When is a site restored? Studies of the suitability of five oak savannah habitats in Ontario for reintroduction of the Karner Blue Butterfly (*Lycaeides melissa samuelis*)

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Abstract

The success of a restoration project is often assessed in terms of the sites' suitability for reintroduction of one or more species which have been extirpated from it. However, the questions remain: 1) If multiple restored sites are available, which site(s) should the species be reintroduced to? 2) From which site should material for reintroduction be chosen? Here we investigate this problem in relation to the globally endangered Karner Blue Butterfly (KBB) (*Lycaeides melissa samuelis*). We evaluated five restored potential KBB reintroduction sites in Ontario by looking at both biotic (vegetation, especially the larval host plant *Lupinus perennis,* 1st and 2nd brood adult nectar source plants, and tending ant species) and abiotic (temperature, relative humidity and light intensity) aspects. By obtaining similar data from three sites where the sub-species persists in relatively large numbers in the U.S.A., we developed minimum environmental standards for KBB reintroduction sites. The results show that all potential reintroduction sites in Ontario are of lower quality, at least in certain aspects, compared to the three potential source butterfly sites in the U.S.A. This suggests that the Ontario sites need further restoration before reintroduction of the butterfly should proceed. Comparison of the Ontario and the U.S. sites also revealed that Indiana Dunes National Lakeshore is the most similar to four of the five Ontario sites in terms of vegetation community and microhabitat structure. Indiana Dune National Lakeshore is therefore identified as the priority source site for KBB reintroduction in Ontario.

Keywords

Restoration, reintroduction, oak savannah, Karner Blue, *Lycaeidea melissa samuelis*.

Introduction

Habitat restoration is currently a common practice in many parts of the world (Bruckner and Bruckner 2001; Cohn 2001; Schultz 2001; Lee et al. 2002; Martin and Chambers 2002; Rogers et al. 2002; Robinson and Uehlinger 2003; Taft and Haig 2003; Wilkie and Mathew 2003). Significant improvement in habitat quality, such as increase in species richness or density of rare native species, is often seen as a result of restoration projects (O'Dwyer and Attiwill 2000; Atkinson 2002; Fletcher and Koford 2002; Sprenger et al. 2002; Tanner et al. 2002; Fletcher and Koford 2003; Heuberger and Putz 2003; Snell and Cristol 2003). Though detection, or even quantification, of improvement in habitat quality is usually relatively easy (Hulme et al. 2002; Roman et al. 2002), it is often difficult to define if a restoration project is truly successful or if the integrity and functioning of the ecosystem are completely restored, especially when little is known about what the habitat was like historically. At sites where historic information is available, success of an ecological restoration project can sometimes be defined as the successful establishment of a persisting population of previously extirpated species which is/are indicator species associated with that habitat type (Majer and Nichols 1998; Schram et al. 1999). To use this criterion to determine the success of habitat restoration, species reintroduction from elsewhere is often required. If the selected indicator species is one with good dispersal ability and is found in neighbouring areas, reintroduction may not be necessary as the species may colonize the restored habitat by itself when the environment of the restored site becomes once again suitable (Carbone et al. 1998; Desrochers et al. 1998; Kiviat et al. 2000; Tajovsky 2001; Shea et al. 2002; Watts and Gibbs 2002; Nakamura et al. 2003; Nichols and Nichols 2003; Tucker et al. 2003); similarly, if the selected indicator species is a plant species with long-living seeds and the seed bank in the restored site is not totally depleted, reintroduction is also not needed because the seeds will geminate if the quality of the habitat is improved and environmental conditions become more favourable (Lewis 1988; Galatowitsch and van der Valk 1996; de Bruijn and Hofstra 1997; Brouwer and Roelofs 2001; Grootjans et al. 2001). Unfortunately, such is not always the case. Therefore, if establishment of a healthy population of a previously extirpated species is used as an indicator of successful habitat restoration, reintroduction of such species by humans is sometimes required (Brown and Bedford 1997; Lundholm and Simser 1999; Nienhuis et al. 2002). This is true when the indicator species is an animal species with poor dispersal ability and is extirpated from the local region.

One of the benefits of using this method to evaluate the success of habitat restoration is that it helps to conserve the selected indicator species and potentially other associated species, especially when the indicator species is endangered and the restored habitat type rare (Brooker 2002). Reestablishment of a previously extirpated population certainly helps to reduce the risk of extinction of an endangered species. Preparation of the restored habitat for reintroduction of such species also benefits the conservation of other species that are dependent on the same habitat type which may also be rare. Nevertheless, reintroduction of previously extirpated species can be viewed as a final step of a habitat restoration project. Hence, reintroduction of an indicator species should be encouraged as both an integral part of habitat restoration and an evaluation tool for habitat restoration success.

Before performing the final test of indicator species reintroduction, it is always useful to assess the potential reintroduction sites to find out if all the minimum ecological requirements of the species to be reintroduced are met. This is particularly important when the species is globally threatened or endangered. The site evaluation process should include quantitative methods that describe environmental variables relevant to the species (Witkowski et al. 1997; Joachim et al. 1998; Merrill et al. 1999). In cases where little is known about the minimum ecological requirements of the species to be reintroduced, studying the sites where healthy populations of the species are found can help to obtain such information provided that healthily persisting populations of the species are still found in the wild. Comparisons between the potential reintroduction sites and the potential source population sites can also help to determine which population will be the best choice for the reintroduction site as source population based on their similarities in species composition and various environmental conditions.

In this research, the eventual goal is to use reintroduction of the Karner Blue Butterfly (KBB) (*Lycaeides melissa samuelis*) to test whether several oak savannah sites in Ontario are sufficiently restored.

Oak savannah has become globally rare due to anthropogenic activities such as residential development, agricultural use and fire suppression. Today, only 0.02% of its original area is left on this planet (Nuzzo 1986). Many species associated with this habitat type are threatened or endangered (Rodgers 1998), such as the Frosted Elfin (*Callophrys irus*), the Persius Dusky Wing (*Erynnis persius*) and the Dusted Skipper (*Atrytonopsis hianna*). Hence, restoration of oak savannah is very important in conserving many rare species which depend on this habitat type, and assessing the success of such restoration, such as using reintroduction of an indicator species, is essential in helping us to review our past restoration efforts and plan for future restoration strategies.

The KBB was chosen to be reintroduced in the oak savannah sites in Ontario as an indication of successful habitat restoration for several reasons. First of all, it has been extirpated from Ontario (Packer 1994) but is still found in the U.S.A. (Baker 1994). It is an indicator of good quality oak savannah because its only larval host plant, wild lupine (*Lupinus perennis*), is a typical savannah species which is drought tolerant, sun-loving and disturbance dependent (Klots 1951; Howe 1975; Olper and Krizek 1984). Secondly, both the KBB (Clough 1992a,b) and its oak savannah habitat (Nuzzo 1986) are globally rare. Reintroduction of this butterfly will contribute to the conservation of both itself and its rare habitat, and probably other species living in the same habitat type. Thirdly, reintroduction of the KBB in Ontario may be critical to its long-term survival due to global climate change (Dirig 1994). As already seen in many species in the northern hemisphere, species' geographic ranges are expanding northward and retreating from their southern edges (Carey 1999; Norment et al. 1999; Parmesan et al. 1999; MacDonald 2001; McCarty 2001; Pratt 2002; Winker et al. 2002; Chevaldonne and Lejeusne 2003; Crozier 2003; Parmesan and Yohe 2003; Zacherl et al. 2003). These are consistent with the predictions based upon global climate change. Since the KBB has poor dispersal ability and habitat fragmentation disallows it from gradually expanding its range northward to Ontario from the U.S.A., reintroduction of this globally endangered butterfly back to Ontario by humans is necessary in order to conserve it to compensate for the foreseeable range retreat from its southern limit. Fourthly, the KBB is an extensively studied butterfly (Lintner 1872, 1873; Saunders 1878, Scudder 1888, 1889, 1901; Lyman 1902; Williams 1903; Nabokov 1943, 1949; Shapiro 1969, 1971, 1974; Dirig and Cryan 1976; Dirig 1976, 1988; Cryan and Dirig 1978; Cryan 1980; Savignano 1990; Schweitzer 1991; Swengel 1995; Swengel and Swengel 1996, 1999; Lane 1999a). Despite the presence of knowledge gaps, the ecological requirements of this sub-species are quite well known. Lastly, the KBB has been successfully reintroduced in Ohio where it was once extirpated (Tolson et al. 1999). This shows that reintroduction of this butterfly is possible and we have the knowledge and techniques to do so.

Although the basic ecological requirements of the KBB are quite clearly known, not much information about the "minimum" ecological requirements is available. This makes the determination of whether reintroduction should proceed at certain restored sites difficult when the sites are not in prime conditions. In the KBB reintroduction project in Ohio, only qualitative assessment had been done before the butterfly was reintroduced. This is so probably because the site was in very good conditions, and it still is (Chan, personal observation). In contrast, despite obvious improvement, the restored oak savannah sites in Ontario are not of the best quality yet. A careful quantitative site evaluation is hence needed to determine if the sites are ready for reintroduction of the KBB, before which minimum standards are required.

To accomplish this, comparisons were made between five potential KBB reintroduction sites and three potential source butterfly sites in the U.S.A. in terms of both biotic (vegetation, especially the larval host plant wild lupine, 1st and 2nd brood adult nectar source plants, and tending ant species) and abiotic (temperature, relative humidity and light intensity) aspects. Our objectives are 1) to set up a series of standards as minimum requirements for potential KBB reintroduction sites; 2) to determine whether the five oak savannah sites in Ontario are ready for reintroduction of the KBB after being restored; and 3) to identify the best potential source butterfly sites in the U.S.A. for reintroduction purposes in each of the Ontario site according to their degree of similarity to these Ontario sites in terms of various biotic and abiotic variables.

Ecological Requirements of the KBB

The KBB is bivoltine, which means that it completes two discrete generations per year. KBB larvae of both generations feed on only one plant species, which is wild lupine, while the two broods of adult KBB feed on nectar of almost any flowering plants they can find (Savignano and Zaremba 1993) even though preferences have been documented when nectar is not a limiting resource and different choices are available (Fried 1987; Bleser 1993; Leach 1993; Bidwell 1994; Lane 1994; Lawrence 1994; Herms 1996). For the 1st brood KBB, wild lupine is sometimes the primary nectar source since not many plant species flower at that time of the year (Chan, personal observation); for the 2nd brood KBB, wild lupine is not available as a nectar source but nectar is usually available from many other plant species that are blooming. Therefore, wild lupine is a necessity for the KBB larvae while the presence of a wide variety of other nectar source plants is beneficial to the adult butterflies.

Both broods of the KBB larvae and pupae are often tended by ants. The larvae have glands on their bodies which secrete a nectar-like solution when stimulated by ants. The tending ants guard the larvae and pupae and collect the nectar-like solution from them. Studies have shown that this tending behaviour of ants significantly increases the survivorship of KBB larvae because the presence of tending ants protects them from predators and parasitoids (Packer 1987; Savignano 1990). Hence, presence of tending ant species is desired to ensure long-term persistence of the KBB.

The KBB requires heterogeneous habitats with different light conditions. They prefer laying their eggs on wild lupine plants growing in the shade (Grundel et al. 1998a; Maxwell 1998; Lane 1999a,b). Studies have shown that KBB larvae feeding on leaves of wild lupine growing in the shade grow faster and have a higher survival rate than those feeding on leaves of wild lupine growing in full sun (Grundel et al. 1998b; Lane 1999a). However, adult KBB are more active under direct sunlight and spend most of the time in well-lit locations (Bidwell 1994; Grundel et al. 1998a). This may have to do with thermoregulation (Lane 1999a). Also, wild lupine requires a lot of sunlight to reproduce. In other words, wild lupine growing in full sun can flower and reproduce properly while the ones growing in the shade can rarely reproduce (Boyonoski 1992) but are better food sources for the KBB larvae. Therefore, KBB prefers having wild lupine growing in both sunny and shady areas. In addition, having wild lupine growing in a wide range of light conditions can buffer against some catastrophic events that may occur, such as severe drought, which is thought to have been the major immediate cause of the extirpation of the KBB in Ontario (Packer 1994). This means that site heterogeneity is desirable.

The KBB have metapopulation dynamics, which consists of several subpopulations that are close to one another (Givnish et al. 1988). The subpopulations are usually not very large and they may undergo periodic extirpation (Savignano 1994). However, the short distance among the subpopulations allows dispersal of the KBB among them, so that areas where subpopulations are extirpated can readily be repopulated by the KBB from neighbouring ones (Harrison et al. 1988). Hence, the metapopulation as a whole can be persistent. Therefore, connectivity of subpopulations may also be important to the persistence of the KBB metapopulation.

In summary, to sustain a persisting KBB population, a large heterogeneous site composed of several areas with a lot of wild lupine, different nectar source plants and tending ants is required. Also, these areas within the site should be either close together or connected to one another with dispersal corridors so that dispersal of the KBB among them is easy.

Site description

Potential Reintroduction Sites in Ontario

Five potential reintroduction sites were included in this research. They are: 1) High Park (HP); 2) Alderville First Nation (AFN); 3) Manestar Tract (MT); 4) The Pinery Provincial Park (PPP); and 5) The Karner Blue Sanctuary (KBS). These sites were selected because they were historic sites of the KBB except AFN where wild lupine was absent until recent plantation in 2002.

<u>High Park</u>

High Park (HP) is a 151-hectare (399-acre) urban park in the city of Toronto. About one third of its 79 hectares (195 acres) of natural habitat is oak savannah and the rest is predominantly oak forest. Other areas are composed of various recreational facilities such as swimming pools, tennis courts, children's playground and picnic areas. It has been assigned the status of Area of Natural and Scientific Interest (ANSI) by Ontario Ministry of Natural Resources (OMNR). Many areas in the park have been actively managed by methods including application of herbicide to control invasive species, planting of native prairie and savannah plant species and prescribed burning. The most recent prescribed burn was performed in spring 2004.

Alderville First Nation

Alderville First Nation (AFN) is located northeast of Toronto, just south of Rice Lake. It contains 44 hectares (109 acres) of remnant tallgrass prairie/savannah type habitat. This area is accessible by unpaved trails, but access to the site is restricted. The Habitat Stewardship Program of Environment Canada included this site in a project which involves reintroduction of the KBB. Prescribed burning has been used to manage the site. Seeding was also done on a 5.1-hectare (12.6-acre) reclaimed old field. Wild lupine was not present at this site. In May 2002, 2348 wild lupine seed plugs germinated from seeds collected from a local natural population were planted in AFN in five different areas. These areas are all included in this study. Additional wild lupine seed plugs were planted in spring 2003, but these additional areas were not included in this study. None of the wild lupine plants flowered in 2003, so it is still uncertain whether these lupine plants will reproduce by themselves and persist in AFN.

Manestar Tract

The Manestar Tract (MT) is a 110-hectare (272-acre) private property attached to the St. Williams Crown Forest located northwest of Long Point. This area is composed of mainly mixed forest with occasional openings that are savannahs and part of the MT is an old field. Limited unpaved trails are present, but access to the area is restricted. Though the MT is managed by OMNR, not much was done to the site in the past five years. Wild lupine is found in several openings in the MT as well as the St. Williams Crown Forest outside the boundary of the MT.

Pinery Provincial Park

The Pinery Provincial Park (PPP) is located on the southeast shore of Lake Huron, about 6 km (3.7 miles) south of Grand Bend. It covers 2532.5 hectares (6258 acres) of dune ridges and interdunal depressions composed of mixed forests and oak savannahs. The park is open to the public with facilities such as campgrounds and recreational trails. Paved roads are present in the park for vehicle access. The PPP is managed by Ontario Parks. Several prescribed burns were performed in the past decade. Wild lupine was planted at several locations in the 1980s. Wild lupine is also found outside of the park in nearby residential areas. The white-tailed deer population has been controlled by deer culling as their overgrazing has had great impact on the vegetation of the park.

Karner Blue Sanctuary

The 14-hectare (35-acre) Karner Blue Sanctuary (KBS) is very close to the PPP, located to the southwest at Fork Franks. It was purchased by Lambton Wildlife Inc. as a conservatory for the KBB before its extirpation. The KBS was fenced off so that automobile access is prohibited. Unpaved trails are present for restricted access. The site has been actively managed by Lambton Wildlife Inc. in the past decade. The last prescribed burn was performed in spring 2004, burning about half of the area. Wild lupine can be found in several areas within the KBS, and some of those plants were planted.

Potential Source Butterfly Sites in the U.S.A.

Three potential source butterfly sites were included in this research. They are: 1) Manistee National Forest (MNF), Michigan; 2) Indiana Dunes National Lakeshore (IDNL), Indiana; and 3) Saratoga County Airport (SCA), New York. These sites were selected because they support some of the largest KBB populations in the U.S.A. The estimated 2nd brood KBB populations at all these sites exceed 10,000. Removal of several individuals for reintroduction purpose elsewhere is unlikely to have any significant impact on these KBB populations. This gives these three sites "potential" as source butterfly sites.

Manistee National Forest

Manistee National Forest (MNF) is located in the mid-western part of lower-Michigan. It covers 360,000 hectares (890,000 acres) of deciduous and mixed forests with occasional openings. Within MNF, both paved and unpaved road systems are present. Small residential homes are present in the area but there is no industrial complex. The forest was managed by the United States Fish and Wildlife Service (USFWS). Wild lupine is present almost everywhere where openings are found within the forest, and also along paved and unpaved roads throughout the forest area.

Indiana Dunes National Lakeshore

Indiana Dunes National Lakeshore (IDNL) covers about 8,400 hectares (20,800 acres) of sand dunes and interdunal depressions on the south shore of Lake Michigan. The area is for public use and industrial buildings are present in this area along the shore. The study area in IDNL is located within the Inland Marsh Trail, which covers about 250 hectares (494 acres). The area is managed by United States National Parks Service (USNPS). Wild lupine is found everywhere along the trail in the Inland Marsh Trail area. It is also found outside of the Inland Marsh Trail in nearby areas within IDNL.

Saratoga County Airport

The 81-hectare (200-acre) Saratoga County Airport (SCA) is a small airport located in northeastern New York. 30 hectares (75 acres) of the airport is covered with grassland with no trees. The airport is managed by Richmor Aviation, Inc. and is under heavy use, but the grasslands are restricted areas. Annual mowing performed in the fall is the only management method being used. Wild lupine is the dominant species in this artificially maintained prairie habitat.

Materials and Methods

In summer 2003, all eight study sites were visited twice between May 1st and August 3rd. Each visit at each site lasted for three days. At least three areas at each study site with the highest lupine density were chosen for field data collection. During each visit at each chosen area, a complete vegetation survey was performed, which included a herbaceous plant survey using the traditional transect-quadrat method (Gleason 1920; Arrhenius 1922), a woody species survey using the nearest-neighbour method (Cottam and Curtis 1949; Cottam et al. 1953; Cottam and Curtis 1956), and a canopy cover estimation.

Ant specimens were collected at all sites. They were not captured in a systematic way but merely hand-picked. They were sent to Professor André Francoeur at the University of Quebec at Chicoutimi for identification.

Cluster Analysis was performed upon herbaceous vegetation data, 1st and 2nd brood KBB nectar source plants data, tree data and ant data using the software PC-ORD. These data were also used to perform Detrended Correspondence Analysis (DCA) and Multi-Response Permutation Procedures (MRPP) using the software CANOCO and PC-ORD respectively.

Temperature, relative humidity and light intensity were measured using portable dataloggers continuously for the 3-day period at each site during each visit. To allow comparison of meteorological data among the sites, the collected data were standardized and transformed according to the weather data collected from the weather stations closest to the study sites between April 1st and September 30th 2003.

Integrated light intensity was measured by using Petri dish lightmeters. One hundred Petri dish lightmeters, each of which contained a stack of photographic paper sandwiched by two pieces of black paper with several layers of light filter on top (Friend 1961; Sullivan and Mix 1983), were left at each site during the first visit. They were picked up during the second visit after being exposed for approximately 40 days. All the Petri dish lightmeters were then brought back to the lab and developed in ammonia vapour. The amount of light energy received by each Petri dish lightmeter was estimated according to the number of layers light had penetrated through the stacks of photographic paper.

The amount of light energy that should have been received by the lightmeters assuming that the sky was totally clear for the 40-day period was calculated by using a formula which takes into account the time of the year and the latitude of the location (Monteith 1962). The amount of light energy received by each lightmeter was then expressed as a percentage of the amount of light energy with the assumption of complete cloudlessness for inter-site comparison.

Results and Discussion

The habitat requirements of the KBB include 1) wild lupine as larval host plant and 1st brood adult nectar source plant; 2) a wide variety of flowering plants as both 1st and 2nd brood KBB nectar source plants; 3) tending ants to protect the KBB larvae and pupae from predators and parasitoids; and 4) heterogeneous conditions that buffer the effect of catastrophic events and benefit different life stages of the KBB. Oak savannah sites in Ontario were therefore assessed based on 1) wild lupine density; 2) nectar source plants density; 3) the number of tending ant species; and 4) spatial heterogeneity in terms of integrated light intensity. Quantification of wild lupine density, nectar source plant density and the number of tending ant species was straightforward, but spatial heterogeneity was quantified indirectly and represented by the standard deviation of the 100 integrated light intensity measurements recorded by the Petri dish lightmeters.

Before determining whether the oak savannahs in Ontario are ready for reintroduction of the KBB, it is necessary to establish a set of minimum standards based on these four habitat requirements. One logical way to do so is by setting the minimum standards as the values acquired from the sites where persisting KBB populations are present. Since those sites sustain persisting KBB populations, sites that are better than the worst of them should therefore also be able to sustain healthy KBB populations.

Field data were collected at both Ontario oak savannah sites and the potential source butterfly sites in the U.S.A. where some of the largest KBB populations are found. The data collected from the U.S. sites were used to set the minimum standards for the habitat requirements. However, instead of directly using the values collected from the U.S. sites as the minimum standards, the minimum standards were set as 90% of the lowest values among the three U.S. sites. This may sound dangerous since values lower than those gathered from the potential source butterfly sites may not guarantee sustainability of healthy KBB populations. However, the 90% cut-off may indeed be very conservative. Since the selected sites in the U.S.A. are the ones with some of the largest KBB populations, the habitat quality at these sites are expected to be, if not optimal, at least high, which is indeed the case. Sites with much lower quality might actually be good enough to support a persisting KBB population. However, how much lower the quality of a site can be and still be able to support a healthy KBB population is unknown and extremely difficult to estimate. We therefore chose to be cautious and used the 90% cut-offs.

A better way to set the minimum standards for reintroduction site requirements is by gathering similar data from the sites in the U.S.A. where persisting KBB populations are smaller than those of the sites included in this study. However, since accidental injury or death of KBB eggs and larvae may result from the data collection process, this may have a great impact upon the KBB populations at those sites because of the small population sizes. Therefore, only the potential KBB source butterfly sites, where the KBB populations were large, were included in this study.

After the minimum standards were established, the data collected from the potential KBB reintroduction sites were compared against these standards. The results show that none of the Ontario sites meets all four minimum habitat requirements. This indicates that all potential KBB reintroduction sites in Ontario are of lower quality, at least in certain aspects, compared to the three potential source butterfly sites in the U.S.A. They do not seem to be ready for KBB reintroduction under the current minimum habitat standards. Further restoration may be required before reintroduction of the butterfly should proceed at these sites unless data collected from the U.S. sites in the future suggest that the current conditions at these sites are actually good enough to sustain KBB populations.

Although, none of the restored oak savannah sites in Ontario seems to be ready for reintroduction of the KBB, identification of the most suitable source butterfly population sites according to their degree of similarity to the Ontario sites is possible. In fact, it is very useful to know which of these sites are most similar to the Ontario sites because the KBB populations at different sites might be adapted to the local environmental conditions of those sites. Picking a source butterfly site that is as similar to the reintroduction site as possible can maximize the chances of survival of reintroduced KBB by reducing the chances of failure due to maladaptation of the KBB to the environment of the reintroduction site. Moreover, to avoid outbreeding depression which may lead to failure in reintroduction (Gharrett et al. 1999; Aspi 2000; Marr et al. 2001; Quilichini et al. 2001), one single source butterfly site should be identified for each one of the potential KBB reintroduction sites. Hence, we compare the potential KBB reintroduction sites in Ontario to the potential source butterfly sites in the U.S.A. focusing on several biological and environmental variables that are relevant to long-term survival of the KBB, which include 1) overall herbaceous plant community structure; 2) KBB nectar source plants; 3) tree community; 4) tending ant species; 5) canopy cover; 6) temperature; 7) relative humidity; and 8) light intensity. These comparisons helped us to identify which U.S. sites are the most similar to which Ontario sites.

The results of the comparisons show that none of the potential reintroduction sites in Ontario matches perfectly with any of the potential source butterfly sites in the U.S.A. The Ontario sites are the most similar to one U.S. site in certain aspects and the most similar to another U.S. site in terms of other environmental variables. However, in terms of overall environmental conditions, SCA is the most similar U.S. site to AFN while IDNL is the most similar to the other four Ontario oak savannah sites. This implies that if we want to maximize the chances of success when reintroducing KBB in Ontario, KBB should be taken from IDNL except for reintroduction in AFN where butterflies should be taken from SCA instead. IDNL, which is the most similar to the other four Ontario sites, is therefore identified as the priority source butterfly site for KBB reintroduction in Ontario.

In conclusion, none of the potential reintroduction sites in Ontario has habitat characteristics as favourable as the potential KBB source butterfly sites in the U.S.A., indicating that under current habitat conditions, success in reintroduction of the KBB at these oak savannahs is not guaranteed. These sites should continue to be managed, aiming at improving site quality by increasing site heterogeneity, density and coverage of wild lupine and KBB nectar source plants. When these sites are shown to be ready for KBB reintroduction, hopefully in the near future, butterflies should then be taken from IDNL for reintroduction in Ontario. By then, we should be able to show that the oak savannah sites in Ontario are fully restored by reintroducing the KBB to them.

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