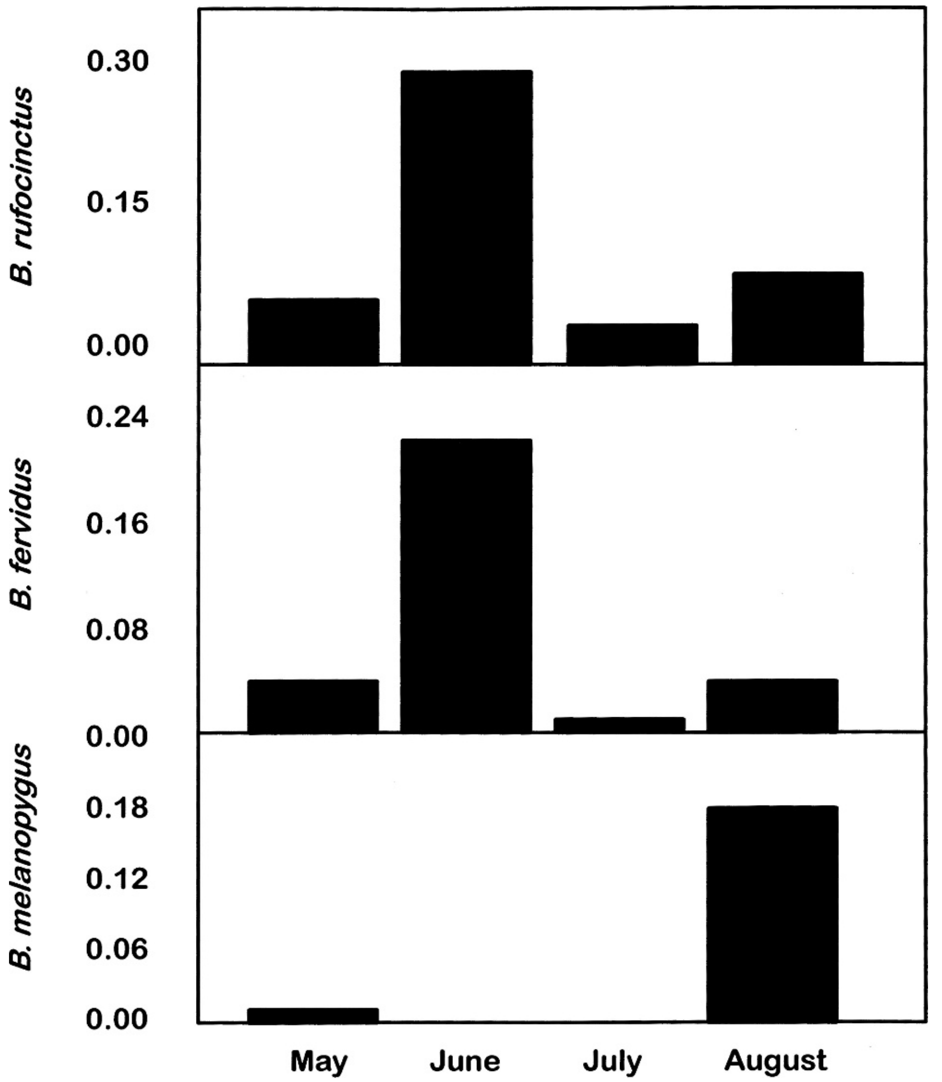

Figure 1. Monthly capture (number of individuals per trap day) of the three most commonly caught species of bumble bees (*B. rufocinctus, B. fervidus* and *B. melanopygus*) at Red Mountain from 2006 through 2009.

seven specimens were captured in August sample periods) and all were collected at the Red Mountain site.

Individual species of *Bombus* were captured in significantly different numbers in the blue versus yellow Japanese beetle traps (Table 2). The three most abundant species captured at Red Mountain were all caught in higher numbers in the yellow traps compared with the blue traps (*B. bifarius* Cresson: $n = 4$ pairs; $t = 2.78$; $[P > t] = 0.0691$; *B. melanopygus*: $n = 11$ pairs; $t = 2.12$; $[P > t] = 0.0598$; *B. rufocinctus*: $n = 11$ pairs; $t = 2.52$; $[P > t] = 0.0306$). At the Lava Lakes site, *B. rufocinctus* was again captured in higher numbers in the yellow traps compared with the blue traps ($n = 15$ pairs; $t = 2.10$; $[P > t] = 0.0541$) but *B. fervidus* was captured in higher

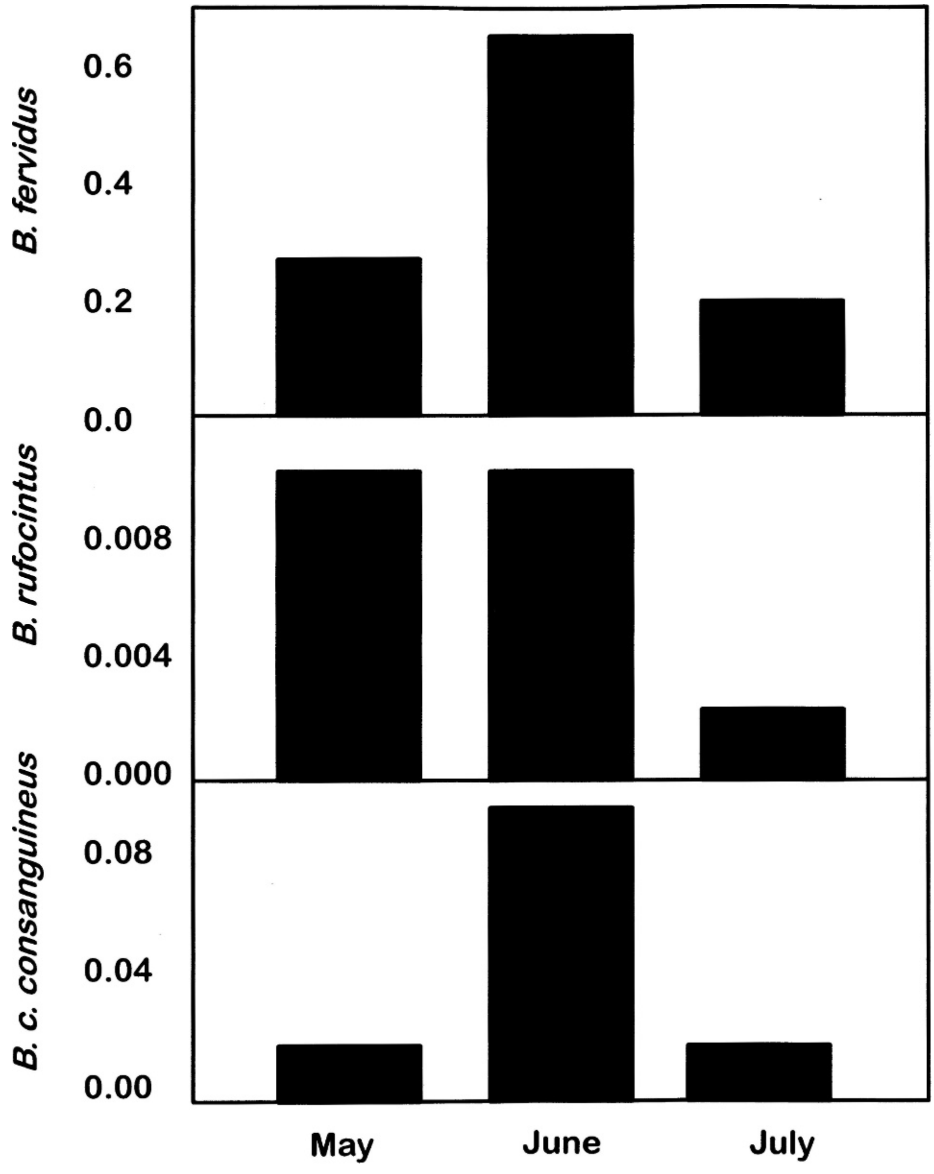

Figure 2. Monthly capture (number of individuals per trap day) of the three most commonly caught species of bumble bees (*B. fervidus, B. rufocinctus* and *B. californicus consanguineus*) at Lava Lake during 2007.

numbers in the blue traps (n = 22 pairs; t = 2.67; [$P >$ t] = 0.0144) and there was no difference in the number of *B. californicus consanguineus* caught between traps of the two different colors (n = 9 pairs; t = 0.92; [$P >$ t] = 0.3842).

All three of the most abundant species of bumble bees captured at Red Mountain during 2009 were more frequently captured in traps placed in the plots with the lowest percentage of sagebrush in the canopy (Table 3). While the differences were not statistically significant for *B. bifarius* (total number captured = 10; n = 3 blocks;

Table 2. Total number of individual *Bombus* captured in blue or yellow Japanese beetle traps at two sagebrush steppe study sites from 2007 through 2009. There were a total of 13 trapping days with 36 pairs of traps at the Red Mountain site (2008–2009) and 15 trapping days with 24 pairs of traps at the Lava Lakes site (2007). Paired Students' *t*-tests were used to determine significant differences between trap catch of individual species of *Bombus* when the total capture of that species was greater than 10 individuals.

	Study site					
	Red Mountain			Lava Lake		
Bombus sp.	Blue	Yellow	*P* > t	Blue	Yellow	*P* > t
B. appositus	2	0	–	1	0	–
B. bifarius	0	12	0.0691			
B. californicus consanguineus	7	0	–	10	5	0.3842
B. centralis	0	1	–	6	3	–
B. fervidus	1	4	–	104	38	0.0144
B. griseocollis	0	1	–	0	3	–
B. huntii	4	2	–			
B. insularus	1	1	–	3	3	–
B. melanopygus	5	30	0.0598			
B. nevadensis	1	7	–	4	0	–
B. occidentalis	3	2	–			
B. rufocinctus	4	13	0.0306	6	18	0.0541
Total	28	73		134	70	

F = 1.03; [$P > F$] = 0.4137) or *B. rufocinctus* (total number captured = 17; n = 5 blocks; F = 0.35; [$P > F$] = 0.7116), there were significantly more *B. melanopygus* captured in the plots with the lowest sagebrush canopy cover (total number captured = 35; n = 6 blocks; F = 2.94; [$P > F$] = 0.0838) compared with the plots with the highest percentage of sagebrush in the canopy.

Discussion

While the overall study was not designed to examine bumble bee populations on these sites, the passive trapping scheme used captured a total of 12 species and 437 individual specimens in the genus *Bombus*. To our knowledge, this is the first report

Table 3. Mean number (± SEM) of the three most abundantly captured species of *Bombus* caught during 2009 in paired (blue and yellow) Japanese beetle traps placed in sagebrush steppe with varying percentages of canopy cover occupied by sagebrush foliage. There were a total of 6 blocks, each with one pair of traps in plots containing one of three canopy coverages (0–10% sagebrush, 10–25% sagebrush and > 25% sagebrush). Only blocks that had the individual species captured were included in the analyses (analysis of variance, complete block design).

	Bombus species		
Canopy cover (% sagebrush)	*B. bifarius*[a]	*B. melanopygus*[a]	*B. rufocinctus*[a]
< 10	2.67 ± 1.76 a	4.33 ± 1.61 a	1.20 ± 0.73 a
10–25	1.00 ± 1.00 a	1.83 ± 0.95 ab	1.00 ± 0.45 a
> 25	0.33 + 0.33 a	0.67 + 0.33 b	0.60 + 0.24 a

[a] Within a column, means followed by the same letter are not significantly different based upon analysis of variance tests.

of Japanese beetle traps being used to sample bumble bees. Prior studies have compared various trapping methods (i.e., Westphal et al. 2008) and colored pan traps are commonly used (i.e., Leong & Thorp 1999, Toler et al. 2005, Roulston et al. 2007). However, pan traps can produce biased samples, frequently catching fewer individual and a less diverse community of bees, including *Bombus* spp. (Toler et al. 2005, Roulston et al. 2007). Indeed, Roulston et al. (2007) did not capture any *Bombus* in pan traps while capturing over 40 individuals representing 5 species using an intensive netting technique. We did not capture any *Bombus* in the other trap types (pitfalls and Lindgren funnel traps) that we had deployed on our sites. The 12 species and 437 individual bumble bees that were captured suggests that the Japanese beetle traps could be a useful tool for examining bumble bee communities. There is no observer bias when using the Japanese beetle traps and the traps can be left in the field for extended periods of time. Further, the traps can be deployed in a multitude of colors that can be matched or compared with flowering plants on a site. One drawback to using the traps is that they do not measure pollination or actual flower visitation by the bees but, comparative data on attraction to multiple colors can be obtained by deploying multiple traps of different colors.

Eleven of the 12 species captured during the current study were non-parasitic and feed on plant nectar and pollen and included *B. occidentalis*, a species thought to be in decline throughout much of its historic range (Evans et al. 2008). The twelfth species, *B. insularis*, employs the different life history strategy of being a social parasite on colonies of other species of bumble bees but does forage and can act as a pollinator. While numerous studies report *Bombus* community membership in various habitats, most of these have a more limited number of community members (2 examples are the 5 species reported by Roulston et al. (2007) in northern Virginia and the single species reported by Tuell and Isaacs (2009) in a Michigan study). One recent investigation identified 12 species of *Bombus* (11 non-parasitic along with *B. insularis*) captured in a community study in montane meadows in the Sierra Nevada Mountains (Hatfield & LeBuhn 2007). The number of species of *Bombus* (species richness) captured at the individual sites during the current study (n = 12 at Red Mountain and n = 8 at Lava Lake) was similar to the species richness values reported for the montane meadow communities in the Sierra Nevada Mountains (Hatfield & LeBuhn 2007) and four- to six-times greater than what was reported for another site dominated by sagebrush steppe in Southern Idaho at the Idaho National Laboratory (Hampton 2005).

Habitat characteristics can influence both the abundance and species richness of bumble bee communities. Plant community characteristics such as the diversity and abundance of flowering plants, vegetation structure and vegetation height influence bumble bee communities (Carvell 2002). Our traps were placed at a height of approximately 1 m to correspond with the height of the sagebrush canopy. A prior study reported that elevated pan traps can be used to monitor bee communities in flowering crops with traps placed at mid- and above-canopy capturing a wide variety of bee species representing several families (including Apidae), but few bumble bees were captured (Tuell & Isaacs 2009).

Vegetative patch size and landscape characteristics can also be important predictors of species richness and abundance for bumble bee communities (Hatfield & LeBuhn 2007). However, these authors suggest that patch size may be less important than habitat quality in determining species richness within the bumble bee community present on a site. These authors further went on to state that the large meadows sampled within their study had large expanses of sagebrush and that this may influence species richness measurements. Our results suggest that patches differentially dominated by sagebrush canopy may also be differentially visited by bees that are present but more frequently captured in areas with a lower percentage of sagebrush in the canopy. Bumble bees can fly long distances to forage for their nectar resource (Dramstad 1996, Osborne et al. 1999) and they may simply by-pass areas with less potential benefits during their foraging activities or in which traps (or flowers) may be obscured by the sagebrush overstory.

All 12 species of *Bombus* captured during this study visit flowers where they can act as pollinators (including *B. insularis* which is a social parasite of other bumble bee nests). To minimize competition among the pollinating species, resource partitioning should involve the differential utilization of three primary components of bumble bee niches (season, food source, nest site and/or habitat) by different species (Schoener 1974). While our study was not designed to provide direct measures of pollination or flower visitation, our data do provide information on monthly flight activity and species attraction to differently colored traps.

Queens were predominantly captured during the May and June sample periods but were also present in the July and August samples. Workers were captured during every month but dominated trap catch during the June–August sample periods. No males were captured during this study.

The most commonly captured species of bumble bees on our study sites did overlap in the timing of their respective captures but there were differences in the timing of peak capture. For example, at the Red Mountain site, both *B. rufocinctus* and *B. fervidus* (both queens and workers) were captured more frequently during June while *B. melanopygus* (only workers) was captured almost exclusively during the August. Competition may be reduced among the various species by such differences in foraging times throughout the summer. Similar differences in the seasonality of activity can be inferred from the flight records of various species (Stephen 1957). In addition to differences in peak foraging times, pollinating species of bumble bees may employ different foraging strategies such as nectar robbing (Dramstad & Fry 1995) or they may have physical differences such as tongue length (Ranta & Lundberg 1980) that dictate flower preferences. Bees captured in the current study represented species with tongue lengths varying from short (i.e., *B. rufocinctus*) to medium (i.e., *B. griseocollis* (DeGeer)) to long (i.e., *B. fervidus*) (Medler 1962). Also, while we did not directly measure visitation to specific flowering plants, our data are similar to prior results (Leong & Thorp 1999), in that some of the species we captured during the current study were differentially captured in traps of different colors (i.e., *B. rufocinctus* in the yellow traps at the Lava Lake site and *B. fervidus* in blue traps).

Both of the sites examined during this project are used for grazing livestock (predominantly sheep) and the USDA-Forest Service conducted prescribed burning on sections of the Red Mountain site in 2003–2004. Livestock grazing and altered fire regimes are among the recognized threats to preserving the ecological integrity of sagebrush steppe (Bunting et al. 2003). However, the creation of disturbance through grazing or fire may be used to create a patchwork of vegetation on a site. The timing, duration and intensity of such disturbances may be important factors in determining the integrity and resilience of the on-site community of bumble bees.

There is currently a concern that individual species of *Bombus* are declining in much of their native ranges (i.e., Goulson et al. 2008, Grixti et al. 2009, Cameron et al. 2011). Three possible reasons for bumble bee declines include loss of habitat, pesticide use and the spread of pathogenic organisms (Thorp & Shepherd 2005). A primary concern regarding the possible decline in bumble bee populations arises because they provide the vital ecosystem service of pollination in many terrestrial systems including sagebrush steppe. Indeed, there are a number of species of wildflowers that are exclusively (or predominantly) pollinated by bumble bees (Corbet et al. 1991). The results of our current study suggest that sagebrush steppe habitats can harbor a diverse community of bumble bees and that multiple *Bombus* species can coexist on these sites. To maintain these diverse communities, a mixture of shrub and forb species (with different colored flowers) could possibly enhance the maintenance of *Bombus* biodiversity. The creation of disturbance through grazing or fire may be used to create a patchwork of vegetation on a site. The timing, duration and intensity of such disturbances may be important factors in determining the integrity and resilience of the on-site community of bumble bees.

Acknowledgments

We would like to thank Targhee-Caribou National Forest and Lava Lake Land and Livestock for allowing us to conduct the study on these sites and the USDA-ARS Pollinating Insect Research Unit for help in species identification. We also thank Jody Anderson, Ashley Lange, Kendra Schotzko and Michael Coey for field and laboratory assistance. Voucher specimens have been placed in the William Barr Insect Museum at the University of Idaho. The project was supported in part by the University of Idaho along with funding provided by the NSF-EPSCoR program, USDA-McIntire Stennis and the USDA-Forest Service, Rocky Mountain Research Station.

Literature Cited

Blaisdell, J. P., R. B. Murray & E. D. McArthur. 1982. *Managing intermountain rangelands-sagebrush-grass ranges*. USDA-Forest Service, Intermoutain Forest and Range Experiment Station. 41 pp.

Bunting, S. C., J. L. Kingery & M. A. Schroeder. 2003. Assessing the restoration potential of altered rangeland ecosystems in the interior Columbia Basin. *Ecological Restoration* 21:77–86.

Cameron, S. A., J. D. Lozier, J. P. Strange, J. B. Koch, N. Cordes, L. F. Solter & T. L. Griswold. 2011. Patterns of widespread decline in North American bumble bees. *Proceedings of the National Academy of Sciences of the United States of America* 108:662–667.

Carvell, C. 2002. Habitat use and conservation of bumblebees (*Bombus* spp.) under different grassland management regimes. *Biological Conservation* 103:33–49.

Corbet, S. A., I. H. Williams & J. L. Osborne. 1991. Bees and the pollination of crops and wildflowers in the European Community. *Bee World* 72:47–49.

Dramstad, W. E. 1996. Do bumblebees (Hymenoptera: Apidae) really forage close to their nests? *Journal of Insect Behavior* 9:163–182.

Dramstad, W. & G. Fry. 1995. Foraging activity of bumblebees in relation to flower resources on arable land. *Agricultural Ecosystems and Environment* 53:123–135.

Goulson, D., G. C. Lye & B. Darvill. 2008. Decline and conservation of bumble bees. *Annual Review of Entomology* 53:191–208.

Grixti, J. C., L. T. Wong, S. A. Cameron & C. Favret. 2009. Decline of bumble bees (*Bombus*) in the North American Midwest. *Biological Conservation* 142:75–84.

Hampton, N. 2005. *Insects of the Idaho National Laboratory: A compilation and review*. USDA-Forest Service Rocky Mountain Research Station, RMRS-P-38. 130 pp.

Hatfield, R. G. & G. LeBuhn. 2007. Patch and landscape factors shape community assemblage of bumble bees, *Bombus* spp. (Hymenoptera: Apidae), in montane meadows. *Biological Conservation* 139:150–158.

Karr, J. R. & D. N. Kimberling. 2003. A terrestrial arthropod index of biological integrity for shrub-steppe landscapes. *Northwest Science* 77:202–213.

Leong, J. M. & R. W. Thorp. 1999. Color-coded sampling: the pan trap color preferences of oligolectic and nonoligolectic bees associated with a vernal pool plant. *Ecological Entomology* 24:329–335.

Medler, J. T. 1962. Morphometric studies on bumble bees. *Annals of the Entomological Society of America* 55:212–218.

Osborne, J. L., S. J. Clark, R. J. Morris, I. H. Williams, J. R. Riley, A. D. Smith, D. R. Reynolds & A. S. Edwards. 1999. A landscape-scale study of bumble bee foraging range and constancy using harmonic radar. *Journal of Applied Ecology* 36:519–533.

Ranta, E. & H. Lundberg. 1980. Resource partitioning in bumblebees: the significance of differences in proboscis length. *Oikos* 35:298–302.

Rosenberg, D. M., D. V. Danks & D. M. Lehmukuhl. 1986. Importance of insects in environmental impact assessment. *Conservation Biology* 6:376–391.

Roulston, T. H., S. A. Smith & A. L. Brewster. 2007. A comparison of pan trap and intensive net sampling techniques for documenting a bee (Hymenoptera: Apiformes) fauna. *Journal of the Kansas Entomological Society* 80:179–181.

Samways, M. J. 1994. *Insect conservation biology*. Chapman & Hall, London, 358 pp.

Schoener, T. W. 1974. Resource partitioning in ecological communities. *Science* 185:27–39.

Statistical Analysis Software. 2003. *SAS System for Windows Software Version 9.1*. SAS Institute Inc., Cary, NC.

Stephen, W. P. 1957. *Bumble bees of western America (Hymenoptera: Apoidea)*. Oregon State College, Technical Bulletin No. 40. 163 pp.

Stephen, W. P., G. E. Bohart & P. F. Torchio. 1969. *The biology and external morphology of bees with a synopsis of genera of Northwestern America*. Oregon State University, Agricultural Experiment Station. 140 pp.

Thorp, R. W. & M. D. Shepherd. 2005. Profile: subgenus *Bombus*. *In*: M. D. Shepherd, D. M. Vaughan & S. H. Black (Eds.). Red list of pollinator insects of North America. CD-ROM Version 1 (May 2005). The Xerces Society for Invertebrate Conservation. Portland, Oregon.

Toler, T. R., E. W. Evans & V. J. Tepedino. 2005. Pan-trapping for bees (Hymenoptera: Apiformes) in Utah's West Desert: the importance of color diversity. *The Pan-Pacific Entomologist* 81:103–113.

Tuell, J. K. & R. Isaacs. 2009. Elevated pan traps to monitor bees in flowering crop canopies. *Entomologia Experimentalis et Applicata* 131:93–98.

Westphal, C., R. Bommarco, G. Carre, E. Lamborn, N. Morison, T. Petanidou, S. G. Potts, S. P. M. Roberts, H. Szentgyorgyi, T. Tscheulin, B. E. Vassiere, M. Woyciechowski, J. C. Biemeijer, W. E. Kunin, J. Settele & I. Steffan-Dewenter. 2008. Measuring bee diversity in different European habitats and biogeographic regions. *Ecological Monographs* 78:653–671.

Received 1 Dec 2010; Accepted 2 Oct 2011 by A. H. Smith-Pardo; Publication date 12 Jan 2012.