FIELD PROTOCOL FOR ASSESSING CHARACTERISTIC SPECIES THRESHOLDS IN POLYGONS ON RECLAMATION AREAS

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ABSTRACT

The *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* 2nd Edition defines criteria and indicators to measure reclamation success. To compare community composition of reclaimed areas with that of target communities a threshold number of characteristic species typical of the target community was developed for five site types. CEMA funded a study to assess characteristic species thresholds on reclamation areas with three objectives: 1) develop a field protocol for assessing characteristic species thresholds; 2) collect species composition and distribution data; and 3) assess the utility of characteristic species thresholds as an indicator of reclamation success. The study sampled 98 plot locations within 16 reclaimed polygons within two oil sands operations north of Fort McMurray, Alberta. The study showed that a minimum of 4 plots should be established within polygons ≤ 6 ha and a plot number equivalent to the polygon area in hectares minus 2 for polygons between 6 and 13 ha. Six of the 16 polygons evaluated achieved the threshold number. The results suggest that reclamation polygons 15-19 years of age can have sufficient species composition to be evaluated using the methods outlined in the manual and can be considered to be successfully reclaimed with respect to this indicator.

KEY WORDS: oil sands, certification, communities, guidelines

INTRODUCTION

The *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (i.e., Revegetation Manual) (Alberta Environment 2010) defines criteria and indicators to measure reclamation success. Creating plant communities with compositions that are characteristic of the local boreal forest is listed as a primary indicator of successful reclamation. To compare community composition of reclaimed

areas with that of target communities prior to application for reclamation certification, a threshold number of characteristic species typical of the target community was developed for each of five site types (Dry, Moist Poor, Moist Rich, Wet Poor and Wet Rich). Targets for the five site types are further grouped into age classes—less than 20 years and greater than or equal to 20 years. A list of species characteristic of each site type was created and a threshold and mean number of characteristic species for each site type was also defined in the Revegetation Manual. The primary objectives of this project study were to:

- Develop a field protocol for assessing characteristic species thresholds in polygons on reclamation areas,
- Collect data on reclamation areas to understand species composition and distribution in time and space by site type, and
- Assess and provide comment on the utility of characteristic species thresholds as an indicator of reclamation success by testing the application of Table 5-3 of the Revegetation Manual.

Two oils sands operations, Syncrude and Suncor, located to the north of Fort McMurray in Alberta, provided sites for inclusion in this study.

METHODS

Polygon Stratification and Selection

Syncrude and Suncor provided spatial files and databases of reclaimed polygons. Key polygon attributes contained in these files included a site identifier, area (ha), reclaimed date, initial planting date and comments. Information on ecosite target, species planted, or secondary treatment was not available for all reclaimed areas. A summary of polygon distribution by age class was produced for each operation. Regeneration survey data collected by TECO (2010) were linked to each operations reclaimed dataset to assist with stratification. This database provided woody stem and species density (stems/ha) for a sub-set of 64 the polygons planted between 1990 and 2005. Since the data could only be applied to sites planted between 1990 and 1995 cover type was categorized as “unknown” for the majority of sites planted prior to 1990. Each record in this dataset was also assigned to a strata cover type (conifer; deciduous; mixed) and density class (high, moderate, low).

Key parameters considered in the final stratification of polygons for selection of field survey sites included cover type and age class. Two age categories were targeted for the final selection process: sites 15-19 years in age (< 20 years age; planted in 1991-95) and sites 20-25 years old (>20 years age; planted in 1986-90). These two age classes were considered for assessment because it would be useful to determine if reclamation treatments are successful in returning target plant communities characteristic of the locally common boreal forest within a timeframe that considers both ecological processes and management planning. A set of 16 target polygons was selected that distributed the available survey days and number of survey points across polygons within the three major cover types and two age classes ranging from about 1.7 to 13 ha in size.

Variables Sampled

Within each plot and subplot, all species were identified and percent cover was recorded by strata. At each plot, site data were collected to provide context for species composition and distribution, and to help characterize site type. Parameters that describe site and stand characteristics such as stand height, surface percent cover of decayed wood, mineral soil, litter/organic material, coarse fragments and water, percent slope, aspect and slope position were also recorded along with UTM coordinates and photographs. Field surveys were complete during August 2011.

Plot Size

Prior to the field survey design, species-area curves were created using existing species percent cover data on reclamation sites in the oil sands region from the Long-Term Plot Network Monitoring Program. Species richness was regressed against plot size, and the optimum plot size was determined by the point at which the curve levels off (i.e., asymptote). Based on the results of the species-area curves, three plot sizes were chosen to further test the optimum plot size to assess species composition (richness) and distribution. At each plot location two nested subplots (2.5 x 2.5 m and 5 x 5 m) within a 10 x 10 m plot (100 m^2) were established around the pre-determined plot center.

To analyze optimum plot size using data collected during this study, percent cover of species occurring in multiple vegetation strata were summed to give total percent cover for each species in each plot and subplot. Species percent cover was averaged for each of the plot sizes for each polygon. The data were summarized into site type (Dry, Moist Rich and Wet Rich) and one-tail, two sample t-tests were used to test average number of characteristic species present within each site type for each plot size (alpha = 0.05).

Sample Size and Intensity

The sampling design developed for this project included the provision for sampling some polygons at a minimum intensity level of 1 plot/ha and others sampled at higher intensity levels (up to 2.3 plots/ha). In general, sampling intensity decreased with an increase in polygon area.

A grid pattern was used for the determination of plot locations within each sampled polygon. The starting point for the grid was randomly chosen using a function in ArcGIS and the grid spacing was determined for each polygon using the following equation (TECO 2010):

$$D = \sqrt{10000\ x\ \frac{A}{n}}$$ *; where* D = interval between grid points in metres, A = area of polygon in hectares, and n = number of plots to be established within a polygon

A uniform grid of points, based on the spacing, was then constructed in ArcGIS and overlaid onto each polygon. If too few points fell within the polygon to meet the minimum sample size, the grid was rotated until the minimum number was met.

Testing Optimum Sampling Intensity

A method was designed to test the optimum number of plots that might be used to measure the average characteristic species. Characteristic species were tallied from each plot within the polygon by target site

type. Plots within each polygon were then ranked from lowest to highest number of observed characteristic species and the min (low) and max (high), mean values and variance of these mean values were calculated by sample size (n). An example of the calculations for Polygon SUN186 evaluated for the Moist Rich site type is provided in Table 1. These variance values were then calculated by sample size from all field data and plotted for comparison. Trendlines were added to scatter plot graphics in Microsoft Excel based on polynomial regression. This trendline type was selected because it had the highest r^2 values (better line fit) compared to other trendline options available.

Table 1: Example Calculation of Mean Characteristic Species Variance for Polygon SUN186

Plot	Number of Characteristic Species Observed	Sample Size (n)	Mean Characteristic Species		
			Low	High	Variance
SUN186C	3	1	3.0	8.0	12.5
SUN186E	3	2	3.0	7.0	8.0
SUN186A	6	3	4.0	6.7	3.6
SUN186D	6	4	4.5	5.8	0.8
SUN186B	8	5	5.2	5.2	0

Species Composition and Distribution

All species observed during field sampling were recorded and tabulated with species percent cover observations. For each plot within a polygon and for each species observed in the 100 m^2 plot, species prominence was calculated using the following formula:

$$Species\ Prominence = \sqrt{Average\ of\ Species\ \%\ Cover\ x\ \frac{\#\ of\ Plots\ Species\ were\ Observed}{Total\ \#\ of\ Plots}}$$

Species prominence was summarized by cover type. Cover type of each polygon was assigned based on percent of overstory species. Polygons with greater than or equal to 80% of total canopy cover of conifer or deciduous species were classified as conifer or deciduous (respectively), polygons were classified as mixedwood when the canopy was composed of less than 80% cover of either conifer or deciduous species.

Site Type Determination and Variance

Site type was determined both in the field and the office for each 10 x 10 m plot area within each polygon surveyed. Site types in the field were based on field observation of plant species and site conditions while site type determination in the office was based solely on the methods provided in Appendix J of the Revegetation Manual. No soils data were collected as part of this project. The presence, absence and composition of plant species on each plot location provided important information about environmental and ecological conditions to indicate a possible moisture and nutrient regime (i.e., edatopic position) of each plot.

Plant species found in multiple strata were collapsed into a single observation for each plot. A subset of the data was created with only those species identified as "characteristic" in Tables 3-1 and 5-4 through 5-8 of the Revegetation Manual. For each ecosite a through h, characteristic species were identified and a count tallied for each 10 x 10 m plot area along with the percent of ecosite characteristic species and total species percent cover (as per Table J.1 of the Revegetation Manual). Because estimating ecosite based on species lists in Appendix J of the Revegetation Manual is largely a qualitative exercise due to a large number of plant species that overlap ecosites, an additional metric (prominence) was calculated to help determine which site type contains the most prominent characteristic species. Characteristic species prominence by ecosite was calculated for each plot. This prominence value was tested along with Appendix J site type results.

Characteristic Species Threshold

Characteristic species, as identified in the Revegetation Manual, were tallied (counted) for each plot by site type. For each polygon, the mean number of characteristic species was calculated by taking the average count from all plots surveyed within the polygon and reported as per the evaluation guidelines. Additional metrics, such as the range (minimum and maximum) and a total count of characteristic species by plot by site type for each polygon were also prepared.

The most frequent site type, as it was determined in the field, was used as the target ecosite for polygon evaluation. In the event two site types were identified as possibilities in the field and both were just as frequent as the other within the polygon, both were evaluated with respect to Table 5-3. Steps to evaluate characteristic species are identified in Section 5.3.4 of the Revegetation Manual. The first step is to evaluate polygon data versus the site type appropriate to target ecosite. If the minimum threshold value of the target site type is achieved (based on an average across the polygon), the assessed area is defined as successfully reclaimed, with respect to this indicator. If it is not met, the threshold is evaluated against another alternate site type and the polygon is reassigned to that site type designation. However, Section 5.3.4 of the Revegetation Manual does not impose any limits to the selection of alternate site types. It was assumed for this study that alternate site types are obtained from different nutrient classes (i.e., left and right on the edatope) and not different moisture classes (i.e., up and down on the edatope). Acceptable site type reassignments assumed for this study are presented in Table 2. If the reassigned site type threshold is achieved, then the polygon is defined as successfully reclaimed with respect to this indicator. If the alternate site type threshold is also not met, the polygon is considered to not meet the conditions for certification for this indicator.

Table 2: Acceptable Site Type Reassignments when Evaluating Characteristic Species

Site Type	Acceptable Site Type Reassignment
Dry	None
Moist Poor	Moist Rich
Moist Rich	Moist Poor
Wet Rich	Wet Poor
Wet Poor	Wet Rich

RESULTS AND DISCUSSION

Plot Size

A total of 294 plots and nested subplots (10 x 10 m; 5 x 5 m; 2.5 by 2.5 m) were sampled from 98 survey plot locations within 16 polygons in reclaimed areas on the two operations. Surveyed polygons ranged from 1.7 to 12.9 ha (5 ha average size). The greatest number of characteristic species was observed in the 10 x 10 m (100 m^2) plot area followed by the 5 x 5 m (25 m^2) and 2.5 x 2.5 (6 m^2) subplots. The number of characteristic species observed in the 25 and 100 m^2 plot areas did not significantly differ for the Dry site type; however, there were significantly more characteristic species observed in both the 25 and 100 m^2 plot areas (p = 0.032 and 0.001, respectively) compared to the 6.25 m^2 plot area. The same trend was observed for plots classified as Moist Rich sites, where significantly more characteristic species were observed in the 25 and 100 m^2 plot areas (p = 0.001 and <0.001, respectively), compared to that observed in the 6.25 m^2 plot area. Although there were more characteristic species observed in the 25 and 100 m^2 plot areas classified as Wet Rich site types, there was no significant difference between species richness of characteristic species for all plot sizes (Figure 1).

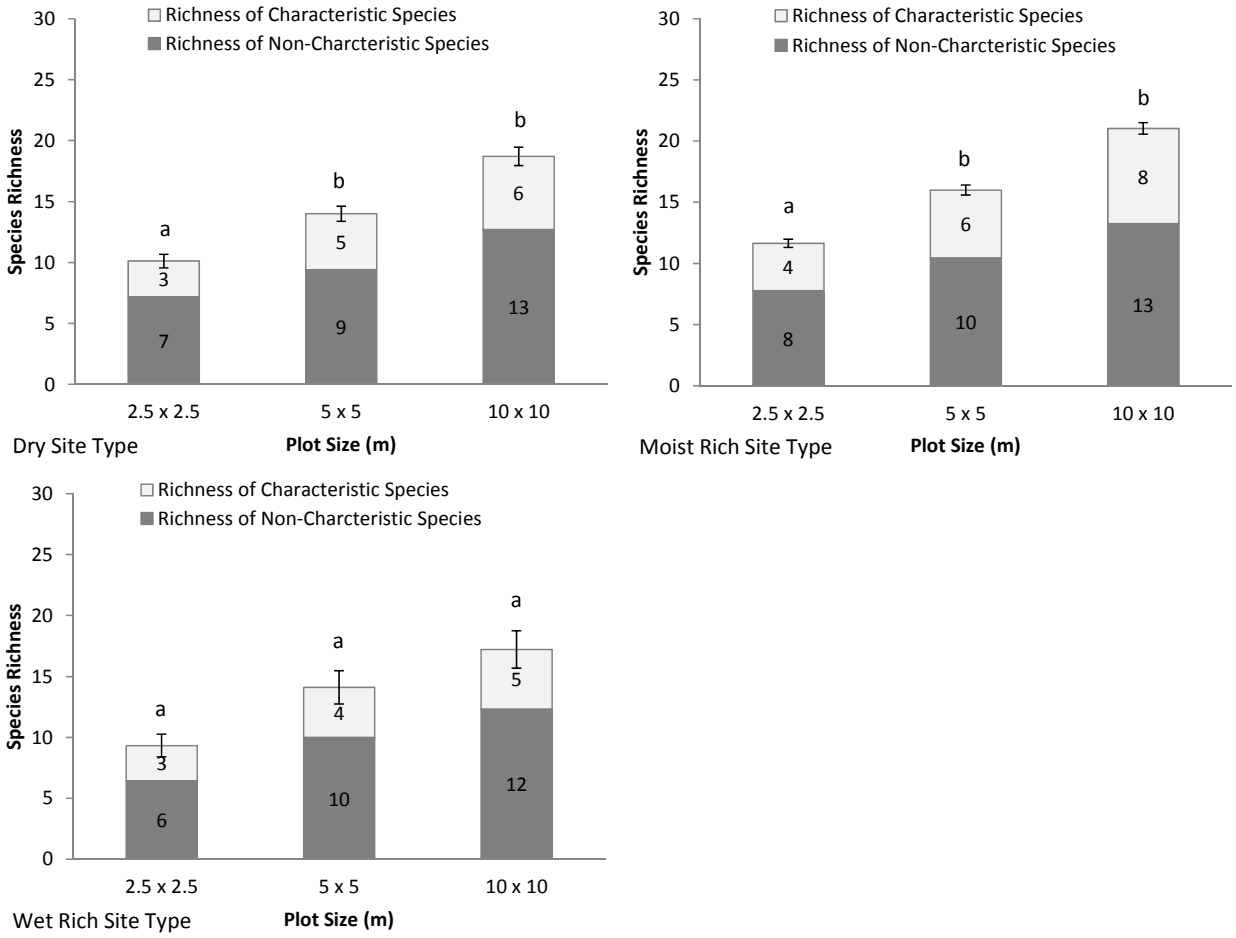

Figure 1: Species Richness by Site Type

The 100 m^2 plot was concluded to be the most appropriate of all the sizes tested to describe characteristic species composition and distribution at any given survey plot location within a target polygon and to use

with evaluation tools outlined in the Revegetation Manual, such as Table 5-3.

Optimum Sampling Intensity

Sampling intensity within the polygons varied between 1.0 to 2.3 plots/ha (1.4 plots/ha average) and sample size ranged from 4 to 13 plots (6 plots average) per polygon. Analysis of the data to test optimal sample size demonstrated greater variability in mean characteristic species values within a polygon when sample size is low compared to when sample size is large (see Figure 2). In polygons with 4 to 6 plots, the trendlines observed appeared to reach their asymptote around a sample size of 4 (Figure 3), while polygons with 7 to 8 plots tended to reach their asymptote around a sample size of 6 (Figure 4). A single polygon with 13 plots surveyed (SYN385) showed a sample size of 11 to be the point where mean characteristic variance was nearly reduced to 0 (Figure 5). The study concluded that a minimum of 4 plots should be established within a reclamation polygon 6 ha in size or smaller and a sample size equivalent to the area of the target polygon in hectares minus 2 should be established in polygons between 6 and 13 ha to determine and evaluate the mean number of characteristic species. Polygons that are less than 4 ha in size should still have a minimum of 4 survey plot locations established to minimize within polygon variability and maximize characteristic species potential. It was recommended that an additional study be undertaken in the future to specifically test sampling intensity on reclamation polygons larger in size than those surveyed in this study at 15-19 years in age. To provide the best scenario for assessment, variability within polygons should be reduced to the extent possible using existing desktop information prior to final polygon delineation and characteristic species assessment.

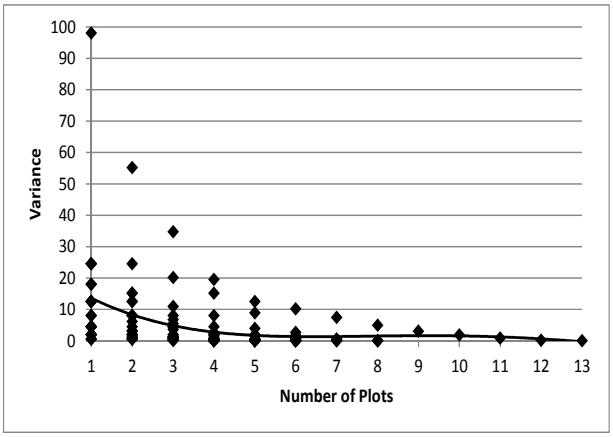

Figure 2: Variance of Mean Characteristic Species, all Polygons

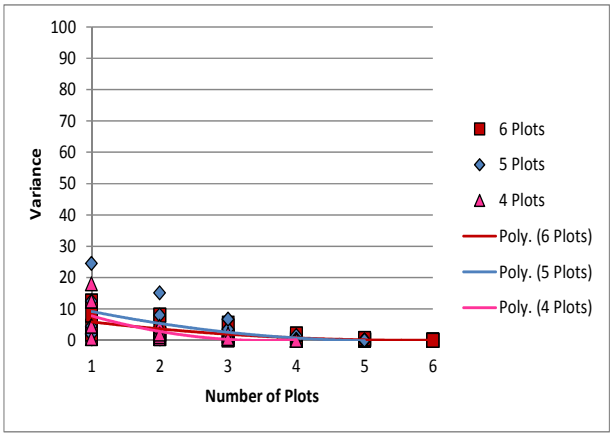

Figure 3: Variance of Mean Characteristic Species, Polygons with 4 to 6 Plots

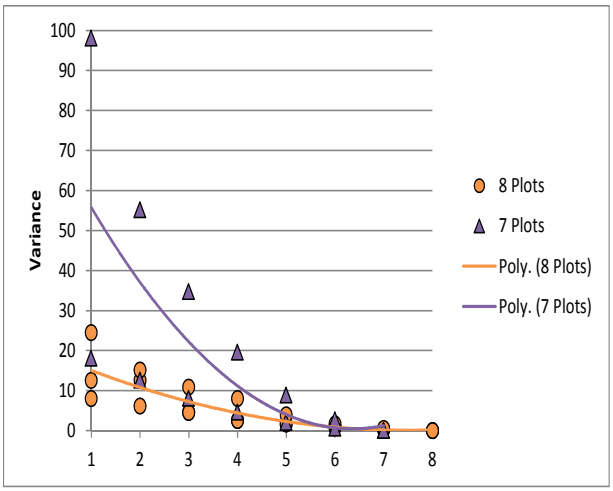

Figure 4: Variance of Mean Characteristic Species, Polygons with 7 or 8 Plots

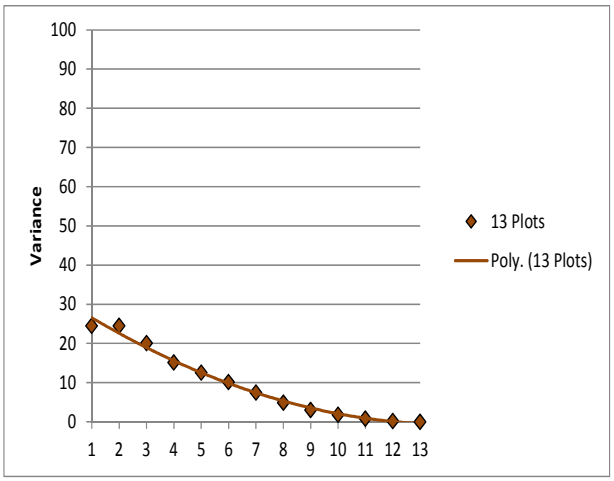

Figure 5: Variance of Mean Characteristic Species, Polygon with 13 Plots

Species Composition

Twenty-one species were found to be prominent within the reclaimed polygons surveyed. Differences in species composition and distribution were observed between the two age classes but were primarily attributed to lack of data (i.e., data gaps between cover types surveyed for each age class). Trees, shrubs and herbaceous species used in reclamation were often prominent. *Ceratodon purpureus* (purple horn-toothed moss) and *Brachythecium salebrosum* (Brachythecium moss) were the only bryophytes observed to have high prominence. No prohibited noxious species were observed but three noxious species (*Cirsium arvense*, 2 plots; *Convolvulus arvensis*, 1 plot; *and Sonchus arvensis*, 29 plots) were noted during field assessments.

Site Type Evaluation

Site types were determined both in the field and in the office for each 10 x 10 m plot area within each polygon surveyed. Site type determined in the field indicated that the majority of sites belong to the Dry or Moist Rich site types; one site was classified as a Moist Poor. Sites were often assigned two possible site types. Site types in the field were based on observation of plant species composition and abundance along with site conditions while site type determination in the office was based solely on the methods provided in Appendix J of the Revegetation Manual. Appendix J results were more variable than field estimates and showed five possible site types (Dry, Moist Poor, Moist Rich, Wet Poor and Wet Rich) and on several occasions could not identify site type at all (None) when there were no characteristic species (n=0) present. When the number and relative cover of characteristic species observed at a survey plot location is high (i.e., prominent), classifying a site type using Appendix J works very well (Table 3). Those plots with a moderate to very high prominence value (i.e., 18 or higher) were consistently classified to one or two site types – equivalent to what was achievable in the field. Site type is critical for the evaluation of characteristic species and thresholds outlined in Table 5-3 in the Revegetation Manual.

Table 3: Relationship between Characteristic Species Prominence, Counts and Site Types on Surveyed Plots

Prominence		Number of Plots	Range of Appendix J Site Type Estimates	Range of Field Site Type Estimates	Characteristic Species	
Group	Range				Count	Mean
Very Low	0-6	14	0-4	1-2	0-3	1.6
Low	6-18	22	1-3	1-2	1-5	2.8
Moderate	18-27	23	1-2	1-2	3-8	5.4
High	27-52	36	1-2	1-2	4-13	7.9
Very High	52+	3	1	1-2	9-14	11.3

Characteristic Species & Threshold Evaluation

A summary of the polygons assessed including area (ha), number of plots, the range, mean, and total number of unique characteristic species present (total count) with each polygon by site type are presented in Tables 4 and 5. Of the 16 polygons evaluated using Table 5-3 of the Revegetation Manual, only six were considered to have successful results with respect to this indicator (i.e., adequate number of threshold species by site type) (Table 4). These six polygons belonged to the younger (under 20 years) age class. Four other polygons belonging to the under 20 age class along with all six polygons belonging to the older (over 20 years) age class were determined to be unsuccessful based on the mean number of characteristic species. These polygons will likely require some type of under-planting prescription with suitable characteristic species to achieve the minimum threshold values for their desired target site type, if the target is to be achieved in the short term (without natural ingress). In general, those polygons that were successful when evaluated against the Moist Rich site type mean threshold typically had more than 10 cumulative characteristic species tallied from all plots across the polygon compared to those polygons that were unsuccessful (usually less than 10 cumulative characteristic species tallied from all plots). Exceptions to this trend include polygon SUN24 that reported 18 cumulative characteristic species for the Moist Rich site type but the calculated polygon average of 8.2 did not meet the minimum mean threshold value of 10 for polygons in the over 20 years age class (Table 5). Similarly, polygon SYN107 also had a relatively high number of characteristic species for the Dry and Moist Rich site types (11 and 14, respectively) but also failed to meet the minimum average threshold value for these site types.

Table 4: Summary of Characteristic Species Threshold Analysis for Polygons Under 20 Years

Polygon	Area (ha)	No. Plots	Target Site Type(s) & Characteristic Species Threshold	Characteristic Species Metrics	Site Type		
					Dry	Moist Poor	Moist Rich
SUN189	6.1	7	Dry (4) or Moist Rich (7)	**Mean**	**4.7**	**1.1**	**8.7**
				Range (Min-Max)	2-8	0-3	2-16
				Total Count	10	4	18
SYN381	2.8	4	Dry (4) or Moist Rich (7)	**Mean**	**4.3**	**1.0**	**6.0**
				Range (Min-Max)	2-7	0-3	3-9

Polygon	Area (ha)	No. Plots	Target Site Type(s) & Characteristic Species Threshold	Characteristic Species Metrics	Site Type		
					Dry	Moist Poor	Moist Rich
				Total Count	9	3	12
SUN250	4.5	6	Moist Rich (7)	**Mean**	**4.5**	**1.7**	**7.2**
				Range (Min-Max)	4-6	0-3	5-10
				Total Count	8	4	12
SYN345	8.3	8	Moist Rich (7)	**Mean**	**4.1**	**0.5**	**7.0**
				Range (Min-Max)	3-6	0-1	3-10
				Total Count	6	2	13
SYN385	12.9	13	Moist Rich (7)	**Mean**	**4.8**	**2.2**	**10.1**
				Range (Min-Max)	2-7	1-4	7-14
				Total Count	12	9	25
SYN364	3.5	5	Moist Poor (3)	**Mean**	**4.6**	**2.2**	**8.0**
				Range (Min-Max)	3-6	0-1	3-10
				Total Count	8	4	14
SUN270	5.9	6	Dry (4)	**Mean**	**2.0**	**0.5**	**2.7**
				Range (Min-Max)	1-3	0-1	2-4
				Total Count	4	1	8
SUN286	7.6	8	Dry (4) or Moist Rich (7)	**Mean**	**2.1**	**1.0**	**3.1**
				Range (Min-Max)	0-4	0-2	1-6
				Total Count	7	3	10
SYN297	1.7	4	Moist Rich (7)	**Mean**	**2.3**	**0.5**	**4.0**
				Range (Min-Max)	2-4	0-2	3-6
				Total Count	5	2	7
SYN390	4.3	6	Moist Poor (3) or Moist Rich (7)	**Mean**	**0.8**	**0.3**	**2.2**
				Range (Min-Max)	0-1	0-1	0-4
				Total Count	2	1	7

Note: Shaded cells indicate threshold has been met

Table 5: Summary of Threshold Results using Table 5-3 Evaluation (Polygons Over 20 years)

Polygon	Area (ha)	No. Plots	Target Site Type(s) & Threshold	Characteristic Species Metrics	Site Type		
					Dry	Moist Poor	Moist Rich
SUN236	2.4	5	Dry (6) or Moist Rich (10)	**Mean**	**1.0**	**0.2**	**1.0**
				Range (Min-Max)	0-2	0-1	0-2
				Total Count	3	1	3
SUN59	4.9	6	Dry (6) or Moist Rich (10)	**Mean**	**2.0**	**0.7**	**2.0**
				Range (Min-Max)	1-4	0-1	1-3
				Total Count	5	2	5
SYN141	2.2	4	Dry (6) or Moist Rich (10)	**Mean**	**3.5**	**1.3**	**4.3**
				Range (Min-Max)	3-4	1-2	3-6
				Total Count	6	2	9
SUN24	2.9	5	Moist Rich (10)	**Mean**	**5.2**	**1.6**	**8.2**
				Range (Min-Max)	3-7	1-3	4-11
				Total Count	6	3	18
SUN186	3.6	5	Moist Rich (10)	**Mean**	**3.2**	**0.4**	**5.2**
				Range (Min-Max)	1-5	0-1	3-8
				Total Count	6	1	9
SYN107	6.2	6	Moist Rich (10)	**Mean**	**4.2**	**0.3**	**6.7**
				Range (Min-Max)	3-6	0-1	4-9
				Total Count	11	2	14

Summary

Steps outlined in Section 5.3.4 of the Revegetation Manual worked relatively well to evaluate polygons. One recommended change would be to impose limits to the selection of alternate polygon site type designations as currently there is no guidance in the Revegetation Manual on how far a unit can be moved on the edatopic grid in Step 2 of the evaluation. Acceptable reassignments (i.e., shift across nutrient regimes) were developed for this project and presented to the TSG for consideration. The thresholds identified in Table 5-3 appeared to be appropriate to provide an indicator of reclamation success; however, only polygons classified to the Dry, Moist Poor and Moist Rich site types were surveyed and evaluated in this project. Given more time and funding, additional site types should be surveyed and tested. A field protocol for assessing characteristic species thresholds in polygons on reclamation areas was created and presented in the project report based on the findings of this study.

Based on the evaluation of Table 5-3 of the Revegetation Manual using plot data collected for this project, it would appear that reclamation polygons 15-19 years of age can have sufficient species composition to be evaluated using the characteristic species methods outlined in the Revegetation Manual and can even be considered to be successfully reclaimed with respect to this indicator. This survey timing follows the conclusion of establishment and regeneration surveys where planting prescriptions can be re-evaluated and remediation activities can be planned as required. With the data collected for this project, however, it is not clear what inferences can be made about whether or not reclaimed sites move along a particular successional trajectory similar to natural sites. Additional data will need to be collected in sequential years within the target reclamation (polygon) area and compared directly over time. Specifically, it is not known whether the under 20 year old sites that met the species threshold will retain the number of characteristic species found at present or achieve the target for the over 20 year old sites in the future. It may also be possible that sites that did not meet the threshold will undergo a change in species over time and meet the target at a future date. It was also recommended that the methods put forward in the field protocol section of this study be repeated in natural stands of similar site types to polygons in reclaimed areas to assist with developing a better understanding of successional trends towards natural ecosystem targets and to further test the application of Table 5-3 of the Revegetation Manual and methods tested in this study.

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