VOLUNTEER MONITORING OF FOREST RESTORATION

A Thesis

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ABSTRACT

VOLUNTEER MONITORING OF FOREST RESTORATION

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A great deal of effort goes into forest restoration but very little is devoted to monitoring the results. In consequence, the progress of many restoration projects is unknown. This thesis discusses the assessment of a suite of straightforward methods that might be used by volunteers to evaluate the progress of forest restoration projects. The effectiveness of these methods was determined by evaluating three forest restorations exhibiting different levels of progress. The vegetation, soils, landscape ecology and faunal use of each the restoration sites were compared with a reference forest. The results showed that this suite of methods can be used to differentiate between levels of restoration progress.

In the second phase of the work, three trials were run with students. Generally, they found the methods easy to use and produced useful results.

This study has shown that a restoration site can be readily characterised by inexperienced workers using these methods.

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Chapter One

Introduction

1.1 Introduction

In Southern Ontario before European settlement, it is estimated that 63.7 % of the land was covered by upland forest (Larson et al. 1999). By 1910, more than 93 % of these original dry-mesic forests had been cut for timber or cleared by fire for agriculture. Another 4% were in ‘managed’ woodlots. By 1921, some regeneration of secondary forest had begun as the more marginal farmland was abandoned, and a total of approximately 10.6 % of upland was forested. Of this it was calculated that less than 1% (60,000 ha) of the original hardwood forest remained at that time, and losses of these old-growth forests continue to this day (Larson et al. 1999).

The 1978 Forest Resources Inventory (FRI) of the Ontario Ministry of Natural Resources (OMNR) showed that a total of about 13% of Southern Ontario was in replacement upland woodland, a slight increase from the 1921 estimate. In the eleven Carolinian counties this number averaged 11.7% and ranged from less than 3% in Essex to over 20% in Halton County (Larson et al. 1999). The total average forest cover for these counties is still estimated to be increasing, but on the rich farmlands of the southwestern region, woodlands continue to be lost as land prices increase and agriculture intensifies (Minielly 2002). Further devastation is inevitable as the activities of insects such as the Emerald Ash Borer and the Asian Long-horned Beetle add their impacts to those of direct human disturbance (Michigan Department of Agriculture 2004).

Large, undisturbed forest ecosystems provide many essential life-support services to mankind (Natural Resources Canada 2003, Costanza et al. 1997, Daily and Erlich 1997, Cairns 1990). The ecosystem services that a good-sized Carolinian forest provides include the generation of oxygen; the conversion of solar energy into biomass that is used for food, shelter, and fuel; the storage and filtration of water supplies; the mitigation of flooding events; and the enrichment and retention of soils (Groffman et al. 2004, Riley and Mohr 1994). Forests also maintain biodiversity, offer landscape diversity, and provide recreational opportunities and aesthetic value for people (Groffman et al. 2004, Jacquemyn et al. 2003, Foote 2001).

Not only are we still losing forest cover in parts of Carolinian Canada, the remnants are highly fragmented (Larson et al. 1999). Services such as water purification, air filtering, erosion resistance, soil building, and the provision of wildlife habitat are compromised as forests are fragmented (Jacquemyn et al. 2003, Foote 2001, Riley and Mohr 1994). How long the remaining bionetwork can continue to sustain our current standard of living is a question that is in need of urgent answers (Hobbs and Harris 2001, Soberón et al. 2000). In the meantime, the conservation of remnant core woodlands in Southwestern Ontario is critical to the maintenance of ecosystem health in this region. And because the remaining coverage of woodland is so low, restoration of buffers for these cores and of functioning corridors to connect them is vitally important to the future integrity of our regional wildlife habitat (Hobbs and Harris 2001, Riley and Mohr 1994, Cairns 1990). Research is beginning to show that approximately 30% forest coverage is required, at least around headwaters and wetlands, to maintain ecosystem functions at healthy levels (Environment Canada 2004).

There are several methods by which the increase of forest cover can be accomplished; the most cost-effective being natural regeneration. However, the time required for this to occur on its own is often considered not acceptable, since it may take 70 years or more for a mature, functioning secondary Eastern Dry Mesic forest to aggrade without intervention where the seedbank is undisturbed or seed sources are nearby and plentiful (Bormann and Likens 1979). A common method favoured by Conservation Authorities seeking to improve watershed function in their jurisdiction is to establish tree plantations (Clinesmith 2001). Historically these were mono-cultures of white pine or other conifers, but these can take even longer than natural regeneration processes to revert to native hardwood mixes. Lately, more sophisticated mixes of early successional hardwoods native to the Carolinian ecozone[1] (Wearing-Wilde et al. 2000) have been used in plantations by the Conservation Authorities (Craig 2002), although deciduous trees are often more difficult to establish. An even more recent arrival on the restoration scene in Ontario is the practice of altering the basic hydrology and topography of agricultural fields to resemble the pit and mound topography of natural woodlands before beginning planting or allowing natural regeneration processes to occur (Natvik 2002, personal communication). This follows work by Mollison (Natvik 2004), who used what he called swaling to trap rainwater for forest restoration in dryland Australia.

Ecological restoration is currently believed to be the best method to most rapidly return a site to an historic vegetation mix and ecological function. It is however the most expensive approach. Ideally, ecological restoration entails time-consuming environmental inventories, modification of the topography and hydrology of a site to return it to chosen historic conditions, and conscious decisions about what native species best represent the local historical conditions (Havinga and Daigle 1998). All of this should occur *before* planting begins. After the vegetation is in place, maintenance and monitoring are required until, one hopes, the community becomes established and self-sustaining. All these activities require large investments of time and money, as well as expertise, commitment, and focus.

In our current social, political and economic climate, our dependence on healthy ecosystems for sustenance is poorly acknowledged (Costanza et al.1997). As a result, the funding and infrastructure for ecosystem reconstruction is extremely limited (Holl and Howarth 2000). If these limited resources are to be used efficiently, restoration projects of all types should be evaluated, so that we can learn what are the most efficient and cost-effective methods of forest restoration (Cooke and Johnson 2002, Henry et al. 2002, Havinga and Daigle 1998, Kershner 1997). Unfortunately, this is not often done; the more frequent practice is to put most of the time and money into planting and very little

[1] Not to be confused with the Forest ecozones as defined by the Canadian Forest Service.

into monitoring and aftercare (Hobbs and Harris 2001, Stanturf et al. 2001, Kershner 1997, Hobbs and Norton 1996). As a result, success is rarer than we would like (Choi 2004, Geist and Galatowitsch 1999, Kondolf 1995). One major barrier to frequent monitoring, for both volunteer and government restoration projects, is the cost of having assessments done by highly trained consultants (Kershner 1997).

1.2 Purpose

In this study, I sought to develop a suite of field methods that might be used by volunteers to monitor the progress of forest restoration projects in Southwestern Ontario. I have selected a group of methods that I think are straightforward to follow without a great deal of training and experience; that yield quantitative information in some cases; and that are robust enough to be used by people of many different experience levels, and still give results that are reproducible. Besides reproducibility and objectivity, time- and cost-effectiveness were key features that were considered in the choice of methods. The questions asked in this work are: can inexperienced volunteer conservation and restoration practitioners discriminate between different levels of restoration progress using this group of methods? and: Do inexperienced workers find these methods user-friendly, and the information they yield valuable enough to make the effort worthwhile?

The individual methods compiled in this study are not new. They were selected from among the large volumes of vegetation and soil characterisation literature (Lee et al. 1999, United States Department of Agriculture 1999, Ontario Soil Resource Centre 1993, Kent and Coker 1992, Krebs 1989) for their ability, in total, to yield sufficient information along several dimensions for an objective judgement to be made about progress at a restoration site. Among the methods chosen, key ones chosen include the Point-centred Quarter method (PQM), a plotless sampling technique for determining population densities of woody vegetation (Krebs 1989); the Quadrat method for cataloguing herbaceous vegetation (Kent and Coker 1992), and the Soil Auger sampling method for determining soil texture and moisture regime (Ontario Soil Resource Centre 1993, Lee et al. 1999).

Restoration progress was measured against vegetation and soil conditions that were found in a reference ecological community (McCoy and Mushinski 2002, Kentula 2000, Whisenant 1999) located nearby each project site. In cases where the restoration was modelled on a specific community, that is the reference that was used. In cases where no specific community was used as a template, the reference was chosen based on the dominant vegetation in the restoration site. The indicators were tested for their ability to objectively and reliably indicate whether the treated site is structurally and functionally moving toward the reference conditions.

I believe that if a group of easy-to-use yet comprehensive methods can be adapted to measure restoration progress in a cost-effective way, and made available to volunteer conservationists in handbook form, this will increase the frequency of restoration monitoring. There are already a few publications available containing information for the use of volunteers and inexperienced workers who would like to do their own restoration monitoring (Association for Canadian Educational Resources 2003, Environment Canada 2003a, Illinois Department of Natural Resources 2003). However, in most cases, these contain methods that are somewhat arduous and require the involvement of consultants, at least up front (ACER), and/or they require some significant training time (Association for Canadian Educational Resources 2003, Illinois Department of Natural Resources 2003). The benefit is that the data produced by the volunteer monitor is accepted by the scientific community, but the drawback is that a significant amount of time is required from the volunteer before monitoring even begins. This study is designed to illustrate that the methods evaluated herein are capable of providing scientifically valid data if properly executed, and yet are simple enough, for the most part, to be used by volunteers with very little experience or training.

This study follows from some work on the evaluation of success of forest restoration in Southern Ontario by Clinesmith (2001). Clinesmith's dissertation focussed on the different methods of restoration used and their impacts on success. Success was evaluated based on interviews with restoration project managers. Evaluations were quite subjective; in several cases project managers felt that their work had been successful, even though the survival rate of the trees at the site was very low. That study pointed up the need for the use of objective methods to measure restoration progress.

1.3 Thesis Layout

In the following chapters there is first a literature review covering relevant topics such as how to measure restoration progress at different stages in development; how to define success for a restoration; the different methods available to characterise vegetation and soils; methods for monitoring wildlife; and some of the monitoring work that has been done by inexperienced workers. The third chapter describes the methods selected for study in this work and their application at three restoration sites exhibiting different levels of progress. It includes the field data obtained, and the analysis and conclusions that were drawn about these sites and the effectiveness of the suite of methods as a whole. This chapter constitutes the first part of the study and its purpose is to show the ability of the methods, as a group, to discriminate between different levels of restoration progress in the hands of workers with some background in the various disciplines but little or no experience in the field. Chapter 4 comprises the second part of the work, and describes the results from pilot studies with three groups of high school students who have little background in environmental studies and no field experience with the methods described in Chapter 3. Due to time constraints, the students were only able to try three of the methods, the PQM, the Quadrat method, and the Soil Auger sampling method. The conclusions of the study and a discussion of further work are included in Chapter 5.

Chapter 2

Literature Review

2.1 Measurement of Forest Restoration Success

2.1.1 Measurement of Success

Progress in restoration projects can be measured in many ways. Compositional and structural indicators such as the quantity, size and mix of native species of plants as compared to a reference system are the most frequently used (McCoy and Mushinski 2002, Kentula 2000, Whisenant 1999). Many authors, however, feel that success in ecological restoration can only truly be claimed when it is shown that the ecological function of the system has been restored as well (Stanturf et al. 2001, Whisenant 1999, Hobbs and Norton 1996, Toth et al. 1995, Bradshaw 1993, King and Keeland 1999). Functions such as erosion control (Whisenant 1999), the control of hydrology and nutrient cycling (Bormann and Likens 1979, Whisenant 1999), the capture of energy, the return of key fauna to the ecosystem (Block et al. 2001, Reive and Stephenson 1994), and the restoration of links – flows of matter, energy and information - to the surrounding landscape (Huxel and Hastings 1999, Bell et al. 1997, Forman and Godron 1986) are all considered to be essential aspects of a fully operational ecosystem. Still others are not satisfied that success has been achieved unless a comprehensive set of goals and objectives were set before the project began, and it can be shown that these have been met (McCoy and Mushinski 2002, Hobbs and Harris 2001, Anderson and Dugger 1998, Dahm et al. 1995, Henry and Amoros 1995, Kondolf 1995, Reive and Stephenson 1994). Finally, there are those who feel that restoration success has not been thoroughly measured unless a full range of structural/compositional, functional, social, cultural, historical, political, aesthetic and moral indicators have been applied (Higgs 1997).

However, the success of a restoration project can be defined differently at different times throughout its development. Successful progress at later stages in the life of a project depends very much on that of earlier phases (Majer 1989 in Reay and Norton 1999, Inouye 1988). By determining progress at these early points we can infer the likelihood of success as the project matures (Reay and Norton 1999). At the very early stages of development, survival rates of plantings might be sufficient for an assessment of 'success' (Camargo et al. 2002, Clinesmith 2001, King & Keeland 1999). As a stand starts to mature, however, more information is required to make judgements about whether the development of ecosystem components are on a trajectory that will lead to the restoration of a fully functioning, self-sustaining natural system well-adapted to the study site (King and Keeland 1999, Reay and Norton 1999).

Research articles that focus on the measurement of success or progress in restoration range from those that describe the success of the restoration in conceptual terms such as the meeting of structural, functional and social goals and objectives (Society for

Ecological Restoration 2002, Block et al. 2001, Hobbs and Harris 2001, Geist and Galatowitsch 1999, Anderson and Dugger 1998, Higgs 1997, Box 1996, Hobbs and Norton 1996, Toth et al. 1995), to those that describe how restoration success was measured for a particular project (Wilkins et al. 2003, Holzworth et al. 2003, Fattorini 2001, Reay and Norton 1999). Authors in the former group are concerned, among other things, about issues like good experimental design and standards for data collection and analysis. Unfortunately, they do not provide much useful information on the actual measurement of restoration progress.

There are a number of published papers, on the other hand, that provide concrete examples of indicators of success for individual projects. The methods used range from very simple to quite complex, and from a broad coverage of many restorations, to detailed investigations of a few. Examples include surveys of restorationists for their opinions about the progress of their own projects (Clinesmith 2001, King and Keeland 1999); the visual assessment of growth and density of native vegetation, sometimes assisted with photographic records (Rzadki and O'Neal 2001); straightforward counting of percent survivorship of trees planted (Matthes et al. 2003, Sweeney et al. 2002); the detailed measurement of species and abundance of vertebrate wildlife communities in a set of 30 restored sites and 30 reference sites in the same region in Florida (McCoy and Mushinski 2002); and remote sensing methods to measure the overall return of forest vegetation on the landscape (Betts et al. 2003, Natural Resources Canada 2003).

Clinesmith (2001) sent surveys to 76 project managers, asking them for information on the restoration methods they used, and to assess the success of their restoration efforts. The drawback with this method is that many were unable to provide an unbiased assessment of the progress of their project, based simply on qualitative judgement of their own work. King and Keeland (1999) obtained information on the amount of land reforested in the Lower Mississippi River Valley, the numbers and species of trees planted, and the planting methods used. However, they felt that more extensive analysis, in addition to information provided by the survey, was required to assess functional success of these efforts.

Rzadki and O'Neal (2001) used rapid visual surveys of sites that had been planted in the Hamilton-Halton watershed region. All the surveys were done by one person, who used qualitative judgment of vegetation development to assess progress. The advantage of this method was that Rzadki had amassed a great deal of experience evaluating projects with similar communities of plants, and so was able to quickly measure relative successes and failures. The disadvantage was that as the only one with this experience, her ability to monitor increasing numbers of projects was limited.

Among the authors who used more rigorous methods to assess restoration progress, Wilkins et al. (2003) used nested quadrats to determine floristic composition using estimates of cover abundance and frequency scores. The restoration treatments were compared with reference woodlands and untreated pasture controls using Bray-Curtis dissimilarity indices and ordination. Holzworth et al. (2003) used quadrats to measure tree population densities to determine the rate of tree regeneration in areas that had been aerial-seeded by grasses to reduce erosion during the regeneration period.

2.1.2 Standard Criteria for Success

Reay and Norton (1999) pointed out that at the end of the 20th century there were few established general criteria for assessing forest restoration progress, especially with respect to ecosystem function. The comprehensive literature search carried out for this study five years later, moreover, has not brought to light many newer articles on the development of a standard set of criteria for measuring the progress of forest restoration. Reay and Norton used species richness, the Shannon-Weiner index of diversity, and the Jaccard coefficient of similarity to track the progress of different aged restoration sites toward floristic compositional similarity with a reference naturally regenerating forest and a reference mature forest. They also assessed the similarity of invertebrate populations between restoration and reference sites as a measure of habitat function.

There are a small number of papers in the restoration literature that directly address the problem of devising more general measures of success for particular ecosystems: *Spencer et al. 2001, Stanturf et al. 2001, Inouye 1998, Hession et al. 2001, and Eshleman et al. 2000.* Spencer et al. (2001) attempted to find a group of reference parameters that could be used for monitoring restoration projects in *bottomland hardwood* forests in southeastern Virginia, based on existing naturally regenerating sites. They studied the development of vegetation, soils and hydrology in a chronosequence of 17 clear-cut sites which had been undergoing natural regeneration for between 2 and 20 years. Unfortunately, among the parameters that they chose, including population densities and dominance values for vegetation, chemical analysis of soils, and biweekly water levels, they found no general indicators that could be 'scientifically justified' as reliable measures of success. Two factors contributed to this conclusion. One was the natural variability in rates of succession due to a complex mix of influencing factors for aggradation in these wetland forests. The other was the ongoing demand for monitoring results early in the life of the project when variability is at its greatest.

Stanturf et al. (2001) mention several possible criteria for the measurement of restoration progress in *bottomland hardwood* forests in the Lower Mississippi Valley. Simple indicators such as canopy closure, and the measure of soil organic carbon and soil dry bulk density appear to be possible approaches. Reference data for soil organic carbon and soil dry bulk density were obtained from a chronosequence of similar sites in the region.

Inouye (1988) discussed the question of how to evaluate whether a restoration project can be deemed to fall within an appropriate range of recovery trajectories given that variability is a constant in nature. Sources of variation in populations of plants and animals are discussed. The idea of evaluating the status of the earliest stage of succession as a way of determining whether a project is on its way to the desired end point is introduced. Data were presented to illustrate the difficulty of obtaining representative population measurements over a short time period. Inouye (1988) concluded that the evaluation of success using only short-term population measurements of key indicator species is difficult if not impossible.

In the reforestation literature, Hession et al. (2000) investigated the ecological benefits of *riparian* reforestation in urban watersheds. They collected a variety of baseline structure and function data for paired forested and unforested stream reaches in southeastern Pennsylvania, and then used these data to determine the effectiveness of riparian reforestation on stream function for a range of levels of urbanisation in Philadelphia area watersheds. Eshleman et al. (2000) investigated the correlation between nitrogen export in streams and forest disturbance in the forested watersheds of Virginia.

None of these papers addressed the problem of general indicators for evaluation of upland forest restoration independent of watershed data. Nor were there any articles that discussed indicators for upland forest communities.

Some recent work has been done in developing a set of general scientific criteria to measure success in the restoration of *wetland* ecosystems. Muotka and Laasonen (2002) used leaf retention as an indicator to compare the progress of restored headwater streams with natural streams and unrestored streams. Rheinhardt et al. (1999) found six indicators, including presence/absence of channelisation, total basal area of trees, and percent litter cover, that combined gave robust assessments of ecological function in headwater ecosystems. Zedler and Callaway (1999) found that soil organic matter content, total Kjeldahl nitrogen, and plant growth could be used to compare restored and natural coastal marshes. Interestingly, Zedler and Callaway (1999) mention that success in the restoration of wetland ecosystems is much easier to follow and monitor than forests, due to the much longer recovery times for the latter.

2.1.3 Criteria specific to the measurement of forest recovery

A great deal of information about appropriate criteria to measure the progress of forest recovery can be found in the literature on the monitoring of natural regeneration of structure and function. Bormann and Likens (1979) comprehensively cover the subject of monitoring natural regeneration in Eastern Deciduous Forest ecosystems. They reference hundreds of articles giving details for methods of monitoring the recovery of vegetation and the control of functions such as nutrient cycling, hydrology and energy capture. A selection of more recent articles includes deGruchy et al. (2001) who studied the recovery of woody species on disturbed talus at Niagara Falls using various soil characteristics, species richness and percent aliens; Qi and Scarrett (1998) who tracked species richness and density of seed banks in an Ontario boreal forest; and Harvey and Brais (2002) who used species densities and height growth to measure the relative recovery of vegetation in disturbed and relatively undisturbed sample plots after careful logging in boreal forest in Quebec.

Articles on the characterisation of old-growth and mature secondary forests in the Eastern Deciduous Forest region are another rich source for criteria and methods suitable for the monitoring of progress in forest restoration in Southwestern Ontario. Larson et al. (1999) surveyed over 30 mature forests in Ontario. The methods they used, such as the Point-centred Quarter Method (PQM), were robust and straightforward, and several of the criteria they measured such as the population densities of trees and seedlings, the species and diversity of understory vegetation, and the presence of coarse woody debris are readily transferred to the problem of measuring progress in forest restoration. Keddy and Drummond (1996) describe 10 possible indicators that might be used to characterise the condition of eastern deciduous forests in North America. These include tree size, canopy composition, amount of coarse woody debris, the number of spring ephemerals, and the density of wildlife trees (snags). They reviewed the literature to identify a typical range of values for each of these indicators in eastern deciduous forests. McCarthy et al. (1987) studied the patterns and structure of woody species in an old-growth forest in Ohio. They used stratified sampling to locate transects within different communities in the forest, and set up circular quadrats along these transects to survey tree populations. The forest vegetation was characterised using stem density, basal area, species richness and Importance Percentages for the tree and sapling components of the vegetation. They also correlated soil and vegetation variables using multivariance analysis. Boerner and Cho (1987) used randomly placed quadrats along randomly placed transects to determine stem densities and size-frequency distributions of trees species in an old-growth forest in northwestern Ohio. Quigley and Pratt (2003) surveyed a sample of forest types at latitudes ranging from 0 to 40^0 north. They used replicate quadrats to count woody stems and characterised stem densities, basal area, and species richness at the different latitudes.

2.2 Vegetation Description and Analysis

A review of the available literature on restoration monitoring soon leads to the conclusion that vegetation development is one of the most fundamental indicators of restoration progress and one of the simplest to measure. There are many texts and articles that contain detailed descriptions of suitable methods for monitoring vegetation structure, population densities and floristic composition. Textbooks describing detailed methods and calculations for quantitative and qualitative vegetation analysis include Krebs (1989), Kent and Coker (1992), Greig-Smith (1983), Moore and Chapman (1986), and Kershaw and Looney (1985).

Internet websites where methods for vegetation monitoring can be readily obtained by those interested in monitoring include the Ecological Monitoring and Assesment Network published by Environment Canada (2003), which posts the Terrestrial Vegetation Biodiversity Monitoring Protocols (Roberts-Pichette and Gillespie 1999) for monitoring upland ecological communities of all kinds, and the Guide to Monitoring Exotic and Invasive Plants (Haber 1997) protocols for monitoring of alien species in a community. Kevin Mitchell (2001), of the Hobart and William Smith Colleges has published a detailed description of the use of the PQM and calculations for surveying tree species in woodlands. Arvanitis and Portier (1997) of the University of Florida, and the Plant Ecology Department (2002) of Ohio University are among several other universities that have done the same.

There is also information available about monitoring methods and their applications to forest recovery in publications from government sources, consultants, and provincial parks (Johnson et al. 2003, Pinto et al. 2003a, 2003b).

2.3 Soil Quality Analysis

One of the first indicators of degradation after forest or grasslands have been cleared is soil erosion and loss of soil structure (Whisenant 1999, Bormann and Likens 1979). It follows that successful forest restoration should lead to improvements in soil retention and physical, chemical, and biological characteristics. Methods of soil analysis that are straightforward, or that do not require more sophisticated equipment, are not as widely available as methods of vegetation description and analysis. One source for methods that are designed to be easy to use in the field, however, is the USDA Soil Test Kit Guide published by the United States Department of Agriculture (1999) on its Natural Resources Conservation Services website. This set of protocols is intended for farmers to test the soils in their own fields, using equipment that they can readily purchase or make themselves. The methods are based on those developed by Doran and Jones (1996) for the ready assessment of soil health and quality on farmland. There are some drawbacks to some of the methods in their application to forest soils, but several provide useful measures of soil development in forest restoration. Oregon State University's Extension and Experiment Station (1999) has also published a Soil Quality Test Card and Guide summarising several extremely simple qualitative tests for measuring key soil quality indicators.

The Ontario Centre for Soil Resource Evaluation (1993) has also issued an excellent publication; 'The Field Manual for Describing Soils in Ontario' which comprises a set of guidelines on how to characterise soils in a qualitative way. The methods in this manual are applicable to both agricultural and forest soils, and are simple to use with some experience and training. The Ontario manual for Ecological Land Classification (Lee et al. 1998) has adapted the methods described in the OCSRE field manual, and they are used as standards for the ecological classification of land in Ontario. EMAN (Environment Canada 2003b) is also announcing that they intend to start publishing methods for soil monitoring.

2.4 Monitoring of Wildlife in Restoration

Restoring ecological function includes the return of native wildlife to the landscape. One of the measures of a successful restoration, or one that is making good progress, is that faunal species native to the area return to live and breed at the restoration site (Kleintjes et al. 2004, Germaine and Germaine 2002, Block et al. 2001, George and Zack 2001). Block et al. (2001) believe that truly scientific measures of wildlife usage at a site include the monitoring of population dynamics of properly selected umbrella species, rather than simple observations of what birds, mammals and herptiles are using the site. However, these techniques are sophisticated, and require time and training to execute. The simple observation and recording of insects and animals using the site on a regular basis can give some useful information about the progress of the site towards a functioning ecosystem.

2.5 Monitoring by Volunteers

There are a number of sources aimed specifically at describing monitoring methods for less experienced workers and volunteers. The Ecological Monitoring and Assessment Network (Environment Canada 2003a), mentioned above, has published several excellent documents describing monitoring protocols for marine, wetland and terrestrial flora and fauna. In the Terrestrial Vegetation Biodiversity Monitoring Protocols, which include several methods that are suitable for monitoring restoration progress, Roberts-Pichette and Gillespie (1999) state that these methods can be used by a 'wide variety of people of differing skill levels'. Included in this document are 'robust methods' for monitoring changes in plant abundance, diversity and community structure. The original purpose of this group of methods was to encourage the collection of quantitative data over many years to understand long term ecosystem variations due to, among other things, climate change. These protocols are used by, among others, the Ontario Niagara Escarpment (ONE) Monitoring Program to monitor some restoration sites along the escarpment, although the focus is currently on survivorship and seed establishment. Most of the monitoring is done by students but volunteer data are welcome if the protocols are followed (Niagara Escarpment Commission 2003).

Another set of monitoring protocols compiled specifically for use by amateurs is 'Measure Up' (Association for Canadian Educational Resources 2003). This programme was designed by the Association of Canadian Educational Resources (ACER) based on international protocols to encourage school and community groups and naturalists' clubs to get involved in monitoring the diversity and health of trees and forests on public land in Southern Ontario. A new component of the programme is aimed at tree planting and the monitoring of 'newly planted restoration and naturalization sites'. The programme involves the establishment of permanent plots. The initial set-up is somewhat expensive and time-consuming, funding has to be obtained, and trained personnel from ACER are required to do the work. On the positive side, the data are externally audited, and can be shared with others globally. The primary driver is to monitor changes brought about in global ecosystems by climate change.

The State of Illinois has a forest monitoring programme called ForestWatch, which is part of the Illinois EcoWatch Network (Illinois Department of Natural Resources 2003). The EcoWatch Network is a volunteer monitoring initiative coordinated by the Illinois Department of Natural Resources. Volunteers are called Citizen Scientists and undergo a 6-8 hour training period with follow-up workshops and practice sessions. Monitoring is done in the spring for ground cover and in the fall for trees, shrubs and vines and involves identifying species and measuring the stem diameter and canopy height of trees. Ground cover is estimated as percentages and site topography and human disturbance are noted.

Invasive species are of special interest and are recorded by abundance and species. The manual for forest monitoring is online, but only data collected by those who have taken the training are accepted by the state.

Brandon et al. (2003) studied the validity of results obtained from volunteer monitoring in the Illinois EcoWatch Network programme. They compared volunteer results of tree and shrub identification, abundance, and size class placements with data collected by botanists at 14 sites. They found that the accuracy of volunteer data was 80% or higher for 12 out of 15 tree genera. Only for *Quercus* and *Ulmus* species did difficulties with identification arise. For shrubs present in large numbers, there were some discrepancies in abundance measurements between the volunteers and scientists. Overall, however, the data obtained by volunteers were found to be sufficiently valid to be useful in monitoring long-term changes in forest ecosystems.

There are a few other volunteer forest monitoring programmes described on the internet, located in such diverse places as Indonesia (Operation Wallacea 2004) and the Phillipines (European Tropical Forest Research Network NO Date). Most of the volunteer monitoring sites on the internet are more concerned with water quality monitoring than with forest restoration.

2.6 Forest Succession

An understanding of the key characteristics of a healthy aggrading Eastern Deciduous forest at any stage in its life cycle can be extremely helpful when identifying or using methods to monitor the progress of a forest restoration project, and when analysing the results. In this work, each restoration site is compared quantitatively and qualitatively directly with a reference woodland community. However, additional relevant information about the general structure and composition of Eastern Deciduous forest vegetation and soils at comparable stages in its development enables a comparison with the results of the monitoring work and enriches the interpretation of the data. Many books and a great deal of literature have been written on this topic by forestry researchers (Kozlowski 2002, Small and McCarthy 2002, Washburn and Arthur 2003, Yaussy 2000, Schmidt et al. 1996, Ferris-Kaan 1995, Oliver and Larson 1990, West et al. 1980, Bormann and Likens 1979).

Bormann and Likens (1979) summarised, in a keystone book, many years of research at the Hubbard Brook Forest. The characteristics of many aspects of an aggrading forest ecosystem after clear-cutting are described in this work, including vegetation structure and composition, biomass accretion, the biogeochemistry of the forest floor and hydrological system, the development of forest soils and energy fluxes. Data on these parameters are presented for all the stages of an aggrading system from the first few years after clear-cutting to maturity at about 170 years.

Oliver and Larson (1990) reviewed and summarised the work of many forestry researchers. This work begins by focussing on the growth and co-development of individual trees in the forest, and then moves up a level to describe the behaviour of forest stands, from initial growth after different types of disturbance or planting up to and including a state of equilibrium where gaps form and close over centuries. The book covers many types of forest ecosystems, but has a great deal of information relevant to the Eastern Deciduous forest type.

Ferris-Kaan (1995) has compiled a series of articles written about forest restoration in Britain, but it contains a wealth of general and practical information about the development of soil and vegetation parameters in a restored temperate forest over time.

2.7 Problems Associated with Measuring Success or Progress

Measuring the *success* of forest restoration projects is not easy, even when clear project goals have been set and a detailed management plan is in place (Holl and Howarth 2000, Reay and Norton 1999). First, methods chosen for the assessment of vegetation, soil, and/or faunal characteristics should be well-accepted, and in the case of inexperienced workers, robust and simple to use. While there are many methods available, as described above, many are complicated and/or time-consuming. A selection must be made carefully. A second challenge is to try to sort out the uncertainty associated with the measurements from the variation inherent in nature. The former is dealt with as much as possible by statistical treatment of the data where appropriate. Natural variation has many sources so that even when a nearby reference site has been used as a model for a restoration, and is itself a source of propagules for the restoration site, there will be many differences between the two due to factors such as dissimilarities in topography, microclimate, and the biotic and abiotic conditions at the time of stand initiation (Choi 2004). These differences are exacerbated, it is believed, by the current accelerated rate of climate change and invasion of alien species (Choi 2004, Hobbs and Norton 1996).

A whole other set of problems in monitoring for success arises when goals and plans are not available (a common occurrence) or very sketchy, whether because they were never fully formulated or are not accessible or have been lost. Under these circumstances the definition of success becomes somewhat arbitrary (Choi 2004, Nienhuis 2002). The first challenge then becomes the choice of appropriate indicators against which to evaluate progress. One complicating factor is that many authors feel that success is very site-specific and must be uniquely defined for each project (McCoy and Mushinski 2002, Reive and Stephenson 1994). Other aspects of this debate are briefly described at the beginning of this chapter. Unless the project has a clear and complete set of goals that define exactly what progress the managers are expecting, the researcher is forced to select what they consider to be an appropriate set of indicators to evaluate for a particular project, depending on the age of the restoration and the vegetation type, among other factors. Holl and Howarth (2000) describe the problem as a ‘notoriously difficult’ one.

For reforestation projects, this challenge is aggravated by fact that the endpoint – a healthy, mature, functioning forest ecosystem – takes so long to aggrade that the will and the means are usually not available to follow the progress of the project and retain records to its conclusion 150 to 200 years after restoration is begun (Nienhuis et al. 2002, Spencer et al. 2001, Reay and Norton 1999).

Many authors recommend comparing the restoration to a reference community (Grayson et al.1999, Anderson and Dugger 1998, Reive and Stephenson 1994). Even in the absence of clear goals and plans, a reference community can be used to define some indicators for restoration progress, at least for the types and structures of vegetation to be expected and the families and even species of fauna that might be found. However, where a reference or target site was not selected prior to the restoration, the problem arises; what is a 'good' reference site? Is the choice based on proximity to the restoration site, similarity in topography and soils to the reference site, similar hydrology, the nearest remnants of historical vegetation, or vegetation similar to that which was chosen for the site? Choosing good reference sites for comparison with a restoration project is difficult (White and Walker 1997). As mentioned above, the natural variation in ecological communities is very great and finding a site that approximates the restoration site in the most relevant ecological components can be quite problematic.

However, the biggest problem in evaluating the 'success' of a project lies in assessing the recovery of ecosystem function to a site relative to what was there in the past (Reay and Norton 1999). The limitations in our scientific understanding of ecosystem function is one part of the problem (Hobbs and Norton 1996), but equally as important for volunteer monitoring work are the practical difficulties associated with accurately or fully measuring ecological functions such as flows of energy, chemicals, and even water through a site or with assessing populations of mammals or invertebrates with scientific accuracy.

Another measure of the success of restoration is whether it is significantly accelerating the return of a site to a condition matching that of a nearby reference. Unless the rate of development of the forest is accelerated relative to natural regeneration, the restoration effort is not worth the time and money spent on it (Norton 1991 as cited in Reay and Norton 1999). How to monitor the rate of acceleration can also be a difficult problem to address. One way to deal with this problem is that where there are untreated sites similar to the restoration site nearby, the rate of development of the restored site can be compared to that of the untreated site (Norton and Reay 1996).

Making a judgement about 'success' or failure of a particular project is difficult (Nienhuis et al. 2002). Some of the challenges described above include a lack of clear goals, the selection of appropriate indicators, the complexity and extent of the measurements required to measure true ecological restoration success (Nienhuis et al. 2002), and the selection of a good reference site. It is difficult, if not impossible, to meet all the requirements of many who lay out a template for measuring restoration success (McCoy and Mushinski 2002, Society for Ecological Restoration 2002, Whisenant 1999, Higgs 1997). However, the measurement of improvements, some aspects of increased ecological function, and progress of a site against some nearby reference is much more readily accomplished and is considered valuable (Reay and Norton 1999, Handel et al. 1994).

It is the measurement of progress against a reference, using simple indicators of vegetation structure and composition, soil characteristics, landscape ecology, and faunal usage where available, that this study aims to provide.

2.8 Goal and Objectives

2.8.1 Research Goal

The goal for this work is to assemble and evaluate a suite or toolkit of robust, yet simple and inexpensive methods that can be used by volunteers to assess the progress of forest restoration projects in Southwestern Ontario.

2.8.2 Research Objectives

1. To assess some pre-existing and pre-selected protocols for their ease of use in the field and laboratory, ease of analysis, and for their ability to provide accurate and precise data that can be reliably reproduced by inexperienced workers.
2. To test the ability of the methods to distinguish between varying levels of progress in forest restorations.
3. To try out some of the methods with inexperienced workers and get their feedback on the ease of use of the methods, the value of the information obtained, and whether they believe that the value of the information was worth the effort.
4. To assess the validity of the results obtained by the inexperienced workers.

Chapter 3

Monitoring Methods for Volunteers –Applications to Assessing Restoration Progress

3.1 Introduction

This chapter describes the rationale for choosing the methods that were studied in this work, the methods themselves, and the results that were obtained by using them to assess three forest restorations of varying levels of progress.

The initial selection of methods to be tested was made based on the literature reviewed in the previous chapter. I looked for techniques that were well-accepted by the disciplines of forestry eg. (Larson et al. 1999), vegetation ecology eg. (Kent and Coker 1992, Krebs 1989), and soil science eg. (Ontario Centre for Soil Resource Evaluation 1993), but that were easy to use in the field and gave information that was relevant to forest restoration science (Lee et al. 1999, Reay and Norton 1999, Bormann and Likens 1979). An attempt was also made to describe how relevant information about the surrounding landscape can be obtained and used to interpret restoration progress following sources such as Huxel and Hastings (1999) and Forman and Godron (1986). The same was done for faunal use of the site. The methods that were chosen are listed in Table 3.1 along with the indicators that they provide.

Once the scope and choice of the methods had been decided upon, there remained the problem of how to test whether untrained workers could use them to discriminate between different levels of progress in forest restoration. Three forest restoration projects of varying levels of progress were sought – poor, moderate, and good – as pre-assessed by experienced practitioners. Using the methods in Table 3.1, these were then evaluated, by the author who had a good deal of background knowledge but very little field experience, and a number of assistants, some with background knowledge in the environmental disciplines, but all with very little or no field experience.

Three suitable candidate restoration sites were identified in Norfolk County, where forest restoration work is very active. All the sites were located on the Norfolk Sand Plain (Chapman and Putnam 1984), which simplified the comparison of soils among the tracts.

Table 3.1. Monitoring Methods and Indicators Chosen for Testing

Method	Indicator
Point Centred Quarter Method for Woody vegetation	Similarity coefficient
	Population densities
	Percent exotics
	Relative frequencies (of species)
Quadrat Method for Herbaceous vegetation	Similarity coefficient
	Population densities
	Relative frequencies (of species)
	Percent exotics
Soil auger sampling method	Soil texture and moisture regime
pH	Evolution of pH as forest soil develops, quantify difference between restoration and reference
Nitrate	Levels of available nitrate in soil
Soil dry bulk density	Soil porosity, development of forest floor
Slake test	Erosion resistance – indicates degree to which restoration is achieving this most basic of ecosystem functions
Soil infiltration rate	Soil porosity, development of erosion resistance
Earthworms	Presence of exotic species in soil Potential for restoration to move in different direction
Soil wet aggregate testing	Development of soil structure
Respiration	Biological activity in soil, soil health
Geographical context research	Surrounding landscape, landscape ecology
Observations of fauna using site	Faunal use, status of habitat function

3.2 Methods

The three study sites were selected based on the fact that they showed different levels of progress. The pre-judgement of 'different levels of progress' was determined by interviewing local professional practitioners of restoration. The site exhibiting the best progress to date was endorsed as successful by all practitioners who were familiar with it. The site exhibiting moderate progress was given mixed reviews by knowledgeable practitioners – some felt that it was doing very well, while others with a more ecological point of view felt that there was room for improvement. The site selected as the poorest performer was judged by all restorationists interviewed to be showing disappointing results (Gagnon 2003, Gartshore and Carson 2003, Holmes 2003, Oliver 2003, Williams 2003, Wynia 2003, personal communications). All the sites were located in Southern Ontario near Walsingham on the Norfolk Sand Plain.

3.2.1 Vegetation

The Point-centred Quarter Method was used for determining the composition, densities and importance of woody species in a community. This method was chosen because it appeared to be straightforward to learn and use, required only equipment that is easy to obtain or make, and has been frequently used to assess population densities of trees in woodlands (Mitchell 2001, Larson et al. 1999). One or more transects were set up through each site. Several points were paced out along each transect. The number of paces between each pair of points was chosen randomly from between a 17 and 30. The minimum distance was designed to separate points sufficiently to avoid double counting of individuals. A maximum was set so that there would be room along the transects for sufficient sample points to represent the site and allow the use of statistical analysis. A point quarter stake was set up at each point, and the nearest tree, sapling, seedling, and shrub in each quarter was identified and measured for distance from the stake, height and diameter at breast height (dbh) if applicable. Species were defined as 'trees' or 'shrubs' before the work began, so that the compositions of restoration and reference sites could be made. Individuals were designated as 'trees' if they were taller 0.5 m, or 'seedlings' if they were less than 0.5 m in height. 'Saplings' were tree species with a dbh between two and ten centimetres, but were included as 'trees' for comparison purposes in young restorations. The results from the points were assumed to be representative of the community, and individual points were treated as 'replicates' (Quigley and Pratt 2003). Pollard's (1971) maximum likelihood estimator (MLE)[2] was used for the calculation of unbiased population densities of categories of woody plants from the PQM surveys. The significance of differences in mean populations between restoration and reference sites was determined using the Student *t*-test on the mean distances to individuals (Greig-Smith 1983). Relative percent frequencies of the different species in each woody category were determined from the PQM data.

Standard, 1m x 1m quadrats were used to obtain data for herbaceous species and ground cover. At each point along a transect, a quadrat was thrown at a random distance perpendicular to the transect. The location of the quadrat to the right or left of the transect was also randomly chosen. For species like grasses and mosses where the individuals were difficult to identify, percent cover within the quadrat was determined based on a modified Domin cover scale (Kent and Coker 1992). For other species, individual stems were counted unless the number of individuals exceeded fifty. Quadrat data were considered representative of the restoration or reference site, and were used to determine herbaceous floristic composition and plant richness for each site. In the final analysis, because the overlap of herbaceous species between restoration and reference sites was so low for these particular study sites, only relative frequency of species based on presence/absence data extracted from the quadrat data was used (Kent and Coker 1992).

An hour-long, random plant collection period or 'walkabout' was carried out at each site, during which as many different plants as could be recognized were collected (Larson et

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[2] Population density (stems/ha) = 4 x (4n-1)/(p x ? $(r)^2$) where n is the number of points measured and r is the distance to the nearest tree, seedling, or shrub.

al. 1999). Both quadrat and walkabout data were used to determine the composition of species and the proportion of exotics on each site.

Restoration progress was assessed by comparing the similarities and differences in vegetation structure and floristic composition between the restoration and reference sites. The relative percent frequencies of species (Mitchell 2001) on each restoration site were assessed against the reference. The Sorensen Coefficient of Similarity[3] (Krebs 1989) for species between the sites was calculated. The relative number of exotics in the restoration and reference sites was also considered as an indicator of restoration progress.

The role of natural regeneration in restoration work is not explicitly explored in this study. Natural regeneration will make a major positive contribution to any restoration that is well-positioned in the landscape with respect to natural seed sources (Reay and Norton 1999). The methods used in this study will differentiate between what is working well due to anthropogenic restoration activities and what is working well due to natural restoration functions, as long as good initial planting information is available. However, these two contributing factors to good progress were not differentiated in this work. Instead, the proximity of natural seed sources is considered under the assessment of landscape context.

3.2.2 Soils

A core group of soil methods was tested for suitability in the assessment of restoration progress by volunteers. These were chosen from a set of methods aimed at farmers interested in the soil quality and health of their fields. The methods had been compiled by Doran et al. (1996) and published on the internet by the United States Department of Agriculture (1999). Methods from this collection were augmented by a suite of qualitative methods developed by the Ontario Centre for Soil Resource Evaluation (OCSRE) (1993). Detailed descriptions of these methods are given in the Field Manual for Describing Soils in Ontario (Ontario Centre for Soil Resource Evaluation 1993), May et al. (to be published 2005), and/or on the internet at USDA (1999). All these methods, with the exception of the Soil Wet Aggregates test, are suitable for many different kinds of soils.

Sampling was done on a systematic basis, using some or all of the same sample points as for the vegetation survey, depending on the method. Nitrate content, pH, and slaking characteristics were determined for the soils at each of the vegetation survey points. Soil wet aggregate stability measurements were attempted for each of these samples as well. Dry bulk density and water content were measured at eight of these points chosen systematically from across the site. Soil respiration and infiltration were determined for four points across each site. Soil profile descriptions and slope and microtopography

[3] $S_s = 2a/2a+b+c$ where a is the number of species in common between the two sites, b is the number of species on the reference not found in restoration, and c is the number of species in the restoration not found in the reference.

characteristics were measured at one to three points depending on variation at the site. Usually only one earthworm count was done at each site.

The slope and microtopography characteristics at the chosen sample points were determined using classes defined by the Ontario Centre for Soil Resource Evaluation (1993). The soil profile description was made by using an auger to obtain a soil core to 120 cm or bedrock, whichever came first. Interpretations of the soil profile description follow OCSRE (1993). Soil texture and class for each layer in the profile was determined using the hand-testing methods described in OCSRE (1993). Moisture regime and internal drainage classes were assessed using methods described in OCSRE (1993).

Soil dry bulk density, total soil porosity, and water content were measured by collecting a structurally intact sample in an aluminum cylinder (5.0 cm long by 4.7 cm i.d.). The sample was taken from the upper 10 cm of the profile, regardless of whether the site was a recent or older restoration or a reference forest. This was done to clearly differentiate between soils which retain agricultural plough layers (A horizons) on the surface, and those which have begun to develop the characteristic humic layer of a true forest soil (OSCRE 1993). Weighing and oven-drying were done in a laboratory using a Mettler Toledo Delta Range (Model PB303-S) or a Sartorius Basic electronic balance and a Fisher IsoTemp (Model 230F) drying oven, but these operations can be performed in a home environment using an inexpensive electronic scale available from various scientific supply companies as well as Forestry Suppliers, Inc. in the US (USDA 1999), and a microwave oven.

Soil nitrate content and pH were measured on each of the eight samples individually and the results treated statistically to determine the mean values and variances for the site. Nitrate was measured semi-quantitatively using AquaChek nitrate/nitrite test strips available from a number of scientific supply companies (USDA 1999). The soil pH was measured in the laboratory using an Orion pH/ISE meter equipped with Calomel electrode, but pH can be measured in a home environment using a portable field instrument available from scientific supply companies (USDA 1999).

Slaking was determined using a kit made from materials available at a hardware store and following instructions given in the USDA Soil Quality Test Kit Guide (1999) for both the kit and the method.

The soil respiration and infiltration tests both required the use of an aluminum cylinder (15 cm long x 15.24 cm i.d.). This was obtained from a local machine shop. Soil infiltration was determined by driving the cylinder into the soil, then measuring the time for a 2.54 cm depth of water to soak into the soil. Details of the method are described in USDA (1999) and May et al. (to be published 2005). Soil respiration was determined by headspace CO_2 analysis using the aluminum cylinder with a cap and a Draeger Tube. The Draeger Tubes and related equipment are available at scientific supply companies, and details of the method are described in USDA (1999).

The presence of earthworms was measured because the majority of earthworms present in Canada are exotic species brought over from Europe by early settlers (University of Minnesota 2003). Earthworms have been observed to degrade natural woodlands (University of Minnesota 2003), and thus are undesirable species for a forest restoration. A worm count was done by digging a pit (30 cm x 30 cm x 30 cm) and counting all of the worms found in the volume of soil excavated. In addition, 2 litres of dry mustard powder in water solution was poured into the bottom of the pit, and any worms that were driven to the surface at the bottom of the pit were counted. Details for this method can be found in the USDA Soil Quality Test Kit Guide (1999) or May et al. (to be published 2005).

The USDA (1999) method for determining soil wet aggregate stability for aggregates between 0.25mm and 2mm in diameter was followed for each of the samples collected for pH and nitrate testing. For comparison, the wet aggregate stability method of Carter (1993) for aggregates between 1mm and 2mm in diameter was also used for the same set of samples in one of the sample sets. The USDA method required equipment which can be obtained from a local hardware store, and sieve equipment available from various scientific supply companies (USDA 1999). Standard dishwasher detergent was used to make the solution for breaking up aggregates. For the Carter (1993) method, pre-constructed stainless steel sieves available from Hubbard Scientific Co., Northbrook, IL were also used. The 0.05M solution for breaking up aggregates was made from Food Grade sodium hexametaphosphate available from Calgon.

For each forest restoration site that was surveyed, a nearby reference forest was assessed using the same sampling protocols and test methods. The results from the restoration site soils were compared with data from the reference forest and the progress of the former was evaluated against the status of the reference.

3.2.3 Surrounding Landscape

The character of the landscapes surrounding the forest restoration and reference sites were determined using and Ontario Base Maps (1:10,000 scale) in digital form. Features such as the topography and hydrology of the landscape, the vegetation cover and the relative position of nearby cultural landscapes were analysed. I was interested in determining the similarities and differences in physiography between the forest restoration and reference sites, and the availability of propagules to the restoration site. I was also interested in the potential impact of human cultural activity on the progress of the restoration. Interviews with local inhabitants interested in restoring and/or using the site were conducted to determine usage of the sites.

3.2.4 Habitat Function

The use of the sites by various fauna was monitored by observations recorded during the vegetation surveys. In addition, wildlife information used to evaluate the progress of each of the sites towards functioning forest habitat was obtained by interview from others who had studied the sites.

3.3 Study Sites

The three study sites are all located on the Norfolk Sand Plain, just north of Long Point (Figure 3.1). The sites were all roughly the same age and size.

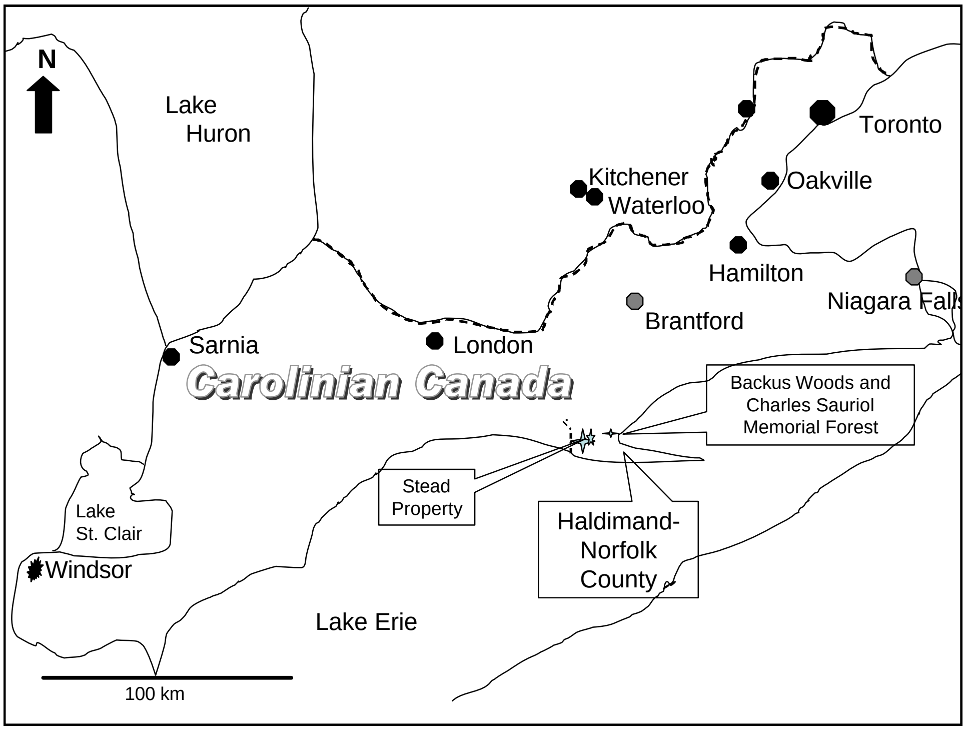

Figure 3.1 Location of Restoration and Reference Sites in Southwestern Ontario

3.3.1 Ken Stead Property

The Stead property consists of several small fields embedded in forest, adjacent to the Wilson Tract of the Long Point Region Conservation Authority Forest. This area is part of the South Walsingham Sand Ridges Area of Natural and Scientific Interest, and a Carolinian Canada Site. The fields were carved out of the forest interior more than 25 years ago to increase tobacco production – see Figure 3.2. The fields had been fallow since 1989 and were nearly devoid of vegetation. The property was purchased by Ken Stead for conservation purposes in 1993. At that time, almost no natural regeneration was visible except for early successional weeds such as Ragweed (*Ambrosia artemisiifolia)*; some use by ATV and four-wheel drive vehicles was greatly retarding progress. In 1994, the main access point to the fields was fenced and signs were posted to discourage vehicular tracks and damage (Gartshore and Carson 1994).

The fields are located on rolling sand dunes on the Norfolk Sand Plain, in UTM Zone 17T at 0536426 mE. 4702710 mN. In the spring of 1994, areas of dense quack grass were sprayed with glyphosate and the fields were planted with a mix of species chosen to emulate that in the woodlands located on dunes to the east. Local native stock was used, in the form of seedlings, rootstock, and seeds. The plantings were done in a random pattern, and at a density of one plant or seed per two square metres (Gartshore and Carson 1994). Since then exotic species have been removed on a regular basis.

The progress in two of the fields (KSF) on the south-west side of the property, adjacent to the Wilson Tract, was evaluated for this study. The smaller one to the south is 0.4 ha in size, while the larger is 2.5 ha – see Figure 3.2. The smaller field was first planted in 1994, with later additions of seeds and removal of exotics, such as Autumn Olive (*Elaeagnus umbellate)*. The larger field was planted in 1994 and 1995. A 10 m wide strip was left open around the outside of the fields to allow naturalisation to proceed (Gartshore and Carson 1994). The KSF sites were monitored in the third week of May, 2003, and the reference woodland (KSR) to the east, a week later.

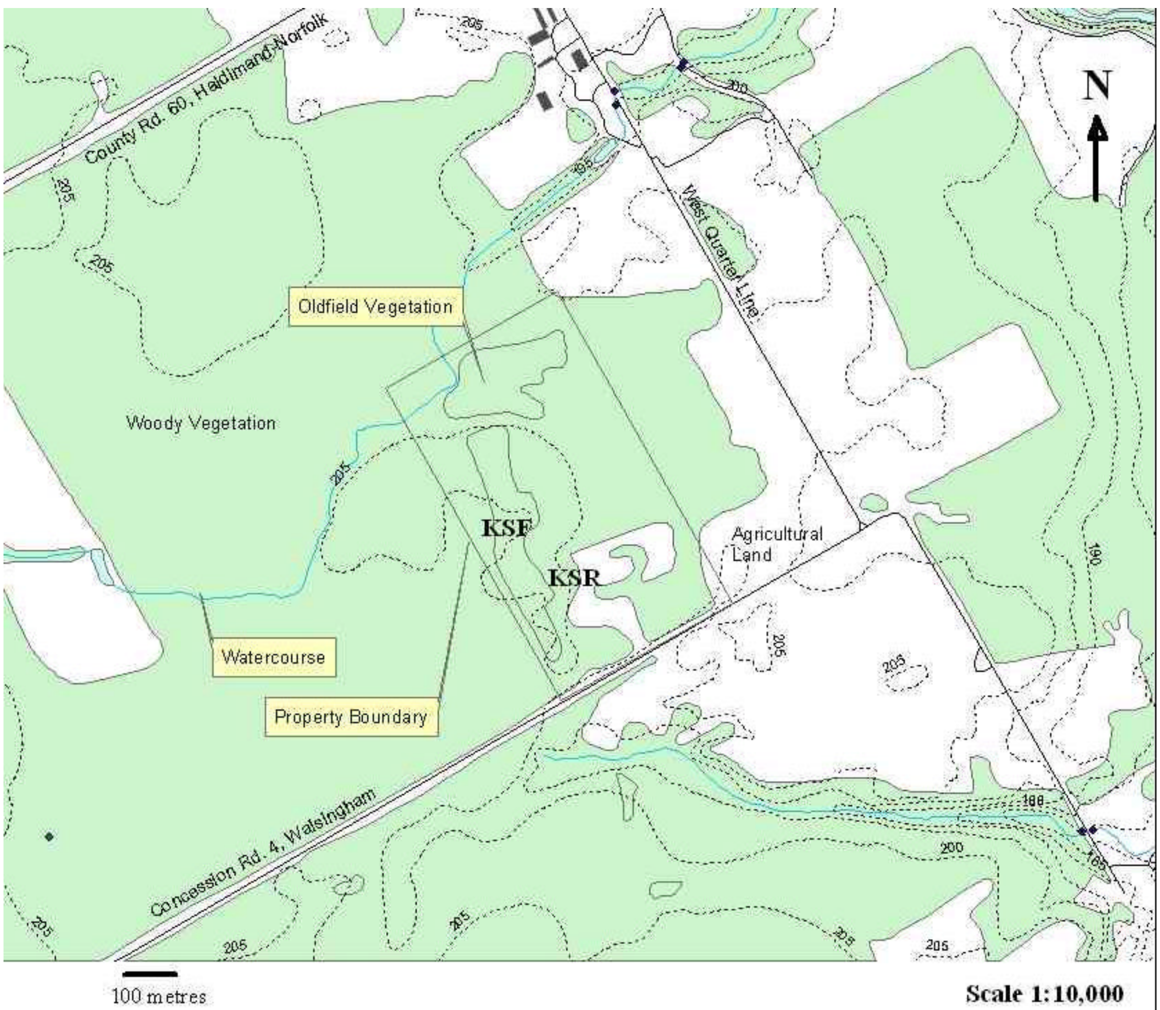

Figure 3.2: Ken Stead Study Site and surrounding landscape. Reproduced here under License with the Ontario Ministry of Natural Resources © Queen's Printer for Ontario 2003.

3.3.2 Charles Sauriol Memorial Forest

This Conservation Area was dedicated to the memory of Charles Sauriol, a longtime advocate of forest restoration. The site was planned as a model for restoration of the ‘Carolinian Forest’, and to increase the extent of Backus Woods which lies to the north and west of the site (Long Point Region Conservation Authority 1993). Two sections of this area were chosen for our monitoring study.

The Charles Sauriol Memorial Forest (CSMF) was planted on a former agricultural field, 60 ha in extent. The field is located to the southeast of the present extent of Backus Woods at UTM Zone 17T 0542883 mE. 4722806mN. (Figure 3.3). The two study sections are located side by side on nearly level ground. The first section (CSA), is 5 ha in size and was planted in 1991 with a mix of tree species dominated by Red Oak (*Quercus rubra)*, and one shrub Flowering Dogwood (*Cornus florida)*. The second section, called CSB hereafter, covers about 4 ha and was planted in 1992 with a similar mix of trees as CSA. The trees were planted in straight rows, plantation style, at a spacing of 2.5 m between rows, and 2 m between trees in a row (Gagnon 2004, personal communication). The ground was pretreated with simazine before the first planting, and the herbaceous layer was mowed for the first three years until the trees were ‘free to grow’. Since then, the only maintenance has been to remove the beaver that were cutting some of the young trees on the eastern border of the plantations (Long Point Region Conservation Authority 1993).

The two study sites are located side by side. CSB lies to the north of CSA and is therefore closer to Backus Woods by 200 m or more. CSA and CSB were monitored in late June 2003 and early July 2003 respectively. The Backus Woods Reference community (BWR) located at UTM Zone 17T 0542368 mE. and 4723478 mN. was monitored in early August 2003.

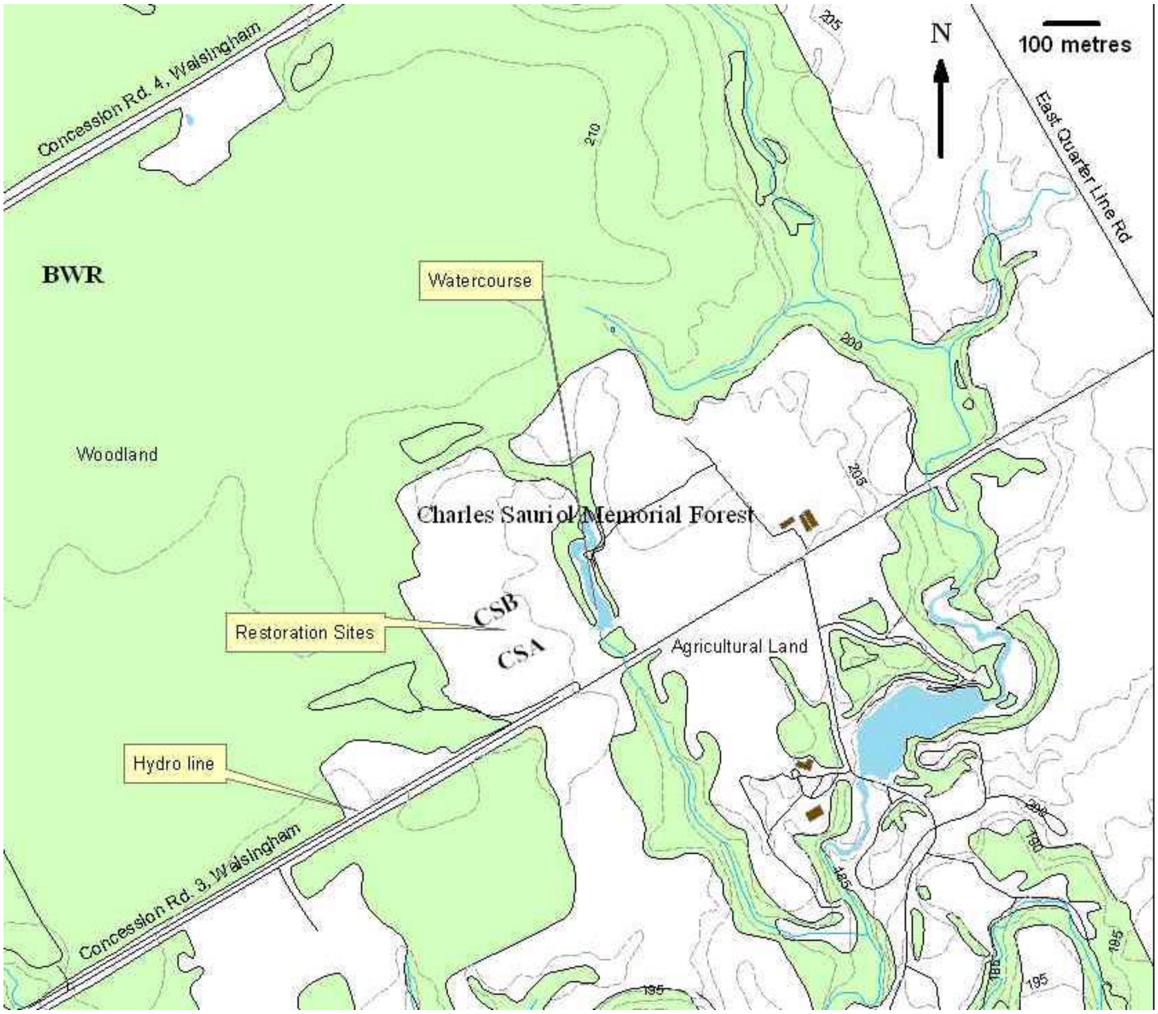

Figure 3.3. Charles Sauriol Memorial Forest, Backus Woods, and surrounding landscape Reproduced here under License with the Ontario Ministry of Natural Resources © Queen's Printer for Ontario 2003.

3.4 Results

We found that most of the methods were straightforward for initially inexperienced personnel to learn and use in the field. In most cases the field equipment was easy to obtain or make inexpensively.

The execution of all of the field tests described above, including descriptions of the site topography and layout, took about three consecutive eight-hour days per site for a pair of investigators. This initially included reading the instructions for each of the methods as we worked our way through them. As I gained experience, and new assistants joined me, I was able to explain the methods as we worked through them. Although the author and one of the assistants had a good background in Environmental Studies, no one initially had much experience with these methods in the field. Two or three more hours were required for pressing plant specimens. The lab work was accomplished in about eight hours per site, although it is more efficient to treat samples from more than one site at a time. When used together these methods yielded a great deal of data about a site. The biggest time requirement for inexperienced personnel lies in the identification of specimens, the analysis of data, and in the research to obtain landscape ecology and ecological function data. Plant identification is particularly difficult in the early part of the season. In total, several days are required to analyse the data, and to seek out information about the site from knowledgeable local people. These time requirements are not quite doubled when comparing a restoration and reference site if the two sites are in the same proximity.

3.4.1 Vegetation Structure

3.4.1.1 Stead Property

Two transects were set up at the restoration site, one in the north end of the area marked KSF in Figure 3.1, and one in the south end. The transects ran roughly north-south through the middle of each of the fields. The woody vegetation was surveyed at ten points and ten quadrats in each field, and the results of the two fields were combined. The fire-suppressed oak savannah community adjacent to KSF on the east had been chosen as a model for the restoration and was a source of propagules for the site (Gartshore and Carson 2003). It was therefore surveyed as a reference (KSR) for measuring the progress of the restoration. The transects in KSR ran east - west, traversing the middle of the woodland in three short parallel lines.

The results for the structural indicators of the restoration progress are shown in Table 3.2. Since the restoration was only 9 years old, there were relatively few trees with a dbh greater than 2 centimetres. Thus, for the purposes of comparison with the reference, the population densities of all tree specimens greater than 0.5 m in height on the restoration site were combined into the ‘tree’ category. The population of trees greater than 0.5 m in height in the restored fields was found to be an order of magnitude greater than the population of trees in the reference woodlands.

The seedling category was confined in both restoration and reference to ‘tree’ specimens less than 0.5 metres in height. The population densities for seedlings were statistically indistinguishable ($p<0.5$) for both restoration and reference. The species defined as ‘trees’ and ‘shrubs’ were the same for both sites (Tables 3.3a and 3.5a), so that these population densities are readily comparable. The shrub population densities were also not significantly different for field and woodland.

Snags were defined as standing dead trees, with a minimum diameter of 0.5 cm. There were none found in the restoration site. Small woody debris cover includes average percent of ground covered by fallen branches and twigs in the quadrats. The amount in the restoration site was very small compared to the reference. Coarse woody debris (CWD) was determined by counting the number of fallen logs of greater than 5 cm diameter within a 10-m radius of each point on the transect. CWD was not yet present in the fields. Leaf litter, moss, and grass cover are the averages calculated from those measured in the quadrats for each site.

3.4.1.2 Charles Sauriol Memorial Forest versus Backus Woods

Several transects were laid out across each of the two sections surveyed (CSA and CSB). A total of 16 points were measured in CSA and 14 points in CSB. The reference community (BWR) in Backus Woods was chosen based on a relatively close match to the mix of trees planted in CSA and CSB.

As for KSF, the population densities for all trees greater than 0.5 m in height and for saplings were combined. CSA and CSB were 12 and 11 years old, respectively, at the time of monitoring, but there were still only a few trees with a dbh greater than 10 centimetres in CSA. As shown in Table 3.2, the combined population of trees and saplings at the CSA site is significantly (Greig-Smith 1983) greater ($p<0.05$) than for Backus Woods (BWR), while the total for the CSB site was significantly less ($p<0.05$). The population densities of both seedlings and shrubs were significantly less ($p<0.05$) for CSA and CSB than for BWR, while the shrub density for CSB was significantly less ($p<0.05$) than CSA. The population density of each vegetation type was significantly different ($p<0.05$) between the three sites, with the exception of the seedling densities for CSA and CSB. These two numbers differ significantly ($p<0.10$) because the number of points measured at CSB was only 14 compared with 16 for CSA and 18 for BWR. As well, the variance in the average distance for the seedlings at CSB was very high, and there were seedlings missing at several points. To get sample sizes large enough to determine significant differences, the number of individuals counted must be high enough to outweigh the amount of variance in the average distances to the individuals (Greig-Smith 1983).

Vegetation debris, consisting of dead grass and forb cover, was a much more noticeable feature of the ground cover in CSA and CSB than was small woody debris or leaf litter. Average percent moss and grass cover was much greater in CSA and CSB than for BWR. The amount of coarse woody debris in the restoration sites was negligible.

Table 3.2: Indicators for Vegetation Structure

Indicator	KSR	KSF	BWR	CSA	CSB
Absolute density-trees/ha (height > 0.5m)	440	4431	460	860	280
Absolute density-seedlings/ha(<0.5m height)	3217	3100	1851	960	555
Absolute density-shrubs/ha	2490	2849	3324	1483	748
Absolute density-snags/ha (includes all dbh > 0.5cm)	630	na	97	na	389
Leaf litter (average %)	87	42	96	32	2.1
Small woody debris (avg%)	<1	13	13	1.2	0
Vegetation debris (avg %)			100	63	96
Moss cover (average %)	<1	9	0	12	10
Grass cover (average %)	<1	3	0	9	13
Coarse woody debris (avg no. per point)	8.7	0	20	0	0
Canopy cover (average %)	95	<1	83	25	7

3.4.2 Vegetation Composition

3.4.2.1 Woody Vegetation - All Sites

The relative frequency of the tree species, as measured at the points along the transects, is shown in Table 3.3a for KSF and KSR and Table 3.3b for CSA, CSB and BWR. The mix of tree species in the restorations is partly due to planting, and partly due to naturalisation processes. Naturalised species include *Rhus typhina, Populus, Salix* and *Prunus* species, some of which were found during the walkabouts. Tables 3.4a and 3.4b show the relative frequencies of seedling species in restoration and reference for KSF, KSR and CSA, CSB and BWR, respectively.

The relative frequency for shrubs is shown in Table 3.5a for the KSF and KSR and 3.5b for CSA, CSB and BWR. Only the most common species are listed.

The Sorensen Similarity Coefficient for woody species at KSF and KSR is 0.64 as shown in Table 3.8. Only one of the woody species (3.4% of the total) found in the reference site was exotic, while 11% of the species found in the restoration were non-native. For BWR and the two Sauriol sites, the Sorensen Similarity Coefficient for woody species was 0.35 for CSA, and 0.33 for CSB as shown in Table 3.8. The number of woody exotics found in BWR was very low (ie. only one, or 3%), while 11.5 % of the woody species were exotic in CSA, and 5 % at CSB.

Table 3.3a: Stead Property; Relative Frequency of Trees

Species	Relative Frequency (%)	
	KSR	KSF
Quercus alba	33	14
Quercus velutina	28	31
Populus grandidentata	17	Found around edges
Sassafras albidum	14	Found around edges
Prunus serotina	6	Found around edges
Carya ovata	3	
Rhus copallina		31
Rhus typhina		20
Populus tremuloides		3

Table 3.3b: Backus and Charles Sauriol; Relative Frequency of Trees

Species	Relative Frequency (%)		
	BWR	CSA	CSB
Acer rubrum	22		4% of saplings
Quercus rubra	20	20	43
Acer saccharum	20		
Betula allegheniensis	13		
Fraxinus spp.	7	10	7
Fagus grandifolia	6		
Rhus typhina		50	25
Salix spp.		3	
Picea glauca		3	4
Populus tremuloides		3	
Platanus occidentalis		3	11
Pinus resinosa			7

Table 3.3c: Backus Woods Trees vs. CSMF Saplings: Relative Frequency

Species	Relative Frequency (%)		
	BWR	CSA	CSB
Acer rubrum	22		4.5
Quercus rubra	20	24	59
Acer saccharum	20		
Betula allegheniensis	13		
Fraxinus spp.	7	16	4.5
Fagus grandifolia	6		
Rhus typhina		22	4.5
Juglans nigra		11	
Picea glauca		8	4
Populus tremuloides		3	
Platanus occidentalis		8	14
Pinus resinosa			4.5

Table 3.4a: Stead: Relative Frequency of Seedlings (height less than 0.5 metre)

Species	Relative Frequency (%)	
	KSR	KSF
Acer rubrum	31	Found around edges
Prunus virginiana	24	
Quercus velutina	14	43
Prunus serotina	14	Found around edges
Sassafras albidum	7	Found around edges
Quercus alba	3	Present
Populus grandidentata	3	Found around edges
Amelanchier arborea	3	
Pinus strobus		Found around edges
Rhus copallina		33
Rhus typhina		20
Populus tremuloides		3

Table 3.4b: Sauriol Backus: Relative Frequency of Seedlings (height less than 0.5 metre)

Species	Relative Frequency (%)		
	BWR (%)	CSA (%)	CSB (%)
Acer saccharum	33		
Acer rubrum	19		4
Sassafras albidum	16		4
Quercus rubra	14	13	7
Fraxinus spp.	5		29
Fagus grandifolia	2		
Rhus typhina		70	43
Salix spp.			4
Picea glauca			4
Populus tremuloides			4
Prunus spp		9	

Table 3.5a: Stead: Relative Frequency of Shrubs

Species	Relative Frequency %	
	KSR	KSF
Corylus americana	48	20
Rosa blanda	10	Present*
Viburnum acerifolia	7	
Vitus spp.	3	7
Vaccinium pallidum	3	
Cratageus flabellate	3	4
Rosa multiflora	3	Found around edges
Rubus allegheniensis	3	22
Lonicera canadensis	3	
Hamamelis virginiana	3	
Rubus flagellaris		17
Ceanothus americanus	Present around edges	15
Rosa carolina	Present*	7
Rubus occidentalis		2
Malus coronaria	Present*	Found in walkabout

*Communication from M. E. Gartshore

Table 3.5b: Sauriol Backus: Relative Frequency of Shrubs

Species	Relative Frequency (%)		
	BWR	**CSA**	**CSB**
Viburnum acerifolia	21		
Parthenocissus vitacea	16		3
Lindera benzoin	13		
Rhus radicans	16		
Vitus spp.	11	38	40
Rubus spp.		33	3
Cornus spp.	found	18	21
Rosa spp.	3	6	18
Salix spp.		6	6

3.4.2.2 Herbaceous Vegetation – All Sites

The relative frequencies of the most abundant herbaceous species, assessed using presence/absence data from the quadrats, are shown in Table 3.6 for the KSF and KSR and Table 3.7 for the CSA, CSB and BWR. The number of 1 m^2 quadrats thrown at each site was small relative to the overall size of each site, so these values are only representative of the relative frequency of these species across the entire site. However, the differences in floristic composition among the forbs between the restoration and reference sites are so great that better accuracy is not required.

Table 3.6. Herbaceous Species at Stead Property:

Species	Percent Quadrats Where Found	
	KSR	KSF
Maianthemum canadensis	53	
Galium spp.	53	
Polygonatum pubescens	53	
Hepatica americana	27	
Smilax herbacea	27	
Solidago spp.	20	
Osmorhiza claytoni	20	
Tragopogon pratensis		30
Hypericum perforatum		25
Vicia villosa		20
Fragaria virginiana		15
Hedyotis longifolia		10
Taraxacum officinalis		10
Potentilla recta		5

Only the most abundant species in both sites are shown in Table 3.6, and there was no overlap in these. The Sorensen Similarity Coefficient was 0.24 between the two sites when the total numbers of herbaceous species were included (Table 3.8). Less than four percent of the species found at KSR were exotic, while 20 % of the herbaceous species found in KSF were exotic.

Table 3.7. Most common herbaceous species in Sauriol and Backus;

Species	Percent Quadrats Where Found		
	BWR	CSA	CSB
Maianthemum canadensis	55.6		
Polygonatum pubescens	44.4		
Trillium spp	33.3		
Osmorhiza claytoni	27.8		
Viola spp	27.8		
Arisaema atrorubens	5.6		
Medeola virginiana	5.6		
Polystichum acrostichoides	5.6		
Galium spp	5.6	31	
Solidago spp		93.8	100
Daucus carota		56.3	93
Equisetum spp.	found	44	21
Taraxacum spp		56	100
Desmodium canadense		38	64

For BWR, CSA and CSB, the similarity coefficient between total numbers of herbaceous species was 0.22 for CSA, and 0.08 for CSB – see Table 3.8. The incidence of herbaceous exotics found was 3.2% in Backus, 37% at CSA, and 29% at CSB.

Table 3.8: Floristic Relationships between Restoration and Reference

Character	Sorensen Similarity Coefficient	Reference Exotics (%)	Restoration Exotics (%)
KSF – Woody	0.64	3.4	11
KSF – Herbaceous	0.24	3.4	20
CSA - Woody	0.35	2.8	11.5
CSA – Herbaceous	0.22	3.2	37
CSB – Woody	0.33	2.8	5
CSB – Herbaceous	0.08	3.2	29

3.4.3 Soils

The soil indicators measured are shown in Table 3.9 for all sites. The texture and moisture regime are determined by qualitative visual inspection and hand-texturing, so that the results do not lend themselves to parametric statistical analysis. The Student t-test was used to determine whether the results for the restoration and reference are the same or significantly different for the pH, nitrate and dry bulk density tests. The data from the slaking, respiration and infiltration tests however, were non-parametric, so the Mann-Whitney U Test was used to determine whether differences are significant for these results. No results are shown for soil wet aggregates and respiration tests because there were so many experimental errors associated with the former, and such scatter in the data from the latter, that the results from these two tests are meaningless. For details of the difficulties encountered, see Appendix III.

Table 3.9: Soil Characteristics

Indicator	KSF	KSR	CSA	CSB	BW
Texture[1]	Fine Sand	Fine Sand	Fine Sand	Very Fine Sand	Fine to very fine sand
Moisture regime[1]	Moderately fresh	Moderately fresh	Fresh	Moist	Moderately fresh to Moist
Average pH[2]	5.9 $\pm$ 0.3(S)	6.0 $\pm$ 0.4	6.5 $\pm$ 0.8(D)	6.6 $\pm$ 0.4 (D)	5.2 $\pm$ 0.6
Average NO_3^{-2} (kg NO_3/ha)[2]	1.4 $\pm$ 0.4(D)	0.5 $\pm$ 0.2	1.6 $\pm$ 0.5(D)	1.9 $\pm$ 0.7 (D)	1.0 $\pm$ 0.5
Average Dry bulk density (g/cm^3)[2]	1.43 $\pm$ 0.04(D)	0.8 $\pm$ 0.1	1.1 $\pm$ 0.2(D)	1.3 $\pm$ 0.1 (D)	0.8 $\pm$ 0.3
Slake test[2] **– mode**	5(D)	6	6 (S)	6 (S)	6
Infiltration[2]	Rapid to very rapid	Very rapid (D)	Very rapid(S)	Very rapid(S)	Very rapid
Earthworms[2]	None found	74/m^3	37/m^3	481/m^3	None found

1. Ontario Centre for Soil Resource Evaluation (1993). 2. USDA (1999)
D: significantly different from reference by Mann-Whitney U test. S: same as reference

3.4.4 Surrounding Landscape

3.4.4.1 Stead Property

The KSF sites were located on rolling upland dunes, as was KSR to the east – see Figure 3.2. The nearest permanent water feature was the Whitney-Townsend Drain, which runs across the north and west about 100 m from the north field boundary. The reference community KSR lies mainly on a dune ridge, but runs down into a low swale about 100 m to the east of KSF. A sand road runs east and west about 70 m to the south of KSF. This is the nearest cultural feature to the fields, only excepting an abandoned field 10 m to the north of the north field, and a partially restored, abandoned field 35 m to the east. The closest currently cultivated fields are more than 300 m to the east, and 150 m to the southeast, and the closest buildings are 600m to the northeast. The west and north sides of the property are bordered by the 80 ha Wilson Tract. This tract is managed for its natural values and is home to several rare bird species. It is also managed for timber and hunting, and ATV use is common. Gunshots and ATVs were heard numerous times in the surrounding forest while we were monitoring the KSF.

3.4.4.2 Charles Sauriol Memorial Forest and Backus Woods

Sites CSA and CSB are located in the southwest corner of a former farm field – see Figure 3.3. Site CSB was located adjacent to CSA to the north. To the southwest of the sections that were evaluated was a White Pine plantation. To the west was an area that appears to have been naturally regenerating for some time. To the north of CSB is a more traditional hardwood plantation, and north of that area, adjacent to Backus Woods, is a section that is being allowed to regenerate naturally. Backus Woods extends to the north and west of the former field, 250 m from the north boundary of CSB and 100 m from the west boundary of both CSMF study sites. Directly to the east of CSA and CSB is an open oldfield that extends about 75 m to a wooded stream and pond inhabited by beavers until the summer of 2003. Beyond this narrow riparian strip is another series of tree plantations that are part of the Charles Sauriol Memorial Forest complex. The nearest residential buildings are 500 m to the east of CSA and CSB. A sand road runs to the south of CSA, 50 m from the south border of CSA. Across the road is another building, and cultivated fields. Single-wire hydro lines run along the road. Road traffic and the sounds of mechanised agriculture were heard while we were on the site, but no hunting or ATVs.

The ecological community in Backus Woods that was chosen as the reference forest (BWR) for CSA and CSB is located about 900 m to the northwest of CSB. There is a quiet sand road running about 150 m to the north of BWR, otherwise it is surrounded by mature hardwood forest, with the exception of a 50 year-old conifer plantation adjacent to the east side of the community. There is also a trail that runs along the south side of the community that is infrequently used by cyclists and pedestrians.

3.4.5 Habitat Function

3.4.5.1 Stead Property - Faunal Use

In the case of KSF, a great deal of information on faunal use was available from Gartshore and Carson (2003). Thus, only rare species or habitat specialists whose use of the site indicates restoration progress are included in Tables 3.10 and 3.11.

Table 3.10. Selected Birds seen at Stead Property

Species	Significance
Piranga rubra	Savannah Species
Dendroica cerulean	Interior Species
Wilsonia citrina	Interior Species
Catharus fuscenscens	Interior Species
Hylocichla mustelina	Interior Species
Seiurus aurocapillus	Interior Species
Piranga olivacea	Interior Species

Table 3.11. Significant Insects and Mammals found on KSF

Species	Significance
*Tachysphex pechumani**	Provincially rare
Cicindela lepida	Provincially rare
Mustela frenata	Common, opportunistic
Microtus pinetorum	COSEWIC Special Concern
Parascalops breweri	Sand dependent
Glaucomys volans	COSEWIC Special Concern
Heterodon Platyrhinus	COSEWIC Threatened

*(Buck 2003, personal communication)

3.4.5.2 Charles Sauriol Memorial Forest

There was not much data available on the faunal use of CSA and CSB. Species that were observed during our work, and common species known to use the site (Holmes 2003, personal communication) are shown in Table 3.12.

Table 3.12: Fauna observed at the Charles Sauriol Memorial Forest

Species	Significance
Odocoileus virginianus	Common
Meleagris gallopavo	Common
Castor canadensis	Common
Danaus plexippus	Common
Papilio polyxenes	Common
Speyeria cybele	Common
Geolthlypis trichas	Common
Cicindela sexguttata	Common

3.5 Discussion

One of the main questions this work tries to answer is:
Can inexperienced volunteer conservation and restoration practitioners discriminate between different levels of restoration progress using this group of methods?

Some of the underlying queries that the broader question entails are:

1. Do these methods provide defensible, scientific evidence relevant to the measurement of restoration progress in the hands of inexperienced workers?
2. How closely does the restoration site plant community resemble the reference plant community at the time of measurement, ‘x’ years after restoration?
3. How closely do the soils of the restoration site match those of the chosen reference?
4. Is the restoration on a trajectory (Zedler and Callaway 1999) to resemble the reference?

A second overarching question investigated in this work is: Do inexperienced workers find these methods user-friendly, and the information they yield valuable, enough to make the effort worthwhile? This question can be reworded as follows:

1. Are the methods easy to use?
2. Do they provide sufficient evidence to draw good conclusions about the restoration progress?

3.5.1 Vegetation Data Discussion

3.5.1.1 Methods – Ease of Use, Accuracy

As mentioned above, the Point-centred Quarter method (PQM), the quadrat method, and the walkabout were simple to execute, and a great deal of data were collected in a short amount of time. The population densities of woody species that we obtained in BWR were comparable to those for an old growth forest in southeast Ohio (McCarthy et al. 1987) 350 to 442 vs 374 trees/ha for BWR. The fact that the population density results for BWR compared well with known values for other older growth forests instils confidence that the PQM method is robust enough to yield accurate data when used by inexperienced personnel. Based on the PQM data, we were also able to obtain relative frequencies of woody species, for detailed vegetation composition comparisons between restoration and reference sites. Since these restoration projects were in the early stages of development, percent overlap of all woody species was the most useful vegetation composition indicator abstracted from the PQM data. However, for older projects where restoration to historical conditions is the goal, the quantitative correlation of species mixes might be a useful indicator for comparisons of similarity in vegetation composition between restoration and reference sites.

From the quadrat and walkabout data, I found that the overlap of herbaceous species between restoration and reference sites was very low at these early stages of restoration development. Thus only presence/absence data were required from the quadrats, and so concerns about the errors associated with estimation of percent cover, and about the time required to count stems in the quadrats were alleviated. As projects mature, it is expected that overlap of herbaceous vegetation would increase, and more quantitative comparisons would be of interest. Presence/absence data are still sufficient to obtain an objective estimate of percentage frequency (Kent and Coker 1992) when more quantitative data and comparisons are required – see Tables 3.6 and 3.7. A difficulty remaining with the use of quadrats is the identification of plant species. The expectation is that volunteer groups who would be interested in doing this work would include some people with a certain level of botanical knowledge, and would have contacts with more expert botanists and herbaria. Examples include naturalist groups, members of Ontario Nature and environmental science educators. Herbaria such as those at the University of Western Ontario and the University of Guelph are available for use by the interested public (LaCroix 2003 and Bowles 2004, personal communications).

3.5.1.2 Stead Property – Woody Vegetation

The goals of this restoration were specifically (Gartshore and Carson 1994):

1. to fill in the gaps in the forest to create more interior forest for significant song birds
2. in the short term, to create sand-barren type habitat for rare sand-loving insects
3. in the long term, to match the plant community in the fire-suppressed oak savannah complex on similar physiography immediately adjacent to the site

There is a very high density of vigorous trees and shrubs on the KSF restoration site relative to the reference KSR, as shown in Table 3.2. This dense woody vegetation is well on its way to filling the forest gaps created when the KSF fields were cleared. There is also a significant overlap of woody species between KSF and KSR, with a Similarity Coefficient of 0.64 as indicated in Table 3.8. The large overlap of woody species between KSF and KSR, observed on the Stead property, suggests that the restoration is well on its way to meeting the third goal of the project.

There is a high density of trees greater than 0.5 m in height in KSF relative to KSR. The population of young trees and saplings that spring up in a young forest, or are planted in a restoration, provides the understory from which the population of mature trees is drawn as competition, disease, and disturbances reduce their numbers (Oliver and Larson 1990). Despite the fact that over half of the 4430 trees and saplings on KSF are shade-intolerant sumacs and poplars which will inevitably die out as the forest aggrades, the population of more shade-tolerant recruits is still high relative to the density of mature trees in the reference. This high population of recruits provides a healthy stock of young trees from which a forest with a population density similar to the reference can develop.

The density of seedlings in both restoration and reference sites was virtually the same. Although they are of similar size, the average age of the more suppressed seedlings in KSR was likely to be greater than for KSF. However, in both cases the high density of seedlings represents a healthy replacement inventory of young trees that will ensure the future development of forest (Horn 1980, Grime 1979). The overlap of KSF seedling species with KSR seedling species is more extensive than that for the larger ‘trees’ and saplings – 0.66 compared to 0.54. This is a good indication that the mix of species in KSF is proceeding toward that in KSR (Thoreau 2003, Oliver and Larson 1990).

The relative density of shrubs in KSF and KSR are the same; the small difference is not significant according to Student's t test ($p<0.05$) (Grieg-Smith 1983). The species overlap between the two sites is relatively high with a Similarity Coefficient of 0.75. The differences are due to species in KSF that are shade-intolerant and will disappear as the canopy closes. It is expected that the mix will evolve to more closely resemble that of the reference site as the canopy closes. In the meantime, the shrubs in KSF provide similar understory habitat to the reference site and includes several species to which forest interior fauna are adapted. This is a good indicator that KSF is proceeding along a trajectory to meet goals 1 and 3 of the restoration project.

3.5.1.3 CSA, CSB and Backus Woods – Woody Vegetation

The restoration goals for the Charles Sauriol Memorial Forest were to:

1. restore it to a forest community 'similar in composition to Backus Woods' (Long Point Region Conservation Authority 1993a).
2. extend the forest cover provided by Backus Woods (Oliver 2003)
3. educate the public about the species unique to the Carolinian Forest and promote awareness of Conservation (Long Point Region CA 1993b)

The Sorensen Similarity Coefficient of woody species between the restoration sites and BWR was 0.35 for CSA and 0.33 for CSB (Tables 3.3b, 3.3c, 3.4b, and 3.5b only show partial listings of species found). For both sites, one of the causes of this relatively low overlap compared to the Stead Property was that the choice of species for the CSMF was based on species found throughout Backus Woods as a whole, and not specifically on any one ecological community. Our reference area in Backus Woods (BWR) was limited to one or two ecological communities. As well, some of the species used at the CSMF were 'left-overs' from other plantings done by the Long Point Region Conservation Authority elsewhere. They were not chosen specifically because they were found in Backus Woods (Oliver 2003).

The population density of trees over 0.5 m in height at CSA was significantly higher than that measured in BWR – see Table 3.2. However, over half of these were early successional species – see Table 3.3b, which leaves only a population of trees about equal to that in BWR that are adapted to survival in a mature forest. It is unlikely that *all* of these individuals will survive. What is more probable is that further recruitment of seedlings will be required, and that it will take longer for the site to reach a forest cover density similar to BWR. This is in contrast to the KSF site, where the population density of forest-adapted small trees is much higher than that of the mature forest. Site CSB is in even poorer condition, with a population of trees and saplings that is significantly lower than BWR, and of these at least 30% are struggling – that is, they are showing signs of dieback and resprouting. The tree population at the CSMF restoration sites has also been negatively impacted by the presence of beaver. All along the east side of the plantation, young healthy trees are being cut down, and although some of them are sprouting from the base, these are less likely to survive to full maturity.[4]

The population density of seedlings at either of the CSMF restoration sites does not compare favourably with that of BWR – see Table 3.2. This is unlike the situation at the Stead property, where KSF and KSR have relatively similar tree seedling populations. Again, CSB is in much poorer shape than CSA; having a lower seedling density relative to that for BWR, than that for CSA. Since the average canopy of BWR is over 80%, canopy cover is only a partial factor affecting seedling density. Where the canopy is open at the CSMF, the ground is densely covered with grasses and forbs, so that strong competition for light and moisture at the seedling stage is probably a major factor in the lower population of seedlings at CSA and CSB. Whatever the cause, the lower seedling densities at the CSMF sites can be taken as an indicator of slower restoration progress when compared with the Stead restoration. A higher seedling density provides a greater opportunity for different aged trees to develop into a mature uneven-aged forest (Oliver and Larson 1990, Horn 1980).

The overlap of seedling tree species between the restoration sites and BWR is greater for CSB than CSA, despite the much lower population density – see Tables 3.2 and 3.4b. This could be due to the fact that the canopy at CSB is more open, and because it is slightly closer to BWR, and thus more susceptible to incoming propagules. It might also be due to the fact that CSB has soil characteristics that better match those of the chosen reference community in BWR.

The population density of shrubs for CSA and CSB are quite low relative to that for BWR – see Table 3.2. This is probably due largely to the fact that very few shrubs were planted at the restoration sites, and so those that have appeared are due to natural regeneration processes. However, it can be seen that one result of this is that the vegetation community at CSA and CSB will probably take longer to approach that of the BWR site, than for KSF to match KSR. The shrub species most typical of the BWR community will have to migrate into CSA and CSB solely under the processes of natural regeneration. Thus, the progress of the ecological restoration at KSF may be said to be more advanced relative to of CSA and CSB based on this factor. Further, shrub populations at CSA would appear to be regenerating much more quickly than at CSB, since the shrub density at CSA is larger than that for CSB. This can be taken as another indicator of the relatively poor progress at CSB relative to CSA, KSF, and BWR. Based on the composition of shrubs at CSA and CSB, the CSMF sites will take significantly longer to reach the goal of matching the reference community than will KSF. It is also expected that CSB will take longer than CSA to resemble BWR, based on these results.

Based on woody plant population densities, KSF is showing much better progress than CSA, and CSB is lagging far behind both. The initial selection of tree species not suitable for the soil conditions is a major factor in the poor performance of CSB. Based on the overlap of species, KSF clearly shows superior performance, while CSA and CSB are essentially equal. According to the population density indicator, the three sites are

[4] As of late summer 2003, the beaver have been removed from the site (Holmes 2004).

ranked according to the initial pre-judgement of the professional restorationists, with KSF progressing faster than CSA, while CSB lags behind both. According to the Similarity Coefficient indicator for woody species, CSB, ranked as showing poor progress, does not appear significantly worse than CSA which was considered to be showing moderate progress (Wynia 2003, Oliver 2003, Holmes 2003), but the Stead restoration (KSF) is confirmed as showing the best progress.

Neither CSA nor CSB have come a long way towards meeting the goals for the Charles Sauriol Memorial Forest. Most species on both sites are not unique to the Carolinian forest. As well, they are both somewhat distant from Backus Woods, and separated from it on one side by plantation and another by open old field vegetation. However, if natural regeneration is allowed to continue along the trajectory that appears to be occurring, these goals will eventually be met.

3.5.1.4 Herbaceous - all

In all cases the overlap of herbaceous species between restoration and reference sites was low, with Similarity Coefficients less than 0.25 (see Table 3.8). This is due to the fact that the restoration projects evaluated in this work are in the early stages of vegetation development and many of the species on these sites are still old-field types (Egler 1954). The canopy has not yet been closed enough, for long enough, to create the microclimate required by most woodland species. Canopy cover was less than 1 % for KSF, 25 % for CSA and 6 % for CSB. When the relative frequencies of the most common species shown in Tables 3.6 and 3.7 are compared, it can be seen that there is almost no overlap between restoration and reference sites. Where overlap in herbaceous species is so low and restoration work is so recent, I have concluded that there is not much value in collecting detailed information on the numbers of individuals in the quadrats, or even percent cover. Only presence/absence data were required to compile Tables 3.6 and 3.7. Where a restoration has been in existence long enough for a significant overlap of forbs to develop, there is more value in comparing relative populations of herbaceous species in order to characterise the progress of the restoration against the reference.

The Sorenson Similarity Coefficients for herbs in KSF and CSA relative to their reference sites are essentially the same, while that for CSB is much lower. The KSF plantings included some forbs, so some overlap of forb species with the model woodland is not surprising. In the case of CSA, the canopy cover has increased to 25%, and there are several small groves of oaks with essentially closed canopies on the site. In this instance, the presence of some shade-adapted forbs might be expected. On the other hand, CSB is still largely an open old-field dominated by shade intolerant herbaceous species.

3.5.2 Soils Discussion

3.5.2.1 Methods

With the exception of the wet soil aggregates test methods, all the soil methods were simple to perform in the field and/or in the laboratory following procedures described in the USDA Soil Kit Guide (1999), the Ontario Centre for Soil Resource Evaluation (1993) or the Handbook of Methods for Volunteer Monitoring of Forest Restoration (May et al. 2005). The wet soil aggregates protocol proved difficult to perform as described in the USDA Soil Kit Guide (1999). Indeed, the method as described did not work at all with the structureless sandy soils encountered during this study. An alternate test, described in Carter (1993), gave better results, but was so tedious to perform that it is really not suitable for volunteers to use. For more details, see Appendix III. In consequence, I discarded the test for wet soil aggregates as a component of this suite of methods reluctantly, because soil aggregates are such a good indicator of healthy soils.

The Soil Respiration test was also discarded at this point in the study, because although it was not difficult to perform in the field, the results were so variable that no significant differences could be found between reference and restoration sites. It would be possible to improve the significance of the results by greater replication in the field, but this test is time-consuming, expensive, and the results are difficult to interpret. The test was therefore considered not suitable to include in a suite of methods for volunteers. See Appendix III for more details.

The calculations for the retained tests are all easy to do and to understand. However, the Texture and Moisture Regime characterisation tests, although they appear quite straightforward, are actually the most problematic. The accurate interpretation of the results of these tests requires a certain amount of judgement based on experience. Some training in properly judging soil colours and textures with an experienced practitioner is recommended for best results.

In terms of equipment, the slaking and infiltration tests can be done using equipment that can be made at home from materials found either in the home or in a local hardware store, or made by a local machine shop. The texture, moisture regime, pH, nitrate, and dry bulk density tests require the purchase of some specialised equipment from Forestry supply companies (Forestry Suppliers Inc. 2004) or Scientific Supply companies (USDA 1999). The measurements can be done in a home workshop or local school laboratory if available. Alternatively, all of the equipment can be purchased in a single kit (USDA 1999), although these are expensive. Further, if a naturalist’s group has ties with a local high school, most of the equipment required for these tests will be available in their labs, with the exception of the Nitrate Test strips. Notwithstanding the cost and/or time required to assemble the equipment to do these tests, the knowledge of soil health and quality revealed by these tests in invaluable. A comparison of the physical condition of the soils at a restoration site and the chosen reference site can often give clear indications of reasons for success or failure of a restoration. Knowing the physical condition of the soils allows the practitioner to evaluate the effect of restoration progress on soil health and quality. A decrease in dry bulk density, a reduction of slaking, and an increase in infiltration rates are three key indicators of improving soil quality (Doran et al. 1994) at a restoration site.

3.5.2.2 Stead Property

The soil on the Stead Property was fine sand (fS) for both KSF and KSR, with a moderately fresh moisture regime – see Table 3.9. Both restoration and reference soils also had similar pH. Based on these three characteristics, it is to be expected that the soils in these two sites would support similar natural vegetation (Moffat and Buckley 1995). It can also be said that based on the similar soils at the two sites, the choice of reference site for this restoration was appropriate.

The two soils differ in dry bulk density as measured at 2 to 5 cm depth – see Table 3.9. At this depth, we were measuring the dry bulk density of the organic LFH layer of the forest soil while at the restoration site next to it we were taking samples from the plough layer created by more than 25 years of cultivation. There was no evidence of an organic layer over most of the 8-9 year-old restoration site, although leaf litter and vegetative debris were observed in hollows and around the base of thickets over about 40% of the surface, and a thick moss layer had grown on other parts. Studies of the forest floor in several clear-cut forests in the northeast US have shown that the existing organic layer decreases in depth for about 15 years after clearing, and then re-develops about 95% of its original depth after a period of 65 years after cutting. It is hypothesised that it takes about 100 years for the surface organic horizon to reach an equilibrium depth in an aggrading northeastern hardwood forest (Bormann and Likens 1979). The dry bulk density test is thus a good measure of the aggradation of a forest floor as the restoration develops. In the early stages, as at KSF where the vegetative ground cover was relatively sparse, it is to be expected that the surface soil dry bulk density more closely resembles that of the agricultural field that it formerly was.

The lower rate of infiltration measured for the KSF soil can also be attributed to the difference in character between the bare mineral soil of KSF and the continuous layer of organic matter on the KSR forest floor (USDA 1999). The fibrous mat of roots and decaying vegetative matter in the organic layer is very porous and absorbs water quickly (Moffat and Buckley 1995). In contrast, the bare sand at the KSF site, with occasional surface roots and intermittent undecayed leaf litter, has lower total soil porosity and is thus more resistant to water infiltration. The lower resistance to slaking of the restoration soil surface can also be attributed to lower organic content and poorer soil structure with weaker soil aggregates (USDA 1999, Doran and Jones 1996). Loss of porosity leading to increased erosion is one of the first major changes to occur in soils after loss of vegetative cover (Whisenant 1999). Recovery of this attribute is one of the first goals of a restoration, since it is a sign of recovery of ecosystem functioning (Whisenant 1999). These two tests provide valuable information about the erosion resistance of the soils.

Levels of nitrate in the KSF soil were higher than in the KSR soil – see Table 3.9. This might be attributed to many years of artificial fertilisation in the cultivated ground (Moffat and Buckley 1995). Healthy forest soils have been shown to contain relatively low levels of free NO_3-N, as much of the nitrogen in a forest ecosystem is strongly retained in the biomass, while the free nitrogen in the forest floor is largely in the form of ammonium ions (Bormann and Likens 1979). Forest soils sampled in northeastern hardwood forests have shown that NH_4^+ undergoes nitrification rapidly if kept moist in the laboratory (Bormann and Likens 1979). All of our samples were tested within 30 hours of having been collected, so that this effect should be similar for all of them.

The sandy soils of the Norfolk Sand Plain discourage the presence of earthworms. The fact that they are missing at KSF is thus not surprising. That we found a few in KSR is discouraging because of the damage that these exotic species can do in our native forests (University of Minnesota 2003). If present in sufficient numbers, they are capable of devouring the entire forest floor within three to five years.

I believe that the data provided by these tests is objective and reproducible by others with little experience. There will be variation in, for example, the pH and nitrate, during different seasons, but because these tests were done at the two sites within a week of each other, I believe that they give an accurate representation of the differences and similarities between site soils.

3.5.2.3 Backus Woods and Charles Sauriol Memorial Forest

The mineral soil in BWR ranged from fine to very fine sand with a moderately fresh to moist moisture regime, covered by a 2 to 5 cm deep layer of organic topsoil. The pH of the soil was 5.2 $\pm$ 0.6, the lowest of all the sites tested. In comparison, the mineral soil in the treed areas at CSA was fine sand with a fresh moisture regime, with no organic topsoil layer and had a much higher pH of 6.5 $\pm$ 0.8 resembling that of cultivated fields (Moffat and Buckley 1995, Brady and Weil 1999). The plough layer that was formed by many years of agricultural use remains essentially unchanged 12 years after the restoration began. The mineral soil at CSB was found to be very fine sand, with a moist moisture regime, and a pH of 6.6 $\pm$ 0.4. Forest soils of older forests are known to be more acidic than those under agriculture (Moffat and Buckley 1995). Many tree species of the Carolinian Forest Region are adapted to the acidic soils that develop in hardwood forests (Waldron 2003). The higher pH at the CSMF sites may slow the rate of influx of some forest species, or the rate of growth of acid-adapted trees, however soil acidity can change over decades as the forest aggrades (Moffat and Buckley 1995).

We surveyed the CSA and CSB fields in late June and late July respectively, and found that the ground at CSB was consistently wetter than CSA with surface water held on the latter long after a rain. This difference was not reflected in our infiltration data. The results from this test indicated that there were no significant differences in infiltration rates between BWR and the two sites at the CSMF. However, this test measures only infiltration rates at the top 10 cm of the soil, and as discussed above, the CSMF fields were covered with a dense layer of old-field vegetation (ie. grasses and forbs) wherever the trees had not grown into thickets with greater canopy cover. This vegetation forms a dense root mass over much of the soil surface, which holds the soil in place and provides channels for infiltration (Whisenant 1999, Brady and Weil 1999).

The soil erosion resistance of CSA and CSB as measured by the Slake Test was not significantly different from that of the BWR soils – both exhibit the highest level of slaking resistance. This is consistent with the infiltration results. The dense root mats in the open areas, and the leaf and vegetation litter under the canopied areas promote the development of soil structure and improve resistance to slaking, and thus, erosion (Brady and Weil 1999, Whisenant 1999).

The average soil dry bulk density for each of CSA and CSB was significantly higher than that for BWR. Except for the shallow root mass, about 2 or 3 cm deep at the surface of the former, the soil exhibited an uniform top layer about 20 cm deep, consistent with a plough layer in these former tobacco fields. In contrast, the fluffy, organic topsoil layer in BWR was deep enough that our dry bulk density samples were taken mainly from this layer. As mentioned above, the organic topsoil layer typical of an Eastern Deciduous Forest such as Backus Woods has been shown to develop under an aggrading forest in about 100 years (Bormann and Likens 1979), so it is to be expected that if the CSMF restoration proceeds as planned, that the dry bulk density of the soils will decrease over time to approach that of the forest soil. Despite the apparently higher dry bulk density of CSB soils than those of CSA, the apparent difference in dry bulk density between these sites was not significant. More data would be needed to determine if, in fact, the soil dry bulk density is higher at CSB.

The higher nitrate levels found at the restoration sites compared to BWR, is, again, not unexpected, given the fact that these fields were under cultivation for many years (Moffat and Buckley 1995). As well, there are significant populations of nitrogen-fixing plants such as *Desmodium* and *Trifolium* species at CSA and CSB.

Evidence of earthworms was highest at CSB, and none were found in BWR. The fact that none were found in BWR is a good sign, because it means that these damaging species haven't yet invaded this archetypal Carolinian Forest, at least to the site of our test plot. The fact that they were most prevalent at CSB could mean that restoration of an indigenous forest ecosystem to this site might be difficult to impossible because of the destructive effects that earthworms have on native forest floors (University of Minnesota 2003).

Overall, the soils at CSA and CSB differ in several ways from the soils in BWR. The soils at the restoration sites have a different dry bulk density and pH than the reference soils. The soil at CSB had much poorer drainage than either the reference or CSA. Since the pH of restoration soils have been seen to decrease over time as the vegetation develops (Moffat and Buckley 1995), and the dry bulk density is projected to decrease (Bormann and Likens 1979, Whisenant 1999), the poor drainage at CSB will likely be the major factor in the rate of progress and direction taken by this restoration site. Until now it has played a key role in slowing the restoration because the species planted here, eg. *Quercus rubra,* were not chosen to match the soil conditions (Holmes 2003,)

As shown in Table 3.2, the density of surviving woody species at CSB is quite low relative to BWR, and even CSA. As well, among the planted tree species, about 40% of the remaining survivors are struggling badly. On the other hand, *Fraxinus* and *Acer rubrum* species, which do better in wetter soils (Waldron 2003), are more prevalent among the seedlings which have naturally moved into the site. This is a promising development, and barring other major catastrophes, may yet lead to a restored hardwood forest at this site. The presence of earthworms, however, leads to questions about how closely this forest will resemble any of the native communities found in Backus Woods.

3.5.3 Surrounding Landscape

3.5.3.1 Ken Stead Property

The topography and soils of KSF are very similar to that of KSR. Neither site has a water feature running through it, so that drainage would be the same for both – subsurface flow. Based on these factors, it is expected that the vegetation communities on both sites would historically have been the same. The location of KSF, surrounded by native forest on three sides, is ideal for regeneration by native species (Jacquemyn et al. 2003). By its location, this restoration project is likely destined for success. Filling in the gaps in the forest created by the clearing of these fields directly follows the precepts of landscape ecology which advocates the connection of smaller into larger patches, and the reduction of edge habitat.

The direct impact of humans on the site has been reduced to use by occasional hunters and naturalists, as well as maintenance activities by restoration practitioners. However, use by ATVs is still prevalent in the nearby woodlands, and the noise impacts the habitat quality of the site. The road traffic is minimal, and due to the 70 m distance between this feature and the field, impact from this source was not noticeable (Trombulak and Frissell 2000).

3.5.3.2 Charles Sauriol Memorial Forest

As mentioned above the reference community in Backus Woods was chosen by the author for its apparent similarity to the dominant trees at CSA. However the topography of BWR is much more varied than that of CSA and CSB, which are both almost level fields. In contrast, BWR is on rolling upland. CSA and CSB were planted with similar mixes of trees, but the soil of CSB is much wetter than CSA – it has poorer drainage than CSA although there are no obvious differences in elevation or slope between the two. As mentioned above, the wetter soil has resulted in a much lower survival rate of the trees on CSB. The entire CSMF site, like KSF on the Stead property, was chosen for restoration because of its proximity to Backus Woods. However, the entire open area is much more extensive than KSF, and the CSA and CSB sites are distant by at least a hundred metres from mature forest on all sides – see Figure 3.2. The immediate area surrounding them is either open old-field vegetation, or naturally regenerating old-field, or White Pine plantation. As a result they are not as ideally set up for success as the Stead sites, although long distance seed dispersal mechanisms are still relevant (Jacquemyn et al. 2003, Grime 1979). In the case of CSA where the tree canopy is actually starting to close in spots, these groves are isolated from other closed canopy clumps by tens of metres, and from continuous closed canopy by hundreds of metres. As a result, the restoration will not be as efficient as the Stead project at decreasing forest fragmentation.

The sites are infrequently used by hunters and naturalists. The adjacent road promotes human access to the sites (Trombulak and Frissell 2000); education is one of the purposes of the restoration. The most persistent impact apparent while we were there was road noise and sounds from the nearby farming operation to the south. As the trees grow, and the vegetation becomes denser, these effects will diminish.

3.5.4 Habitat Function

The values for this indicator were obtained largely from interviews with local naturalists and any scientists who might have studied the sites. The results therefore depend as much on the interest shown in the site as on the actual presence of species with high conservation value. They therefore reflect to some extent the success of the restoration from a cultural standpoint, that is, how much value is placed on a site by the local naturalist community. The greatest source of error in this measure is the completeness of the research; how thoroughly were the local naturalists interviewed for their knowledge of the faunal use of the site?

3.5.4.1 Stead Property – Faunal use

One of the major goals of the restoration was to create habitat for sand-loving insects. Significant species that have been observed using KSF include those listed in Table 3.11. A second goal was to fill in the gaps in forest to restore its function. Evidence of the progress towards this goal includes the use of the site edge by classical interior birds listed in Table 3.10 (Gartshore 2003.). A third goal was to restore the site to an oak savannah complex. Species typical of this habitat that have been observed using the site are listed in Tables 3.10 and 3.11 (Gartshore 2003.). A great deal of interest has been shown in KSF by the restorationists themselves and by other naturalists and scientists (Gartshore and Carson 2003, Buck 2003.). As a result, this information about the faunal use of KSF was readily available. Two measures of early success of this project are illustrated here; the restoration of the habitat function of the site, and the cultural value evidenced by the interest that has been generated in the site.

3.5.4.2 Charles Sauriol Memorial Forest

The faunal use of CSA and CSB was more difficult to track down than for KSF. The restoration project managers had very little information on the faunal use of the site. The only species that they, or we, had observed at the site were common species that are seen also on farmland. At this point it is difficult to assess the success of the site as a habitat restoration undertaking due to this lack of information about what less common species might be using the site.

<u>3.6 Conclusions</u>

3.6.1 Ability to Differentiate between Levels of Progress

The data and indicators presented in Chapter 3 illustrate significant differences in progress among the three sites. The populations of woody species in the Stead restoration (KSF) are significantly healthier than those of CSA, while those of CSB have poor health due to poor survival on the wetter substrate. The Sorenson Similarity Coefficient shows a much greater resemblance between the woody species in the KSF and reference (KSR) than for the two Charles Sauriol sites, and the soil characteristics at KSF match those at KSR more closely than those of the CSA and CSB restoration sites and their Backus Woods reference (BWR).

Some of these factors, such as the lower Similarity Index between the woody species, and the lack of exact correspondence in soil texture and moisture regime can be ascribed to the fact that the reference selected by the author for the Charles Sauriol Memorial Forest restorations may not have been the optimum choice. The CSA and CSB restorations were not originally modelled on any one ecological community in the Backus Woods reference (as the KSF was modelled on KSR), but were instead, based on the ‘Carolinian Forest’ as a whole. As a result, the author was obliged to select a reference community based on a botanical inventory previously done by Varga (1989) and the dominant tree species planted at the Charles Sauriol restoration site. The choice was based on apparent overlap between the species mix. On the other hand, there is a good probability that there is no really good match with any single community in Backus Woods, because of the somewhat arbitrary selection of species planted in CSA and CSB. Aside from this difficulty, the structural vegetation indicators which are somewhat independent of speciation, clearly point to the superior progress of KSF over CSA and CSB.

Taken together, the results indicate that KSF is moving more quickly toward a structural and compositional state similar to its reference forest than are CSA and CSB. After only nine years, KSF more closely resembles KSR, than either CSA or CSB resemble BWR after twelve years, in vegetation structure and composition, and in soil characteristics. Since one of the implicit goals of all restoration is to accelerate the return of a site to an ecosystem resembling that of its chosen reference (Norton 1991 *in* Reay and Norton 1999), these data confirms the initial assessment by knowledgeable workers that, of the three projects, KSF is progressing more quickly towards its goals. It is also clear from these data that CSB is lagging behind the others in development towards the goal of restoring a ‘Carolinian Forest’.

3.6.2 Monitoring by Inexperienced Workers

It can also be concluded from these results that the methods and indicators used in this study are capable of determining differences in restoration progress in the hands of relatively inexperienced workers. As mentioned previously, the work in this chapter was carried out by the author and assistants. The experience level with the field methods among this group was quite low at the beginning of the study in 2003, but the results from the early work on the Stead Property appear to be equally as valid as those from later work during that summer. The investigators in this work had the possible advantage over volunteers of a formal background in Environmental Studies in general and some focussed study in the disciplines of monitoring and forest ecology. A little knowledge in the areas of plant identification and soil characterisation went a long way during this study. To fully test the ability of these methods to distinguish differences in restoration progress in the hands of inexperienced workers, they need to be tested with groups having little or no experience or knowledge.

To further understand the potential usefulness of these methods to volunteers, and the challenges that might be faced by inexperienced workers, several trials were undertaken with high school student groups. The positive and negative outcomes of these trials are described in the next chapter.

Chapter 4

Use of Methods by Inexperienced Workers

4.1 Introduction

This chapter describes initial efforts to answer Question 3 from Section 2.8.2, that is: whether the methods described in Chapters 2 and 3 are straightforward and provide reliable results when practiced by inexperienced workers. Three short trials were run with teenagers with no previous exposure to these methods.

The first two try-outs were with high school classes, and were included as part of their curriculum. The time frames for these ranged from two 50-minute periods to half a day, since they were fitted into the class schedule in a somewhat *ad hoc* manner. In these trials, the Point-centred Quarter Method (PQM), the quadrat method, and the soil auger method for soil texture and moisture regime were used by the students. A more lengthy and intensive two-day test was run with a group of four Ontario Stewardship Network Junior Rangers. In this trial, the Rangers had enough time to thoroughly learn and apply the PQM and the soil auger method.

4.2 Paris High School CELP Students

4.2.1 Background and Methods

The first group was from the Paris High School (PHS) Community Environmental Leadership Programme (CELP) in Brant County. This trial involved one half school day at the restoration site, with a class of 15 to 20 students, and one half day at a corresponding reference forest with a smaller group of 6 students. The students used the quadrat method to survey the vegetation and the soil auger sampling method to characterise the soil at the restoration site. A very short trial of the PQM was carried out at the reference forest.

The restoration site is located in Paris Ontario, along the Nith River at UTM 548539 E and 4781791 N. At the time of the trial, it was just under a year old and had been direct seeded in June of 2003 with Oak and Hickory seeds, and several herbaceous species. Eastern White Pine had been planted around the edges by previous CELP students from Paris High School. The site comprises 3.2 hectares on two adjacent level terraces in a bend of the Nith River. The site was tilled and then sprayed with glyphosate, before being machine planted at a rate of 1 seed/m^2 in a hexagonal, random pattern.

The site had been previously surveyed using 2m x 2m quadrats in October, 2003 by the author with one summer of field experience, and a volunteer assistant. The inexperienced CELP students used the same method of 2m x 2m quadrats, laid out along a straight transect through the field. In both cases, the quadrats were placed at random intervals along the transect. The two surveys differed in the direction that the transects ran in the upper field (E-W for the 2003 survey, and NW-SE for the student survey), and in the fact that the students used two shorter transects in each field in June, 2004 while the more experienced workers used one longer transect in each field the previous October.

The soil at the site was evaluated by the students using soil augers and the method developed by the Ontario Centre for Soil Resource Evaluation (OCSRE) and the Ecological Land Classification (ELC) groups (Lee et al. 1998, Ontario Centre for Soil Resource Evaluation 1993). Five samples were taken in the upper field, and one in the lower field.

A month later, six of the students volunteered to come out and try their hand at surveying a reference woodland that had been identified at Camp Onondaga, about 14 km from the Nith River site. The PQM was used. In an hour and a half they surveyed one point as a group to learn the method, and then two three-person groups each surveyed one point on their own.

4.2.2 Results and Discussion of Survey – Vegetation

The results from the two quadrat surveys of the Nith River site are shown in Tables 4.1 and 4.5. There are major discrepancies between the numbers of individuals – see Table 4.1 - obtained by the CELP students in 2004 and more experienced workers in 2003. The differences in the numbers cannot be fully explained by differing survival and recruitment rates between the two seasons. The differences are too great in some of the cases; for example, the apparent increase in black and red oak populations from a total of 5,750 to 11,578; and the trends are inconsistent in others – *Carya cordiformis* have decreased in numbers while *Carya ovata* populations have increased.

In an attempt to determine if the student data had any validity, it was analysed at a coarser level so that instead of using numbers of individuals and species in the quadrats, only the presence or absence of each genus in each quadrat was included. Even at this level, only the student results for the *Quercus* spp. approached those of the researchers, as shown in Table 4.5. Negligible numbers of *Fraxinus americana* and *Populus deltoides* were found by the students. The decrease in relative frequency of total *Carya* species found by the students compared to that found in the fall of 2003 might be due to mortality; this would need to be confirmed by a third assessment of the site. The concomitant increase in *Acer Negundo* might be due to more seedlings appearing in the 6 months between the counts.

The results from the PQM survey of the Camp Onondaga woodland were not sufficient to enable the results to be analysed. Only three points were surveyed, and the accuracy of identification of some of the plants was doubtful.

Table 4.1. Vegetation Survey of Nith River Restoration Site

Species	Individuals/ha Researchers	Individuals/ha CELP
Carya cordiformis	3875	1250
Quercus rubra	3375	11578 (incl. *Q. velutina*)
Quercus velutina	2375	
Carya ovata	1375	2697
Acer Negundo	1125	16710
Rhus typhina	1125	
Quercus bicolor	875	526
Carya glabra	375	658
Fraxinus americana	375	
Quercus macrocarpa	250	
Populus deltoides	250	
Amaranthus retroflexus	25500	
Oxalis europea	22125	
Solidago canadensis	16000	526
Hypericum perforatum	10500	2500+
Chenopodium album	10625	417
Verbascum thapsus	6500	1710
Cirsium arvense	4875	263
Plantago major	4875	2368
Desmodium canadense	3500	789
Daucus carota	3250	1315
Taraxacum spp.	2125	526
Ambrosia artemesiifolia	1375	395
Potentilla recta	1125	132
Asclepias syriaca	125	8815
Erigeron anuus	125	4342

4.2.3 Results and Discussion of Survey - Soils

Of the six auger samples that were taken and evaluated, three gave sufficient information to draw conclusions about the soil characteristics for the upper terrace. The soil consists of three or four layers with silty clay overlying fine to medium sand in most of the field. As might be expected for the upper terrace, neither the water table, nor bedrock was encountered in sampling up to one metre deep. There is some moderate surface stoniness. Overall, the soil in the field can be classified as moderately well drained with a fresh moisture regime.

4.2.4 Results and Discussion – Feedback from Participants

For this study, the students were interviewed as a group for their feedback on the quadrat and soil surveys of the Nith River site. After the point-quarter survey of the Camp Onondaga woodland, some of them filled in a questionnaire. The teacher who organised the field trips also filled out a questionnaire regarding his thoughts about the student monitoring experience (Wittchen 2004.). The questionnaires are included in Appendix I.

4.2.4.1 Vegetation Surveys

The most likely explanation for the inconsistencies in the population density and relative frequency data described in Section 4.2.2 and Table 4.1 above is a lack of knowledge of plant identification combined with a shortage of time to properly check initial plant identification with keys. The students had had only a few hours of plant identification training in their programme. This had occurred several months prior to their work at the Nith River site and was not focussed just on the species found there. Although the students were given booklets with diagrams and descriptions of the most common plants included in the survey at the site, they were not able to properly identify many of the plants to the species level without a lot of help. In fact, at the beginning of the day's exercise, most were not able to tell the difference between an oak and a hickory seedling. The only person with plant identification experience in the group was the author, and there were five groups working simultaneously, and with time constraints. As a result, a good deal of the student identification was done with only a very cursory review of the provided reference material. Counting the numbers of individuals of each species in each quadrat also presented difficulties due to the diligence required, as well as the challenges of getting each individual identification correct.

The students themselves mentioned plant identification as the most challenging part of the experience. They also felt that if the field training had included a full run-through of one quadrat, they would have been better prepared to do a quadrat on their own. Suggestions for improvement included providing a picture of key parts of each plant right on the tally sheet, and reducing the number of plants to look for in the survey. The students also complained that the equipment used to make the quadrats (four stakes and pre-measured string) was awkward to use and needed upgrading so that it was more robust and easier to use. They felt much more comfortable with the point quarter stakes and associated equipment used in the woodland survey.

A third major factor contributing to the errors was the varying levels of commitment to doing a careful job shown by the students. As in most typical high school classes, the students' interest in the subject varied and the resulting efforts to do the work properly were mixed.

Feedback from the CELP class teacher (Wittchen 2004.) confirmed that plant identification had not been a strong part of the curriculum, and that further preparation in this area would have been very beneficial to the students. He also felt that more time spent on training, both before the field day, and in the field would have improved the students' confidence, and that more field experience would have been beneficial to their learning experience. The time that might be available for this subject in the curriculum of the CELP programme was also discussed. Fitting more time into the curriculum for a subject like this one would take some planning due to the number of topics covered in the programme.

4.2.4.2 Soil Surveys

The students felt relatively comfortable using the soil augers and following the OCSRE/ELC procedures for soil testing. However, the results indicated that not all of them were following the procedures correctly, and there were missing, as well as inconsistent data on some of the field forms turned in. The inconsistent quality of the results for this method was most likely due to lack of commitment on the part of some of the teams, since other teams were able to produce relatively good data with the given training.

4.2.4.3 Instructor Feedback on Methods

Wittchen (2004.) felt that the monitoring field work could be a good fit with the CELP student curriculum, and he planned to recommend it to the teaching staff at Paris High School as a permanent part of the lesson plan.

4.3 Guelph Nature Centre High School Students

4.3.1 Background and Methods

The second group of high school students came from the Environmental Science programme in Guelph. They were involved in a programme that entailed 3 50-minute sessions a week at the Nature Centre on Guelph Lake. In this trial, the class of 15 to 20 students attempted to use the PQM to assess the progress of a 3 year-old forest restoration, in one 50-minute period, and the soil auger sampling method to characterise the soil at the restoration site in another 50-minute period. The third 50-minute session was used to discuss the results and implications of the work.

The 2 hectare restoration site, Kiera's Forest, is located near the Guelph Lake Nature Centre north of the City of Guelph at UTM 559183 E and 4827667 N. It had been planted with a mix of mostly native species such as *Fraxinus* spp., *Rhus typhina*, *Quercus alba, Quercus macrocarpa*, *Thuja occidentalis,* and *Juglans nigra*. The shrub, *Physocarpus opulifolius,* was included in the planting mix. Large logs had been set down in scattered locations to create a microclimate for woodland-adapted plants. The site was not pre-treated with pesticides, and old-field species such as goldenrod and asters have been allowed to grow unchecked around the trees and shrubs. The aspect is a 20 % slope facing south east.

On day 1, the students were given a 15-minute introduction to the PQM, and then groups of 3 students each surveyed one point. A total of five points were laid out in two transects that ran down the slope. Trees over 0.5 m in height, and trees under 0.5 m in height were the main components of the survey. There were only two points where shrubs were found.

On day 2, the students were given a 20-minute run-through of the soil method developed by the Ontario Centre for Soil Resource Evaluation (OCSRE) and the Ecological Land Classification (ELC) groups (Lee et al. 1998, Ontario Centre for Soil Resource Evaluation 1993). They were shown how to use a soil auger, and then how to analyse the components of the soil profile thus obtained. Three groups of students subsequently did the best they could in the following 30 minutes to obtain a soil profile with the auger and analyse the components. The three samples were taken from near the crest of the slope, in the middle, and at the toe by a small wetland.

4.3.2 Results and Discussion of Survey - Vegetation

The vegetation results are shown in Table 4.2. The range of percent variation was calculated using the variance in the distance between the stake and individuals and dividing by the mean distance and is expressed as a percentage following Greig-Smith (1983).

Table 4.2. Results from Point-quarter Survey of Woody Species at Kiera's Forest

Indicator Component	Population Densities Per hectare	Variation in distance as percent of the mean
No. of points	5	
Trees > 0.5m	161	203
Trees < 0.5m	98	103
Shrubs	102	162

The range of percent variation is similar to other restorations and woodlands discussed in Chapter 3. These woodlands and restorations were evaluated using many more points and by more experienced workers in the cases of KSR and BWR. Given the much smaller number of points assessed at the Guelph Nature Centre (GNC) restoration, it might be expected that the precision would be less than for restorations and woodlands surveyed using more points. However, as mentioned in Chapter 3, the greatest cause for the variation in results is the natural variation in the placement of the individuals. Considering the range of variation of the numbers for the GNC restoration, it would appear that the trees were planted at intervals which mimic a random natural system reasonably well.

The accuracy of these numbers can only be approximately estimated from the planting plan (Schneider 2001) drawn up for the first set of plantings in 2001. At that time, roughly 137 saplings and 206 seedlings were planted per hectare. Additional saplings and seedlings were planted in 2002 and 2003 but the records for these are not available (Schneider 2004). Based on the 2001 numbers, the population density of saplings determined by the students is reasonably accurate – see Table 4.2, while the seedling density is low. The latter were very hard to find in the old-field vegetation that dominates the restoration.

Table 4.3. Relative Frequency of Species – Kiera's Forest

Species	**Relative Frequency (%) 2004 assessment**	***Est. Relative Frequency (%) from Planting Plan***
Fraxinus spp.	30	*25*
Rhus typhina	20	*40*
Quercus alba	10	*0*
Quercus macrocarpa	20	*0*
Acer saccharum	10	*10*
Juglans nigra	10	*6*
Thuja occidentalis	10	20

The relative frequencies of tree species are shown in Table 4.3. The only shrub species found was *Physocarpus opulifolius,* as expected from the planting records and the youth of the restoration.

The relative frequency as assessed by the students is comparable to the estimated relative frequency based on the planting plan (Schneider 2001) for some species such as *Fraxinus* spp. and *Acer saccharum.* However, in some cases, such as the *Quercus* spp. the 2004 assessment appears quite wrong. Some of this inaccuracy is due to the fact that there were additional plantings at the site in 2002 and 2003. Some may be due to mortality. And some will be due to missed individuals or mis-identification.

4.3.3 Results and Discussion of Survey - Soil

Of the three student groups who did the auger samples, only one recorded sufficient information to make a determination about the soil at the site. This group found four layers in the soil profile, mottles at 35 cm and gley at 79 cm. The information they provided indicate that the drainage class for this site is imperfect, and that the moisture regime is moist. The other two groups were not able to complete their record-keeping in the time allotted for this test. It is a credit to Group 1 that they were able to provide the information that they did in less than half an hour. They had focussed on the soil description, and skipped the site description requested on the Field form (See Appendix II). The other two groups spent more time on the site description than the first group.

4.3.4 Feedback from Participants

This group made an attempt to evaluate restoration progress under extremely challenging conditions. Not only did they have no prior experience with the techniques, and very little background in plant identification as with the CELP group, but they also had a particularly short training period before they were asked to do a real measurement. On top of these handicaps, they were asked to do a complete point in about a half hour, and they worked under conditions where the young trees and seedlings were often hidden by the old-field vegetation growing around them.

Despite these difficulties, the students were able to use the method to obtain some preliminary information about structural and special characteristics of the site as shown in Tables 4.2 and 4.3.

The population densities of trees and seedlings determined by the students for Kiera's Forest are low relative to the KSF, CSA and CSB. These low numbers are partly due to the difficulties of locating small trees and shrubs in a field where the herbaceous vegetation is growing thickly at heights which overtop many of the woody individuals, and partly due to the original planting densities of the individuals which was about 137 stems/ha for the larger trees (Schneider 2004). The characterisation of species was in some ways easier for the GNC students than for the CELP students, because the possible numbers of species were much fewer, and the individuals were more mature than at the Nith River site. However, these students also had little background in plant identification and there is likely to be a certain amount of error in the mix of species given in Table 4.3. There will also be error associated with lack of focus on the part of some of the students, who were expected to arrive at the site in the middle of a normal school day scheduled with several other subjects, and do something quite outside their normal experience, and for which they had been given little or no background information.

Feedback from the instructor (Schneider 2004) was very positive. In this case, contact with the instructor concerning the possibility of working with his students had occurred in February, four months prior to the actual workdays. As a result, Schneider was able to incorporate restoration monitoring into his overall lesson plan. He had discussed with the students the idea that restoration was part of a source protection plan in watershed management, prior to the field work in June. Schneider felt that the monitoring methods developed in this study were reasonably appropriate for use by students with relatively little time to devote to this subject, and had already incorporated them permanently into his overall Field Study Plan for the Environmental and Resource Management course provided to Grade 11 and 12 students.

4.4 Ontario Stewardship Rangers at Camp Onondaga

4.4.1 Background and Methods

Rob Wallis (2004) of the Ontario Stewardship Network (OSN) offered the services of a group of four members of the Ontario Stewardship Rangers (OSR) for two days to help with this project. The OSR are high school students with an interest in stewardship and restoration work who have little or no experience in fieldwork. They are hired for a summer to assist with various conservation projects, so that they can obtain practical experience in the field of natural resources.

The OSR carried out an evaluation of a woodlot that was identified as a possible reference community for the Nith River restoration site described in the first part of this chapter. The woodlot was located at Camp Onandaga, a Tim Hortons children's camp north of Brantford, at UTM Zone 17T 0557975mE. 4791729 mN. The Point quarter method was used to assess the population densities and relative abundances of the woody vegetation. The community that was surveyed lies on a small ridge between two ponds. The higher ground mimicking the tableland of the Nith River restoration site is somewhat limited in extent, so that only 10 points were obtained.

4.4.2 Results and Discussion of Survey

Table 4.4 shows the population density results from the vegetation survey of the Camp Onondaga Woodlot (CO) by the OSR students. These are compared with relevant indicators for the Ken Stead Reference (KSR) and Backus Woods (BWR) obtained by the more experienced researchers involved in this study, in order to assess the validity of the numbers. The range of error associated with each of the values is included in brackets. This error is calculated using the variance in the mean distance to individuals following Greig-Smith (1983), and dividing by the mean distance and is expressed as a percentage.

Table 4.4: Indicators of Vegetation Structure; Woodlands Comparison

Population Densities Indicators	CO (OSR)	KSR Researchers	BWR Researchers
No. of points	10	15	18
Trees > 0.5m	568 (183)	551 (163)	374 (142)
Saplings (2-10 cm)	458 (201)	361 (230)	590 (107)
Trees < 0.5m	3547 (104)	3251 (125)	1851 (113)
Shrubs	2600 (86)	2490 (63)	3324 (123)
Snags	266 (177)	630 (111)	97 (440)
Coarse woody debris (avg no. per point)	10.6	8.7	20
Canopy cover (average %)	71	95	83

The values obtained by the OSR for Camp Onondaga Woods appear to be comparable in validity with those obtained by more experienced workers at Backus Woods and the Ken Stead Reference. The range of error, indicated by the percentage value of the variance divided by the mean, is in the same order of magnitude for the population densities in all three cases. This is despite the fact that only ten points were surveyed at COW compared to 15 at KSR and 18 at BWR. The amount of variance in the average distances to the individuals is large for natural communities (Greig-Smith 1983), and in general, the measurement of a smaller number of points is expected to lead to a larger relative variance for the PQM. The errors due to inaccuracies in measurement or recording of numbers are expected to be small relative to the natural variance.

The first line of Table 4.5 shows the combined population densities of all the trees, saplings and seedlings found at CO compared with the absolute population densities of tree seedlings obtained from the Nith River restoration site by the CELP students (June 2004) and the more experienced researchers involved in this study (October 2003). The remainder of Table 4.5 compares the relative frequencies of the tree species determined for the two sites by the three groups.

Neither the relative frequencies of tree species obtained by the students or the more experienced workers at Nith River agree very closely with the species mix at COW. In the cases of species such as *Acer saccharum* and *Prunus serotina*, this is because these species were not included in the planting mix at Nith River. As well, these species are not prominent in the sparse woodlands surrounding the Nith River restoration, and it may be some time before they will make an appearance naturally.

Table 4.5: Comparison of Nith Restoration and Onandaga Reference

Indicator	**CO (OSR)**	**Nith River (Researchers)**	**Nith River (CELP)**
Absolute density-all tree categories	4573	14,000	33,419
Species	**Relative Frequency (%)**		
Acer saccharum	90	0	0
***Quercus* spp.**	80	19 (+26)	28 (+14)
Prunus serotina	80	0	0
Acer rubra	70	0	0
Fraxinus americana	70	5	0
Quercus alba	30	0	0
Prunus pensylvanica	20	0	0
***Populus balsamifera* (*Populus deltoides*)**	10	(2)	0
Pinus strobus	10	0	0
Betula papyrifera	10	0	0
***Carya* spp.**	10	41	27
Acer Negundo	0	9	30

The focus of the planting at Nith River was on oak and hickory because these are dominant species found in woodland remnants on higher ground around the Nith River, and because they are large-seeded species that can be sown directly. The fact that the ratio of oak to hickory is so different for the Nith River planting compared to the Camp Onandaga Woodlot can be ascribed to the difficulty of finding a suitable reference woodland for this restoration which was modelled on very small wooded remnants found around the Grand River and its tributaries.

The results of the soil auger test for COW indicated that the soil texture for this site varies from clay loam to silty clay; that the site is well drained; and that the moisture regime is fresh. This site therefore has a similar soil texture and moisture regime as for the Nith River restoration, and the Camp Onandaga Woodlot is a good choice for a reference based on these soil characteristics.

4.4.3 Feedback from Participants

Feedback from the Rangers was obtained by a group interview. The students enjoyed the experience, and questioning showed that they understood the purpose of what they were doing, and retained some of the background information they had been given as part of the field training.

Based on feedback from the CELP students, more time was spent on training in the field for the Rangers. As well, since there were only four students involved in this exercise and they had two full days to devote to the work, a lot more time was available to spend one-on-one. As a result, the Rangers felt that they had been given adequate training in the field. This amounted to about one hour for the PQM with all four students actively involved in the training. Another full hour was spent on hands-on training for the soil test, just before the students did that test in the field. They also had enough time to become quite comfortable with the methods in this time-frame. Most importantly, given the number of participants, it was a straightforward matter to give adequate help with plant identification as the work proceeded.

The results and feedback from these two exercises indicate that the PQM and the OCSRE soil evaluation method are both easily and quickly learned and applied by previously inexperienced workers, provided that they are given at least an hour of hands-on training in the field before doing the tests on their own, and that they are able to do several replicate points using each method. A certain minimum level of commitment to producing useful results also contributes to valid data.

Plant identification was mentioned again as one of the challenges in doing a good job, but this did not stand out as glaringly as with the CELP group – probably because assistance was much more readily available. The physical difficulties associated with the work were also mentioned; working in the bush and in adverse weather conditions were two factors that were raised. Finally, the Rangers had learned enough to realise that more experience would enable them to produce even better quality results.

4.5 Conclusions – Monitoring by Inexperienced Workers

This chapter has attempted to show that students with no previous experience and very little training were able to use the point-quarter method (PQM), the quadrat method, and the soil auger method to provide useful results. Moreover, they were able to accomplish this in a small amount of time. The instructors who worked with these students were impressed with the potential of these methods for enabling the students to do some meaningful field work with a small investment of time and training (Schneider 2004, Sheppard 2004, Wittchen 2004).

Data which are comparable in precision to that provided by the investigators in Chapter 3 were produced by the Rangers who had hour-long training sessions and two days in which to do the work – cf Table 4.5. They also had no difficulty in producing useful soil texture and moisture regime data. The rate at which they worked was a little slower than the investigators, but increased as their experience level increased. It needs to be emphasised that they did not have an opportunity to try all the methods described in Chapter 3, and so even this quite successful trial was not a complete test of the usefulness of all the methods.

The poorest quality results were delivered by the CELP group from Paris High School, but these students were part of the first trial and as a result, received only very cursory training sessions. They were also given the most complex mix of vegetation to record, and this was a primary reason for the poor quality of the data. Some of the more committed among them were able to produce useful soil data from the soil auger sampling method. Their instructor considered the trial to be successful as a learning experience for the students, and is planning to recommend it to be included in the CELP curriculum (Wittchen 2004).

The Guelph Nature Centre students were able to devote only 50 minutes each to a trial of PQM and the soil auger sampling method. In this time frame, each student was able to work in a team on one point. Because of the number of students involved, the results were amenable to analysis and showed a similar range of variation to the work of the investigators and of the Rangers. The main reservation concerning the data is the accuracy of the tree identification. These students had had even less plant identification training than the CELP students. The soil texture and moisture regime data is also in question due to the fact that a full data set was recorded for only one point. Considering the quality of the data obtained under extremely limited time constraints, and the feedback from the instructor, this trial was considered to demonstrate that the PQM and the soil auger method can be readily learned, and the results are considered of value by volunteer restorationists (Schneider 2004). However, there is a learning curve, and some minimum amount of field experience, background knowledge, or a desire to gain these, is required.

Two of the trials described in this chapter were done by students who were required to do the work as part of their curriculum. In this sense, they qualified as inexperienced workers, but not as volunteers. The third trial involved summer students who were also not given a choice about doing the work. One of the areas of further work, (see Section 5.4), is to do a fuller test of these methods with a group of interested volunteers to determine whether they would find the effort worthwhile.

An attempt was made, near the end of this work, to gather together a group of volunteers in a Naturalists' group to do a more extensive survey of a plantation in Lambton County. Many people were enthusiastic about the idea when first approached, but when it came to scheduling actual time to do the work, even the most enthusiastic could not find more than half a day to devote to the project. As a result there were not enough man-hours available to do a thorough test of the methods and the analysis.

Some of the causes for the failure of this attempt included the timing; to meet this study schedule, the trial had to be run during prime vacation time and the lead time for the planning was too short. Another possible cause for this failure may have been the fact that this group did not actually have a forest restoration project for which they were responsible. The proposed project to be studied was a local Conservation Authority plantation on some land that the group helps to manage.

Chapter 5

Conclusions and Further Work

This final chapter summarises the conclusions drawn in the previous chapters, and pulls together a picture of the methods as a toolkit that can be readily used by volunteers to obtain valid information about forest restoration progress. The applicability of the methods and indicators at different stages of restoration progress is discussed. In the last section some suggestions for further work are outlined.

5.1 Methods – Ease of Use

The methods described in Chapter 3 were, with the exceptions of the soil respiration and wet aggregates tests, straightforward to use in the field and/or laboratory. About three days were required for two investigators with little or no field experience with the methods to make a complete assessment of a site. This time frame included the period spent reading over the instructions for each of the methods. A great deal of quantitative and qualitative information were obtained for each of the sites in this short amount of time.

As described in Chapter 4, students with no previous experience and very little training were able to use the point-quarter method, the quadrat method, and the soil auger method to provide useful results. Moreover, they were able to accomplish this in a small amount of time. The instructors who worked with these students were impressed with the potential of these methods for enabling the students to do some meaningful field work with a small investment of time and training.

The soil aggregates and respiration tests, although of great interest in the determination of soil quality development at a restoration site, were not found to be suitable for use by inexperienced workers. The respiration test was costly, gave widely varying results, and was difficult to interpret. The soil wet aggregates methods that were tested were found to be either so prone to experimental error or so complex to perform that we judged that volunteers who have limited time, or access to training, would not be able to obtain meaningful results from them.

As discussed further below, the compilation and analysis of results was somewhat tedious and time-consuming. Although spreadsheet calculators have been developed to help speed up these steps, it was not possible to test the response of volunteers to the use of these tools within the scope of this study.

5.2 Ability to Differentiate between Levels of Progress

The data and indicators presented in Chapter 3 illustrate distinct differences in progress among the three sites. The Similarity Coefficient shows a much greater resemblance between the woody species in the Stead restoration (KSF) and reference (KSR) than for either of the two Charles Sauriol sites (CSA and CSB); the populations of woody species are significantly healthier in KSF than for CSA, and those for CSB are extremely low, relative to the Backus Woods reference (BWR). KSF has the same soil texture, moisture regime, and pH as the adjacent reference woodland (KSR). In contrast, the soil texture and moisture regime in each of CSA and CSB resemble only parts of the BWR community evaluated, while the pH of the CSA and CSB soils are significantly different from the reference woodland.

Some of these factors, such as the lower Similarity Index between the woody species, and the lack of exact resemblance in texture and moisture regime can be ascribed to the fact that the reference selected for the Charles Sauriol Memorial Forest restorations may not have been the optimum choice. On the other hand, the CSA and CSB restorations were not modelled on any one ecological community in the Backus Woods reference (as the KSF was modelled on KSR), but were instead, based on the ‘Carolinian Forest’ as a whole. As a result, the selection of species planted in these restorations, especially for CSB, is not necessarily an optimum one for these sites.

Altogether the results indicate that KSF is moving more quickly toward a structural and compositional state similar to its reference forest than are CSA and CSB. After only nine years, KSF more closely resembles KSR, than either CSA or CSB resemble BWR after twelve. We can also conclude from these results that the methods and indicators used in this study are capable of determining differences in restoration progress.

Not all the methods proved to give useful, or usable, information at all stages of a restoration. The point-centred quarter method (PQM), the quadrat method for restorations in the seedling stages, and soil auger tests for texture and moisture regime, which were all tested with the students in Chapter 4, provided a good basic set of data for restoration and reference sites and are recommended to be used as a minimum toolkit when assessing restoration progress. On the other hand, indicators such as the similarity coefficient for herbaceous species and soil dry bulk density were not useful in differentiating between good and poor restoration progress at the early stages of the projects studied here.

As a restoration develops along the desired trajectory, characteristics such as soil dry bulk density, soil pH, and the floristic composition of herbaceous species are expected to begin to resemble those of the reference forest. These indicators, which can be considered optional measures at the early stages in restoration development, will later on become useful measures of good or poor progress and are recommended for restorations of about 30 years age and older. Table 5.1 summarises the indicators studied in this work, and when each of these might be expected to give useful information. This table was put together based on experience in the field and background research on the characteristics of forest aggradation.

Table 5.1. Recommended methods for different stages of restoration progress

Method	**Indicator**	**1-15 years**	**> 15 years**
Point Centred Quarter Method for Woody vegetation	Similarity Coefficient	R[1]	R
	Population densities	R	R
	Percent exotics	R	R
	Relative Frequencies (of species)	O[2]	R
Quadrat Method for Herbaceous vegetation	Similarity Coefficient	O	R
	Population densities	O	O-R[3]
	Relative Frequencies (of species)	O	O-R
	Percent exotics	R	R
Soil auger sampling method	Soil texture and moisture regime	R	R
pH	Evolution of pH, quantify difference between restoration and reference	O	O-R
Nitrate	Levels of available nitrate in soil	O	O
Soil dry bulk density	Soil porosity, development of forest floor	O	O-R
Slake test	Erosion resistance – indicates degree to which restoration is achieving this most basic of ecosystem functions	R	R
Soil infiltration rate	Soil porosity, development of erosion resistance	R	R
Earthworms	Presence of these exotics in soil Potential for restoration to move in different direction	R	R
Soil wet aggregate testing	Development of soil structure	Of great interest but testing methods very difficult	
Respiration	Biological activity in soil, soil health	Of interest, but expensive, and interpretation of results very difficult	
Geographical context research	Surrounding landscape, landscape ecology	R	R
Observations of fauna using site	Faunal use, status of habitat function	R	R

1. Recommended. 2. Optional. 3. Optional to recommended, recommended after 30 years.

5.3 Monitoring by Volunteer Workers

With a short training period and a few hours to do the work, committed workers can use the techniques described in Chapter 3 to obtain a reasonable amount of good quality data. Even with extremely short training and work periods, several groups of students who were totally unfamiliar with field methods of this type were able to deliver usable data. The poorest quality results were delivered by the CELP group from Paris High School, but these students were part of the first trial and as a result, received only very cursory training sessions. They were also given the most complex mix of vegetation to record, and this was a primary reason for the poor quality of the data.

Two of the trials described in Chapter 4 were done by students who were required to do the work as part of their curriculum. In this sense, they qualified as inexperienced workers, but not as volunteers. The third trial involved summer students who were also not given a choice about doing the work. One of the areas of further work, discussed below, is to do a fuller test of these methods with a group of interested volunteers to determine whether they would find the effort worthwhile.

All three groups who tried the field methods found them relatively simple to learn. Two of them, the Guelph and OSR groups, produced results that gave useful information about the sites. However, only the OSR group had enough time and experience with the methods to really start to understand the possible sources of error in the results that they were able to obtain. The other two groups were only able to go through the motions and fill in the sheets, with a vague understanding of why the results were of interest. They did not really understand the implications of any errors in the results. All three groups found the plant identification the most challenging part of the vegetation survey methods.

Some of the methods used in this work have proven to be of interest to teachers as a way of giving their students a meaningful field exercise from which they can learn several aspects of the natural world and produce some useful data at the same time (Schneider 2004, Wittchen 2004). Restoration managers pointed out that the advantage of having students do this work is that the monitoring gets done on a more regular basis, and the students learn about the practice and importance of forest restoration (Gartshore 2004, personal communication). Rob Wallis of the Ontario Stewardship Council (2004) felt that this was an excellent way to give the Junior Rangers some practical experience in restoration practices.

Although I was not able to test the suite of methods with a Naturalists' group, a number of clubs have shown an interest. These clubs are a logical fit for this work, because they generally have a wide variety of skills and knowledge of flora and fauna among their members that would enable them, as a group, to do this work. Individuals who own land where reforestation work has been done are also possible customers for this work.

5.4 Further Work

This study has shown that the methods described in Chapter 3 are straightforward to use by inexperienced workers, and give results that can be used to differentiate between different rates of progress in restoration projects. Chapter 4 describes some preliminary trials with inexperienced groups of workers other than those directly involved in this project. These groups also found the methods easy to use, but working with them gave us some ideas about the main complications associated with a lack of experience. These included problems with plant identification and difficulties with characterisation of soil features such as mottles and gley.

However, much more extensive trials of this suite of techniques are required to determine the full extent of difficulties associated with obtaining some of the equipment required for such tests as pH, or even a soil auger. Questions need to be answered as to what are the greatest perceived barriers to doing this work. Is cost of the equipment a big factor? Is the difficulty of obtaining the equipment a bigger barrier than cost? How about the time required to do the testing, or the analysis? Or are apparently simple difficulties such as trying to find the time to do the work among the biggest problems?

Some of the bigger problems I believe will arise with volunteer monitoring are discussed here. Although collection of the data was straightforward, the analysis was time-consuming. A great deal of time was required to identify all the plants collected at the sites, and many hours were spent analysing the data. Interpretation of the data was also not entirely straightforward. The results were mixed, and some research was required to interpret the data in a meaningful way. The choice of reference site is critical to the results obtained (White and Walker 1997) and to the conclusions that can be drawn. If the project managers have modelled their work on a particular geographically-fixed community, the choice is already made, and this is not an issue. However, in cases where the restoration model is a more general one – for example: the 'Carolinian Forest', the choice of vegetation community to survey as a reference can be quite problematic.

Further work is planned in order to simplify and streamline some of these steps. A workbook containing all the methods with the required equipment for each, and where to obtain it will be published. The data analysis will be simplified by including a how-to workbook, and Excel spreadsheets that are set up to input data. None of the calculations are complicated; all that is required is some experience with Excel, and some background in high school science and math. Some of the other key issues can be addressed by trying to involve experienced amateur botanists, and other naturalists in the groups that do this work. These are the people most likely to be interested in this kind of monitoring anyway, and several are usually to be found in most naturalists' clubs.

References Cited

Allen, G. M, Eagles, P.F.J., and S.D. Price 1990. Conserving Carolinian Canada. University of Waterloo Press, Waterloo, Ontario.

Allen E.B, Covington, W.W., and D.A. Falk 1997. Developing the Conceptual Basis for Restoration Ecology. Restoration Ecology, 5(4): 275-276

Anderson, D. H. and B. D. Dugger 1998. A conceptual basis for evaluating restoration success. Transactions of the 63rd North American Wildlife and Natural Resource Conference (No. 37);111-121.

Arvanitis, L.C. and K. M. Portier 1997. Natural Resource Sampling: Point Quarter Center Method. University of Florida. Available: http://ifasstat.ufl.edu/nrs/PQC.htm. Accessed: June 24, 2004.

Association for Canadian Educational Resources 2003. Measure Up. Available: http://www.acer-acre.org/index.html. Accessed: May 18, 2004,

Bakker, J. P., Grootyans, A. P., Henry, H., and P. Poscholod 2000. How to define targets for Ecological restoration. Applied Vegetation Science, 3:3-6.

Bell, S.S., Fonseca, M.S. and L.B. Motten 1997. Linking restoration and landscape ecology. Restoration Ecology 5(4): 318-323.

Betts, M.G., Franklin, S.E. and R.G. Taylor 2003. Interpretation of landscape pattern and habitat change for local indicator species using satellite imagery and geographic information system data in New Brunswick, Canada. Canadian Journal of Forest Research 33(10): 1821-1831.

Block, W. A., Franklin, A. B., Ward, J. P. Ganey, J.L., and G.C. White 2001. Design and implementation of monitoring studies to evaluate the success of ecological restoration on wildlife. Restoration Ecology, 9(3): 293-303.

Boerner, Ralph E. J. and Do-Soon Cho 1987. Structure and composition of Goll Woods, an old-growth forest remnant in northwestern Ohio. Bulletin of the Torrey Botanical Club 114(2): 173-179.

Bormann, F. H. and G. E. Likens 1979. Pattern and Process in a Forested Ecosystem, Springer-Verlag New York Incorporated, New York, New York.

Bowles, J. 2004. Curator, University of Western Ontario Herbarium. Personal communication, May 2004.

Box, J. 1996. Setting objectives and defining outputs for ecological restoration and habitat creation. Restoration Ecology 4(4): 427-432.

Bradshaw, A. D. 1993. Restoration ecology as a science. Restoration Ecology 1: 71-73.

Brady N.C. and Weil, R.R. 1999. The Nature and Properties of Soils. Prentice-Hall Inc., Upper Saddle River, New Jersey.

Brandon, A., Spyreas, G., Molano-Flores, B., Carroll, C., and J. Ellis 2003. Can volunteers provide reliable data for forest vegetation surveys? Natural Areas Journal 23(3): 254-262.

Buck, M. 2003. Curator, Insect Collection. Dept. of Environmental Biology, University of Guelph. Personal communication, October 27, 2003.

Buckley, G.P. and A.J. Moffat 1995. Soils and Restoration ecology. *In:* The Ecology of Woodland Creation. Ed. Ferris-Kaan R. John Wiley & Sons, Chichester, UK.

Cairns, J. 1990. Prediction, Validation, monitoring, and mitigation of anthropogenic effects upon natural systems. Environmental Auditor ENVAE8 2 (1): 19-25.

Camargo, J.L.C., Ferraz, I.D.K., and A.M. Imakawa 2002. Rehabilitation of degraded areas of Central Amazonia using direct sowing of forest seeds. Restoration Ecology 10(4): 636-644.

Carter, M.R. (Editor) 1993. Soil sampling and methods of analysis. Lewis Publishers, Boca Raton

Chapman, L.J. and D.F. Putnam 1984. Physiography of Southern Ontario. Third edition. University of Toronto Press, Toronto, Ontario.

Choi, Y.D. 2004. Theories for ecological restoration in changing environment: Toward 'futuristic' restoration. Ecological Research 19(1): 75-81.

Clinesmith, J. (2001). An Assessment of Forest Restoration in Southern Ontario: Methods used and their Impact on Success, University of Guelph, Guelph, Ontario.

Cooke, J.A. and M.S. Johnson 2002. Ecological restoration of land with particular reference to the mining of metals and industrial minerals: A review of theory. Environ Rev. 10 (1): 41-71.

Costanza, R. R. d., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., and M. van den Belt 1997. The value of the world's ecosystem services and natural capital. Nature, 387: 263-269.

Craig, D. 2002. Forestry technician, St. Clair Region Conservation Authority. Phone conversation; June 2002.

Dailey, G.C. and P. R. Erlich 1997. Issues in Ecology 2: 1-16

Dahm, C.N., Cummins, K. W., Valett, H. M., and R. L. Coleman 1995. An ecosystem view of the restoration of the Kissimmee River. Restoration Ecology 3(3): 225-238

Dale, Mark R.T. 1999. Spatial pattern analysis in plant ecology. Cambridge University Press, New York, New York.

de Gruchy, M. A., U. Matthes, J. A. Gerrath, and D. W. Larson 2001. Natural recovery and restoration potential of severely disturbed talus vegetation at Niagara Falls: Assessment Using a Reference System. 9(3): 311-325.

Doran, J.W., Coleman, D.C., Bezdicek, D.F., and B.A.Stewart (Eds) 1994. Defining Soil Quality for a Sustainable Environment. SSSA Special Publication Number 35. Soil Science Society of America, Inc., American Society of Agronomy Inc. Madison, Wisconsin.

Doran, J.W., and A.J. Jones (editors) 1996. Methods for Assessing Soil Quality. SSSA Special Publication Number 49. Soil Science Society of America, Inc. Madison, Wisconsin.

Egan, D. and E.A. Howell 2001. The Historical Ecology Handbook. A Restorationist's Guide to Reference Ecosystems. Island Press. Washington USA.

Egler, F.E. 1954. Vegetation science concepts I: Intial floristic composition, a factor in old-field vegetation development. Vegetatio 412-417.

Environment Canada 2003a. Ecological Monitoring and Assessment Network; Terrestrial Ecosystems. Available: http://www.eman-rese.ca/eman/ecotools/protocols/intro.html. Accessed; May 18, 2004,

Environment Canada 2003b. Ecological Monitoring and Assessment Network; Terrestrial Ecosystems. Soil Temperature protocols 'Coming Soon'. Available: http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/. Accessed: June 24, 2004.

Environment Canada 2004. How Much Habitat is Enough? Second Edition. Ministry of Public Works and Government Services Canada.

Eshleman, K. N., Gardner, R. H., Seagle, S. W., Castro, N. M., Fiscus, D. A., Webb, J. R., Galloway, J. N., Deviney, F. A., and A. T. Herlihy 2000. Effects of disturbance on nitrogen export from forested lands of the Chesapeake Bay Watershed. 63: 187-197.

European Tropical Research Forest Network NO DATE. ETFRN NEWS 36: New Instruments for Monitoring and Evaluation: Forest Surveys Using Non-specialist Volunteers. Available: http://www.etfrn.org/etfrn/newsletter/news36/nl36_oip7.html. Accessed: June 25, 2004.

Fattorini, M. 2001. Establishment of transplants on machine-graded ski runs above timberline in the Swiss Alps. Restoration Ecology, 9(2): 119-126.

Ferris-Kaan, R. (Editor) 1995. The Ecology of Woodland Creation. John Wiley & Sons, Chichester, UK.

Foote, V. 2001. Woodlands at Risk, Federation of Ontario Naturalists, Toronto.

Forestry Suppliers Inc. 2004. Available: http://www.forestry-suppliers.com/search.asp. Accessed: April 30, 2004.

Forman, R.T.T. and M. Godron 1986. Landscape Ecology. Wiley and Sons, New York.

Gagnon, P. 2003. Lands and Waters Supervisor. Long Point Region Conservation Authority. Personal communication, April 2003.

Gartshore, M. E. and P. Carson 1994. Plan of Work: Ken Stead Property Project #35-000274.

Gartshore, M.E. and P. Carson 2003. Restorationists. Personal communications. April through November 2003.

Geist, C. and S. M. Galatowitsch 1999. Reciprocal model for meeting ecological and human needs in restoration projects. Conservation Biology, 13(5): 970-979.

George, T.L. and S. Zack 2001. Spatial and temporal considerations in restoring habitat for wildlife. Restoration Ecology 9(3): 272-279.

Germaine, H.L. and S.S. Germaine 2002. Forest Restoration treatment effects on the nesting success of Western Bluebirds (*Sialia mexicana*). Restoration Ecology 10(2): 362-367.

Grayson, J. E., Chapman, M. G., and A. J. Underwood 1999. The assessment of restoration of habitat in urban wetlands. Landscape and Urban Planning, 43: 227-236.

Greig-Smith, P. 1983. Quantitative Plant Ecology, 3rd Edition. Volume 9 in Studies in Ecology. University of California Press, Berkeley, CA.

Grime, J.P. 1979. Plant Strategies and Vegetation Processes. John Wiley & Sons. Chichester, U.K.

Groffman, P.M., Driscoll, C.T., Likens, G.E., Fahey T. E., Holmes, R.T., Eagar, C. and J.D. Aber 2004. Nor gloom of night: A new conceptual model for the Hubbard Brook ecosystem study. BioScience 54(2): 139-148.

Haber, E. 1997. Guide to Monitoring Exotic and Invasive Plants. Ecological Monitoring and Assessment Network. Environment Canada. Ottawa, Ontario. Available: http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/exotics/intro.html. Accessed: June 24, 2004.

Handel, S.N., Robinson, G.R. and A.J. Beattie 1994. Biodiversity resources for restoration ecology. Restoration Ecology 2(4): 230-241.

Harvey, B. and S.Brais 2002. Effects of mechanized careful logging on natural regeneration and vegetation competition in the southeastern Canadian boreal forest. Canadian Journal of Forest Research, 32 (4): 653-666.

Havinga, D. and Daigle, J. M. 1997. The Naturalized Landscape, University of Guelph, Guelph, Ontario.

Henry, C.P., and C. Amoros 1995. Restoration ecology of riverine wetlands: A scientific base. Environmental Management 19(6): 891-902.

Henry C. P., Amoros C., and Nicolas Roset 2002. Restoration ecology of riverine wetlands: A 5-year post-operation survey on the Rhône River, France. Ecological Engineering 18(5): 543-554.

Hession, W. C., Johnson, T. E., Charles, D. F., Hart, D. D., Horwitz, R. J., Kreeger, D. A., Pizzuto, J. E., Velinsky, D. J., Newbold, J. D. , Cianfrani, C., Clasen, T., Compton, A. M., Coulter, N., Fuselier, L., Marshall, B. D., and J. Reed 2000. Ecological benefits of riparian reforestation in urban watersheds: study design and preliminary results. Environmental Monitoring and Assessment 63: 211-222.

Higgs, E. S. 1997. What is good ecological restoration? Conservation Biology, 11(2): 338-348.

Hobbs, R.J. and J.A.Harris 2001. Restoration Ecology: Repairing the earth's ecosystems in the new millennium. Restoration Ecology 9 (2): 239-246.

Hobbs, R. J. and D. A. Norton 1996. Towards a conceptual framework for restoration ecology. Restoration Ecology, 4(2): 93-110.

Holl, K. D. and R. B. Howarth 2000. Paying for restoration. Restoration Ecology, 8(3): 260-267.

Holmes, D. 2004. Field Superintendant. Long Point Region Conservation Authority. Personal communication, June 2004.

Holzworth L. K., Hunter, H. E. and S. R.Winslow 2003. Disturbed forestland revegetation effectiveness monitoring – Results of 30 years. 2003 National Meeting of the American Society of Mining and Reclamation and The 9th Billings Land Reclamation Symposium, Billings, MT, June 3-6, 2003. ASMR, Lexington, KY.

Horn, H.S.1980. Some causes of variety in patterns of secondary succession. *In* West, D.C., Shugart, H.H., and D.B. Botkin (Eds.), Forest Succession: Concepts and Application. Springer-Verlag, New York.

Huxel, G.R. and A. Hastings 1999. Habitat loss, fragmentation and restoration. Restoration Ecology 7(3): 309-315.

Hutchinson, G.L. and P. Rochette 2003. Non-flow-through steady-state chambers for measuring soil respiration. Soil Science Society of America Journal 67:166-187.

Illinois Department of Natural Resources 2003. ForestWatch. Available: http://dnr.state.il.us/orep/ecowatch/FOREST/. Accessed: September 10, 2004.

Inouye, D. W. 1988. Variations in undisturbed plant and animal populations and its implications for studies of recovering ecosystems. Pages 39-50 in John Cairns (editor) Rehabilitating Damaged Ecosystems. CRC Press, Boca Raton, Florida.

Jacquemyn, H., Butaye, J., and M. Hermy 2003. Impacts of restored patch density and distance from natural forests on colonization success. Restoration Ecology 11(4): 417-423.

Johnson, M.A., B. Tegler and S. Dobbyn. 2003. Monitoring the effects of prescribed burns in oak savannahs and woodlands: Field Methods. Ontario Ministry of Natural Resources, Ontario Parks. Unpublished report.

Keddy, P.A. and C.G. Drummond 1996. Ecological properties for the evaluation, management and restoration of termperate deciduous forest ecosystems. Ecological Applications, 6(3): 748-762.

Kent, M. and P. Coker 1992. Vegetation Description and Analysis. A Practical Approach, Belhaven Press, London, England.

Kentula, M.E. 2000. Perspectives on setting success criteria for wetland restoration. Ecological Engineering 15(3-4): 199-209.

Kershaw, K.A, and J.H.H. Looney 1985. Quantitative and Dynamic Plant Ecology. Edward Arnold Publishers. London, U.K.

Kershner, J.L. 1997. Monitoring and adaptive management. *In* J.E. Williams, M.P. Dombeck, and C.A. Wood, eds. Watershed Restoration: Principles and Practices. American Fisheries Society Special Publication. pp. 116-134.

King, S.L., and B.D. Keeland 1999. Evaluation of reforestation in the Lower Mississippi River alluvial valley. Restoration Ecology 7(4): 348-359.

Kleintjes, P.K., Jacobs, B.F., and S.M. Fettig 2004. Initial response of butterflies to an overstory reduction and slash mulching treatment of a degraded Pinon-Juniper woodland. Restoration Ecology 12(2) 231-238.

Kondolf, G. M. 1995. Five elements for effective evaluation of stream restoration. Restoration Ecology 3(2) 133-136.

Kondolf, G. M. and E. R. Micheli 1995. Evaluating stream restoration projects. Environmental Management, 19(1): 1-15.

Kozlowksi, T.T. 2002. Physiological ecology of natural regeneration of harvested and disturbed forest stands: implications for forest management. Forest Ecology and Management. 158: 195-221.

Krebs, C. J. 1989. Ecological Methodology. Harper & Row, Publishers. New York, New York.

LaCroix, C-A. 2003. Assistant curator, Herbarium. University of Guelph. Personal communication. March, 2003.

Larson, B. M., Riley, J. L., Snell, E. A., and H. G. Godschalk 1999. The Woodland Heritage of Southern Ontario. A Study of Ecological Change, Distribution and Significance. Federation of Ontario Naturalists, Toronto, Ontario.

Lee, H.T., Bakowsky, W.D., Riley, J., Bowles, J., Puddister, M., Uhlig, P., and S. McMurray 1998. Ecological Land Classification for Southern Ontraio: First Approximation and Its Application. Ontario Ministry of Natural Resources, Southcentral Science Section, Science Development and transfer Branch. SCSS Field Guide FG-02.

Long Point Region Conservation Authority 1993. Charles Sauriol Carolinian Regeneration Forest Management Plan Memo. LPRCA, Simcoe, Ontario.

Matthes, U., Gerrath, J.A., and D.W. Larson 2003. Experimental restoration of disturbed cliff-edge forests in Bruce Peninsula National Park, Ontario, Canada. Restoration Ecology 11(2): 174-184.

May, N. S., Hilts, S.G., and Pisani, T. 2005 (To be published). Handbook of Methods for Volunteer Monitoring of Forest Restoration. University of Guelph, Guelph, Ontario.

McCarthy, B.C., Hammer, C.A., Kauffman, G.L., and P.D. Cantino 1987. Vegetation patterns and structure of an old-growth forest in southeastern Ohio. Bulletin of the Torrey Botanical Club 114(1): 33-45.

McCoy, E.D., and H.R. Mushinski 2002. Measuring the success of wildlife community restoration. Ecological Applications 12(6): 1861-1871.

Michigan Department of Agriculture 2004. Enerald Ash Borer Changes Southeast Michigan Landscape. Available: http://80-www.michigan.gov.cerberus.lib.uoguelph.ca/mda/0,1607,7-125-1568_2390_18298-68970--,00.html, Accessed: August 31, 2004.

Miller, F. 2002. Image Analysis Keeps Eye on Forest Floor. Life Science, Column NO. 71. University of Arkansas Division of Agriculture. Available: http://www.uark.edu/depts/agripub/Publications/Agnews/agnews02-99.html. Accessed October 18, 2004.

Minielly, Rob 2002. County forester, Lambton County. Phone conversation, April 2002.

Mitchell, Kevin 2001. Quantitative analysis by the point-centered quarter method. Hobart and William Smith Colleges. Available: people.hws.edu/mitchell/PCQM.pdf. Accessed on June 24, 2004.

Moffat, A.J. and G.P. Buckley 1995. Soils and restoration ecology. *In* The Ecology of Woodland Creation. Edited by Ferris-Kaan, R. John Wiley & Sons. Chichester, UK.

Montalvo A.M., Williams Rice, S.L., Buchman S.L., Cory, C., Handel, S.N., Nabhan, G.P., Primack R., and Robichaux, R.H. 1997. Restoration Biology: A Population Biology Perspective. Restoration Ecology, 5(4): 277-290.

Moore, P.D., and S. B. Chapman 1986. Methods in Plant Ecology. Blackwell Scientific Publications. Oxford, U.K.

Muotka, T. and P. Laasonen 2002. Ecosystem recovery in restored headwater streams: the role of enhanced leaf retention. Journal of Applied Ecology, 39: 145-156.

Natural Resources Canada 2003. Fundamentals of Remote Sensing. Applications in Forestry. Available: http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/fundam/chapter5/chapter5_5_e.html. Accessed: July 13, 2004.

Natvik, M. 2004. Pits and Mounds. Published by the North American Native Plant Society, Available: http://www.nanps.org/feature/pitsandmounds.html. Accessed: November 10, 2004.

Natvik, M. 2002. Restoration practitioner. Personal communication.

Niagara Escarpment Commission 2003. Ontario's Niagara Escarpment Monitoring Program. Available: http://www.escarpment.org/Monitoring/onemonitoring.htm. Accessed: May 19, 2004.

Nienhuis, P.H., Buijse, A.D., Leuven, R.S.E.W., Smits, A.J.M., de Nooij, R.J.W., and E.M. Samborska. 2002. Ecological rehabilitation of the lowland basin of the river Rhine (NW Europe). Hydrobiologia 478: 53–72.

Norton, D.A. 1991. Restoration of indigenous vegetation on sites disturbed by alluvial gold mining in Westland. Resource allocation report 3. Energy and Resources Division, Ministry of Commerce, Wellington, New Zealand.

Oliver, C.D. and B.C. Larson 1990. Forest Stand Dynamics. McGraw-Hill., Inc. New York, New York.

Oliver, J. 2003. General Manager, Long Point Region Conservation Authority, Personal communication, November 2003.

Ontario Centre for Soil Resource Evaluation 1993. Field Manual for Describing Soils in Ontario. 4th Edition. Ontario Centre for Soil Resource Evaluation. Publication Nol 93-1. Guelph, Ontario.

Ontario Ministry of Natural Resources 2003. Ontario Base Maps. Queen's Printer, Toronto, Ontario.

Operation Wallacea 2004. Forest Projects for General Volunteers. Available: http://www.opwall.com/2004%20general%20forest%20projects.htm. Accessed: June 25, 2004.

Oregon State University Extension and Experiment Station 1999. Willamette Valley Soil Quality Card Guide. Available: http://eesc.orst.edu/agcomwebfile/edmat/em8710.pdf. Accessed; June 24, 2004.

Pinto, F. Pearce, D. and D. Nesbitt 2003a. Silviculture Treatment Assessment and Reporting System (STARS): Background and Field Manual. Ministry of Natural Resources. Natural Resources Information Centre. Peterborough, Ontario.

Pinto, F. Venhola, N., Pearce, D., Nesbitt D. and M. Orpen 2003b. Silviculture Treatment Assessment and Reporting System (STARS) for Microsoft Windows Version 2: Installation Guide and User Manual. Ministry of Natural Resources. Natural Resources Information Centre. Peterborough, Ontario.

Plant Ecology Department 2002. Forest Vegetation Sampling & Point-centered Quarter Sampling Method. Ohio University. Available: http://www.plantbio.ohiou.edu/epb/instruct/ecology/lab3.pdf. Accessed: June 24, 2004.

Pollard, J.H. 1971. On distance estimators of density in randomly distributed forests. Biometrics 27(4): 991-1002.

Pratt, JR; Stevens, J 1992. Restoration ecology: Repaying the national ecological debt Proceedings: High altitude revegetation workshop No. 10., Colorado water resources Research Inst., Colorado State University, Fort Collins, CO 80523 (USA), 1992, pp. 40-49, inf. Ser. Colorado Water resources Res. Inst., vol. 71.

Qi, M. and J. B. Scarrett, 1998. Effect of harvesting method on seed bank dynamics in a boreal mixedwood forest in northwestern Ontario. Canadian Journal of Botany, 76(5): 872-883.

Quigley, M. F and W. J. Platt 2003. Composition and structure of seasonally deciduous forests in the Americas. Ecological Monographs 73(1): 87 – 106.

Reay, S.D and Norton, D.A. 1999. Assessing the success of restoration plantings in a temperate New Zealand forest. Restoration Ecology 7(3): 298-308.

Reive, D., Sharp, M., and W. Stephenson 1994. Integrating ecological restoration with ecosystem-conservation objectives: Point Pelee National Park. Ecological Restoration of National Parks - Proceedings of a Symposium at the 4th Annual Conference of the Society for Ecological Restoration, 7-18.

Rheinhardt, R. D., Rheinhardt, M. C., Brinson, M. M., and K. E. Faser, Jr. 1999. Application of reference data for assessing and restoring headwater ecosystems. Restoration Ecology, 7(3): 241-251.

Riley, J. L. and P. Mohr 1994. The Natural Heritage of Southern Ontario's Settled Landscapes; A review of conservation and restoration ecology for land-use and landscape planning. Ontario Ministry of Natural Resources, Southern Region. Aurora, Ontario.

Roberts-Pichette, P. and L. Gillespie 1999. Terrestrial vegetation biodiversity monitoring protocols. EMAN Occasional Paper Series, Report No. 9. Ecological Monitoring Coordinating Office, Burlington, Ontario.

Rzadki, J. and O'Neal, S. 2001. Monitoring Report of Planting Projects Undertaken Since 1994 in the Hamilton Harbour Watershed. Hamilton Conservation Authority. Ancaster, Ontario.

Schmidt, T.L., Spencer, J.S.Jr., and M.H.Hansen 1996. Old and potential old forest in the Lake States, USA. Forest Ecology and Management 86: 81-96.

Schneider, D. 2004. Resource Interpreter, Grand River Conservation Authority. Personal communication, April through October 2004.

Sheppard, C. 2004. Ontario Junior Rangers Supervisor. Personal communication, August 2004.

Small C.J. and B.C. McCarthy 2002. Effects of simulated post-harvest light availability and soil compaction on deciduous forest herbs. Canadian Journal of Forest Research. 32(10): 1753-1762

Soberón, J., Rodriguez, P., and E. Vázquez-Dominguez 2000. Implications of the hierarchical structure of biodiversity for the development of ecological indicators of sustainable use. Ambio, 29(3): 136-142..

Society for Ecological Restoration 2002. The SER Primer on Ecological Restoration. USA, Science and Policy Working Group, SER.

Spencer, D. R., Perry, J. E., and G. E. Silberhorn 2001. Early secondary succession in bottomland hardwood forests of southeastern Virginia. Environmental Management, 27(4): 559-570.

Spurr, S.H. and B.V. Barnes 1980. Forest Ecology. Third Edition. John Wiley and Sons, New York, New York.

Stanturf, J. A., Schoenholtz, S. H., and Schweitzer, C. J. 2001. Achieving restoration success: Myths in bottomland hardwood forests. Restoration Ecology, 9(2): 189-200.

Sweeney, B.W., Czapka, S.J., and T. Yerkes 2002. Riparian forest restoration: increasing success by reducing plant competition and herbivory. Restoration Ecology 10(2): 392-400.

Thoreau, H. D. 1993. Faith in a Seed. The Dispersion of Seeds and Other Natural History Writings. Island Press, Washington D.C. (Edited by B. P. Dean)

Toth, L.A., Arrington, D.A., Brady, M.A., and D.A. Muszick 1995. Conceptual evaluation of factors potentially affecting restoration of habitat structure within the channelized Kissimmee River ecosystem. Restoration Ecology 3(3): 160-180.

Trombulak, C.S. and A.C. Frissell 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology. 14(1): 18-30.

United States Department of Agriculture 1999. Soil Quality Test Kit Guide. Natural Resources Conservation Services. Available: http://soils.usda.gov/sqi/soil_quality/assessment/kit2.html. Accessed; June 24, 2004.

University of Minnesota 2003. Minnesota Worm Watch. Soil and the Forest Floor. Available: http://www.nrri.umn.edu/worms/withsoil.html. Accessed: March 19, 2004.

Varga, S. 1989. A Vegetation Inventory of Backus Woods. Ontario Ministry of Natural Resources. Unpublished report for Backus Woods Inventory. 190 pp.

Wackernagel, M. and W. Rees 1996. Our Ecological Footprint. Reducing Human Impact on the Earth, New Society Publishers, Gabriola Island, British Columbia.

Waldron, G. 2003. Trees of the Carolinian Forest. A Guide to Species, Their Ecology and Uses. The Boston Mills Press. Erin, Ontario.

Wallis, R. 2004. Personal communication, May through July 2004.

Washburn, C.S.M. and M.A. Arthur 2003. Spatial variability in nutrient availability in an oak-pine forest: potential effects of tree species. Canadian Journal of Forest Research 33(12): 2321-2330.

Wearing-Wilde, J., Lynn D.H., Hebert, P.D.N., Barker, D., Hincks, S., Robinson, M. and Anderson, C. 2000. Natural History of Ontario Course Reader. University of Guelph, Guelph, Ontario.

West, D.C., Botkin, D.B., and Shugart, H.H. (Editors) 1981. Forest Succession: Concepts and Applications, Springer-Verlag, New York, New York.

Whisenant, S. G. 1999. Repairing Damaged Wildlands A Process Orientated, Landscape-Scale Approach, Cambridge University Press, Cambridge, U.K.

White, P.S. and J.L.Walker 1997. Approximating nature's variation: Selecting and using reference information in restoration ecology. Restoration Ecology 5(4): 338-349.

Wilkins, S., Keith, D.A., and P.Adam 2003. Measuring success: evaluating the restoration of a grassy eucalypt woodland on the Cumberland Plain, Sydney, Australia. Restoration Ecology 11(4): 489-503.

Williams, O. 2003. Ontario Stewardship Network Coordinator. Personal communication. May 2003.

Wittchen, M. 2004. Teacher. Paris High School. Personal communication. April through July 2004.

Wynia, A. 2003. Retired Forester, Ministry of Natural Resources. Personal communication, May 2003.

Yaussy, D.A. 2000. Comparison of an empirical forest growth and yield simulator and a forest gap simulator using actual 30-year growth from two even-aged forests in Kentucky. Forest Ecology and Management, 126: 385-398.

Zedler, J. B. and J. C. Callaway 1999. Tracking wetland restoration - do mitigation sites follow desired trajectories. Restoration Ecology 7(1): 69-73.

Appendix I

Questions for students – Forest and restoration monitoring June/July 2004

Simplicity of use and training

1. did you find the equipment easy to use?
2. were the methods as written (or instructions as given) easy to follow?
3. would you have liked more
   a. training or
   b. practice or
   c. background information before you started the field work?

   Please specify in what area if you have some suggestions.

4. would you have like more
   a. training in the field
   b. practice in the field

   Again, please specify if you have any suggestions.

5. what was the hardest part of the field work?

Open questions:

What did you learn from this experience/work?

What suggestions would you make to improve the learning experience given the time we had?

Questions for teachers:

Time:

1. do you think that given more time, the students would have learned more?
2. do you think that the time spent would have been more effective with more preparation: eg lessons in plant identification, plant community and soil characteristics?
3. do you think that it would be appropriate to devote more time to this subject (monitoring of restoration and/or woodlot characteristics) in your curriculum?
4. is there discretionary time in your curriculum?

Subject fit in curriculum:

1. do you think that the students would have learned more if they had a chance to do the calculations for the results themselves?
2. do you think that learning the calculations and characteristics of the plant community would fit within the curriculum in a way that complements other things that CELP or environmental studies students are learning?

Open question:

What suggestions would you have for improving this experience for the students?

Appendix II

Site Description (page 3 of Field Manual for Describing Soils)

Slope type: _____(Complex or Simple)   Slope Position (p4): ______(1- 7)
Slope percent: _________

Microtopography: Ht. of mounds__________dist between mounds_________(Ht < 0.3/0.3-1/>1, dist. >7/0.3-7/>3 or <3)

Soil Description:

Surface stoniness: _____________________________Manual page 5

Surface rockiness: _____________________________ Manual page 6

Depth of organic layer: ________________   (spongy, rooty topsoil in woodlands)
Class: _________________________ (L – lvs and needles, F – partly decomposed, H – decomposed organic matter) – see Manual pages 10, 22

Depth of mineral soil: ____________   Layers (#): ___________ Manual pp 7, 8, 15.

Depth of layers: 1. ________ 2. ________3. _________ 4. _________5. __________

Particle size/%: 1___________ 2. __________3.__________4.__________5.__________

Depth to mottles (different coloured patches in soil matrix); _________ Weak, distinct or prominent: _______________Manual p 27

Depth to gley (greyer, bluer, permanently wetted layer):________________________

Depth to watertable(water depth in hole, depth of soaking wet soil) : ______________

Depth of carbonates (where soil bubbles and fizzes when treated with 10% HCl): ______

Texture Class 1: __________________________(eg. vfS, LcS, CL, SCL) pp 18 - 21

Texture Class 2: __________________________(eg. vfS, LcS, CL, SCL)

Texture Class 3: __________________________(eg. vfS, LcS, CL, SCL)

Texture Class 4: __________________________(eg. vfS, LcS, CL, SCL)

Texture Class 5: __________________________(eg. vfS, LcS, CL, SCL)

Drainage Class: _______________(p. 26) **Moisture Regime: ____________(**p 29, 32**)**

Appendix III

Further Details on Methods

The purpose of this appendix is to further clarify why the Soil Respiration and Soil Wet Aggregates methods were discarded. As well, other methods that were tried, then abandoned because it was felt that they did not add any useful additional information to this work are described.

Soil Respiration (United States Department of Agriculture 1999)

This protocol was used at the three restoration sites and two reference sites described in Chapter 3. A maximum of four replicates were run at each site, due to the expense of the Draeger tubes that were required for the test. Two of the sets of results had a great deal of scatter, the worst being a range of 4 units for a mean of 3.6 g CO_2-C/m^2/day in the Backus Woods ecological community. Another difficulty with the results was that the mean result at CSB was 3.4 g CO_2-C/m^2/day higher than that for the neighbouring CSA. The test was run at CSB a month later than for CSA, because this was the interval between when the two sites were assessed. It was both warmer and wetter during the time when the CSB tests were run relative to CSA. Sources of error in the results included error in reading the results from the graduated Draeger tubes and error in the relative contribution to respiration results from vegetative matter in the soil such as roots (as compared to measuring simple microbe respiration) – a sampling error.

This protocol was discarded as a candidate for use by volunteers, both because of the expense and difficulties of sampling correctly, and because of the difficulty in interpreting the data. The possible errors associated with the test itself described above are compounded by the effects of temperature and moisture content in the soil. The method is designed to include corrections for these, but in at least two cases the temperature correction did not reduce the scatter in the results, and the difference in values between the results for CSA and CSB are not amenable to interpretation, at least by someone of my limited experience.

An alternative test is well known, where the respired CO_2 collected in the headspace of the sampling cylinder is absorbed by alkali solution or soda lime (Hutchinson and Rochette 2003). The resulting dissolved CO_2 is assessed and the total mass of respired CO_2 calculated. This test will not have the error associated with reading the Draeger tubes, but there will be other experimental errors associated with the method, and the problem of interpretation of the results remains. As well, the test takes a long time and so would most likely not appeal to volunteers from that standpoint. However, if anyone is seriously interested in measuring soil respiration, this option is available.

Soil Wet Aggregates Test

Two versions of this test were attempted for the sandy soils at the five sites described in Chapter 3. The method described in the Soil Kit Guide by the United States Department of Agriculture (1999) involved the use of home-made sieves, dipping, and drying equipment. The first problem my assistants and I encountered was that when we tried to weigh the dry samples in the sieves according to Step 1, part of the sample leaked through the sieves, introducing an immediate source of error in the initial sample weight. In every step after that, part of the sample leaked through the sieve, although this problem is not described in the protocol. Apparently the soils of this area are known for being structureless (McBride 2004, personal communication). So this behaviour might have been expected by an experienced soil scientist. However, even if the soils had behaved as implied by the protocol, the test is very long and involves multiple dipping and drying steps over at least two days. It did not seem to me that this test was one that volunteers would be willing to use.

Another version of the test is given in Carter (1993). Again, our attempts to follow this protocol also failed to produce a useful result. Again this might have been expected by an experienced soil scientist for this type of soil. However, this test requires standard soil sieves, and again requires multiple steps that are time-consuming.

The information to be gained from this test is interesting and can give the monitor some insight into the soil structure development at a restoration site (Whisenant 1999). However, tests which measure erosion resistance are almost as informative at a practical level for the typical citizen scientist interested in the progress at a restoration site.

Microclimate Tests

The differences in microclimate between an extensive closed canopy forest and an open field have been studied (Bormann and Likens 1979). Temperature, humidity, and light intensity at breast height were measured for three of the sites; CSA, CSB and the Backus Woods community (BWR). Temperature and humidity were measured using a wet-dry bulb hygrometer. The results showed that the temperature was cooler and the humidity was higher in the interior of the mature forest (BWR) than at the restoration site. However, in these 12-year old restorations, there was no significant difference between measurements in the open parts of the site and those in the small groves. It was concluded that there is probably not a significant difference in temperature and humidity for small or immature forest stands relative to open fields, and that this indicator would probably only be useful for extensive and older restorations where the canopy was closed and edge effects were small.

In order to determine if light intensity was a suitable indicator of restoration progress for volunteers to use, light intensity was measured using both a LICOR light meter with a sensor for the visible spectrum and a hand-held Sekonic Auto-Leader (Model L-188) light meter sold for photographers. A grey neutral card was mounted on a wooden board and the Sekonic light metre aimed at the card for readings. The sensor for the LICOR was mounted on top of the card so that the light reading for the LICOR and that for the Sekonic were taken close together. The board was carried at chest height through CSA and measurements taken at every point where the vegetation had been sampled. The results from the two instruments were correlated and it was found that the Sekonic readings had a 0.96 correlation coefficient with the LICOR reading. It appears that a photographer's light metre can be used to do this kind of work. The test was not followed up because the range in light intensities was extreme at the one site, and it became obvious that the readings in the mature forest would be much lower. The question of how to treat the data in a comparison of two sites arose, and time being short, further testing was abandoned.