Targeted rare plant surveys for the Lower Athabasca: A report on 2012 activities

Report to the Ecological Monitoring Committee for the Lower Athabasca (EMCLA)

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Contents

Figures

Tables

1. Executive Summary

Vascular plant species richness and rarity were sampled in the summer of 2012 in 150 quarter hectare plots targeted to different habitats and places where rare plants were considered likely in the Lower Athabasca region of northeast Alberta. In total, 405 vascular plant species were recorded in the 150 plots (37.5 hectares), 73 (18%) of which are considered rare (S-Rank of S1, S2, or S3). Species richness and detection of rare plants were compared among 9 ecosites, as well as with ABMI plots from the Lower Athabasca region. We found that rare plants were more likely to be detected in EMCLA plots, and that EMCLA plots had greater plant diversity than similar sized ABMI plots that were limited to a 20 minute survey effort and were placed in a systematic survey design. We report on initial patterns of species richness and rarity for the 9 ecosites and briefly describe future objectives that include increasing sample size, mapping patterns of rarity to assist with constraint planning, and general descriptions of diversity and rarity in plants for the Lower Athabasca region.

2. Background

In 2010, the Ecological Monitoring Committee for the Lower Athabasca (EMCLA) initiated the rare plants project with the goal of designing and implementing a rare plant monitoring program for the Lower Athabasca Planning Region (LAPR). Much of the monitoring that currently takes place in the LAPR is conducted to satisfy clauses in *Environmental Protection and Enhancement Act* approvals for oil sands developments, and is focused at the scale of individual development projects. These individual efforts lack the integration and consistency needed to effectively monitor biodiversity at a regional scale.

Although the Alberta Biodiversity Monitoring Institute (ABMI) has also been conducting inventories of vascular plants throughout Alberta since 2003, there is concern that ABMI site selection and survey methodology may result in an under-representation of rare species (Nielsen et al. 2009). Because ABMI surveys were designed to capture many aspects of terrestrial biodiversity at a large scale (province-wide), systematic site selection (location of survey) and field survey protocols (20 minute surveys) may be less effective at 'capturing' rare species. The EMCLA Rare Plants project was designed to fill these gaps by providing a coordinated monitoring effort using a protocol modified from ABMI surveys and traditional rare plant meander surveys (ANPC 2012) to enhance detection of rare species. Whereas ABMI monitoring sites are selected based on a 20 km systematic grid of the province, the EMCLA's Rare Plant Project uses a stratified (habitats) and model-based (targeted) system for selecting sites to sample. The advantage of the model-based system is that it allows for increased sampling in rare habitat types (which are more likely to have rare plants), while reducing effort spent sampling common and species-poor habitats (Guisan et al. 2006). Likewise, whereas the time-limited nature of ABMI surveys (20 minutes per quarter hectare plot) may restrict a technician's ability to concentrate effort in rare habitats and areas of high species richness, EMCLA protocols provide technicians with unlimited time and therefore presumably an increased detection rate of rare species per unit area. It was hypothesized that the time unlimited protocol and the targeted location of plots would increase rare species detections.

In 2011, existing location data on rare plants in the Lower Athabasca region were assembled from several sources. Habitat suitability models – using a presence-only modeling design – were developed for a set of focal rare plants (vascular plants, bryophytes, and lichens) with regional importance in northeast Alberta (Nielsen 2011). In 2012, habitat suitability models were further refined for vascular plants and used to map and predict distributions for focal species across the LAPR. Targeted locations for sampling were then identified from these models and general land cover from Ducks Unlimited enhanced wetland classification. Field crews conducted quarter hectare, time-unlimited vascular plant surveys at these sites to gather additional rare plant records in the LAPR, better understand habitat-rarity relationships, test field protocols, and further refine habitat suitability models. The following report is an overview and analysis of data collected in the first year of field sampling for the EMCLA's Rare Plant project (2012) and provides a comparison of these data to those collected by ABMI in the Lower Athabasca over the period 2007 to 2011. The first section of the report focuses on a summary of rare species and total vascular plant richness detected in the 2012 field season. The second section highlights differences between the EMCLA and the ABMI plots in the LAPR based on estimates of vascular plant richness, and in particular rare vascular plants. By emphasizing the differences between the two sampling designs in detection rates of plant species, both rare and common, here we provide the first test of the success of the EMCLA's model-based sampling protocol.

3. Methods

3.1 EMCLA Time Unlimited Survey

3.1.1 Site selection and establishment

At each target site selected by habitat suitability models, accessibility and selected land cover types, two 50 × 50 m (quarter hectare) plots (plots A and B) were established (Chai et al. 2012). Plot A was the target site defined by model-based sampling, while plot B was located at a maximum distance of 200 m from Plot A and placed in a nearby, but 'different' habitat type (the plots were not adjoining). This paired plot design was done to accommodate safety protocols at the University of Alberta as it relates to the maximum distance that co-workers should be separated from one another in the field when equipped with communication devices. Plots were positioned to avoid roads, have less than 25% of their area affected by human disturbance, and possess rare plant microhabitats (e.g. open sand, rock faces, ephemeral habitats, or in transition zones between habitats). Plots were established by laying out a 0.25 ha square boundary with the plot edges running in ordinal directions. All vascular plant surveys were conducted in July and August of 2012.

3.1.2 Physical characteristics of the plot

Physical characteristics were determined at the centre of each plot. The primary ecological site type (ecosite) of each plot was determined based on the dominant vegetation community and structural stage within the 0.25 hectare plot (Appendix I). Any secondary ecosite taking up more than 0.1 ha of continuous habitat within the plot was also recorded, if present. The GPS location, elevation, slope, aspect and the type and percent cover of human and natural disturbance were also recorded (Appendix II). At each plot, six photographs were taken: four photographs in the subordinal directions, one canopy photograph and one photograph representative of the site. A soil probe was used to measure soil conductivity if mineral soil was present (soil measurements were not taken in fens or bogs).

3.1.3 Vascular plant surveys

Plots A and B were each surveyed for vascular plants by a technician capable of identifying more than 80% of species encountered. Starting in the northwest corner of the plot, the technician searched for plants while walking in a pattern that mimics a series of 50 m parallel belt transects where technicians scan a 2 to 4 m wide (1-2 m per side) zone (Figure 1). Each new species observed was recorded, along with the time of discovery (rounded down to the nearest minute). Unknown species were collected for later identification. Searches had no time limit and were terminated when the technician had surveyed the entire area thoroughly. Species still unidentified after further work by the technician with the use of keys and taxonomic guides were pressed, labeled with a unique identifier and sent to a specialist at the Royal Alberta Museum for identification.

When a rare species (or suspected rare species) was encountered during a survey, the location of the population was marked using flagging tape and additional information was collected on the population after the survey was complete so that time of observation was not affected by additional information being collected on each rare species. Information collected on each rare species was based on the Alberta Conservation Information System (ACIMS) Rare Native Plant Survey Form. This included GPS location, population size (number of individuals and extent of population), phenological stage, microsite habitat, moisture, light levels, and land use. This information also sent to the ACIMS after the field survey. Specimens of rare species were collected for verification by a specialist if the populations had more than 20 individuals and appeared healthy. For populations under 20 individuals photographs were taken and if there was more than one individual, a voucher specimen of the diagnostic features of the species (e.g. leaf) was also collected for verification by a specialist.

3.1.4 Detectability and observer bias

Eight sites were randomly selected for an examination of species detectability and observer bias between technicians. At these sites, each technician surveyed both A and B plots using the methods described above at different times (once each plot was completed) so that neither technician was aware of what information were collected by the other technician. We will not report on the results of this until more data is available from the 2013 field season.

3.2 ABMI Time Limited Survey

3.2.1 Site selection and establishment

ABMI vascular plant surveys were conducted in 50 × 50 m quadrants within each one hectare (100 × 100 m) site. A total of four plots were thus completed per site (NE, NW, SE and SW quadrants). Locations of sample sites were based on a systematically spaced 20 × 20 km grid of Alberta. Sites were established by placing a marker at the precise GPS coordinates of each site centre and establishing a 1 ha square boundary around this point, with the site edges running in ordinal directions. Vascular plant surveys were conducted annually across Alberta in June and July from 2007 to 2011.

3.2.2 Physical characteristics of the plot

Physical characteristics were recorded at site centre and at the centre of each quadrant. At site centre, the primary ecosite of the 1ha site was determined based on the dominant vegetation community and structural stage in a 150 m radius around site centre (Appendix I). Any secondary ecosite taking up more than 0.1 ha of continuous habitat within the plot was also recorded, if present. Elevation, slope, aspect, and the type and percent cover of human and natural disturbance were also recorded (Appendix II). Six photographs were taken at site centre: four photographs in the subordinal directions, one canopy photograph and one photograph representative of the site.

At the centre of each quadrant, ecosite was recorded based on the dominant vegetation community and structural stage within a 5 × 5 m square that had its corner at the quadrant centre (Figure 2). Elevation, slope, aspect, and the type and percent cover of human and natural disturbance (Appendix II) were also recorded for each plot centre.

3.2.3 Vascular plant surveys

Each quadrant was surveyed for vascular plants by a technician capable of identifying over 80% of species encountered. Prior to starting the survey, 10 minutes was spent recording the names of all species seen at the site (1 ha). The technician then searched for vascular plants for 20 minutes in each quadrant, starting at the quadrant centre and walking in a roughly square pattern clockwise around the quadrant while staying 5–10 m away from the site boundary (Figure 2). Each new species observed was recorded, and unknown species were collected for later identification. Quadrants were searched in the order NE (northeast), SE (southeast), SW (southwest) and NW (northwest). Species still unidentified after further work by the technician with the use of keys and taxonomic guides were pressed, labeled with a unique identifier, and sent to a specialist at the Royal Alberta Museum for identification.

3.3 Analysis Methods

3.3.1 EMCLA diversity and rarity

Alpha diversity of species composition was analyzed by ecosite (primary ecosite defined by observer) using species richness and graphical demonstrations. To assess species richness within each ecosite, two separate species rarefaction curves were produced: one to analyze the rate of species accumulation over the number of sampled sites within each ecosite, and the other to analyze the species accumulation over survey time per ecosite. The latter was extrapolated to predict the rate of discovering new species over the duration of 200 minutes.

3.3.2 Comparing EMCLA with ABMI methods

ABMI and EMCLA surveys differed in two key aspects of plot methodology: time spent surveying and area surveyed. While the ABMI surveys one hectare as four quarter hectare plots in 80 minutes, the EMCLA surveys a quarter hectare plot in an unlimited amount of time. To compare among the two methods, data from each were separated into four possible methods that varied in area surveyed and time spent surveying. These included: (1) EMCLA plot with a 20 minute cut-off survey time (only those records observed in the first 20 minutes of the survey were used); (2) EMCLA plot with an unlimited survey time; (3) one ABMI plot (0.25 ha NE quadrant) with its 20 minute survey effort; and (4) four ABMI plots (4 × 0.25 ha) representing the 1 ha 'site' and an 80 minute total survey effort. Records with a taxonomic resolution courser than species were excluded from analyses (ex: genus, family) and species with an ACIMS ranking of S1, S2 or S3 were considered rare (Appendix III).

To predict average species richness expected among each of the four methods, generalized linear models were used with the number of species detected as the response variable and ecosite as the predictor variable. A quasipoisson distribution was used due to the count-type nature of the data and overdispersion in the model and fitted values were averaged to get predicted number of species and predicted number of rare species for each ecosite. The same method was used for predicted number of rare species.

To determine the probability of detecting a rare species using each method, generalized linear models were generated with the presence or absence of any rare species as the response variable and ecosite as the predictor variable. A binomial distribution was used and fitted values were averaged to get predicted number of species and predicted number of rare species at each ecosite. The same method was used to test for probability of detecting a species in each of the three rarity classes (S1, S2, and S3). All analyses were performed using the R 2.15.0 software (R Development Core Team, 2012).

4. Results

4.1 EMCLA species richness

In 2012, a total of 150 plots were surveyed not including plots that were removed due to very small sample sizes within ecosite types and those were repeated surveys were used for assessing detectability and observer bias. Across the 150 plots, 405 species were recorded, 73 (18%) of which are considered rare (S-Rank of S1, S2, or S3) (Table 1, Appendix III). The majority of recorded ‘rare’ species were S3 ranked species comprising 65 of the 73 detections. The most diverse ecosite, not considering sample effort (number of plots), was Rich Fen (RD) with 276 species, followed by Buffaloberry (MM) with 254 species. S1 and S2 rare species were most common, however, in Lab Tea (PM) and Horsetail (MX) ecosites (Table 1).

Species incidence-based rarefaction curves present the accumulation of new species recorded in surveys over a set number of sites. They are often used to determine if sampling exhaustion has been achieved and if the rate of new species accumulation has slowed to demonstrate that diversity has been adequately measured. The curves produced for each ecosite using 2012 EMCLA plot data (Figure 3) have not plateaued, indicating that more data collection per ecosite is needed to fully characterize diversity within each plant community. Here, rarefaction was also used to compare species richness between ecosites because the number of plots per ecosite was uneven and the time spent sampling each ecosite was uneven.

In addition to rarefaction curves of sites for each ecosite, species rarefaction curves were also estimated for each ecosite using species accumulations by time of observation (minute of survey that a new species was recorded) resulting in species accumulation curves by ecosite across length of survey in minutes (Figure 4). A 20 minute mark was superimposed on this figure to demonstrate where ABMI time-limited protocols would impose a stopping rule. These curves were extrapolated from recorded data to predict species richness values at longer time intervals not achieved through sampling. Table 2 presents predicted species diversity at three time intervals: 20 minutes (ABMI effort), 60 minutes (typical for some ecosites), and 200 minutes (extrapolation). Average time to completion of EMCLA plots was 81 minutes which is close to the total time spent for the four ABMI plots at a site. In the first 20 minutes of the survey, average percent of species detected ranged from a low of 42% for Lab Tea (PM), Rich Fen (RD), and Poor Fen (MD) ecosites to a high of 71% average detection of species in Bearberry (PX). By 60 minutes detections increased to a low of 66% in Poor Fen (MD) to a high of 85% in Wild Rye (MX). Figure 3 illustrates that some ecosites are predicted to continue to increase in species even after 200 minutes of survey effort.

Rare species detection rates for EMCLA plots were presented in Table 3 using two time intervals: species recorded in the first 20 minutes and species recorded after the first 20 minutes of the survey. Rare species detected after 20 minutes (9.26% of plant observations) was ~58% higher than that of the first 20 minutes of the survey (5.85% of plant observations; Table 3). This demonstrates that an increase in survey effort (time) within a fixed area improves detection rates of rare species.

4.2 Comparing EMCLA and ABMI methods

EMCLA plots surveyed in 2012 represented about 45% of the total area and nearly twice the total survey time of ABMI plots surveyed within the Lower Athabasca over a 5-year period (Table 4). Despite representing less than half the total area of ABMI plots, EMCLA surveys detected 11% more species (405 vs. 365 species) and 46% more rare species than ABMI surveys (73 vs. 50 species). EMCLA plots had a higher rate of rare species detections per hectare (1.95 species/ha vs. 0.6 species/ha), but a lower rate of rare species detection per hour (Table 4). Of the twenty five rare species selected by the EMCLA as targets, the ABMI plots detected four species while the EMCLA plots detected eleven (Table 4).

Species richness predicted using the EMCLA time unlimited method (quarter hectare) was higher in every ecosite than richness predicted using a conventional 20 minute, quarter hectare ABMI survey (Figure 5). Surveying an entire hectare (20 minutes per quarter hectare quadrant for a total of 80 minutes) by ABMI (Table 6) yielded similar results to time unlimited surveys of quarter hectare EMCLA plots (Table 7) for most ecosites, although this did not standardize for habitat diversity since a 1 hectare plot with ABMI is more likely to contain more habitats (we assigned a single dominant ecosite to a ABMI hectare plot). Differences between predicted species richness among the ABMI hectare (Table 6) and the EMCLA quarter hectare time unlimited survey (Table 7) were found in the Fern (more species detected using ABMI hectare method) and Horsetail ecosites (more species detected using EMCLA quarter hectare time unlimited method). However, these results should be viewed with caution since only one site of each of these two ecosites was surveyed using the ABMI hectare method. Predicted species richness using an EMCLA 20 minute cut-off was similar in all ecosites to richness predicted in ABMI surveys with the same time (20 minutes) and area (quarter hectare) constraints.

The probability of detecting a rare species follows a similar pattern to that observed for species richness, with increasing time or area resulting in more rare species detected or a greater probability of detecting a rare species (Tables 6 and 7; Figure 6). The probability of detecting rare species was substantially higher in 4 ecosites (Lab Tea, Bearberry, Poor Fen and Wild Rye) using the EMCLA 20 minute quarter hectare survey than the ABMI quarter hectare survey.

Despite a smaller survey area, the number of rare species predicted for an EMCLA quarter hectare time unlimited survey was equal to or higher than that using an ABMI survey across a hectare for all ecosites (Tables 6 and 7; Figure 7). EMCLA 20 minute surveys were similar, however, to ABMI quarter hectare surveys in almost every ecosite. In many ecosites, surveys using the EMCLA 20 minute cut-off yielded a similar number of rare species as an 80 minute full hectare ABMI plot.

In EMCLA time unlimited surveys, we found that Rich Fen, Horsetail, Poor Fen, and Fern ecosites had the highest number of rare species. These four ecosites also had the longest average length (time) of survey (Table 7) suggesting that spending more time at these sites (> 80 minutes) increased detections of rare species. Notably, the 80 minute length of survey for these ecosites is the same as the total length of time spent surveying a one hectare ABMI site. Targeting these ecosites in ABMI plots using a time unlimited design may be an effective way of detecting more rare species for those sites in which the species may be more likely.

For all 150 plots together, there was a strong relationship (Pearson correlation, $R^2 = 0.62$, p value < 0.0001) between total number of species detected and total survey time (Figure 8). This relationship was stronger than the relationship (R^2 =0.40, p value < 0.0001) between number of rare species detected and total survey time (Figure 9). While a positive relationship between survey time and species detected is evident for most ecosites, weak negative relationship was apparent for Buffaloberry (MM; $R^2 = -0.28$, p value = 0.1129) and Bearberry (PX; $R^2 = -0.39$, p value = 0.6124) ecosites whereby more time surveying a plot was associated with fewer detections of rare species. This trend may help explain why these two ecosites are the only ecosites where the EMCLA time unlimited method does not result in a higher number of rare species than an ABMI full hectare method.

The time spent surveying and the area surveyed strongly affected the total number of species detected, the number of rare species detected, and the probability of detecting a rare species. When area and time are held constant by comparing the ABMI quarter hectare plot to the first 20 minutes of an EMCLA quarter hectare plot, the EMCLA plot will allow more rare species to be detected. It is important to note that although time spent surveying and total possible area surveyed can in theory be held constant by comparing the ABMI quarter hectare method and the EMCLA 20 minute cut-off method, the actual area surveyed using the two methods may be very different due to the nature of the ABMI and EMCLA search patterns. Whereas the ABMI survey always involves a 20 minute ‘long broad’ search of the entire quarter hectare, the first 20 minutes of an EMCLA survey have no area constraints, and is often spent surveying a much smaller area. Although the comparison between these two methods is imperfect in this way, it is still beneficial to compare these two methods as they have a consistent time and area constraint.

Several key differences between EMCLA and ABMI protocols could have contributed to the higher number of rare species detected in the EMCLA. First, plots were selected using habitat models designed to identify potential habitat for 25 target rare species (Table 5), whereas ABMI plots were systematically selected. Second, EMCLA technicians had specialized training in identifying rare plant species. And finally, due to the time unlimited nature of EMCLA surveys, technicians were able to target and more thoroughly survey areas of high diversity within each plot. How these differences in survey methodology may have affected the detection of rare plant species remains to be determined. Further research is needed to elucidate the effects of such variations in survey methodology and rare species detection.

5. Future Work – 2013

Field work in 2013 will focus on three key components and questions: (1) protocols around cost-effectiveness of EMCLA and ABMI methods; (2) model-based sampling to improve our understanding of landscape patterns in rare vascular plants; and (3) better understanding diversity-rarity relationships for vascular plants in the Lower Athabasca region.

For better understanding of protocols and to more formally test differences among ABMI and EMCLA protocols, we plan to use EMCLA methods to survey ~20 ABMI sites during the same visit to the site with ABMI crews. We will complete one EMCLA plot over the NE quadrant (quarter hectare) of the ABMI plots. We also plan to add 20 minute ABMI-style surveys for 50% of EMCLA plots established in 2013 by switching observers between the "A" and "B" plots. Based on 2012 data and that collected in 2013, we plan to make a recommendation to ABMI about the efficacy of augmenting their vascular plant surveys with an EMCLA-style rare plant survey for perhaps one ABMI quadrant.

Our second objective for 2013 is to boost sample sizes for target habitats (uplands and fens) and model representations to improve species habitat modeling and development of constraint maps that indicate how likely rare species will be present within different sites.

And finally, our third objective for 2013 is to assess general patterns of diversity and rarity among habitats (ecosites and land cover classes). This will involve further analyses of species accumulation curves by habitat.

6. References

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Tables

Table 1. Summary of species records encountered by ecosite for the 150 EMCLA plots established in 2012 in the Lower Athabasca region of Alberta.

Ecosite	*Number of Plots*	Number of Species						
		S1	**S2**	**S3**	**S4**	**S5**	***Total***	***Mean±SD***
Buffaloberry (MM)	33	1	0	26	34	168	254	50±12
Lab Tea (PM)	30	2	2	30	35	151	231	41±20
Peat Moss (PD)	12	0	1	19	25	84	131	28±15
Bearberry (PX)	5	0	0	3	7	52	65	26±6
Rich Fen (RD)	31	1	0	42	57	174	276	41±20
Poor Fen (MD)	19	0	0	20	20	88	193	37±23
Horsetail (MG)	9	1	1	20	30	149	210	65±24
Wild Rye (MX)	6	0	0	5	5	64	77	38±6
Fern (RG)	5	0	0	16	23	103	147	54±20
All sampled ecosites	150	2	6	65	67	239	405	43±20

NOTE: S1: Critically Imperiled; S2: Imperiled; S3: Vulnerable; S4: Apparently Secure; S5: Secure. See the details in the Appendix III.

Table 2. Estimated values of species richness based on survey duration.

Ecosite	*t* = 20 min	*t* = 60 min	*t* = 200 min
Buffaloberry (MM)	48 (62%)	64 (82%)	78 (100%)
Lab Tea (PM)	31 (42%)	58 (79%)	73 (100%)
Peat Moss (PD)	23 (44%)	37 (71%)	52 (100%)
Bearberry (PX)	27 (71%)	31 (82%)	38 (100%)
Rich Fen (RD)	30 (42%)	50 (70%)	71 (100%)
Poor Fen (MD)	27 (42%)	42 (66%)	64 (100%)
Horsetail (MG)	43 (48%)	69 (78%)	89 (100%)
Wild Rye (MX)	26 (65%)	34 (85%)	40 (100%)
Fern (RG)	33 (52%)	52 (83%)	63 (100%)
Average (%)	52%	77%	100%

Table 3. Total species and number of rare species surveyed in EMCLA plots using two time intervals (20 minute cut-off and post-20 minutes).

Survey Time	Total species observations	Rare species observations	Rate of rarity (%)
≤ 20 minutes	3,968	232	5.85
> 20 minutes	2,440	226	9.26

Table 4. General summary of ABMI and EMCLA surveys for the Lower Athabasca.

Variables	ABMI	EMCLA
Years of survey	2007-2011	2012
Number of sites	83	75
Number of technicians	18	8
Number of quarter hectare plots	332	150
Area surveyed (hectares)	83	37.5
Total survey time (hours)	110.6	202.4
Time (min) per quarter hectare plot	20	81 (mean)
No. of species detected	365	405
No. of rare species detected	50	73
Rare species/hour	0.45	0.36
Rare species/hectare	0.60	1.95

Table 5. Detection by the ABMI and the EMCLA surveys in the Lower Athabasca of 25 target species.

EMCLA Target Species		ABMI	EMCLA
Scientific Name	Common Name		
Artemisia tilesii spp. elatior	Herriot's sagewort		
Cardamine pratensis	Cuckoo-flower		
Carex backii	Back's Sedge		✓
Carex capitata	Capitate Sedge		✓
Carex heleonastes	Hudson Bay Sedge		
Carex houghtoniana	Houghton's Sedge	✓	✓
Carex oligosperma	Few-seed Sedge		
Carex retrorsa	Retrorse Sedge	✓	✓
Carex supina	Weak Arctic Sedge		
Carex umbellata	Hidden Sedge		✓
Chrysosplenium iowense	Iowa Golden-saxifrage		✓
Chrysosplenium tetrandrum	Northern Golden-carpet		✓
Cypripedium acaule	Pink Lady's-slipper	✓	
Drosera linearis	Slenderleaf Sundew		✓
Eupatorium maculatum	Spotted Joe-pyeweed		
Hypericum majus	Larger Canadian St. John's-wort		✓
Juncus brevicaudatus	Narrow-panicle Rush		✓
Lycopodiella inundata	Bog Clubmoss		
Malaxis paludosa	Bog Adder's-mouth Orchid		
Panicum acuminatum	Tapered Rosette Grass		
Potentilla multifida	Divided Cinquefoil		
Sarracenia purpurea	Northern Pitcherplant	✓	✓
Spiranthes lacera	Northern Slender Ladies'-tresses		
Stellaria arenicola	Lake Athabasca Starwort		
Tanacetum bipinnatum ssp. huronense	Lake Huron Tansy		

Table 6. Predicted species richness ($\hat{S}$), predicted rare species ($\hat{S}_{rare}$), and probability of finding rare species in nine ecosites for two ABMI survey methods where survey area and time varies. *N* indicates the number of quarter hectare or hectare plots of each ecosite.

	ABMI Hectare (80 Minutes)							**ABMI Quarter Hectare (20 Minutes)**						
				Probability of rare species							Probability of rare species			
Ecosite	*N*	$\hat{S}$	$\hat{S}_{rare}$	All	S1	S2	S3	*N*	$\hat{S}$	$\hat{S}_{rare}$	All	S1	S2	S3
Buffaloberry (MM)	18	48.8	1.8	0.89	0.06	0.00	0.89	83	32.4	0.7	0.52	0.05	0.00	0.52
Lab Tea (PM)	20	37.3	2.7	0.80	0.15	0.00	0.80	71	24.1	1.1	0.56	0.00	0.01	0.56
Peat Moss (PD)	13	26.2	1.6	0.92	0.00	0.08	0.92	61	18.9	1.2	0.76	0.06	0.00	0.76
Bearberry (PX)	13	37.5	2.2	1.00	0.15	0.00	0.92	37	22.0	1.4	0.75	0.25	0.00	0.62
Rich Fen (RD)	8	39.8	1.9	0.75	0.00	0.13	0.75	32	22.6	1.3	0.89	0.00	0.00	0.89
Poor Fen (MD)	6	23.5	2.2	1.00	0.00	0.00	1.00	27	20.1	0.9	0.57	0.00	0.00	0.57
Horsetail (MG)	1	21.0	0.0	0.00	0.00	0.00	0.00	14	37.0	2.0	0.75	0.25	0.00	0.75
Wild Rye (MX)	3	46.0	2.0	0.67	0.33	0.33	0.67	7	34.5	0.5	0.50	0.00	0.00	0.50
Fern (RG)	1	70.0	2.0	1.00	0.00	0.00	1.00	0	---	---	---	---	---	---

Table 7. Predicted species richness ($\hat{S}$), predicted rare species ($\hat{S}_{rare}$) and probability of finding rare species in nine ecosites for each of two EMCLA survey methods where survey time (minutes) varies. *N* indicates the number of quarter hectare plots by each ecosite.

	EMCLA Quarter Hectare (Time Unlimited)								**EMCLA Quarter Hectare (20 Minute Cut-off)**						
					Probability of rare species							Probability of rare species			
Ecosite	*N*	Mean Time	$\hat{S}$	$\hat{S}_{rare}$	All	S1	S2	S3	*N*	$\hat{S}$	$\hat{S}_{rare}$	All	S1	S2	S3
Buffaloberry (MM)	33	79	50.1	1.8	0.82	0.03	0.00	0.82	33	34.2	0.7	0.52	0.00	0.00	0.52
Lab Tea (PM)	29	79	41.3	3.0	0.86	0.07	0.10	0.86	29	24.9	1.6	0.72	0.07	0.03	0.72
Peat Moss (PD)	13	67	28.4	2.5	0.85	0.00	0.15	0.85	13	19.5	1.2	0.69	0.00	0.00	0.69
Bearberry (PX)	4	49	26.5	2.3	1.00	0.00	0.00	1.00	4	21.8	2.0	1.00	0.00	0.00	1.00
Rich Fen (RD)	30	91	41.1	4.0	0.93	0.03	0.00	0.90	30	22.6	2.1	0.73	0.00	0.00	0.73
Poor Fen (MD)	21	89	36.7	3.9	1.00	0.00	0.05	1.00	21	21.7	2.0	0.81	0.00	0.00	0.81
Horsetail (MG)	9	86	64.8	3.6	1.00	0.11	0.11	1.00	9	34.1	1.3	0.67	0.00	0.00	0.67
Wild Rye (MX)	6	64	37.7	2.2	1.00	0.00	0.00	1.00	6	29.3	1.7	1.00	0.00	0.00	1.00
Fern (RG)	5	82	53.8	5.0	1.00	0.00	0.00	1.00	5	32.0	2.6	0.80	0.00	0.00	0.80

Figures

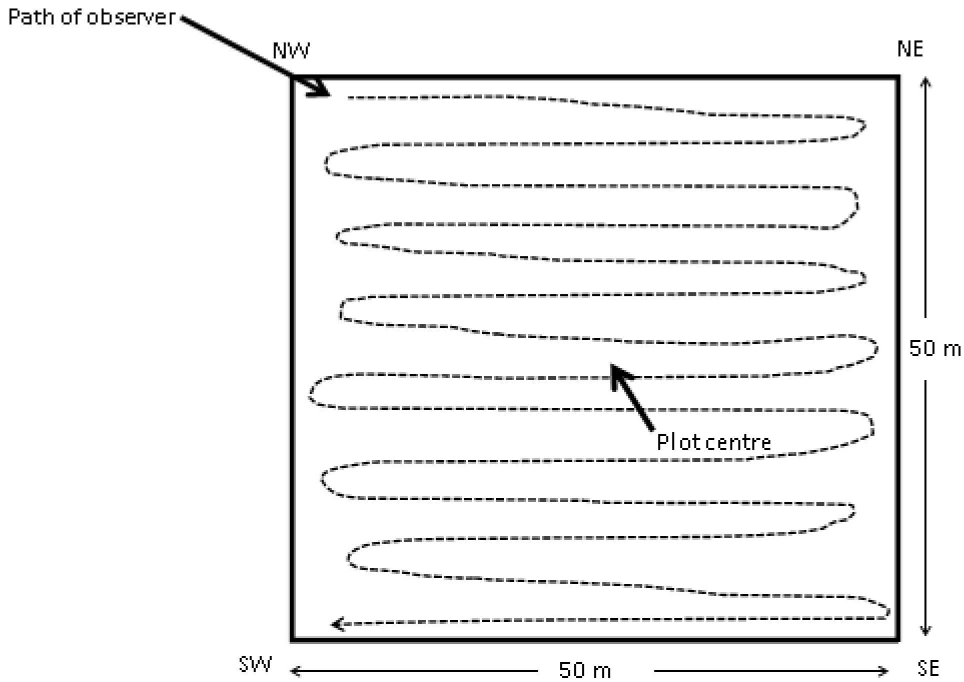

Figure 1. Quasi-parallel (50 m × 2 m) belt transect survey to be conducted by the observer within each 0.25 ha EMCLA plot.

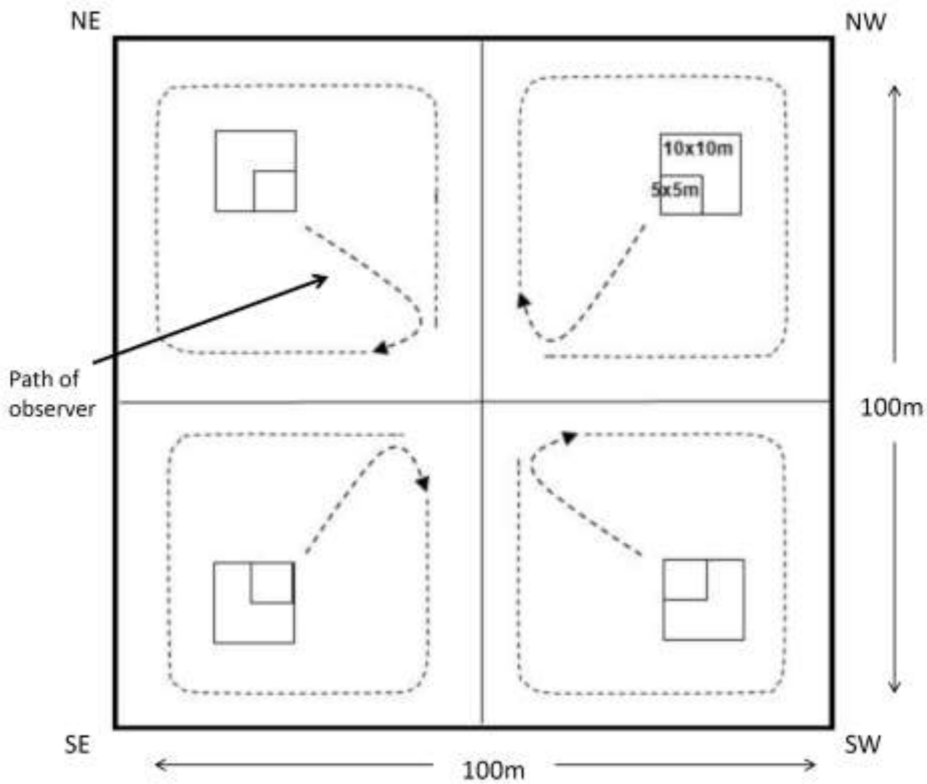

Figure 2. Path of transect survey to be conducted by the observer within each 0.25 ha ABMI quadrant (plot).

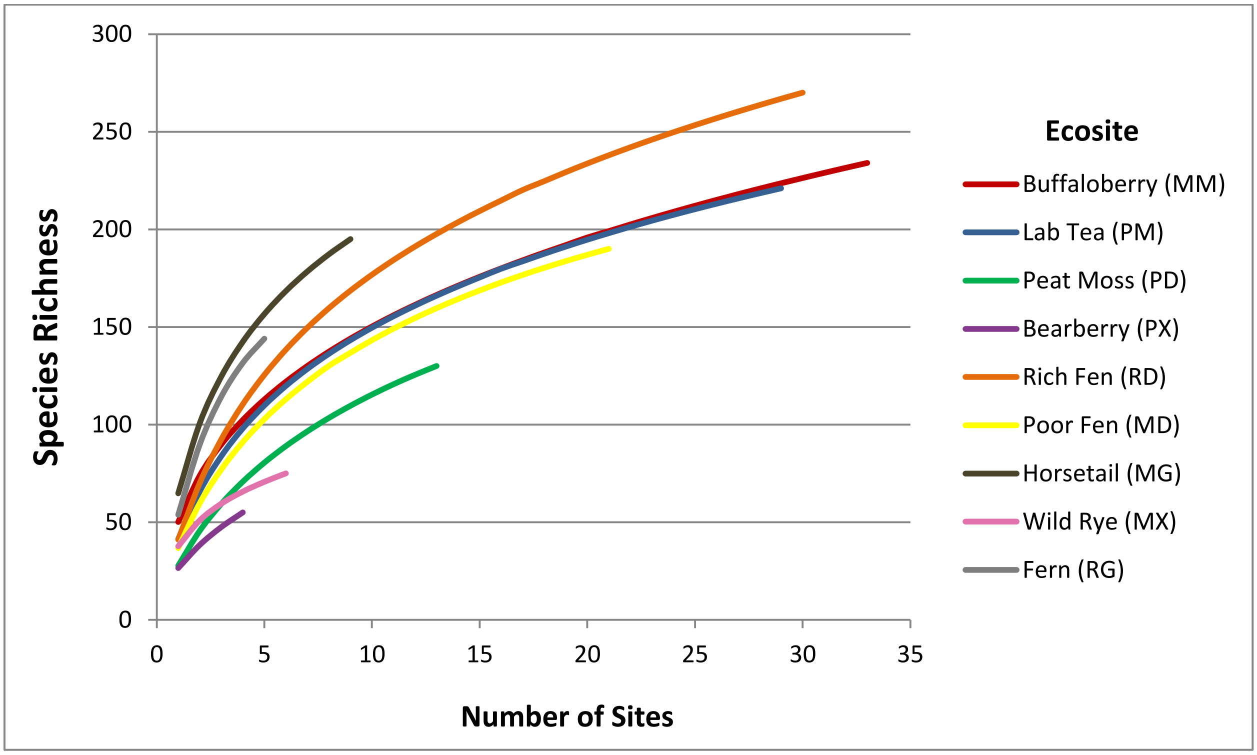

Figure 3. Species incidence-based rarefaction curves by ecosite.

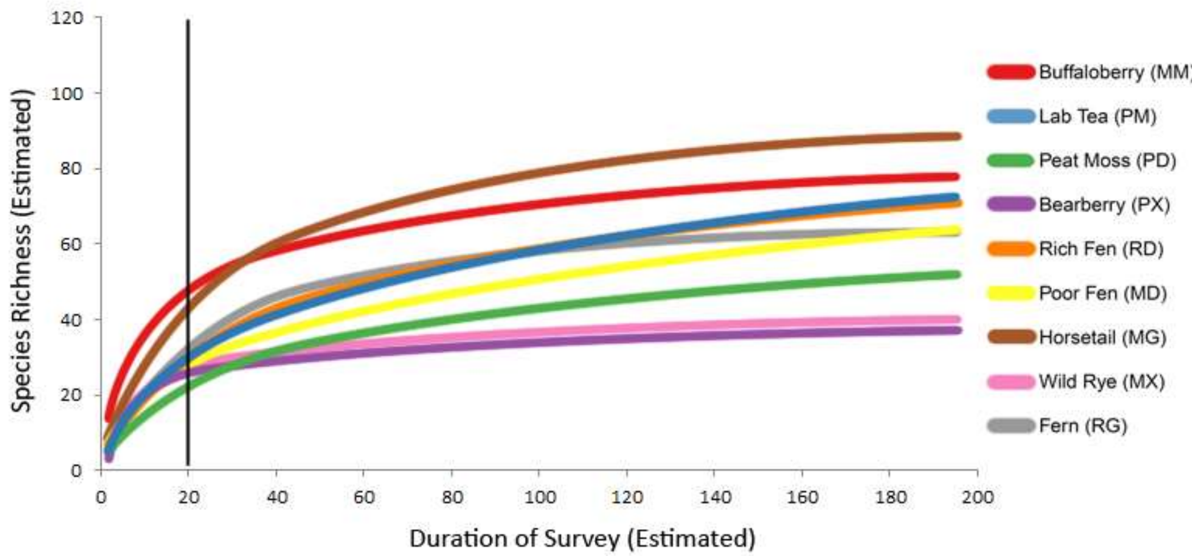

Figure 4. Species incidence-based rarefaction curves per survey duration by ecosite.

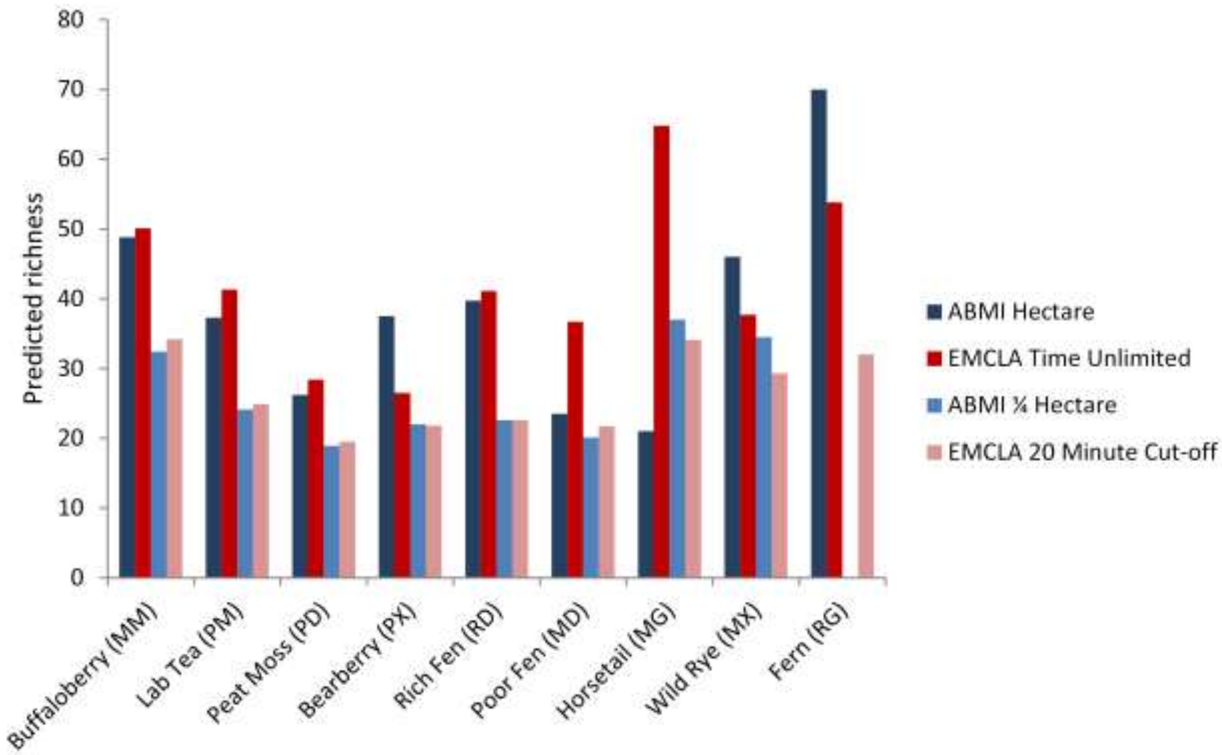

Figure 5. Predicted species richness detected in nine ecosites for each of four survey methods varying in survey area and time.

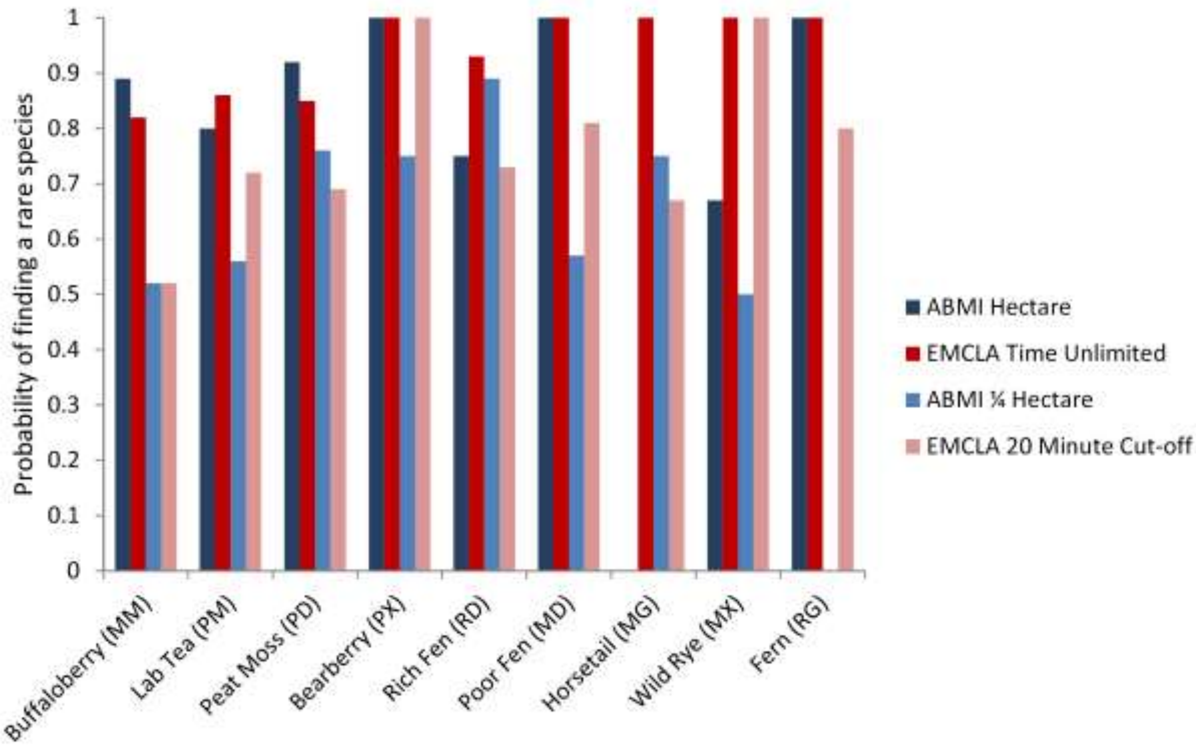

Figure 6. Probability of detecting a rare species (S1-S3) in nine ecosites for each of four survey methods varying in survey area and time.

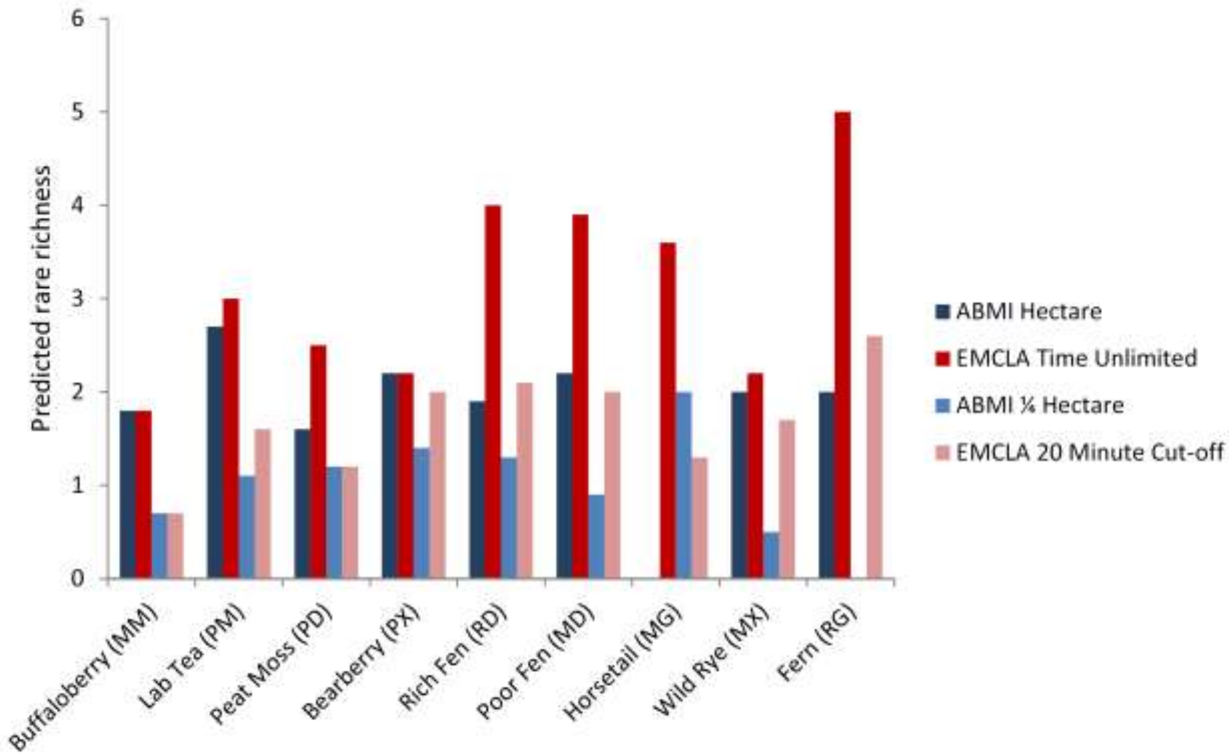

Figure 7. Predicted rare species (S1-S3) richness detected in nine ecosites for each of four survey methods varying in survey area and time.

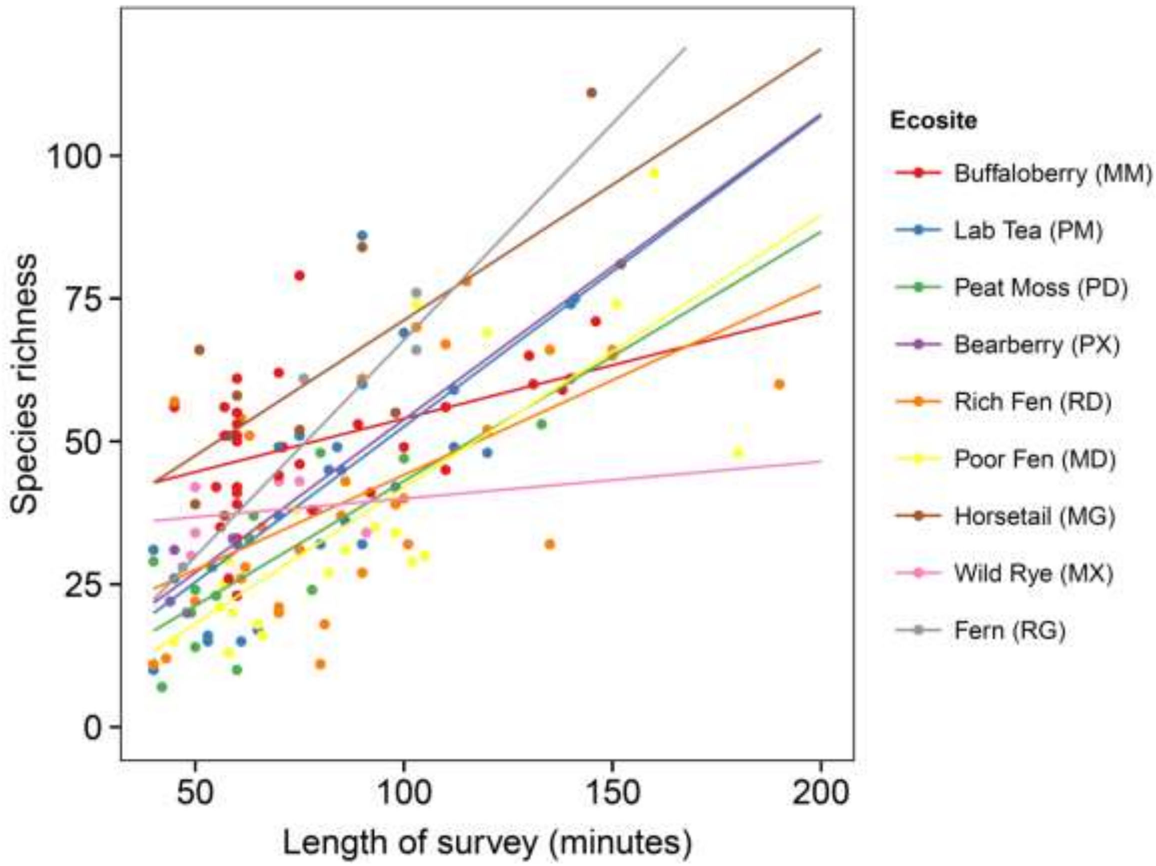

Figure 8. Relationship between length of survey (minutes) and species richness detected using the EMCLA time unlimited method for nine ecosites.

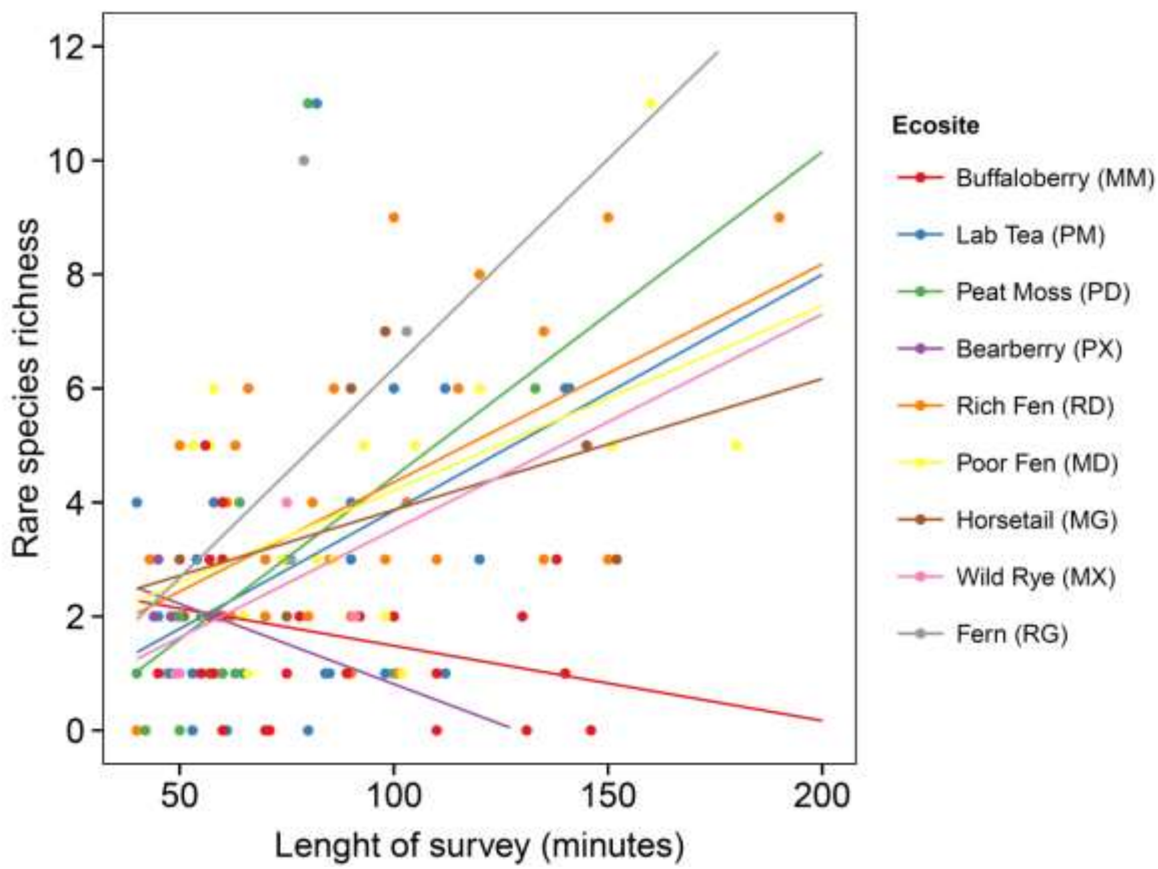

Figure 9. Relationship between length of survey (minutes) and rare species richness detected using the EMCLA time unlimited method for nine ecosites.

Appendix I

Ecosite categories used to define physical characteristics of each plot using a simplified forest classification system used by the ABMI.

Dominant Shrub/Herb/Ground Cover	Nutr./ Moist. Code [1]	Tree Species Modifier	Tree Species Composition [2] (In an area without human disturbance)	Structural Stage [3]
Upland Vegetation Communities				
Bearberry/Lichen Bog Cranberry common at some sites	1 - **PX**	1a **Pine**	Pj + Fd > 80%	<u>**A. Tree Dominated Ecosites**</u> *(Trees ≥10% cover)* – Add 4-letter code combining tree height, density, and arrangement. <u>Tree Height</u> **(TS) Short** – ≥50% of canopy cover <10 m tall. **(TT) Tall** – >50% of canopy cover ≥10 m tall. <u>Tree Density</u> **(D) Dense** – Trees ≥1.3 m tall are ≤2 m apart. **(S) Sparse** – Trees ≥1.3 m tall are >2 m apart. <u>Tree Arrangement</u> **(C) Complex (Spatially)** – Tallest trees ≥10 m apart, with smaller trees (~ ½ height) between that receive direct sunlight from above. **(N) Non-complex (Spatially)** – Tallest trees <10 m apart, with few or no smaller trees (~ ½ height) between, that receive direct light from above. <u>**B. Non-Tree Dominated Ecosites**</u> *(Trees <10% cover)* **Non-Vegetated** *(<10% Vegetation Cover)* – Add 2-letter code describing dominant substrate type. **(NR) –** Bedrock, cliff, talus, bolder **(NS) –** Sand bar in river/stream (cobble, gravel, sand) **(NB)** – Beach at edge of a lake or wetland **(NM) –** Mineral soil any other reason **(NO) –** Organic soil any other reason **Note:** If standing water is present, refer to Open Water Communities **Only Ground Vegetation Present** *(Shrubs <10%; Trees <10%; Other Vasc. >10%)* – Add 3-letter code combining dominant vegetation type and density <u>Vegetation Type</u> **(GB) Bryoid/Lichen** – Bryophyte and lichen **(GF) Forb** – Non-graminoid herbs and ferns **(GG) Graminoid** – grasses, sedges **(GR) Marsh** – reeds, and rushes <u>Vegetation Density</u> **(D) Dense** – Cover >75% **(M) Moderate** – Cover 25-75% **(S) Sparse** – Cover <25% **Shrubs Present** *(Shrubs >10%; Trees <10%)* – Add 3 letter code combining shrub height and density. <u>Shrub Height</u>
Labrador Tea / Feather Moss Bog Cranberry, Bilberry, Grouse-berry common at some sites	2 - **PM**	2a **Pine**	Pj + Pl > 50%	
		2b **Other**	Aw + Sw + Se +Fa +Pw > 50%	
		2c **Sb**	Sb > 50%	
Hairy Wild Rye Bearberry, Canada Buffalo-berry, Feather Moss common at some sites	3 - **MX**	3a **None**	No Trees	
		3b **Pine**	Pj + Pl > 50%	
		3c **AwMix**	Aw > 20%	
		3d **Spruce**	Sw + Se + La >50%	
Low-bush Cranberry / Canada Buffalo-berry Blueberry, Rose, Alder, Labrador Tea, Bearberry, Thimbleberry, Bog Cranberry, Feather Moss common at some sites	4 -**MM**	4a **Pine**	Pj + Pl + Fa >50%	
		4b **PjMix**	Aw + Bp + Sw >20%, AND Pj >20%	
		4c **Aw**	Aw > 50%	
		4d **AwMix**	Aw >20% AND Sw + Sb + Pl > 20%	
		4e **Spruce**	Sw > 50%	
Horsetail Dogwood, Rose, Willow, Feather Moss common at some sites	5 - **MG**	5a **Poplar**	Pb + Aw > 50%	
		5b **Spruce**	Sw + Se > 50%	
		5c **Sb**	Sb > 50%	
Dogwood / Fern / Feather Moss Rose, Alder, Bracted Honeysuckle, Devil"s Club Fir common at some sites	6 - **RG**	6a **Pine**	Pl > 50%	
		6b **Poplar**	Pb + Aw > 50%	
		6c **Spruce**	Sw + Se + Fa > 50%	
Not Treed	7 - **NT**	7a **Alpine**	Elevation above tree line	
		7b **Flood**	Site disturbed frequently by flooding	
		7c **Ice**	Site disturbed frequently by ice or snow	
		7d Dry	Site in prairies/parkland and receives little precipitation	
		7e **Geo**	Geological features not suitable for tree growth	
		7f **Human**[4]	Site disturbed recently by humans	

Aw - trembling aspen, Sw - white spruce, Pb - balsam poplar, Sb - black spruce, Bp - paper birch, Se - Engelmann spruce, Pl - lodgepole pine, Fa - subalpine fir, Pj - jack pine, Fd - Douglas fir, Pw – white pine, Fb - balsam fir, and Lt - larch	**(SL) Low** – Shrubby vegetation <2 m tall **(ST) Tall** – Shrubby vegetation >2 m tall Shrub Density **(D) Dense** – Shrubs cover >75% **(M) Moderate** – Shrubs cover 25-75% **(S) Sparse** – Shrubs cover <25%

Dominant Shrub/Herb/Ground Cover	**Nutr./ Moist. Code** [1]	**Tree Species Modifier**	**Tree Species Composition** [2] (In an area without human disturbance)	**Structural Stage** [3]
Lowland/Wetland Vegetation Communities				
Bog - Labrador Tea / Peat Moss / Lichen Bog cranberry and cloudberry may also be present (Soil saturated for part or all the year)	**8 - PD**	**8a SbLt**	≥10% tree cover (may only be in shrub/ground strata) Sb + Lt > 50%	**C. Open Water Dominated Communities** *(Emergent Vegetation <10%)* – Add 4-letter code combining dominant vegetation type, height and density Vegetation Type **(OV) Vegetated** – Floating or submerged plants ≥ 10% cover **(ON) Non-Vegetated** – Floating or submerged plants < 10% cover (note that only a 2-letter code is used for this category → vegetation height and density are not added to the code) Vegetation Height **(S) Short Submerged** – ≥50% of vegetation extending 0.0 – <0.3 m above the substrate **(M) Medium Submerged** – ≥50% of vegetation extending 0.3 – 1.3 m above the substrate **(T) Tall Submerged** – ≥50% of vegetation extending >1.3 m above the substrate **(F) Floating** – ≥50% of vegetation with floating leaves on the water surface. Vegetation Density **(D) Dense** – Aquatic vegetation covering >75% of the substrate. **(M) Moderate** – Aquatic vegetation covering 25-75% of the substrate. **(S) Sparse** – Aquatic vegetation covering <25% of the substrate.
		8b Shrub	<10% tree cover	
Poor Fen - Labrador Tea / Peat Moss / Sedge Bog cranberry, dwarf birch and river alder may also be present (Soil saturated for part or all the year)	**9 - MD**	**9a SbLt**	≥10% tree cover (may only be in shrub/ground strata) Sb + Lt > 50%	
		9b Shrub	<10% tree cover	
Rich Fen - Dwarf Birch / Willow / Sedge / Grass / Moss (Soil saturated for part or all the year; includes floating mats of vegetation)	**10-RD**	**10a SbLt**	≥10% tree cover (may only be in shrub/ground strata) Sb + Lt ≥ 50%	
		10b Shrub	<10% tree cover AND ≥10% shrub cover	
		10c None	<10% tree cover AND <10% shrub cover	
Swamp Conductivity <15 mS/cm, trees and shrubs present, (Water is above the rooting zone for some of the year)	**11-SD**	**11a Tree**	>10% tree cover	
		11b Shrub	<10% tree cover	
Marsh – Cattail / Rush /Reed Conductivity <15 mS/cm, sedge and grass may also be present (Water is above the rooting zone for most or all of the year)	**12-VD**	**12a None**	usually along a water body edge ≥10% emergent vegetation cover <10% tree cover	
Alkali Conductivity >15 mS/cm, white salt flats at water"s edge, saltwater widgeon grass dominates (Water is above the rooting zone for most or all of the year)	**13-AD**	**13a None**	<10% shrub/tree cover	
Open Water	**14-OW**	**14a Lake**	In standing water <10% emergent vegetation cover	
		14b River	In flowing water <10% emergent vegetation cover	

Appendix II

Categories of disturbances (human and natural) and their definitions used to characterize EMCLA plots.

Categories of human disturbance	
HARV	Any type of forest harvesting (i.e., clear-cut, partial-cut, understory retention, etc.) <30 years old)
PIPE	Pipeline
POWER	Power line
SEIS	Any type of cutline or seismic line
RAIL	Railway
WELL	Any type of area cleared for oil/gas/coal-bed-methane including pump jacks or well heads
ROADP	Any type of road with paved surface
ROADG	Any type of road with gravel surface
TRAIL	Any type of truck or ATV trail with an unimproved surface
CULT	Any type of cultivated field that is used to grow agriculture crops including forage
PAST	Any type of uncultivated pasture (tame or native) with grazing
RES	Any type of residential dwelling, farm building, or farm yard in a rural or acreage setting
URB	Any type of human dwelling, associated building, or yard/driveway/road in an urban setting
IND	Any type of building, roadway, yard, etc. associated with industrial development
BARE	Human caused bare ground for which the cause cannot be determined
OTHER	

Categories of natural disturbance	
Fire	Any evidence of scarring or burning (may be human caused); may coincide with salvage-harvesting
Wind	Evidence of wind throw
Erosion	Evidence of soil removal by precipitation or wind; potentially human induced
Flooding	Evidence of high water mark, dead trees, etc.; potentially human induced;
Snow/Ice	Evidence of vegetation breakage caused by snow or ice
Insect	Any evidence of vegetation experiencing insect damage
Disease	Any evidence of vegetation experiencing disease outbreak
Beaver	Any evidence of beaver activity altering landscape or vegetation
Other	

Appendix III

ACIMS Variant Subnational Conservation Status Ranks

Rank	Definition
S1	Known from five or fewer occurrences or especially vulnerable to extirpation because of other factor(s).
S2	Known from twenty or fewer occurrences or vulnerable to extirpation because of other factors.
S3	Known from 100 or fewer occurrences, or somewhat vulnerable due to other factors, such as restricted range, relatively small population sizes, or other factors.
S4	• Apparently secure. • Taxon is uncommon but not rare. • Potentially some cause for long term concern due to declines or other factors.
S5	Secure - taxon is common, widespread, and abundant.
SX	• Taxon is believed to be extirpated from the province. • Not located despite intensive searches of historical sites and other appropriate habitat. • Virtually no likelihood that it will be rediscovered.
SH	• Known from only historical records but still some hope of rediscovery. • Evidence that the taxon may no longer be present but not enough to state this with certainty.
SU	Taxon is currently unrankable due to lack of information or substantially conflicting information. Example - native versus non-native status not resolved.
SNR	• Not ranked • Conservation status not yet assessed.
SNA	• Not applicable. • A conservation status rank is not applicable because the species or ecosystem is not a suitable target for conservation activities. Example - introduced species.