THE EFFECTS OF LOCAL PATCH FIRE SEVERITIES ON LEPIDOPTERA OF THE PACIFIC NORTHWEST

by

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This study investigates the impact of varying fire severities on Lepidoptera populations in the Pacific Northwest, focusing on areas affected by the Holiday Farm, Beachie Creek, Dixie, and Claremont Fires in Oregon and California. By employing multiple collection methods, including netting, pan traps, and Blue Vane Traps (BVTs), Lepidoptera abundance, diversity, and overall richness were assessed across different fire severities. The results reveal that areas with heterogeneous fire severities exhibit greater Lepidoptera species richness and abundance compared to homogeneous fire regimes. Moreover, BVTs emerged as the most effective collection method, capturing the majority of recorded Lepidoptera specimens. However, this study acknowledges limitations such as small sample size and methodological biases. Overall, this research contributes valuable insights into the complex interactions between fire severity, landscape heterogeneity, and Lepidoptera communities, informing conservation and management strategies for promoting biodiversity conservation and eco-system resilience in fire-prone landscapes.

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1. INTRODUCTION

1.1. The Importance of Pollinators and Fire

Over 80% of angiosperms rely on pollinators to reproduce, supporting a wide range of global ecosystem functions and services (Ze-Yu, 2011). A subset of angiosperms rely specifically on Lepidoptera, the insect order that includes butterflies, skippers, and moths. These insects perform numerous vital ecological roles as pollinators, herbivores, and food for other animals (Ross, 2003). They link the plant energy that they consume as primary producers to the animals (carnivores) that consume them. Due to their integral role in maintaining numerous life forms, butterflies and moths also quickly reflect changes in the biological and physical factors that affect them (Ross, 2003). Different events, such as climate change or wildfires, can affect the biological and physical characteristics that sustain pollination, leading to vastly decreasing pollinator populations and fewer resources to help keep native ecosystems healthy.

Fire is critical for maintaining species diversity (Carbone et al., 2019). Prescribed fire, the controlled application of fire by experts, aims to restore health to ecosystems that depend on fire to survive (He et al., 2019). Prescribed fire is especially beneficial for native Oregon butterflies and moths, like the Fender's Blue and Taylor's checkerspot (Andrusyszyn, 2013). Oregon's Fender's Blue butterfly and Taylor's Checkerspot butterfly, among many other Lepidoptera species, live in habitats now dominated by invasive grasses, affecting their reproduction. This habitat loss can have long-term effects on the migration and colonization of Oregon Lepidoptera. These invasive grasses can be removed using prescribed fire, and this essential habitat can be maintained, promoting butterfly reproduction for years to come (Severns, 2008).

The benefits of prescribed fire are far-reaching, not only for pollinators, but for the ecosystem as a whole. Prescribed fire can stimulate plant growth, create open habitat, and decrease the risk of catastrophic wildfires, all while supporting populations of endangered and threatened species (Andrusyszyn, 2013). Some areas treated with prescribed fire rebound so significantly that new plant and animal life are present almost immediately after the burning. A recent study showed that regular prescribed fires showed exceptional levels of species richness dominated by native plants and animals. Greater species richness and native biodiversity occur because the topography, vegetation, and weather conditions during a prescribed burn generate a landscape suited to promote growth and biodiversity across local and regional scales (He et al., 2019).

Wildfires have been shown to produce similar effects to prescribed fires. An increase in climate change-induced wildfires has led to negative interactions between plants and pollinators and an overall decline in pollinator populations (He et al., 2019). Fire can negatively affect plant-pollinator interactions directly through increased mortality rates, or indirectly by modifying habitat (Brown et al., 2017). Changing the habitat structure can affect the butterflies' and moths' visibility, resources, and flowering pattern, thereby affecting pollination (Carbone et al., 2019). Climate change-induced wildfires may also impact Lepidoptera reproductive rates as the fires destroy the plants that host butterfly and moth larvae, which can lead to quickly declining populations (Ross, 2003).

Current research is aimed at disentangling the effects of wildfires and prescribed burns, especially in relation to pollinator populations (Brown et al., 2017). Prescribed burns are done in set intervals to best promote plant growth and pollinator health, whereas wildfires can happen at any time, and could reoccur over short intervals, effectively wiping out habitats (He et al., 2019). A recent study has shown that high fire frequency negatively affects pollinator populations, but low fire frequency was shown to increase both Lepidoptera species richness and abundance

(Carbone et al., 2019). In addition, short fire intervals may prevent plants from reaching maturity and flowering, whereas longer fire intervals promote native plant growth and increase pollination rates.

Patchy environments, induced by heterogeneous fire severity, benefit pollinators (Brown et al., 2017). Heterogeneous fire severity is a "mixed severity" fire regime, meaning that it combines low and medium fire severities with high fire severities to promote species diversity and limit the spread and effects of wildfires (Belote, 2015). Prescribed fires also promote "landscape memory," which refers to interactions between present and subsequent fires (Keeley, 2009). A subsequent, heterogeneous fire has the potential to limit the spread of homogenous wildfires, which may lead to proportionally higher severity burns, and instead promote ecosystem function and biological diversity (Belote, 2015).

As climate conditions have changed over the years, insect populations have experienced declines in their populations, while others have increased. Using community science and over 26 years of data, Crossley et al. showed a large amount of heterogeneity in butterfly and moth abundance, with overall mass population decline. Butterflies and moths were found to be clustering into regions of increase, decrease, or relative stasis. Some Lepidoptera populations were increasing in areas that were wet and cold, whereas other Lepidoptera populations were decreasing in dry, hot areas (Crossley et al., 2021). A changing climate affects not only pollinator survival, but human survival as well. Humans rely on pollinators because of the crucial role that they play in food production and the reproduction of flowering plants. Community science has shown that pollinator populations are negatively affected by habitat alteration and habitat disturbances, such as wildfire events (Carvalheiro et al., 2010).

In order to survey pollinators and their relationships with post-fire landscapes, different collection methods must be utilized. Comparing pollinator collection methods reveals significant differences in their effectiveness and biases. Studies have demonstrated that net collection methods are highly effective for capturing flying insects, including pollinators like butterflies and bees (Nicolson et al., 2017; Petanidou et al., 2018). Netting allows for targeted sampling of specific habitats and can capture a wide range of insect taxa, making it a valuable tool for biodiversity assessments (Corbert et al., 2001). However, net collection may underestimate ground-dwelling or cryptic species and is subject to observer bias and skill (Nicolson et al., 2017). Pan trap collections, on the other hand, provide a standardized method for sampling pollinators and are particularly effective for capturing small bees and flower-visiting flies (Westphal et al., 2008). Pan traps offer a less-invasive sampling approach and can be deployed over large spatial scales, facilitating comparisons across sites and habitats (Nicolson et al., 2017).

Blue Vane Traps (BVTs) have emerged as a powerful tool for sampling flying insects, including pollinators, over large spatial scales (Campbell et al., 2007). BVTs attract flying insects using visual cues and can be deployed in diverse habitats, providing comprehensive assessments of pollinator diversity and abundance (Campbell et al., 2007; Proença et al., 2017). However, BVTs may overestimate certain pollinator taxa attracted to their visual stimuli and may not effectively sample ground-dwelling or cryptic species (Proença et al., 2017). Understanding the strengths and limitations of different pollinator collection methods is essential for comprehensively assessing the impacts of varying fire severities on pollinator communities.

Fire can have both positive and negative effects on ecosystems. Understanding how distinct types of fires and different fire severities affect butterflies and moths is important in predicting the future of pollination. In pursuit of this project, I collected data on butterfly and moth abundance, diversity, and richness relative to different fire severities. My work spans different areas in Oregon where I can focus on native Oregon plant-pollinator interactions. Through this project, I contribute to our understanding of how fire can be used to support pollinator health.

1.2. Research Questions and Hypotheses

The purpose of this research is to understand how varying local patch fire severities affect pollinator populations, specifically Lepidopteran populations. The central question of my research is: how does fire severity impact butterflies and moths? To answer this question, I tested whether (1) Lepidoptera collection method effectiveness will vary across different fire severities; (2) Lepidoptera biodiversity will vary across different fire severities; and (3) Lepidoptera richness will increase in localities of heterogeneous fire severities and decrease in localities of homogeneous fire severities.. That is, I expect that fire localities with heterogeneous patch severities will be more beneficial for butterflies and moths compared to fire localities with homogeneous patch severities.

2. MATERIALS AND METHODS

2.1. Study System

To make comparisons between heterogenous fires and homogenous fires, I looked at four different fires throughout the Pacific Northwest. Two of the fires, the Holiday Farm fire and Beachie Creek fire were located in Oregon, and the other two fires, the Dixie fire and Claremont fire, were located in Northern California.

Figure 1: Map of the fire locations provided by the Ponisio Lab. The Beachie Creek fire (44.85°N, -122.42°W), the Holiday Farm fire (44.18°N, -122.25°W), the Claremont fire (39.85°N, 120.96°W), and the Dixie fire (39.87°N, 121.39°W). The Riverside fire was not used in this study.

The majority of my data collection was related to the Holiday Farm fire in 2020, which significantly affected numerous areas along the McKenzie River. The Holiday Farm fire burned over 165,000 acres of land along the McKenzie River, 124,700 acres of which were burned with medium and high severity. 89,000 acres burned at high severity, 26,900 acres burned at medium severity, and 20,100 acres burned at low severity (OregonForests.org, 2021). To collect data for the Holiday Farm fire, I worked with Whitewater Ranch, an organic blueberry and timber farm off of the McKenzie River, as well as on the land of a private industrial timber company, nearby Whitewater Ranch.

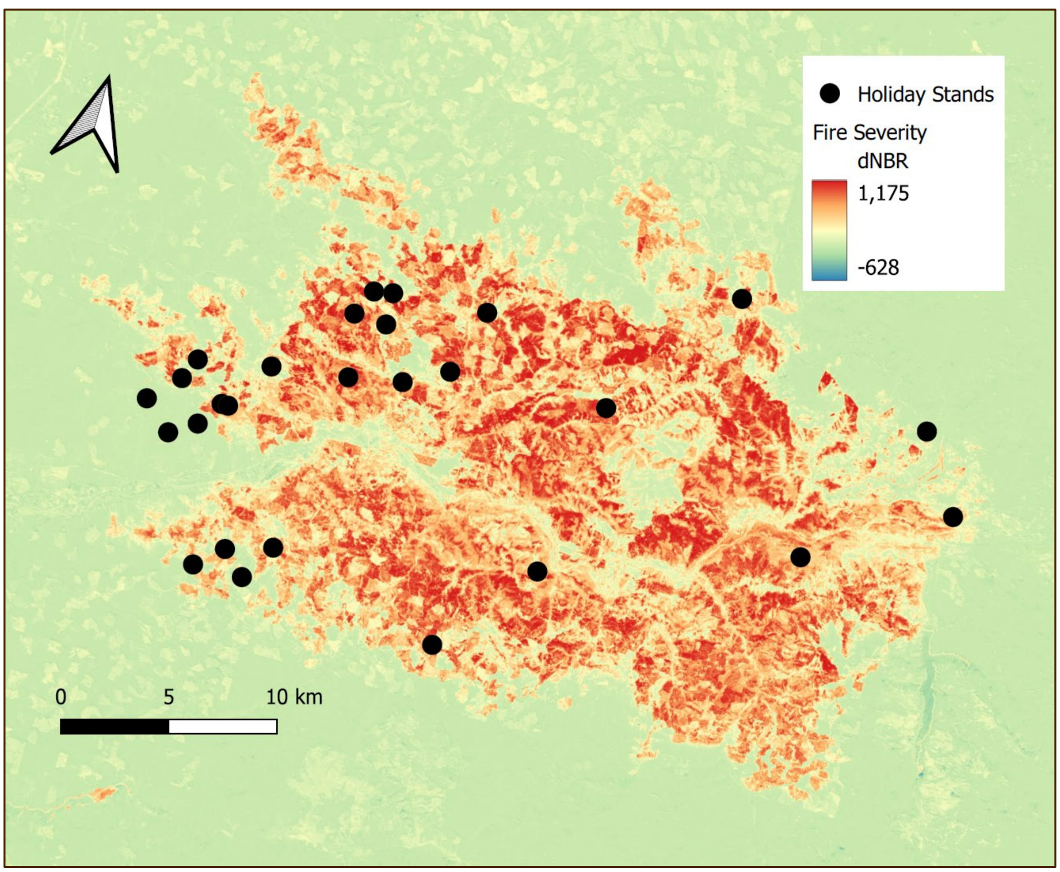


Figure 2: Fire severity map of the Holiday Farm fire from the Ponisio Lab. Red indicates 91-100% vegetation loss. Orange indicates 76-90% vegetation loss. Yellow indicates 51-75% vegetation loss. Light green indicates 26-50% vegetation loss. Dark green indicates 11-25% vegetation loss. Light blue indicates 1-10% vegetation loss. Dark blue indicates no vegetation loss.

The second location was the Beachie Creek fire, which burned over 183,000 acres of land near Portland, Oregon, 122,700 acres of which burned at medium and high severity. 86,000 acres burned at high severity, 28,800 acres burned at medium severity, and 25,800 acres burned at low severity (OregonForests.org, 2021). The Beachie Creek fire burned through the Willamette forest and our data was collected on the land of a private industrial timber company near Portland, Oregon.

The third location was the Dixie fire that occurred in 2021 in Northern California. The Dixie fire, California's second-largest wildfire, burned over 963,000 acres of land, over 73,000 acres of which were located within Lassen Volcanic National Park. Within the park, 23,493 acres burned at high severity, 34,450 acres burned at low to medium severity, and 12,845 acres remained unburned (National Park Service, 2022). The majority of the intense impacts from these fires were concentrated along the park's southern boundary, where intense winds pushed the fire into the area.

The fourth location was the Claremont fire, which occurred in Northern California in 2020. The Claremont fire was a part of the North Complex fire, which consisted of 21 separate fires, with Claremont being one of the biggest. The North Complex fire burned almost 319,000 acres through the Plumas and Lassen National Forests. Over 170,000 acres were burned at high severity, generating a high-severity burn landscape unlike any fire that the Sierra-Nevada region had seen before (Sierra Nevada Conservancy, 2021).

I determined the fire severity of the localities where each Lepidoptera was collected using data calculated from the dNBR, or the Postfire Normalized Burn Ratio subtracted from the Prefire Normalized Burn Ratio, proposed by the US Geological Survey (Keeley, 2009). I then cross verified the fire severities at each collection location with field collected data, including canopy cover information and tree mortality rates. Comparing collection location and fire severity will allow me to determine how butterflies and moths are impacted differently between low severity and high severity fire patches.

2.2. Collection Methods

To collect data from all three fires, the Ponisio Lab collaborated with the National Council for Air and Stream Improvement (NCASI). Each study site was divided into multiple stands (#600, #620), which each had three different sites (1, 2, 3), which had two thirty-two meter transects per site (A, B). There was also a singular transect along the road (R), to collect data in a further disturbed zone.

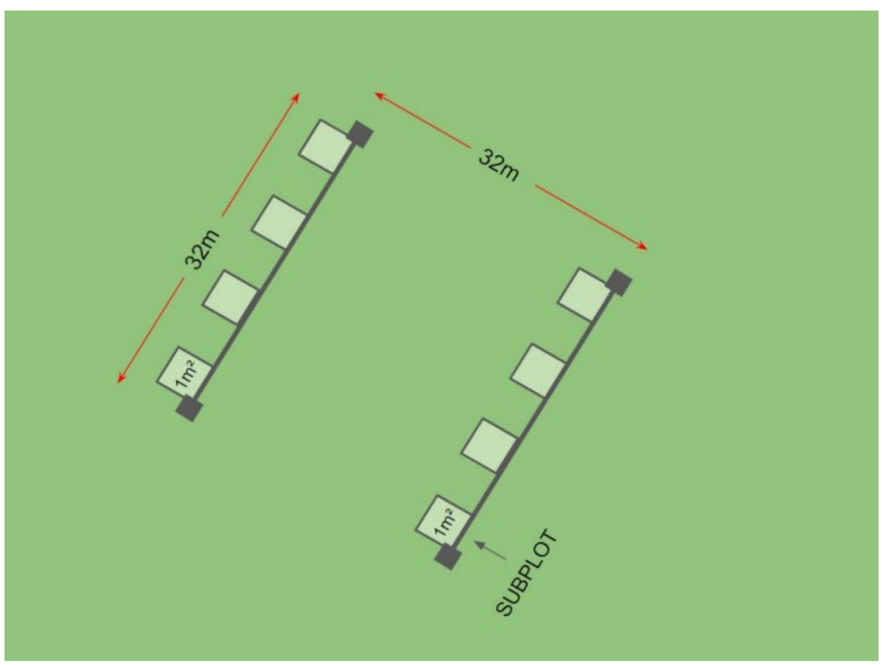


Figure 3: Model of paired transects and the subplots that were used during vegetation surveys. Image by Clare Massaro.

Vegetation surveys were conducted at each transect to monitor the effects of mixed fire severities on plant survival. A 1 m x 1 m quadrat was placed at each subplot (0m, 4m, 8m, 12m, 16m, 20m, 24 m, 28m), and I counted any blooming forbs, shrubs, or trees that were rooted in that quadrat. For my data collection, I classified blooming as having visible pollen-bearing structures, excluding wind-pollinated plants like grasses or conifers.

Netting Collection

At each transect, I caught all insects visiting flowers, including butterflies and moths for 10-minute periods using nets. Once the collection period began, I surveyed both sides of the transect and caught any insects that were touching the reproductive parts of a flower. Anytime an insect was caught, the timer would be paused. For butterflies and moths, I would place the insect in a wax paper envelope and label the envelope with date, time, location, and the plant the insect was visiting. After the butterfly was removed from the net, I resumed the 10-minute net walk. After the 10 minutes was completed, I moved on to the next transect and repeated the process.

Pan Trap Collection

I also collected data using pan traps, which were set up near the road before starting net capture. Pan traps were an array of nine colored (blue, yellow, white) pans that I filled half full of soapy water. The pans were arranged in three evenly spaced spokes with alternating orders of colors. After completing the net capture, I could collect the insects that were caught in the pan traps. The insects would be strained out of the pans and placed into vials filled with 70% ethanol and sorted by pan color. This process was repeated at each stand I visited.

Blue Vane Collection

Blue Vane traps (BVT) were also used to passively collect insects. Two traps were set up at each stand and they were taken down no more than two weeks after they were set up. The trap was hung from a hook attached to a four' wooden stake, hammered into the ground. The trap was then filled with 250mL of propylene glycol and conditions were taken. At the time of data collection, the trap is carefully detached from the stake and the contents of the trap are poured through a strainer. The collected insects are then transferred to a collection vial filled with 70% ethanol until they are fully covered. This process was repeated every two weeks.

Figure 4: Collection methods utilized in study. (A) Net collection, (B) Pan Trap collection, (C) Blue Vane Trap collection.

2.3. Data Analysis

After Lepidoptera were collected at each fire location (Holiday Farm, Beachie Creek, Dixie, and Claremont), I pinned and identified each specimen. Once the Lepidoptera were identified, I conducted un-paired, two-tailed t-tests in Microsoft Excel to compare the abundance and species richness of Lepidoptera caught at each fire locality and severity. Similarly, I used Shannon's Diversity Index and Equitability Index to measure the species richness and evenness of the Lepidoptera species collected at each fire locality. I then used the calculated diversity and equitability indices to compare the community composition of Lepidoptera in areas of heterogeneous fire severities and homogeneous fire severities.

3. RESULTS

3.1. General Analysis

There was a visual difference in the proportion of Lepidoptera between the unburned, low severity, medium severity, and high severity fire sites (Figure 4). The most Lepidoptera were recorded at medium severity sites, then high severity sites, with unburned and low severity sites having the lowest number of Lepidoptera recorded. Of a total of 197 Lepidoptera captured, 17 were recorded at low severity sites, 101 were recorded at medium severity sites, 74 were recorded at high severity sites, and 5 were recorded at unburned sites.

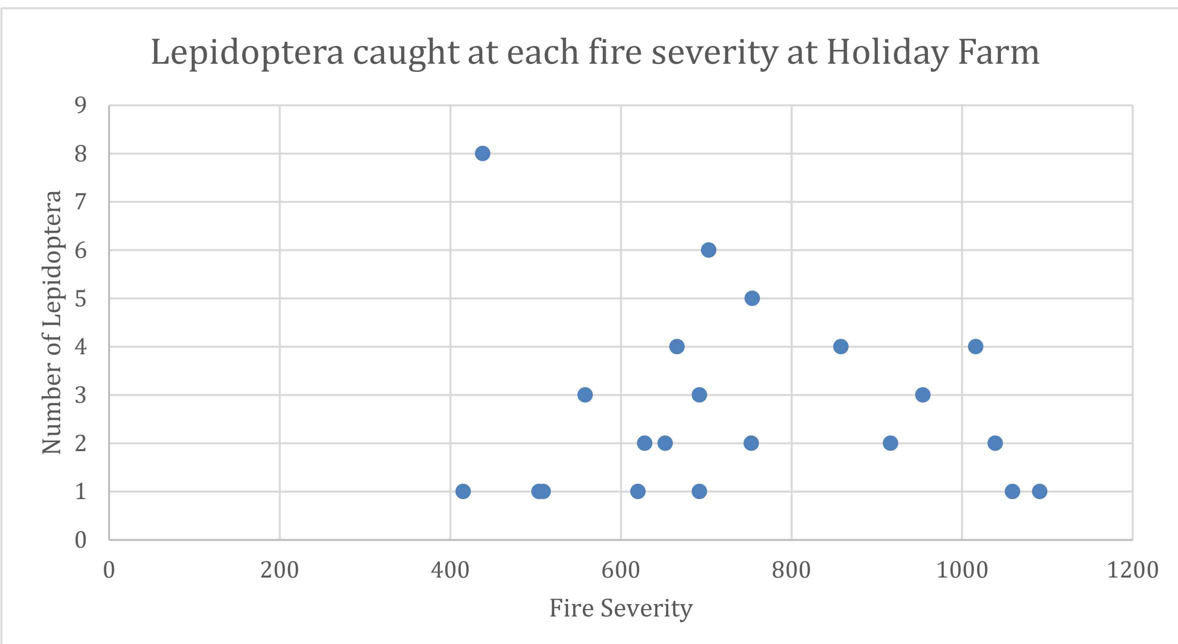


Figure 5: Graph depicting the Lepidoptera that were caught at each fire severity at the Holiday Farm fire. Fire severity numbers are classified by: Low severity (+100 to +269), Moderate-low severity (+270 to +439), Moderate-high severity (+440 to +659), and High severity (+660 to +1300) (Keeley, 2009). All Lepidoptera collected at the Holiday Farm fire site were in areas of Moderate-high to High fire severity.

Of the three collection methods utilized (net collection, pan collection and BVT collection), most of the recorded Lepidoptera were collected using BVT (Figure 5). Out of a total of 197 insects, 176 were collected using Blue Vane Traps (BVT), 16 were collected through netting techniques, and only 5 were collected through pan-capture techniques.

3.2. Blue Vane Trap Data

I analyzed BVT data from all four fires outlined in this study: 36 specimens were collected from the Beachie Creek fire, 73 collected from the Claremont fire, 18 collected from the Dixie fire, 48 collected from the Holiday Farm fire, and one was collected from non-fire sites.

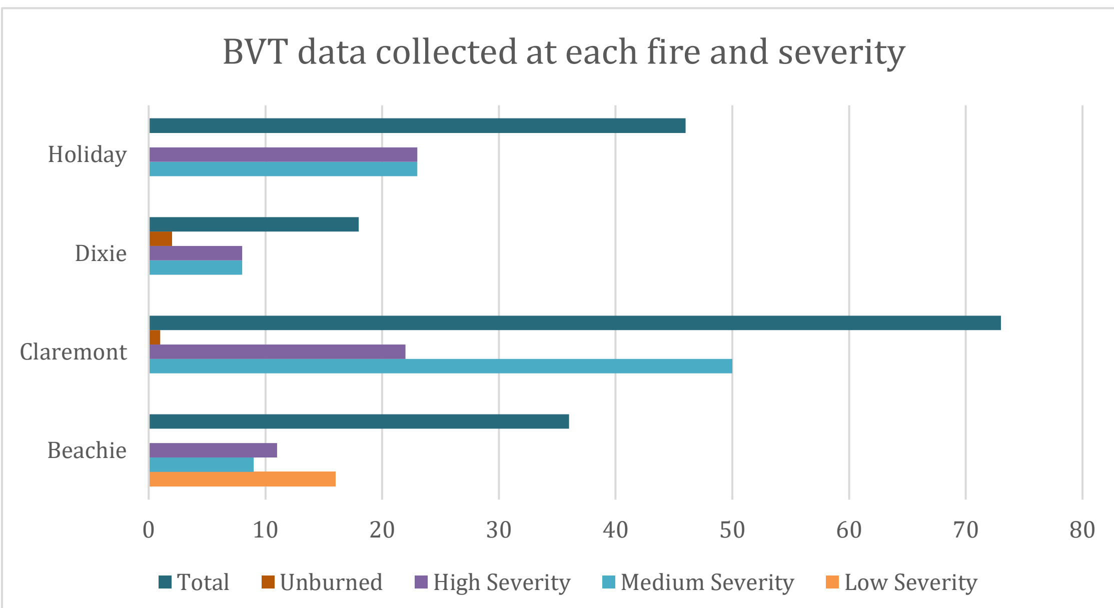


Figure 6: Graph depicting the Lepidoptera that were caught using BVTs. The graph is divided by fire (Holiday, Dixie, Claremont, and Beachie), as well as by severity (Unburned, High Severity, Medium Severity, and Low Severity). Data collected from unburned sites appeared only at the Dixie and Claremont fires in California. Data collected from low severity site appeared only at the Beachie Creek fire in Oregon. The majority of data was collected from the Claremont fire, in medium severity sites.

3.3. Netted Data

My netted data came solely from the Holiday Farm fire and consisted of a total of 16 specimens. The specimens were collected across eight different stands: one caught in an area of low severity burns, six caught in an area of medium severity burns, and nine caught in an area of high severity burns.

3.4. Pan Trap Data

My pan trap data also came solely from the Holiday Farm fire, and it consisted of only 5 specimens. The specimens were collected across three different stands: zero collected in an area of low severity burns, four collected in an area of medium severity burns, and one collected in an area of high severity burns.

3.5 T-Tests Calculations

Table 1: T-test Results for Lepidopteran Abundance at Low, Medium, and High Severity Sites

Abundance	t	df	Std. Error Difference	Mean Difference	Sig. (2-tailed)	**Significant?**
Low Severity vs. Medium Severity	0.717	105	5.79	18.75	0.12667916	**No**
Low Severity vs. High Severity	2.12	78	-0.193	12	0.07277453	**No**
Medium Severity vs. High Severity	1.39	153	5.98	6.75	0.54434328	**No**

Table 2: T-test Results for Lepidopteran Species Richness at Low, Medium, and High Severity Sites

Richness	t	df	Std. Error Difference	Mean Difference	Sig. (2-tailed)	**Significant?**
Low Severity vs. Medium Severity	15.75	25	1.37132	5.25	0.05837387	**Yes**
Low Severity vs. High Severity	8.42	31	0.882993	6.25	0.01317392	**Yes**
Medium Severity vs. High Severity	3	52	-0.21543	0.5	0.84605252	**No**

3.6 Shannon's Biodiversity Index Calculations

Using Shannon's Biodiversity Index and Shannon's Equitability Index, I calculated the species richness and evenness for both the Claremont and Holiday Farm fires. To do this, I counted the number of distinct species and the abundance of each species at each fire locality to compute the proportion of each species. Then, for each species, I calculated the natural logarithm of its proportion and multiplied it by the proportion itself. The results were then summed for Shannon's Biodiversity Index, which measures species richness in an ecosystem. Shannon's Equitability Index is calculated by dividing Shannon's Biodiversity Index by the natural logarithm of the total number of species observed. This index helps standardize diversity values across different ecosystems (low severity, medium severity, high severity). Higher values for Shannon's Biodiversity and Equitability indices indicate high species diversity and evenness, respectively. The Claremont fire had a species richness of 1.4281 and a species evenness of 0.59. The Holiday Farm fire has a species richness of 2.466 and a species evenness of 0.8.

$$\frac{8\ Pale\ Swallowtail}{70\ Total\ Butterflies} = 0.114(\ln(0.114)) = -2.48$$

$$-2.48 + -0.0597 + -0.0597 + -0.163 + -0.163$$

$$+ -0.133 + -0.306 + -0.0597 + -0.133$$

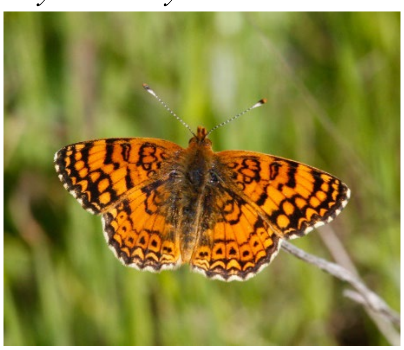
$$+ -0.103 = -1.428(-1) = 1.428$$

$$\frac{1.4281}{\ln(11\ species)} = \mathbf{0.59}$$

Figure 7: Example of the calculations for Shannon's Biodiversity Index and Shannon's Equitability Index for the Claremont Fire. The number of individuals per species present (8), was divided by the total number of specimens at that locality (70). The natural logarithm of the quotient was taken and multiplied by the quotient (-2.48). This process was repeated for each species present, and the proportions were added together to produce Shannon's Biodiversity Index (1.428). To Find Shannon's Equitability Index (0.59), Shannon's Biodiversity Index was divided by the natural log of the number of distinct species in that locality.

3.7. Butterflies

Table 3: Butterfly Species Identification Guide

ID	Number of Specimens	Capture Method	Fire Location	Fire Severity	State
Parnassius clodius 	37	34 BVT 2 Net 1 Pan	21 Beachie 16 Holiday	13 High 10 Low 7 Medium	OR
Phyciodes mylitta 	16	0 BVT 12 Net 4 Pan	16 Holiday	9 Medium 1 Low 6 High	OR
Papilio eurymedon 	10	10 BVT 0 Net 0 Pan	2 Holiday 1 Dixie 7 Claremont	7 High 3 Medium	OR, CA

Ochlodes sylvanoides 	8	8 BVT 0 Net 0 Pan	4 Beachie 4 Claremont	5 Medium 3 High	OR, CA
Boloria myrina 	5	5 BVT 0 Net 0 Pan	4 Beachie 1 Claremont	4 Low 1 Medium	OR, CA
Atalopedes campestris 	4	4 BVT 0 Net 0 Pan	Claremont	3 Medium 1 High	CA
Euphyes vestris 	2	2 BVT 0 Net 0 Pan	1 Holiday 1 Dixie	1 High 1 Medium	OR, CA

Limenitis lorquini 	1	1 BVT 0 Net 0 Pan	Claremont	Medium	CA
Nymphalis californica 	1	1 BVT 0 Net 0 Pan	Dixie	High	CA
Cercyonis sthenle 	1	1 BVT 0 Net 0 Pans	Holiday	Medium	OR
Plebjus argyrognomon 	1	0 BVT 1 Net 0 Pan	Holiday	Medium	OR

Strymon melinus 	1	1 BVT 0 Net 0 Pan	Holiday	High	OR

4. DISCUSSION

4.1. Effectiveness of Collection Methods of Lepidoptera

The effectiveness of different collection methods in capturing Lepidoptera species across varying fire severities emerges as a critical consideration in understanding post-fire Lepidoptera community dynamics (Corbert et al., 2001). My findings reveal notable disparities in the abundance and distribution of Lepidoptera species among net collection, pan collection, and Blue Vane Trap (BVT) collection methods. Despite the inherent biases and limitations associated with each technique, BVT collection emerged as the most efficient method, collecting the majority of recorded Lepidoptera specimens. This efficiency is likely attributed to the BVT's ability to attract flying insects, especially Lepidoptera, over a large spatial scale, making it particularly suitable for sampling diverse insect communities in post fire landscapes (Campbell et al., 2007). Conversely, net collection techniques yielded fewer Lepidoptera specimens, indicating its' lower efficacy in collecting flying insects, especially in open habitats created by high-severity fires.

The observed variation in collection method effectiveness underscores the importance of considering methodological biases and ecological contexts when designing sampling protocols in fire-affected ecosystems. While BVT's excel in capturing Lepidoptera cross a range of fire severities, their reliance on wind patterns and placement locations may introduce spatial biases and influence capture rates (Campbell et al., 2007). Net collection, although labor intensive and potentially biased towards certain habitat types, offers opportunities to capture a broader range of insect taxa, including non-flying species (Corbert et al., 2001). Pan traps, while less effective for capturing Lepidoptera, may still provide valuable insights into insect communities, particularly in more disturbed areas, like the roadside (Westphal et al., 2008).

Overall, my results highlight the importance of employing multiple collection methods to capture the full spectrum of Lepidoptera diversity and abundance in fire-affected landscapes. By integrating complementary techniques and accounting for their respective strengths and limitations, future research can enhance the comprehensiveness and robustness of insect surveys, thus facilitating more accurate assessments of post-fire ecological recovery and conservation.

4.2. Biodiversity of Lepidoptera Species

In order to calculate the biodiversity of Lepidoptera species across differing fire severities, I used Shannon's Biodiversity and Equitability Indices. The calculations of these indices provide valuable insights into the biodiversity patterns of Lepidoptera communities across fire-affected landscapes. The higher species richness and evenness observed at the Holiday Farm fire compared to the Claremont fire suggest differences in habitat structure, disturbance severity, and post fire recovery trajectories between the two sites (New, 2014). The Holiday Farm fire, categorized by a more heterogeneous landscape and a mosaic of fire severities, likely created diverse microhabitats and resource niches, fostering the coexistence of numerous Lepidoptera species (Carbone et al., 2019). In contrast, the Claremont fire, with its relatively uniform severity, may have supported fewer species with less distribution across the landscape.

These findings underscore the complex interplay between fire regimes, habitat heterogeneity, and the biodiversity dynamics that shape post-fire Lepidoptera communities (Kwon et al., 2013). However, it's essential to acknowledge the potential influence of other factors, such as site specific environmental conditions, dispersal limitations, and historical land use, which may contribute to the observed variation in Lepidoptera diversity (O'Connor et al., 2019). Further research incorporating long-term monitoring and experimental manipulations is needed to better understand the mechanisms driving biodiversity patterns in post-fire ecosystems and inform effective conservation strategies for maintaining Lepidoptera diversity in the face of increasing wildfire intensity and frequency.

4.3. Lepidoptera Richness

The examination of Lepidoptera abundance and diversity across the four studied fires- Holiday Farm, Beachie Creek, Dixie, and Claremont- reveals intriguing patterns in relation to fire severity and landscape heterogeneity. Despite the extreme burn severity of the Claremont fire, characterized by high severity patches covering over 55% of the landscape, it emerged as the fire site with the most Lepidoptera abundance. However, this abundance contrasts with the fire's lower species richness, exhibiting only five butterfly species and seven moth species. In comparison, the Holiday Farm fire, while hosting fewer Lepidoptera overall, boasted a higher species richness with seven butterfly species and eleven moth species.

The disparity in Lepidoptera abundance across fire sites underscores the significant influence of landscape heterogeneity and fire severities on insect communities (Kwon et al., 2013). The distribution of Lepidoptera collection was notably influenced by the spatial diversity of stands within each fire site. Although the majority of stands were located in the Holiday Farm fire and were at high severity sites, the highest proportion of Lepidoptera were collected in medium severity sites. This suggests that areas characterized by mixed fires severities and greater landscape heterogeneity tend to support increased species richness and abundance. Conversely, homogeneous fire regimes, as observed in the Claremont fire, may result in reduced species diversity despite high abundance in certain areas (New, 2014).

These findings shed light on the complex interplay between fire severity, landscape heterogeneity, and Lepidoptera community dynamics. These implications extend beyond

Lepidoptera to broader ecological processes, highlighting the importance of heterogeneous fire regimes to maintain biodiversity and ecosystem resilience in fire-prone landscapes (Kwon et al, 2013). Further research integrating larger sample sizes is needed to deepen our understanding of these relationships and contribute to the preservation of biodiversity and ecological resilience in post-fire landscapes.

4.4. Study Limitations

While this study contributes valuable insights into the relationship between pollinators and fire, several limitations should be acknowledged. Firstly, the sample size was relatively small and focused solely on Lepidoptera, potentially constraining the generalizability of the findings to other insect taxa. Additionally, the uneven utilization of data collection methods, with a predominant reliance on Blue Vane Traps for specimen collection, may introduce bias and limit comparability with studies employing more balanced sampling approaches. Moreover, the study's reliance on visual observation over statistical analysis, while providing a nuanced understanding of the impacts of varying fire severities on the Lepidoptera of the Pacific Northwest, may hinder the quantification and generalizability of results. Finally, despite efforts to control confounding variables, unaccounted factors may have influenced the study outcomes. Future research endeavors could address these limitations by adopting larger and more diverse sample sizes, ensuring equal utilization of collection methods, and employing statistical analyses to enhance the robustness and interpretability of the findings. By addressing these limitations, future studies can further elucidate the complex interactions between fire, pollinators, and ecosystem dynamics in post-fire landscapes.

5. CONCLUSION

In conclusion, this study sheds light on the intricate relationship between fire severity, landscape heterogeneity, and Lepidoptera communities in the Pacific Northwest. My findings highlight the significant influence of fire severity on Lepidoptera abundance and diversity, with areas of heterogeneous severity exhibiting greater species richness and abundance compared to homogeneous fire regimes. Moreover, the examination of biodiversity indices underscores the importance of considering both species' evenness and richness in assessing post-fire Lepidoptera communities. Furthermore, the effectiveness of different collection methods in capturing Lepidoptera specimens emphasizes the importance of methodological considerations in post-fire pollinator surveys. While the study has provided valuable insights into the relationships between fire and pollinators, it is important to acknowledge limitations, including small sample size, limited taxonomic focus, and methodological biases. Future research should aim to address these limitations and further elucidate the underlying mechanisms driving post-fire Lepidoptera dynamics. By advancing our understanding of fire ecology and its impacts on Lepidoptera communities, we can inform more effective conservation and management strategies to promote biodiversity conservation and ecosystem resilience in fire-prone landscapes.

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