SOILS AND FORAGE PLANTS ON THE THUNDER BAY COMMUNITY PASTURE:

BASELINE INFORMATION 2019

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Photo credit: Allysa Lovatt

SUMMARY

Established between 1954 and 1972, the Thunder Bay Community Pasture has served the community well, but has received little attention in terms of forage improvement. Today, interest has grown among users to increase carrying capacity by means of rotational grazing of cattle on the pasture. Toward this end, installation of a first set of interior fences began in the main pasture area in August 2019. Toward a goal of continuous monitoring and improvement, baseline soil and forage data were collected in June and July 2019, before fencing. Although limited to one sample in the main pasture, soil analysis indicated a silty clay loam soil in good condition but with high acidity and consequently limited phosphorus. One early-season yield measurement and a pasture composition survey were carried out in two areas of the main pasture, one heavier grazed than the other; a third reference area adjacent to the main pasture was also surveyed. Some whole-plant study was done in the main pasture.

Prognosis for improvement is good. Above- and below-ground concentrations of nitrogen and most micronutrients are normal or above average in forage plants, especially where heavier browsed. However, grass and legume yields are lower in the heavier browsed area. This area has an abundant grass and legume population, but it is comprised of smaller plants with lower above-ground growth investment compared to the less grazed area. Heavy grazing may be associated with a shift to higher yields and larger plants of less palatable forb species. More extensive soil and yield surveys are recommended to track the plan for staged implementation of grazing management.

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INTRODUCTION

The Thunder Bay Community Pasture is located in the agricultural belt southwest of the City of Thunder Bay, near the junction of Highways 590 and 595 in O'Connor Township, and spans about 400 ha over four parcels. The pasture was developed between 1954 and 1972 when the Federal and Provincial governments acknowledged that the lack of expansion in the beef industry in the region was due to limited carrying capacity on the average family farm. The community pasture initiative was common across Canada since the 1930s. Since 1972, minimal cattle management and forage improvement has occurred on the Thunder Bay Community Pasture. Today, interest has grown among users of the pasture to increase carrying capacity by means of rotational grazing. Installation of a first set of interior fences began in August 2019, toward a first objective to mitigate effects of heavy grazing near the watering area and main entry gate along Highway 595.

This report is on baseline data collected to track improvement as stages of rotational grazing are implemented in the main area of the Thunder Bay Community Pasture. It is divided into sections on soil properties, forage yields, pasture composition, forage plant structure, and plant chemical analysis. Through most of the report, two areas of the main pasture are compared, one labeled 'West,' which served to study the effects of heavy grazing near the main entry gate along Highway 595, and another labeled 'North,' which served to study the partially treed area along Highway 590, where grazing is less heavy. A third area, labeled 'Fletcher,' is compared as a means to track forward a reference area, known as Fletcher's Field, where there are no immediate plans for rotational grazing. Through the various sections, individual personnel and funding sources are acknowledged, but special mention is deserving here of two students of Lakehead University, Allysa Lovatt, who was granted a Natural Science and Engineering Research Council (NSERC) Undergraduate Student Research Award to support the summer fieldwork and research, and Trent Francis, who completed chemical analysis of the plant tissues toward an undergraduate thesis. Diane and Larry Bockus of the Thunder Bay Community Pasture, Kendal Donahue, Christine O'Reilly and Barry Potter of the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA), Glenn Clausen of the Science Workshop, and students Paul Benalcazar, Silpa Kanchi, Prashant Kanwar, Sampada Neupane, all of Lakehead University, are also deserving of thanks for their assistance and encouragement in this study.

The resource used for grass identification was Jack Kyle's 'Pasture Grasses Identified' factsheet on the OMAFRA website (www.omafra.gov.on.ca/english/livestock/beef/facts/06-095.htm). Resource lists helpful to interpretation of the forage plant survey came from J. Kyle's 'Pasture Production' (2015) Publication 19 on the OMAFRA website (www.omafra.gov.on.ca/english/crops/pub19/Publication19.pdf), and from the feedipedia.org website. Information on the establishment of the Thunder Bay Community Pasture can be found in the article by R. S. Dilley and T. F. Loghrin (1975), Canadian Geographer 19(4), 299-305. Test statistics for site comparisons used Statistical Package for the Social Sciences (SPSS), and ordination of forage plant community composition used the 'vegan' package in R.

SOIL PROPERTIES

Soil was collected at one location (lat. 48º 23' 13" N and long. 89º 42' 00" W) in the southwestern section of main area on June 14, 2019 by a doctoral student at Lakehead University, Paul Benalcazar. The samples were added to a set used for his own research project with analysis at the Soil Testing Laboratory at Cornell University, where costs of consumables were absorbed. There were two composite samples taken from 15 cores extracted with a 5-cm soil sampler with a top mounted hammer, one corresponding to the top 5 cm of soil and the other to 5-15 cm depth. The cores were taken at 10 m intervals in three transects laid out in letter-Z fashion. The samples were divided by depth, homogenized and air dried, then stored at 4 ºC to ship to Cornell University.

According to Cornell's health ratings, soil at the Thunder Bay Community Pasture is overall in 'good' condition at both depths (Table 1). There is no indication of a high sand component, typical for the region and sometimes a symptom of overgrazing. The texture class is silty clay loam. Low ratings occur for soil acidity (pH), particularly at the deeper level. Low to fair ratings occur for the minor elements, and for soil protein at 5-15 cm, resulting in the lower overall rating for the lower depth. One interpretation is that soils are somewhat depleted, with the surface enriched by saliva, faeces and urine. However, concern should not be high for most important measures, and with remedial actions (see Recommendations), the soil can support forage improvement.

Table 1. Soil properties in the southwestern section of main area of the Thunder Bay Community Pasture. Ratings are quality percentiles assigned by the Cornell University Soil Testing Laboratory.

	Sample depth			
	0-5 cm		5-15 cm	
		Ratings		Ratings
Sand (%)	10.3		12.3	
Silt (%)	53.3		48.8	
Clay (%)	36.4		39.0	
Water holding capacity	0.3	97.7	0.3	91.8
Aggregate stability	69.6	96.6	58.4	89.1
Organic matter (%)	9.1	100.0	5.2	91.2
Citrate extractable soil protein	17.8	100.0	6.9	63.6
Respiration	2.1	100.0	1.0	92.1
Active carbon (ppm)	1058.7	99.2	679.4	69.9
pH	5.8	49.3	5.7	25.3
Phosphorus	8.1	100.0	4.3	100.0
Potassium	233.1	100.0	148.4	100.0
Magnesium	625.6		522.0	
Iron	66.9		44.3	
Manganese	26.3		12.6	
Zinc	1.3		0.9	
Minor elements rating		56.0		56.0
Overall rating		89.9		77.9

FORAGE YIELDS

Forage yields were estimated by hand clipping, drying and weighing samples collected in late June 2019, before much grazing had occurred. Exclosures were discussed as a means to continue yield estimates throughout the season controlling for the effect of grazing, but logistics did not allow it. The plant collections were done over an approximately two-week period, beginning with 15 plots at the West site, followed by

15 plots at the Fletcher site, and finally 15 plots at the North site. Some delay was created by using the same plots for an assessment of forage plant community composition, and each plot took between one and three hours to complete both tasks. The staggered collections may have introduced some bias with higher estimates of yield for the later collections at the Fletcher and North sites. The hypothesis tested was for higher yields at the lesser grazed North site.

Plots of 1 m × 1 m were established randomly along a single transect, spacing them at 10 m intervals. All plants were cut with clippers or scissors close to the root collar, separating the functional groups of grasses, forbs and legumes; yield by species could not have been done easily with the early sampling period that was prior to inflorescence for many species, particularly grasses. Samples from the transported to the laboratory was in paper bags. Later sampling periods were not possible given laboratory processing times for collections from the first period. Drying was at 105 ºC for 24 hours before weighing on an electronic balance. Field and laboratory work were subsidized by a grant from the Lakehead University Agricultural Research Station, from an NSERC Undergraduate Student Research Award, and from a First Nations and Inuit Youth Employment Strategy grant from Indigenous Services Canada via the Summer Work Experience Program. Field and laboratory components of forage yield estimates were carried out by Lakehead University undergraduate students Allysa Lovatt and Sydney Dru Lorenowich.

A two-way ANOVA was used to compare forage yields at the three field sites by plant functional group. There were differences in yield both across the sites ($F_{2,126}$ = 12.4, p < 0.01) and directionally by plant functional group ($F_{4,126}$ = 5.4, p < 0.01). In particular, yields were consistently lower comparing the heavier grazed West site to the North site of the main pasture area, and also comparing the Fletcher field, with the exception of a similar early-season yield of grasses in the West and Fletcher sites (Figure 1). Yield of forbs (non-legume broadleaved plants) was higher, and yield of

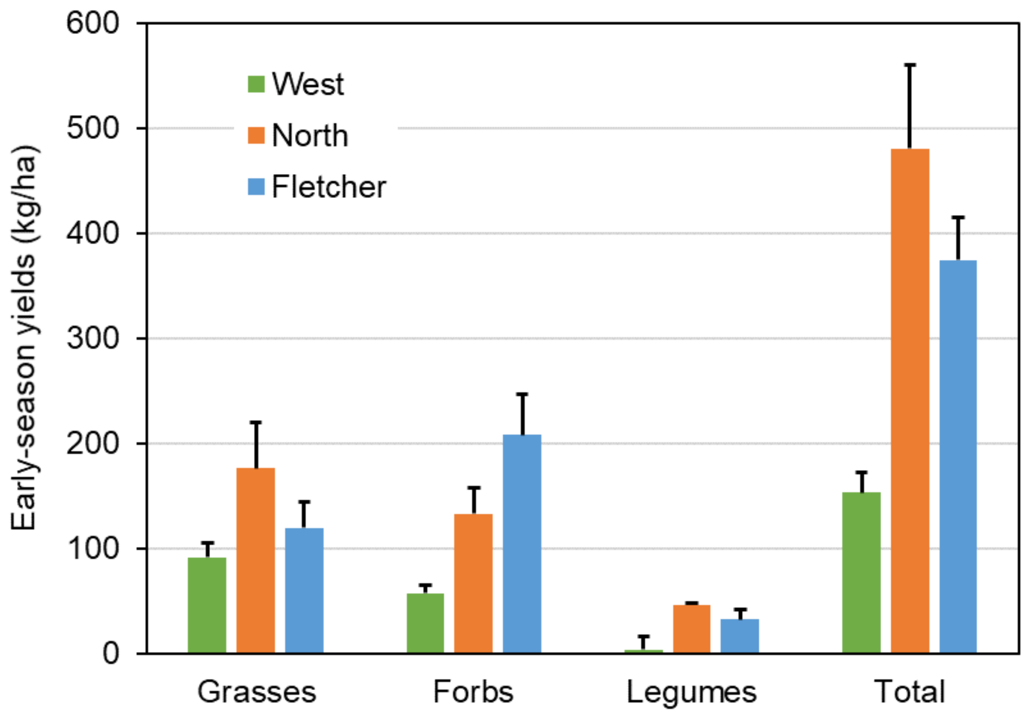

Figure 1. Early-season yields (to late June 2019) in three functional groups of forage plants at the Thunder Bay Community Pasture. Yields are significantly lower in the West field comparing the North field, and except for grasses, the same is true comparing the Fletcher field. There are significantly higher yields of forbs in the Fletcher field than either of the other sampling sites. Most forbs are not considered forage plants: a list of species is found in Appendix 1.

grasses was somewhat (but not significantly) lower in the Fletcher field, comparing the less intensively grazed field in the North area of the main pasture.

The overall smaller yields in the West area of the main pasture are confirmation that this area, near the watering area for most of the cattle, is overgrazed. Constant plant removal by grazing above a threshold of about five days per month limits the potential for good yields throughout the season. Early-season differences comparing less occupied areas of the main pasture suggest that depletion of root reserves with any later-season regrowth in forage plants in the West area is one effect of overgrazing. An effect of trampling may be another, particularly with very low yields of legumes in the West field obvious from Figure 1. Trampling both kills plants and compacts soils in a manner to limit root penetration.

Many plants classified as forbs in this survey are unpalatable or non-nutritious to cattle, so the relatively good total yield in June at the Fletcher site should not suggest overgrazing is not an effect of the size of the group of cattle kept here. In fact, cattle were observed in the same general area of the Fletcher field on many successive days in July 2019. A shift to forbs from grasses may be a result of competitive advantage to forbs in the plant community when grasses are overgrazed. It is easy from Figure 1 to describe the general ratio of yields by plant functional group to be optimal in the North site, making this ratio a good early target during continued monitoring that should occur with improved livestock management. However, even at the North site, total forage yields are much lower than is typical for good pasture in all of Ontario, even given the early-season collection. The conclusion that forage yields are limited by a fairly acidic soil and a history of unmanaged grazing throughout the Thunder Bay Community Pasture is a fair one.

In future years, later transects to assess forage yields should be possible with additional human resources, but consideration must be given to reduced hours of fieldwork during the hottest days. Bias in future years of monitoring should be avoided by rotating progress through the transects on successive days. Ideally, exclosures can be constructed to show potential in forage improvement, including by seeding, by means of control against grazing in one or more small areas of the main pasture. Electric fences may be the best option to implement these exclosure sites, which may serve as better future references for management than the Fletcher field.

PASTURE COMPOSITION

As above, transects were implemented to collect baseline data at three sites in the Thunder Bay Community Pasture. The same 45 points were used to survey the plant community composition as those used to compare the forage yields at the three sites. At each point, 2 m × 2 m plots were laid out and complete grass and broadleaf plant counts were done systematically using four grids of 10 cm string markers along a one-metre square frame to avoid duplicate counts. Surveys in June prohibited confident grass identification and no attempt was made to identify sedges (*Carex* spp.), hawkweeds (*Hieracium* spp.) or goldenrods (*Solidago* spp.) to the level of species. It was also difficult to create general rules for the counts of all species. Some spreading plants were traced to one or a few main root collars. Grasses, which often occurred in small swards, were classified into 1, 5, or 10 stems with rough estimates of the sward size.

Matched to the quality of the count estimates, just the fraction of grass and of legume stems were compared, the legume community was qualitatively described, and richness and diversity (Shannon evenness index, log base 2) of the forb community were calculated for the three sites. Additionally, composition by species or genus excluding grasses was summarized using nonmetric multidimensional scaling (NMDS) in the vegan package in R. Allysa Lovatt and Paul Benalcazar assisted with the data collection in the field, and Ms. Lovatt assisted with the data analysis.

The fraction of grasses was not the same at all sites ($F_{2,42}$ = 8.7, p < 0.01), notably higher (44%) at the North end of the main pasture than at its West end (21%) or at Fletcher Field (18%). By mid July, the common grasses were identified at all sites, leading to a nearly complete list of non-woody species at the Thunder Bay Community Pasture (Appendix 1). The fraction of legumes was also different across sites ($F_{2,42}$ = 3.6, p = 0.04), this time higher (32%) at the West site than the North (20%) and Fletcher sites (21%). All sites had the three common legumes, Black medick (*Medicago lupulina*), White clover (*Trifolium repens*), and Red clover (*T. pratense*), although at the West site, White clover was notably more abundant and Red clover less abundant than at the other two sites. Bird vetch (*Vicia cracca*) occurred uncommonly and only at the North site. Bird's-foot trefoil (*Lotus corniculatus*), a common legume on poor, disturbed and compacted sites, did not occur on any of the transects and is possibly absent from much of the pasture. Typically seeded as part of pasture management to enhance nitrogen capture, frost seeding of Bird's-foot trefoil is a recommendation of this report (repeated below).

Forbs had the highest overall richness at the North site, 21 species, followed by the West, 16 species, and Fletcher sites. However, comparing plot diversity, the Shannon index was similar for all three sites (in the order above, 2.49, 2.84, and 2.77). This measure of evenness was somewhat lower at the North site, while the number of species per plot was highest at the West site (in the order above, ranging from 8-12, 9-16, and 7-11 species). At the North site, the higher number of species overall included less common forbs found at just one or two plots each: Saskatoon serviceberry (*Amelanchier alnifolia*), Creeping dogwood (*Cornus canadensis*), Smooth rose (*Rosa blanda*), Red raspberry (*Rubus idaeus*), Blue-eyed grass, (*Sisyrinchium mucronatum*), and Western snowberry (*Symphoricarpos occidentalis*).

Rarer elements typically distinguish groups in an NMDS, and the less common forbs and Bird vetch typify the less grazed North community of pasture plants, while the less palatable goldenrods and Northern bedstraw (*Galium boreale*) are common and less common components, respectively, of the Fletcher field (Figure 2). The most common plant species, near the centre of an NMDS, including White clover and

Common plantain (*Plantago major*), typify the more heavily grazed West site. They have low and prostrate growth forms, and this character likely allows them to avoid grazing. One explanation for the higher number of forb species per plot and higher evenness of forb species at the West site is the heavy grazing of the grasses and legumes. The higher overall number of forb species at the North site is likely due to the shaded microhabitats provided by the trees. The less common plants are not at-risk species.

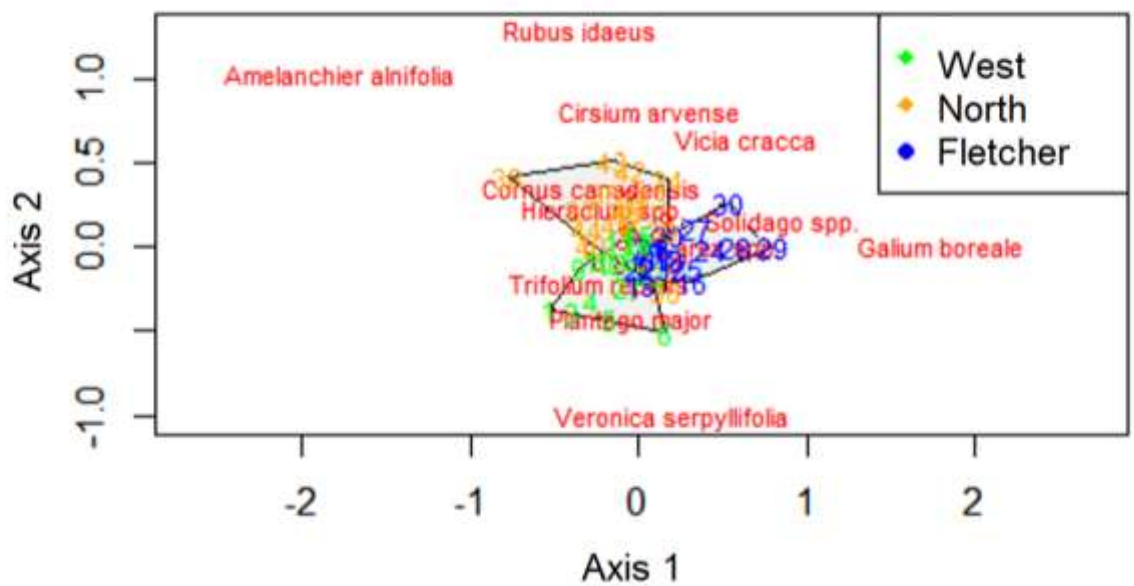

Figure 2. Summary of broadleaved plant community composition at two sites (West and North) of the main pasture and the adjacent Fletcher field. The axes show arbitrary nonmetric multidimensional scaling (NMDS) used to separate plant communities based on all forbs and legumes surveyed (Appendix I). The positions of some forbs and two legumes (*Vicia cracca* and *Trifolium repens*) are shown in the multidimensional space and their nearness to any cluster of pasture plots illustrates stronger association with a site.

Overall diversity at both scales, i.e. the high local species evenness within the West site and the higher species count moving toward the North site, is a positive element from the perspective of ecosystem services, such as providing for a healthy pollinator community. Some native forbs, like goldenrods, provide no value as forage, and some weedy invasive plants, like Canada thistle, can improve forage quality. Presence of the Canada thistle does not appear to be an indicator of overgrazing, as the only location it occurred in a plot was in the less grazed North field. Thyme-leaved speedwell (*Veronica serpyllifolia*), a tolerant perennial, was the only non-native plant unique to the heavily grazed site according to the plot work.

FORAGE PLANT STRUCTURE

In July and early August 2019, whole-plant samples were excavated with a 15-cm steel core inserted about 20 cm into soil by means of a hammer mounted on the core's handle. The target was three random samples of the four common grass species, the three common legumes, and three frequently encountered forbs (Yarrow, *Achillea millifolium*, Hawkweed, Swamp aster, *Symphyotrichum puniceum*), at each of the three sites. Random sampling was achieved by tossing a trowel at least 10 m, then locating the target plant closest to the trowel. Hardened summer soils made the coring effort difficult, including on equipment, and the only site where the target of three samples was achieved was the West site. The field season allowed one sample of each plant to be taken at the North site, allowing some comparison to the West site. A single Swamp aster was sampled at the Fletcher site.

The intent of the whole-plant sampling was to investigate how the three field sites, equivalent to different levels of grazing, may have affected plant structure and carbon allocation, comparing above- and below-ground plant parts, respectively, the stems and leaves available to grazers, and the roots that serve as energy stores for plant regrowth. Core samples with the plants were taken to the laboratory to separate soil from roots. Many fine roots were lost in this sieving and sorting process, but the resulting bias in weights was assumed to be consistent across the samples. Above- and below-ground portions of the plants were separated, then oven-dried at 105 ºC for 24 hours before weighing on an electronic balance. Dried samples were retained for chemical analysis (next section). Fieldwork and laboratory work were conducted by Allysa Lovatt and Sydney Dru Lorenovich.

Statistical analysis was limited by the lack of replication at the North site, but trends were apparent and differed by functional group. Among the grasses, the Redtop (*Agrostis gigantea*) sample at the North site had a larger above- and below-ground mass, comparing the samples at the West site; this was not the case for the Canada blue grass (*Poa compressa*) sample (Figure 3). More pertinent to the objective of this analysis, the other two grasses, Perennial ryegrass (*Lolium perenne*) and Timothy grass (*Phleum pratense*), were relatively higher in above-ground mass in the North site sample, with relatively higher below-ground mass in the West site samples. The same trend occurred for the three legumes, but not for the forbs. A smaller sample plant was taken of Yarrow at the North site, and its above- to below-ground mass ratio was smaller than the average of the three samples at the West site.

What is illustrated in the trends described can be attributed to the effects of grazing on competition in the forage plant community. A less palatable and tolerant grass, Redtop is unsurprisingly larger at the less grazed North site. The more palatable Perennial ryegrass and Timothy grass show effects of overgrazing at the West site, where below-ground allocation is relatively higher than for the same species at the less grazed North site. The below-ground allocation is still strong at the West site for these forage grasses, indicating both good soil health and high recovery potential with grazing management. The same is true for the legumes, which are more numerous in the stem counts at the West site, but more invested in root development and less available and more vulnerable above-ground due to grazing at this site. Hawkweed and Swamp aster may also be showing effects of grazing in lower above-ground mass at the West site, while Yarrow may be experiencing competitive release with the grazing. These results are less complete than they might be if plant sampling was more extensive. If this avenue of investigation is to be pursued further, a machine-powered excavator of soils and roots is a logical recommendation.

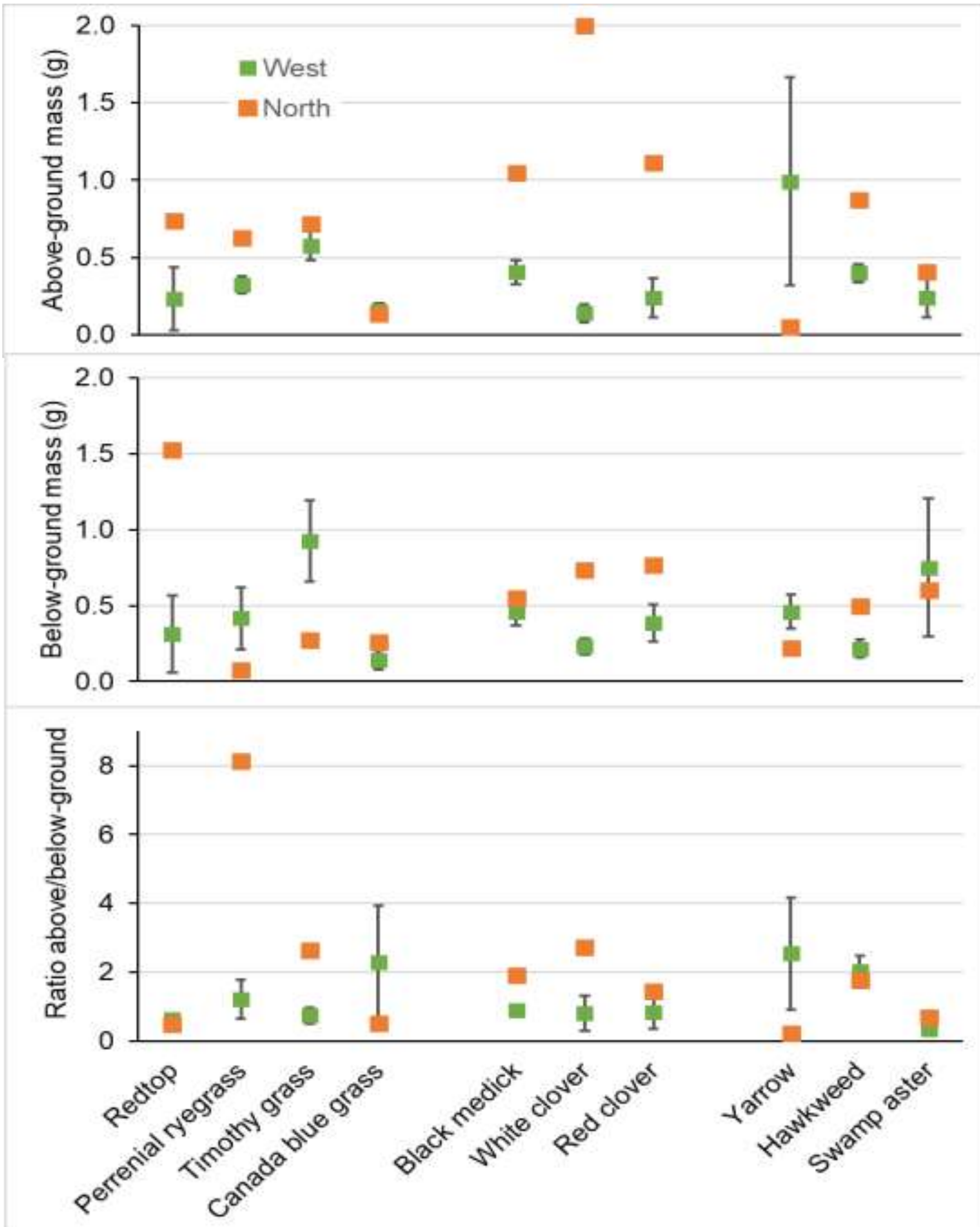

Figure 3. Above- and below-ground masses of common grasses, legumes and forbs at two sites on the Thunder Bay Community Pasture. Means (green squares) and standard errors of the means (small bars) are illustrated for the West site on the main pasture, while only one sample was taken and is illustrated for the less grazed North site (orange squares).

PLANT CHEMICAL ANALYSIS

For plant tissues collected as described in the section above, if they were of sufficient mass for chemical analysis, shoots and roots were ground separately in a coffee mill, then further crushed with a mortar and pestle. Fragments were sieved to a maximum size of 180 microns. The smallest amount of sample, 0.05 g, was sufficient for a measure of total nitrogen, which was estimated with an Autoanalyzer Skalar SANSystem that performs in-line UV digestion, colour developing, and spectro-photometric measurement. Total organic carbon was estimated by oven-drying 2 g of the samples, if this amount was available, to a stable mass at 105 ºC for 24 hours, then combusting it in a muffle furnace at 550 ºC for 2 hours. Loss on ignition (%) was calculated from the difference in mass on an electronic balance before and after combustion. For several samples, there was sufficient material for additional colorimetric methods to provide estimates of metal fractions that included plant macro- and micronutrients. Trent Francis prepared the samples and carried out the loss-on-ignition estimates. Johane Joncas at the Lakehead University Environmental Laboratory assisted with metals analysis, and the Lakehead University Centre for Analytical Services measured total nitrogen.

Thirty-one tissue samples were sufficiently large to estimate total organic carbon, but this set excluded any roots. Therefore, changes to carbon allocation within a plant were not possible to track. Organic carbon content could be compared for samples at the West site (N = 20) and North site (N = 11), but because plant samples were not replicated at the North site, the comparison was by combined replicates within a functional group (distinguishing only grasses, legumes and forbs), using a two-way ANOVA in SPSS. There were 18 above- and 21 below-ground samples for which total nitrogen was measured, and metal concentrations were measured for 25 samples; combined, the results were reported for all macro- and micronutrients (Appendix II). High variability in nutrient concentrations within a site allowed for generalization only.

No differences occurred between the West and North sites in above-ground organic carbon ($F_{8,22} = 0.49$, $p = 0.85$). Similarly, where total nitrogen could be compared for the same species at the two sites (for Redtop, Canada blue grass, Hawkweed, Swamp aster, and the three common legumes), differences were minor; however, total nitrogen was typically slightly higher in both above- and below-ground tissues from the West site. Other macro- and micro-nutrients could only be compared in above-ground tissues and only across sites for three species (Redtop, Swamp aster, and Black medick). In three of four samples, nutrient concentrations were generally lower at the North site, once (in the case of Swamp aster) comparing the Fletcher site.

A number of reasons might explain lower nutrient concentrations at the North site, primary among them less visitation by cattle and therein lower rates of nutrient inputs from urine, faeces and saliva. Two other reasons are the larger size of the forage plants already noted for this field, which can dilute nutrient concentrations, and the high variability in soil microhabitats that occurs within a field. Nutrient concentrations in all sampled plants fall within or above normal ranges for pasture from published literature, which also acknowledges high inter-plant variability. It is unfortunate in the survey conducted at the Thunder Bay Community Pasture that soil samples were not more extensive, that more sampling of individual plants was not possible, and that matches did not occur for the total organic carbon above- and below-ground and with total nitrogen for the same tissues with a degree of replication that might have allowed comparison of C:N ratios. Future sampling should target higher tissue masses for a more complete analysis; it might be best to consider additional measures typical of forage surveys: crude protein digestibility, fibre content, and sugar or energy content.

RECOMMENDATIONS

Grazing management will have a staged implementation. Monitoring limited to two or three areas, as for this baseline data collection, should track just the first stage, during which less grazed areas like the North site should receive more grazing, and heavier grazed areas like the West site should receive less grazing, and effectiveness of this recommended management plan can thus be measured.

Early activities to consider as part of this plan include frost seeding with Bird's-foot trefoil and lime application, the latter important given the high soil acidity. Phosphorus is likely low in availability as a result of the high acidity. Lime application to improve degraded pasture is a very common recommendation and can be feasibly implemented by broadcast application over portions of the pasture over a period of several years. Liming will make crop nutrients more available, and make legume nodulation more successful, which will in turn improve the productivity of the pasture.

A second stage of management will begin when sufficient fencing is in place to ensure that any paddock is evenly grazed and any area receives no more than 5 days of grazing in one month. Prior to this second stage, a more extensive survey of pasture soils and plants should serve as a more complete baseline. Two plant collections are recommended, one in the early season (June) and one in the late season (September). Yield is ideally measured in late June, early August, and late September. Maintaining and monitoring an unmanaged reference site like Fletcher’s Field is useful; implementing, maintaining and monitoring exclosure (control, ungrazed) sections of the main pasture where rotational grazing is to occur will be even more useful. Tracking beyond baseline measures should occur every two to five seasons as funds allow. Soil testing at a certified Ontario laboratory should occur so that the methodology is consistent with OMAFRA monitoring and soil health can be compared to other Ontario sites. Clearly, soil and plant sampling at a few more locations on the pasture should occur, beyond what was achieved for this report, with the recommendation that a machine-powered sampler will facilitate soil collection and plant excavation.

APPENDIX I: FORAGE PLANT SPECIES IDENTIFIED ON THE PASTURE

GRASSES
Agrostis gigantea (Redtop)
Lolium perenne (Perennial ryegrass)
Phleum pratense (Timothy grass)
Poa compressa (Canada blue grass)
Other Grasses

FORBS
Achillea millefolium (Yarrow)
Amelanchier alnifolia (Saskatoon serviceberry)
Cirsium arvense (Creeping thistle)
Cornus canadensis (Creeping dogwood)
Fragaria virginiana (Wild strawberry)
Galium boreale (Northern bedstraw)
Hieracium spp. (Hawkweed)
Leucanthemum vulgare (Oxeye daisy)
Plantago major (Broadleaf plantain)
Potentilla norvegica (Rough cinquefoil)
Prunella vulgaris (Heal-all)
Ranunculus acris (Common buttercup)
Rosa blanda (Smooth rose)
Rubus idaeus (Red raspberry)
Solidago spp. (Goldenrod)
Stellaria graminea (Common starwort)
Symphoricarpos occidentalis (Western snowberry)
Symphyotrichum puniceum (Swamp aster)
Sisyrinchium angustifolium (Blue-eyed grass)
Taraxacum officinale (Common dandelion)
Veronica serpyllifolia (Thyme-leaved speedwell)

LEGUMES
Medicago lupulina (Black medick)
Trifolium repens (White clover)
Trifolium pratense (Red clover)
Vicia cracca (Bird vetch)

APPENDIX II: FORAGE PLANT CHEMICAL ANALYSIS

Location	N	P	K	Ca	Mg	S	Fe	Mn	Bo	Cu	Zn	Co
Redtop												
West	1.51	1300	3870	6780	2790	887	5540	215	39	49	47	3.61
below	1.31											
North	1.20	1320	18100	4390	2100	558	1160	108	14	14	25	0.54
below	0.77	763	5070	6560	4580	602	11700	379	10	42	66	9.26
North		11500	317000	68500	19100	1650	5840	548	312	409	485	3.31
Perennial ryegrass												
West	1.46											
below	1.24	1290	2610	10100	4810	985	13100	588	< 3	38	85	6.27
Timothy grass												
West	1.05											
below	0.80	1180	5610	8020	1570	584	2490	129	12	84	48	1.51
West	0.89											
below	0.69	720	3500	6720	5760	573	15200	497	6	46	76	10.40
Canada blue grass												
West		14400	252000	84900	20700	3560	10900	869	410	1450	1113	5.95
below	1.13											
North												
below	1.18											
Yarrow												
West	2.14	18100	304000	89200	22500	2100	1440	272	488	381	777	0.68
below	0.57	994	11900	2160	2350	586	1940	96	15	18	31	1.49
West	1.70	1960	17500	7720	2170	578	2130	84	26	32	41	1.14
below	1.13											
West		2710	28000	9530	2710	1120	1800	117	32	61	47	0.97
below	0.93											
Hawkweed												
West	1.52											
below	0.89											
North	0.94	799	36100	10400	3530	761	2800	104	48	30	56	1.89
below	0.63											
Swamp aster												
West	1.70	852	4350	10700	4500	794	7340	282	21	33	47	4.50
below	0.95											
North	1.69	1090	55300	12400	3290	970	987	67	55	62	74	0.78
below		33800	245000	107000	10200	9620	3080	403	373	392	357	2.71
Fletcher		10800	108000	82400	20000	4960	26900	1720	163	200	312	14.60
Black medick												
West	2.30	12600	106000	31000	14900	2030	22300	895	73	272	338	13.30
below	1.80	861	9890	8340	2500	801	3730	104	49	36	42	2.21
West	2.88											
below	1.84											
West	2.62											
North	2.19	1670	21100	11300	3340	986	981	42	39	25	55	0.51
below	1.76											

Nitrogen (N) is in percent (%) of sample; other nutrients are in parts per million (µg/g).

(Table is continued from the previous page.)

Location	N	P	K	Ca	Mg	S	Fe	Mn	Bo	Cu	Zn	Co
White clover												
West												
below	2.48											
North	2.20	1010	7380	7880	6510	1060	14100	425	10	52	64	9.60
below	1.60	1600	18900	12200	3290	1220	3400	105	27	18	65	2.03
Red clover												
West	2.46											
below	2.39											
West												
below	2.24											
North	1.73											
below	1.25											

Nitrogen (N) is in percent (%) of sample; other nutrients are in parts per million (µg/g).