Plant Communities in Oak Savannahs in Ontario: Are We Ready for Reintroduction of the Karner Blue Butterfly (*Lycaeides melissa samuelis*)?

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ABSTRACT

The endangered Karner Blue Butterfly (KBB) (*Lycaeides melissa samuelis* Nabokov) is an indicator taxon for the globally rare oak savannah habitat. Since the extirpation of the KBB from Ontario, which is the only province in Canada where the butterfly was originally found, a Recovery Team was established in 1991 and restoration work has been done, trying to improve the quality of various potential KBB reintroduction sites in Ontario as preparation for reintroduction of the butterfly from the U.S.A. Though promising results have been observed, no systematic scheme has been employed to evaluate the quality of these restored oak savannah sites to see if they are ready for KBB reintroduction. This study evaluated five potential KBB reintroduction sites in Ontario by looking at both biotic (vegetation, especially the larval host plant wild lupine (*Lupinus perennis*), 1st and 2nd brood adult nectar source plants, and tending ant species) and abiotic (temperature, relative humidity and light intensity) aspects. Field data were collected in the summers of 2002 and 2003 from these five sites and in 2003 from three potential founder KBB sites in the U.S.A. The Ontario and U.S. sites were then compared in terms of the ecological requirements of the KBB. The results show that all five potential reintroduction sites in Ontario are of lower quality, at least in certain aspects, compared to the three potential founder butterfly sites in the U.S.A. This implies that success is not guaranteed if the KBB is reintroduced to these sites in Ontario under current habitat conditions. Comparisons of the Ontario and the U.S. sites also reveal that Indiana Dunes National Lakeshore (IDNL) is the most similar to four of the five Ontario sites in terms of biological community and microhabitat structure. IDNL is therefore identified as the priority source butterfly site for KBB reintroduction in Ontario. Meanwhile, restoration and management of the potential KBB reintroduction sites in Ontario should continue and request for permission from the U.S. Fish and Wildlife Service to take butterflies from IDNL for experimentation in captive rearing techniques in the Metropolitan Toronto Zoo is strongly recommended.

KEYWORDS

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

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Ecological Requirements of the Karner Blue Butterfly

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) as an energy supplement, although 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 often the primary nectar source since not many savannah species flower in May (Chan, personal observation); for the 2nd brood KBB, wild lupine, is usually not available as a nectar source despite previous documentation of such cases (Bleser 1992; Swengel and Swengel 1993) which are exceptions rather than the rule. Nectar is available from many other plant species that are blooming in mid- and late-summer. Hence, wild lupine is a necessity for the KBB larvae while the presence of other nectar source plants, especially the ones for the 2nd brood adult butterflies, is necessary, and preferably in a wide variety.

Both broods of the KBB larvae and pupae are often tended by ants (Packer 1987; Savignano 1990, 1994; Herms 1996; Lane 1999b). The larvae have glands on their bodies which secrete a nectar-like solution when stimulated by ants (Savignano 1990). The tending ants guard the larvae and pupae and collect the nectar-like solution from them as a food source (Savignano 1990). Studies have shown that this tending behaviour of ants significantly increases the survivorship of the KBB larvae presumably because the presence of tending ants protects the KBB larvae from predators and parasitoids (Packer 1987; Savignano 1990, 1994; Lane 1999b). Laboratory studies have also shown that KBB

CHAPTER 1: General Introduction

Restoration Ecology

Restoration of natural habitats has a very long history. Clearing a piece of land by "slash and burn", using it for agriculture for several years, and then leaving it and burning another one can be viewed as a practice of restoration, with the restoration strategy being leaving the land alone and letting nature take care of itself. This type of restoration is only a by-product of agriculture. Restoration effort intentionally carried out by humans to restore disturbed natural communities was not documented until the 1900s (Jordan 1988).

Difference between Ecological Restoration and Restoration Ecology

Despite the long history of habitat restoration, the terms "ecological restoration" and "restoration ecology" are very often mixed up. The differences between these two terms are best explained by Clewell (1993). He explained that restoration ecology as to ecological restoration was analogous to medical researchers as to physicians. Restoration ecologists, similar to medical researchers, provide the most up-to-date information and technology to ecological restorationists, who act as physicians and try to "cure" the "diseased" environment. In turn, ecological restorationists share their first-hand experience and discoveries with restoration ecologists, just as physicians do with medical researchers. Clewell (1993) described this close relationship between ecological restoration and restoration ecology as two sides of the same coin. Though this sounds perfectly logical, this "modern" view was nothing close to the concepts of ecological restoration in the early 20th century.

First Systematic Attempt of Ecological Restoration

Although local-scale environmental "improvement" work has been documented since the 1900s (Jordan 1988), large-scale systematic ecological restoration was not attempted until the early 1930s when Aldo Leopold and his colleagues at the University of Wisconsin proposed to restore a collection of communities native to Wisconsin and the Upper Midwest for biological research purposes. They did so because a large proportion of the native communities in Wisconsin had already been disturbed or altered, and only remnant fragments of natural communities were left scattered across the area (Jordan 1991). This proposal led to the establishment of the Madison Arboretum in the University of Wisconsin in 1934 (Berger 1990; Jordan 1988), which was comprised of around 120 hectares (300 acres) of derelict farmland where more than 30 distinct native communities were to be restored (Jordan 1991).

This first ecological restoration attempt was clearly product-oriented (Jordan 1988), scientific and educational (Jordan 1991) as the objective was to "gather" all native communities in one place for future biological research. One could also say that the objective was environmental since the restoration work tried to prevent the "extinction", or at least "extirpation", of native communities. However, this was not really the case because if protecting natural communities had been one of the objectives, effort would have been put to conserve the remnants of the communities instead of recreating them on abandoned farmland.

Results and Consequences of the Madison Arboretum

The result of the establishment of the Madison Arboretum was a failure because the communities being restored were still distinctly different from the undisturbed habitat remnants after 50 years of work (Jordan 1991). Despite this, soon after the restoration had started, scientists saw a lot of research opportunities in this project (Jordan 1988). Many new ideas and knowledge were generated from the ecological restoration process (Jordan 1991). One of the classic examples was the discovery of the critical role of fire in maintenance of tall-grass prairie (Jordan 1988, 1991).

In the 1940s, restorationists John Curtis and Ted Sperry tried to restore a tall-grass prairie in the Madison Arboretum. They cleared a piece of land and planted it with prairie species. It did not take long before they found that non-prairie species kept invading the land and there was no way the land would become a true tall-grass prairie unless something was done. They later realized that fire was the only element missing and therefore started performing prescribed burns. The non-prairie species were largely eliminated as a result (Jordan 1988, 1991). The role of fire as a non-prairie species suppresser in tall-grass prairies was hence discovered and verified.

Even though it was obvious that restoration work generated knowledge in the field of ecology, scientists were not very conscious about this heuristic value of ecological restoration from the 1940s to 1960s. They generally viewed the generated knowledge as a by-product of the trial-and-error process in their restoration work (Jordan 1988). They knew their experience could tell them what would work and what would not work, but they overlooked the fact that it might also suggest why and how one approach worked but not others (Jordan 1988).

Change of View since the 1970s

The heuristic value of ecological restoration had been overlooked until the 1970s. Firstly, there was a need to explain to the public the significance of the Madison Arboretum since it had low value as a teaching and research centre for native communities because the restored communities differed from natural undisturbed ones (Jordan 1991). This forced the scientists to come up with alternative explanations and start rethinking the educational value of this project. That was when they started to realize the heuristic value of the process of ecological restoration. Secondly, the green movement also started in the 1970s. In 1977, the Surface Mine and Reclamation Act was passed in the U.S.A. (Jackson *et al* 1995; Jordan 1988). These incidents attracted public attention and people started to realize that we had already caused too much environmental damage. Conservation, as well as restoration, of natural habitats, was necessary. In fact, in some situations, restoration was compulsory under the Surface Mine and Reclamation Act (Jackson *et al* 1995).

In the 1970s and early 1980s, restoration was still product-oriented as the primary goal was to reverse the damage that had been done. However, this product-oriented view was quite different from the original view of those who started the Madison Arboretum in 1934 (Jordan 1991). The motive for ecological restoration had changed. Ecological restoration was no longer done just to gather a collection of natural communities for educational purpose and scientific research, but to restore rare or lost habitats and communities as a conservation measure.

Criticisms of Ecological Restoration

As more people realized how much damage humans had done to the environment, more and more people joined the field of ecological restoration. These people include biologists, chemists, environmentalists, social scientists and politicians. The diverse background of this group led to two major disagreements. The first was upon a common definition for the term “ecological restoration,” and the second was that some non-scientists started to question and criticize the usefulness of ecological restoration as a conservation strategy.

The first criticism to the practice of restoration was that it offered a license to kill (Berger 1990; Cairns 1988). Once restoration was widely accepted and shown to have successfully repaired damaged habitats, people might no longer support conservation of pristine natural communities. They would damage the environment without hesitation, thinking that restoration would be “the” solution. The rate of environmental destruction would then be so much greater than that of ecological restoration, making our environment even worse.

Many restorationists opposed this criticism as they emphasized that conservation was always the top priority (Jordan 1991). They knew the limitations of ecological restoration. When an ecosystem was disturbed, in many cases, there was no way to return it to its original state (Cairns 1988; Jackson *et al* 1995). Therefore, restoration could not replace, but only compliment conservation (Berger 1990; Nilsen 1991). In fact, this compliment was necessary since too much damage had already been done and simply conserving what was left undisturbed was far from enough.

The second criticism was an argument that stated that ecological restoration was not a science (Turner 1987). It was a mere application of knowledge and technology to accomplish a task, and therefore had no scientific value (Bradshaw 1993; Jordan 1988). Opposition to this criticism was expressed by many scientists who thought of the heuristic value of ecological restoration (Bradshaw 1993; Jordan *et al* 1987). They explained their views in the symposium on restoration ecology in 1984.

Symposium on Restoration Ecology in 1984

In October 1984, a symposium on restoration ecology was held as one of the many events that celebrated the 50th anniversary of the Madison Arboretum (Jordan 1988). In this symposium, many scientists expressed their views on the heuristic value of ecological restoration, which they thought was undoubtedly a branch of science. Anthony Bradshaw stated that restoration could be considered as an "acid test" for ecological hypotheses that were based on observation (Jordan 1988). John Harper's idea was similar. He pointed out that agriculture was a new paradigm for ecology (Jordan 1988). Ecologists should work as farmers who manipulated and experimented in their field instead of generating new ideas based only on field observation. The best experimental approach would be to find an undisturbed system, describe it, disturb it and then restore it, and observe the response of the system at all stages (Jordan 1988). However, since there were already too many disturbed systems, it would be too environmental-unfriendly to disturb another piece of untouched land. Restoring disturbed systems was therefore the most practical approach. William R. Jordan III took it even further. Not only did he point out that ecological restoration was perhaps the best way of learning about the systems being restored, he also argued that we should not just focus on restoring the natural communities, but our historical harmonious relationship with them (Jordan 1991). This idea was perfectly illustrated by the example of fire management of tall-grass prairie.

To restore a tall-grass prairie, we have to use prescribed burns because prairie species were pre-adapted to occasional fire that was sometimes anthropogenic. If we had aimed at restoring a "natural" community with no human disturbance, a tall-grass prairie would have never been successfully restored. In contrast, when prescribed burns were employed to mimic anthropogenic fire disturbances in the past, a harmony could be reached between human disturbance and the fire-tolerant prairie species, and hence the tall-grass prairie community could successfully be restored.

Post-1984 View of Ecological Restoration

The ideas of Bradshaw, Harper and Jordan presented in the symposium on restoration ecology in 1984 all agreed upon the heuristic value of ecological restoration. The approach of using ecological restoration as a research tool for ecology was referred to as "restoration ecology" (Jordan 1991.) This confirmed that ecological restoration was indeed a form of knowledge-generating science instead of a mere application of knowledge and technology. It also changed people's view towards ecological restoration from a product-oriented to a product- and process-oriented one because the restoration process generates information and knowledge that flow in a loop from ecologists to restorationists and vice versa. Ecological restoration was not only environmental, but also scientific and educational. It became a ground for ecological hypothesis testing and was aimed at restoring a harmonious relationship between human and the environment.

The concepts of ecological restoration and restoration ecology have not changed much since the symposium on restoration ecology in 1984. Despite an agreement on the heuristic value of ecological restoration, there was still not a common definition for the term "ecological restoration." This problem was solved in 1994 by the Society for Ecological Restoration, which was established in 1988. After spending one year consulting and gathering opinion from its members, the Society for Ecological Restoration came up with a single-line definition for "ecological restoration", which was "the process of repairing damages caused by humans to the diversity and dynamics of indigenous ecosystems" (Jackson *et al* 1995). Under this definition, restoration aimed at reversing changes due to human disturbances only if they have caused damage to the diversity and dynamics of ecosystems. Historical anthropogenic disturbances to which ecosystems were pre-adapted should not be removed or compensated for in ecological restoration. Clearly, Jordan's idea of restoring a harmonious relationship between human and the environment was embedded in this definition.

Despite the change of view since 1984, there are still many small-scale restoration projects that are product- but not process-oriented (Heckman and Cairns 1988). In many such cases, restorationists use the knowledge provided by ecologists to restore their target communities without sharing their experience and findings with them. In the future, restorationists should be encouraged to give feedback to ecologists about their restoration work (Jordan 1991). This can ensure the flow of information between ecologists and restorationists to form a complete loop and accelerate the development of restoration techniques and ecological knowledge.

Summary

The practice of restoration has not really changed much since the 1930s, but the way people view it has changed substantially over time. Ecological restoration started as a process of gathering natural communities for biological research in 1934 in the University of Wisconsin, which was product-oriented with scientific and educational motives. Because of the green movement in the 1970s and 1980s and the passage of the Surface Mine and Reclamation Act in the U.S.A. in 1977, ecological restoration evolved into an applied environmental technology which was solely environmental, and not until the symposium on restoration ecology in 1984 did ecological restoration turn into a practice that was product- and process-oriented, with both environmental and educational motives. Unfortunately, despite the change of view, many restorationists who work on local small-scale restoration projects still overlook the importance of the heuristic value of their restoration work. Hence, encouragement of feedback from restorationists to ecologists is still in need.

Species Reintroduction

Species Reintroduction as an indicator of Restoration Success

Ecological 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, 2003; Sprenger *et al* 2002; Tanner *et al* 2002; 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 historical 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 method, 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 with long-lived 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 or extirpated from the local region.

The Reintroduction Specialist Group

The Reintroduction Specialist Group (RSG) was established as a Specialist Group of the International Union for Conservation of Nature (IUCN)/Species Survival Commision (SSC) in 1988 due to increasing numbers of translocations and reintroductions worldwide (Sarrazin 1996; Stanley Price and Soorae 2003). Its mission is "to promote the reestablishment or reinforcement of self-sustaining populations of plants and animals in the wild" (Stanley Price and Soorae 2003). Reintroduction was defined by the IUCN/SSC RSG as "an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct" (IUCN

1998). The IUCN/SSC RSG had also drafted the IUCN guidelines for reintroduction since 1992, which became official IUCN policy in 1995 (IUCN 1998; Stanley and Soorae 2003). These are intended to act as a guide for procedures useful to reintroduction programs and to help ensure that the reintroductions achieve their intended conservation benefit, and do not cause adverse side-effects of greater impact (IUCN 1998).

Trends in Species Reintroduction

Reintroduction has become more common in recent years. This is evident from the study by Beck *et al* (1994) and the RSG's Reintroduction Practitioners Directory (Soorae and Seddon 1998). Beck *et al* (1994) compiled a list of all known reintroductions from 1900 to 1992 while the Reintroduction Practitioners Directory contains a list of all reintroduction projects known to the RSG, including those that were ongoing in 1998

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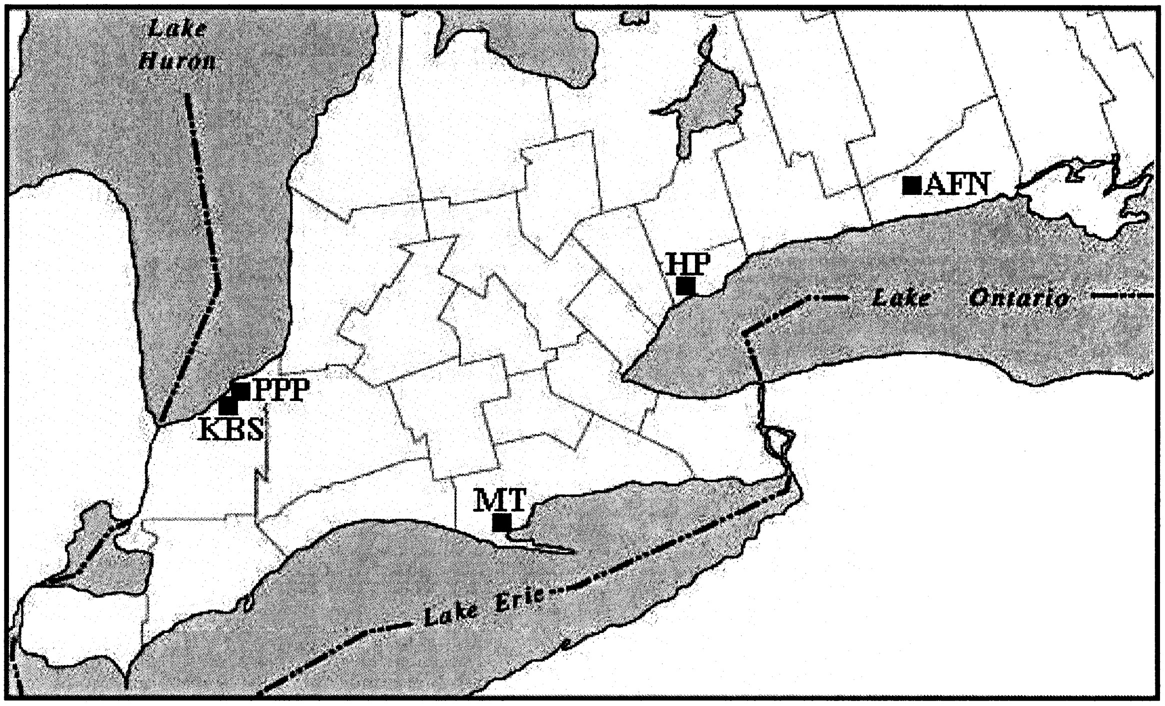
CHAPTER 2: Study Site Description

Potential Reintroduction Sites in Ontario

Oak savannah, which covered most of southern Ontario before European settlement, is now globally rare. Most of it that is still present is either degraded to various extents or very restricted in size. In this study, five oak savannah sites were chosen as potential KBB reintroduction sites. They are: 1. High Park, Toronto; 2. Alderville First Nation; 3. the Manestar Tract (MT), St. Williams; 4. Pinery Provincial Park (PPP), Grand Bend; and 5. the Karner Blue Sanctuary (KBS), Port Franks (Map 2.1). These sites were selected because they were historic sites of the KBB except Alderville First Nation where wild lupine was absent until recent plantation in 2002.



Map 2.1 Locations of the five potential Karner Blue Butterfly reintroduction sites.

In the following, I describe these five Ontario sites (Map 2.1). At each of them, at least three areas with the highest lupine density were selected for detailed study of their vegetation community structure, ant species composition and microhabitat characteristics. These study areas are also described.

1. High Park

High Park (HP) (N43.65° W79.47°) 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 black oak savannah and the rest are different deciduous and mixed forest vegetation communities with white oaks and red oaks. Other areas are developed with various recreational facilities such as swimming pools, tennis courts, children's playgrounds, picnic areas and formal gardens. It has been assigned the status of Area of Natural and Scientific Interest (ANSI) by Ontario Ministry of Natural Resources (OMNR). In the early 1990s, the City of Toronto undertook efforts to protect and restore black oak savannah in High Park to its pre-European settlement conditions. In 1996, the High Park Volunteer Stewardship Program (VSP) established by the High Park Community Advisory Council (HPCAC) became a valuable partner in the High Park Black Oak Savannah restoration program. This program includes methods to control invasive species by application of herbicide (e.g. using RoundUp to control Dog-strangling Vine (*Vincetoxicum rossicum* Kleopov)), planting of native prairie and savannah plant species and prescribed burning. In 2000, a program of prescribed burning was started. In the remedial phase of this program, 2000 to 2005, a prescribed burn is implemented frequently to restore the native prairie plants. The most recent burn was performed in spring 2004.

High Park – 456 (HP 456)

This 0.5-hectare (1.2-acre) area is located on the west side of West Road close to the lamp post numbered 456. This is the old plot "M" where test burns were performed in 1997 and 1998. Scattered mature oak trees are present in this area while the canopy cover of the surrounding areas is much higher. This area was burnt again in spring 2003 and 2004.

High Park – 444 (HP 444)

This is a 0.4-hectare (1.0-acre) area again located on the west side of West Road. It is south of HP 456, close to the lamp post numbered 444. This is the management unit 1C of the park. Habitat of this area is very similar to that of HP 456, except that the canopy cover is a bit higher here. HP 444 was burnt in spring 2001, 2003 and 2004.

High Park – Soccer Field (HP SF)

This area of 0.3 hectare (0.7 acre) is located on the east side of West Road, southeast of HP 456, close to a soccer field. This area is very open with only a few mature trees. This area was burnt in 2000 and 2001.

High Park – Soccer Field Extension (HP SFX)

This 0.4-hectare (1.0-acre) area is also located on the east side of West Road, about 50m south of HP SF. The habitat here is extremely similar to that of HP SF. In fact these two areas are only separated by a small area of similar habitat where wild lupine is absent. This area was also burnt in the same years as HP SF (2000 and 2001).

The range of wild lupine in HP is not restricted to these 4 areas. Wild lupine plants were also observed west of HP 444 near the western edge of the park.

2. Alderville First Nation

Alderville First Nation (AFN) (N44.17° W78.09°) is located 1km (0.6 mile) west of Highway 45 and approximately 25km (16 miles) north of Cobourg, 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 funded a project aimed at preparing this site for reintroduction of the KBB. Prescribed burning has been used to manage the site. Seeding was also done on 1.2 hectares (3 acres) of a 5.1-hectare (12.6-acre) reclaimed old field. Wild lupine was not originally found 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 and 2004 in areas adjacent to the 2002 wild lupine plantations, but these additional areas were not included in this study.

Alderville First Nation – Roadside (AFN RS)

This 0.2-hectare (0.5-acre) area is close to the entrance of AFN on Country Road 18. Trees were present and the area is quite wet compared to the others, especially under the shade where a few typical forest species such as White Trillium (*Trillium grandiflorum* Michaux) dominated the vegetation community. This area was burnt in spring 2003. Only a few lupine plants were found in summer 2003 from the planting in 2002.

Alderville First Nation – North Pit (AFN NP)

This 0.1-hectare (0.2-acre) area is about 150m west of AFN RS. No tree is present and the area is therefore drier. This area was also burnt in spring 2003. Only several lupine plants survived until summer 2003 from the 2002 plantation.

Alderville First Nation – Bowl (AFN BO)

This area, sized about 0.3 hectare (0.7 acre), is a southwest-facing slope with some canopy cover northwest of AFN NP. More than 60 wild lupine seedlings were observed in summer 2003 in this area and they were larger in size than the ones in other areas in AFN.

Alderville First Nation – Hog's Back North (AFN HBN)

This 0.4-hectare (1.0-acre) area is located west of AFN BO. Trees are present in part of this area. No more than 20 wild lupine plants planted in 2002 were found in summer 2003 and they were concentrated near the trees.

Alderville First Nation – Peninsula (AFN PE)

This area of 0.2 hectare (0.5 acre) is located east of AFN BO, south of the seeded reclaimed old field. No tree is found in this area but in the surrounding areas in high density. In summer 2003, only 2 wild lupine plants were found in this area which is dominated by Poison Ivy (*Rhus radicans* L.).

3. The Manestar Tract

The Manestar Tract (MT) (N42.69° W80.46°) is an 81-hectare (200-acre) private property attached to the St. Williams Crown Forest located on the south side of the sixth concession northwest of Long Point. This site 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 this site by motorized vehicles is prohibited. Though the MT is managed by Ontario Ministry of Natural Resources (OMNR), not much restoration work was performed to the site over the past five years.

Manestar Tract – #1 (MT #1)

This 1-hecatre (2.5-acre) area is located at the centre of the MT. It is composed of several connected forest openings where wild lupine plants are present. There is no trail in MT #1. This area has been burnt and trees were selectively removed from this area in the early 1990s.

Manestar Tract – #2 (MT #2)

This is a 2-hectare (5.0-acre) area located northwest of MT #1, to which it is very similar in terms of vegetation and environmental conditions. Again, no trail is present in this area. MT #2 has not been burnt but woody species were purposely removed to open up the canopy in the 1990s.

Manestar Tract – #3 (MT #3)

This area of 3 hectares (7.4 acres) is located northeast of MT #1. Unpaved trails are present in this area and relatively large openings with wild lupine are found. No management method has been applied to this area in the past ten years.

Wild Lupine is not restricted in these three areas in the MT. It is also found in St. Williams Crown Forest outside the boundary of the MT.

4. Pinery Provincial Park

The Pinery Provincial Park (PPP) (N43.24° W81.84°) is located on the southeast shore of Lake Huron, about 8 km (5 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. PPP alone now contains almost 50% of the remaining oak savannah on this planet. 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. 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 a great impact on the vegetation of the park.

Pinery Provincial Park – Roundabout (PPP RA)

This 0.5-hectare (1.2-acre) area is close to the roundabout northwest of the main entrance of the park. A dense population of wild lupine which was planted there in the 1980s is still present in the small opening on the side of the paved road. This area was last burnt in 2000.

Pinery Provincial Park – Ski-hill (PPP SH)

This area of 1.5 hectares (3.7 acres) is located next to the small hut where children's programs are held. The area is almost treeless with only a few shrubs at the centre and dense tree stands at the peripheries. Twenty wild lupine plants were planted in this area along the edge of the canopy cover in the 1980s. They survived and successfully reproduced. This area has not been burnt recently.

Pinery Provincial Park – Deer Exclosure (PPP EX)

This 0.5-hectare (1.2-acre) fenced-off deer exclosure is located at the southeast end of the park next to Highway 21. Density of tree seedlings, especially Sassafras (*Sassafras albidum* (Nutt.) Nees), is quite high near the southeastern edge of the exclosure. When protected from deer herbivory, wild lupine thrived in this exclosure while only a few wild lupine plants were found outside of it. This area was burnt in 1993.

Wild lupine is also found in many other locations in PPP, but in most cases, they grow in populations of only a few individuals. Lupine is also found outside of the park close to the residential homes on the southeast side of Highway 21.

5. The Karner Blue Sanctuary

The 15-hectare (37-acre) (N43.22° W81.88°) Karner Blue Sanctuary (KBS) is very close to the PPP, located to the southwest at Port Franks. It was purchased by Lambton Wildlife Inc. (LWI), a nonprofit, volunteer, naturalist organization dedicated to conservation of the natural environment in Lambton County, Ontario, as a conservatory for the KBB in 1988 before the butterfly was extirpated from this site the following year. 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 LWI in the past decade. The last two prescribed burns were performed in spring 2003 and 2004, burning about half of the site each time. The following study areas were burnt in 2004 but not in 2003.

Karner Blue Sanctuary – Trail (KBS TR)

This 1.5-hectare (3.7-acre) area is located at the centre of the KBS beside an unpaved trail. It includes a flat area and a northeast-facing slope. Wild lupine was present in this area, but additional wild lupine plants have been planted along the trail. Other than being burnt in 2004, this area was also burnt in 1999.

Karner Blue Sanctuary – Bowl (KBS BO)

This area of 0.8 hectare (2.0 acres) is located at the northwest corner of the KBS. The area is composed of a "bowl", a central depression where trees are absent and peripheral slopes with tree canopy cover. Wild lupine plants grow mainly under half shaded areas between the bowl and the canopy covered slope where Poison Ivy is the dominant species. The centre of the bowl, which is treeless, was once covered with a dense population of wild lupine in the 1980s before the severe drought in late 1980s. KBS BO was not recently burnt until 2004.

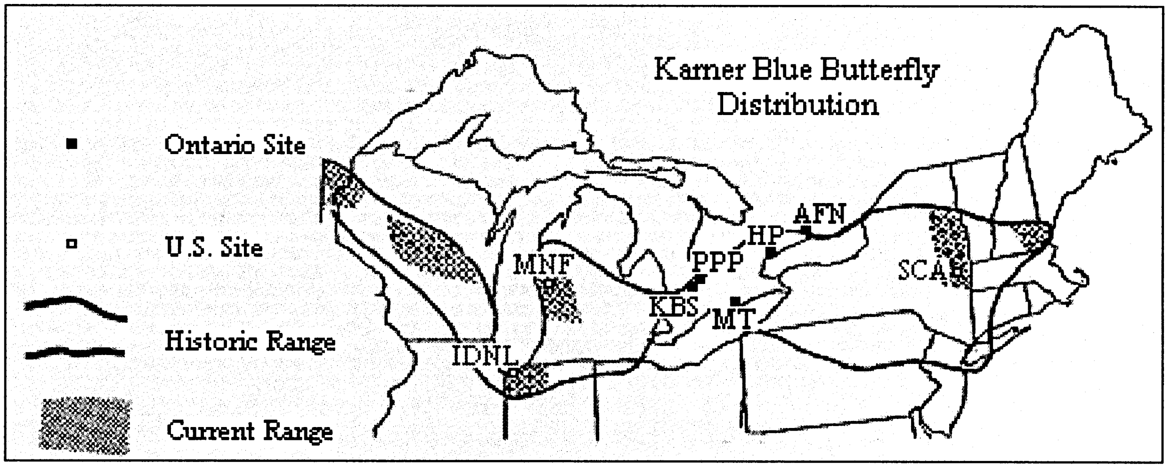
Karner Blue Sancturay – Historic (KBS HIS)

The 0.7-hectare (1.7-acre) area is south west of KBS BO. This area is where the Karner Blue was last observed in the KBS. Most of this area is covered with dense shrub except for a few very small openings. This area was not recently burnt until 2004.

Wild lupine can be found in areas other than these three areas within the KBS. In fact, there is another wild lupine population quite close to the three study areas. This wild lupine population was observed to be expanding after the prescribed fire in spring 2003.

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

Three potential founder KBB sites were included in this research study. They are: 6. Manistee National Forest (MNF), Michigan; 7. Indiana Dunes National Lakeshore (IDNL), Indiana; and 8. the Saratoga County Airport (SCA), New York (Map 2.2). 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 somewhere else will unlikely have any significant impact on these KBB populations or their long-term persistence at these sites. This gives these three sites "potential" as founder butterfly sites.



Map 2.2 Locations of all study sites included in this research.

There are other large KBB populations in the states of Wisconsin and Minnesota. However, those sites were not included in this study because a study by Nice *et al* (2000) using mitochondrial (mt) DNA suggested that the KBB populations could be divided into two genetically distinct groups. One group includes all the KBB populations west of Lake Michigan; the other group includes the KBB population in IDNL and all those east of it. This means that the extirpated KBB populations in Ontario probably belonged to the "eastern" group and were likely genetically distinct from the Wisconsin and Minnesota populations. Since the IUCN guidelines for reintroductions recommended that the founder population should be genetically closely related to the extirpated one (IUCN 1998), sites from Wisconsin and Minnesota were excluded from the list of potential founder butterfly sites for KBB reintroduction in Ontario.

Same as the potential reintroduction sites, at each of the potential founder butterfly site, three areas with the highest lupine densities were selected for detailed study of their vegetation community structure, ant species composition and microhabitat characteristics.

CHAPTER 3: Are We Ready to Reintroduce the Karner Blue Butterfly?

Introduction

Several oak savannahs in Ontario, which are historic localities of the KBB, have been restored and actively managed. Though promising results have been observed from the restoration work done at these restored oak savannah sites, no systematic scheme has been employed to evaluate these restored sites to see if they are ready for reintroduction of the KBB.

According to the IUCN guidelines for reintroductions, at reintroduction sites that have undergone "substantial degradation caused by human activities", a habitat restoration program should be initiated before reintroduction (IUCN 1998). However, after implementation of the restoration program, what method should be used to determine if habitat quality has improved to the extent that reintroduction can proceed is not suggested.

The Ohio KBB Recovery Team chose the Kitty Todd Preserve (KTP) in Lucas County as the first KBB reintroduction site in Ohio based upon qualitative comparison of several potential reintroduction sites in 1996 (Ohio Division of Wildlife 1998). Then, Tolson (1997) quantitatively measured environmental variables that were relevant to the KBB, including densities of wild lupine and KBB nectar source plants, canopy cover, light intensity, temperature and relative humidity at several locations in the KTP and the Allegan State Game Area (ASGA) in Allegan County, Michigan, where the KBB was to be taken for reintroduction in the KTP. He compared the potential reintroduction areas in the KTP and the potential founder butterfly areas in the ASGA in terms of these variables and identified the most suitable locations for initial release of the KBB.

In this study, I evaluated the potential reintroduction sites in Ontario by collecting similar data as Tolsen (1997) did. I also collected ant specimens, which Tolsen (1997) did not, to see if tending ant species were present at these sites. I then generated a set of minimum standards for KBB reintroduction sites using similar data collected from the potential founder butterfly sites in the U.S.A., against which the data collected from the Ontario sites were compared.

Methodology

Field Data Collection

In summer 2002, four (HP, MT, PPP & KBS) of the five potential KBB reintroduction sites in Ontario were visited twice between May 1st and July 23rd; in summer 2003, all five potential KBB reintroduction sites in Ontario and three potential founder KBB sites in the U.S.A. were visited twice between May 1st and August 3rd. The two visits to the U.S. sites coincided with the flight periods of the 1st and 2nd brood KBB. Each visit at each site lasted for 3 to 4 days. Dates of all field visits are listed in Table 3.1 in chronological order.

At least three areas at each study site with the highest lupine densities were chosen for field data collection. Detailed description and management history of these study areas can be found in Chapter 2.

Dates	Site visited
1st visit in 2002	
07/02/2002 – 07/04/2002	High Park (HP)
07/09/2002 – 07/11/2002	Manestar Tract (MT)
07/23/2002 – 07/25/2002	Pinery Provincial Park (PPP)
07/25/2002 – 07/27/2002	Karner Blue Sanctuary (KBS)
2nd visit in 2002	
07/30/2002 – 08/01/2002	High Park (HP)
08/10/2002	Manestar Tract (MT)
08/18/2002 – 08/24/2002	Pinery Provincial Park (PPP)
08/18/2002 – 08/24/2002	Karner Blue Sanctuary (KBS)
1st visit in 2003	
05/14/2003 – 05/17/2003	High Park (HP)
05/20/2003 – 05/22/2003	Alderville First Nation (AFN)
05/28/2003 – 05/30/2003	Manestar Tract (MT)
05/30/2003 – 06/01/2003	Pinery Provincial Park (PPP)
06/01/2003 – 06/03/2003	Karner Blue Sanctuary (KBS)
06/04/2003 – 06/06/2003	Manistee National Forest (MNF)
06/07/2003 – 06/09/2003	Indiana Dunes National Lakeshore (IDNL)
06/10/2003 – 06/12/2003	Saratoga County Airport (SCA)
2nd visit in 2003	
06/25/2003 – 06/27/2003	High Park (HP)
07/02/2003 – 07/04/2003	Alderville First Nation (AFN)
07/18/2003 – 07/20/2003	Manestar Tract (MT)
07/20/2003 – 07/22/2003	Pinery Provincial Park (PPP)
07/22/2003 – 07/24/2003	Karner Blue Sanctuary (KBS)
07/24/2003 – 07/26/2003	Manistee National Forest (MNF)
07/27/2003 – 07/29/2003	Indiana Dunes National Lakeshore (IDNL)
07/30/2003 – 08/01/2003	Saratoga County Airport (SCA)

Table 3.1 Chronological list of dates of all field visits in 2002 and 2003.

Understory Vegetation Survey

During each visit at each chosen area, a herbaceous layer vegetation survey was performed using the traditional transect-quadrat method (Gleason 1920; Arrhenius 1922; Sorrells and Glenn 1991) similar to the one used by Tolsen (1997).

The transect-quadrat method was designed to quantitatively describe vegetation communities (Gleason 1920; Arrhenius 1922). It has been widely used in vegetation surveys in grassland type of habitats (Sorrells and Glenn 1991) and is considered efficient, accurate and reliable in reflecting species density and composition (Anderson 1942; Bauer 1943; Parker and Savage 1944).

To perform the herbaceous layer vegetation survey, four 50-metre north-running transects were laid out at each chosen area. The locations of these transects were particularly chosen to cut through areas with the highest wild lupine densities. Longitudes and latitudes of the endpoints of the 50-metre transects were recorded using a portable Global Positioning System (GPS) device (model number GPS 12) manufactured by GARMIN Corporation. The 5-, 15-, 25-, 35- and 45-metre points of each 50-metre transect were used as the centre points of the five 1m x 1m quadrats. This is illustrated in Figure 3.1. In each quadrat, the number of individuals, number of stems or the percentage ground cover, whichever applicable, of each plant species present was recorded. Plant species were identified in the field whenever possible, or a plant specimen, which contained stems and leaves, and flowers or fruits if present, was collected for future identification. When identification to the specific level is impossible, usually due to lack of reproductive parts, the plants were identified to genus.

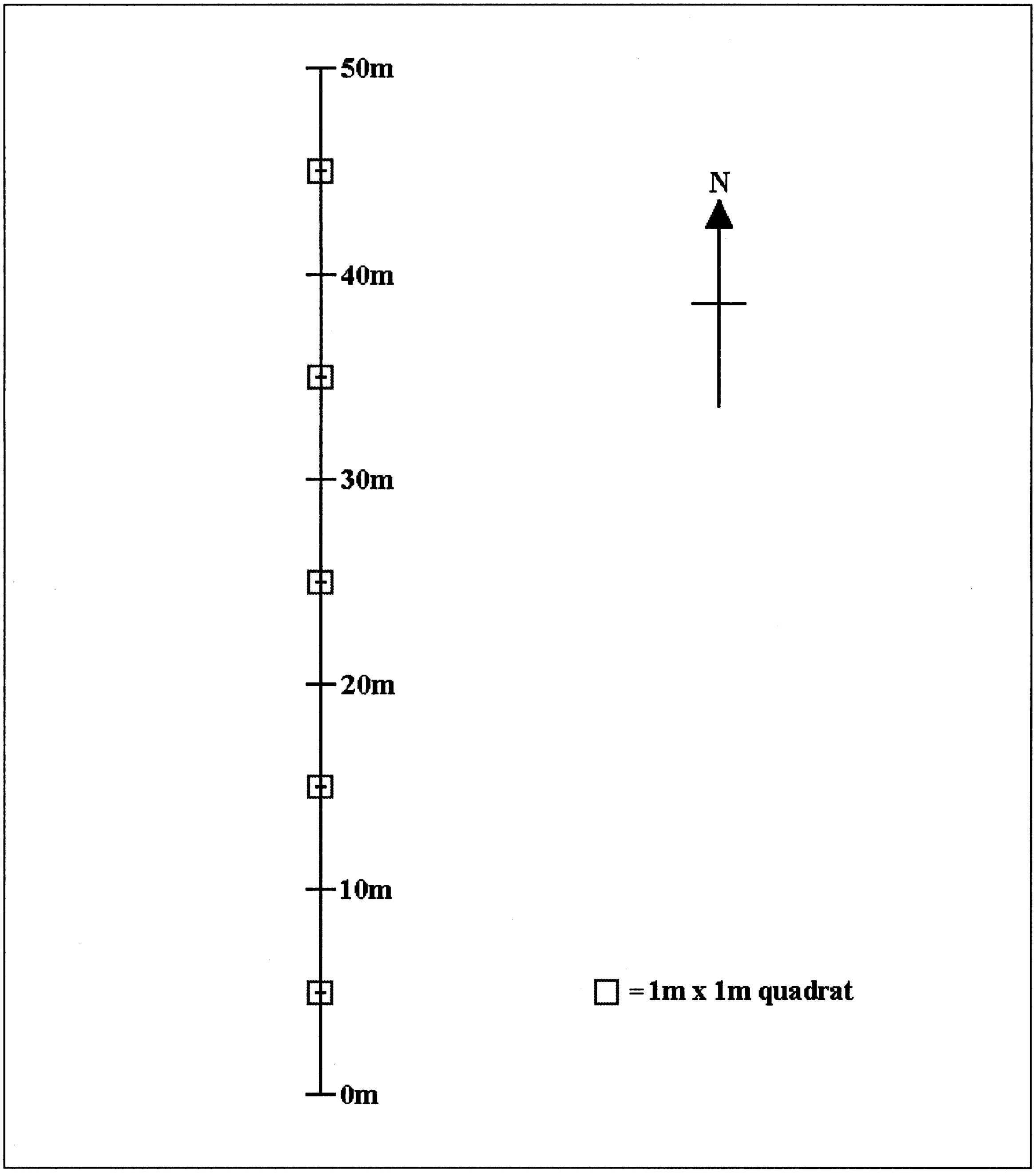


Figure 3.1 Diagrammatic illustration of the transect-quadrat method used for herbaceous vegetation survey.

number of flowers in each inflorescence and the percentage of individuals that flower are all different in different species, not to mention the difference in nectar quality in different species and the variation in amount of competition from other nectarivores. Therefore, there really is not a simple method which allows accurate measurement of nectar source plant density and reflects directly the quantity of nectar available for the KBB.

Even though getting an accurate estimation is almost impossible, a rough estimate can be obtained readily by using stem density or percentage cover, which to a certain extent can reflect the availability of nectar. However, when percentage cover is used, estimation can be quite subjective depending on how the estimation is made. To avoid any subjectivity, stem density was used to report nectar source plant density instead.

Nevertheless, Tolsen (1997) used the number of stems instead of percentage ground cover when quantifying KBB nectar source plant density. However, he included only the flowering stems when reporting nectar source plant densities. This was impossible in this study because not all the sites were visited when the 1st and 2nd brood KBB were, or expected to be, in flight. Recording the number of flowering stems at times other than the flight periods of the adult KBB may not reflect the availability of nectar to them. Therefore, instead of reporting the number of flowering stems, the total number of stems, including flowering and non-flowering ones, was used in this study.

Ant Specimens Collection

Ant specimens were collected at all sites in summer 2003. They were not collected in any systematic way but merely hand-picked in the study areas. Standard methods, such as collection by pitfall traps, could have been used to sample the ant community. However, because of the patchy distribution of ants with high concentrations around their nests and on their trails and low density elsewhere, very different results may be obtained when the pitfall traps are placed even at nearby locations. Therefore, a method that is just as effective but a lot simpler, which is collection of ant specimens simply by hand-picking, is used instead of standard methods such as usage of pitfall traps. The ant specimens were preserved in vials filled with 70% ethanol immediately after collection and sent to Professor André Francoeur at the University of Quebec, Chicoutimi for identification.

Integrated Light Intensity Measurement

Spatial variation of environmental variables at a microhabitat scale is often determined by the spatial variation in solar radiation. For example, air temperature is usually determined by the availability of light energy, especially at microhabitat scale close to the ground surface where atmospheric turbulence can hardly homogenize the air temperature spatially (Oke 1987). Relative humidity is, to a certain extent, also governed by the availability of light energy. However, other factors such as availability of moisture and rate of transpiration also play an important role on vegetated ground surfaces (Oke 1987). Nevertheless, topographic variation, such as orientation of slopes, can also be reflected by variation in light intensity (Oke 1987). As a result, integrated light intensity was chosen as the single measurement for site heterogeneity.

Another advantage of estimating site heterogeneity by measuring light intensity is that it could be done by using a relatively cheap method, which is using Petri dish lightmeters (Friend 1961; Sullivan and Mix 1983). This allowed me to measure integrated light intensity at a large number (100 in this study) of point locations at each site. This large sample size could then give me a reasonable estimate of site heterogeneity in terms of light conditions.

Tolsen (1997) measured light intensity at different areas for extensive periods of time by using dataloggers. However, due to small number of sample locations, his light intensity data could not be used to represent the spatial heterogeneity of his study areas.

Integrated light intensity was measured in both 2002 and 2003. One hundred Petri dish lightmeters, 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 of the year. These Petri dish lightmeters were prepared as described in Sullivan and Mix (1983) with two modifications. First, the light filters used were made of fibre glass instead of aluminum insect screening. Second, the stacks of photographic paper in the Petri dish lightmeters contained 15 sheets of photographic paper instead of 12.

The Petri dish lightmeters were fixed on stands made from galvanized wires at the height of lupine crown (about 10cm) above the ground beside wild lupine plants. This ensured that the light energy received by them would represent the light conditions experienced by the wild lupine plants at the sites, and therefore those by the KBB larvae and adults. They were spaced so that each one was at least 2m away from its neighbours. This prevents them from measuring the light conditions experienced by the same individual wild lupine plant. They were left at the sites for light exposure for approximately 40 days and picked up during the second visit of the year.

Additional Petri dish lightmeters were used for calibration. Light intensity was measured using portable dataloggers (model LI-1400, manufactured by LI-COR Incorporated) continuously for the 3-day period at two of the study areas at each site during each visit in 2002 and 2003. The dataloggers were connected to pyranometer sensors (model LI-200SZ, LI-COR Inc.) using 3-metre extension cables. The sensors were fixed on stands at about 10cm above ground beside wild lupine plants. To protect the dataloggers from harsh weather conditions and vandalism, they were stored in wooden vented enclosures and chained to a tree. The Petri dish lightmeters used for calibration purposes were placed no more than 5cm away from the pyranometer sensors. Their exact periods of exposure were recorded.

Data Analysis

Understory Vegetation Data

Vegetation data collected using the transect-quadrat method in the two visits of the same year were pooled. The higher density/coverage of each species between the two visits was used for data analysis. This was done because different plant species germinate and thrive in different times of the year. The mean numbers of stems of wild lupine and

1^{st} brood and 2^{nd} brood LBB nectar source plants per $1m^2$ quadrat were calculated for each site.

Ant Species Data

Since ant specimens were not collected in any systematic way, using the number of specimens collected for each species as quantitative data is not appropriate because they may not reflecting the relative abundance of each ant species despite similar effort spent to collect the ant specimens at all sites. Therefore, when compared among study sites, only the number of tending ant species found at each site was used.

Integrated Light Intensity Data

Petri dish lightmeters were brought back to the lab after exposed for approximately 40 days. The stacks of photographic paper in the Petri dish lightmeters were then developed in ammonia vapour (Friend 1961; Sullivan and Mix 1983). The layers light had penetrated through were "bleached" by light energy and therefore appeared white while the unexposed layers underneath turned black (Sullivan and Mix 1983). The number of layers light had penetrated through each stack of photographic paper was estimated to the nearest ¼ layer according to the darkness of the "image" on the last sheet light has reached (Sullivan and Mix 1983).

Since the amount of light energy received and the number of layers light penetrates through the stacks of photographic paper have a log-linear relationship (Friend 1961; Sullivan and Mix 1983), the natural logarithm of the amount of light energy received by the pyranometer sensor was plotted against the number of layers light had penetrated through the stacks of photographic paper in the calibration lightmeters. The linear regression equation of this graph was then used to calculate the amount of light energy received by the 100 Petri dish lightmeters (Friend 1961; Sullivan and Mix 1983).

Since the integrated light intensity measurements were not done at all sites simultaneously and the length of exposure was not exactly the same for all sites even though it was approximately 40 days for all of them, I used an equation which takes into account the latitude of the location and time of the year to calculate the total amount of light energy that should have been received by the Petri dish lightmeters during their exposure period with the assumption of complete cloudlessness (Monteith 1962). The integrated light intensity measurements were then expressed as percentages of the total amount of light energy that should have been received assuming that the whole period of exposure was completely cloudless. By standardizing the data this way, the effect of differences in time of the year of exposure and length of exposure were both discounted. However, the difference due to latitudinal differences of site locations was also discounted, but this difference should be negligible since all the sites were within a narrow latitudinal range (<0.7°N latitude).

All the study sites were then compared in terms of densities of wild lupine and KBB nectar source plants, number of tending ant species and site heterogeneity. I set the minimum standards for reintroduction sites in terms of these four variables as 90% of the lowest values among the U.S. sites. All Ontario sites were then compared against these minimum standards to see if these requirements as KBB reintroduction site were met.

Results

Understory Vegetation and Tending Ants

All the understory plant species sampled in the herbaceous layer vegetation survey and all the ant species found at all the sites are listed in Tables 3.2 and 3.3 respectively. In these two tables, an "X" represents presence of the species in the corresponding sites. Absence of an "X" does not necessarily mean that the plant (Table 3.2) or ant (Table 3.3) species is absent from the corresponding site. It only means that the plant species (Table 3.2) was not present in any of the quadrats in the vegetation survey or no specimen of the ant species (Table 3.3) was collected from the corresponding site. In Table 3.2, the plants species that have been observed to be utilized by 1st brood KBB as nectar sources are marked with "*", and those by 2nd brood KBB with "**". They were the only species included in the calculations of 1st and 2nd brood KBB nectar source plant densities respectively. In Table 3.3, ant species that are known to tend the KBB larvae are marked with "*". Those that have been observed to tend both KBB larvae and pupae are marked with "**". These marked species were the only ones recorded as KBB tending ant species.

Table 3.2 List of understory plant species sampled at all study sites.

Scientific Name	Common Name	Site								References
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Acalypha virginica L.	Three-seeded Mercury	X								
Achillea millefolium L.*,**	Common Yarrow		X		X	X			X	1,4,6,7,10,12
Agropyron repens L.	Quack Grass	X	X			X				
Ambrosia artemisiifolia L.	Common Ragweed	X	X						X	
Andropogon gerardii Vitman	Big Bluestem				X	X				
Andropogon scoparius Michx.	Little Bluestem	X	X		X	X	X	X	X	
Anemone cylindrical Gray*	Long-fruited Anemone		X	X	X	X	X			4,6
Anemone quinquefolia L.	Wood Anemone				X	X				
Anemone virginiana L.	Thimbleweed					X	X			
Antennaria neglecta Greene	Field Pussytoes	X	X		X	X			X	
Antennaria parlinii Fern	Smooth Pussytoes				X	X				
Apocynum androsaemifolium L.	Spreading Dogbane	X		X	X	X			X	
Aquilegia Canadensis L.	Wild Columbine			X	X	X			X	
Arabis hirsute L.	Hairy Rock Cress					X		X		
Arabis lyrata L.*,**	Lyre-leaved Rockcress				X	X		X		1,4,6,7,8,9,12,
Arctostaphylos uva-ursi L.	Bearberry				X	X				
Arenaria serpyllifolia L.*	Thyme-leaved Sandwort				X	X				9
Asclepias syriaca L.**	Common Milkweed	X		X	X			X		1,6
Asclepias tuberose L.**	Butterfly Weed		X		X	X		X		1,2,3,4,5,6,7,9,10,11
Asclepias variegate L.	White Milkweed	X		X						
Aster cordifolius L.	Heart-leaved Aster	X	X	X	X	X	X		X	
Aster macrophyllus L.	Large-leaved Aster	X	X	X	X	X				
Aster sagittifolius Wedam.	Arrow-leaved Aster	X	X							
Aster spp.	Aster	X	X		X	X	X			
Bromus pumpellianus Scribn.					X					
Campanula rotundifolia L.**	Harebell			X	X	X	X			1,8,12
Carex pensylvanica Lam.	Pennsylvania Sedge	X	X	X	X	X	X	X	X	

(continued)

Table 3.2 (continued). List of understory plant species sampled at all study sites.

Scientific Name	Common Name	Site								References
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Carex richardsonii Br.			X						X	
Carex spp.	Sedge	X				X	X	X	X	
Ceanothus americanus L.*,**	New Jersey Tea	X	X	X	X	X				1,2,3,4,7,9,12
Ceanothus herbaceous Raf.*,**	Narrow-leaved New Jersey Tea				X	X				6,9
Centaurea maculosa Lam.	Spotted Knapweed		X		X				X	
Cerastium vulgatum L.*	Mouse-ear Chickweed	X			X	X				6
Chimaphila maculate L.	Prince's Pine			X						
Clinopodium vulgare L.	Wild Basil				X	X				
Commandra umbellate Nutt.*	Bastard Toadflax	X	X	X	X	X	X	X	X	10,11
Comptonia peregrine Coult.	Sweet Fern			X					X	
Convolvulus spithamaeus L.	Upright Bindweed	X	X	X			X			
Cyperus esculentus L.	Nut Sedge							X		
Cyperus schweinitzii Torr.								X		
Cyperus spp.	Umbrella Sedge	X								
Danthonia spicata Beauv.	Poverty Grass		X	X	X	X				
Daucus carota L.	Wild Carrot	X	X		X					
Deschampsia flexuosa Trin.	Hair Grass			X	X	X	X			
Desmodium canadense L.	Showy Tick Trefoil	X	X							
Desmodium illinoense Gray	Illinois Tick Trefoil	X								
Dianthus armeria L.**	Deptford Pink								X	10
Diervilla lonicera Mill.	Bush Honeysuckle	X		X		X	X			
Elymus Canadensis L.	Canada Wild Rye							X		
Elymus repens Gould					X	X				
Equisetum arvense L.	Horsetail							X		
Equisetum hyemale L.	Scouring Rush			X	X	X			X	
Euphorbia corollata L.*,**	Flowering Spurge			X	X		X	X		1,4,5,6,7,8,10,11
Euphorbia esula L.	Leafy Spurge	X			X	X				

(continued)

Table 3.2 (continued). List of understory plant species sampled at all study sites.

Scientific Name	Common Name	Site								References
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Euphorbia glytosperma Engelm.	Ridge-seeded Spurge	X								
Festuca occidentalis Hook.	Western Fescue						X			
Festuca octoflora Walt.	Six-weeks Fescue							X		
Festuca ovina L.	Sheep Fescue	X			X	X	X			
Festuca rubra L.	Red Fescue				X	X				
Festuca spp.	Fescue	X			X	X			X	
Fragaria virginiana Duchesne*	Wild Strawberry	X	X	X	X	X	X	X	X	2,4,6
Galium asprellum Michx.	Rough Bedstaw				X					
Galium circaezans Michx.	Wild Licorice				X					
Galium pilosum Ait.	Hairy Bedstaw			X	X	X	X	X		
Gaultheria procumbens L.	Wintergreen			X	X	X	X			
Geranium maculatum L.*	Wild Geranium					X				9
Geranium molle L.	Dove's-foot Cranebill		X							
Geum macrophyllum Willd.	Large-leaved Avens	X								
Haplopappus armerioides Gray							X			
Hedyotis longifolia Hook.***	Long-leaved houstonia			X						6,8,12
Helianthemum bicknellii Fern.	Frostweed			X						
Helianthemum canadense Michx.***	Frostweed			X	X	X	X	X	X	4,8
Helianthus divaricatus L.**	Woodland Sunflower	X			X	X				4,7,10
Helianthus spp.	Sunflower	X	X	X	X	X		X		
Helianthus strumosus L.	Pale-leaved Sunflower	X	X							
Hieracium aurantiacum L.***	Orange Hawkweed						X			1,6,8,12
Hieracium floribundum Wimm. & Grabb.	Pale Hawkweed	X	X	X	X	X	X		X	
Hieracium pilosella L.**	Mouse Ear				X	X			X	10
Hieracium spp.	Hawkweed				X	X			X	
Hypericum perforatum L.**	Common St. John's Wort	X		X	X	X	X			10
Hypericum spp.	St. John's Wort				X					

(continued)

Table 3.2 (continued). List of understory plant species sampled at all study sites.

Scientific Name	Common Name	Site								References
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Koeleria cristata L.	June Grass				X	X				
Krigia virginica Willd.	Dwarf Dandelion						X	X	X	
Lactuca canadensis L.	Wild Lettuce						X			
Lepidium campestre Ait. f.	Field Peppergrass					X				
Lepidium spp.	Peppergrass								X	
Lepidium virginicum L.	Wild Peppergrass	X				X				
Leptoloma cognatum Schult.	Fall Witch Grass							X		
Lespedeza capitata Michx.**	Round-headed Bush Clover	X	X					X		1,12
Lespedeza intermedia Britt.	Wandlike Bush Clover				X					
Lespedeza spp.	Bush Clover		X							
Liatris aspera Michx.**	Rough Blazing Star					X				1,5,6,8,10,12
Liatris squarrosa Michx.	Scaly Blazing Star					X				
Linaria canadensis Dum.**	Blue Toadflax							X		1
Linaria vulgaris P. Mill.**	Butter-and-eggs								X	1
*Lithospermum canescens**	Hoary Puccoon				X	X	X	X		4
Lithospermum croceum Fern.	Hairy Puccoon				X	X				
Lonicera canadensis Bartr.	American Fly Honeysuckle	X				X				
Lupinus perennis L.***	Wild Lupine	X	X	X	X	X	X	X	X	1,4,6,8,9,10,12
Luzula spp.	Wood Rush			X						
Lycopodium spp.				X						
Lysimachia quadrifolia L.	Four-leaved Loosestrife			X						
Maianthemum canadense Desf.	Canada Mayflower	X	X	X	X	X		X		
Medeola virginiana L.	Indian Cucumber Root			X						
Medicago lupulina L.***	Black Medic	X								1,6,8
Melampyrum lineare Desr.	Cow wheat			X	X	X	X	X		
Melilotus alba Medikus**	White Sweet Clover		X					X		1,4,6,7,8,12
Mitchella repens L.	Partridgeberry			X			X			

(continued)

Table 3.2 (continued). List of understory plant species sampled at all study sites.

Scientific Name	Common Name	Site								References
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Mollugo verticillata L.	Carpetweed							X		
Monarda fistulosa L.**	Wild Bergamot		X	X	X	X	X	X		4,7,8,12
Opuntia humifusa Raf.	Prickly Pear							X		
Oryzopsis racemosa Ricker	Rice-grass			X						
Oxalis stricta L.	Upright Yellow Wood Sorrel	X								
Panicum columbianum Sribn.				X					X	
Panicum commonsianum Ashe								X		
Panicum depauperatum Muhl.				X	X					
Panicum lancearium Trin.						X				
Panicum linearifolium Scribn.					X	X				
Panicum perlongum Nash.				X	X	X	X		X	
Panicum spp.	Panic Grass			X	X	X				
Panicum villosissimum Nash.								X	X	
Panicum virgatum L.	Switch Grass							X		
Panicum willowsissimum			X							
Parthenocissus quinquefolia Planch.	Virginia Creeper			X				X		
Pedicularis Canadensis L.	Wood Betony				X	X				
Phleum pratense L.	Timothy	X	X							
Physalis heterophylla Nees.	Clammy Ground Cherry	X								
Plantago major L.	Common Platian	X				X				
Poa compressa L.	Canada Bluegrass		X	X	X	X			X	
Poa pratense L.	Kentucky Bluegrass	X		X	X	X	X	X	X	
Polygala paucifolia Willd.	Fringed Polygala			X				X		
Polygala polygama Walt.**	Racemed Milkwort			X	X	X	X	X		10
Polygonatum pubescens Pursh.	Hairy Solomon's Seal			X	X	X				
Polygonum convolvulus L.	Black Bindweed	X								
Potentilla norvegica L.	Rough Cinquefoil	X								

(continued)

Table 3.2 (continued). List of understory plant species sampled at all study sites.

Scientific Name	Common Name	Site								References
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Potentilla recta L.*,**	Rough-fruited Cinquefoil		X		X	X			X	1,4
Potentilla simplex Michx.*,**	Common Cinquefoil			X	X	X	X		X	1,4,6,11,12
Prenanthes boottii Gray	Boott's Rattlesnake Root				X					
Pteridium aquilinum Kuhn	Bracken Fern		X	X	X	X	X	X		
Pyrola elliptica Nutt.	Shinleaf			X						
Pyrola rotundifolia L.	Round-leaved Pyrola					X				
Ranunculus fascicularis Muhl.	Prairie Buttercup		X							
Ranunculus repens L.	Creeping Buttercup	X								
Rhus radicans L.	Poison Ivy	X	X	X	X	X				
Rosa blanda Ait.	Smooth Rose		X	X	X	X		X		
Rosa Carolina L.*,**	Pasture Rose	X	X	X	X	X	X	X		4
Rosa multiflora Thunb.	Multiflora Rose			X						
Rosa spp.	Rose		X							
Rubus allegheniensis Porter*	Common Blackberry	X		X	X	X	X	X		6
Rubus flagellaris Willd.*	Northern Dewberry			X	X	X	X	X		4,5,6,7,11
Rubus idaeus L.	Wild Red Raspberry		X	X	X					
Rudbeckia hirta L.**	Black-eyed Susan	X				X	X			1,4,6,8,9,10,12
Rumex acetosella L.*	Field Sorrel			X	X	X	X	X	X	1
Sanicula marilandica L.	Black Snakeroot		X							
Satureja vulgaris Fritsch	Wild Basil				X	X				
Senecio pauperculus Michx.*	Balsam Ragwort				X	X	X			6
Shepherdia Canadensis Nutt.	Soapberry					X				
Silene antirrhina L.	Sleepy Catchfly					X				
Sisyrinchium montanum Greene	Common Blue-eyed Grass		X							
Smilacina racemosa Desf.*	False Solomon's Seal	X	X	X	X	X		X		1,6
Smilax herbacea L.	Carrion Flower			X						
Solanum dulcamara L.	Bittersweet Nightshade	X								

(continued)

Table 3.2 (continued). List of understory plant species sampled at all study sites.

Scientific Name	Common Name	Site								References
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Solanum nigrum L.	Common Nightshade							X		
Solidago Canadensis L.	Canada Goldenrod	X	X							
Solidago gigantean Ait.	Giant Goldenrod	X								
Solidago juncea Ait.	Early Goldenrod	X	X	X	X	X				
Solidago nemoralis Ait.	Gray Goldenrod	X		X						
Solidago spp.	Goldenrod	X	X	X	X	X		X		
Stellaria media Vill.	Common Chickweed	X								
Streptopus roseus Michx.	Rose Twisted Stalk		X		X			X		
Symphoricarpos albus Blake	Snowberry				X	X				
Taraxacum officinale Wiggers	Common Dandelion	X	X		X	X		X		
Thalictrum dioicum L.	Early Meadow Rue		X							
Tradescantia virginiana L.**	Spiderwort							X		10
Tragopogon dubius Scop.	Yellow Goat's Beard	X				X	X	X		
Tragopogon pratensis L.	Yellow Goat's Beard	X			X					
Trientalis borealis Raf.	Starflower			X						
Trifolium agrarium L.	Hop Clover		X							
Trifolium pratense L.***	Red Clover	X	X							1,6,12
Trifolium repens L.***	White Clover	X								1,6,12
Trillium grandiflorum Salisb.	White Trillium		X							
Vaccinium angustifolium Ait.	Early Low Blueberry			X	X	X	X		X	
Vaccinium corymbosum L.	High-bush Blueberry			X						
Vaccinium pallidum Ait.	Late Low Blueberry	X		X	X			X	X	
Verbascum thapsus L.	Common Mullein	X	X		X		X		X	
Verbena stricta Vent.	Hoary Vervain	X								
Veronica serpyllifolia L.	Thyme-leaved Speedwell	X								
Vicia caroliniana Walt.	Wood Vetch							X		
Vicia cracca L.	Cow Vetch	X	X							

(continued)

Table 3.2 (continued). List of understory plant species sampled at all study sites.

Scientific Name	Common Name	Site								References
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Vicia tetrasperma Schreb.	Slender Vetch		X							
Viola adunca Sm.	Sand Violet						X			
Viola fimbriatula Sm.	Ovate-leaved Violet		X	X						
Viola lanceolata L.	Lance-leaved Violet	X	X							
Viola sagittata Ait.	Arrow-leaved Violet						X			
Viola spp.	Violet	X	X	X	X	X	X			
Vitis palmate Vahl.	Red Grape							X		
Vitis riparia Michx.	Riverbank Grape	X			X	X		X		
Waldsteinia fragarioides Tratt.	Barren Strawberry		X							

* species that have been observed to be 1st brood Karner Blue nectar source plants

** species that have been observed to be 2nd brood Karner Blue nectar source plants

References: 1 = Bleser 1992; 2 = Dirig 1976; 3 = Fried 1987; 4 = Grundel and Pavlovic 2000; 5 = Lawrence 1994; 6 = Leach 1993; 7 = Marin 1994; 8 = Maxwell and Givnish 1994; 9 = Packer 1990; 10 = Papp 1993; 11 = Sferra *et al* 1993; 12 = Swengel and Swengel 1993.

Table 3.3 List of ant species collected from all study sites.

Scientific Name	Site								References
	HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA	
Aphaenogaster rudis complex Buckley*	X			X	X				4
Aphaenogaster traetae					X		X		
Camponotus americanus Mayr*		X			X				6
Camponotus nearcticus Emery	X		X				X		
Camponotus novaeboracensis Fitch*					X	X			6
Camponotus pennsylvanicus DeGeer*	X		X	X	X				4
Crematogaster cerasi Fitch*		X			X		X		6
Crematogaster lineolata Say**			X	X		X			2, 3
Formica exsectoides Forel*			X						4
Formica fusca Vikberg			X	X			X		
Formica incerta Emery*					X	X			3, 6
Formica integra Nylander			X						
Formica lasioides Emery*	X				X	X		X	6
Formica neogagates Emery*			X		X				2
Formica nitidiventris Emery*	X	X	X		X	X	X		6
Formica obscuriventris Mayr*				X			X		2
Formica planipilis Creighton						X			
Formica schaufussi Mayr*							X		1
Formica subsericea Say*	X		X		X	X	X		2, 3, 6
Lasius neoniger Emery**	X	X			X	X	X	X	2, 3, 6
Lasius umbratus Foerster	X								
Leptothorax ambiguous Emery					X				
Leptothorax longispinosus Roger					X				
Leptothorax texanus Wheeler			X		X				
Monomorium minimum Buckley	X							X	
Myrmica Americana Weber*	X	X				X		X	2, 3, 6

(continued)

Table 3.3 (continued). List of ant species collected from all study sites.

Scientific Name	**Site**								**References**
	HP	**AFN**	**MT**	**PPP**	**KBS**	**MNF**	**IDNL**	**SCA**	
Myrmica pinetorum Wheeler					X			X	
Myrmica rubra Vikberg	X								
Myrmica sculptilis Francouer*	X		X	X					5
Myrmica smithana Francouer			X	X	X	X	X		
Paratrechina parvula Mayr*				X	X				6
Pheidole spp.						X			
Prenolepsis impairs Say*	X	X		X					3
Tapinoma sessile Say**	X	X	X	X		X			1, 3, 6
Tetramorium caespitum L.*	X			X					1

* species that have been observed to tend Karner Blue larvae

** species that have been observed to tend both Karner Blue larvae and pupae

References: 1 = Bleser 1992; 2 = Herms 1996; 3 = Lane 1999; 4 = Packer 1990; 5 = Savignano 1990; 6 = Savignano 1994a

Integrated Light Intensity

Figure 3.2 shows the regression of the natural logarithm of the amount of solar energy received by the pyranometer sensors against the number of layers light has penetrated through the stacks of photographic paper in the calibration lightmeters. The r^2 of this linear regression is 0.7131. The linear regression equation,

$y = 1.7021x - 1.4962$

where y = ln(amount of energy received by the pyranometer sensors [kJ/m^2]);

and x = number of layers light has penetrated through the stacks of photographic paper [estimated to the nearest ¼ layer]

was used to convert the number of layers light had penetrated through the stacks of photographic paper in the Petri dish lightmeters into the amount of solar energy received. These data were then expressed as percentages of the total amount of light energy that should have been received assuming that it had been completely cloudless throughout the entire period of light exposure (Monteith 1962).

Summary of Comparisons

The densities of wild lupine and nectar source plants for both broods of the KBB, the number of tending ant species and the standard deviation of the 100 integrated light intensity measurements at each site, together with their associated standard errors, are summarized in Table 3.4. The lowest wild lupine density reported by Tolsen (1997) from three study areas in the ASGA is also included in Table 3.4 for comparison. The lowest values among the three (in the case of wild lupine density, four) potential founder butterfly sites in the U.S.A. are underlined in Table 3.4. The italicized numbers shown in the bottom row in Table 3.4 are 90% of the underlined values. The values for the Ontario sites that are larger than these italicized values are shown in bold, indicating that those conditions are probably good enough for reintroduction of the KBB.

Site	**Lupine density [stems/m^2]**	**Nectar plant density [stems/m^2]**		**Number of tending ant species**	**Standard deviation of integrated light intensity [%]**
		1st brood	**2nd brood**		
HP	**9.74**±2.43	25.43±2.87	**51.83**±3.29	**15**	**18.98%**±2.13%
AFN	0.37±0.16	**104.45**±8.76	**121.10**±8.70	**7**	**19.65%**±1.60%
MT	**3.15**±0.73	45.40±2.56	34.43±3.59	**13**	15.07%±1.23%
PPP	**4.27**±1.73	**84.17**±9.64	36.73±3.97	**11**	**18.64%**±1.41%
KBS	**2.12**±0.68	**63.73**±5.66	**49.83**±4.33	**18**	16.54%±1.35%
MNF	**14.27**±2.85	**67.22**±4.35	**75.80**±8.30	**12**	**23.46%**±1.92%
IDNL	**15.97**±3.18	**52.50**±3.71	**53.17**±4.08	**10**	**18.79%**±1.46%
SCA	**7.47**±1.69	**100.85**±9.69	**72.00**±9.92	**5**	**18.68%**±1.44%
ASGA	**1.67**				
cut-off	***1.50***	***47.25***	***47.85***	***5***	***16.82%***

Table 3.4 Summary of comparison of wild lupine density, nectar source plants density, number of tending ant species and site heterogeneity among all study sites.

As seen in Table 3.4, AFN is the only Ontario site that has a wild lupine density lower than the lowest among the U.S. sites which is the ASGA (Tolsen 1997); AFN and the KBS have sufficient nectar plants for both 1st and 2nd brood KBB while HP and PPP have enough for only one of the two broods; In the SCA, only five species of tending ants were collected while all the Ontario sites have more than that; the MT and the KBS are the only two Ontario sites in which the standard deviation of the 100 integrated light intensity measurement is lower than that of the SCA, which is the lowest among the U.S. sites. None of the Ontario sites shows bolded values in all five columns.

Discussion

As mentioned in Chapter 1, survival and persistence of the KBB depend on four important habitat characteristics: 1) wild lupine; 2) nectar source plants; 3) tending ants; and 4) site heterogeneity. However, not much is known about the minimum requirement for each of these site characteristics to sustain a healthy KBB population.

Wild Lupine

Although I used quadrats of $1m^2$ in size while Tolsen (1997) used ones of $0.5m^2$, our results for wild lupine density are comparable because both of us counted the number of stems instead of individuals of wild lupine and we used the same transect-quadrat method that should have given us objective and reasonably accurate results (Anderson 1942; Bauer 1943; Parker and Savage 1944). Therefore, the lowest wild lupine density reported by Tolsen (1997) for the KBB habitats in the ASGA was presented in Table 3.4

and included in setting the minimum standard for wild lupine density in reintroduction sites. In fact, it turned out that the ASGA has the lowest wild lupine density among the four U.S. sites. 90% of the wild lupine density there, which is 1.67 stems/m^2 x 90% = 1.50 stems/m^2 (Table 3.4), was therefore used as the minimum requirement of wild lupine density for reintroduction sites.

AFN is the only Ontario site with a wild lupine density lower than 1.5 stems/m^2 (Table 3.4). This means that the density of wild lupine in AFN might be too low to support a healthy KBB population. In contrast, in all other Ontario sites, the wild lupine densities are probably high enough to support healthy KBB populations since they are higher than that of a study area in the ASGA (Tolsen 1997) where healthy population of the KBB persisted.

Nectar Source Plants

1st and 2nd brood KBB nectar source plant densities were also reported by Tolsen (1997) for his study areas in the ASGA. However, even though we used comparable methods to measure the stem densities, he reported those densities including only the flowering stems during the flight periods of the adult KBB while I could not differentiate flowering and non-flowering stems in my study because vegetation surveys at some sites were done at times other than the flight periods of the KBB. Hence, our results of nectar source plant stem densities are incomparable. Only the three U.S. sites I visited were included in setting the minimum standards for 1st and 2nd brood nectar source plant densities.

Despite a shortage of wild lupine plants, AFN has the highest KBB nectar source plant densities among all sites (Table 3.4). Among the U.S. sites, the lowest 1st and 2nd brood KBB nectar source plant densities were found in IDNL, which are 52.50 and 53.17 stems/m^2 respectively. The minimum requirements for them are therefore set as 52.50 x 90% = 47.25 stems/m^2 and 53.17 x 90% = 47.85 stems/m^2 respectively. In the KBS, both 1st and 2nd brood nectar source plant densities exceed these requirements. This indicates that both AFN and the KBS have enough nectar source plants to support a persisting KBB population. In HP and PPP, nectar plant density was high enough for only one of the two broods of KBB, while in the MT, both 1st and 2nd brood nectar source plants do not meet the 90% requirement. This suggests that these three sites may require further restoration to increase the KBB nectar source plant density before KBB reintroduction should proceed.

Tending Ants

Tolsen (1997) did not collect any data on tending ant species in the ASGA. The minimum standard for the number of tending ant species was therefore determined using the data I collected from the three potential founder butterfly sites in the U.S.A.

The lowest number of tending ant species, which is five, was found in the SCA (see Table 3.2). In all the Ontario sites, the number of tending ant species collected was more than six. Lack of tending ants is therefore unlikely a concern in the five potential KBB reintroduction sites in Ontario.

Site Heterogeneity

In Figure 3.2, the r^2 of the linear regression between the natural log of the amount of solar energy received by the pyranometer sensors and the number of layers of photographic paper that light has penetrated thorough is 0.7131. This r^2 value is not very high provided that the linear relationship between the two variables is known (Friend 1961; Sullivan and Mix 1983). This is not surprising because the numbers of layers of photographic paper light has penetrated through were all estimated only to the nearest ¼ layer. Despite this, the r^2 of this regression is higher than 0.7. This clearly demonstrates a positive correlation between the two variables.

All the integrated light intensities, expressed as percentages, are less than 100% because the sky was not completely cloudless over the 40-day exposure period. Clouds blocked and absorbed some of the solar radiation and canopy cover, if present, also reflected and absorbed part of the light energy. The difference between these two is that the effect of clouds varies at a regional scale, but not at a micro scale. Its effect on all the Petri dish lightmeters at the same site should therefore be very similar. In contrast, the effect of canopy cover varies in a micro scale and Petri dish lightmeters that were not under canopy cover could have received a lot more light energy than the ones directly under the trees. Therefore, the variation in the measurements of integrated light intensity actually represents the variation in canopy cover across the wild lupine growing areas, and the standard deviation of the 100 integrated light intensity measurements at each site represents the heterogeneity of the light conditions under which the wild lupine plants grow at those sites.

Tolsen (1997) measured light intensity in the ASGA. However, his method of light measurement was totally different from mine. He measured instantaneous light intensity continuously for an extensive period of time, concurrently at several different locations and reported the maximum and minimum values at different locations but did not calculate the averages and standard deviations, while I measured the integrated light intensity over a 40-day period at 100 locations at each study site. Therefore, it is impossible to compare our results. Again, only the three U.S. sites I visited were included in setting the minimum standards for site heterogeneity in terms of light conditions.

In Table 3.4, the lowest standard deviation of integrated light intensity was found in the SCA among all U.S. sites. This was not surprising because there was no tree in the SCA and the only source of light intensity variation comes from a small number of low growing shrubs and the directional signs erected for the aircraft in the airport. In Ontario, the MT and the KBS were the only sites where the standard deviation of integrated light intensity was lower than 90% of that of SCA, which is 18.68% x 90% = 16.82%. In the MT, the low variability in light conditions under which wild lupine plants grow is caused by the high percentage of canopy cover. Under high canopy cover, there are not many sunny spots where wild lupine can thrive, and most wild lupine plants grow under semi-shade conditions. That limits the width of the range of light conditions under which wild lupine can grow. In the KBS, even though the site is heterogeneous and there were quite some openings, wild lupine does not grow in areas where they once did before the prolonged drought in the late 1980s. Most wild lupine plants were concentrated in the semi-shade regions. Therefore, in both the MT and the KBS, the standard deviation of integrated light intensity was smaller compared to other sites. This means that the wild lupine populations at these two sites were growing under a narrower spectrum of light conditions than those at the other sites, hence making them not optimal for KBB reintroduction.

Summary and Conclusions

In the IUCN guidelines for reintroductions, methods to determine whether a restored site is good enough for reintroduction of a previously extirpated species are not discussed (IUCN 1998). This research provides an example of how this can be done, using the case of the KBB. First, all the basic ecological requirements of the KBB were identified. Minimum standards for these ecological requirements were set from quantitative field data collected at sites where healthy populations of the butterfly were still present. Similar data were then collected from potential reintroduction sites and compared against the minimum standards. A potential reintroduction site is identified as "ready for reintroduction" only if the minimum standards for all ecological requirements are met. These procedures are not only useful for this particular study. They can also be applied to evaluate potential reintroduction sites in other reintroduction projects.

In addition, these procedures can identify specific problems at the potential reintroduction sites by comparing data collected from them against the minimum standards. This provides valuable information for revision of restoration and management techniques employed in the past and determining restoration and management strategies in the future.

In summary, according to the minimum standards set in this research, none of the Ontario sites met all four criteria: HP lacks 1st brood KBB nectar source plants; wild lupine density in AFN is too low; the MT does not have enough nectar source plants for both broods of KBB and its site heterogeneity is too low; PPP needs more 2nd brood KBB nectar source plants; and the KBS requires wild lupine that grows in a wider range of light conditions. This suggests that all these sites do not seem to be ready for reintroduction of the KBB. However, the standards were set by applying the 90% cut-off rule, and this is 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 is expected to be, if not optimal, at least high. 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 predict. I therefore chose to be more 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 would have a proportionately greater impact upon smaller KBB populations at those sites. Therefore, only the potential founder butterfly sites, where the KBB populations were large, were included in this study.

Even though all five sites do not seem to be ready for reintroduction of the KBB, HP seems to be one of the best among them in terms of site quality because of its high wild lupine density which is comparable to those of the potential founder KBB sites in the U.S.A. However, HP may not necessarily be the best potential KBB reintroduction site in Ontario because of its small wild lupine range and heavy usage by city residents. Wild lupine covers less than 2 hectares in HP. Despite the high lupine density, the area is probably too small overall to sustain a persistent KBB population because of high susceptibility to catastrophic events. Also, HP is a heavily used urban park. The wild lupine areas were frequently accessed by unleashed dogs and park users, especially when the lupines were in bloom, attracting a lot of attention. In fact, when Petri dish lightmeters were left at the sites, the rate of vandalism was the highest in HP (26%, compared to less than 5% at all other sites). This will be a threat to the KBB if it is reintroduced there. Therefore, with its current conditions, HP is unlikely the best potential KBB reintroduction site in Ontario.

In contrast, AFN also seems to be a very good quality site but the only problem with it is lack of wild lupine. However, I have two major concerns with this site: 1) wild lupine was not found there until they were planted in 2002, with low survival rate; and 2) the vegetation community structure in AFN was very different from those of all other sites, including both the Ontario and the U.S. sites. The wild lupine plugs planted in 2002 bloomed in 2004 for the first time, and whether these wild lupine plants can successfully reproduce by themselves remains to be seen. Since wild lupine was absent from AFN and the planted plugs had a low survival rate, even if they can reproduce by themselves at this site, it is still questionable whether this site is suitable for their establishment. Coupled with the fact that the vegetation community structure in AFN is distinctly different from other sites where wild lupine thrives, the environmental conditions in AFN are likely quite different from all the other sites, and hence might not be ideal for wild lupine. Also, even if wild lupine can survive there, KBB may not do well because of the distinctly different environmental conditions. Therefore, AFN should not be one of the priority KBB reintroduction sites and reintroducing KBB to AFN should be done with extreme caution.

Under current conditions, the KBS seems to be the best potential reintroduction site in Ontario instead of HP or AFN. Even though the wild lupine density in the KBS is relatively low compared to that in HP, the wild lupine populations there have good connectivity which is not seen in most other sites. The three lupine areas in the KBS are no more than 500m from one another and there is another lupine area not included in this study that is also very close to these areas. In between these areas, there are individual wild lupine plants growing. In fact, at some of these areas (e.g. KBS-TR), some wild lupine have been planted along the trail which connects different wild lupine populations. With such connectivity, establishment of a KBB metapopulation, with each wild lupine population supporting a subpopulation is possible. In terms of site heterogeneity, not many of the wild lupine plants in the KBS grow in full sun condition. However, the wild lupine areas were burnt in spring 2004 and the burn successfully removed some of the woody plants (personal observation). This will open up the canopy and give some of the wild lupine plants a sunnier environment. With such improvement, I suggest that if the KBB is to be reintroduced in Ontario, the KBS should be one of the priority reintroduction sites.

The MT and PPP do not seem to be ready for KBB reintroduction. KBB nectar source plant densities for both broods of the KBB and site heterogeneity are too low at the MT. This is probably due to canopy overgrowth which has led to reduced light and hence low density of savannah plant species as nectar sources for the KBB. In PPP, lack of 2nd brood KBB nectar source plants is probably due to low species richness at the study areas within the park, especially at PPP-SH where grasses and *Rubus spp.* dominated the area. Over-grazing by white-tailed deer (*Odocoileus virginianus* Boddaert) in the 1980s and early 1990s could have also contributed to this problem.

In conclusion, none of the potential KBB reintroduction sites included in this study has habitat characteristics as favourable as the potential founder butterfly sites in the U.S.A., indicating that under current conditions, successful reintroduction of the KBB at these restored oak savannah sites in Ontario is not guaranteed. Despite this, the KBS has been identified as the priority KBB reintroduction site in Ontario. Meanwhile, further studies which include KBB sites of lower quality are required to help define a set of more realistic standards for KBB reintroduction. Such studies might show that U.S. sites of similar quality to the oak savannah sites in Ontario can support persisting KBB populations (as in the case of wild lupine density in the ASGA (Tolsen 1997)), which might then suggest that the potential KBB reintroduction sites included in this study are in fact able to support healthy KBB populations and KBB reintroduction can therefore proceed in Ontario. Also, future restoration and management of the potential KBB reintroduction sites in Ontario should focus on their particular problems identified in this study.

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CHAPTER 4: Identification of the Most Suitable Founder Butterfly Sites

Introduction

In species reintroduction, the choice of founder population may be crucially important in determining success. To avoid outbreeding depression (Templeton 1986; Gharrett *et al* 1999; Aspi 2000; Marr *et al* 2001; Quilichini *et al* 2001), individuals to be reintroduced to a site should come from no more than one founder population. This founder population should, ideally, be genetically closely related and show similar ecological characteristics (morphology, physiology, behaviour and habitat preference) to the extirpated one (IUCN 1998). This can maximize their chances of survival and reduce the probability of their being mal-adaptated to the environment of the reintroduction site. However, since the original native population has already been extirpated, genetic comparison between the extirpated population and the potential founder populations are often difficult if not impossible. Also, when the reintroduction site is not a historic site of the species to be reintroduced, no such genetic comparison can be made. In such cases, the choice of founder population may be determined based upon the similarity of the reintroduction site and the potential founder population sites in terms of environmental variables relevant to the species to be reintroduced.

Although, as concluded in Chapter 3, none of the restored oak savannah sites in Ontario is in such good quality that we can be certain that it is ready for reintroduction of the KBB, identification of the most suitable founder butterfly population sites according to their degree of similarity to the Ontario sites is still possible. In this chapter, I compared the potential KBB reintroduction sites in Ontario to the potential founder population sites in the U.S.A. in terms of environmental variables relevant to the KBB. I then identified the most similar potential founder population site to each of the potential reintroduction site.

The comparison between the potential KBB reintroduction sites and the potential founder KBB sites focused on several biological and environmental variables that are relevant to the long-term survival of the KBB. They include 1) overall herbaceous plant community structure; 2) 1st brood KBB nectar source plants; 3) 2nd brood KBB nectar source plants; 4) tree community; 5) tending ant species; 6) canopy cover; 7) light intensity; 8) temperature; and 9) relative humidity. All except three of these variables were measured by Tolsen (1997) for comparison between potential reintroduction areas in the KTP in Ohio and the founder butterfly areas in the ASGA in Michigan. His study led to the determination of whether the oak openings in the KTP are similar enough to the founder KBB population areas in the ASGA for reintroduction of the KBB in the KTP.

First, the overall herbaceous plant community structure, which was not compared by Tolsen (1997), was compared in this study between the potential KBB reintroduction sites and the potential founder butterfly sites. This is because not only does it distinguish how closely the plant communities among the sites are, but it also reflects to a certain extent the similarity of the overall environmental conditions among the sites. When two sites share a very similar herbaceous species community structure, they tend to also share similar fauna and microhabitat conditions such as temperature and relative humidity. Hence, such comparison gives a good indication of the overall similarity of the sites being compared.

Another additional variable that was compared between potential KBB reintroduction sites and potential founder butterfly sites in this study but not in Tolsen's (1997) was the tree community. As for the herbaceous species, tree species composition can reflect to a certain extent the overall environmental conditions of the sites. Also, the tree community plays an important role in determining canopy cover and light conditions, which are important variables directly affecting the survival of KBB and were measured by Tolsen (1997). Moreover, difference in tree species composition can alter other environmental variables as well. For example, if one site is composed of mainly coniferous trees while another is dominated by deciduous trees, the change in light conditions throughout the year, the nutrient cycles, the soil pH and many other environmental variables will differ between the two sites. Therefore, comparing the tree community between potential KBB reintroduction sites and potential founder butterfly sites can provide additional information in the overall similarity among the sites.

Since the presence of tending ants is important to the survival of KBB in the larval stage (Savignano 1990, 1994), comparison was also made in terms of tending ant species community between the potential KBB reintroduction sites and potential founder butterfly sites even though Tolsen (1997) did not do so in his study. Such a comparison may not be necessary if all ant species are equally effective in tending KBB larvae. However, this is not the case. Studies have shown that some ant species are more effective in protecting the KBB larvae from predators and parasitoids than others (Savignano 1990, 1994). Moreover, some tending ants were observed to remove the KBB larvae from wild lupine plants (Spoor 1993). Whether they are trying to raise the KBB larvae elsewhere or preying on them is unknown. It is also unclear whether the KBB at different locations have developed adaptations to cope with different tending ant species available at different sites. Hence, comparison of tending ant communities was necessary to match potential KBB reintroduction sites with potential founder butterfly sites.

Methodology

Field Data Collection

Field data described in Chapter 3 were also used in this chapter. Additional data collected include woody species surveys using the nearest-neighbour method (Cottam & Curtis 1949; Cottam *et al* 1953; Cottam and Curtis 1956), canopy cover estimation using a simple device that worked as a tubular densitometer (Emlen 1967; Vales and Bunnell 1988; Bunnell and Vales 1990; Stumpf 1993) and meteorological (temperature and relative humidity) data collection using portable dataloggers.

Woody Species Survey

The 50-metre transects used for the herbaceous plant community survey described in Chapter 3 were also used for woody species surveys by the nearest-neighbour method. In this method, distances between neighbouring shrubs/trees are measured. Since these distances decrease with increasing tree density, they can then be converted to woody species density estimations (Cottam & Curtis 1949; Cottam *et al* 1953; Cottam and Curtis 1956).

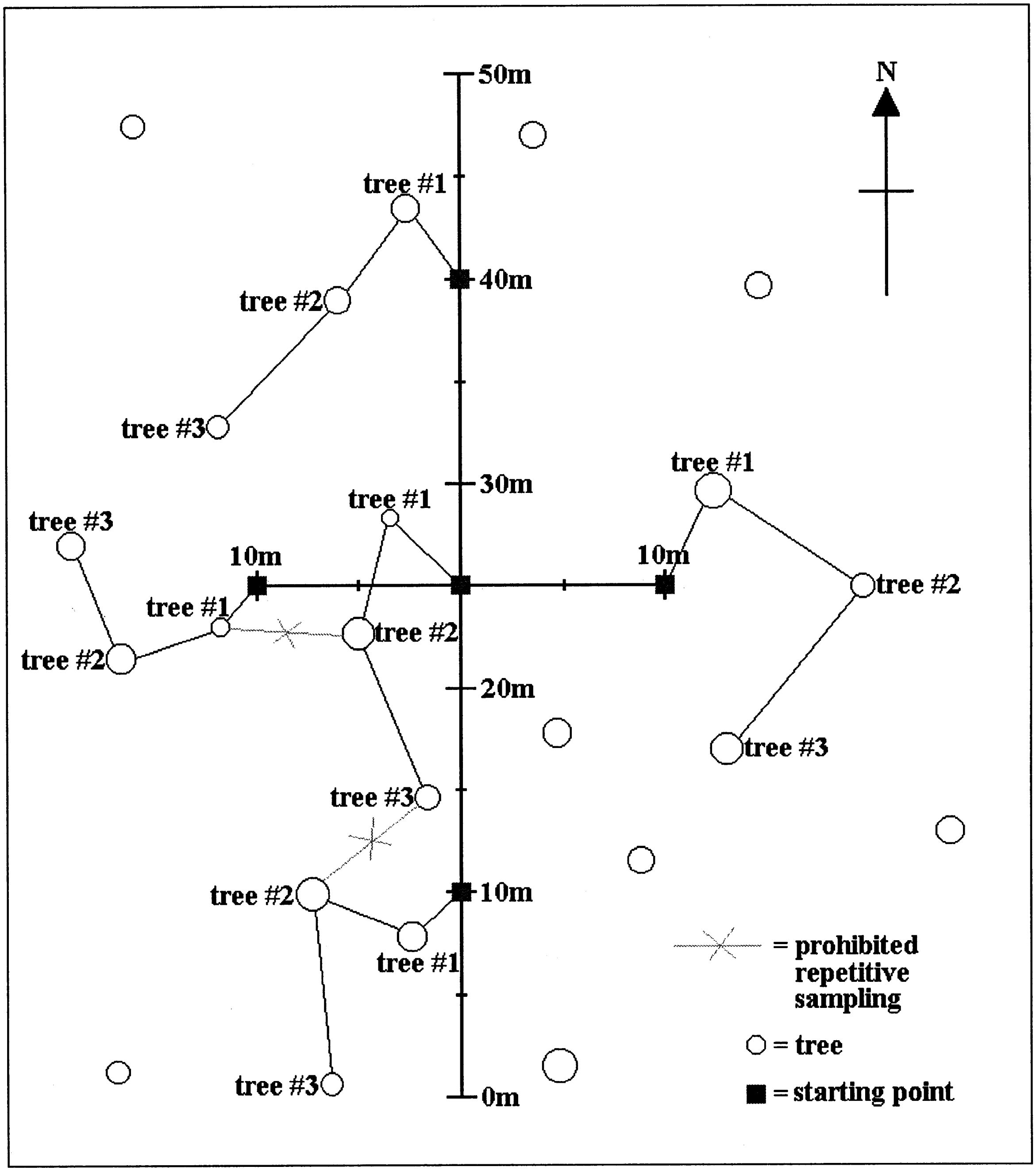

Figure 4.1 Diagrammatic illustration of the nearest-neighbour method used for woody species survey.

Canopy Cover Estimation

The 50-metre transects were also used for canopy cover estimation with simple devices that worked the same way as a tubular densitometer, which is a standard tool for canopy cover estimation that reflects an image vertically above the sample location to the observer (Emlen 1967; Vales and Bunnell 1988; Bunnell and Vales 1990; Stumpf 1993). The 50-metre transects were marked with tapes at 1-metre intervals, so that there were a total of 51 markings on each transect including both ends. A hollow tube was placed above each 1-metre mark, except for the 0-metre mark, and a mirror was placed underneath to observe vertically above to see if the markings are vertically under the tree canopy. Figure 4.2 illustrates how this method works. The results were recorded as "Yes" when the marks were directly under canopy cover and "No" when they were not.

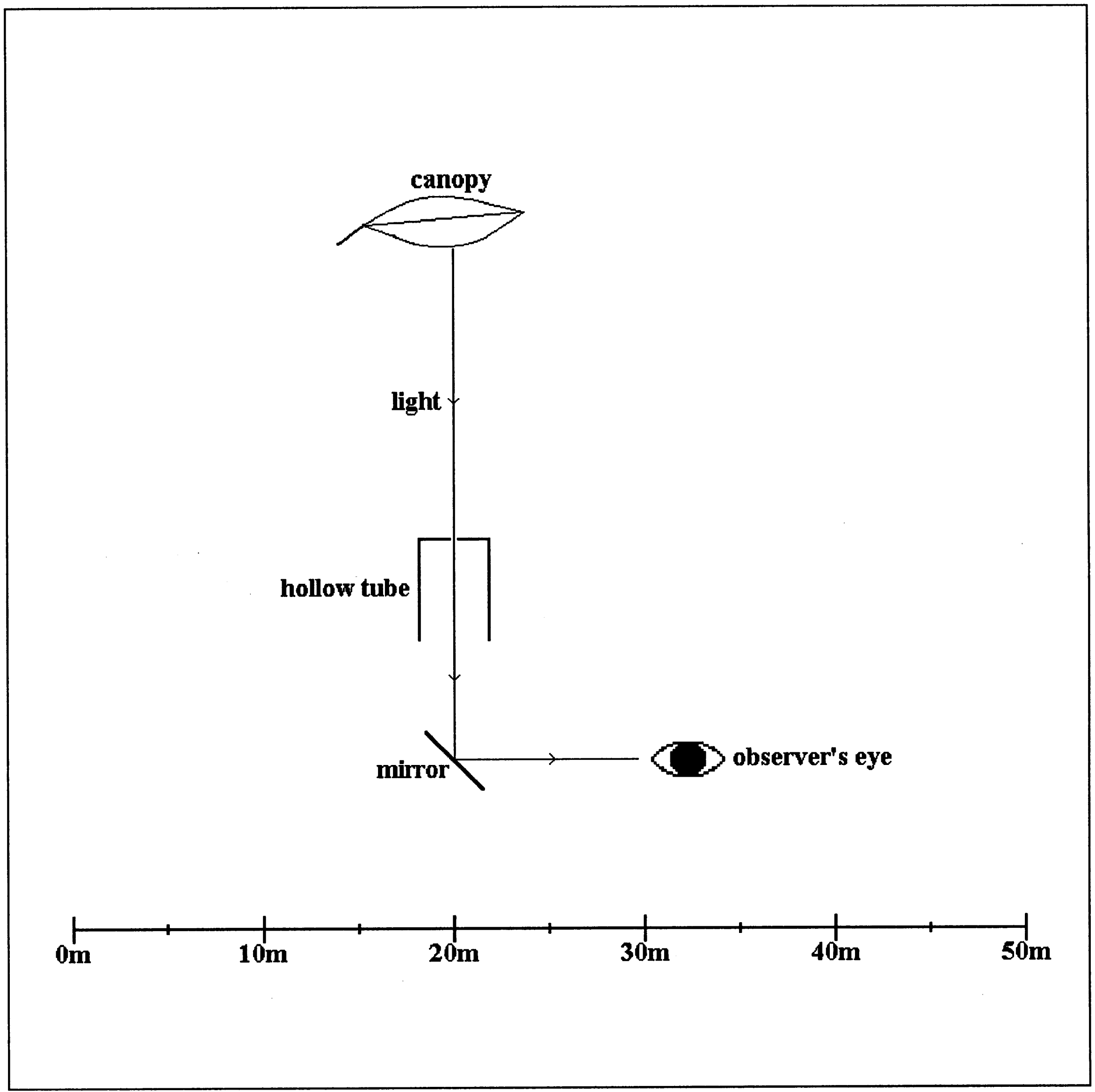

Figure 4.2 Diagrammatic illustration of the method used for canopy cover estimation.

Temperature and Relative Humidity Measurement

In addition to light intensity, air temperature and relative humidity were also measured using portable dataloggers continuously for the 3-day visitation period at two of the chosen areas at each site during each visit. The dataloggers were connected to the relative humidity/air temperature sensors (model 1400-104, LI-COR Inc.) through 3-metre extension cables. These sensors were fixed on vented stands at about 10cm above ground beside a wild lupine plant, but at least 2m away from the pyranometer sensors, so that they would not cast shadows on the pyranometer sensors and affect the light intensity measurement.

Data Analysis

Woody Species

Overall tree density at each site was calculated using the following equation:

$D = 10{,}000 / (1.67 \times d^2)$

where D = overall tree density [number of individual/ha]; and

d = mean distance of neighbouring trees at each site [m]

In this equation, the number 10,000 is the correction factor from square metres [m^2] to hectares [ha], and 1.67 is a conversion factor which converts the distance measurements to density (Cottam and Curtis 1949; Cottam *et al* 1953; Cottam 1956; Mueller-Domdois and Ellenberg 1974).

Relative abundance of each woody species was calculated by dividing the number of individuals of each species by the total number of trees recorded at each site. Density of each species, which was used for data analysis, was then calculated by multiplying the overall tree density (D) by the relative abundance of each species.

Multivariate Analysis of Biological Communities

To identify the most similar potential founder butterfly sites for each of the potential KBB reintroduction sites in terms of vegetation and tending ant community, comparisons among the sites were made using three different analytical tools.

Cluster Analysis

First, Cluster Analysis was used to group the sites. Cluster Analysis is a hierarchical classification method that uses a bottom-up rather than a top-down approach (Giri 1996; Lepš and Šmilauer 1999; Rencher 2002). It starts by grouping the most similar samples together as subgroups and then joins the subgroups to form larger groups (Sneath and Sokal 1973; Gauch 1982). The results are then displayed in a dendrogram. This is particularly useful in this study because I was interested in the similarities rather than the differences among the sites as I tried to match the most similar U.S. site with each Ontario site.

Cluster Analysis is powerful for biological community comparisons because it takes into account the differences in the abundance of all species at all sites and shows which sites belong to the same group and which do not. However, this method fails to identify the most similar potential founder butterfly site to a particular potential reintroduction sites when more than one potential founder butterfly site is grouped together with that potential reintroduction site. Also, this method does not allow down-weighting of rare species which tend to be overrepresented by their frequencies in vegetation surveys (Jongman *et al* 1995). This may skew the results and exaggerates the effect of the presence of rare species. Despite these shortcomings, it is still useful in showing the similarities among all the sites. Cluster Analysis was performed using the software PC-ORD version 4.0 using Sorensen distance measure, which generally gives the best performance (Beals 1984).

Detrended Correspondence Analysis

When Cluster Analysis fails to pinpoint which U.S. site is the most similar to each of the Ontario sites, Detrended Correspondence Analysis (DCA) was performed using the software CANOCO version 4.5. DCA is an ordination technique that tries to explain the maximum amount of variation among different samples by using hypothetical environmental gradients to which species abundance has a unimodal response (Hill and Gauch 1980; ter Braak 1986, 1994; Jongman *et al* 1995; Lepš and Šmilauer 2003). Instead of showing dendrograms with sites grouped together, DCA display the sites in a 2-dimensional plot where the similarity of the sites is represented by the distances among them. This allows comparisons of potential KBB reintroduction sites to various potential founder butterfly sites, which may not be possible in a dendrogram.

In DCA plots, the two ordination axes are shown in standard deviation (S.D.) units. A distance of four S.D. units represents a complete species turnover (Hill and Gauch 1980; Jongman *et al* 1995; Lepš and Šmilauer 2003). That means when the distance between two sites on a DCA diagram is more than four S.D. units, these sites do not have any species in common.

Sometimes, a "tongue-effect" may occur on a DCA diagram. It is a possible statistical artifact in DCA, in which one end of the first axis is artificially compressed along the second axis. Its occurrence often indicates that the samples at the tip of the "tongue" are very different from all the others, so that such difference dominates the first axis. Exclusion of these outliers from DCA usually eliminates the tongue-effect and allows a better display of the other samples on the DCA diagram.

DCA allows down-weighting of rare species (Lepš and Šmilauer 2003) which is not an option in Cluster Analysis. This helps to discount the overrepresentation of rare species found at each site. However, DCA is not perfect. It displays the sites on the 2-dimensional plot made from the 1st and 2nd axes resulting from the analysis, which very rarely explain all the variation among the sites. In fact, they often account for no more than 30% of the variation, which was the case in six of the seven DCA diagrams (Figures 4.8 to Figure 4.14) in this study. Moreover, DCA assumes a unimodal response of species along environmental gradients (Hill and Gauch 1980; Jongman *et al* 1995; Lepš and Šmilauer 2003). This is generally true if the sites included cover a wide range of environmental conditions. However, if the included sites share very similar environmental conditions, some of the species' response may resemble a straight line and the assumption of unimodal distribution may not hold (Jongman *et al* 1995; Lepš and Šmilauer 2003). As a result, DCA diagrams may not very accurately reflect the relative similarity among the sites. Because of this, DCA was only used to identify which single U.S. site is the most similar to the Ontario ones when Cluster Analysis failed to do so.

Multi-Response Permutation Procedures

Sometimes, it is still difficult to determine which of the potential founder butterfly sites is the most similar to the potential KBB reintroduction sites after performing Cluster Analysis and DCA because both methods fail to return a numerical value that quantifies the differences between different pairs of sites. In such cases, Multi-Response Permutation Procedures (MRPP) was performed using the software PC-ORD version 4.0 to solve this problem. MRPP is a nonparametric test that does not depend on multivariate normality and homogeneity of variances in the data set (Berry *et al* 1983; Mielke 1984, 2000). It uses a theoretical approach similar to that of ANalysis Of VAriance (ANOVA). It compares the within-group and between-group distances and returns the probability value of getting such difference between the two assuming that the sites are not different from one another (Berry *et al* 1983; Mielke 1984, 2000). Hence, it is very powerful in the sense that it provides probability values that can be used for hypothesis testing. However, it does have its limitations.

When a single variable is compared among multiple groups, ANOVA gives one single probability value that measures the chances of all these groups being the same. If a significant difference among the groups is detected, the Tukey test is used to distinguish which group(s) is/are significantly different from which (Zar 1996). Including two groups at a time and re-running ANOVA instead is not appropriate because the sample size is changed and the probability values obtained this way are not comparable among one another (Zar 1996). They cannot truly reflect their relative difference among the groups. Similarly, when multiple variables are compared, MRPP also returns one single probability value. However, there is no multivariate version of the Tukey test that could distinguish which group(s) is/are different from which when a significant difference is detected. Including two groups at a time to re-run MRPP will result in probability values that are not useful in determining significant differences between pairs of groups.

Fortunately, in this study, I am not trying to compare all sites to all the other ones. Nor am I interested in detecting significant differences. I am only comparing the three U.S. sites with each of the Ontario sites. By pairing up the three U.S. sites to one Ontario site and then performing MRPP three times, the three probability values could still be used to compare the "relative" similarity of the three U.S. sites to the Ontario site as the sample sizes are all the same in the U.S. sites and the Ontario site is common in all three MRPP.

However, such probability values are still of limited use in comparing the relative similarities among different pairs of sites because of their dependence on within-group distances. Since I was trying to identify the most similar U.S. site to the Ontario sites, I was interested in the between-group distances but not the within-group distances. If two U.S. sites have the same between-group distance with an Ontario site, but their within-group variances are different, the one with a smaller within-group variance will return a smaller probability value in its comparison with the Ontario site using MRPP. This means that the probability values obtained from MRPP can quantify the "probability" of the samples being the same, but not necessarily reflect the degree of difference among them.

Because of its limitations, MRPP was used to distinguish which potential founder butterfly site is the most similar to the Ontario sites only when both Cluster Analysis and DCA fail to give a definite answer. Also, the probability values were only used to detect the "relative" similarity of different pairs of sites and the 95% confidence interval was not used to determine the significance of the difference between the sites being compared. When the results of MRPP contradicted those of Cluster Analysis and DCA, conclusions were drawn based upon the results of Cluster Analysis and DCA instead of those of MRPP.

Canopy Cover

Canopy cover data were expressed as percentages of 1-metre transect markings that were under direct canopy cover at each site. The data collected in the two visits at the same site were compared and the higher value, which was always the summer instead of the spring estimation, was used for comparison among different sites.

Integrated Light Intensity

Integrated light intensity data were expressed in percentages as described in Chapter 3. The mean and standard deviation of integrated light intensity were then calculated for the 100 measurements at each site. These means and standard deviations were then substituted into the normal distribution equation (Zar 1996) to generate normal distribution curves of integrated light intensity for site comparison.

Temperature and Relative Humidity

Temperature and relative humidity were measured continuously for three days during each site visit and the measurements were not done simultaneously at all sites. Because of the temporal variability of temperature and relative humidity, the measurements recorded may not reflect the "average" condition of the sites. Therefore, the recorded data were standardized and transformed according to the data collected from the weather stations closest to the study sites between April 1st and September 30th 2003 before site comparison was done. The six-month period of April 1st to September 30th 2003 instead of a 12-month period was chosen because the over-wintering KBB eggs do not hatch until April and the 2nd brood adult butterflies all die before the end of September even in years with a wet and cool summer (Swengel and Swengel 1996). Also, since the annual frequency distribution of daily average temperature is usually bimodal for temperate areas, inclusion of the period from April to September captures only one of the two "modes", making the frequency distribution of temperature of the chosen period resemble a normal distribution. This allows a better estimation of the frequency distribution of temperature by generating normal distribution curves from the estimated means and standard deviations resulted from the linear regression between data recorded at the sites and those gathered from the closest weather stations.

Site Comparison

The three U.S. sites were ranked according to their relative similarity to each Ontario site in terms of 1) overall herbaceous plant community structure; 2) 1st brood KBB nectar source plants; 3) 2nd brood KBB nectar source plants; 4) tree community; 5) tending ant species; 6) canopy cover; 7) light intensity; 8) temperature; and 9) relative humidity based upon the results of Cluster Analysis, DCA, MRPP and direct graphical comparisons. For each individual variable at each Ontario site, the most similar U.S. site was given the similarity score of "3"; the next similar one the score of "2"; and the least similar one the score of "1". When the results of the comparison were inconclusive between two U.S. sites, the ranking scores of these two sites were averaged. For example, instead of giving a "3" and a "2", the similarity score of "2.5" was given to the two U.S. sites that are more similar to the Ontario site than the third one which received a similarity score of "1". I then calculated the overall similarity scores for the U.S. sites for each Ontario site by averaging the nine scores given in terms of the nine individual variables. The U.S. site with the highest overall similarity score was then identified for each Ontario site.

Results

Woody Species

All the woody plant species sampled using the nearest-neighbour method are listed in Tables 4.1. An "X" in Table 4.1 represents presence of the species in the corresponding sites. Absence of an "X" does not necessarily mean that the species is absent from the corresponding site. It only means that the species was not sampled by the nearest-neighbour method from the corresponding site.

Table 4.1 List of woody plant species sampled at all study sites.

Scientific Name	Common Name	Site							
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA
Acer rubrum L.	Red Maple			X			X		
Acer saccharum Marsh	Sugar Maple	X							
Amelanchier arborea Michx.	Downy Serviceberry			X	X	X	X		
Amelanchier Canadensis Medik.	Oblong-leaf Juneberry				X	X	X		
Cornus florida L.	Flowering Dogwood			X					
Cornus racemosa Lam.	Panicled Dogwood	X				X			
Corylus Americana Walt.	American Hazel			X			X		
Crataegus spp.	Hawthorn			X	X	X	X		
Fraxinus Americana L.	White Ash	X		X					
Hamamelis virginiana L.	Witch-hazel			X			X		
Juniperus communis L.	Common Juniper					X			
Juniperus virginiana L.	Eastern Red Cedar				X	X			
Malus angustifolia Michx.	Southern Crab Apple							X	
Malus coronaria Mill.	American Crab Apple				X	X			
Ostrya virginiana Koch.	Ironwood			X			X		
Pinus resinosa Ait.	Red Pine	X			X	X	X		
Pinus strobes L.	White Pine	X		X	X		X		
Populus alba L.	White Poplar	X		X					
Populus grandidentata Michx.	Big-tooth Aspen	X		X					
Populus spp.	Aspen								X
Populus tremuloides Michx.	Trembling Aspen		X	X			X	X	
Prunus pensylvanica L.	Pin Cherry			X					
Prunus pumila L.	Sand Cherry								X
Prunus serotina Ehrh.	Black Cherry	X	X	X	X	X	X	X	
Prunus virginiana L.	Chokecherry			X	X	X	X	X	
Quercus alba L.	White Oak	X	X	X	X	X	X	X	

(continued)

Table 4.1 (continued). List of woody plant species sampled at all study sites.

Scientific Name	Common Name	Site							
		HP	AFN	MT	PPP	KBS	MNF	IDNL	SCA
Quercus macrocarpa Michx.	Bur Oak	X			X		X		
Quercus rubra L.	Red Oak	X	X	X	X		X	X	
Quercus velutina Lam.	Black Oak	X	X	X	X	X	X	X	
Rhamnus cathartica L.	Common Buckthorn	X		X					
Rhus aromatica Ait.	Fragrant Sumac				X	X			
Rhus copallinum L.	Winged Sumac							X	
Rhus typhina L.	Staghorn Sumac		X	X					
Robinia pseudoacacia L.	Black Locust	X						X	
Salix discolour Muhl.	Pussy Willow		X					X	X
Salix spp.	Willow	X		X					
Sassafras albidum Nees	Sassafras	X		X	X		X	X	
Thuja occidentalis L.	Northern White Cedar					X			
Ulmus Americana L.	American Elm	X							
Viburnum rafinesquianum Schult.	Downy Arrowwood			X		X			

6. Manistee National Forest

Manistee National Forest (MNF) (N43.48° W86.22°) is located in the northwestern part of lower-Michigan. It covers 360,000 hectares (890,000 acres) of deciduous and mixed forests with occasional openings. The forest is not one continuous mass but broken by private properties and towns. Much of the land had been abandoned by logging companies after being logged out a century ago. Small residential homes are present in the area but there is no industrial complex. Within MNF, both paved and unpaved road systems are present. The forest is managed by the Forest Service of United States Department of Agriculture (USDA).

Manistee National Forest – #1 (MNF #1)

This area is about 1.2 hectares (3.0 acres) in size, close to an unpaved road. This is an opening with low tree density within a much denser forest habitat. Brush hogging has been used to reduce the canopy cover in this area. Signs of deer herbivory were obvious at this site, with about 10% of the wild lupine inflorescences having been selectively browsed.

Manistee National Forest – #2 (MNF #2)

This 2.8-hectare (7.0-acre) area is north of MNF #1. It is much more open compared to MNF #1, with large open areas with scattered mature trees surrounded by forests. Abandoned unpaved trails are found in this area. It has also been managed using the method of brush hogging. The problem of deer herbivory is more serious at this site, with 20% of the wild lupine inflorescences browsed.

Manistee National Forest – #3 (MNF #3)

This area is about 8.5 hectares (21 acres) in size, northeast to MNF #1 and MNF #2. The habitat of this area is very similar to that of MNF #2. Also, abandoned unpaved trails are present in several parts of this area. Brush hogging was used to manage this area. Deer herbivory is not very serious in this area. Less than 5% of the wild lupine inflorescences were consumed.

Wild lupine is present almost everywhere where openings are found within the forest, and also along paved and unpaved roads throughout the forest area.

7. Indiana Dunes National Lakeshore

Indiana Dunes National Lakeshore (IDNL) (N41.61° W87.19°) covers about 6,095 hectares (15,060 acres) of dunes, oak savannas, swamps, bogs, marshes, prairies, rivers, and forests running about 24km (15 miles) on the south shore of Lake Michigan approximately 80km (50 miles) southeast of Chicago, Illinois in the counties of Lake, Porter, and LaPorte in Northwest Indiana. 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).

Indiana Dunes National Lakeshore – #1 (IDNL #1)

This 3-hectare (7.4-acre) area is on the west side of the trail close to the entrance of the Inland Marsh Trail on a dune ridge. This area is quite shady with quite a lot of mature trees contributing to the relatively dense canopy cover. This area was burnt in spring 2003.

Indiana Dunes National Lakeshore – #2 (IDNL #2)

This area of 2 hectares (5 acres) is located on the east side and west side of the trail south of IDNL #1. This long and narrow area is quite open with only a few trees right beside the trail. This area was also burnt in 2003.

Indiana Dunes National Lakeshore – #3 (IDNL #3)

This 4-hectare (10-acre) area includes one northeast-facing slope and one southeast facing slope located at the southeast corner of the Inland Marsh Trail. This area is very open, especially on the northeast-facing slope, and is totally dominated by wild lupine. This area was also burnt in 2003.

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.

Wild lupine is found in locations other than these three areas within the SCA. In fact, wild lupine is the dominant herbaceous species in this artificially maintained prairie habitat. Wild lupine is also found in nearby areas outside of the SCA.

References

Nice, C. C., G. Gelembiuk, N. Anthony and R. ffrench-Constant. 2000. Population genetics and phylogeography of the butterfly genus *Lycaeides*. Report to the U.S. Fish and Wildlife Service, Fort Snelling, Minnesota. 44 pp.

IUCN 1998. IUCN guidelines for re-introductions. IUCN, Cambridge, U.K.

Cluster Analysis

Dendrograms generated by performing cluster analyses upon 1) all herbaceous species; 2) only 1st brood KBB nectar source plants; 3) only 2nd brood KBB nectar source plants; 4) all woody species; and 5) all tending ant species are presented as Figures 4.3 to 4.7 respectively. In all these figures, the potential KBB reintroduction sites in Ontario are represented by the colour black while the potential founder butterfly sites in the U.S.A. are in grey. This colour scheme will also be used in all subsequent Figures and Tables.

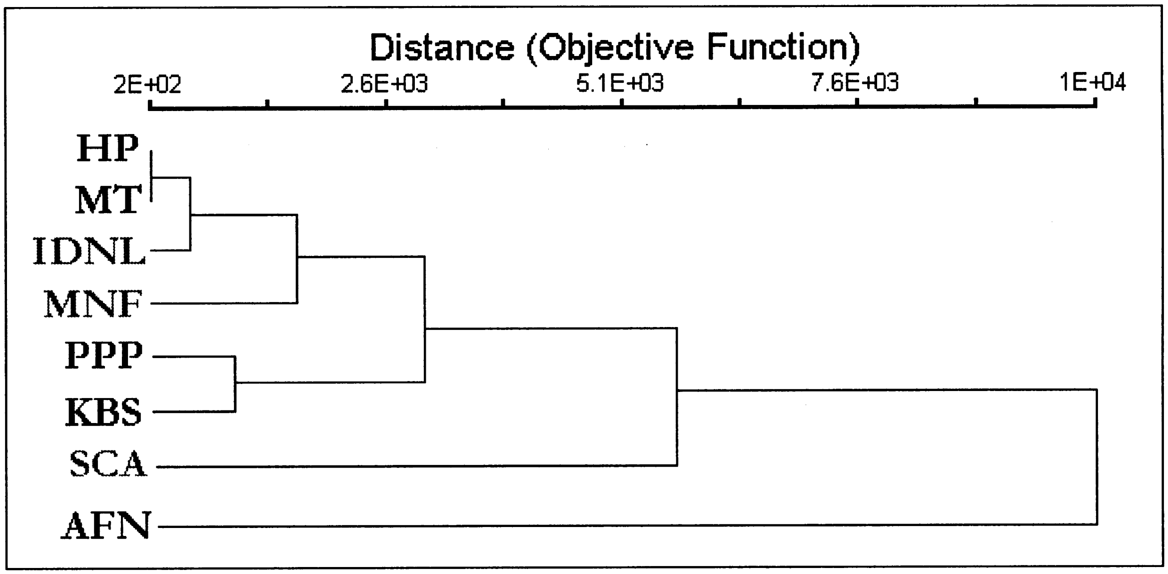

Figure 4.3 Dendrogram showing results of cluster analysis (including all herbaceous species) of all study sites.

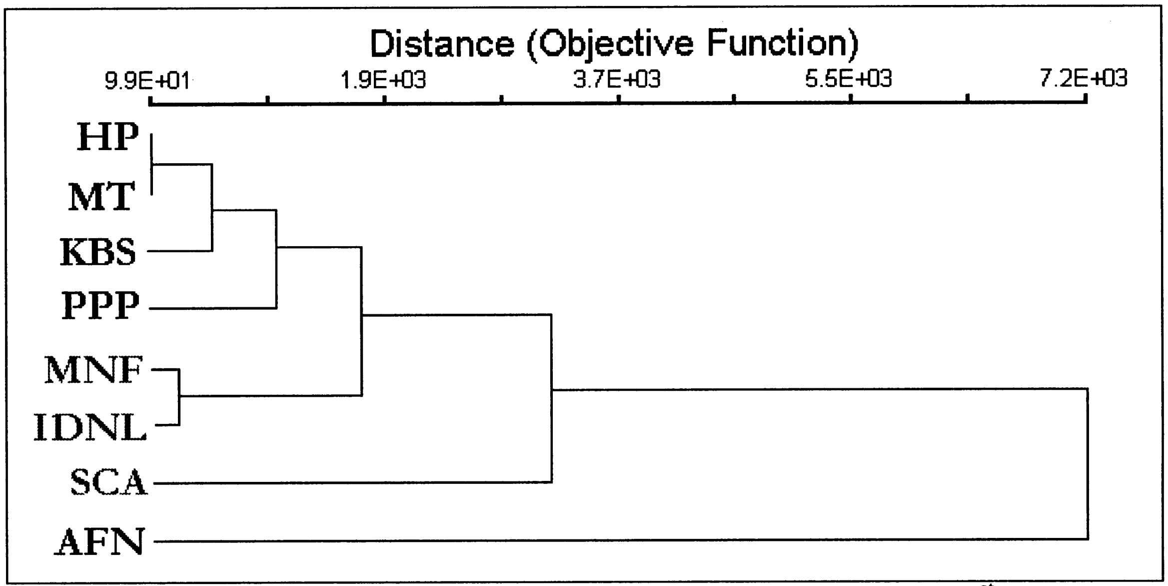

Figure 4.4 Dendrogram showing results of cluster analysis (including 1st brood KBB nectar source plants) of all study sites.

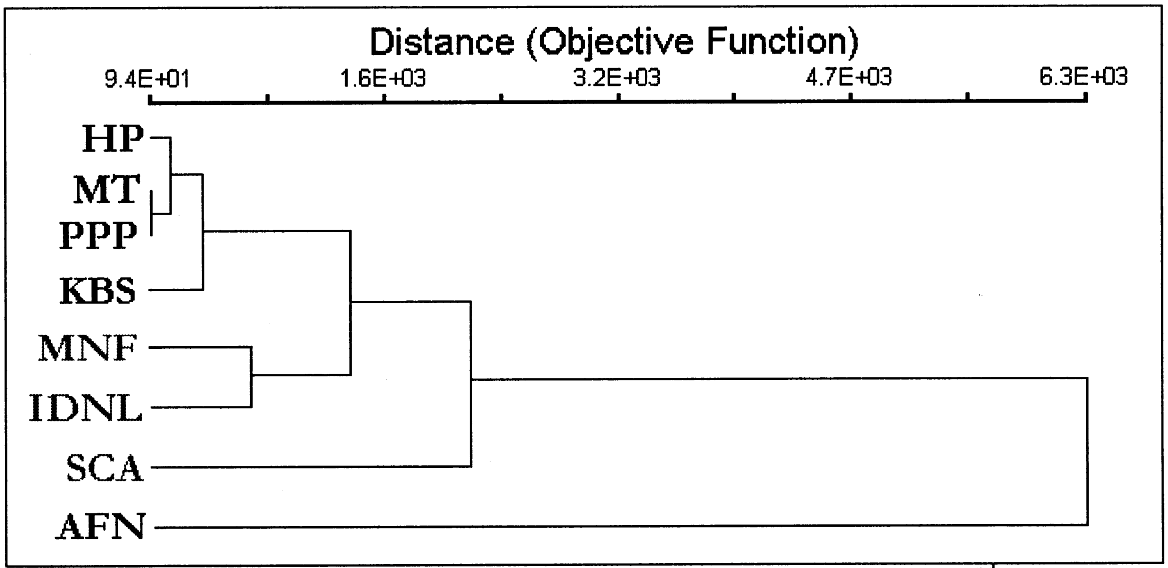

Figure 4.5 Dendrogram showing results of cluster analysis (including 2nd brood KBB nectar source plants) of all study sites.

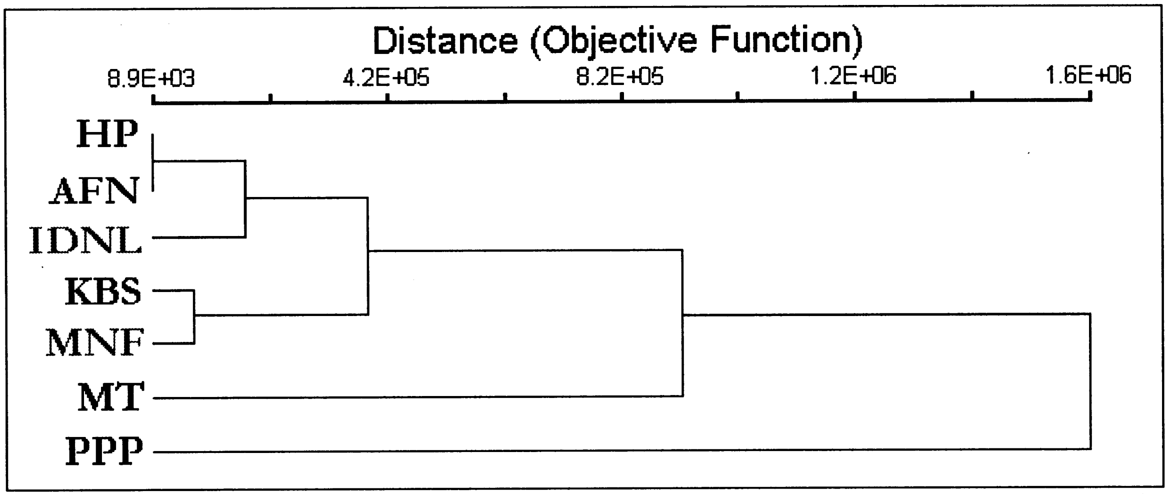

Figure 4.6 Dendrogram showing results of cluster analysis (including all woody species) of all study sites (except the Saratoga County Airport).

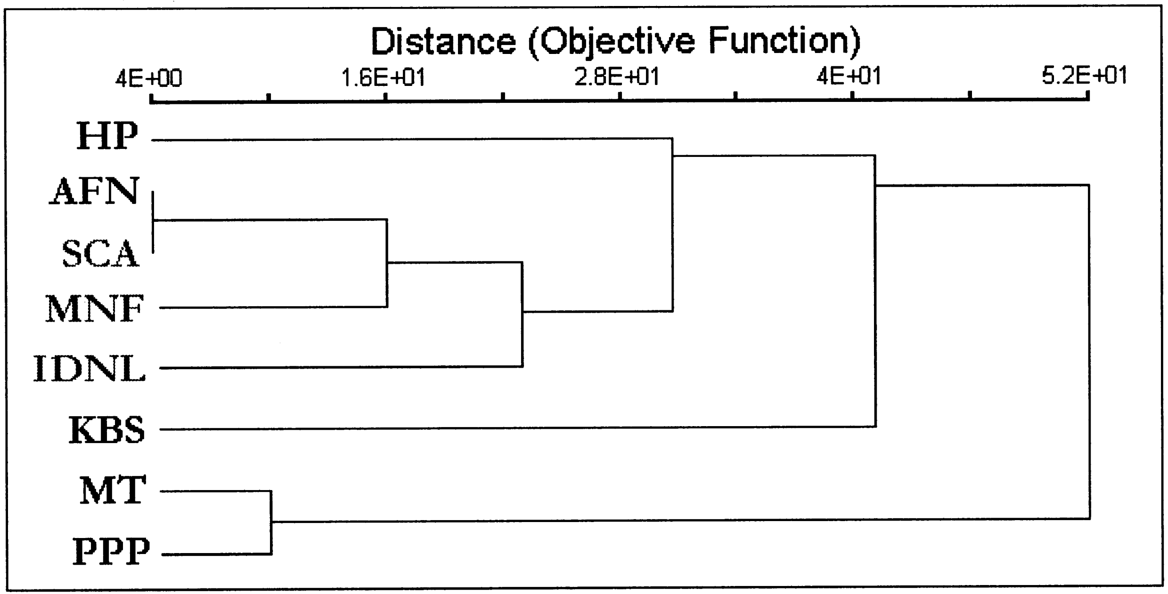

Figure 4.7 Dendrogram showing results of cluster analysis (including all tending ant species) of all study sites.

As seen in Figure 4.3, in terms of overall herbaceous vegetation, AFN is clearly an outlier. The SCA also forms a group by itself. In contrast, HP, the MT and IDNL cluster together as a group. So do PPP and the KBS.

In Figure 4.4 where data on 1st brood KBB nectar source plants were used, AFN is again an outlier and the SCA is also alone in one branch. All the Ontario sites except AFN are clustered in one group and MNF and IDNL form another group.

Again, very similar results were obtained in Figure 4.5 when only 2nd brood KBB nectar source plants were included. AFN and the SCA are two separate outlying groups. The other four Ontario sites form one group and MNF and IDNL form another.

When tree community data were used (Figure 4.6), HP, AFN and IDNL are grouped together. The KBS and MNF form one group while the MT and PPP form two separate outlying groups.

In terms of tending ant community (Figure 4.7), HP, AFN, the SCA, MNF and IDNL are grouped together with AFN and the SCA in a tight subgroup within. The MT and PPP form another group.

Detrended Correspondence Analysis

The DCA diagrams generated by including 1) all herbaceous species; 2) all herbaceous species excluding the site of AFN; 3) only 1st brood KBB nectar source plants; 4) only 2nd brood KBB nectar source plants; 5) only 2nd brood KBB nectar source plants excluding the site of SCA; 6) all woody species; and 7) all tending ant species are shown as Figures 4.8 to 4.14 respectively. To have a simply and clear picture, instead of showing individual samples (i.e. qudrats, transects) on the DCA diagrams, the centroids representing the averages of each study area are displayed on Figures 4.8 to 4.14.

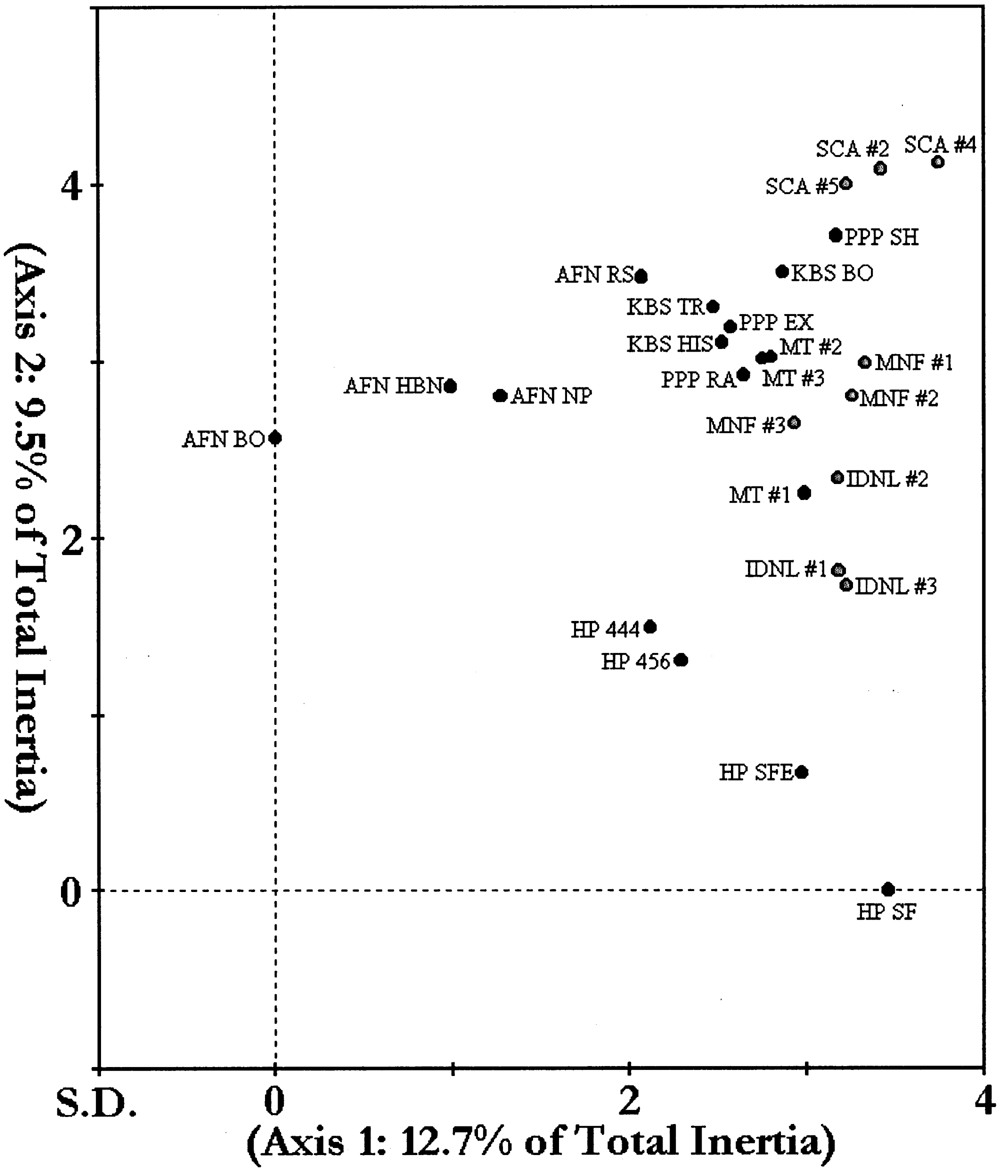

Figure 4.8 Diagram of DCA (including all herbaceous species) showing the scatter plot of the centroids representing the study areas of all study sites.

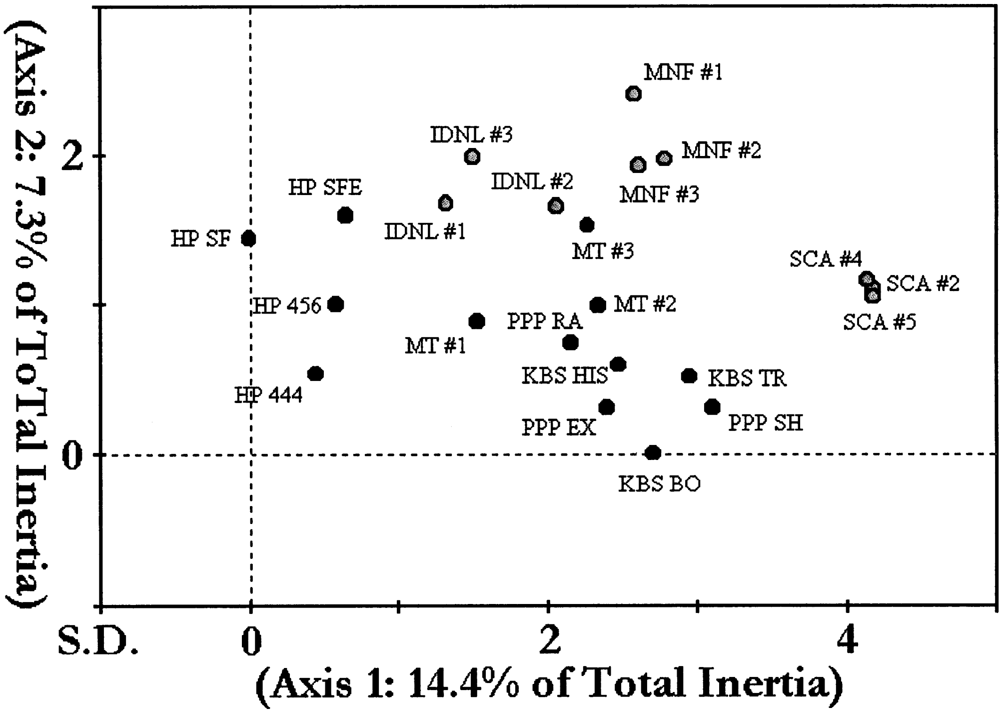

Figure 4.9 Diagram of DCA (including all herbaceous species) showing the scatter plot of the centroids representing the study areas of all study sites (except Alderville First Nation).

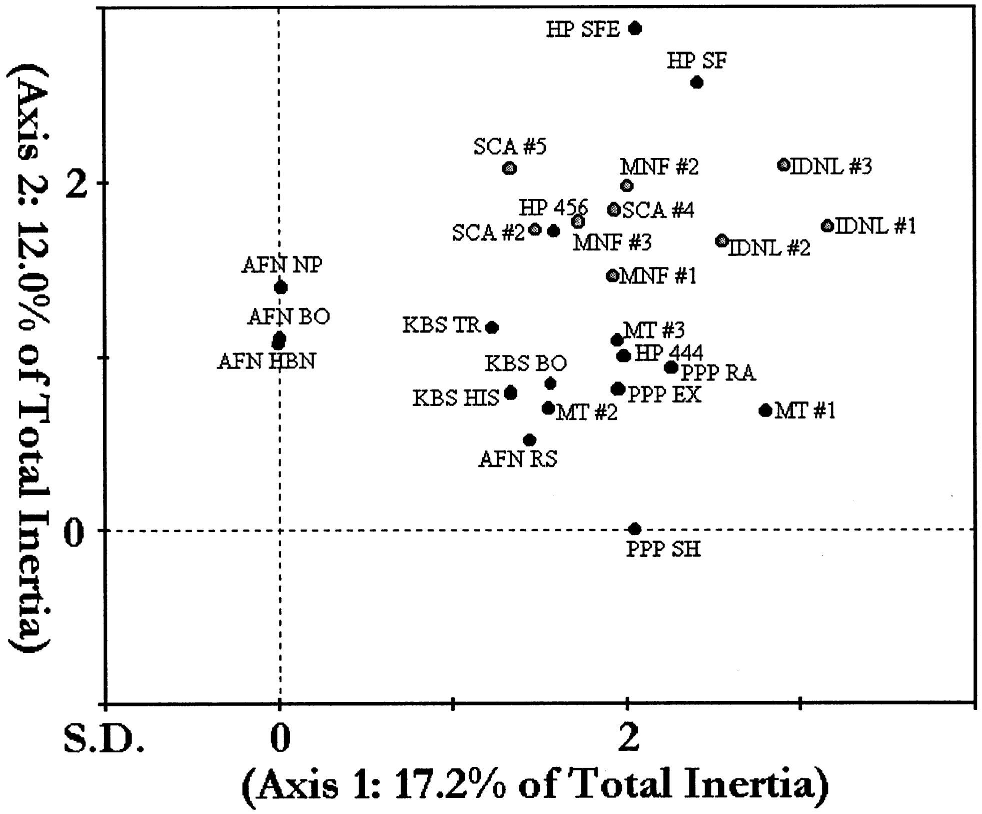

Figure 4.10 Diagram of DCA (including 1^{st} brood KBB nectar source plants) showing the scatter plot of the centroids representing the study areas of all study sites.

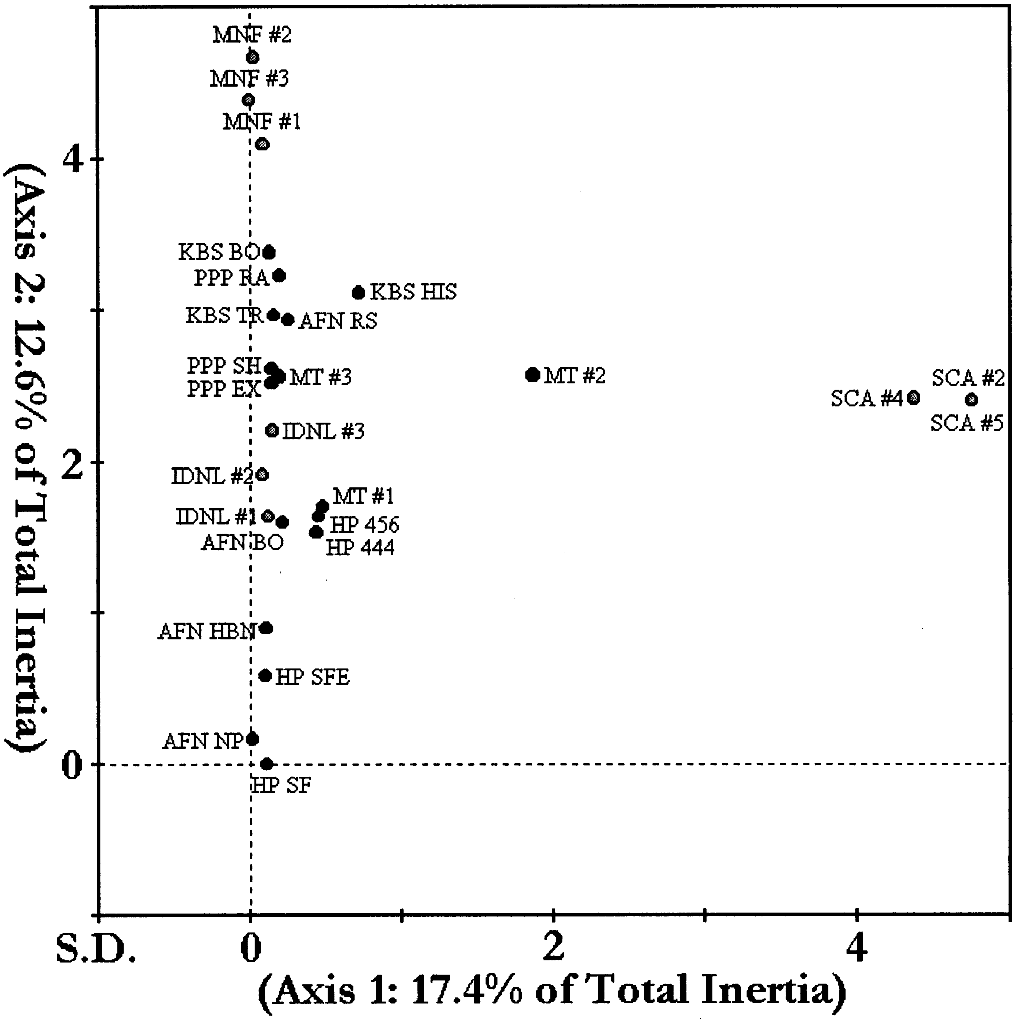

Figure 4.11 Diagram of DCA (including 2nd brood KBB nectar source plants) showing the scatter plot of the centroids representing the study areas of all study sites.

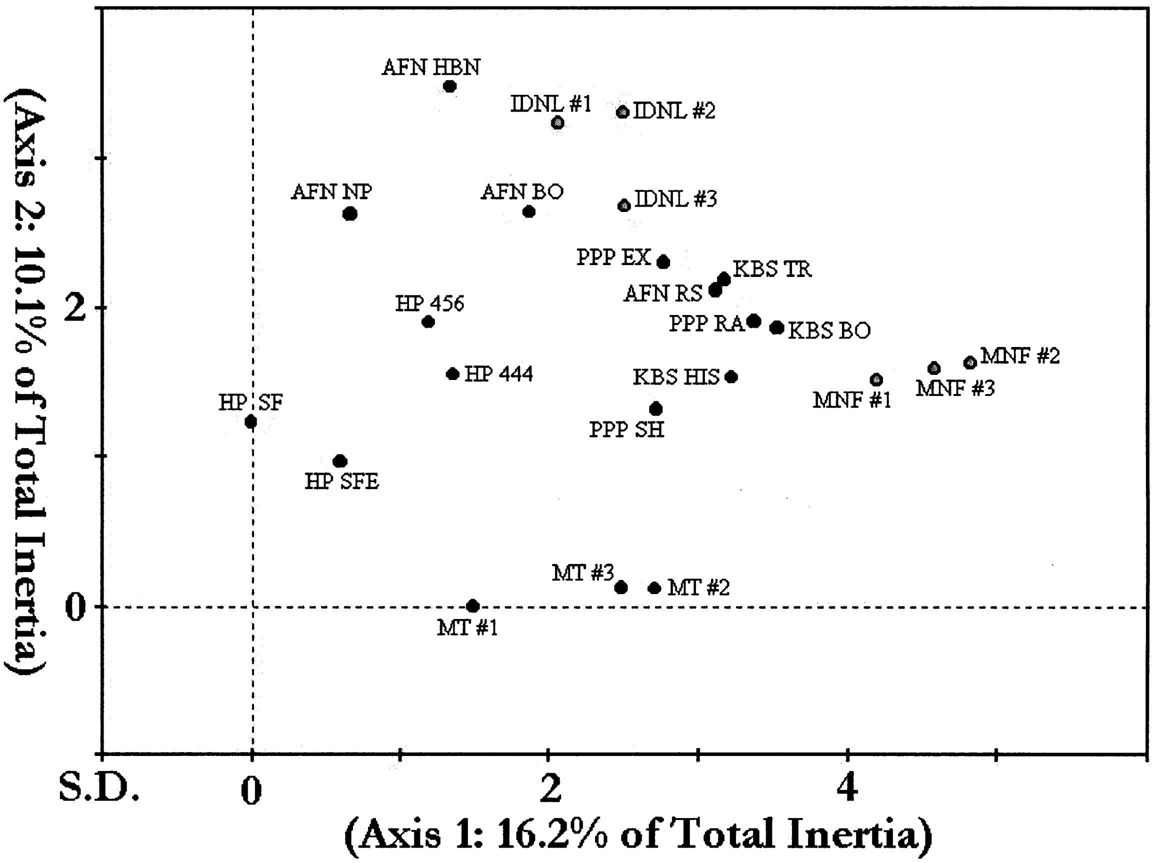

Figure 4.12 Diagram of DCA (including 2nd brood KBB nectar source plants) showing the scatter plot of the centroids representing the study areas of all study sites (except the Saratoga County Airport).

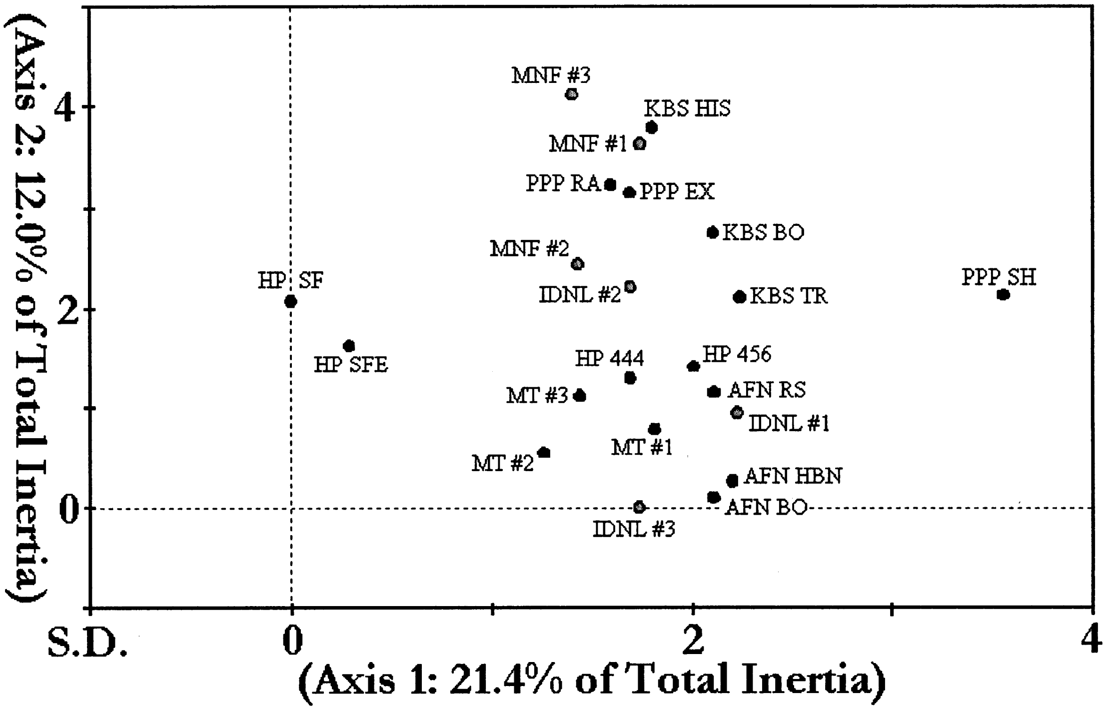

Figure 4.13 Diagram of DCA (including all woody species) showing the scatter plot of the centroids representing the study areas of all study sites.

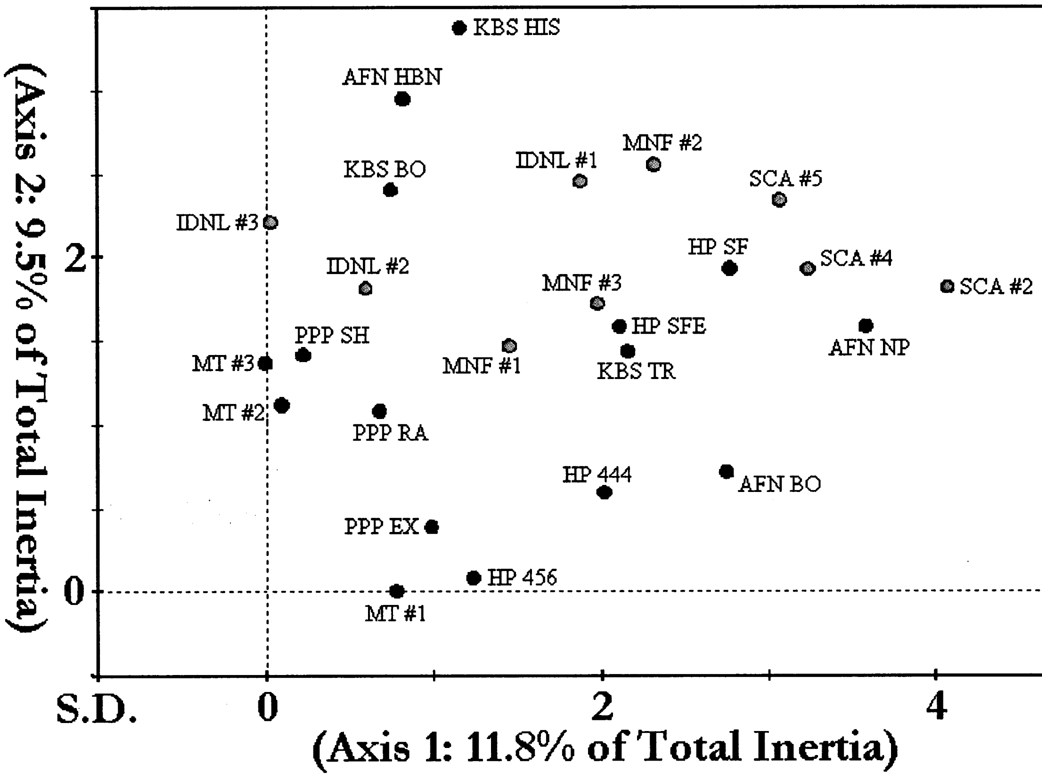

Figure 4.14 Diagram of DCA (including all tending ant species) showing the scatter plot of the centroids representing the study areas of all study sites.

In Figure 4.8 where all herbaceous data were included, a tongue-effect is observed, with the tip of the tongue on the left, generated by the presence of the points representing the study areas of AFN.

In Figure 4.9, AFN was excluded from the DCA of overall herbaceous vegetation. There seems to be a clear cut line separating the Ontario sites and the U.S. sites that runs from the top left to the bottom right corner. Points representing the different study areas in the same site are generally clustered together. Points representing HP are closest to those of IDNL, while points representing the MT, PPP and the KBS are about the same distance from those of MNF and IDNL, but farther away from those of the SCA.

Similar to Figure 4.9, a clear cut difference is observed between Ontario sites and the U.S. sites with the border between them running from the top left to the bottom right in Figure 4.10 where only 1st brood KBB nectar source plants were included, except that three of the four areas in HP appear in the U.S. "region" of the diagram. Points representing AFN, which are close to one another, are far from all the others. Points representing HP are close to those representing MNF and IDNL. The ones for the MT, PPP and the KBS are closer to the ones representing MNF than those of IDNL.

When only 2nd brood KBB nectar source plants were used for DCA (Figure 4.11), a tongue-effect even more serious than that in Figure 4.8 is observed, with the tip of the tongue on the right side composed of points representing the study areas of the SCA.

In Figure 4.12, the SCA was excluded from the DCA using 2nd brood KBB nectar source plant data. No clear distinction can be observed between Ontario and the U.S. sites. Points representing HP and AFN are closest to the ones representing IDNL than those of MNF, The ones for PPP and the KBS, which are clustered together, are between those of MNF and IDNL. The points of the MT are close to the 1st axis and quite far from all the others.

In Figure 4.13, where woody species data were used, the SCA was again excluded from the analysis because of absence of trees at this site. Points representing HP, AFN and the MT are closer to those of IDNL than MNF, while PPP and the KBS are closer to MNF rather than IDNL.

In terms of tending ant community (Figure 4.14), points representing AFN are closest to the SCA while points of HP are closest to MNF. Points representing the MT, PPP and the KBS are close to those of MNF and IDNL, but not to the ones of the SCA.

Multi-Response Permutation Procedures

Results of MRPP of the five potential KBB reintroduction sites in Ontario against the three potential founder butterfly sites in the U.S.A. for 1) all herbaceous species; 2) only 1st brood KBB nectar source plants; 3) only 2nd brood KBB nectar source plants; 4) all woody species; and 5) all tending ant species are shown as Tables 4.2 to 4.6 respectively. The values shown in Tables 4.2 to 4.6 are probability values resulting from the MRPP and the numbers in brackets are the similarity scores based upon the results of Cluster Analysis, DCA and MRPP. The bold numbers are the highest probability values and similarity scores resulting from the multiple comparison of each Ontario site with the U.S. sites, and the underlined similarity scores show where the results of Cluster Analysis and DCA disagree with those of MRPP.

	MNF	IDNL	SCA
HP	0.0117 (2)	**0.0835 (3)**	0.0086 (1)
AFN	**0.0515 (3)**	0.0423 (2)	0.0259 (1)
MT	0.0227 (2)	**0.0275 (3)**	0.0226 (1)
PPP	**0.0332 (3)**	0.0263 (2)	0.0285 (1)
KBS	0.0223 (2)	**0.0231 (3)**	0.0209 (1)

Table 4.2 Probability values resulting from MRPP (including all herbaceous species) between the potential KBB reintroduction sites in Ontario and the potential founder KBB sites in the U.S.A.

	MNF	IDNL	SCA
HP	**0.0217 (3)**	0.0099 (2)	0.0090 (1)
AFN	0.0499 (2)	0.0326 (1)	**0.0516 (3)**
MT	0.0248 (2)	**0.0314 (3)**	0.0229 (1)
PPP	**0.0699 (3)**	0.0505 (2)	0.0421 (1)
KBS	**0.0247 (3)**	0.0224 (2)	0.0231 (1)

Table 4.3 Probability values resulting from MRPP (including 1st brood KBB nectar source plants) between the potential KBB reintroduction sites in Ontario and the potential founder KBB sites in the U.S.A.

	MNF	IDNL	SCA
HP	0.0215 (2)	**0.0694 (3)**	0.0192 (1)
AFN	0.0689 (1)	0.0363 (2)	**0.0845 (3)**
MT	0.0254 (2)	**0.0307 (3)**	0.0259 (1)
PPP	0.0323 (2)	**0.0416 (3)**	0.0248 (1)
KBS	**0.0285 (3)**	0.0227 (2)	0.0227 (1)

Table 4.4 Probability values resulting from MRPP (including 2nd brood KBB nectar source plants) between the potential KBB reintroduction sites in Ontario and the potential founder KBB sites in the U.S.A.

	MNF	IDNL	SCA
HP	0.0120 (2)	**0.0121 (3)**	(1)
AFN	0.0242 (2)	**0.0344 (3)**	(1)
MT	0.0241 (2)	**0.0301 (3)**	(1)
PPP	**0.4842 (3)**	0.0636 (2)	(1)
KBS	**0.5649 (3)**	0.1605 (2)	(1)

Table 4.5 Probability values resulting from MRPP (including all woody species) between the potential KBB reintroduction sites in Ontario and the potential founder KBB sites in the U.S.A. (except the Saratoga County Airport).

	MNF	IDNL	SCA
HP	**0.0315 (3)**	0.0170 (1)	0.0225 (2)
AFN	0.0209 (2)	0.0237 (1)	**0.0572 (3)**
MT	0.0243 (2)	**0.1862 (3)**	0.0258 (1)
PPP	0.0248 (2)	**0.1629 (3)**	0.0217 (1)
KBS	**0.0818 (3)**	0.0420 (2)	0.0329 (1)

Table 4.6 Probability values resulting from MRPP (including all tending ant species) between the potential KBB reintroduction sites in Ontario and the potential founder KBB sites in the U.S.A.

When overall herbaceous vegetation is compared (Table 4.2), the highest probability values were found in the comparisons between IDNL and HP ($P = 0.0835$), the MT ($P = 0.0275$) and the KBS ($P = 0.0231$) and between MNF and AFN ($P = 0.0515$) and PPP ($P = 0.0332$). In the comparisons with PPP, disagreement of results between Cluster Analysis and MRPP is seen between MNF and the SCA.

In the comparisons of 1st brood KBB nectar source plants (Table 4.3), MNF gave the highest probability values in the comparisons of the U.S. sites with HP ($P =0.0217$), PPP ($P = 0.0699$) and the KBS ($P = 0.0247$). Comparisons of AFN and the MT with the U.S. sites return highest probability values from the SCA ($P = 0.0516$) and IDNL ($P = 0.0314$) respectively. Results of Cluster Analysis, DCA and MRPP all agree with one another.

When only 2nd brood nectar source plants were included in the comparisons (Table 4.4), IDNL gave the highest probability values in the comparisons with HP ($P = 0.0694$), the MT ($P = 0.0307$) and PPP ($P = 0.0416$) while the SCA and MNF returned the highest probability values in the comparisons with AFN and the KBS respectively. Disagreement of results between Cluster Analysis and MRPP is observed in the comparisons with AFN between the U.S. sites MNF and IDNL.

In the comparisons of the tree communities (Table 4.5), the highest probability values were returned from IDNL in the comparisons with HP ($P = 0.0121$), AFN ($P = 0.0344$) and the MT ($P = 0.0301$). For PPP ($P = 0.4842$) and the KBS ($P = 0.5649$), the highest probability values returned from MNF. Results of Cluster Analysis, DCA and MRPP all agree with one another in the comparison of tree community.

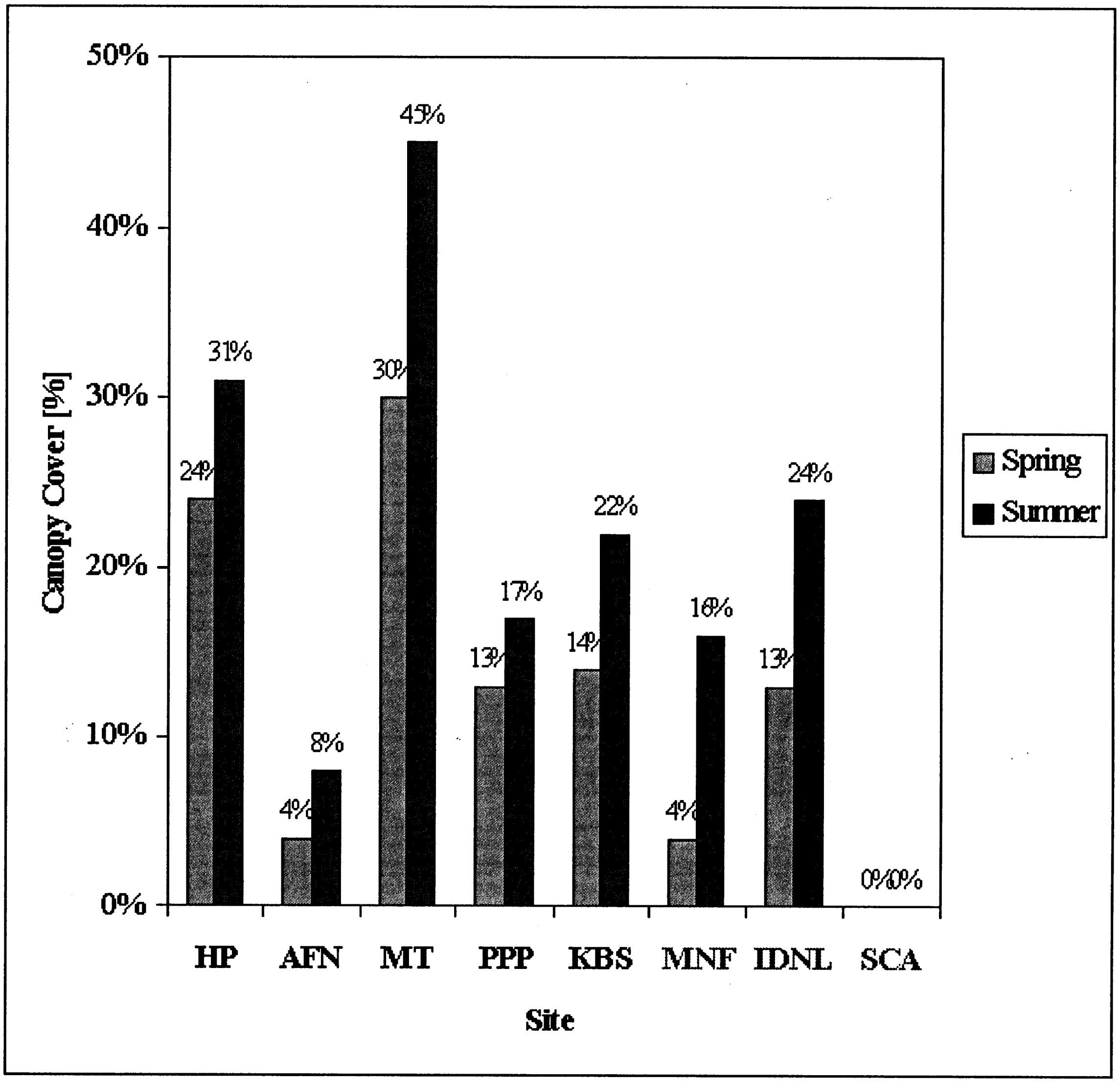

Figure 4.15 Spring and summer percentage canopy cover at all study sites.

	MNF	IDNL	SCA
HP	2	3	1
AFN	3	2	1
MT	2	3	1
PPP	3	2	1
KBS	2	3	1

Table 4.7 Similarity scores of potential founder KBB sites in the U.S.A. for each potential KBB reintroduction sites in Ontario based upon percentage canopy cover.

Integrated Light Intensity

Figure 4.16 shows the normal distribution curves generated by the means and standard deviations of integrated light intensity for all sites. The lines representing HP and the SCA share a very similar shape and show the highest mean integrated light intensities among all sites. The line representing MNF is particularly flat, showing a high standard deviation of integrated light intensity. Both the MT and the KBS show low mean and standard deviation in integrated light intensities, and the U.S. site with the most similar pattern is IDNL, which also shares similar pattern with AFN and PPP.

The similarity scores of the U.S. site to each Ontario site based upon the results of the integrated light intensity measurements are summarized in Table 4.8.

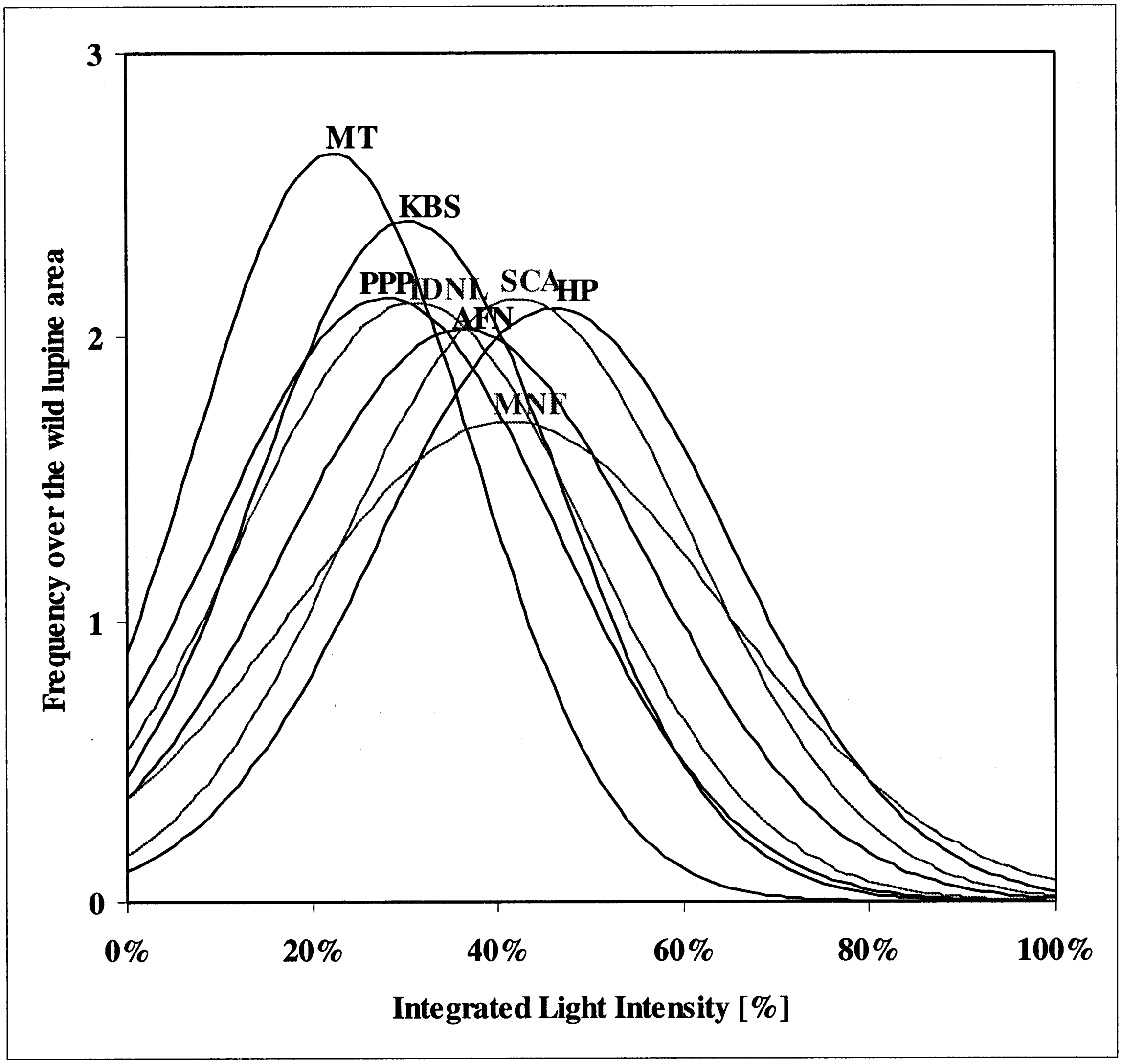

Figure 4.16 Spatial frequency distribution of integrated light intensity at all study sites.

	MNF	IDNL	SCA
HP	1	2	3
AFN	1	2.5	2.5
MT	1	3	2
PPP	1	3	2
KBS	1	3	2

Table 4.8 Similarity scores of potential founder KBB sites in the U.S.A. for each potential KBB reintroduction sites in Ontario based upon integrated light intensity.

Air Temperature and Relative Humidity

Data collected by the dataloggers were adjusted and transformed according to the meteorological data collected from the weather stations closest to my study sites. Figures 4.17 and 4.18 were generated according to the "estimated" means and standard deviations of daily average temperature and relative humidity at each site from April 1st to September 30th 2003. They show the frequency distribution of the daily average temperature and relative humidity within the 6-month period assuming the frequencies are normally distributed.

The similarity scores of the U.S. site to each Ontario site based upon temperature and relative humidity data are summarized in Tables 4.9 and 4.10 respectively.

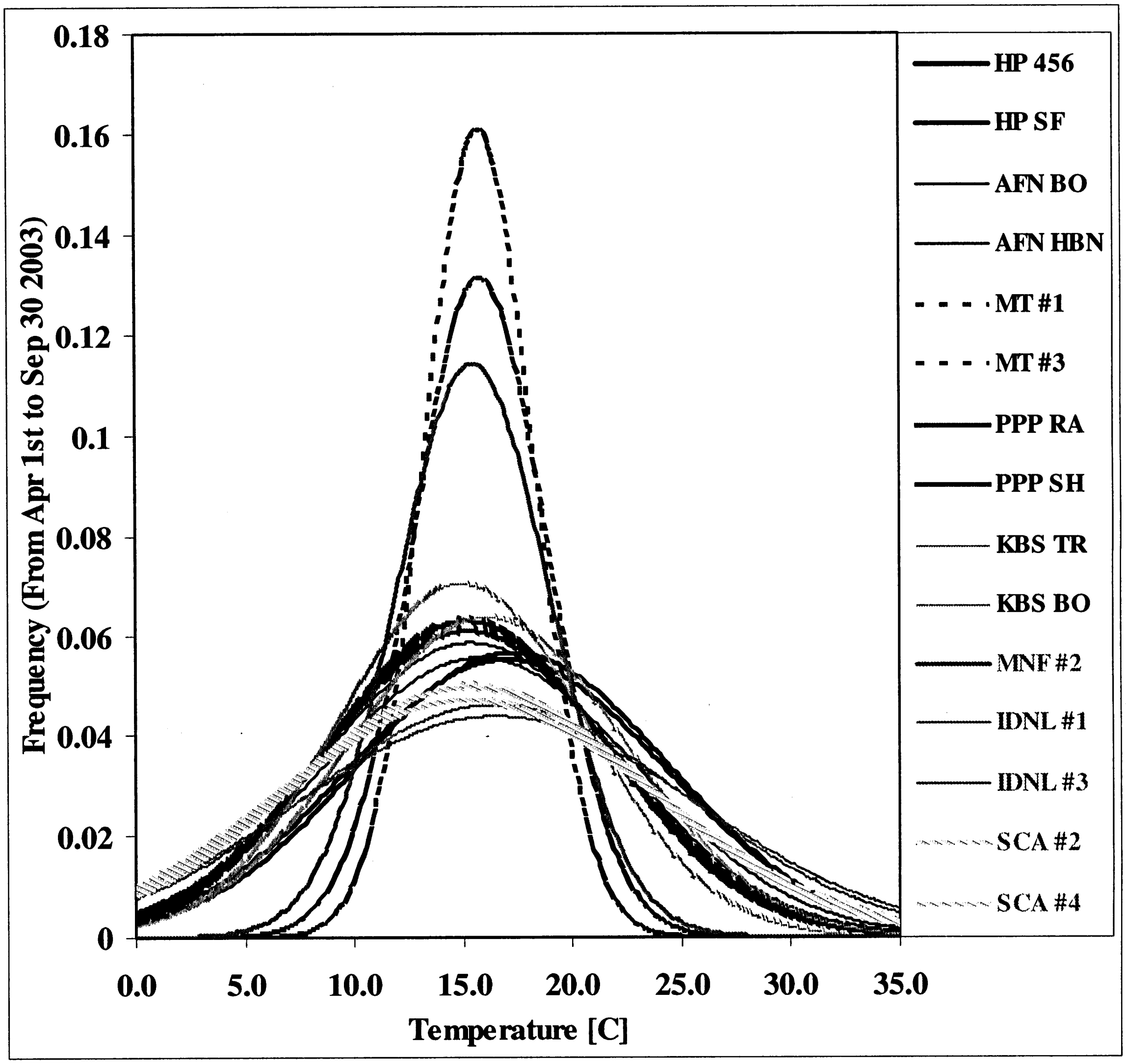

Figure 4.17 Estimated frequency distribution of daily average temperature from 04/01/2003 to 09/30/2003 in selected study areas.

	MNF	IDNL	SCA
HP	1	2	3
AFN	1	2	3
MT	3	1	2
PPP	1	2	3
KBS	1	2	3

Table 4.9 Similarity scores of potential founder KBB sites in the U.S.A. for each potential KBB reintroduction sites in Ontario based upon temperature.

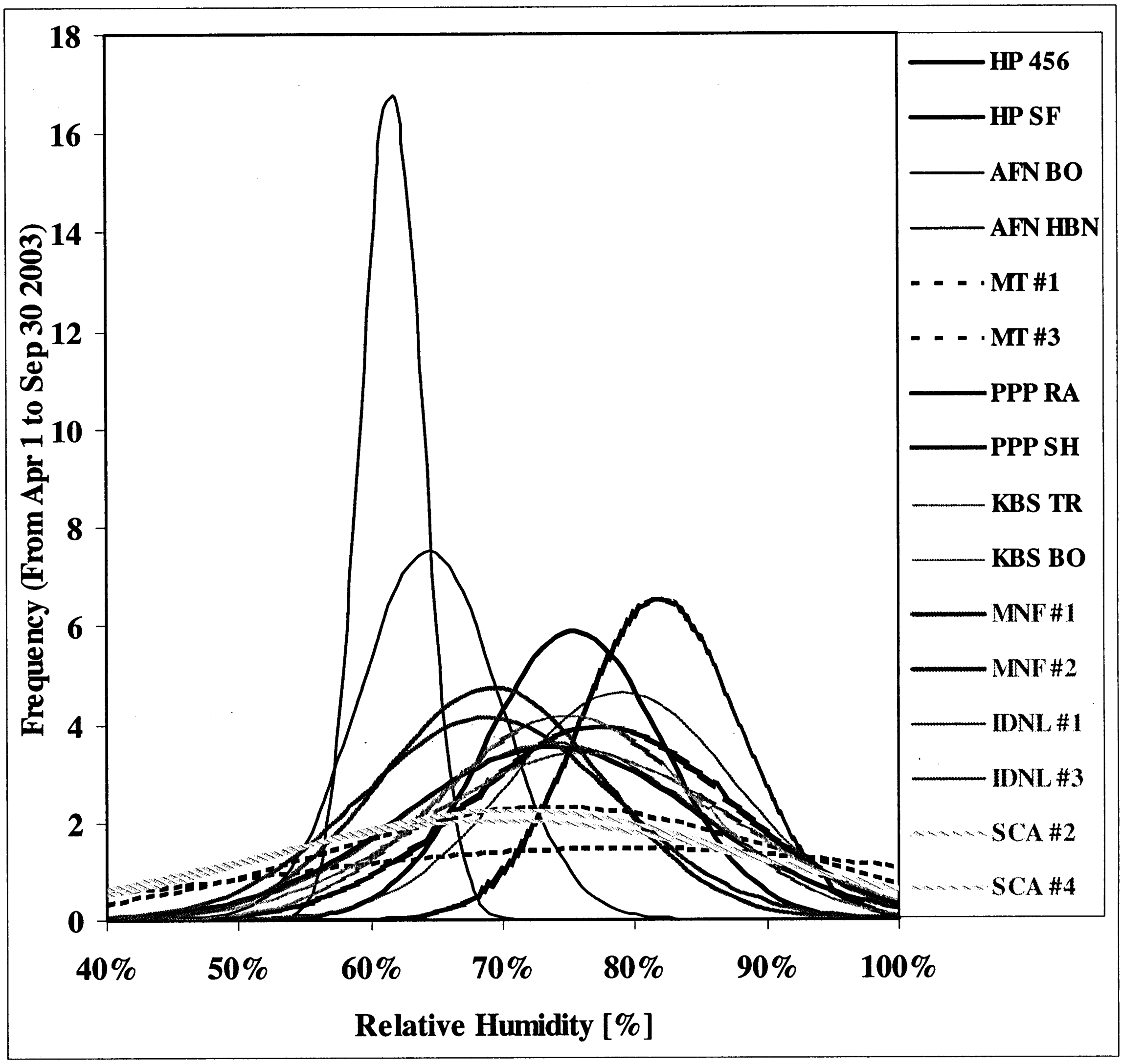

Figure 4.18 Estimated frequency distribution of daily average relative humidity from 04/01/2003 to 09/30/2003 in selected study areas.

	MNF	IDNL	SCA
HP	2	3	1
AFN	3	2	1
MT	2	1	3
PPP	2	3	1
KBS	2	3	1

Table 4.10 Similarity scores of potential founder KBB sites in the U.S.A. for each potential KBB reintroduction sites in Ontario based upon relative humidity.

In Figure 4.17, two areas were included from each site except for MNF where only one area was included due to technical problem with one of the dataloggers. The estimated mean daily average temperatures from April to September 2003 of all sites are very similar to one another. However, in the two areas in the MT and MNF #2, the standard deviation of the daily average temperature is much smaller than all the other sites which share standard deviations of similar magnitude. For all the other sites, the lines representing them are very close to one another.

In contrast, variation in daily average relative humidity over the six-month period is quite different among the study sites. The lowest estimated mean daily average relative humidity was found at AFN, and the standard deviation of the daily average relative humidity at this site is also lower than those of all other sites (Figure 4.18). The lines representing the MT and the SCA show very flat shapes, indicating that the standard deviation of daily average relative humidity is high at both of these sites. The lines representing PPP show the highest mean daily average relative humidity among all the sites followed those of IDNL. Lines representing HP and the KBS also share similar very shape with those of IDNL.

Table 4.11 summarizes the overall similarity scores for the U.S. sites for each Ontario site by averaging the nine scores given in terms of the nine individual environmental variables. The highest average similarity score among the U.S. sites for each Ontario site is shown in bold in Table 4.11, indicating that that particular U.S. site is the most similar potential source KBB site to the corresponding Ontario potential KBB reintroduction site.

	MNF	IDNL	SCA
HP	2	**2.44**	1.56
AFN	2	1.94	**2.06**
MT	1.78	**2.56**	1.67
PPP	2.22	**2.33**	1.44
KBS	2.22	**2.28**	1.5

Table 4.11 Summary of the most similar potential founder KBB sites in the U.S.A. identified for each potential KBB reintroduction sites in Ontario based on average similarity ranking of different biotic and abiotic characteristics.

Discussion

Overall Herbaceous Vegetation

When the overall herbaceous vegetation is compared among all sites using Cluster Analysis, it is clear that AFN is an outlier (see Figure 4.3), which means that the vegetation community structure in AFN is very different from all the other sites. HP and the MT grouped together with IDNL. This means that the most similar potential source butterfly site in terms of overall vegetation community to these two Ontario sites is IDNL, which is therefore assigned a similarity score of "3" to its comparisons with HP and the MT (Table 4.2). For PPP and the KBS, Figure 4.3 cannot tell which of MNF or IDNL is more similar to them in terms of overall vegetation community structure.

The results of DCA reconfirm those of the Cluster Analysis for the overall herbaceous vegetation. AFN was excluded from the DCA shown in Figure 4.9 because it causes a "tongue-effect" in the DCA diagram when it is included in the analysis (Figure 4.8), indicating that it is an outlier. As in the cluster analysis, the points representing HP and the MT are closer to those representing IDNL than those of MNF and the SCA, meaning that IDNL is the U.S. site most similar to these two Ontario sites in terms of overall herbaceous plant composition. In Figure 4.9, it is still hard to tell if the points representing PPP and the KBS are closer to those of MNF or those of IDNL. This means that it is still uncertain whether MNF or IDNL is more similar to PPP and the KBS in terms of overall herbaceous vegetation.

The results of MRPP confirm those of Cluster Analysis and DCA. For HP and the MT, the highest probability values were obtained from the comparison with IDNL (Table 4.2). This again suggests that IDNL is the most similar potential founder butterfly site to HP and the MT. The highest probability value for AFN is returned from MNF (P = 0.0515). This means that even though AFN is very different from all the U.S. sites, it is the least different from MNF in terms of overall herbaceous plants, which was therefore given the similarity score of "3" in this case (Table 4.2). For PPP and the KBS, the highest probability values were returned from the comparisons with MNF and IDNL respectively, indicating that MNF and IDNL are the most similar U.S. sites to them respectively in terms of overall herbaceous species composition.

According to the results of MRPP (Table 4.2), the SCA is more similar to PPP than IDNL is. This contradicts with the results of Cluster Analysis, where the SCA is shown as one of the outliers while the MNF and IDNL can be grouped together with PPP (Figure 4.3), indicating that IDNL is more similar to PPP than the SCA is. Because of the limitations of MRPP and the uncertainty of its reliability using for such paired-up comparisons, IDNL is identified as the second most similar (similarity score = 2) and the SCA the least similar (similarity score = 1) to PPP (Table 4.2).

1st Brood Karner Blue Butterfly Nectar Source Plants

When only 1st brood KBB nectar source plants are included in the Cluster Analysis, AFN is again an outlier from all the other sites (Figure 4.4). The other four Ontario sites are grouped together and their neighbouring group contains both MNF and IDNL. This means that it is impossible to tell from Figure 4.4 whether MNF or IDNL is the most similar to the four Ontario sites in terms of 1st brood nectar source plants.

In Figure 4.10, the points representing AFN is closest to the ones of the SCA. This suggests that the SCA is the best match for AFN in terms of 1st brood KBB nectar source plants. The points of HP and the KBS are also closer to the ones representing MNF than those of IDNL, indicating that MNF rather than IDNL is the most similar U.S. site to HP and the KBS in terms of 1st brood nectar source plants. On the other hand, it is difficult to determine if the points of the MT and PPP are closer to those of MNF or IDNL. Therefore, it is still unresolved whether MNF or IDNL is more similar to the MT and PPP for 1st brood KBB nectar source plant community.

In Table 4.3, results of the MRPP confirm those obtained from Cluster Analysis and DCA. The most similar U.S. site in terms of 1st brood nectar plants for HP ($P = 0.0217$) and the KBS ($P = 0.0247$) is MNF, and for AFN ($P = 0.0516$) is the SCA. For the MT and PPP, the highest probability values were returned from the comparisons with IDNL ($P = 0.0314$) and MNF ($P = 0.0699$) respectively. This implies that IDNL is the most similar to the MT and MNF the most similar to PPP in terms of 1st brood KBB nectar source plants. Since the results of Cluster Analysis and DCA agree with those of

MRPP in terms of 1st brood KBB nectar source plants, similarity scores were assigned according to the probability values in Table 4.3 to all Ontario-U.S. site comparisons.

2nd Brood Karner Blue Butterfly Nectar Source Plants

With respect to 2nd brood KBB nectar source plants, results of Cluster Analysis (Figure 4.5) were similar to those for 1st brood (Figure 4.4). AFN is an outlier and the other four Ontario sites form a sister group with MNF and IDNL. This again makes it impossible to tell which of MNF or IDNL is the most similar to the four Ontario sites in terms of 2nd brood nectar source plants based on Figure 4.5 alone.

In contrast, the DCA diagrams for 1st (Figure 4.10) and 2nd brood (Figure 4.12) nectar source plants look quite different. First of all, the SCA was excluded from the DCA because inclusion of it causes a "tongue effect" (Figure 4.11). This indicates that the SCA is very different from all the other sites in terms of 2nd brood nectar source plants. HP, AFN and PPP are closest to the U.S. site IDNL while the KBS is closest to MNF. The points representing the MT are somewhat in between those of IDNL and MNF, so which of these two sites is more similar to MT in 2nd brood nectar source plant composition is inconclusive from the results of Cluster Analysis and DCA.

The results of MRPP (Table 4.4) for 2nd brood nectar source plants generally agree with the results of Cluster Analysis and DCA, with HP, and PPP matching up with IDNL and the KBS matching up with MNF. However, instead of matching up with IDNL, the highest probability value for AFN ($P = 0.0845$) was obtained from the comparison with the SCA. In fact, IDNL returned the lowest probability value among the three U.S. sites. This disagreement was probably a result of exclusion of the SCA in the DCA. According to the results of Cluster Analysis (Figure 4.5), it is not known which of the three U.S. sites is the most similar to AFN, and in the DCA diagram (Figure 4.12), the SCA was excluded. This suggests that if the SCA had been included in the DCA, the points of AFN could have been closer to those of the SCA than IDNL. However, this is not the case as seen in Figure 4.11 because of exaggeration in the first axis due to the tongue-effect. Even though the SCA is quite different from all the other sites, AFN is in between the SCA and the other sites, and actually more similar to the SCA than the other sites. Hence, the best match for AFN should be the SCA instead of IDNL in terms of 2^{nd} brood nectar source plants. Between IDNL and MNF, since the DCA diagram (Figure 4.12) suggests that IDNL is more similar to AFN than MNF is, similarity scores of "2" and "1" were given to IDNL and MNF respectively even though IDNL gave a lower probability value in Table 4.4. In the case of the MT, the highest probability value ($P = 0.0307$) was obtained from IDNL, meaning that IDNL is the most similar in terms of 2^{nd} brood KBB nectar source plants to the MT.

Woody Species Community

When woody species community data is used for Cluster Analysis (Figure 4.6), the SCA was excluded from the analysis because the site was completely treeless. PPP instead of AFN is the outlier. The MT is also quite different from all the other sites. Therefore, which of the U.S. sites is the most similar to PPP and the MT is unknown from the results of Cluster Analysis. In contrast, in Figure 4.6, HP and AFN is grouped together with IDNL, meaning that IDNL is the most similar U.S. Site to HP and AFN in terms of tree community. Also, the KBS forms a group with MNF. This means MNF is the most similar potential founder butterfly site to the KBS in terms of tree community.

The DCA using tree density data yields very similar results (Figure 4.13). Again, the SCA was excluded because of lack of trees at that site. The points representing HP and AFN are closer to those of IDNL than those of MNF, supporting the notion that these two Ontario sites are more similar to IDNL than MNF in terms of tree community. Also, the points of the KBS and those representing MNF are close together, suggesting that MNF is the best match for the KBS. In the cases of the MT and PPP where inconclusive results were obtained from Cluster Analysis, the points representing the MT are closer to the ones of IDNL while the ones representing PPP are closer to those of MNF, suggesting that IDNL is the most similar in terms of tree community to the MT and MNF the most similar to PPP.

The results of MRPP (Table 4.5) further reassure the results of Cluster Analysis (Figure 4.6) and DCA (Figure 4.13) for the comparisons in tree community. The SCA is again excluded from the analysis. The higher probability was obtained from IDNL for HP, AFN and the MT, and from MNF for PPP and the KBS. This suggests that IDNL is the most similar U.S. site to HP, AFN and the MT while MNF is the most similar to PPP and the KBS in terms of tree community, which is exactly what the results of the DCA diagram implies (Figure 4.13). Similarity scores were once again assigned according to the probability values in Table 4.5 due to complete agreement between the results of Cluster Analysis, DCA and MRPP.

Tending Ant Species

Figure 4.7 shows the results of Cluster Analysis using the presence/absence data of tending ant species. There is no single outlier detected in this case. AFN forms a group with the three potential source butterfly sites with a close association with the SCA. This means that AFN is the most similar to the SCA in terms of tending ant community. For the other four Ontario sites, it is impossible to tell which of the three U.S. sites is the most similar to them with this dendrogram alone (Figure 4.7).

In the DCA diagram (Figure 4.14), the points of AFN are closest to those representing the SCA as expected from the results of Cluster Analysis. This further confirms that the SCA is the most similar potential source butterfly site to AFN in terms of ant community. The points representing HP and AFN are closest to those of MNF and the SCA respectively. This means that the best match in terms of tending ant community for HP is MNF, and for AFN is SCA. For the points of MT and the KBS, it is hard to tell if they are closer to those representing IDNL or those representing MNF, but either one of these two U.S. sites should be the most similar to the MT and the KBS in terms of tending ant community according to this DCA diagram (Figure 4.14).

In Table 4.6 where results of MRPP are shown for comparisons in tending ant community, the highest probability values were returned from MNF for HP, from the SCA for AFN, and from IDNL for PPP. This reassures the results of the DCA (Figure 4.14). In the cases of the MT and the KBS, The highest probability values were obtained from IDNL and MNF respectively, suggesting that the most similar potential founder butterfly site in terms of tending ant community for the MT is IDNL, and for the KBS is

MNF. Two disagreements did occur between the results of Cluster Analysis and DCA and those of MRPP in the case of tending ant community. The dendrogram (Figure 4.7) suggests that AFN is more closely associated with MNF than IDNL while the probability values obtained from MRPP implies the opposite. Also, the DCA diagram (Figure 4.14) shows that the points of MT are closer to those of MNF rather than the SCA while the results of MRPP suggest the opposite. Therefore, similarity scores were assigned according to the results of Cluster Analysis and DCA instead of those of MRPP in these two cases.

Canopy Cover

Unlike vegetation and tending ants, canopy cover can be directly compared among all study sites without going through multivariate analysis. As seen in Figure 4.15, The SCA is completely canopy-free. The similarity score of "1" is therefore given to all comparisons of Ontario sites with the SCA (Table 4.7). IDNL is shadier than MNF. It is the most similar U.S. site to HP and the MT, which are even shadier than IDNL, as well as the KBS which has a very similar summer percent canopy cover as IDNL. For AFN and PPP, MNF is the better match because of its lower percentage canopy cover.

Integrated Light Intensity

Similarly, integrated light intensity can also be compared directly among the sites. As seen in Figure 4.16, the line representing HP is very similar to the one representing the SCA. This means that the sites share similar light conditions. MT, PPP and the KBS have comparatively low light intensities. Hence, they are more similar to IDNL than the other two U.S. sites which have higher light intensities than IDNL. AFN is equally similar to both IDNL and the SCA. Therefore, both IDNL and the SCA were identified as the most similar sites to AFN in terms of light intensity and a tied similarity score of "2.5" was assigned to both of them to the comparisons with AFN (Table 4.8).

Air Temperature and Relative Humidity

In contrast, temperature and relative humidity data cannot be compared directly without transformation. Even after transformation according to the weather data collected fro the weather stations closest to the study sites, one may still question how representative these transformed data are because the effect of interannual variation of temperature and relative humidity is discounted in direct comparisons of the variables among the study sites based upon data collected in one season. If the weather had been particularly hot at one site and unusually cool at another in 2003, direct comparison would have been inappropriate and cannot reflect the "normal" differences among the sites. Fortunately, this is not the case according to the weather data collected from the closest weather stations from the study sites. The mean monthly temperatures in April, May, June and July 2003 were lower than the averages from 1961 to 1990 by 1.7°C to 2.1°C, 1.3°C to 1.7°C, 0.9°C to 1.0°C and 1.3°C to 1.8°C respectively at the weather stations closest to the study sites. In August and September 2003, the mean monthly temperatures were higher than the averages from 1961 to 1990 with differences ranging from 1.3°C to 1.7°C and 1.1°C to 1.2°C respectively among the weather stations. This means that although the temperature is lower than average in the months from April to July and higher than average in August and September in 2003, the deviations from the average are consistent and in very similar magnitude among all study sites. When relative humidity data is compared in a similar fashion, the mean monthly relative humidity is very close (differences less than 1.2%) to the averages between 1961 and 1990 at all study sites in all six months. Direct comparison of temperature and relative humidity among them using only the data collected in 2003 should therefore reliably reflect the differences among the sites instead of being overwhelmed by the unusual temperature in 2003.

Another problem of direct comparison of the transformed temperature and relative humidity data is that it fails to account for the spatial variation in temperature and relative humidity within the sites. Data were collected at only two points at each site. Such small sample sizes can hardly represent the spatial heterogeneity of temperature and relative humidity if these variables are highly spatially heterogeneous. However, unlike light levels, temperature and relative humidity have only limited spatial heterogeneity because air turbulence tends to homogenize them across entire sites (Oke 1987). Hence, despite the failure in capturing spatial heterogeneity, the data collected from two points should be able to represent an "average" condition at each site. Moreover, by performing a paired t-test upon daily average temperature and relative humidity data collected from the two sets of dataloggers, the high probability values (P = 0.976 and 0.979 respectively) imply that the daily average data collected by the two sets of equipment at different locations at the same site show very little differences although maximum (P = 0.004) and minimum

(P = 0.373) temperatures could be quite different between different areas with different light intensities (P = 0.062) as shown by the results of paired t-tests. This further suggests that spatial heterogeneity of daily average temperature and relative humidity is limited and will unlikely have a significant impact in the comparison of temperature and relative humidity among the study sites.

Even though spatial variation in temperature and relative humidity do not seem to be high enough to affect direct comparison among different sites, reconstruction of the spatial heterogeneity of temperature was attempted by using the integrated light intensity data collected by the Petri dish lightmeters (Bello, personal communications). It was assumed that the difference in temperature at two locations was directly related to the difference in the amount of light energy available. Unfortunately, this method does not seem to work as the two variables do not show a clear correlation. This is so probably because availability of light energy is only one of the many determining factors influencing air temperature. Also, not all the light energy available is used to heat up the air on vegetated surfaces. At least some of the energy is used for transpiration. In addition, the pyranometer sensor and the temperature/relative humidity sensor that were attached to the same datalogger were placed at least 2m apart from each other. This was so because such a distance between them guarantees that the temperature/relative humidity sensor would not cast a shadow on the pyranometer, affecting the light intensity measurement. This means that the temperature and light intensity were not recorded at the same spot, but at two different spots that were at least 2m apart. Due to the highly spatially variable nature of light intensity, the measured light intensity could have been

of "1" in the comparisons with them. These four Ontario sites are more similar to the SCA than to IDNL, the areas of which were represented by the two lines with the lowest peaks. Hence, similarity scores of "2" and "1" were assigned to the SCA and IDNL in the comparisons with these Ontario sites (Table 4.9).

As seen in Figure 4.18, the lowest estimated mean daily average relative humidity was found at AFN with the lowest standard deviation among all sites. The most similar U.S. site to AFN is MNF which has the lowest estimated mean and standard deviation of daily average relative humidity among all U.S. sites, and the next most similar one is IDNL. In contrast, the curves for the MT and the SCA are both very flat, indicating that the daily average relative humidity is highly variable at both of these sites. This makes the SCA the best match for the MT (Table 4.10). In the case of HP, PPP and the KBS, they all share a relatively high estimated mean daily average humidity with an intermediate standard deviation. The most similar U.S. site to such conditions is IDNL and the least similar one is the SCA (Table 4.10).

Overall Results

After averaging the similarity scores assigned to the potential founder KBB sites for each of the potential reintroduction site with respect to individual biotic and abiotic environmental variables, IDNL turned out to be the most similar U.S. site to all Ontario sites except AFN, where the SCA is the most similar U.S. site instead (Table 4.11). 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 the SCA instead.

Even though MNF rather IDNL is closer to the Ontario sites in terms of physical distance, IDNL is more similar in terms overall environment to four of the five Ontario sites (Table 4.11). This is probably because MNF is an inland site while IDNL and those four Ontario sites are located very close to the shoreline of the Great Lakes (Map 2.2).

The SCA was expected to be the least similar to the Ontario sites because the habitat there was not savannah but artificially maintained prairie. However, this is only true in four of the five cases, with AFN being the exception (Table 4.11). One possible explanation for this is that AFN is physically closer to the SCA than to MNF and IDNL; another probable reason is that AFN has the lowest canopy cover (Figure 4.15) and the second highest mean integrated light intensity (Figure 4.16) among all Ontario sites. In fact, the light intensity at AFN should be the highest among the all Ontario sites. Integrated light intensity measurement only captured the light conditions under which wild lupine could survive. Because of a particularly dry summer in 2002, very few wild lupine plugs planted under full sun in 2002 at AFN could survive until 2003. This affected the results of integrated light intensity measurement in favour of more shady conditions at AFN. Hence, the overall light levels at AFN should have been higher than what was suggested by the integrated light intensity measurements. Such high light intensity at AFN, which is similar to the treeless condition at the SCA, may therefore be one of the reasons why AFN is more similar to SCA than to MNF.

The rank-averaging technique used to generate Table 4.11 is very useful in identifying one single most similar site when multiple variables are involved. However, one could go a step further and use weighted-averaging methods to calculate the overall similarity score when some of the variables are known to be much more important than others or their variation may cause a much greater impact than the variation of others to the species of interest. However, in this study, not enough information is available to determine if any of the biotic or abiotic variables I measured is more important to the KBB than others. Nor is enough information available to determine if the variation of any of these variables may cause greater impact than that of others. Therefore, I assumed that all these variables were equally important to the KBB and their variations might cause similar impact to the KBB, and I calculated the overall similarity scores by simply averaging the similarity scores from all individual variables.

Summary and Conclusions

In the IUCN guidelines for reintroductions, the importance of the founder stock being genetically closely related to the extirpated one is emphasized (IUCN 1998). However, methods to select such founder stock from numerous available founder populations are not recommended in these guidelines (IUCN 1998). Genetic comparison using molecular techniques is obviously a straight-forward option. However, this is not always practical. This research provides an example of how the most suitable founder population can be identified when genetic comparison is impossible, using the case of the KBB. Potential founder population sites were compared to the reintroduction sites in terms of biological and environmental variables relevant to the KBB. The sites were first compared in terms of individual variables. Similarity scores were assigned to the potential founder population sites according to their relative similarity to each of the reintroduction site. The scores assigned to individual variables for the same potential founder population site were then averaged to calculate the overall similarity scores for the potential founder population sites. These overall scores can then be used to determine which potential founder population site is the most similar to each reintroduction site, hence the most suitable as the source of the founder stock. These procedures are not only useful for this particular study. They can also be applied to select one single founder population out of several available ones in other reintroduction projects.

In summary, results of this study suggests that none of the potential founder KBB sites in the U.S.A. matches perfectly with any of the potential KBB reintroduction sites in Ontario in terms of various biotic and abiotic variables relevant to the survival and persistence of the KBB. However, overall, IDNL is the most similar to four of the five Ontario sites. It is therefore identified as the priority founder butterfly site for KBB reintroduction in Ontario. Once the oak savannah sites in Ontario are shown to be ready for KBB reintroduction, hopefully in the near future, butterflies from IDNL should be taken, with permission from the United States Fish and Wildlife Service (USFWS), for reintroduction in Ontario.

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CHAPTER 5: Restoration and Management Recommendations

Introduction

As discussed in Chapter 3, all the restored oak savannah sites in Ontario included in this study are of lower quality, at least in certain aspects, compared to the three potential founder KBB sites in the U.S.A. This means that we are not certain if these sites are ready for reintroduction of the KBB despite obvious site quality improvement resulting from habitat restoration. Further restoration and continuous management are required if the ultimate goal is to reestablish persisting KBB populations at these sites. Such restoration and management efforts should follow the adaptive management approach which emphasizes the importance of experimental approaches and continuous monitoring to better adjust the management strategies for individual sites to suit our goals (Walter 1986).

In this chapter, recommendations are made for future restoration and management strategies at each of the potential KBB reintroduction sites in Ontario. These recommendations are made with respect to specific problems identified at each site in Chapter 3 and are aimed at improving habitat quality to meet the requirements of a KBB reintroduction site.

Site Specific Recommendations

1. High Park

The study areas in HP are some of the best quality oak savannah sites in Ontario. They are the only study areas in Ontario with wild lupine densities comparable to those of the three potential founder butterfly sites in the U.S.A. (Table 3.1). However, such high quality habitat only covers a small area (less than 2 hectares) in the park which is far from enough to support a healthy KBB population in the long run. Therefore, the wild lupine areas in HP should be expanded.

One way to enlarge the area of wild lupine coverage is to use prescribed burns which have been used in HP since the 1980s. In fact, in spring 2003 and 2004, the two areas HP 456 and HP 444 and their adjacent areas were treated with a prescribed burn, and the range of wild lupine was observed to have slightly expanded (personal observation), possibly as a response to this. However, the effect of prescribed burns on the range expansion of wild lupine in HP is very limited.

Wild lupine does not disperse its seeds for a long distance. The seeds disperse when the seedpods dry up and crack open, "shooting" the seeds to about 2m to 3m away from the parent plant (Chan, personal observation). No other dispersal method is known for wild lupine. Since wild lupine is a perennial which does not start reproducing until the second year of establishment, even if the adjacent areas are perfect for wild lupine establishment, the range of the wild lupine can be expected to expand by itself by only 2m to 3m every two years, or 0.5m to 2m per year as suggested by Celebrezze (1996). In fact, the actual rate of wild lupine range expansion is likely to be even slower than that in HP because the areas adjacent to HP 456 and HP 444 are covered with dense canopy which means that they are not ideal for establishment of wild lupine. Prescribed fire has helped to remove some of the shrubs, but quite a lot of tall woody plants survived the burn in spring 2003. The shady condition of the adjacent areas limits the potential of

KBB being too low and the light conditions under which wild lupine plants grow being not heterogeneous enough. Both problems are probably the results of a dense canopy. Evidence that supports this notion includes low integrated light intensity (Graph 4.2), high canopy cover (Graph 4.1) and the presence of typical forest species such as Starflower (*Trientalis borealis* Rafinesque) which is absent in all other sites. To improve habitat quality, opening up the canopy is therefore essential.

Prescribed burning is a good way of reducing canopy cover. However, in the case of the MT, physical means such as selective cutting and brush hogging may be more effective under current conditions. This is because the canopy is largely composed of mature trees and tree saplings which could probably withstand a low intensity burn. Selective cutting or brush hogging followed by a burn will probably yield the best result. Using these methods to create dispersal corridors among the wild lupine populations in different areas is also recommended as these plots are quite far from one another. Wild lupine can be planted along these corridors to further encourage dispersal of the KBB among these areas when the KBB is reintroduced to the MT.

Seeding of wild lupine and nectar source plants may be considered after reduction of canopy cover. However, this may not be necessary if these species respond positively to the change in canopy cover and light conditions, which they probably will.

4. Pinery Provincial Park

Although density of wild lupine in PPP is the second highest among the Ontario sites, it is still much lower than those of the three potential founder KBB sites in the

U.S.A. In addition, the area of wild lupine coverage is too small and needs to be enlarged. To accomplish these, seeding or planting with wild lupine is recommended.

At the area of PPP RA, wild lupine density is very high close to the edge of the paved road where canopy cover is absent and a lot of sunlight is available. However, in the interior parts, where trees are present and the shrub layer is dominated by Fragrant Sumac (*Rhus aromatica* Aiton), wild lupine cannot survive the heavy shade. Therefore, to increase the area of wild lupine coverage, the open space beside the paved road should be expanded by selective cutting and mowing in the adjacent area. Seeding may then follow to accelerate the process of wild lupine establishment in the newly cleared area. Fire is also an alternative that could be used to open up the canopy.

For the area of PPP SH, the wild lupine population is very small (approx. 30 plants) and is concentrated on the southern edge of the bowl-shaped habitat where the circular, almost treeless central depression meets the tree line surrounding it. The distribution of wild lupine in this area suggests that the central part of the bowl may be too hot and dry. Hence, wild lupine plantation should be focused along the edge of the bowl where at least some shade is available. To expand the wild lupine population towards the centre of the bowl, seeding can be tried at the centre where a few chokecherry saplings are present to provide some shade. Alternatively, wild lupine plant plugs can be situated at the centre of the bowl and tended carefully by, for example, watering.

Connecting PPP RA and PPP SH by dispersal corridors through clear cutting and wild lupine plantation along the path is also recommended, but expansion of the wild lupine populations in these two areas should be the main focus at present time.

Wild lupine density in PPP EX is high, but at the southeastern edge of the exclosure, the density is relatively low due to overcast by tree seedlings, especially Sassafras (*Sassafras albidum* (Nutt.) Nees). Removal of at least some of these seedlings, either by selective cutting or prescribed burning, will improve the situation and allow the density of wild lupine to increase, and is therefore recommended. In areas just outside the deer exclosure, only a few wild lupine plants were observed even though many have been planted right next to the exclosure. This suggests that deer herbivory, at least for a certain period of time in the past, was once a problem. Since the deer population has been under control for the past decade, plantation of wild lupine should be tried again just outside the deer exclosure. This will help not just to expand the area of wild lupine coverage but also to test whether the current deer population level is still high enough to affect wild lupine establishment.

Not enough second brood KBB nectar source plants is also one of the concerns in the study areas of PPP. This problem can be solved by seeding/planting these areas with 2nd brood KBB nectar source plants such as New Jersey Tea (*Ceanothus americanus* L.) and Butterfly Weed (*Asclepias tuberose* L.), both of which are found in other parts of the park. Seeds of these species can be collected from the park for plantation in these three study areas.

5. The Karner Blue Sanctuary

Like other Ontario sites, relatively low density of wild lupine compared to the three potential founder butterfly sites in the U.S.A. is one of the concerns in the KBS. To increase the density of wild lupine, burning the site is one of the best methods. This was actually done in spring 2004. All three study areas in the KBS were burnt in this prescribed fire. Wild lupine density will probably increase as a result of the burn because fire often initiates germination of wild lupine seeds which have hard seed coats that make them hard to germinate otherwise. Another part of the KBS was burnt in spring 2003 and an increase in wild lupine coverage was observed after the burn (Chan, personal observation). Meanwhile, instead of seeding/planting the area with wild lupine to increase wild lupine density, monitoring of the wild lupine populations in the burnt areas is recommended to see if fire actually stimulated growth. Since wild lupine is already there, planting should be an option if the burn does not sufficiently increase their density.

Other than monitoring the wild lupine populations, planting should be done along the trails that connect the different populations. Expansion of areas of wild lupine coverage is preferable but not necessary at this point as the response of wild lupine coverage after the prescribed fire is yet to be seen. In contrast, increasing the connectivity among the study areas is beneficial and should be done immediately.

Low heterogeneity in light conditions under which wild lupine grows is another concern in the KBS. The situation here is similar to that of the MT, with low mean and standard deviation in integrated light intensity (Graph 4.2), indicating that wild lupine plants are not doing well under full sun as they should be. This is particularly true in the area of KBS BO where wild lupine is found in high density under semi-shade conditions at the edge of the central opening, and in much lower density in the completely open area centrally as at PPP SH. The burn in spring 2004 should have at least improved the light conditions by removing some of the canopy cover. To further improve the current situation, wild lupine establishment should be encouraged at the centre of the bowl where quite a large wild lupine population existed before the drought in the late 1980s. This should use the method suggested for PPP SH. However, this may not be necessary if the site responds well after the prescribed burn in spring 2004.

Other Recommendations

As mentioned in Chapter 1, due to global climate change, reintroduction of the KBB to Ontario is urgently required to secure its long-term persistence. Before the Ontario sites are ready and actual reintroduction of the KBB takes place in Ontario, I suggest that the KBB Recovery Team should request permission from the USFWS to take a few KBB from IDNL, which is the identified best founder butterfly site for KBB reintroduction in Ontario (Chapter 3), and rear the butterflies in captivity in the Metropolitan Toronto Zoo where experimentation with captive rearing methods have been tested with the Eastern Tailed Blue. The butterflies reared in captivity can be released back to IDNL or transferred to other sites in the U.S.A. for reintroduction purposes, such as the Ivanhoe Nature Preserve in West Gary, Indiana where butterflies have been reintroduced from IDNL since 2001, while the Ontario sites are being restored and prepared for KBB reintroduction. This will provide an opportunity for the Metropolitan Toronto Zoo to test the methods developed from using the Eastern Tailed Blue and accumulate first-hand experience in captive rearing of KBB in Ontario. Once the oak savannah sites in Ontario are ready for reintroduction, not only will we have total confidence in our rearing capabilities, there will also be more KBB available for immediate reintroduction from the Metropolitan Toronto Zoo. Therefore, instead of waiting till the oak savannah sites in Ontario are ready for KBB reintroduction, I strongly encourage the KBB Recovery Team to immediately apply for permission from the USFWS to take a few KBB from IDNL for captive breeding in the Metropolitan Toronto Zoo.

Concluding Remarks

Although the restored oak savannah sites in Ontario are of lower quality compared to the three potential founder butterfly sites in the U.S.A., the quality of these sites has improved due to restoration work and will probably continue to improve with further restoration efforts. Restoration and management should therefore continue at all potential KBB reintroduction sites in Ontario, following the adaptive management approach and the recommendations suggested in this chapter. Hopefully, the quality of the sites in Ontario will further improve and reintroduction of the KBB will soon take place in Ontario, bringing this endangered butterfly back to the oak savannahs in Ontario where it once thrived.

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