Using Ecological Land Classification (ELC) to determine scientifically sound benchmarks for optimal natural area sizes in Muskoka, Ontario

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ABSTRACT

The district municipality of Muskoka, Ontario is a primarily forested environment that supports extensive cottage, recreational and tourism activities. Standards for the amount of natural area to be maintained are constantly changing as anthropogenic influences increase. Ecosystem monitoring is essential for maintaining ecosystem integrity as development increases. The Muskoka Watershed Council (MWC) focuses on developing scientifically sound benchmarks for the amount of natural areas to be maintained for use in the 2014 Muskoka Watershed Report Card. Our objectives are to establish baseline empirical data using Ecological Land Classification (ELC) and analyze the current states of four types of ecosystems in the Muskoka region: meadow, wetland, rock barren and forest. Using our data, we assess the biodiversity of each site and make recommendations for optimal natural area sizes that will maintain ecosystem function, health and resistance to further human disturbance at each site. The areas in the study should be maintained by preventing fragmentation and habitat loss to ensure ecosystem integrity. Fragmentation was viewed at Bracebridge Resource Management Centre, where one area of the forest was converted to a red pine plantation. The area demonstrated low biodiversity and heterogeneity. It is recommended that fragmentation be avoided to maintain diversity in rock barren ecosystems. We also recommended that wetlands remain completely undisturbed to prevent the release of greenhouse gases and the loss of high levels of diversity. Further study to determine a specific number of hectares to be maintained would involve issues of landscape connectivity, nutrient and water cycling, and extensive biodiversity analysis.

1.0 INTRODUCTION

Habitat fragmentation is a disturbance that can occur both naturally or as a result of human activity. Fragmentation is becoming an increasingly pressing issue due to rising populations and urban sprawl, causing more anthropogenic barriers between habitat patches. Habitat fragmentation is common in North America and is now impacting Northern Canada in the Muskoka region. Human development in terms of cottage building, recreation and tourism is taking its toll on the ecosystems present there. However, it is not often clear why habitat fragmentation causes such a large problem with regards to ecosystem health which can be defined as a systematic approach to the preventative, diagnostic, and prognostic aspects of ecosystem management, and to the understanding of relationships between ecosystem health and human health (UWO, 2012); but there is literature on the subject that might add clarification. Habitat fragmentation can be defined as “an event that creates a greater number of habitat patches that are smaller in size than the original contiguous tract(s) of habitat” (Bender et al. 1998), a concept common in an anthropogenically influenced world. Forest clearing and agricultural land expansions are two of the main causes of fragmentation in landscapes (Bender et al. 1998).

Patch size effects the population of animals living in these patches differently depending on the location of the species (Bender et al. 1998). Generalist species decline is directly proportional to habitat loss, but for interior species population decline is higher than what is predicted by habitat loss alone and for edge species, decline in population will be less than predicted by habitat loss (Bender et al. 1998). Many articles use more than one source of data so there is a higher certainty in their results because they have both evidence from models and field sampling data. Models are not always reliable in this case though, because anthropogenic influences and changes to species interactions within fragments are always different between ecosystems (MacNally et al. 2000). According to Fahrig (2003), empirical studies of habitat fragmentation are often difficult to relate to one another and interpret because many researchers measure habitat fragmentation on a patch scale rather than a landscape scale. Failing to distinguish between loss of habitat and fragmentation are also an issue in empirical research on the subject (Fahrig, 2003). Habitat loss has a greater affect on a species than fragmentation because it is crucial to interior species as a main factor causing their extinction (Fahrig, 1999). This is an issue since fragmentation is a landscape scale process; it is measured correctly when measurements are made on a landscape scale (Fahrig, 2003).

Connectivity is often described as an asset to biodiversity. However, the term has many different connotations in literature so Fischer and Lindenmayer (2007) described three different types of connectivity: habitat connectivity or the connectedness between patches for a species, landscape connectivity which can be attributed to the human perspective of connections of native vegetation cover, and ecological connectivity which encompasses connectedness of ecological processes over multiple scales. Isolation effects start to take place as the proportion of suitable habitat decreases on the landscape scale, which has a drastic effect on population size of a given species (Andren, 1994). With this and other relevant literature, it is safe to assume that increased habitat fragmentation and isolation of patches directly correlates to a decline in the population of the species. Patch occupancy remains a large problem for species however. Most species have a limited ability to disperse themselves so the rate of recolonization of empty patches will decrease with isolation of these patches (Hanski, 1994). Patch restoration is necessary in these cases but there is often a lag experienced in projects of this nature wherein a significant number of patches need to be restored before there is a positive influence on populations (Tilman et al. 1997; Huxel and Hastings, 1999). However, the study by Huxel and Hastings (1999) concluded that either restoring patches adjacent to occupied patches or reintroducing species to vacant patches drastically improves success of restoration of the patch.

Given that increased isolation between patches directly correlates to a loss of species, loss of biodiversity is also an issue. As the population of a given species declines, the existence of the species within the ecosystem becomes unstable because population is reaching the point wherein the species will not be able to replenish itself. Biodiversity is important not only for ecosystem health which also relates to watershed health, but the health of the economy in Muskoka as well because its natural diversity is one of the main attractors of tourism. Biodiversity, or species richness, is a term used to describe the degree of diversity of life present at the gene, species and ecosystem level, over either a narrowed or a broad geographical area (Kapos et al. 2000). Biodiversity plays a fundamental role in many aspects of human life, the intrinsic value relevant to conservation efforts. Areas that are managed by people emphasize a need to preserve the integrity of ecological communities through protected areas, national parks, biological reserves and conservation areas (Alho, 2008). Preservation of biodiversity is necessary for human existence as it enhances the resilience of desirable ecosystem states necessary to assure essential ecosystem service production (Elmqvist et al. 2003).

The insurance hypothesis predicts that an increased species richness and diversity increases stability of community and ecosystem properties (Leary & Petchey, 2009). Forests are crucial in maintaining global diversity as they provide habitat for over fifty percent of the world's species (Kapos et al. 2000; Groombridge & Jenkins, 2000). Human impacts pose a large threat in depletion of the world's biodiversity, especially in forested ecosystems (Kapos et al. 2000). There are three main ways that humans impact forest biodiversity: total area of forest remaining, configuration of the remaining forest cover, and structure and composition of the remaining forest (Kapos et al. 2000). It is these effects that make conservations of ecosystems, such as forests, with high biodiversity essential to human survival. Without these ecosystems that are often referred to as “biodiversity hotspots”, many aspects of human life would cease to exist. Lindenmayer et al. (2006) propose the following guiding principles for conservation of forest biodiversity: maintenance of habitat connectivity and landscape heterogeneity, the maintenance of stand structural complexity, maintenance of aquatic ecosystem integrity, and the use of natural disturbance regimes as a guide for anthropogenic disturbance regimes. Biodiversity is important following ecological disruption because the distribution of species within and across ecosystem scales is what allows regeneration and renewal to occur (Peterson et al. 1998). Biodiversity is not only important to humans but to other species. In many areas, plant species richness affects the assemblages of bird species and other fauna (Rompre et al. 2007). Biodiversity loss is a current risk to humanity due to the trend for unregulated exploitation of living natural resources (Alho, 2008).

The goal of the Muskoka Watershed Council (MWC) is “to sustain and enhance the air, water and terrestrial ecosystems of the watersheds of Muskoka for the environmental, health, economic, spiritual and intrinsic values they provide” (Muskoka Watershed Council, 2012). The MWC has approved the University of Waterloo to address their objectives which are: to evaluate the watersheds by developing and implementing science-based programs to research, assess, monitor and evaluate the health of Muskoka’s watersheds; to advocate for the watersheds through sound, air, land and water use planning and management practices and policies that sustain and improve the health of Muskoka’s watersheds; to communicate and educate by developing and implementing public information and education programs that promote understanding of the impact of human actions on the watersheds and encouraging lifestyle choices that are compatible with healthy and functioning watersheds; and to promote and facilitate demonstration activities and best practices that support and environmentally sustainable economy and healthy community structure (Muskoka Watershed Council, 2012). The MWC has a mandate that focuses on developing scientifically sound benchmarks for the amount of natural areas to be maintained for use in the 2014 Muskoka Watershed Report Card. Consistent with this mandate, the Muskoka Watershed Council is focused on how anthropogenic disturbances affect biodiversity in the region. Because Muskoka is a forested environment which supports extensive cottage, recreational and tourism activities, it is important to monitor ecosystem health. Monitoring ecosystem health ensures that sufficient natural areas are maintained to preserve essential biodiversity. We examined natural area conservation in four types of ecosystems: wetlands, forest, rock barrens and open meadows. Baseline data was collected from Bracebridge Resource Management Centre, Torrance Barrens Provincial Nature Reserve, and Pen Lake Farms Nature Reserve and extrapolated to gauge ecological integrity benchmarks for the amount of natural areas to be maintained, and strategies for conservation of biodiversity.

Our specific objective, consistent with the mandate of MWC, was to use baseline data collected at these sites to determine standards for natural areas in the light of tourism, recreation and urbanization of the Muskoka region.

To address our objective, we used Ecological Land Classification (ELC) to identify landscapes of the region. ELC was developed in 1998 by the Ontario Ministry of Natural Resources. It is a hierarchical classification that defines similar and dissimilar areas using patterns among soil, vegetation, geology, climate and the general landscape. Ecozones are the ecological context for Ontario planning and policy and ELC uses the Ecozone classification unit (an area of 10,000-1,000,000 km^2) and breaks it down into smaller, hierarchical units. The ELC framework is organized into six classification units, each helping the researcher identify landscapes. Hierarchically nested levels, from largest to smallest, are as follows: Ecozone, ecoregion, system, community class, ecosite and finally ecoelement, which includes vegetation and substrate type. This hierarchy allows researchers to incorporate spatial aspects with community-related organization to understand where and what they are studying. It establishes a uniform and consistent management tool for the natural environment (Acosta, Carranza and Giancola 2005; Chu and Jones 2010; Dolan and Parker 2005; Host et al 1996; Lee et al 1998; Nadeau, Li and Hans 2004).

The process of identifying all attributes of a system, including soil, vegetation, geology, climate and landscape of an area, is a key component to ELC. The term “ecosite”, in ELC, refers to a polygon-level attribute that represents a combination of substrate and vegetation types which are used in conjunction with other observations to classify the site. The structure of the system is based on substrate characteristics, moisture regime as well as canopy composition to identify and qualify the importance of a given area (Pokharel & Dech, 2011). ELC operates under the rubric that landscape heterogeneity is a function of the scale of observation and the hierarchical structure is dependent on the limits imposed by the higher ecosystem levels (Acosta et al. 2005). This is particularly important for systems that lack heterogeneity. The problem can often be found in the higher levels of the hierarchy and managed properly.

Ecological Land Classification has been used most commonly in forest classification as it provides ecosite scale units often amenable for forest management because ELC allows forest managers to facilitate on-site, community-level evaluations of forests including planning, inventory, impact assessments, biodiversity monitoring, fire management, and invasive controls (Pokharel & Dech, 2011; Lee et al. 1998). ELC provides a holistic, community-level analysis of timber potential, vegetation structure, composition and disturbance levels (Lee et al. 1998). ELC can be used in forest management to project timber yield, identify future protected areas, locate rare species and is also used in the US to protect and manage national forests, nature preserves, recreation areas, and public lands (Dolan & Parker, 2005; Lee et al. 1998; Wuest & Betts, 2010).

By 2009, the ELC system was expanded and combined with the Forest Ecological Classification system to include the entire land base, not just forested ecosystems (Pokharel & Dech, 2011). This meant that it could be used for management and conservation of biodiversity (Chu, 2010; Culman et al. 2010; Pesch et al. 2011; Wuest & Betts, 2010). More broadly, ELC has become a classification of landscapes that considers both current land-cover patterns and their dynamics. This type of system is important in marginal cultural landscapes because these areas have experienced dramatic land-use changes that have affected the land-cover (Reger et al. 2007). It now provides a cross-scalar (ecosite to landscape scales) method of understanding, identifying, and classifying the interactions between different ecosystem factors using the structure and function of soils, vegetation and physiography (Bryan, 2006; Dolan & Parker, 2005). At core, the technique within ELC is that it groups like areas and isolates uncommon areas. In doing so, it reduces variation by categorizing those similarities and dissimilarities to better understand the landscape (Dolan & Parker, 2005).

2.0 SITE DESCRIPTIONS

2.1 *Bracebridge Resource Management Centre*

Bracebridge Resource Management Centre (BRMC) is found north of Bracebridge, Ontario and consists of 8 km of walking, biking and snowmobile trails. The recreation area is a forested system east of Highway 11 (45.127193N and -79.310453W). The small area adjacent to the highway is a failed attempt at homesteading which was subsequently turned into a Red Pine plantation to quickly establish economically productive. More natural forests stands surround the pine plantation. Two forest polygons were chosen at this site due to variability in vegetation composition.

2.2 *Torrance Barrens*

Torrance Barrens was classified as a Dark Sky Reserve in 1999 and is located northwest of Gravenhurst at 44.975201N and -79.568739S. The site spans over 4500 ha on the Canadian Shield consisting of undisturbed bedrock and wetlands (Bergsma, 1994). Rock was exposed as a result of the wave action of the receding glacial lakes during the previous glaciation. Wave action of these lakes also prevented soil accumulation. Lake organic deposits were likely formed on lacustrine sand and silt material which were washed into the low-lying regions. Glacial action resulted in the low elevation and irregularly shaped lakes and linear wetland complexes. This area contains high diversity of flora, fauna, and rare species in a series of acidic rock barrens, upland forests, and wetlands including swamps, marshes, and fens, all inhabiting extensive unfragmented habitat. Rock barren and wetlands were chosen as polygons at this site for the purposes of our study.

2.3 *Pen Lake Farms Nature Reserve*

Pen Lake Farms, adjacent to Peninsula Lake at 45.362672N and -79.099159S, is over 121 acres of land consisting of about 60% woodland, 25% meadow/grassland, and 15% wetlands. The meadow site, which was previously a farmed area, is currently undergoing active restoration using Silver Maple (a nurse species used here to facilitate wetland development) and White Pine saplings. For the purposes of our research, we studied the meadow area portion of the land for our meadow polygon.

3.0 METHODS

Primary research was gathered around Huntsville, Ontario on the dates October 12-14, 2011. On October 12, 2011 we met with Jan McDonnell. Jan is the area Wildlife Biologist for the Ontario Ministry of Natural Resources, serving the Muskoka Region and based in Bracebridge, Ontario. Jan provided us with the most appropriate area of study. Judi Brouse, the Director of Watersheds Program of the Muskoka Watershed Council, recommended our sites include a rock barren, wetland, forest and meadow, do understand and develop standards for natural areas. Sites include, Bracebridge Resource Management Centre, Torrance Barrens and Pen Lake Farms Nature Reserve, and will be described in further detail when Ecological Land Classification is applied to them.

3.1 *Application of ELC for Natural Heritage Planning and Protection*

The goal of the Muskoka Watershed Council is “to sustain and enhance the air, water and terrestrial ecosystems of the watersheds of Muskoka for the environmental, health, economic, spiritual and intrinsic values they provide” (Muskoka Watershed Council, 2012). To protect the integrity of these ecosystems so they can provide these services, it is imperative that focus be placed on habitat for we must conserve the habitat upon which species depend (Lee et al. 1998). As many groups, individuals and agencies are attempting to restore lost or degraded ecosystems, ELC can be used to develop recovery plans for species of interest by locating existing suitable habitat (Lee et al. 1998). Muskoka is a forested environment that supports extensive cottage, recreational and tourism activities, as well as three small towns and several medium sized villages within the area. As development occurs in both the built-up areas and the rural and waterfront areas, standards for the amount of natural areas to be maintained are required. Area of importance can be classified with ELC and with that classification, current levels of disturbance and impacts on the systems by surrounding areas can be determined.

4.0 RESULTS

4.1 Applying ELC to Site Locations

4.1.1 *Site 1 (Forest) – Bracebridge Resource Management Centre*

BRMC was the first site accessed on October 12, 2011. The area currently consists of two apparently (at first glance) different community structures, particularly in vegetation composition. Our first polygon, an area (approx. 500m by 100m) of similar vegetation and soil characteristics, was directly adjacent to Highway 11. According to trail information signage, this area was converted to a red pine dominated plantation to quickly establish a productive forest after homesteading ventures failed. The stand structure, shown in Fig. 3, was obviously dominated by red pine with a relative average of 82.7% while red oak, eastern white pine and balsam fir made up the remaining 17.3%. Ground-layer vegetation was sparse with the occasional patch of bracken fern (*Pteridium aquilinum* L.) and poverty oat grass (*Danthonia spicata)* with a litter layer consisting of between 5-cm to 10-cm of pine needles. Soil structure ranged from medium sand (mS) to loamy fine sand (LfS) with depths beyond the auger length (>120 cm). The first site's soil profile, shown in Fig. 2, demonstrated mottling at a depth of 24.5-cm resulting in a moisture regime of moderately fresh with a rapid to well drainage (1/R-W). Mottling was not found in the other two sites giving a moisture regime of arid with rapid to very rapid drainage (0/R-VR) for both. Based on stand structure and description, and demonstrated in Fig. 1, community classification for the first polygon was determined to be a Coarse Mineral Coniferous (Red Pine) Plantation (Code: TAGM1). Vegetation characteristics of the Coniferous Plantation landscape mentions that coniferous tree species represent >75% of the canopy cover, which is consistent with our findings.

ELC	Site: BRMC			Polygon: 1	
Community Description &	Surveyors: Alicia and Kaitlin		Date: Oct 12, 2011		
Classification				UTMZ:	4996675
POLYGON DESCRIPTION					
SYSTEM	SUBSTRATE	TOPOGRAPHIC FEATURE	HISTORY	PLANT FORM	COMMUNITY
Terestrial X	Organic	Lacustrine	Natural	**Plantation X**	Lake
Wetland	**Mineral Soil X**	Riverine	**Cultural X**	Submerged	Pond
Aquatic	Parent Min	Bottomland		Floating-lvd	River
	Acidic Rock	Terrace		Graminoid	Marsh
	Basic Bedrk	Valley Slope		Forb	Swamp
	Carb. Bedrk	Roll. Upland		Lichen	Fen
		Cliff		Bryophyte	Bog
		Talus		Deciduous	Barren
		Crevace/Cave		**Coniferous X**	Meadow
SITE		Alvar	COVER	Mixed	Prairie
Open Water		Rockland	Open		Thicket
Shallow Water		Beach/Bar	Shrub		Savannah
Surficial Dep. X		Sand Dune	**Treed X**		Woodland
Bedrock		Bluff			**Forest X**
STAND DESCRIPTION					
LAYER	HT/CVR	SPECIES IN ORDER OF DECREASING DOMINANCE >>, >, =			
1 - Canopy		Red Pine>>Red Oak>Balsam Fir			
2 - Sub-canopy		Red Oak>>			
3 - Understory		Balsam Fir>>American Beech=Eastern White Pine			
4 - Grd. Layer		Poverty Oat Grass>Bracken Fern			
HT Codes: 1=>25m 2=10<HT 25m 3=2<HT 10m 4=1<HT 2m 5=0.5<HT 1m 6=0.2<HT 0.5m 7+HT<0.2m					
CVR Codes 0=NONE 1=0%<CVR= 10% 2=10<CVR=25% 3+25<CVR=60% 4=CVR>60%					
COMMUNITY CLASSIFICATION:					
Community Class:	**Cultural Agricultural**			Code:	**AG**
Community Series:	**Treed Agricultur**	**Coniferous Plantation**		Code:	**TAG**
Vegetation Type:	**Coarse Mineral Coniferous (Red Pine) Plantatio**			Code:	**TAGM1**
Notes: (inclusion/complex - code)					

Fig. 1 – BRMC Polygon 1 – Community Description and Classification Data Sheet

Community Classification: Coarse Mineral Coniferous (Red Pine) Plantation Code TAGM1

Classification based from information provided in Fig. 2-3

ELC	Site:			BRMC
Plant Species	Polygon:			1
List	Date:			Oct. 12
Layers: 1 = Canopy > 10m 2=Sub-canopy 3=Understory 4= Ground				
Abundance Codes: R= Rare O= Occasional A= Abundant D= Domina				
Species	Layers			COLL.
Code	1	2	3	4	
Poverty Oat Grass				X	O
Wood Fern				X	A
Red Pine	X				D
Red Oak		X			O
American Beech			X		A
Eastern White Pine			X		O
Balsam Fir			X		O
~~	~	~	~	~	~~~~~~~~~
Red Pine	X				D
Bracken Fern				X	O
Poverty Oat Grass				X	O
Balsam Fir			X		O
~~	~	~	~	~	~~~~~~~~~
Black Cherry			X		R
Red Oak	X				A
Red Pine	X				D
Poverty Oat Grass				X	A
Balsam Fir	X		X		O

Fig. 2 – BRMC Polygon 1 – Plant Species List Data Sheet

ELC	Site:	BRMC	by the highway			
Stand & Soil	Polygon:	1	Prism Factor	10		
Characteristics	Date:	Oct. 12				
TREE TALLY BY SPECIES						
Species	Tally 1	Tally 2	Tally 3	Tally 4	Total	Relative Average
Red Pine	9	18	16		43	82.7
Red Oak	1	0	4		5	9.6
Eastern White Pine	3	0	0		3	5.8
Balsam Fir	0	0	1		1	2
Total	13	18	21		52	100
Basal Area (BA)						Mean
Dead					0	
Soil Assessment:	1	2	3	4		
Texture	mS	mS	LfS			
Depth to Mottles	g=24.5 c	none	none			
Depth to Gley	none	none	none			
Depth to Bedrock	120+cm	120+cm	120+cm			
Moisture Regime	1/R-W	0/R-VR	0/R-VR			

Fig. 3 – BRMC Polygon 1 – Stand and Soil Characteristics Data Sheet

The red pine plantation at BRMC has an approximate area of 500m by 100m. Pine tree growth abruptly ends around the edges where the forest changes into a more natural mixed forest. Due to the variation from the pine plantation vegetation composition and stand structure, a second polygon was done to achieve an accurate representation of the area. The second polygon stand structure was not dominated by any particular tree species. There were a mix of eastern hemlock (*Tsuga canadensis* L.), balsam fir (*Abies balsamea* L.), yellow birch (*Betula alleghaniensis* Britt.), American beech (*Fagus grandifolia* Ehrh.), red and sugar maples (*Acer rubrum* L. and *Acer saccharum* Marshall) existent in the stand structure and shown in Fig. 6. Ground-layer species were again very sparse with small patches of bracken fern and little other species present. Soil characteristics, represented in Fig. 5, were consistent for all three sites done in the second polygon. Effective texture was loamy fine sand (LfS) with no mottling or gley found in the soil profile leading to a moisture regime of dry with rapid to very rapid drainage (0/R-VR) for all sites. Depth to bedrock was not as nearly as deep as at the first polygon, where bedrock could not be reached. Depths ranged from 40.5-cm to 54-cm. Based on stand structure and description, community classification for the second polygon was determined to be a Dry-Fresh Hardwood – Hemlock Mixed Forest (Code: FOM3-1), shown in Fig. 4. Vegetation characteristics for FOM3 states that Hemlock be present with Sugar Maple, Red Maple or Red Oak as varying dominant species while shrub and herb cover and species richness is low, which is again consistent with the findings (Lee et al. 1998).

Fig. 4 – BRMC Polygon 2 – Community Description and Classification Data Sheet

ELC	Site: BRMC - further from highway			Polygon: 2	
Community Description &	Surveyors: Alicia and Kaitlin			Date: Oct. 12, 2011	
Classification	Start	End		UTMZ 4996613	UTMN
POLYGON DESCRIPTION					
SYSTEM	SUBSTRATE	TOPOGRAPHIC FEATURE	HISTORY	PLANT FORM	COMMUNITY
Terestrial	Organic	Lacustrine	Natural	Plantation	Lake
Wetland	**Mineral Soil**	Riverine	**Cultural**	Submerged	Pond
Aquatic	Parent Min	Bottomland		Floating-lvd	River
	Acidic Rock	Terrace		Graminoid	Marsh
	Basic Bedrk	Valley Slope		Forb	Swamp
	Carb. Bedrk	Roll. Upland		Lichen	Fen
		Cliff		Bryophyte	Bog
		Talus		Deciduous	Barren
		Crevace/Cave		Coniferous	Meadow
SITE		Alvar	COVER	**Mixed**	Prairie
Open Water		Rockland	Open		Thicket
Shallow Water		Beach/Bar	Shrub		Savannah
Surficial Dep.		Sand Dune	**Treed**		Woodland
Bedrock		Bluff			**Forest**
STAND DESCRIPTION					
LAYER	HT/CVR	SPECIES IN ORDER OF DECREASING DOMINANCE			>>, >, =
1 - Canopy		Yellow Birch = Eastern Hemlock > Balsam Fir >Red Maple			
2 - Sub-canopy		Yellow Birch = American Beech > Eastern Hemlock			
3 - Understory		Eastern Hemlock = Yellow Birch > Balsam Fir			
4 - Grd. Layer		Bracken Fern			
COMMUNITY CLASSIFICATION:					
Community Class	**Forest**			Code: **FO**	
Community Serie	**Mixed Forest**			Code: **FOM**	
Vegetation Type:	**Dry-Fresh Hardwood - Hemlock Mixed Forest**			Code: **FOM3-1**	
Notes: (inclusion/complex - code)					

Community Classification: Dry-Fresh Hardwood-Hemlock Mixed Forest Code FOM3-1
Classification based from information provided in Fig. 5-6

ELC	Site:			BRMC
Plant Species	Polygon:			2
List	Date:			Oct. 12
Layers: 1 = Canopy > 10m 2=Sub-canopy 3=Understory 4= Ground				
Abundance Codes: R= Rare O= Occasional A= Abundant D= Domina				
Species	Layers			COLL.
Code	1	2	3	4	
Balsam Fir	X		X		O
Yellow Birch	X	X	X		A
American Beech		X			A
Red Maple	X				O
Bracken Fern				X	O
~~	~	~	~	~	~~~~~~~~~
Yellow Birch	X				A
Sugar Maple		X	X		D
Bracken Fern				X	A
American Beech				X	A
Balsam Fir		X	X		A
~~	~	~	~	~	~~~~~~~~~
Yellow Birch	X	X	X		A
Bracken Fern				X	A
Eastern Hemlock	X	X	X		A

Fig. 5 – BRMC Polygon 2 – Plant Species List Data Sheet

ELC	Site:	BRMC			
Stand & Soil	Polygon:	2	Prism Factor	10	
Characteristics	Date:	Oct. 12			
TREE TALLY BY SPECIES					
Species	Tally 1	Tally 2	Tally 3	Tally 4	Total	Relative Average
Red Maple	3	2	0		5	17.2
Yellow Birch	3	4	2		9	31
American Beech	3	2	0		5	17.2
Balsam Fir	0	2	0		2	6.9
Eastern Hemlock	0	0	8		8	27.6
Total	9	10	10		29	100
Basal Area (BA)						Mean
Dead	2	3	1		6	
Soil Assessment:	1	2	3	4		
Effective Texture	LfS	LfS	LfS			
Depth to Mottles	none	none	none			
Depth to Gley	none	none	none			
Depth to Bedrock	40.5 cm	54 cm	49 cm			
Moisture Regime	0/R-VR	0/R-VR	0/R-VR			

Fig. 6 – BRMC Polygon 2 – Stand and Soil Characteristics Data Sheet

4.1.2 *Site 2 (Rock Barren) – Torrance Barrens Dark Sky Reserve*

Torrance Barrens boasts extensive wetlands and rock barrens. We chose to do two sites each for the rock barren and the wetland since consistencies prevailed. For the rock barren, we found many vegetation species consistent with the geography including common juniper (*Juniperus communis* L.), staghorn sumac (*Rhus typhina* L.) and an abundance of reindeer lichen (*Cladonia rangiferina* L.) and poverty oat grass. Our second rock barren polygon was similar yet hosted more tree species, particularly red oak (*Quercus rubra* L.) and eastern white pine (*Pinus strobus* L.*)* (See Fig. 8). The soils, determined to consist solely of silty fine sand (SifS), found in between large rock outcrops, were quite shallow, never deeper than 17-cm, which did not allow us to determine a moisture regime, as the process requires soils at depths of 31-cm or greater. Based on vegetation structure and description, community classification for the first polygon at Torrance Barrens was determined to be a Common Juniper Acidic Shrub Rock Barren (Code: RBS3-2), as described in Fig. 7. Shrub rock barren was chosen since <25% of the area was tree covered and >25% was shrub covered. Understory species include poverty oat grass, however lichen was not mentioned. Consistent with the geography, the environmental characteristics of RBS3-2 state that conditions may be less extreme (than an open rock barren) where rock may be broken/cracked where soil has been allowed to develop (Lee et al. 1998).

ELC	Site: Torrance Barrens Rock Barren			Polygon: 1	
Community Description &	Surveyors: Alicia and Kaitlin			Date: Oct 13, 2011	
Classification	Start	End			
POLYGON DESCRIPTION					
SYSTEM	SUBSTRATE	TOPOGRAPHIC FEATURE	HISTORY	PLANT FORM	COMMUNITY
Terestrial	Organic	Lacustrine	**Natural**	Plantation	Lake
Wetland	Mineral Soil	Riverine	Cultural	Submerged	Pond
Aquatic	Parent Min	Bottomland		Floating-lvd	River
	Acidic Rock	Terrace		Graminoid	Marsh
	Basic Bedrk	Valley Slope		Forb	Swamp
	Carb. Bedrk	Roll. Upland		Lichen	Fen
		Cliff		Bryophyte	Bog
		Talus		**Deciduous**	**Barren**
		Crevace/Cave		Coniferous	Meadow
SITE		Alvar	COVER	Mixed	Prairie
Open Water		Rockland	Open		Thicket
Shallow Water		Beach/Bar	**Shrub**		Savannah
Surficial Dep.		Sand Dune	Treed		Woodland
Bedrock		Bluff			Forest
STAND DESCRIPTION					
LAYER	HT/CVR	SPECIES IN ORDER OF DECREASING DOMINANCE			>>, >, =
1 - Canopy		Red Oak			
2 - Sub-canopy		Pin Cherry			
3 - Understory		Common Juniper=Staghorn Sumac=White Pine			
4 - Grd. Layer		Reindeer Lichen=Poverty Oat Grass			
COMMUNITY CLASSIFICATION:					
Community Class:	**Rock Barren**			Code: **RB**	
Community Series	**Shrub Rock Barren**			Code: **RBS**	
Vegetation Type:	**Common Juniper Acidic Shrub Rock Barren**			Code: **RBS3-2**	
Notes: (inclusion/complex - code)					

Fig. 7 – Torrance Barrens Rock Barren Polygon – Community Description and Classification Data Sheet
Community Classification: Common Juniper Acidic Shrub Rock Barren Code RBS3-2
Classification based from information provided in Fig. 8-9

ELC Plant Species List	Site:				TB Rock Barren
	Polygon:				2
	Date:				Oct. 13
Layers: 1 = Canopy > 10m 2=Sub-canopy 3=Understory 4= Ground l					
Abundance Codes: R= Rare O= Occasional A= Abundant D= Dominan					
Species	Layers				COLL.
Code	1	2	3	4	
White Pine	X		X		R
Pin Cherry		X			A
Staghorn Sumac		X			A
Common Juniper			X		A
Poverty Oat Grass				X	D
Reindeer Lichen				X	A
Braken Fern				X	O
Red Oak	X				O
~~	~	~	~	~	~~~~~~~~~
Red Oak	X				O
Common Fern Moss				X	O
Reindeer Lichen				X	D
Staghorn Sumac		X			O
Common Juniper			X		A
White Pine	X				O
Poverty Oat Grass				X	D

Fig. 8 – Torrance Barrens Rock Barren Polygon – Plant Species List Data Sheet

ELC	Site:	TB Rock Barren				
Stand & Soil	Polygon:	1	Prism Factor	10		
Characteristics	Date:	Oct. 13				
TREE TALLY BY SPECIES						
Species	Tally 1	Tally 2	Tally 3	Tally 4	Total	Relative Average
Red Oak		3			3	33.30%
Total	0	3	0		3	100
Basal Area (BA)						Mean
Dead	0	0	0		0	
Soil Assessment:	1	2	3	4		
Effective Texture	SiFS	SiFS				
Depth to Mottles	none	none				
Depth to Gley	none	none				
Depth to Bedrock	17 cm	15 cm				
Moisture Regime	-	-				

Fig. 9 – Torrance Barrens Rock Barren Polygon – Stand and Soil Characteristics Data Sheet

4.1.3 Site *3 (Wetland) – Torrance Barrens Dark Sky Reserve*

Since Torrance Barrens offered wetland ecosystems, as well as rock barrens, we chose to do our wetland polygon at this site as well. We chose to do two sites for the polygon again due to similar vegetation patterns and soil structure. Vegetation, shown in Fig. 11, at both sites consisted of wire sedge (*Carex lasiocarpa*), the dominant vegetation type as well as soft rush (*Juncus effusus)*, common fern moss (*Thiclium delicatulum)*, common winterberry (*Ilex verticillata*), leatherleaf (*Chamaedaphne calyculata*), cotton grass (*Eriophorum spp.)* and watershield (*Brasenia schrebri)*. The first wetland site consisted of a floating root mat a 6-cm depth with 13-cm of organic material on the surface. There was about a 65-cm depth from the surface to the bedrock beneath. The second wetland site also had a floating root mat with upraised hummocks. Root mat was between 5-cm at the lowest points and 30-cm depths in hummocky areas. There was a depth of >120-cm from surface to bedrock. Soils at both sites were >50% of organics with fibric material closer to the surface and mesic material further down. Based on vegetation structure and environmental characteristics, community classification for the second polygon at Torrance Barrens was determined to be a Slender Sedge Open Fen Type (Code: FEO1-2), demonstrated in Fig. 10. This classification was chosen because the most dominant vegetation type was wire sedge, slender sedge according to the classification. The vegetation characteristics were consistent with the site showing <10% tree cover and <25% shrub cover (Lee et al. 1998).

ELC	Site: Torrance Barrens Wetland			Polygon: 2	
Community Description & Classification	Surveyors: Kaitlin Richardson and Alicia Vacing			Date: Oct 13th/2011	
	Start	End			
POLYGON DESCRIPTION					
SYSTEM	SUBSTRATE	TOPOGRAPHIC FEATURE	HISTORY	PLANT FORM	COMMUNITY
Terestrial	**Organic**	Lacustrine	**Natural**	Plantation	Lake
Wetland	Mineral Soil	Riverine	Cultural	**Submerged**	Pond
Aquatic	Parent Min	Bottomland		**Floating-lvd**	River
	Acidic Rock	Terrace		Graminoid	Marsh
	Basic Bedrk	Valley Slope		Forb	Swamp
	Carb. Bedrk	Roll. Upland		Lichen	**Fen**
		Cliff		Bryophyte	Bog
		Talus		Deciduous	Barren
		Crevace/Cave		Coniferous	Meadow
SITE		Alvar	COVER	Mixed	Prairie
Open Water		Rockland	**Open**		Thicket
Shallow Water		Beach/Bar	Shrub		Savannah
Surficial Dep.		Sand Dune	Treed		Woodland
Bedrock		Bluff			Forest
STAND DESCRIPTION					
LAYER	HT/CVR	SPECIES IN ORDER OF DECREASING DOMINANCE			>>, >, =
1 - Canopy					
2 - Sub-canopy		Common Winterberry			
3 - Understory					
4 - Grd. Layer		Wire Sedge = Common Fern Moss = Cotton Grass = Leatherleaf > Water Shield >> Soft Rush			
COMMUNITY CLASSIFICATION:					
Community Class:	**Fen**			Code: **FE**	
Community Series:	**Open Fen**			Code: **FEO**	
Vegetation Type:	**Slender Sedge Open Fen Type**			Code: **FEO1-2**	

Fig. 10 – Torrance Barrens Wetland Polygon – Community Description and Classification Data Sheet
Community Classification: Slender Sedge Open Fen Type Code FEO1-2
Classification based from information provided in Fig. 11 and observations of soil

ELC	Site:				TB Wetland
Plant Species	Polygon:				1
List	Date:				Oct. 13
Layers: 1 = Canopy > 10m 2=Sub-canopy 3=Understory 4= Ground					
Abundance Codes: R= Rare O= Occasional A= Abundant D= Dominan					
Species	Layers				COLL.
Code	1	2	3	4	
Common Winterberry			X		O
Wire Sedge				X	D
Common Fern Moss				X	A
Bryophyte				X	A
Soft Rush				X	O
~~	~	~	~	~	~~~~~~~~~
Wire Sedge				X	D
Common Fern Moss				X	A
Bryophyte				X	A
Water Shield				X	O
Soft Rush				X	O

Fig. 11 – Torrance Barrens Wetland Polygon – Plant Species List Data Sheet

4.1.4 *Site 4 (meadow) – Pen Lake Farms Nature Reserve*

Our final study site provided by the Muskoka Heritage Foundation was Pen Lake Farms Nature Reserve, located near Peninsula Lake, east of Huntsville. We used this area for to ecologically classify a meadow for the purposes of our research. Here, we chose to do four different sites within the polygon because of the difference in the first site compared to the others. The first site, a small marshy area dominated by robust emergents, was by the roadside where water would likely drain to. The clay proved extremely wet leading to a moisture regime of very moist with poor drainage (6/P), which was reinforced by the presence of mottles at the surface (0-cm) and gleying at 2-cm. The 3 subsequent sites were very similar in terms of vegetation. The meadow species present included: bush clover, orchard grass, fowl meadow grass and yarrow. Soil types we not thoroughly uniform. However, there was consistency in that all the soil types were either silty clay loam (SiCL) or silty clay (SiC). Each site had the same moisture regime of very fresh with moderately well drainage (3/MW-1). The meadow is currently under active restoration using Silver Maple and White Pine but no tree species was tall enough to include a tree tally in the stand composition. Based on vegetation structure and environmental characteristics, community classification for the Pen Lake Farms site was determined to be a Dry-Moist Old Field Meadow Type (CUM1-1). This was a cultural site due to past farming activity and meadow was chosen since the site had <25% tree cover and <25% shrub cover

(Muskoka Heritage Trust, 2012). It was evident that farming activities occurred previously due to a lack of an A horizon and homogeneity in the soil column, also known as soil deflation. Soil deflation occurs in areas that that were left unprotected from the elements and resulted in a truncated soil column, often a visible loss in the O and A horizons (McPherson & Timmer, 2002). O horizon has developed at Pen Lake Farms, indicating the area has been allowed to fallow for some time.

ELC Community Description & Classification	Site: Pen Lake Farms			Polygon: 1	
	Surveyors: Alicia and Kaitlin			Date: Oct 14, 2011	
	Start	End			
POLYGON DESCRIPTION					
SYSTEM	SUBSTRATE	TOPOGRAPHIC FEATURE	HISTORY	PLANT FORM	COMMUNITY
Terestrial	Organic	Lacustrine	Natural	Plantation	Lake
Wetland	**Mineral Soil**	Riverine	**Cultural**	Submerged	Pond
Aquatic	Parent Min	Bottomland		Floating-lvd	River
	Acidic Rock	Terrace		**Graminoid**	Marsh
	Basic Bedrk	Valley Slope		Forb	Swamp
	Carb. Bedrk	Roll. Upland		Lichen	Fen
		Cliff		Bryophyte	Bog
		Talus		Deciduous	Barren
		Crevace/Cave		Coniferous	**Meadow**
SITE		Alvar	COVER	Mixed	Prairie
Open Water		Rockland	**Open**		Thicket
Shallow Water		Beach/Bar	Shrub		Savannah
Surficial Dep.		Sand Dune	Treed		Woodland
Bedrock		Bluff			Forest
STAND DESCRIPTION					
LAYER	HT/CVR	SPECIES IN ORDER OF DECREASING DOMINANCE			>>, >, =
1 - Canopy					
2 - Sub-canopy					
3 - Understory		Silver Maple=White Pine			
4 - Grd. Layer		Orchard Grass>Fowl Meadow Grass>>Golden Rod=Yarrow			
COMMUNITY CLASSIFICATION:					
Community Class:	**Cultural**			Code: **CU**	
Community Series	**Cultural Meadow**			Code: **CUM**	
Vegetation Type:	**Dry-Moist Old Field Meadow Type**			Code: **CUM1-1**	
Notes: (inclusion/complex - code)					

Fig. 12 – Pen Lake Farms Polygon – Community Description and Classification Data Sheet
Community Classification: Dry-Moist Old Field Meadow Type Code CUM1-1
Classification based from information provided in Fig. 13-14

ELC	Site:				Pen Lake Farms
Plant Species	Polygon:				1
List	Date:				Oct. 14
Layers: 1 = Canopy > 10m 2=Sub-canopy 3=Understory 4= Ground					
Abundance Codes: R= Rare O= Occasional A= Abundant D= Dominai					
Species	Layers				COLL.
Code	1	2	3	4	
Canada Golden Rod				X	O
Fowl Meadow Grass				X	A
Bed Staw				X	O
Yarrow				X	O
Orchard Grass				X	D
Silver Maple			X		A
White Pine			X		A
~~	~	~	~	~	~~~~~~~~~
Orchard Grass				X	D
Wild Strawberry				X	O
Fowl Meadow Grass				X	A
~~	~	~	~	~	~~~~~~~~~
Orchard Grass				X	D
Fowl Meadow Grass				X	A

Fig. 13 – Pen Lake Farms Polygon – Plant Species List Data Sheet

ELC	Site:	Pen Lake Farms		
Soil	Polygon:	1		
Characteristics	Date:	Oct. 14		
Soil Assessment:	1	2	3	4
Effective Texture	SiC	SiCL	SiC	SiC
Depth to Mottles	0cm	43cm	32cm	35cm
Depth to Gley	2cm	43cm	32cm	35cm
Depth to Bedrock	120cm +	120cm +	120cm +	120cm +
Moisture Regime	6/P	3/MW-1	3/MW-1	3/MW-1

Fig. 14 – Pen Lake Farms Polygon – Soil Characteristics Data Sheet

5.0 DISCUSSION

5.1 *BRMC*

Efforts have begun to assess and monitor forests for the goods and services and biological diversity they provide. The older approach was to describe only the physical attributes of the forest, e.g. total area and timber supply (Kapos et al. 2000). At BMRC, the Red Pine plantations are similar to many found in Ontario. Some of these were established at the time of European settlement for the purposes of commercial logging and were one of many land altering activities during colonization (Parker et al. 2008). Based on available information, it is unsure when the plantation was established. In some cases, the original intent was to establish a plantation but in the case of BMRC, there was a prior land clearing scheme and intent to utilize the land for agriculture purposes. This involved fires that were used to clear the area for farming. The intensity and frequency of the fires usually led to soil nutrient depletion particularly in area with coarse textured soil, like that found in BRMC (Parker et al. 2008). This decrease in stored soil nutrients made crop production unfeasible for the area, despite efforts, which further reduced the fertility of the land.

At BMRC, homesteading attempts were abandoned, possibly due to the fire driven error, which rendered the soil infertile for agricultural purposes. The area was converted into a pine plantation to provide revenue to the current landowner to compensate for the failed homesteading. Conversion to a pine plantation was likely considered by the owner to be a more desirable outcome given the alternative of abandoning the area completely, leaving the soil exposed to erosion. Comparatively, in other areas of Ontario where farming failed, thousands of hectares of unproductive land were left barren, susceptible to non-native invasion and further physical degradation (Parker et al. 2008).

Our results show that the current problem at BRMC is not that the area is not forested, but that it lacks biodiversity, both within the stand and beneath it. Two other tree species exist in the canopy and sub-canopy and two in the understory. Ground layer diversity is poor with only one species of fern and poverty oat grass, a *Danthonia* species that often only appears in areas of nutrient poor soil where other vegetation cannot grow, consistent with the history of the site and the lack vegetation diversity (Knobel, 1977). Due to the lack of Red Pine within the sub-canopy and understory, successional movement away from Red Pine domination may be the future, natural trajectory of this site.

Despite the lack of diversity, this site is important for social activities. Local residents and tourists use BRMC to experience the natural environment through a series of trails made accessible to the public, which are used year round for hiking and cross-country skiing (Tourism Bracebridge, 2012). Such activities are often beneficial for human health (De Vries et al. 2003; Maas et al. 2006). The use of BRMC for recreational purposes has ensured the area's protection from urban expansion and logging purposes. Since red pine plantations in Southern Ontario provide essential forest and soil cover in highly urbanized area, it is not recommended that the area be removed (McPherson & Timmer, 2002). Instead, management should be modified to included higher biodiversity to increase ecosystem goods and services, such as enhanced nutrient cycling, habitat creation leading to further diversity and aesthetic value (Parker et al. 2008). Management to rehabilitate the site should include introducing an array of native species that can withstand low light beneath the red pine canopy and poor soil conditions, such as nurse species like oaks that require less light or pioneering species like ash that can establish quickly in the canopy gaps. Parker et al. used white pine, red oak and white ash to restore red pine plantations located around the Oak Ridges Moraine (2008). These species were chosen for their ability to grow under low light and poor soil conditions. Red oak showed the least amount of success but with increased thinning, the species may thrive and contribute to diversity (Parker et al. 2008). Thinning of the stand is a management strategy that may facilitate growth of existing species on site, reducing costs of rehabilitation and providing possible economic input through the sale of valuable red pine timber (Parker et al. 2008). Increasing diversity may enhance the resilience of the site to disturbance, mismanagement and degradation. Degradation and disturbances include, but are not limited to, the spread of invasive species, loss of ecosystem services, and increased susceptibility to pests and disease (MNR, 2010).

5.2 *Torrance Barrens*

Torrance Barrens provides extensive wetland complexes, rock barren outcrops and high levels of biodiversity. These may become uncommon in southern and mid-central Ontario as they are a target for urbanization as large areas are already clear of trees and wetlands contain highly valuable peat (Bergsma, 1994). An inventory of flora and fauna was done but the Muskoka Heritage Area Program in 1990 and 1991 which found 417 native vascular plants and 58 non-native species. Of the 475 plant species, 19 are considered provincially rare including the White Fringed Orchid (*Platanthera blephariglottis*), among others that have already been catalogued and can be viewed in the Torrance Barrens: Vegetation and Significant Features Inventory and Evaluation by Bergsma (1994), provided to the Ontario Ministry of Natural Resources. Over 94 species of bird have been catalogued in the area, including 6 rare species like the nationally and provincially rare Cooper's hawk. The provincially rare Southern Bog Lemming is the only rare mammal found at the site (Bergsma, 1994). Because the habitat has a high connectivity, this area is used by interior species like the Black Bear, Moose and Coyote.

Because of the areas sheer size of unfragmented habitat, it was chosen to be Canada's first Dark Sky Reserve in 1999. Fragmentation is defined as the loss of habitat area into smaller and smaller patches and reduced connectivity between such patches (Andren, 1994). Should Torrance Barren ever experience fragmentation, species population will decline along with the high level of diversity and overall species richness (Debinski et al. 2001). Generalist species, those that use edge or the interior of a habitat, will decline in population size correlated to the level of habitat loss (Bender et al. 1998). However, they will be more adaptable as they can live in either area of a habitat. Interior species are the most susceptible to habitat fragmentation because as further fragmentation occurs, more edges are created, reducing the size of the interior and thus suitable habitat for interior species (Bender et al. 1998). Edge species are less likely to be affected by the fragmentation of the habitat as fragmentation usually denotes an increase in edge type habitats, although initial loss of species through destruction of habitat will be expected (Bender et al. 1998). Human development has been known to create isolated wetlands through the creation of levees, dams and river alteration (Tiner, 2003). However, fragmentation and destruction of wetlands can lead to an alteration of the eco-hydrological dynamic, resulting in a release of CO_2, CH_4, N_2O and a loss of habitat function and structure (Tousignant, 2010). The question now remains: how much habitat is enough? Fahrig (2001) suggests that we simply cannot measure the amount of critical habitat for each ecosystem. However, there is a threshold level, that when reached, will result in ecosystem collapse. Fahrig (2001) states that each hectare loss of a habitat may be minuscule in terms of overall habitat failure. However, if there is a threshold for each ecosystem and each hectare lost puts that system closer to the threshold, then that small area of loss may not be worth the threat on the system that its removal poses.

5.3 *Pen Lake Farms*

Pen Lake Farms was previously an agricultural area, mainly a grassland for cattle grazing and then converted into hay harvesting site, which would have proved fertile based on the soil type of silty clay loam and silty clay, especially in comparison to the soils found at BRMC. This site remained farmed until it was donated to the Muskoka Heritage Trust with the intention of ensuring the site's natural integrity (Muskoka Heritage Trust, 2012). The site s currently under restoration activities whereby 1000 native trees, including white pine and silver maple, and 1000 highbush cranberry to promote wetland processes. Higher levels of diversity surround the meadow site in the woodland and wetland areas. The woodland contains a sub-carpet of Jack-in-pulpit, indicating high levels of biodiversity, as well as some large shrubs like the Striped Maple and locally rare ferns (Muskoka Heritage Trust, 2012). There is a diversity of edge species Blue birds, Savannah sparrow, bobolink, deer and salamanders.

Heterogeneity is the root of biological diversity and as such we can determine diversity by the level of heterogeneity within the system (Fuhlendorf & Engle, 2004). As a managed ecosystem, the heterogeneity of the meadow portion of Pen Lake farms is inherently reduced. Homogeneity is found at the meadow site, particularly in the soil column. There was a definite lack of A horizon in all soil samples taken at the site, consistent with the past agricultural land use that put pressure on the soil surface by exposing it to wind and water erosion, which often results in an overall loss of the O and A horizons (Stavi & Lal, 2011; McPherson & Timmer, 2002). The erosion of the first soil horizon results in a significant decrease in soil organic matter and soil organic carbon content, which has implications for the amount of nutrients within the soil and the ability of those nutrients to remain in the soil (Stavi & Lal, 2011). Nutrient retention capacity is reduced proportionally with the reduction of organic matter. A lack of soil nutrients may have caused the sites lack of vegetation biodiversity. Homogeneity of site vegetation reflects a lack of biodiversity. Only four species exist at ground layer: Orchard Grass, Fowl Meadow Grass, Golden Rod and Yarrow, excluding common grass spp. Understory species exist only because the site is currently undergoing restoration with Silver Maple and White Pine sapling planted on site in 2009 (Muskoka Heritage Trust, 2012).

6.0 CONCLUSIONS

The areas in the study should be maintained by preventing fragmentation and habitat loss to ensure ecosystem integrity. Fragmentation was viewed at Bracebridge Resource Management Centre, where one area of the forest was converted to a red pine plantation. The area demonstrated low biodiversity and heterogeneity. Forests are important sources of soil cover and habitats for wildlife. To ensure biodiversity, the integrity of forests stands should be maintained by ensuring fragmentation and habitat loss does not occur. Restoration at Penn Lake Farms exemplifies work that needs to be done in repairing anthropogenic ecosystem fragmentation and increasing system resilience to future disturbances. Given the degree of natural habitat patch isolation in rock barren ecosystems, it is recommended that fragmentation be avoided to maintain diversity. In the event of increased isolation of patches (i.e. as a result of human disturbance), certain vulnerable species (particularly interior species) may become locally extirpated, thus decreasing ecosystem diversity and landscape heterogeneity. It is recommended that wetlands remain completely undisturbed to prevent the release of greenhouse gases and the loss of high levels of diversity (particularly those seen at Torrance Barrens).

Using ELC to classify the landscapes of interest is a major first step in identifying a physical number of hectares to protect to maintain ecosystem goods and service and important wildlife habitat. Further studies to determine hectares to protect would involve a series of projects looking at the landscape issues of connectivity and ecosystem processes like nutrient and water cycling. Data would have to be collected over a period of 5-10 years to identify a number. Our baseline data can be used to determine direction and recommendation for further study to determine the physical number of hectares the Muskoka Watershed Council should protect from human induced landscape change.

7.0 RECOMMENDATIONS for expanding the scope beyond our study

In our primary research, barriers exist surrounding the length of the study period. Our samples on the forested, rock barren, wetland and meadow sites were taken during one season of one given year. Our conclusions and findings in this paper are based on secondary literature combined with our data collection. This can be used to establish a baseline for future research on the sites studied. Extending the study and the collection of data over a longer period of time and during different times of the year will yield more conclusive results for benchmarks of ecosystem health at the study sites.

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