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Research Note

Pollinator Abundance and Diversity under Differing Wet Prairie Management

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ABSTRACT

Pollinator species have seen recent declines in abundance, generating conservation concern as well as alarm about the ecosystem services they provide. A common approach to alleviate pollinator decline is through habitat management, including restoration of degraded habitats and removal of invasive species, but apparent habitat improvement does not necessarily mean an improvement in pollinator abundance and diversity. We collected pollinators in colored pan traps at three sites at the Lacamas Prairie Natural Area, Washington: remnant wet prairie, restored wet prairie, and an area invaded by reed canary grass (*Phalaris arundinacea*). We used model selection to assess whether site and trap color explained variation in pollinator abundance, richness, and diversity. Pollinator abundance was similar at the native and restored sites with predicted averages of 9.06 (7.15, 11.48) and 9.51 (7.52, 12.03), respectively while a heavily invaded reed canary grass site had a significantly lower predicted mean of 7.26 (5.69, 9.26). Site was not included in the top model for species richness or diversity. All three measures varied with trap color. Habitat restoration and invasive species control at Lacamas Prairie appear to have benefited local pollinator populations, but evidence for differences in pollinator richness and diversity was weak. Further work, both characterizing the response of pollinator communities to wet prairie restoration and optimizing trap colors for monitoring in this area, is warranted.

Index terms: invasive species; pollinators; prairie restoration

INTRODUCTION

Pollinators are critical members of their ecological communities, and their ongoing decline is a significant conservation concern. Pollinator biodiversity increases ecosystem productivity, enriches plant diversity, and buffers ecosystems from disturbances (Balvanera et al. 2006; Carvalheiro et al. 2013). Anthropogenic land use changes and the industrialization of agriculture have contributed to widespread declines in pollinators, and evidence from managed populations suggests that other factors may also be contributing to declines, particularly the introduction of invasive species (Winfree et al. 2007; Muñoz and Cavieres 2008; Carvalheiro et al. 2013). Communities may be nearing a tipping point where sudden ecosystem collapse will occur if declines in pollinator species continue (Kremen et al. 2007).

Thriving pollinators require ample amounts of foraging and nesting resources within home ranges. Thus, the efforts to conserve pollinators rely on the creation of high-quality habitats with diverse host plants and microhabitats (Steffan-Dewenter and Tscharntke 1999; Donaldson et al. 2002; Kremen et al. 2002; Ricketts et al. 2008; Wratten et al. 2012). Prime pollinator habitat is created through the restoration of landscapes, the enrichment of borders, and establishment of corridors (Albrecht et al. 2007; Dicks et al. 2015; Lowe et al. 2021). Although establishment of pollinator populations supports conservation and restoration success, restoration work often assumes that the creation of suitable habitat is sufficient to ensure pollinator recovery (Memmott et al. 2004; Fontaine et al. 2006; Forup et al. 2008; Vázquez et al. 2012; Kaiser-Bunbury et al. 2014).

Our objective was to assess whether habitat restoration efforts focused on the plants in a wet prairie in the Pacific Northwest were also associated with increased pollinator abundance and diversity. Moreover, because high pollinator diversity is indicative of robust ecosystem function (Balvanera et al. 2006; Fontaine et al. 2006; Albrecht et al. 2007; Senapathi et al. 2015), evaluation of the pollinator community can also offer insight into the effect of restoration on ecosystem processes. A major concern in the area is invasive reed canary grass (*Phalaris arundinacea*), which has been associated with decreased diversity and abundance of bees and butterflies in an agricultural setting, due to lack of foraging diversity through competitive exclusion of plants (Semere and Slater 2007). If habitat restoration has been effective, pollinator abundance and diversity in restored prairie should be similar to that in remnant prairie and higher than in areas dominated by invasive reed canary grass.

METHODS

Study Site

The Lacamas Prairie Natural Area encompasses a remnant wet prairie ecosystem near Vancouver, Washington, managed by the Washington Department of Natural Resources (DNR). The prairie area is adjacent to an oak savannah habitat to the west and south, private property to the north, and a two-lane highway to the east. We selected three sampling locations within the prairie that reflected different land use history and current cover:

a native site, a restoration site, and a reed canary grass site. The native site is remnant prairie that has been relatively undisturbed (C. Abbruzzese, pers. comm. 4 Oct 2021). The DNR's management focus in this area is controlling woody plants, including Oregon ash (*Fraxinus latifolia*), native and nonnative roses, and native and nonnative hawthorn. Additionally, DNR has done minor spot spraying or pulling of tansy ragwort (*Jacobaea vulgaris*).

The two other sampling locations were in agricultural use for several decades prior to the acquisition of the land by the DNR (C. Abbruzzese, pers. comm. 4 Oct 2021). Previously installed agricultural ditches were partially removed within the restoration area to restore natural hydrogeology, whereas the hydrogeology has not been restored in the reed canary grass (RCG) area. The DNR burned both study areas in 2017. After the burn, they sprayed nonnative meadow foxtail (*Alopecurus pratensis*) and reed canary grass with a grass-specific herbicide (Fusilade) and planted native grasses and forbs. These measures were effective at the restoration site and have nearly eradicated the RCG population there. In contrast, native species have not successfully established at the RCG site. Despite the burn, herbicide application, and native plantings, this area maintains 70–90% RCG cover, perhaps due to its altered hydrogeology. The restoration site is maintained by annual hand-pulling of common teasel (*Dipsacus fullonum*) and planting of native grasses and forbs.

Data Collection

Within each sampling location, we established three 10-m^2 quadrats. We sampled once a month June through August of 2020 and May through August of 2021. On each sampling occasion, we placed six pan traps (two each of red, blue, and white) in each quadrat, filled them with diluted dish detergent, and left them out for 96 hours (Dorado et al. 2011; Lebuhn et al. 2013). The selected bowl colors were similar to the colors of flowers found in the study area because color of adjacent flowers influences visitation rates (Hegland and Totland 2012).

We then emptied the trap contents into labeled containers filled with 70% isopropyl alcohol to preserve the specimens until they could be processed. Each sample included all individual insects collected for each day in a particular color trap for a sampling quadrat. We identified specimens to species level, when possible (Amateur Entomologists' Society 1997; insectidentification.org). If the key was lacking detail, we referenced a secondary identification text, *Insects of the Pacific Northwest*, offering pictures and descriptions of species found in the study site (Haggard and Haggard 2006).

Data Analysis

We used the *tidyverse* and *vegan* packages to conduct data analysis in program R (Wickham et al. 2019; Oksanen et al. 2020; R Core Team 2021). For this study, we included 35 species identified as effective pollinators (Appendix). For each pan trap on each sampling occasion, we calculated three response variables: abundance, richness, and diversity. We determined the species richness in each sample, and we quantified diversity by calculating e^H, the effective number of species based on the Shannon index (H).

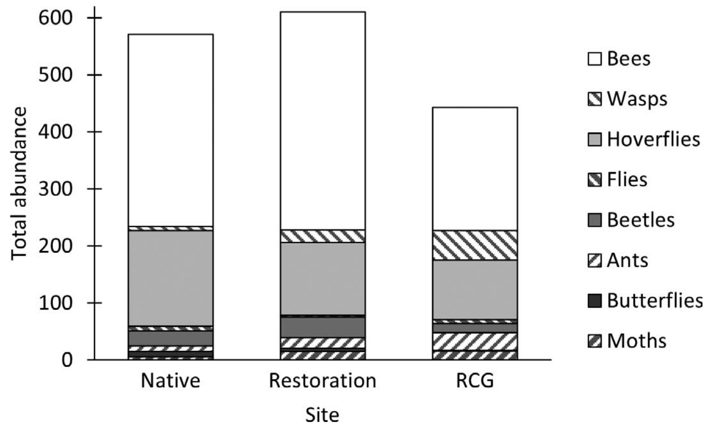

Figure 1.—Total abundance of pollinator groups in samples from native, restoration, and reed canary grass (RCG) sites at Lacamas Prairie Natural Area, Washington, 2020–2021.

We fit a suite of 5 generalized linear models to each response variable, using combinations of site and trap color as predictors. The sample date was included in all models as a random effect to account for stochastic environmental conditions. Both abundance and species richness were count data, and we modeled their errors accordingly. We used negative binomial regression to model abundance because the average abundance (8.60) was much less than the variance in abundance (46.37). Species richness had similar mean (2.96) and variance (2.62), so we used Poisson regression to model richness. We assessed q-q plots for assumption violations and used the corrected Akaike information criterion (AICc) to compare models for each response (Hurvich and Tsai 1989).

RESULTS

We analyzed 189 samples with a combined total of 1625 individual pollinators. Seventeen pollinator species were observed at all three sites and accounted for 97.3% of all observations. Bees were the most common pollinators observed at every site, although they comprised a smaller proportion in the RCG site (Figure 1). Samples from the native site had a greater proportion of hoverflies than the other sites, while samples from the RCG site had a greater proportion of wasps (Figure 1).

On average (95% CI), there were 8.60 (7.62, 9.57) pollinators from 2.96 (2.73, 3.20) species in each sample. The mean diversity, measured as the effective number of pollinator species per sample, was 2.46 (2.28, 2.65). The widest part of the sample distribution of each metric tended to be highest in the native site, intermediate at the restoration site, and lowest at the RCG site (Figure 2).

Trap color was included in the top models for all three metrics, but site was only in the top model for abundance (Table 1). Model results indicated that white traps generally captured more individuals of more species, while red traps caught the fewest individuals and the fewest species (Figure 3). According to the top model for pollinator abundance, native and restoration sites were comparable, with predicted averages of 9.06 (7.15, 11.48) and 9.51 (7.52, 12.03), respectively. However,

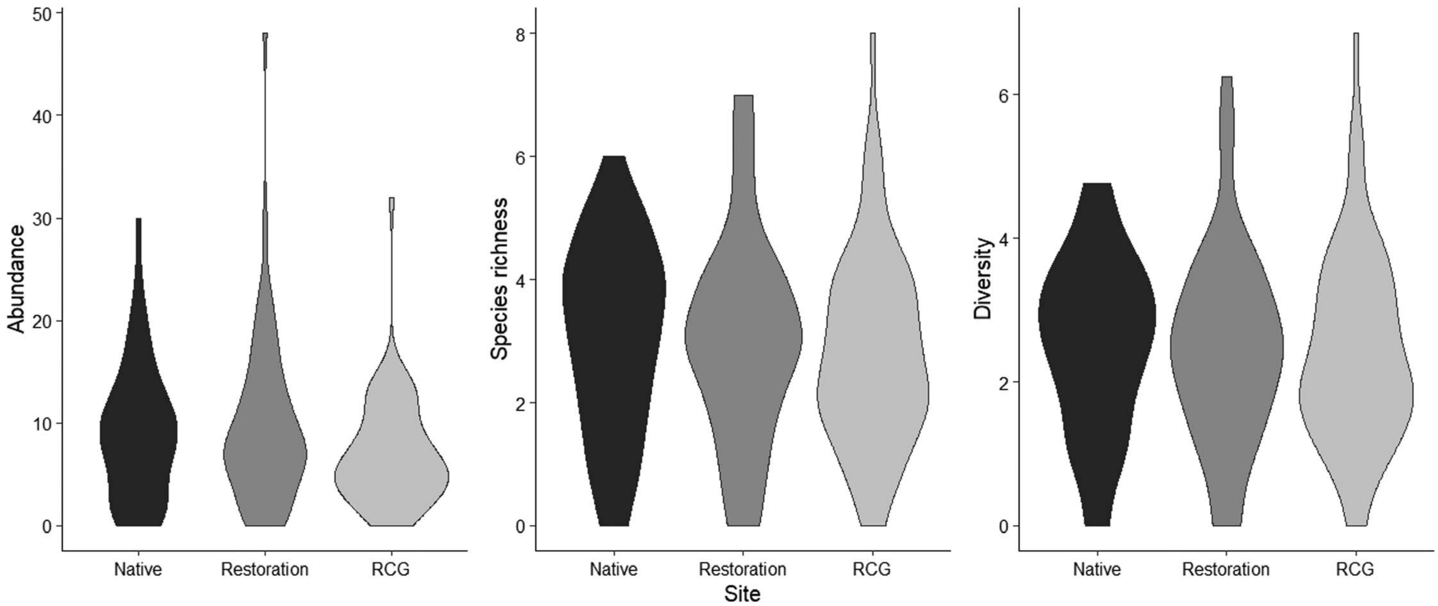

Figure 2.—Violin plots showing the distributions of pollinator community metrics for samples from native remnant prairie, restored prairie, and an area dominated by reed canary grass (RCG) at Lacamas Prairie Natural Area, Washington, 2019–2020. Diversity is the effective number of species based on the Shannon index.

the RCG site had a significantly lower predicted mean abundance of 7.26 (5.69, 9.26; Figure 3).

DISCUSSION

The area with effective habitat restoration and invasive species control had a pollinator abundance similar to the remnant native area and higher than the site heavily invaded by reed canary grass. Although restoration status was not included in the top models for species richness or diversity, comparisons of the distributions of these measures across the three sites provided weak evidence that these other aspects of pollinator communities were also positively associated with restoration. These observations are likely driven by plant–pollinator relationships. Increased floral diversity has been found to increase pollinator visitation and large diverse pollen rewards increased the likelihood of visits by hymenopteran and dipteran pollinators (Harder 1990; Makino et al. 2007; Semere and Slater 2007; Vaudo et al. 2015). Diversity in the timing of flowering can also provide resources throughout the season to support more abundant and diverse pollinator communities (Harder 1990; Makino et al. 2007; Weiner et al. 2014; Pyke 2016). Relative to the native and restored areas, the invaded site likely had a much lower potential nutritional reward for pollinators, as reed canary grass only flowers until early July and is wind-pollinated (Merigliano and Lesica 1998; Runkel et al. 2009). Further, reduced floral diversity from competitive exclusion by reed canary grass within the invaded site may account for lowered pollinator diversity (Semere and Slater 2007).

Table 1.—Model selection results for the Lacamas Prairie pollinator community metrics. The ΔAICc for the best models of each metric is in bold.

	Abundance		Richness		Diversity	
Model	K	ΔAICc	K	ΔAICc	K	ΔAICc
Color + date	10	4.64	9	**0.00**	10	**0.00**
Site + color + date	12	**0.00**	11	3.70	12	4.27
Site * color + date	16	0.02	15	10.30	16	9.26
Date	8	60.10	7	15.88	8	23.56
Site + date	10	62.48	9	19.48	10	27.76

Differences among the sites, particularly in species richness and diversity, may have been reduced by their proximity to one another and to edge habitat. When connectivity is high, many pollinators readily move between prime foraging areas and sites that provide refuge or other resources (Klein et al. 2007; Ricketts et al. 2008; Garibaldi et al. 2011; Kennedy et al. 2013; Lowe et al. 2021). Similarly, the colored pan traps may have attracted pollinators from beyond the edge of each site, essentially sampling species that did not really occur at the site.

The colors of the traps themselves likewise had strong effects on the abundance and diversity of pollinator samples, with white and blue traps performing better than red traps. Previous work has similarly found that red pan traps captured a lower abundance and richness of pollinators than blue or white traps (Campbell and Hanula 2007). However, our results are inconsistent with several studies in which blue traps captured greater abundance and richness of pollinators than white traps (Campbell and Hanula 2007; Nuttman et al. 2011; Moreira et al. 2016). It is possible that our white traps were more effective because they had higher reflectance (Vrdoljak and Samways 2012).

While the study area showed visible differences in habitat condition, not all pollinator community metrics we measured showed statistically significant differences. However, habitat connectivity is increasingly recognized as a key component to the restoration of pollinator populations, and the proximity of

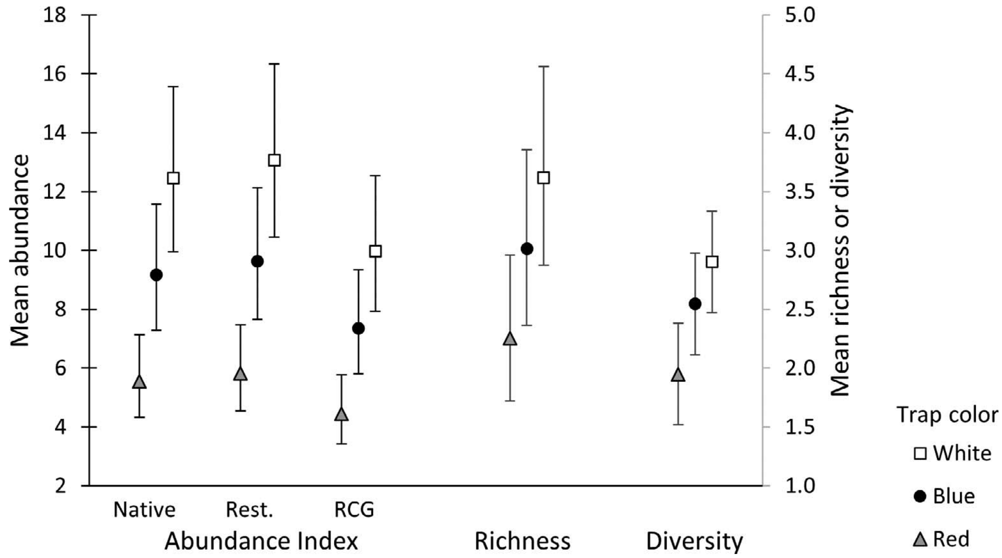

Figure 3.—Mean abundance, species richness, and diversity (effective number of species) of pollinators caught at Lacamas Prairie Natural Area, Washington, 2020–2021, varied over time and with the color of pan trap. The abundance also differed between the native, restoration (Rest.), and reed canary grass (RCG) sites. Error bars show 95% confidence intervals after removing the effect of sample date.

our study sites to one another may have served to reduce observable differences among them. The lack of geographically independent replicates also restricts the generalizability of our results. Despite these limitations, our findings suggest that habitat restoration has benefited pollinators at the Lacamas Prairie Natural Area. Additionally, the observed effects of trap color warrant further investigation for optimizing post-restoration monitoring of pollinators.

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APPENDIX.—Pollinators observed in pan traps at Lacamas Prairie Natural Area, Washington, 2020–2021.

Order	Family	Scientific name	Common name of species or group
Coleoptera	Cerambycidae	*Brachysomida californica*	Longhorn beetle
		Stenostrophia amabilis	Flower longhorn beetle
		Callimoxys sanguinicollis	Longhorn beetle
Diptera	Calliphoridae	*Lucilia sericata*	Common green bottle fly
	Syrphidae	*Eupeodes lapponicus*	Lapland syrphid fly
		Eupeodes spp.	Hoverfly
		Syrphus ribesii	Hoverfly
		Toxomerus gemenatus	Eastern calligrapher
		Toxomerus spp.	Hoverfly
Hemiptera	Membracidae	*Stictocephala* spp.	Treehopper
Hymenoptera	Apidae	*Apis mellifera*	Western honey bee
		Bombus vosnesenskii	Yellow-faced bumblebee
		Bombus mixtus	Fuzzy-horned bumblebee
		Bombus nevadensis	Nevada bumblebee
		Bombus spp.	Bumblebee
	Formicidae	*Formica obscuripes*	Western thatching ant
	Halictidae	*Agapostemon viriscens*	Bicolored striped-sweat bee
		Augochlora pura	Sweat bee
	Megachilidae	*Osmia* spp.	Mason bee
	Sphecidae	*Ammophila procera*	Common thread-waisted wasp
		Bembix spp.	Sand wasp
	Vespidae	*Polistes* spp.	Paper wasp
Lepidoptera	Arctiinae	*Pyrrharctia isabella*	Isabella tiger moth
		Tyria jacobaeae	Cinnabar moth
	Erebidae	*Spilosoma vagans*	Wandering tiger moth
	Hesperiidae	*Ochlodes sylvanoides*	Woodland skipper
	Lasiocampidae	*Malacosoma disstria*	Forest tent caterpillar moth
	Lycaenidae	*Callophrys augustinus*	Brown elfin
	Noctuidae	*Leucania farcta*	Meadow wainscot moth
		Papaipema sauzalitae	Figwort stem borer
	Notodontidae	*Nadata oregonensis*	Prominent moth
	Papilionidae	*Papilio rutulus*	Western tiger swallowtail
		Papilio multicaudatus	Two-tailed swallowtail
	Psychidae	*Hyaloscotes fumosa*	Moth
	Sesiidae	*Synanthedon bibionipennis*	Strawberry crown moth