Insect communities after fire and mechanical treatment in Long Island pitch pine stands

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I. ABSTRACT

Pitch pine-scrub oak barrens are a globally imperiled ecosystem adapted to fire. Insect communities in pitch pine (*Pinus rigida*) woodlands are affected by fire and other disturbances, and periodic fires can negatively or positively influence insect habitat depending on insect species and fire characteristics. In this project, visual surveys for relatively large insects (≥ 2 cm) were conducted along 500-meter transects in pitch pine and pitch pine-oak stands at Brookhaven National Laboratory representing different combinations of disturbances such as mechanical thinning, prescribed fire, and wildfire. Insect taxa present in each stand were recorded and richness and diversity were estimated across disturbance categories. The stands which experienced fire were found to support greater insect diversity, though not always greater richness, than the control stand. This work could inform conservation of the pine barrens ecosystem and of threatened insect species, aligning with the Department of Energy's goals in addressing the nation's environmental challenges. By doing this project, I have improved my experimental design and sampling skills, reviewed and gained practical experience with insect survey methods and insect identification, researched and learned to use statistical methods for

estimating diversity and analyzing and comparing ecological communities, learned characteristics of pitch pine barrens, and gained familiarity with mapping software.

II. INTRODUCTION

Long Island's pitch pine barrens are a set of rare ecological communities dependent on fire, with woody plant assemblages dominated by pitch pine, *Pinus rigida,* and shrub oaks, *Quercus ilicifolia*, along with other oak (*Quercus*) species, and a lower shrub layer dominated by blueberry, *Vaccinium* spp., and huckleberry, *Gaylussacia* baccata.[1,2] Due to fire suppression and other human activity, pine barrens on Long Island are slowly being converted into pitch pine-oak woodlands and forests, putting species which depend on these early successional, fire-dependent habitats at risk.[1] Fire affects insects through direct mortality as well as through changing habitat suitability for different insect groups; larger, more mobile species and life stages are less vulnerable to direct fire mortality.[3] Many insect groups, including threatened and endangered species, depend on early successional habitats maintained by fire and disturbance, although other insects are vulnerable to fire.[1,4] For example, some Coleoptera (beetles), plant-feeding Hemiptera (true bugs) and Orthoptera (grasshoppers and crickets) benefit from fire, while some Lepidoptera (moths and butterflies) have a more complicated relationship with fire and may be vulnerable at least in the short term.[4] Many specialist grassland and barrens butterflies do best with non-fire management or infrequent wildfire rather than frequent burning of habitat patches.[4,5] However, fire-dependent insects are present in many taxonomic groups, including the Lepidoptera.[6] Since insects provide crucial ecosystem services such as pollination and nutrient cycling, and are an essential part of food webs, the recovery of the larger ecological community in an area after fire may depend on the recovery of the insect community[7]. At Brookhaven National Laboratory, where this project was conducted, several stands of pitch pine/mixed oak-heath woodland have been maintained under differing management and pine barrens restoration regimes and have experienced different wildfire conditions over the past fifteen years, producing different plant communities and potentially different insect communities.[2,8] Surveying a portion of these insect communities could improve our understanding of insect responses to fire and disturbance patterns and the resultant plant communities, and insect diversity across these disturbance regimes. This project aims to compare insect communities among different forest stands that have undergone prescribed fire, wildfire, a combination of prescribed fire, wildfire, and mechanical treatment, and no management or wildfire. It was hypothesized that stands that had experienced fire within the past fifteen years would have greater insect species richness and diversity than stands which did not, and that the insect taxa found in visual surveys would differ between the four stands.

III. METHODS

A. Stands used

Four pitch pine and pitch pine-oak stands on Brookhaven National Laboratory ("BNL") property were used: a stand with no management or wildfire ("control stand"), a stand which underwent a prescribed burn in 2023 ("prescribed fire stand" or "prescribed fire only stand"), a stand which experienced a wildfire in 2012, mechanical treatment in 2022, and then a prescribed fire in 2023 ("prescribed fire, wildfire, and mechanical treatment stand" or "all disturbance types stand"), and a stand which underwent two wildfires in 2012 and 2020 ("2 wildfires stand"). Figure 1 shows the area occupied by each stand on the BNL site.

B. Data collection

In each stand, 500 meters of transect for visual surveys were established by walking through the stand in a relatively straight line and tracking the path using Avenza Maps, turning when necessary to avoid impassable terrain, avoid encroaching on a 10-meter buffer established to avoid edge effects, and to remain within the stand (see Figure 1). Transects were marked in the field using flagging tape and broken up into sections of approximately 50 meters each. In the control stand and 2 wildfires stand, old trails were used for part of the transects, mainly parts of the old trails where the trail was narrow, and the surrounding habitat did not visually appear different to that away from the trail, while trails were not used in the prescribed fire, wildfire, and mechanical treatment stand and the prescribed fire only stand.

To survey a portion of the insect fauna in each treatment, transects were walked at a slow pace and all relatively large insects within an imaginary box, 2.5m to each side of and 5m in front of and above the observer, were recorded and when possible photographed, as is often done in butterfly surveys.[9] Photographs were taken using a Canon EOS 30D camera with a Sigma 18-200mm 1:3.5-6.3 zoom lens and with an iPhone 6s Plus. "Relatively large insects," for the purposes of this assessment, were defined as approximately 2 centimeters or larger in any dimension when in some natural, non-airborne position, excluding the length of the antennae but including all other appendages such as legs, wings, and ovipositors. For simplicity, ants (Hymenoptera, family Formicidae) were universally excluded from the "relatively large insect" category, even though the largest local ants (e.g. *Camponotus* carpenter ants) may approach the arbitrary size cutoff. Sizes were usually estimated to determine whether insects would measure at least 2 centimeters in at least one dimension, but some insects close to that length were captured and measured with a small section of measuring tape to improve the accuracy of this determination. Live and relatively large adult insects, larvae, and nymphs were counted in these surveys; pupae, egg masses, dead insects, and signs and structures created by insects were not assessed. For each transect, the date and start and end times were recorded, the temperature and wind speed were recorded using the Apple Weather app at the start and end of the transect walk, and other weather conditions were observed and recorded on the beginning and end of each transect walk. In cases in which the transect was walked in two or more parts with a break involving leaving the treatment area in between, this was noted, and conditions were recorded at the start and end of each part. Insects which could be seen and identified in the field at least to the family level or recognized in the field as a previously photographed morphospecies, but were not able to be photographed, were still recorded. For each relatively large insect sighting, the number observed and the general microhabitat or location where the insect or insects were sighted were recorded. Insects were captured with a net or with screw-top containers when necessary to photograph them. When stopping to photograph insects or record data, other insects observed before returning to the transect, releasing any insects captured, and beginning to walk once more were not recorded, with the exceptions of any insects captured incidentally along with an intended insect, and of multiple insects of a single morphospecies observed at roughly the same time, adding to the number observed in a sighting. At the end of each 50-meter transect section, records were briefly reviewed to ensure that insect types and numbers of each were correctly recorded and photographs were matched with records before continuing to the next section.

Data collection procedures were repeated three times for each stand during the summer of 2024. The first surveys for each stand were performed from June 25 to July 2, the second round of surveys was from July 3 to July 15, and the third set of surveys was performed between July 15 and July 30. During the first and third sets of surveys, the prescribed fire only stand was surveyed first, then the 2 wildfires stand, followed by the all disturbance types stand, and finally the control stand. For the second set of surveys, this order was the same, except that the all disturbance types stand was surveyed before the 2 wildfires stand. Photographed insects were identified at least to the family level using the images when possible. Insects were identified using insect guides[10,11,12] and the iNaturalist[13] and BugGuide[14] websites.

C. Analysis

Data were analyzed using SpadeR.[15] The iChao1 richness estimator[16] was used to estimate and compare family-level richness across disturbance categories, and the Shannon diversity estimator calculated by Chao et al.[17] was used to estimate and compare diversity. Jaccard and Sorensen similarity indices were used to estimate the proportions of families shared between stands, and the Horn similarity index was used to estimate similarity between stands while taking abundance into account. The few insects which were not identified at least to the family level were excluded from these analyses.

IV. RESULTS

The kinds of insects found differed somewhat across stands; Tables 1 through 4 show the insect families observed in each stand. A total of 37 families were observed between all stands and surveys combined. The most abundant families observed differed between stands: gossamer-winged butterflies, Lycaenidae, were most abundant in the control stand and all disturbance types stand, short-horned grasshoppers, Acrididae, were most abundant in the prescribed fire only stand, and skimmer dragonflies, Libellulidae, were most abundant in the 2 wildfires stand.

Over 90% of the insect families in each stand were estimated to be shared with other stands (see table 5). From the perspective of the larger community, around three quarters of the families in the group of sites were shared between all of them, and when abundance was taken into account, the stands were about 85% similar (table 5). The most similar pair of stands, using the Horn similarity index based on all families, was the prescribed fire only stand and the 2 wildfires stand, which were estimated to be 88.2% (± 2.5%) similar (see table 6). The least similar pair was the prescribed fire, wildfire, and mechanical treatment stand and the control stand, which were estimated to be 77.7% (± 4.9%) similar (table 6). Interestingly, when data was pooled across stands and compared between sampling runs, the assemblages found in different sampling runs were estimated to be 93.69% (± 11.14%) similar using the Sorensen index with all families, 83.20% (± 18.82%) similar using the Jaccard index, and 71.81% (± 1.80%) similar using the Horn index; the two indices using the proportion of families shared were higher between times than between stands, but the Horn index was lower between times than between stands.

The 2 wildfires stand had the highest richness at the family level, with 31 insect families represented by relatively large insects observed and 52 ± 10 such families estimated to be present (see Figure 2). The prescribed fire, wildfire, and mechanical treatment stand had an observed 25 families and an estimated 38 ± 15, the control stand had 23 families observed and 27 ± 2 estimated, and the prescribed fire only stand had the least richness, with 21 families observed and 23 ± 2 estimated. Diversity was highest in the 2 wildfires stand, with a Shannon diversity estimate of 19.032 ± 1.152, followed by the all disturbance types stand with an estimate of 16.350 ± 1.082, the prescribed fire only stand with an estimate of 14.033 ± 0.811, and the control stand with an estimate of 10.394 ± 0.826 (see Figure 3).

V. DISCUSSION

The hypothesis that the stands which experienced fire in the last fifteen years would all have greater insect richness and diversity than the control stand was partially supported by the results; greater richness than the control stand was not found in the prescribed fire only stand, but greater diversity than the control was found in all three of the stands which experienced fire. It is also possible that a form of bias in sampling affected the results such that lower richness was observed in the prescribed fire only stand; because the prescribed fire only stand was sampled first in both rounds of sampling and the visual surveys were performed by a relatively inexperienced observer, later stands may have been sampled more thoroughly. Fewer insects were recorded during the first round of sampling than the second and third rounds, potentially supporting this idea. It is also possible that more relatively large insects were present across stands later in the summer. Qualitatively, some types of insect nymphs which were not found to be more than 2 centimeters long at the beginning of the project were found at larger sizes later in the summer and were thus only counted in later visual surveys. The fact that variation within species could change whether individuals were counted in the surveys was a limitation of this project which created biases in the data.

While most of the families in each stand were shared with other stands, this may still leave an important number of families unique to each stand within this system. Although family diversity is not a perfect measure of species diversity, family-level richness and diversity are strongly correlated with species-level richness and diversity, with species richness and diversity being roughly two to five times family-level richness and diversity in insects.[18] This implies that the family-level differences found in this project may indicate greater differences in richness and diversity at the species level. A species-level or morphospecies-level analysis of the insects photographed could provide greater insight into the insects making up these communities and the similarities and differences between stands. These results are consistent with findings that fire changes the composition of insect communities, and that variation in fire conditions may support greater insect diversity on a broader scale.[4,5,7] Further study is needed, but it may be that spatially varied management practices could support insect diversity and other biodiversity on a landscape scale.[5] Further research could also provide more information on the life cycles of the insects found; several families in this survey were found during only one of the sampling runs, likely because of seasonal changes in life stage and behavior. In future work, a larger number of shorter transect walks could be used to sample different stands on the same days, reducing biases due to timing and clarifying when events occur in the life cycles of the insects studied. Understanding which insects can thrive under different conditions and how our management practices affect them will help us conserve these small but crucial animals.

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The research described herein is Fundamental Research as defined in the ITAR (22 CFR 120.34(a)(8)), EAR (15 CFR 734.8), or Part 810 (10 CFR 810.3), as applicable, and as described in the USD (AT&L) memoranda on Fundamental Research, dated May 24, 2010, and on Contracted Fundamental Research, dated June 26, 2008.

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VIII. TABLES

Prescribed fire only stand				
Family	Number observed, Survey 1	Number observed, Survey 2	Number observed, Survey 3	Number observed, total across surveys
Acrididae	7	28	2	37
Lycaenidae	0	0	34	34
Erebidae	0	0	21	21
Asilidae	5	6	9	20
Nymphalidae	4	11	0	15
Geometridae	2	12	0	14
Lestidae	0	10	4	14
Tettigoniidae	0	6	8	14
Ichneumonidae	1	3	2	6
Tipulidae	1	3	1	5
Mantidae	0	3	1	4
Vespidae	0	3	1	4
Apidae	2	0	1	3
Braconidae	2	0	1	3
Coenagrionidae	0	3	0	3
Libellulidae	1	0	2	3
Noctuidae	0	1	2	3
Sphecidae	1	1	1	3
Myrmelontidae	0	2	0	2
Elateridae	0	1	0	1
Reduviidae	0	0	1	1

Table 1: Observed insect abundances at the family level in the prescribed fire stand, grouped by survey and sorted by total number of insects observed.

2 wildfires				
Family	Number observed, Survey 1	Number observed, Survey 2	Number observed, Survey 3	Number observed, total across surveys

Libellulidae	8	19	7	34
Nymphalidae	13	12	3	28
Asilidae	1	13	13	27
Lycaenidae	0	2	25	27
Lestidae	1	17	8	26
Erebidae	0	1	23	24
Acrididae	5	13	1	19
Ichneumonidae	6	8	5	19
Tettigoniidae	1	12	4	17
Tipulidae	3	8	0	11
Vespidae	0	4	7	11
Coenagrionidae	0	2	5	7
Geometridae	3	2	2	7
Mantidae	0	7	0	7
Saturniidae	4	0	0	4
Limoniidae	0	2	1	3
Lycidae	0	0	3	3
Syrphidae	0	0	3	3
Apidae	1	1	0	2
Notodontidae	0	1	1	2
Sphecidae	0	2	0	2
Cerambycidae	0	1	0	1
Crabronidae	0	1	0	1
Hesperiidae	0	1	0	1
Myrmelontidae	0	1	0	1
Noctuidae	0	1	0	1
Reduviidae	1	0	0	1
Sphingidae	0	1	0	1
Staphylinidae	0	1	0	1
Tabanidae	0	1	0	1
Tachinidae	0	1	0	1

Table 2: Observed insect abundances at the family level in the 2 wildfires stand, grouped by survey and sorted by total number of insects observed.

Prescribed fire, wildfire, and mechanical treatment stand				
Family	Number observed, Survey 1	Number observed, Survey 2	Number observed, Survey 3	Number observed, total across surveys
Lycaenidae	1	1	39	41
Lycidae	0	0	28	28
Vespidae	1	15	11	27
Acrididae	9	12	2	23
Erebidae	1	0	17	18
Asilidae	9	4	4	17
Libellulidae	0	1	10	11
Apidae	6	3	0	9
Mantidae	5	3	0	8
Braconidae	2	1	3	6
Chrysopidae	0	3	2	5
Lestidae	1	3	1	5
Tettigoniidae	0	0	5	5
Coenagrionidae	1	0	3	4
Ichneumonidae	0	1	3	4
Myrmelontidae	1	3	0	4
Nymphalidae	0	3	1	4
Saturniidae	2	2	0	4
Bombyliidae	0	3	0	3
Geometridae	0	2	0	2
Buprestidae	0	1	0	1
Crabronidae	0	0	1	1
Noctuidae	1	0	0	1
Syrphidae	1	0	0	1
Tabanidae	0	1	0	1

Table 3: Observed insect abundances at the family level in the all disturbance types stand, grouped by survey and sorted by total number of insects observed.

Control stand (no management or wildfire)				
Family	Number observed, Survey 1	Number observed, Survey 2	Number observed, Survey 3	Number observed, total across surveys
Lycaenidae	1	3	81	85
Lestidae	21	8	6	35
Vespidae	5	14	6	25
Erebidae	1	4	14	19
Asilidae	9	5	2	16
Nymphalidae	7	1	3	11
Geometridae	2	4	1	7
Sphecidae	0	1	5	6
Tipulidae	3	1	2	6
Ichneumonidae	1	1	3	5
Libellulidae	0	1	3	4
Tettigoniidae	3	0	1	4
Apidae	2	1	0	3
Staphylinidae	1	2	0	3
Cerambycidae	1	1	0	2
Mantidae	0	2	0	2
Reduviidae	1	0	1	2
Tabanidae	0	2	0	2
Bombyliidae	0	1	0	1
Coenagrionidae	0	0	1	1
Crambidae	1	0	0	1
Elateridae	1	0	0	1
Lycidae	0	0	1	1

Table 4: Observed insect abundances at the family level in the control stand, grouped by survey number and sorted by total number of insects observed.

Similarity Index	Purpose of Index	Value Based on Observed Families Only	Value Based on Observed and Estimated Families
Sorensen	To calculate the average proportion of families in each stand also found in other stands	84.00% (± 1.97%)	92.46% (± 5.90%)
Jaccard	To calculate the proportion of the families present in the pooled set of stands present in every stand	56.76% (± 3.27%)	75.40% (± 13.63%)
Horn	To calculate the similarity between communities based on both families present and the abundances of each	83.18% (± 1.28 %)	84.05% (± 1.29%)

Table 5: A comparison of similarity indices evaluating how similar the large insect communities in the different stands are.

	Prescribed fire	2 wildfires	All disturbance types	Control
Prescribed fire	100%	87.80%	78.10%	79.60%
2 wildfires		100%	82.70%	79.10%
All disturbance types			100%	77.70%
Control				100%

Table 6: Similarity values between each pair of stands calculated using the Horn similarity index.

IX. FIGURE CAPTIONS

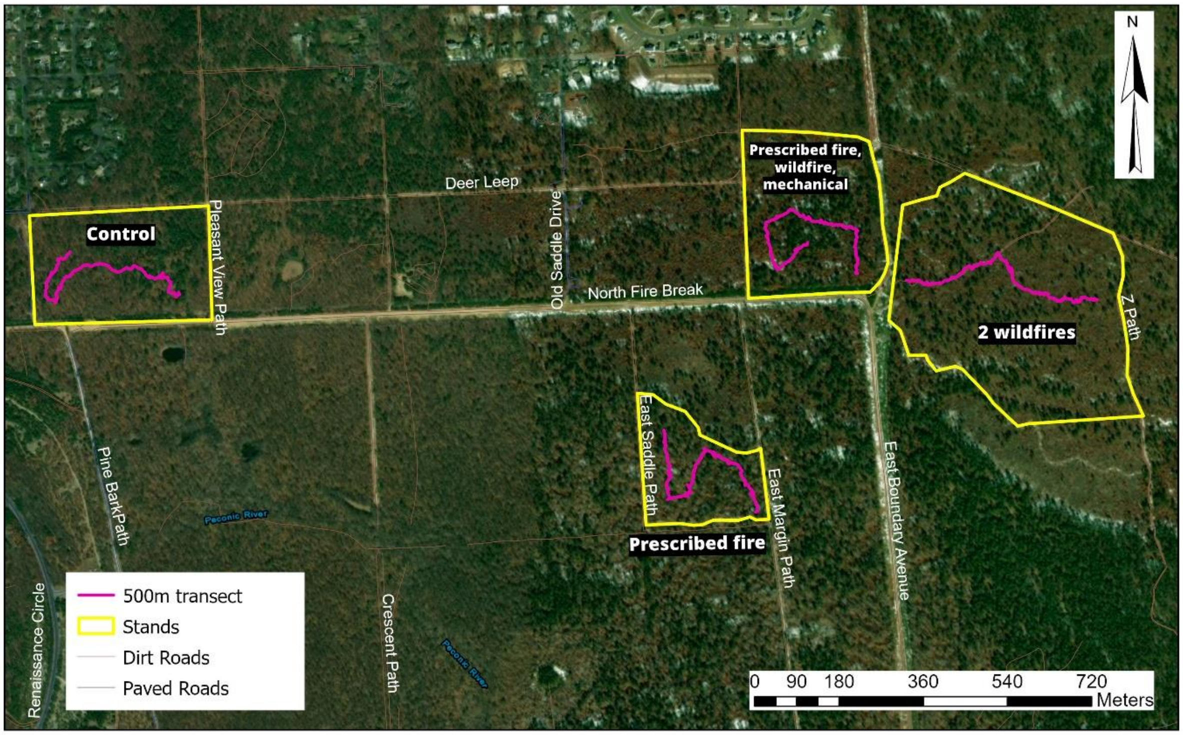
Figure 1: A map showing the locations of and labeling the stands surveyed and the transect paths taken through each stand.

Figure 2: Observed and estimated numbers of insect families with relatively large representatives present in each stand. Error bars represent standard errors.

Figure 3: Estimated family-level Shannon diversity in each stand. Error bars represent standard errors.

X. FIGURES

Figure 1


Control
Prescribed fire, wildfire, mechanical
2 wildfires
Prescribed fire
Deer Leep
Old Saddle Drive
North Fire Break
Pleasant View Path
Pine BarkPath
Renaissance Circle
Crescent Path
Peconic River
East Saddle Path
East Margin Path
East Boundary Avenue
Z Path
N
500m transect
Stands
Dirt Roads
Paved Roads
0 90 180 360 540 720
Meters

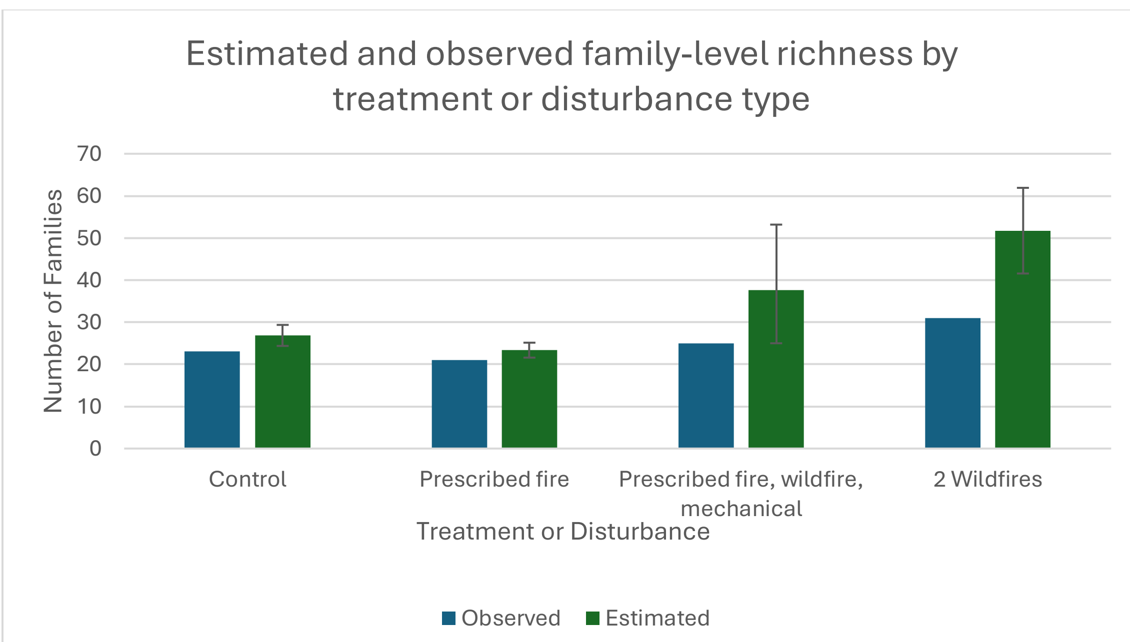
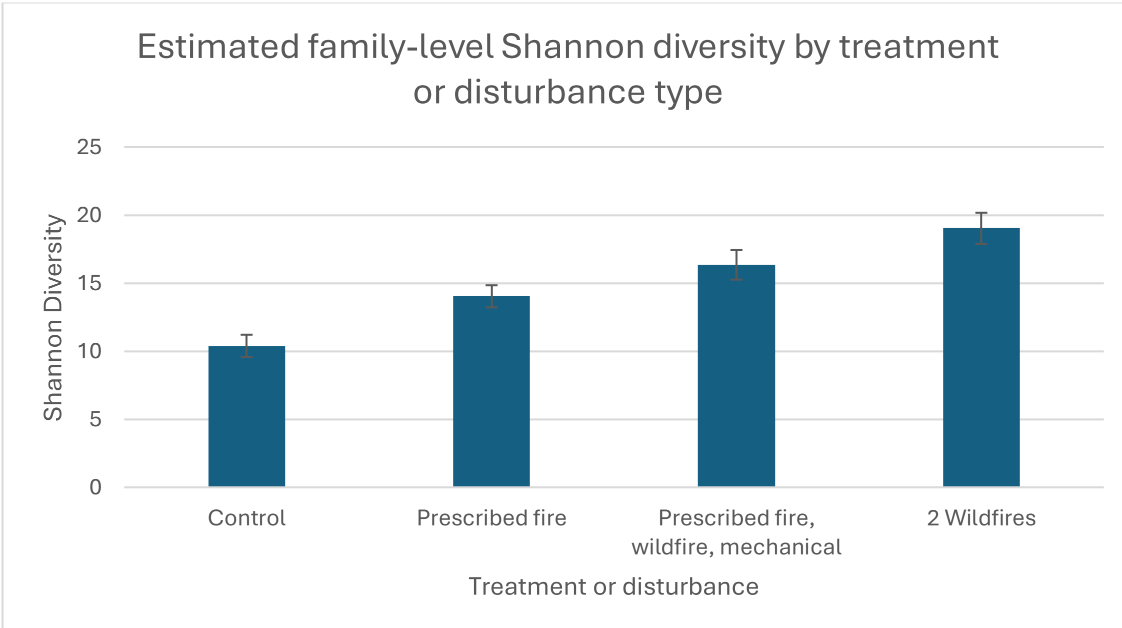

Estimated and observed family-level richness by treatment or disturbance type
Number of Families
70
60
50
40
30
20
10
0
Control
Prescribed fire
Prescribed fire, wildfire, mechanical
2 Wildfires
Treatment or Disturbance
Observed
Estimated

Figure 2


Estimated family-level Shannon diversity by treatment or disturbance type
25
20
15
10
5
0
Shannon Diversity
Control
Prescribed fire
Prescribed fire, wildfire, mechanical
2 Wildfires
Treatment or disturbance
Figure 3