Results of Karner blue butterfly surveys on State Lands in Michigan

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Cover: Karner blue butterflies (*Lycaeides melissa samuelis*) congregating on butterfly milkweed (*Asclepias tuberosa*) along the pipeline at Allegan State Game Area in August 2023. Photo: A. Cole-Wick

EXECUTIVE SUMMARY

In 2023, the Michigan Department of Natural Resources (MDNR) funded the Michigan Natural Features Inventory (MNFI) to continue occupancy-based surveys for the Karner blue butterfly (*Lycaeides melissa samuelis;* KBB) at Allegan and Flat River State Game Areas. Surveys conducted in 2023 were designed to address multiple goals: 1) determine occupancy status of habitat patches to inform regulatory and management decisions; 2) track population status to evaluate progress toward recovery plan goals; and 3) evaluate the response of KBB to management actions.

We built upon our existing occupancy-based sample design and survey methodology developed for KBB and implemented between 2015-2021 (Monfils and Cuthrell 2015, 2018, Monfils et al. 2021). The protocol consists of two visits to all sites during the second KBB flight. During each visit to a site, a modified Pollard-Yates (Pollard and Yates 1993) survey was conducted in which surveyors followed a series of transects paralleling the outer boundary of the survey site polygon. We collected geographic locations for all KBB observations.

In 2023, we completed 112 surveys at 57 survey sites. We surveyed 95% of the survey sites twice, with all sites on state lands having two visits. We detected KBBs at 26 (46%) of the 57 sites surveyed, with 1,087 KBBs detected across all site visits. The maximum season count was 859 individuals, which represents the sum of the greatest single visit count from each site. We now have six years of data gathered on KBB populations on state lands between 2015 and 2023 using a consistent sample design and protocol. KBB occupancy and relative abundance in 2023 was the lowest of the six-year period when considering sites surveyed every year. Results from 2021 and 2023 indicate a decline in populations at these sites since 2018. Additional surveys are needed to assess whether this represents normal variation in population parameters or a downward trend.

To aid those tasked with managing for KBB on state lands in Michigan, we developed preliminary management recommendations for sites occupied by KBB in 2023. These recommendations were based on site characterization data collected during surveys, our knowledge of the sites from multiple visits, and an understanding of KBB habitat requirements. It is our hope that these recommendations can serve as a quick reference to help land managers prioritize management locations and actions.

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INTRODUCTION

The Karner blue butterfly (*Lycaeides melissa samuelis*; KBB) is found in oak-pine barrens and oak savannas in Michigan where its only host plant, wild lupine (*Lupinus perennis*; lupine), grows. This butterfly was listed as Federally Endangered by the United States in 1992 and is listed as State Threatened in Michigan (Clough 1992). The KBB is bivoltine, with the first generation of adults flying in late May to June and a second generation of adults in mid-July into early August, and overwintering as eggs (Savignano 1990, Swengel and Swengel 1999). The KBB is inextricably linked to lupine, which is a disturbance-dependent perennial legume commonly found in savannas and barrens. Declines in KBB populations are driven by the loss of barrens and savanna systems that meet the rare butterfly's habitat requirements (USFWS 2003). Habitat losses are driven by conversion to agriculture, development, and vegetative succession due to a lack of disturbance (USFWS 2003). To maintain habitat for this rare species on state lands in Michigan, regular disturbance through prescribed fire and mowing is needed to set back succession of oak barrens to forest. Intact barren and savanna habitats in Michigan have become increasingly fragmented and isolated. This leaves KBB subpopulations more vulnerable to local extinction and reduces genetic exchange between occupied habitat patches, as adults are unlikely to move between habitats separated by more than 300 m (Knutson et al. 1999). This lack of genetic exchange limits their adaptive capacity, increasing their vulnerability to threats such as climate change.

Long-term monitoring of KBB populations is challenging due to multiple survey objectives, limited resources, and dynamic ecosystem conditions. In 2023, the Michigan Department of Natural Resources (MDNR) funded the Michigan Natural Features Inventory (MNFI) to conduct occupancy-based surveys for this rare butterfly at Allegan and Flat River State Game Areas (hereafter referred to as Allegan and Flat River). The purpose of our work is to provide data to the MDNR to address multiple goals: 1) determine occupancy status of habitat patches to inform regulatory and management decisions; 2) track population status to evaluate progress toward recovery plan goals; and 3) evaluate the response of KBB to management actions. The MNFI worked with the MDNR in 2014-2015 to develop an occupancy-based survey that expanded beyond sites traditionally monitored with distance sampling (Monfils and Cuthrell 2015). We have since implemented this survey in 2015-2018 (Monfils and Cuthrell 2018) and 2021 (Monfils et al. 2021). Results have provided information to MDNR staff responsible for planning and implementing management, as well as tracking progress toward recovery goals.

Consistent monitoring over space and time is crucial for effective management and compliance with U.S. Fish and Wildlife Service regulations. These data also enable MDNR biologists to assess the status of the species and make necessary adjustments to conservation activities. In 2023 we implemented occupancy-based surveys to provide data to local, State, and regional partners working to recover KBB populations. Conducting surveys at the same sites over time allows for the evaluation of the long-term effects of management efforts on KBB occupancy and abundance.

METHODS

Sample Design

We built upon our existing occupancy-based sample design and survey methods developed for the KBB and previously implemented between 2015 and 2021 (Monfils and Cuthrell 2015, 2018, Monfils et al. 2021). Potential sites were originally identified using a combination of KBB element occurrences (MNFI 2023), lupine areas, and digitized non-forested upland openings occurring on state lands. We based our surveys off of the same sample frame of sites used for surveys conducted during 2016-2018 and in 2021, which consisted of areas occupied by KBB during pilot occupancy surveys conducted in 2015, unoccupied sites connected to or within 200 m of sites occupied in 2015, four previously occupied sites surveyed using distance sampling in the past, and occupied sites located on private lands for which the MDNR has provided management assistance.

Given that lupine populations change over time in response to competition from herbaceous and woody plants, we re-evaluated survey sites in the spring of 2023 during peak lupine bloom, when the host plants – and therefore KBB habitat – are easiest to find. We did this in two ways. First, we searched for new patches of suitable KBB habitat at Allegan. Using information from 2022 lupine surveys conducted by Allegan MDNR staff, we identified areas containing lupine that were not included in our existing sample frame. We visited these areas and used the DAFOR scale to rank the relative abundance of lupine as dominant, abundant, frequent, occasional, or rare (see Appendix A). Areas containing lupine ranked as dominant, abundant, or frequent with suitable habitat structure (i.e., ≤ 60% canopy cover) were added as new survey sites. We used Field Maps (ESRI 2023) to record coordinates of site boundaries. This process resulted in the addition of eight new sites at Allegan (Figure 1). Second, we visited sites that we thought may be eliminated from surveys based on a lack of both KBB and lupine in 2021 surveys (Monfils et al. 2021). We removed 10 sites from Allegan. Removing sites that had been monitored in previous years, but no longer contain suitable habitat nor KBB, allowed us time to survey additional sites and possibly document new populations of the rare butterfly. Despite declining lupine cover and increasing woody plant succession at some Flat River sites, we retained these sites in our survey frame because we wanted to continue monitoring occupancy at the small number of potential KBB sites remaining within this area (Figure 2). When schedules, weather, and landowner permission allowed, we visited private sites that had been surveyed as part of this sample frame in previous years.

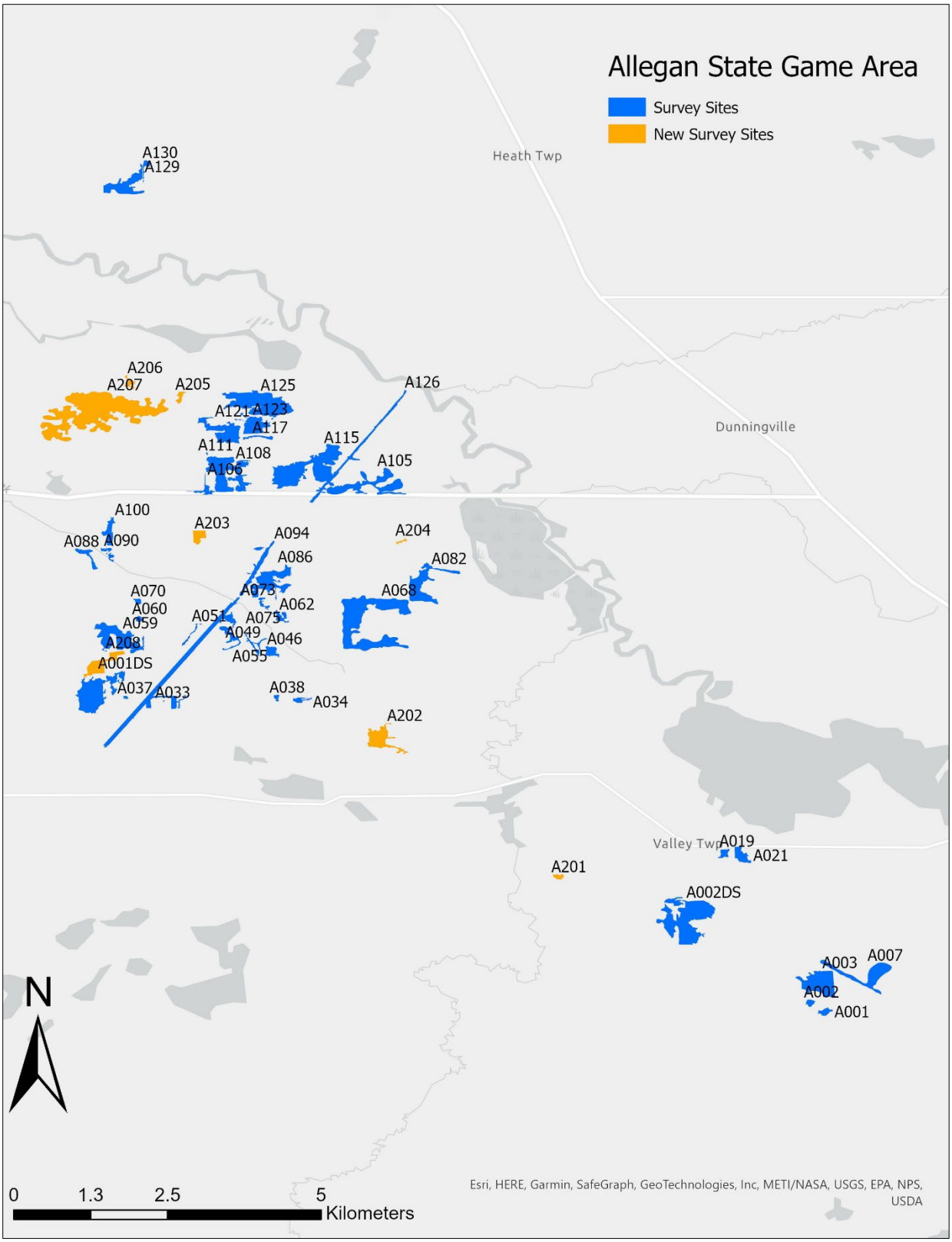

Figure 1. Existing (blue) and newly added (orange) Karner blue butterfly survey sites in Allegan State Game Area visited during 2023.

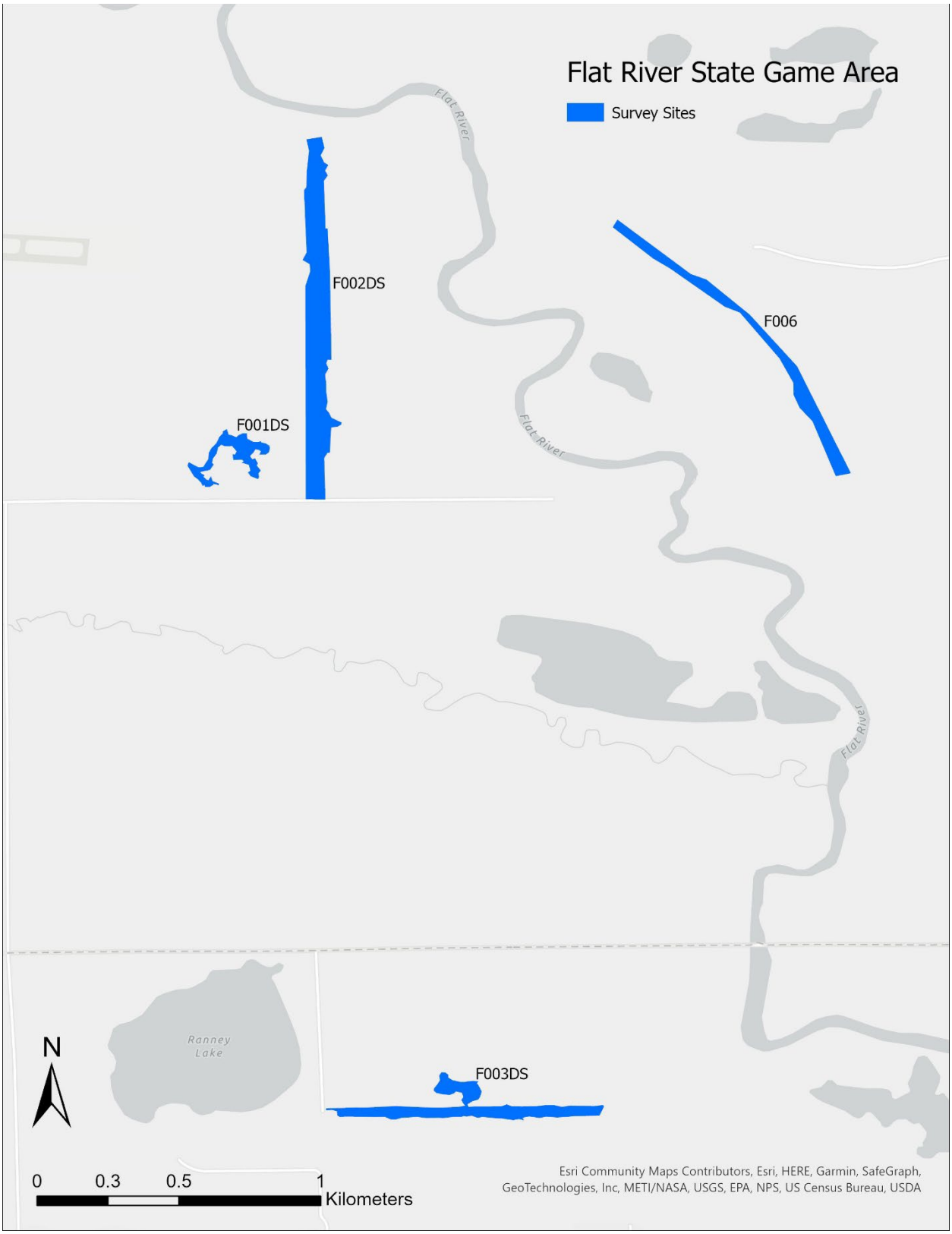

Figure 2. Karner blue butterfly survey sites in Flat River State Game Area visited during 2023.

Butterfly Surveys

We generated maps of the 2023 survey sites with ArcGIS Pro and Field Maps (ESRI 2023) and uploaded them to smart devices (i.e., tablet computers, smartphones) to assist surveyors as they navigated among and within sites. We focused surveys on areas having ≤ 60% tree canopy cover (Grundel et al. 1998a). Areas within the polygons having one or more of the following conditions were excluded from the survey: 1) > 60% tree canopy cover; 2) > 75% bare soil and no lupine; and 3) planted crops or ground cover (e.g., grassland, lawn) lacking lupine and nectar sources. Areas of potential habitat (i.e., ≤ 60% canopy cover with lupine/nectar sources) located immediately outside of the identified polygons were added to the survey. In addition to navigating through the sites using Field Maps, surveyors recorded their tracks to document which areas were surveyed.

Once in the field, surveyors collected habitat and butterfly occurrence data in a Survey 123 form that we created for this project (ESRI 2023). The occupancy-based survey method used for KBB since 2015 requires two visits to each site during the second flight (mid-July to early August). Observations (presence/absence) of other butterfly species, including the monarch butterfly (*Danaus plexippus*), were recorded during both visits. We limited surveys to periods when the temperature was above 15° C (60° F), there was no rain, and when winds were ≤ 25 km/h (15 mph). If temperatures were 15 - 21° C (60 - 70° F), surveys were only conducted when cloud cover was ≤ 50%. There was no cloud cover restriction if the temperature was above 21° C (70° F). If weather conditions deteriorated during a visit, we terminated the survey and resurveyed the entire site on a suitable day. Surveys were conducted between 9 AM and 6 PM.

We conducted modified Pollard-Yates (Pollard and Yates 1993) surveys in which we followed a series of transects paralleling the outer boundary of the survey site polygon (Figure 3). The first transect began 5 m inward from the outer edge of the patch, with one surveyor slowly walking along the first transect until the entire periphery of the site was surveyed. A second transect was located 10 m inward from the first transect and was surveyed in the same manner. Additional transects were added until the entire patch of suitable habitat was surveyed. At large sites, two or more people conducted the survey together, with transects spaced 10 m apart. Observers looked for and counted KBB butterflies within an area 5 m to either side of the transect, 5 m forward along the transect, and 5 m above the transect (10 m x 5 m x 5 m, rectangular survey area). Surveyors walked at a steady, slow speed of approximately 35 m/min. If butterflies flew ahead of an observer, they were ignored if the surveyor was certain the individual was already counted.

To facilitate an accurate count of the KBB and understand their distributions within and among sites, we collected geospatial information for each butterfly. We collected GPS coordinates in the Survey123 form for each KBB observed, however in the case that butterflies were grouped together, we took one point for a group and recorded the number of individuals in that group. For example, if five butterflies were seen on one nectar source, one point was collected at the location for the five individuals. Observers avoided disturbing or flushing butterflies when

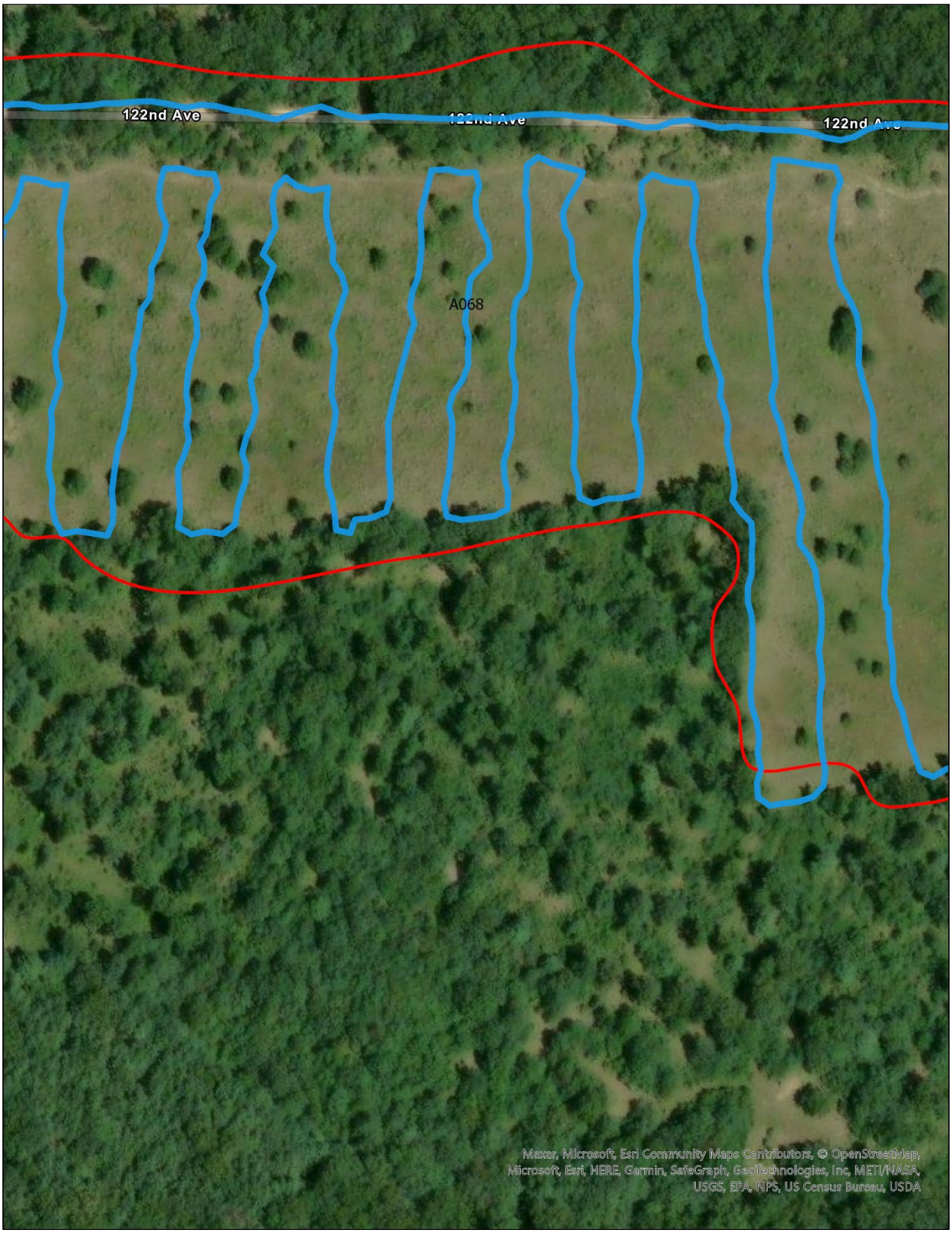

Figure 3. Survey tracks (blue) from a 2023 MNFI surveyor exemplifying how a series of parallel transects were followed until all suitable habitat (red outline) within a site had been surveyed.

collecting data. We recorded sex (male, female, unknown), wing wear (a scale from 1 to 5), and activity (perched, flying, nectaring, copulating) of each adult KBB. We recorded all other butterfly species detected during surveys on a checklist for each site. However, to avoid distracting surveyors from collecting essential data on the KBBs, we did not attempt to estimate relative abundance for non-target species.

We characterized environmental and habitat characteristics at each site by collecting information on variables that may influence KBB detection and occupancy, as well as those that could be included in models used to estimate population parameters. At the start and end of a survey, we recorded the temperature (°C), percent relative humidity, cloud cover (expressed as the % of sky occluded), and maximum wind speed (km/h). Surveyors collected general information about potential threats to target species and their habitats and ranked the relative abundance of lupine, nectar sources, and invasive plant species. We used the DAFOR scale to rank the relative abundance of lupine, nectar sources, and invasive species as dominant, abundant, frequent, occasional, or rare (see Appendix A).

Areas of site A115 at Allegan State Game Area contained no Karner blue butterflies, possibly due to a lack of canopy cover and an abundance of woody encroachment by oaks after a recent cut. Photo: A. Cole-Wick

RESULTS

Karner Blue

In 2023 we surveyed 53 sites during the second KBB flight at two state game areas (Allegan and Flat River), as well as four private properties. We surveyed 95% of the sites twice, with all sites on state lands having two visits. Approximately 257 person hours were spent surveying for KBBs during July and August in 2023. We detected KBBs at 26 (46%) of the 57 sites surveyed and recorded 1,087 KBB detections across all site visits. We observed KBB at 22 out of 49 sites at Allegan (Figure 4), one out of four sites at Flat River (Figure 5), and at three out of four sites surveyed on private lands (Table 1). Our maximum season count was 859 individuals, which we calculated by taking the sum of the maximum number of KBBs observed during a single visit to each site. Out of the 26 occupied sites, 42% (11) had maximum counts ≤ four individuals. Two sites, A059 (located North of Horseman's Campground) and A073 (the main stretch of pipeline KBB habitat located between 122nd and 118th Ave), accounted for 51% of the maximum season count. We documented KBBs at two out of the eight new sites added in 2023. Maximum abundance was low at both occupied sites, with two individuals detected at A203 (located just north of 123rd Ave) and six individuals at A208 (located just north of Horseman's Campground). A208 likely had higher KBB numbers but was surveyed later in the flight.

Table 1. Number of sites surveyed, number of surveys completed, and number of sites occupied by Karner blue butterflies during the second flight in 2023.

	Sites	Surveys Completed	Occupied Sites
Allegan State Game Area	49	98	22
Flat River State Game Area	4	8	1
Private	4	6	3
Total	57	112	26

We implemented the same methods and protocol used to survey KBB in 2015-2021, allowing us to compare our 2023 results to previous years. Thirty-eight sites were surveyed in all six years (2015-2018, 2021 and 2023; Appendix B). At these sites, naïve occupancy (i.e., proportion of sites occupied by KBB) and maximum abundance were lower than all previous years, and only 2015 had a lower raw density (i.e., KBBs per hectare; Table 2). For all sites surveyed across the six years, 2023 had the lowest recorded naïve occupancy and only 2015 had lower maximum abundance and raw density (Table 2).

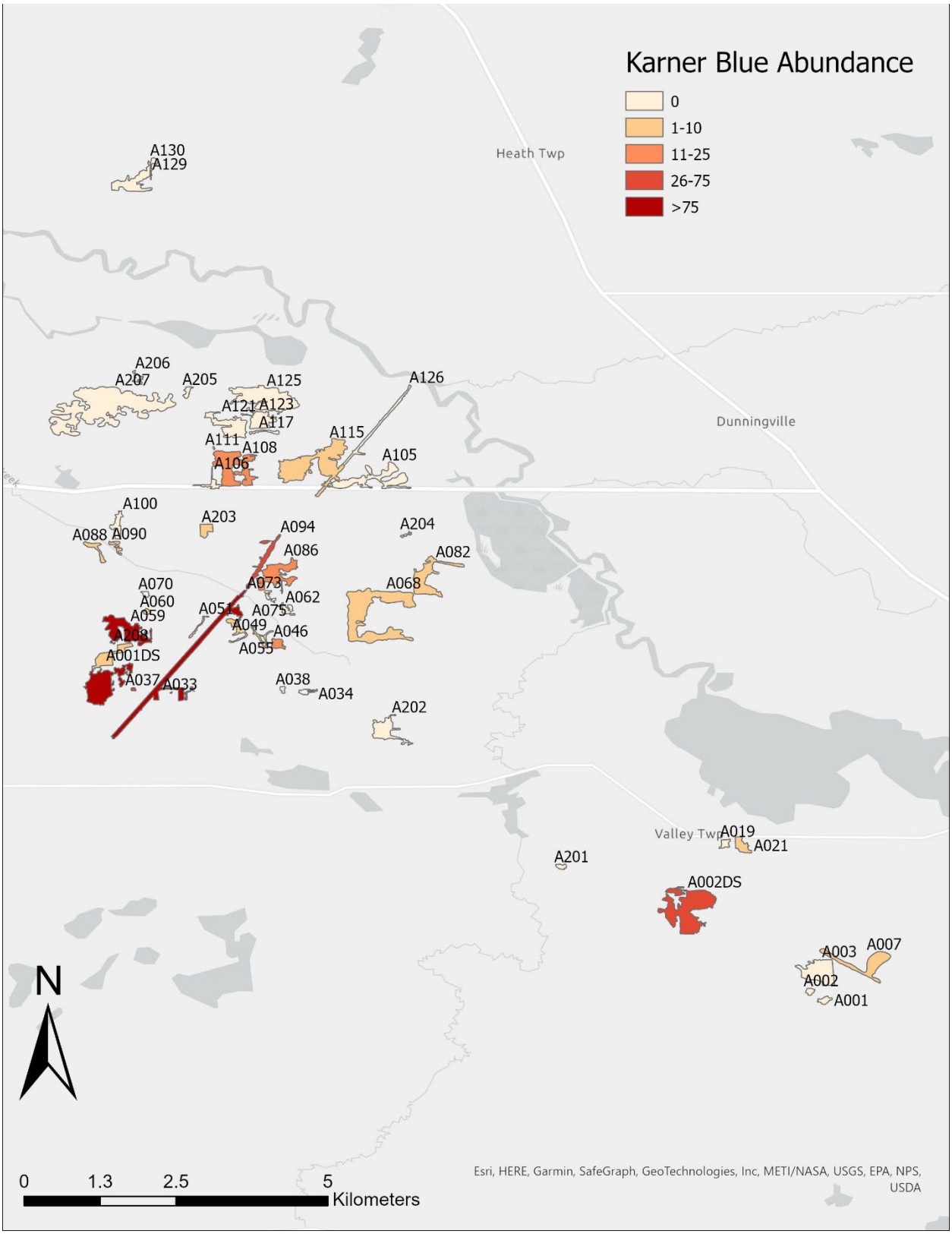

Figure 4. Number of Karner blue butterflies detected by site during 2023 surveys at Allegan State Game Area.

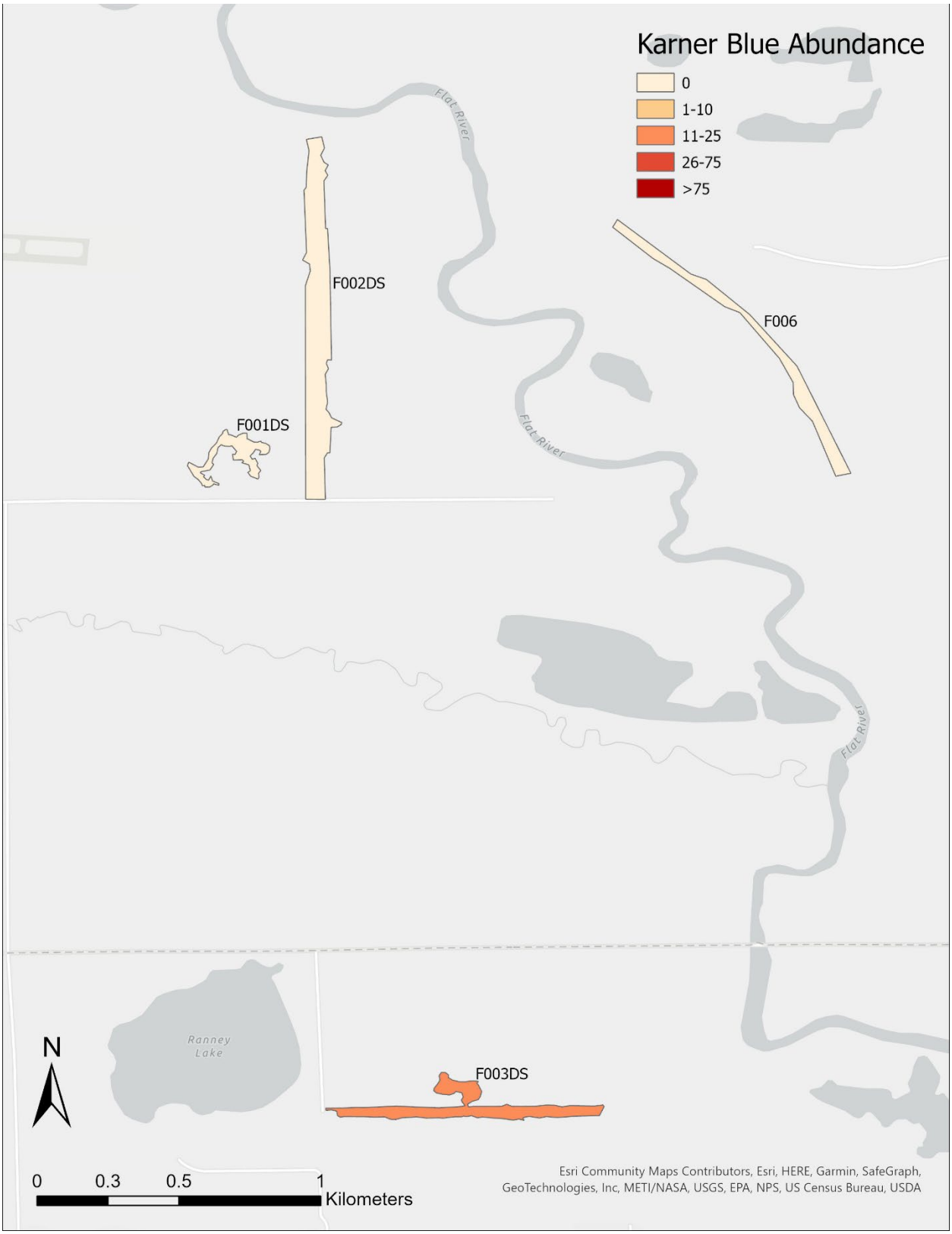

Figure 5. Number of Karner blue butterflies detected by site during 2023 surveys at Flat River State Game Area.

Table 2. Naïve occupancy (proportion of sites occupied), maximum abundance (sum of greatest single visit count from each site), and raw density (KBBs per hectare) of Karner blue butterflies by year for all sites surveyed and a subset of sites surveyed every year (n = 38).

	Naïve Occupancy		Maximum Abundance		Raw Density	
Year	All Sites	Sites Surveyed Every Year	All Sites	Sites Surveyed Every Year	All Sites	Sites Surveyed Every Year
2015	0.471	0.579	658	650	4.2	5.8
2016	0.672	0.711	4,986	1,606	25.4	21.4
2017	0.672	0.763	4,867	1,573	19.6	15.7
2018	0.690	0.684	5,384	1,028	24.2	11.1
2021	0.492	0.526	1,808	657	8.9	8.8
2023	0.456	0.474	859	609	5.6	7.9

Forty-seven sites were surveyed in both 2021 and 2023, the last year surveys were conducted. At these sites, total maximum abundance decreased in 2023 by 955 individuals. Mean abundance of the 47 sites decreased by approximately 20 individuals (Mean ± SE: -20.319 ± 13.648), whereas mean density decreased by approximately three individuals (Mean ± SE: -3.110 ± 2.407; Appendix C). Although 21 sites (45%) had lower abundance in 2023, only 11 sites (23%) had an increase in abundance. The most precipitous declines in abundance were recorded at the private Gamez property, P007 (-614 individuals), and A002DS (-132 individuals) located off 42nd Street in Allegan. Only one site, A059, located North of Horseman's Campground in Allegan had a notable increase in abundance (+107 individuals).

Site Characterization

We identified threats to KBB habitat and populations during surveys in 2023. Barrens and savanna habitat, and therefore lupine populations, change over time in response to succession, disturbance, and management. Woody plant encroachment was the most common threat, with surveyors identifying it as a potential threat at 53 sites (93%). Although KBBs benefit from the presence of some shaded lupine (Benjamins 2003, Grundel et al. 1998b), most sites contained large amounts of young, brushy native tree species, such as oak (*Quercus spp.*) and sassafras (*Sassafras albidum*), which suppresses lupine establishment or growth. The relative abundance of Pennsylvania sedge (*Carex pensylvanica*) was classified as a threat (frequent or higher rank) at 46 sites (81%). Off-road recreational vehicle (ORV) damage and human development were identified as additional potential threats, although these were present at only a small number of sites. We primarily listed ORV damage as a threat because KBBs often congregated along roads and two-tracks that are free of heavy Pennsylvania sedge and woody cover, allowing lupine and other barrens species to thrive despite occasional vehicle, foot, and horse traffic. As woody cover increases, Pennsylvania sedge starts to dominate many sites, outcompeting lupine and creating a thick thatch, which prevents lupine from thriving and/or germinating.

Spotted knapweed (*Centaurea stoebe*) was the most abundant invasive species, with all other invasives being recorded at fewer sites. Spotted knapweed, flowering spurge (*Euphorbia corollata*), lanceleaf tickseed (*Coreopsis lanceolata*) and common St. John's wort (*Hypericum perforatum*) were the most abundant nectar sources. The most common nectar sources utilized by KBB were butterfly milkweed (*Asclepias tuberosa*), spotted knapweed, lanceleaf tickseed, and flowering spurge (*Euphorbia corollata*). While it was lower in abundance, we also observed KBBs nectaring on cylindrical blazing-star (*Liatris cylindracea*).

Karner blue butterfly nectaring on cylindrical blazing-star at Allegan State Game Area in 2023. Photo: A. Cole-Wick

Based on our assessments of KBB habitats and potential threats, we developed preliminary management recommendations for each occupied site (Table 3, Figures 6-9). This table is meant to provide land managers with a quick reference as they strategically use limited resources to work towards managing for KBB and other rare species that rely on lupine and barrens. We divided KBB sites into management unit areas consisting of one or more occupied sites, we included only sites occupied by KBB in 2023 in this quick reference table. These recommendations are based on both data collected and our on-the-ground knowledge of these sites from multiple visits.

Table 3. Management priorities for sites at Allegan and Flat River State Game Areas that were occupied by Karner Blue Butterflies (KBB) in 2023. KBB density is the maximum abundance for 2023 per hectare. Nectar score was calculated as the sum of recorded nectar abundance (None = 0, R = 1, O = 2, F = 3, A = 4, D = 5) across visits. Abundance for Pennsylvania sedge (Pen sedge) and wild lupine were measured using DAFOR (Dominant, Abundant, Frequent, Occasional, and Rare; Appendix 1) and includes a range from different surveyors. Every site but A203 had woody encroachment as a potential threat, so we left it out of the table. Sites written in ***bold italics*** contained State Threatened frosted elfin populations in 2021 surveys, and this rare butterfly species will also benefit from the proposed management recommendations for KBB.

Site	Size (Ha)	KBB Density	Nectar Score	Pen Sedge	Wild Lupine	Management Recommendations	Comments
Central Pipeline Management Area (Figure 6)							
A046	2.01	6.97	17.5	O-A	O-A	Monitor Pen sedge	Good habitat, nectar resources relatively abundant, monitor for Pen sedge as it increases in dominance.
A049	1.66	0.60	4.5	F-A	R-O	Increase lupine / Increase nectar sources	Site contains many active ant mounds surrounded by Pen sedge and is depauperate of native nectar sources and lupine.
A051	0.80	3.74	4.0	A	Absent	Increase lupine	Small site that is closing in yet is very close to pipeline to facilitate genetic exchange. Populations persist despite absence of lupine and low abundance of nectar sources.
A055	2.85	2.10	2.0	F-A	R-O	Reduce woody cover / Increase nectar sources	Lupine is currently low in density due to increasing woody encroachment but still has potential to host a large KBB population with removal of woody species and an increase in nectar sources. Many active ant mounds.
A073	21.20	11.88	19.5	A	R-O	Increase lupine / Increase nectar sources / Monitor woody cover	This stretch of pipeline contains a large population of KBBs that allow for exchange of individuals to many small polygons across the SGA and is vital to ASGA's population. While there were very few individual *Asclepias tuberosa* plants in this area, KBBs were disproportionately using them, as we found butterflies using each plant. Spur off of 120th Ave contains no lupine. Increase/seed/remove shrubs in this area.
A086	11.70	1.54	16.5	A-D	R-F	Increase lupine	Moderate increase in KBB density relative to 2021 despite the fact that lupine was rare in portions of site and was not well-distributed. Increase lupine throughout site.
A094	5.03	6.76	19.0	F-A	R-O	Increase lupine	Lupine abundance appeared low with good KBB numbers and relatively good nectar availability.

Horseman's Management Area (Figure 7)							
A001DS	18.14	4.63	11.0	A	O-F	Reduce Pen sedge / Increase lupine / Increase nectar sources	Few nectar sources in NW portion of the site. Most lupine is concentrated along forest edge or trails (two tracks and horse trails), so ORV damage is a threat. Site extends south of 120th Ave and needs more management in this area. KBBs found on 120th Ave and paths were nectaring on invasive plants (*Melilotus albus* & *Centaurea stoebe*) due to a lack of native nectar sources.
A037	0.24	242.55	3.5	F	A	Reduce woody cover to expand habitat / Increase nectar sources	This small site has the highest density of KBBs at ASGA. Expand habitat, maintain shrub cover in central area. Use as a connector between Pipeline population and Horseman's complex.
A059	14.41	13.05	10.5	A	O	Increase nectar sources / Reduce woody cover	This site contained the second-highest abundance of KBBs in 2023. Northern section has become closed in but the southern portion is excellent with large scattered shrubs and many ant mounds. Many available nectar sources in areas were spotted knapweed. Add native nectar sources throughout. With time, woody encroachment may become a problem.
A060	0.57	7.01	1.0	F-A	R-O	Increase lupine / Increase nectar sources	Small, isolated site lacking nectar sources but near densely populated Horseman's complex.
A208	6.41	0.94	8.0	A	F	Reduce woody cover / Increase nectar sources	Site added in 2023 between two existing polygons. Excellent habitat work has allowed KBBs to move in, however woody cover and pen sedge are the leading issues. Many butterflies using *Centaurea stoebe* as nectar sources because of a lack of native sources. ORV damage is a threat because of KBBs concentrating along roads for invasive nectar sources.
North Pipeline & 124th Ave (Figure 8)							
A108	17.65	0.62	16.0	A	A	Monitor and reduce Pen sedge	Restoration/prescribed fire recently executed here - monitor and evaluate pen sedge as site recovers from fire.
A115	29.23	0.07	17.5	A-D	F	Increase lupine	Lupine score reflects small area surveyed around periphery where lupine occurs. Lupine is not well-distributed throughout habitat. We did not survey portions of site that contained no lupine with >75% canopy cover. Lack of ant mounds.
115th Ave (Figure 9)							
A002DS	27.45	2.62	15.5	A	F	Increase lupine / Reduce woody cover / Increase nectar sources / Expand habitat	This was once one of the best KBB sites at ASGA with lots of barrens and ideal structure. KBBs have been declining in recent years due to woody cover increasing and Pen sedge dominating

							(particularly the NE section). Most KBBs are currently found in two narrow corridors running along 42nd Street, focus management farther from road in western and northeastern pockets.
A007	10.65	0.09	10.0	F-A	Absent -O	Increase lupine	Lupine is sparse throughout site and not observed by surveyors who walked portions of the site.
A021	3.08	0.97	6.5	A	F	Reduce woody cover	Manage together along with neighboring A019 as they are separated by ~70m. These sites had a large decline from monitoring in 2021, with 1 KBB in 2023, and >30 KBBs observed in 2021. A019 is not included in this table, as no KBBs were observed there in 2023 compared to 11 in 2019, but it could be managed together with these sites.
Miscellaneous Sites							
A068	33.57	0.30	24.0	A-D	F	Reduce Pen sedge	Recent management evident with a diversity of nectar sources. Monitoring and managing for Pen sedge is highest priority.
A082	11.61	0.09	10.5	A	F	Reduce Pen sedge / Increase nectar sources/ Increase lupine	Site recently burned, continue to monitor site and manage Pen sedge. Burn breaks have been disced and offer opportunities for planting lupine seeds.
A088	2.17	0.92	10.0	A	R	Reduce woody cover	Small, isolated site that may be important as a stepping stone for KBBs to move between larger sites.
A090	1.21	0.83	7.0	A	R	Reduce Pen sedge / Reduce woody cover	Small and isolated site with marginal habitat, but KBBs persist and site may act as a stepping stone to connect larger populations.
A203	6.41	3.51	5.0	O-F	A	Increase nectar sources	Small, isolated, recently burned site added as a new polygon in 2023. Shaded lupine was abundant and in excellent condition in late season. Polygon expanded to the north after exploring and finding an additional KBB.
F003DS	3.45	5.22	14.5	F	F	Reduce woody cover	Site contains a high diversity of nectar sources and a decent amount of lupine. Aside from a dense pocket located in an opening just north of the trail, lupine is primarily restricted to the main trail. Focus on opening up habitat, in turn increasing lupine.

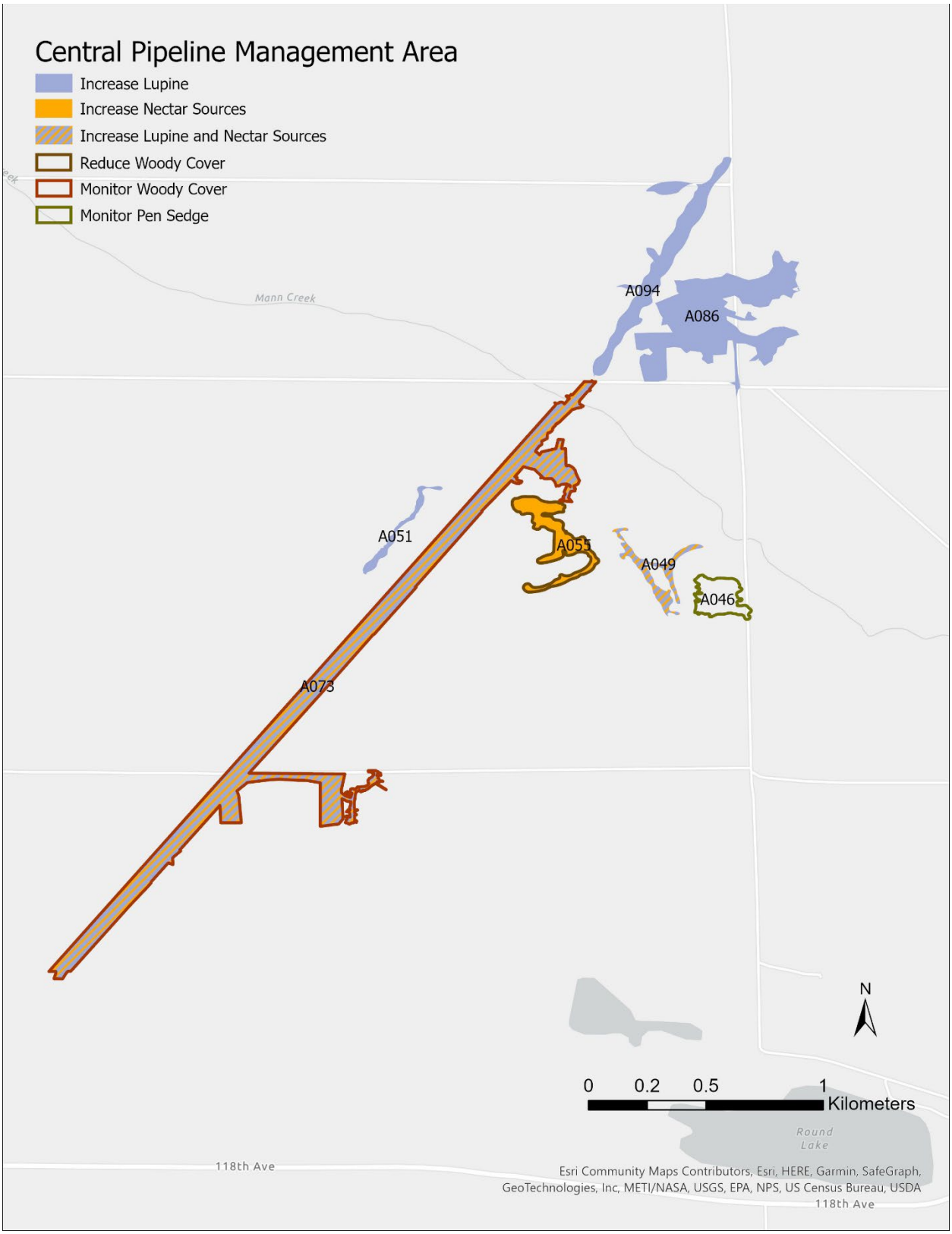

Figure 6. Survey sites located within the Central Pipeline Management Area, displayed with unique symbology according to preliminary management recommendations.

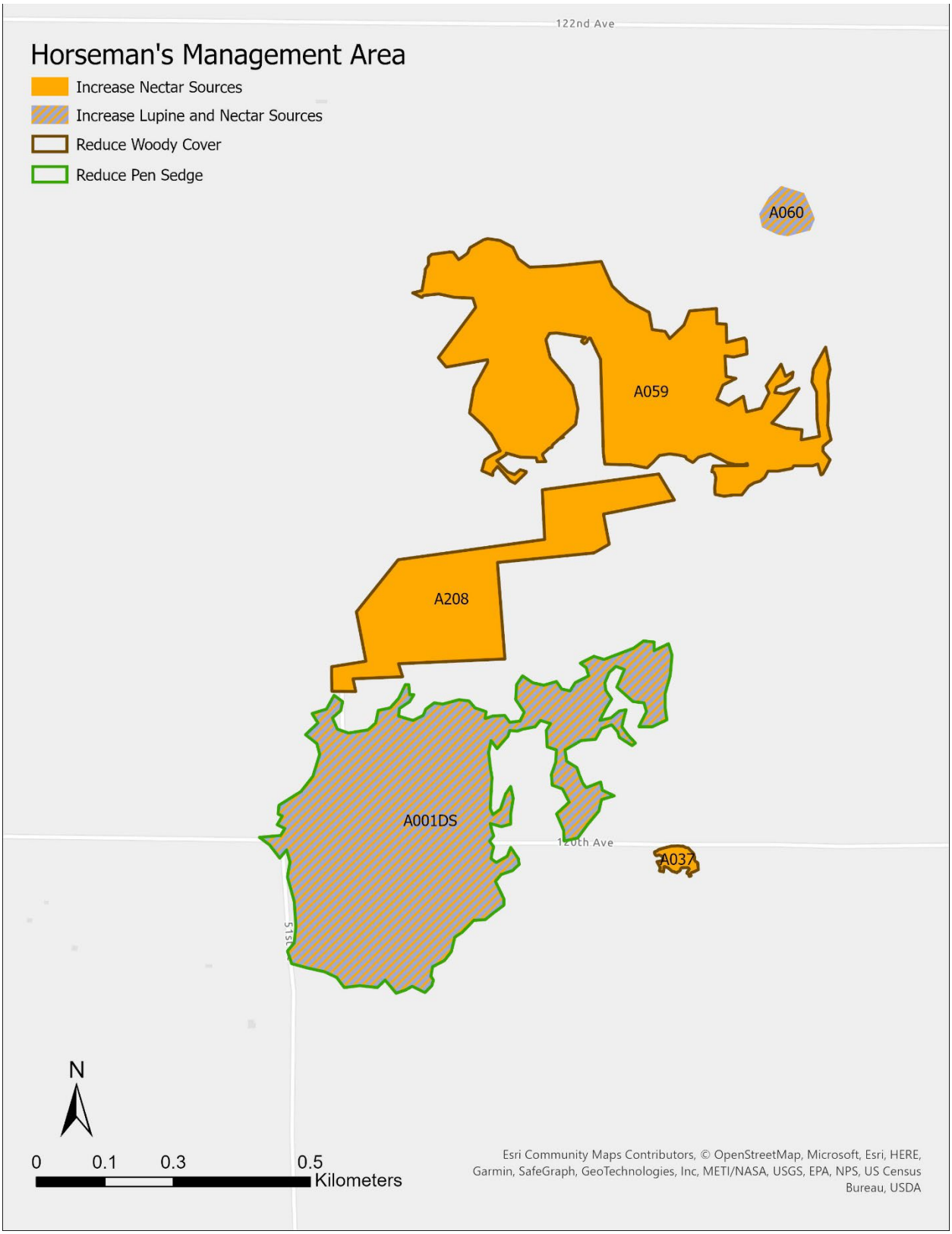

Figure 7. Survey sites located within Horseman's Management Area, displayed with unique symbology according to preliminary management recommendations.

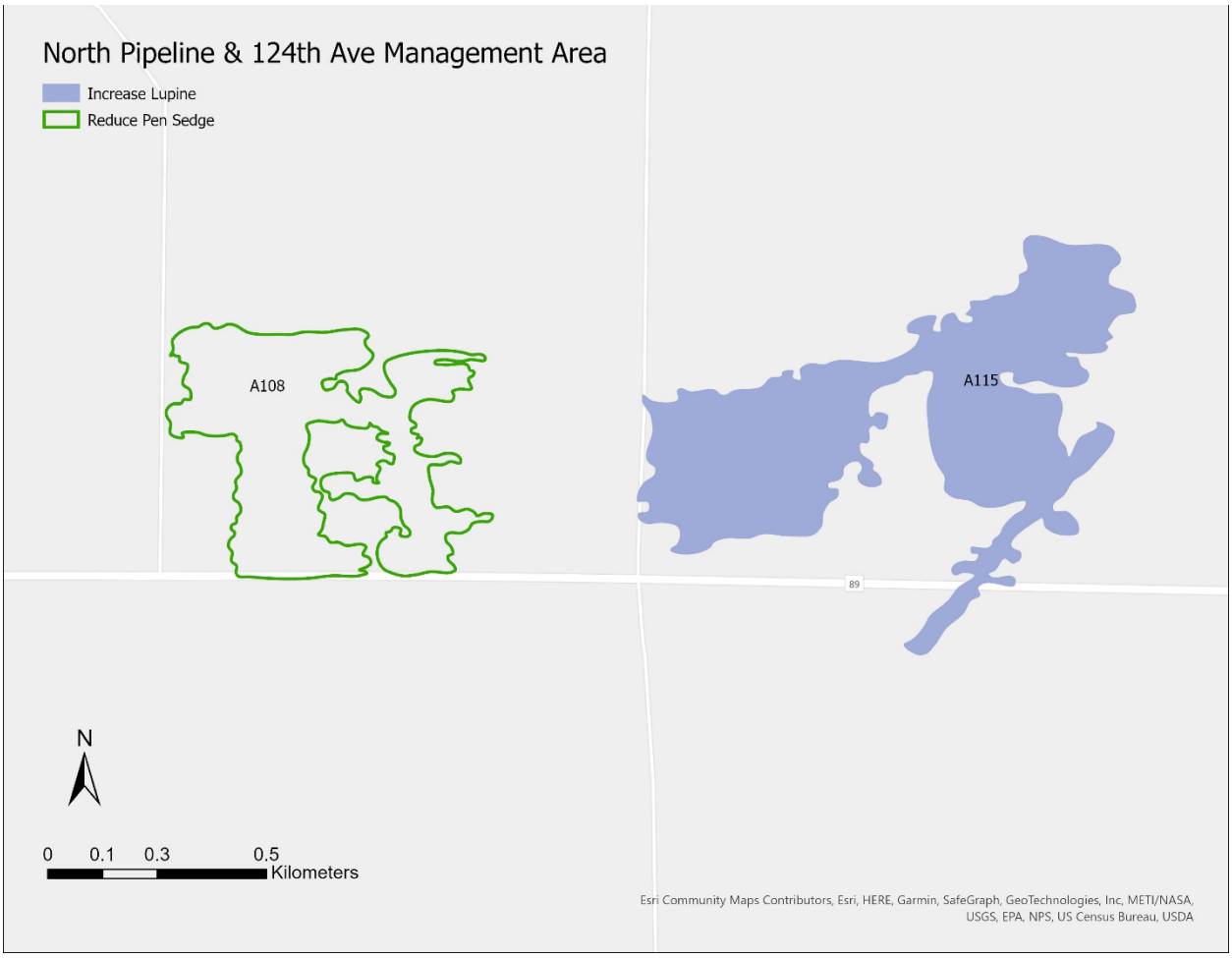

Figure 8. Survey sites located within the North Pipeline & 124th Ave Management Area, displayed with unique symbology according to preliminary management recommendations.

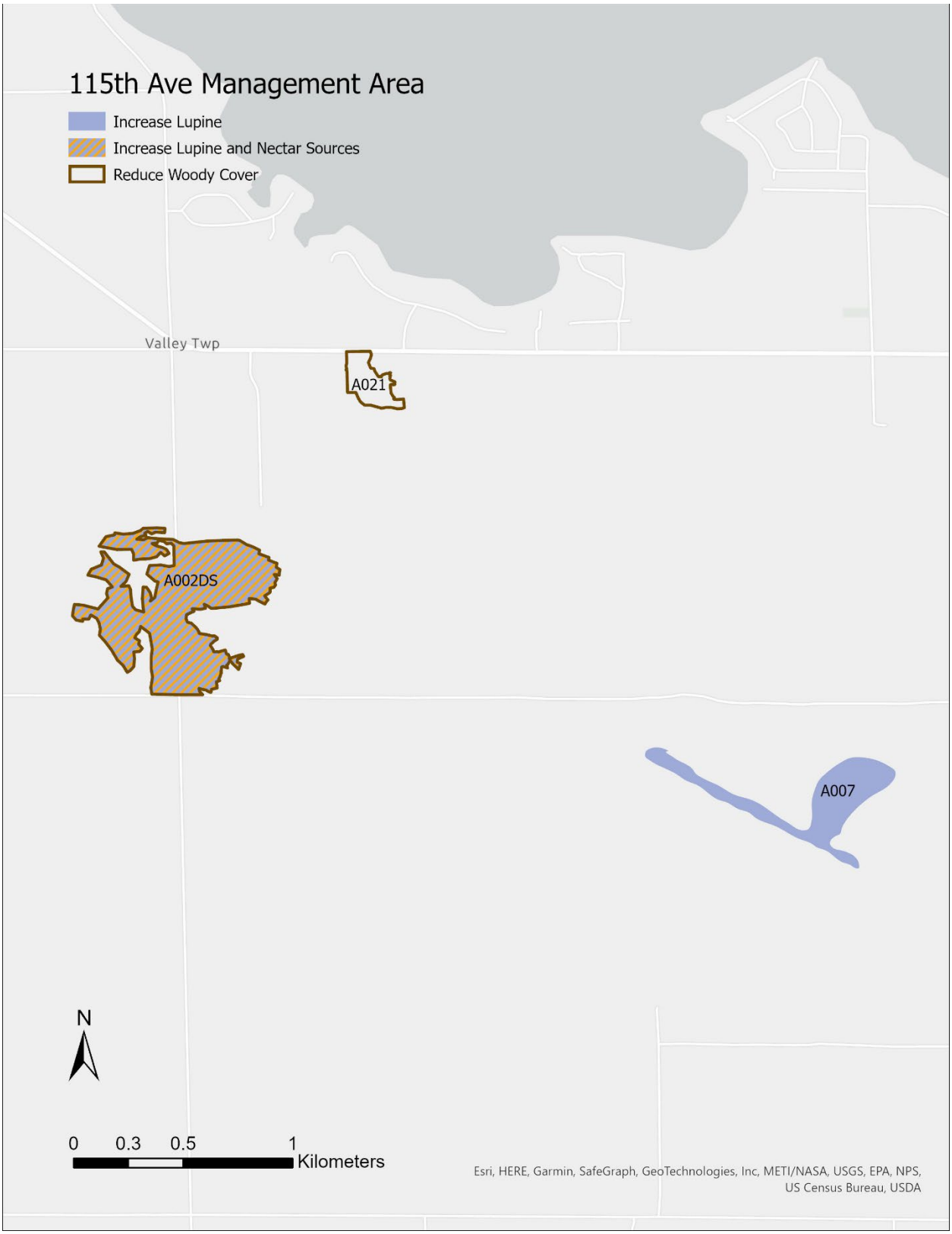

Figure 9. Survey sites located within the 115th Ave Management Area, displayed with unique symbology according to preliminary management recommendations.

DISCUSSION

Michigan, along with Wisconsin, plays a crucial role in supporting some of the largest extant populations of the Federally Endangered KBB (USFWS 2003). Population monitoring the MNFI conducted in 2023 will assist land managers in making informed decisions about where and when to conduct habitat management to positively impact this rare butterfly species. Its only host plant, lupine, is disturbance dependent and therefore populations of KBB rely heavily on thoughtful and timely conservation land management actions. After completing surveys in 2023, we now have six years of data (between 2015 and 2023) on KBB populations on state and private lands in southwestern Michigan. The use of a standardized sample design and protocol allows us to assess trends in population parameters across these years. These data can be used to assess progress toward recovery goals and evaluate the response of KBB to management actions. Understanding occupancy patterns and abundance of individual habitat patches can aid land managers in prioritizing management locations and identifying patches to connect via corridors. At a finer scale, site characterization data can be used to identify management needs for individual habitat patches.

Copulating Karner blue butterflies in July 2023 at Allegan State Game Area.
Photo: A. Cole-Wick

While this project focused on KBB, several other rare species, Species of Greatest Conservation Need (SGCN; Derosier et al. 2015), and DNR featured species benefit from KBB-centric management. The frosted elfin (*Callophrys irus*, State Threatened, SGCN), and Persius duskywing (*Erynnis persius persius*, State Threatened, SGCN) both use the same habitat and host plant as the KBB, while the rare mottled duskywing (*Erynnis martialis*, Special Concern, SGCN) is found in barrens habitats. Supplementing existing KBB monitoring programs with targeted surveys for these rare and listed species may prove beneficial. Aside from addressing important gaps in knowledge related to population status, these data could provide additional information on habitat patch quality and management effectiveness for multiple species. Rare non-insect species such as red-headed woodpecker (*Melanerpes erythrocephalus*, Special Concern, SGCN, DNR Featured Species) and Eastern box turtle (*Terrapene carolina carolina*, State Threatened, SGCN) – both of which we incidentally observed while surveying for KBB at Allegan State Game Area – also benefit from barrens management, as well as wild turkey (*Meleagris gallopavo,* DNR Featured Species).

Eastern box turtle (*Terrapene carolina carolina*) incidentally observed while surveying for KBB at Allegan State Game Area in July 2023. Photo: A. Cole-Wick

Although KBB occupancy appeared to be increasing at survey sites during 2015-2018 (Monfils and Cuthrell 2018), results from surveys in 2021 (Monfils et al. 2021) and 2023 suggest a downward trend. Proportion of sites occupied in 2023 was the lowest of the six years surveyed, and maximum abundance was second lowest when considering all sites and lowest when only using data from sites surveyed every year. These results could represent normal variation in population parameters, but progressively lower occupancy and relative abundance indicate a possible downward trend at sites we monitored across all years. At Flat River, only one KBB population persists. This population declined in abundance by 2,416 individuals between 2018 and 2021 and declined by an additional 29 individuals between 2021 and 2023. We recommend a timely and thoughtful approach to the management of these areas by decreasing woody encroachment and Pennsylvania sedge dominance in these sites, as well as increasing lupine and native nectar sources, as outlined in Table 3. Continued monitoring of these sites on a regular basis will provide data land managers can use to plan and assess KBB response to management actions. Consistent data across successive years will permit a better understanding of expected variation between years and increase our capacity to assess overall population trends.

KBB occupancy patterns and patch use are complex and dependent on multiple factors including microclimate, resource availability, patch size, and matrix quality (Grundel and Pavlovic 2007, Walsh 2017). Lower occupancy rates, abundance, and density estimates in 2023 are likely associated with a combination of factors. Below average precipitation and above average temperatures in May and June may have negatively impacted lupine health and availability, thereby affecting larval feeding and survival to second flight. Drought can decrease lupine growth and lead to early senescence and has been correlated with substantial declines and local extinction of Midwest populations (Patterson et al. 2020, Walsh 2017). We observed wilted and water-stressed lupine while conducting surveys, which may have led to higher larval mortality and fewer second-generation adults. Supplementing the existing monitoring program with first-flight surveys could help to determine whether declines are primarily driven by factors affecting over-winter egg survival or by those affecting larval survival between generations. Declines may also be associated with decreased habitat availability. Shrub encroachment and Pennsylvania sedge were pervasive threats across monitored sites, both of which limit host plant and nectar availability and reduce the area of suitable habitat. Quantifying shrub encroachment in greater detail (e.g., percent woody vegetation cover estimates, mapping of potential woody treatment areas) at surveyed sites may help to assess trends in habitat availability and quality.

We recommend continued mapping of lupine distribution by MDNR staff as frequently as resources allow. Information on lupine distribution allows for the identification of new potential KBB habitats and aids in determining which historically occupied sites may no longer be suitable. This information could also be utilized to assess how lupine populations respond to different management activities. Lupine mapping completed by MDNR staff in 2022 led to the addition of eight new sites to the 2023 sample frame and the discovery of two new KBB populations. We recommend continued monitoring of these occupied sites to determine if the populations persist and if so, to track changes in abundance and density. While the other six

sites were not occupied by KBB, lupine abundance at these sites may be sufficient to support populations of State Threatened frosted elfin and Persius duskywing. We recommend including these sites in any surveys conducted for these species at Allegan. Because their flights overlap with the first KBB flight, such surveys would permit simultaneous monitoring of KBB occupancy. Any sites colonized by KBB could be thoroughly surveyed during the second flight.

Wilted lupine observed at Flat River State Game Area during late June 2023. Photo: E. Branch

Nectar Resource Availability

Lupine is inextricably linked to the occurrence and survival of KBBs, but it is only one of the critical habitat factors necessary for KBB success. In some cases, we observed sites that contained a high density of lupine yet a low density of nectar sources, or vice-versa, as evident in Table 3. Lupine has already fruited and released seed by the second KBB flight, so a balance of both resources is required to sustain KBB populations. When lupine and nectar sources are spatially separated, adult KBBs can face a tradeoff between maximizing foraging and reproductive success (Scheirs and De Bruyn 2002). Indeed, KBB densities in Wisconsin were

lowest in occupied habitats containing high densities of either resource but low densities of the other and highest in habitats where both resources were present in approximately equal ratios (Chau et al. 2020). Local KBB populations may therefore benefit from management focused on increasing habitat that contains both resources in approximately equal proportions. In Table 3, we provided recommendations for which sites would benefit from an increase of one or both vital resources.

Two Karner blue butterflies nectar on butterfly milkweed (*Asclepias tuberosa*) at Allegan State Game Area in 2023. Photo: A. Cole-Wick

Lawrence and Cook (1989) indicated a lack of nectar sources could limit KBB at Allegan. As noted in Table 3, we think planting of nectar sources may be beneficial in some instances, and we highly recommend butterfly milkweed as a late season nectar source in KBB habitat. In 2023, butterfly milkweed was the only nectar source to have observations of multiple KBB nectaring on a single individual plant, even though it was low in abundance – ranking 8th in terms of relative abundance. Our results are consistent with Herms (1996), who noted KBB nectared most often on butterfly milkweed despite it being consistently rare at all sites. The apparent preference for butterfly milkweed therefore appears unrelated to its overall availability. We also frequently observed KBBs nectaring on spotted knapweed. It is likely this is not a preferred nectar source, but adults are more likely to use this nectar resource if it is the only one readily available when foraging. We recommend continued monitoring of KBB nectar source selection, particularly in relation to relative abundance, to gain a better understanding

of nectar preferences. This information could be used to inform planting activities focused on improving habitat quality.

Lupine and Shade Heterogeneity

Maintaining a variety of canopy cover types (i.e., open, partial, and closed canopy) within and adjacent to occupied habitats is important for promoting the success of KBBs across their life cycle. Maintaining open habitats is important for lupine survival and abundance, as lupine seedling survival is up to four times greater in openings and sun-exposed lupine (< 30% canopy cover) emerge earlier, grow denser, and are more abundant than shaded lupine (Pavlovic and Grundel 2009). Openings where lupine is more abundant are important for adults, particularly males, who preferentially use open habitats for mating and nectaring activities (Grundel et al. 1998a). In contrast, shaded and partially shaded habitats are important for females and the larval stage. Shaded lupine (> 70% canopy cover) emerge and senesce later in the season (Pavlovic and Grundel 2009) and provide higher quality forage for second-generation larvae. First-flight females preferentially oviposit on shaded lupine (Grundel et al. 1998a), which increases larval growth (Grundel et al. 1998b) and survivorship (Lane 1999, Benjamins 2003). Management focused on maintaining shade heterogeneity within occupied habitats is likely to benefit KBB populations by ensuring the presence of both openings and shaded and partially shaded lupine, which can serve as refugia for KBB during hot and dry years (Patterson et al. 2020). This is likely to become an increasingly important consideration as climate change continues to increase the frequency of extreme weather events such as droughts.

Future Monitoring

We recommend continued communication and collaboration between MDNR and MNFI regarding monitoring goals and objectives. Codeveloping a long-term monitoring plan to achieve these goals and objectives, along with mechanisms to efficiently communicate information across organizations, could improve conservation efforts. Many historically occupied sites surveyed this year no longer contained suitable habitat (e.g., no lupine due to increasing woody plant or sedge competition). Discussions centered around the value of continued monitoring of these sites for purposes of population monitoring and management assessment relative to concentrating survey effort in suitable habitat and searching for new KBB populations would be beneficial. Additionally, increased communication regarding locations of management activities by MDNR staff would ensure that MNFI evaluates areas that allow us to provide pre-management data and later assess responses to management. These discussions could inform the development of a plan that balances the many needs of a KBB monitoring program, such as determining the occupancy status of habitat patches to assist management planning, assessing changes in distribution and relative abundance over time, and evaluating population response to management actions.

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APPENDIX A. KARNER BLUE SURVEY PROTOCOL WITH DESCRIPTIONS OF DAFOR RANKINGS.

MICHIGAN NATURAL FEATURES INVENTORY

KARNER BLUE (*LYCAEIDES MELISSA SAMUELIS*) SURVEY PROTOCOL

Acceptable Survey Conditions

Surveys should not be conducted when the temperature is below 15° C (60° F), during rain, or when winds exceed 25 km/h (15 mph). When temperatures are 15 - 21° C (60 - 70° F), cloud cover should be ≤50% of the sky. There is no cloud cover restriction if the temperature is above 21° C (70° F). If weather conditions deteriorate during a survey, observers should terminate the survey and resurvey the entire site on a suitable day. Be sure to note that the survey was ended on the data form and record the final weather conditions.

Survey Area

We identified preliminary survey areas using ArcMap and data layers of known Karner blue element occurrences, mapped lupine patches, and non-forested openings digitized using aerial imagery. Surveys were focused on portions of Karner blue element occurrences having (1) mapped lupine and digitized openings; (2) mapped lupine; and (3) digitized openings. All locations having these conditions were merged to create our preliminary survey polygons. We then expanded our survey areas to include digitized openings and mapped lupine patches that were within 200 m of known Karner blue occurrences. These final survey polygons will be used to target on-the-ground Karner blue surveys. Although we are targeting surveys at these polygons, we are using a flexible survey approach to allow final survey routes to be modified as needed in the field. When in the field, areas within the polygons having one or more of the following conditions can be excluded from the survey: (1) > 60% tree canopy cover; (2) > 75% bare soil and no lupine; (3) planted crops or ground cover (e.g., grassland, lawn) lacking lupine and nectar sources; and/or (4) located on private land. Conversely, areas of potential habitat (i.e., ≤60% canopy cover with lupine/nectar sources) located on public land immediately outside of the polygon should be added to the survey. If a survey site needs to be modified in the field, map the new boundary using Field Maps or a GPS application.

Timing

Surveys can be conducted between 9 AM and 6 PM (EDT). Two surveys of each site should be conducted during the second Karner blue flight (approximately early July to early August).

Survey Methodology

Visual survey: The survey will typically consist of a series of transects paralleling the outer boundary of the identified habitat patch. The first transect will begin 5 m inward from the outer edge of the survey area (e.g., patch of savanna, opening). One surveyor

will slowly walk along the first transect until the entire periphery of the site has been surveyed. The second transect will be located 10 m inward from the first transect and will be surveyed in the same manner. Additional transects are added until the entire patch has been surveyed. When possible, additional surveyors can be used to cover large sites or smaller sites more quickly, as long as all transects are separated by 10 m. Each surveyor will look for and count butterflies within an area 5 m to either side of the transect, 5 m forward along the transect, and 5 m above the transect (imagine a 10 m x 5 m x 5 m, box-shaped, survey area). Surveyors should walk at a steady, slow speed of approximately 35 m/min. When Karner blues fly ahead of the observer, they can be ignored if the surveyor is certain that the individual was already counted. If the observer is uncertain as to whether or not the individual was counted, it should be counted and considered a new individual. When more than one person is surveying a site, It will be important that team members communicate about butterflies moving between transects (e.g., individual counted by one team member that flies into the area being surveyed by the other team member).

Survey data will be gathered using the Karner blue Survey123 form, so be sure to download the form to your tablet/phone before starting field work. A separate Survey123 form should be completed for each survey polygon. If multiple people survey the same site, each person can fill out a separate form to gather data on Karner detections, but information about weather, lupine, nectar sources, and threats only needs to be collected by one person. Karner blue detections will be recorded by individual or groups of butterflies when located within 5 m of one another. For each detection, surveyors will record the number of Karners observed, sex of the individual(s), wing wear rankings, behavior/activity, distance away from the transect, and a GPS waypoint. The total number observed for each detection will be recorded in the “total number detected” field; leave this field blank if no Karners are observed at a site. Next, break down the number observed by sex and use the “unknown” category if you are unable to determine the sex. For example, if you detect 5 Karners, you might enter 2 males, 2 females, and 1 unknown. Similarly, surveyors will break down the total number detected into the five wing wear categories described by Watt et al. (1977): (1) freshly emerged, wings still damp; (2) wings and other cuticle dry and hard, no visible damage; (3) noticeable wear of scales from wings or body; (4) wings showing fraying or tearing in their cuticle; and (5) wings with extensive scale wear and cuticle damage. Using the same example of 5 Karners detected, you could have 1 individual in wing wear category 1, 3 in category 2, and 1 in category 3. Next, break down the number observed in a detection into the following behavior/activity categories: nectaring, flying, perched, copulating, and ovipositing. For example, a detection of 5 Karners might be recorded as 4 nectaring and 1 flying. Surveyors will then enter the distance away from the transect that each individual/group was first detected using the following 0.5-meter bins provided in the form: 0.0–0.5 m, 0.5–1.0 m, 1.0–1.5 m, 1.5–2.0 m, 2.0–2.5 m, 2.5–3.0 m, 3.0–3.5 m, 3.5–4.0 m, 4.0–4.5 m, 4.5–5.0 m, and >5.0 m). Lastly, a waypoint will be collected for the individual/group using the button in the Survey123 form. If you walk off of a transect to collect a waypoint, be sure to move back to the point where you left off before continuing on with the survey. As much as possible, avoid flushing butterflies when collecting waypoints.

Surveyors should record their survey tracks using their tablet or phone. This could be done using the Field Maps or a GPS application. Set the application to record your location along the track at 30-sec intervals. Once your track has been recorded during the first visit to a particular site, the tracking function can be turned off during the second visit and the same tracks can be followed during the second survey. It will be critical that each surveyor download their survey tracks at the end of the season to describe survey effort and facilitate surveying the same routes in future years. Use the following naming format when saving your survey tracks: year_observer last name_kbb_tracks (e.g., 2023_smith_kbb_tracks).

Overall butterfly diversity: All butterfly species seen during Karner blue surveys should be recorded in the Survey123 form used for each site (polygon). Because estimating relative abundance would be difficult for multiple species and likely to distract observers from surveying for Karners, observers should simply check off species of butterflies seen in the pull-down menu of the form and should not attempt to count species other than Karner blue.

Weather: At the start and end of the survey, record the temperature (°C), percent relative humidity, cloud cover (expressed as the % of sky occluded), and maximum wind speed (km/h). If a survey needs to be terminated because of poor weather conditions, collect that same weather information at the time the survey is ended.

Site characterization: Observers will collect general information about survey sites during each visit, such as potential threats, presence of lupine, and nectar sources. At least one representative photograph should be taken of each survey site during one of the two visits. Several potential threats to Karner blue and its habitats are listed on the data form. Place a check mark next to all those that apply to the survey site. Potential threats not listed can be entered by checking “Other” in the pull-down menu. For invasive plant species, rank the abundance of those species observed as dominant (D), abundant (A), frequent (F), occasional (O), or rare (R) in the form. Invasive species not listed can be added in the form under the “Other” field. Below is specific guidance on using the DAFOR scale.

Dominant (D): In practice, the dominant ranking is rarely, if ever used. To be scored as D, a species would have to be the most common plant by far, covering over 75% of the site. If you are not sure if a species should be scored as D, then assign it a score of A.

Abundant (A): Only use A if the species is common in many parts of the survey site. For most species, this would mean that there are thousands of individual plants present. At most sites, few species will be ranked as A. If you are unsure if a species should be scored as A or F, then give it a ranking of F.

Frequent (F): Use F if you find a species at several places within the survey site and more than just a few individuals are present at each location. You could also use F if

a plant species only occurs at one part of the site but is common at that location, with many individuals observed and a substantial area covered (e.g., between one eighth and one quarter of the site). If you are not sure if a species should be scored as F or O, then assign it a score of O.

Occasional (O): Use O for species that occurs in several places in the site, but whose populations are small at those locations. You could also use O for species that are common at one location but occupy a small area (e.g., less than one eighth of the site). If you are not sure if a species should be ranked as O or R, then give it a score of R.

Rare (R): Use R for species that occur as a small number of individuals within the site. These individuals may be located in one place or scattered over several locations. If you are unsure if a species should be scored O or R, then assign it a score of R.

A list of possible nectar plant species for Karner blue is provided in the form. Rank the abundance of each available (i.e., flowering) nectar species observed at the site using the same DAFOR scale described above for invasive plant species. Nectar sources not on the list can be added in the “Other” field.

Because lupine is the larval host plant and a potential nectar source for Karner blue, we will rank is relative abundance in two ways on the data form using the DAFOR scale. First, the relative abundance of flowering lupine can be ranked under the nectar source section of the data form. Second, you should rank the overall abundance of lupine (both flowering and non-flowering plants) within the “Site info (end)” section of the form. In dry years, lupine can begin senescing early, which can be noted in the “Additional notes” field of the form.

APPENDIX B. MAXIMUM ABUNDANCE AND RAW DENSITIES OF SITES SURVEYED EVERY YEAR.

	Maximum Abundance						Density					
Site	**2015**	**2016**	**2017**	**2018**	**2021**	**2023**	**2015**	**2016**	**2017**	**2018**	**2021**	**2023**
A001	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
A003	0	0	1	0	0	0	0.00	0.00	0.08	0.00	0.00	0.00
A007	4	5	0	0	2	1	0.07	0.09	0.00	0.00	0.04	0.09
A019	0	13	32	26	13	0	0.00	10.23	25.19	20.47	10.23	0.00
A021	9	23	40	28	33	3	2.93	7.48	13.01	9.10	10.73	0.97
A033	0	12	6	1	0	0	0.00	306.98	153.49	25.28	0.00	0.00
A034	13	2	0	0	2	0	13.18	2.03	0.00	0.00	2.03	0.00
A037	29	66	36	40	44	58	121.33	276.13	150.62	167.35	184.09	242.55
A038	2	0	6	16	0	0	3.97	0.00	11.90	31.74	0.00	0.00
A046	6	50	28	42	24	14	3.39	28.27	15.83	23.75	13.57	6.97
A049	0	1	2	0	0	1	0.00	0.73	1.47	0.00	0.00	0.60
A051	6	9	20	4	2	3	21.19	31.78	70.62	14.12	7.06	3.74
A055	8	5	17	9	0	6	7.35	4.59	15.62	8.27	0.00	2.10
A059	20	291	408	309	81	188	1.39	20.21	28.33	21.46	5.63	13.05
A060	2	12	19	25	20	4	3.50	21.03	33.30	43.81	35.05	7.01
A062	0	5	6	9	0	0	0.00	2.81	3.37	5.06	0.00	0.00
A068	11	3	3	0	4	10	0.50	0.14	0.14	0.00	0.18	0.30
A070	1	1	0	2	1	0	1.56	1.56	0.00	3.13	1.56	0.00
A073	403	868	830	396	331	252	21.49	46.29	44.27	21.12	17.65	11.88
A075	0	0	4	1	2	0	0.00	0.00	4.38	1.10	2.19	0.00
A082	0	0	5	12	0	1	0.00	0.00	1.12	2.70	0.00	0.09
A086	26	46	10	12	11	18	2.22	3.93	0.85	1.02	0.94	1.54
A088	1	4	1	2	17	2	1.44	5.77	1.44	2.89	24.54	0.92
A090	0	0	1	1	0	1	0.00	0.00	2.49	2.49	0.00	0.83
A094	0	81	34	16	49	34	0.00	27.26	11.44	5.39	16.49	6.76
A100	2	9	5	7	2	0	0.59	2.66	1.48	2.07	0.59	0.00
A105	0	3	0	2	2	0	0.00	0.68	0.00	0.46	0.46	0.00
A106	0	4	1	0	0	0	0.00	2.20	0.55	0.00	0.00	0.00
A108	1	5	13	3	6	11	0.07	0.34	0.89	0.21	0.41	0.62
A111	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
A115	2	8	19	9	0	2	0.08	0.31	0.73	0.35	0.00	0.07
A117	2	1	3	3	0	0	1.78	0.89	2.67	2.67	0.00	0.00
A121	99	68	18	51	11	0	11.05	7.59	2.01	5.69	1.23	0.00
A123	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
A126	0	11	4	2	0	0	0.00	2.43	0.88	0.44	0.00	0.00
A129	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00
A130	1	0	0	0	0	0	0.49	0.00	0.00	0.00	0.00	0.00
F006	2	0	1	0	0	0	0.19	0.00	0.09	0.00	0.00	0.00
Naïve Occ	**0.579**	**0.711**	**0.763**	**0.684**	**0.526**	**0.474**	---	---	---	---	---	---
Max Abu	**650**	**1,606**	**1,573**	**1,028**	**657**	**609**	---	---	---	---	---	---
Raw Den	---	---	---	---	---	---	**5.78**	**21.43**	**15.74**	**11.11**	**8.81**	**7.90**

APPENDIX C. THE CHANGE IN MAXIMUM ABUNDANCE AND RAW DENSITY FROM 2021 TO 2023 FOR THE 47 SITES SURVEYED BOTH YEARS.

Site	21 Max Abundance	23 Max Abundance	Change	21 Density	23 Density	Change
A001	0	0	0	0.00	0.00	0.00
A001DS	125	84	-41	6.89	4.63	-2.26
A002	0	0	0	0.00	0.00	0.00
A002DS	204	72	-132	7.62	2.62	-5.00
A003	0	0	0	0.00	0.00	0.00
A007	2	1	-1	0.04	0.09	0.05
A019	13	0	-13	10.23	0.00	-10.23
A021	33	3	-30	10.73	0.97	-9.76
A033	0	0	0	0.00	0.00	0.00
A034	2	0	-2	2.03	0.00	-2.03
A037	44	58	14	184.09	242.55	58.46
A038	0	0	0	0.00	0.00	0.00
A046	24	14	-10	13.57	6.97	-6.60
A049	0	1	1	0.00	0.60	0.60
A051	2	3	1	7.06	3.74	-3.32
A055	0	6	6	0.00	2.10	2.10
A059	81	188	107	5.63	13.05	7.42
A060	20	4	-16	35.05	7.01	-28.04
A062	0	0	0	0.00	0.00	0.00
A068	4	10	6	0.18	0.30	0.12
A070	1	0	-1	1.56	0.00	-1.56
A073	331	252	-79	17.65	11.88	-5.77
A075	2	0	-2	2.19	0.00	-2.19
A082	0	1	1	0.00	0.09	0.09
A086	11	18	7	0.94	1.54	0.60
A088	17	2	-15	24.54	0.92	-23.62
A090	0	1	1	0.00	0.83	0.83
A094	49	34	-15	16.49	6.76	-9.73
A100	2	0	-2	0.59	0.00	-0.59
A105	2	0	-2	0.46	0.00	-0.46
A106	0	0	0	0.00	0.00	0.00
A108	6	11	5	0.41	0.62	0.21
A111	0	0	0	0.00	0.00	0.00
A115	0	2	2	0.00	0.07	0.07
A117	0	0	0	0.00	0.00	0.00
A121	11	0	-11	1.23	0.00	-1.23
A123	0	0	0	0.00	0.00	0.00
A126	0	0	0	0.00	0.00	0.00
A129	0	0	0	0.00	0.00	0.00
A130	0	0	0	0.00	0.00	0.00
F001DS	0	0	0	0.00	0.00	0.00

Appendix C. Continued.

F002DS	1	0	-1	0.13	0.00	-0.13
F003DS	47	18	-29	13.64	5.22	-8.42
F006	0	0	0	0.00	0.00	0.00
P002	71	3	-68	8.07	0.34	-7.73
P007	623	9	-614	88.44	1.28	-87.16
P009	78	56	-22	3.23	2.32	-0.91