



Long-term Lichen Community Monitoring Remeasure in Bering Land Bridge National Preserve

2019 Data Summary

Natural Resource Report NPS/ARCN/NRR—2022/2466



ON THE COVER

A volcanic rock on the Lost Jim Lava Flow surrounded by a thick mat of *Cladina stellaris* and other fruticose lichens.

NPS / PETER NEITLICH

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Contents

	Page
Figures.....	iv
Tables.....	iv
Abstract.....	v
Introduction.....	1
Methods.....	2
Results.....	4
Species richness.....	4
Abundance.....	4
Species pool similarity	5
Indicator species analysis	6
Ordination.....	9
Functional group cover change	11
Discussion	15
Future Directions	16
Literature Cited	17

Figures

	Page
Figure 1. ARCN-wide lichen community composition long-term monitoring plot locations, 2003–2007 in WEAR and 2012 in GAAR.	1
Figure 2. Correlation between number of species in a given plot over the two measurements.....	4
Figure 3. Distribution of recorded abundances by each observer.	5
Figure 4. Histogram of percentage of species in common between re-measures.	6
Figure 5. Shift in percentage overlap of species pools between the unsynonymized and synonymized datasets.....	8
Figure 6. Change in Bray-Curtis dissimilarity between the unsynonymized and synonymized datasets.....	9
Figure 7. Ordination with binary presence-absence data.	10
Figure 8. Ordination with all abundance categories < 4 grouped together.	11
Figure 9. Scatterplots comparing all cover estimates measured between iterations.	13
Figure 10. Violin plot of changes in estimated shrub cover between 2003 and 2019.	14

Tables

	Page
Table 1. Abundance categories.	2
Table 2. Functional groups recorded.....	3
Table 3. Indicator species for each measurement year.....	7
Table 4. Paired t-tests between estimates of plot cover in 2003 and 2019.....	12

Abstract

In the summer of 2019, a subset of 33 lichen community composition plots in Bering Land Bridge National Preserve (BELA) were re-visited. A total of 78 plots were installed in 2003 in BELA, part of 313 plots across the Arctic Network in 2004–2012 to inventory lichen diversity, and establish a baseline of lichen diversity, cover and biomass. Plots record lichen species identity and abundance, estimate abiotic and functional group cover, and capture a number of environmental covariates. We present analysis of the data for changes in lichen community species richness, similarity, community-wide change, and shrub increase across remeasures. We found similar species richness at re-measured plots, but there was low correspondence between species pools. We did not detect directional shifts in lichen communities. No notable change in shrub cover was found between 2003 and 2019. For future remeasures, we conclude that sampling a subset of plots is adequate for monitoring and advantageous in terms of budget, time, and collections management. However, greater efforts are needed to ensure taxonomic consistency between remeasures.

Introduction

The objective of this study is to detect major changes in lichen community composition, diversity, and abundance. ARCN has an existing set of 313 lichen community composition plots that were established by probabilistic design in the four western ARCN parks during the period 2003–2007 (Fig. 1; Holt and Neitlich 2010a,b) and partly probabilistic design in GAAR in 2012 (Nelson et al. 2015). They were sampled using the national FIA lichen monitoring protocol (USFS 2011), with some adaptation to arctic conditions that are documented in the ARCN monitoring protocol (Swanson and Neitlich 2016). Data gathered include community composition and diversity in relation to environmental gradients such as climate, landform, and herbivory.

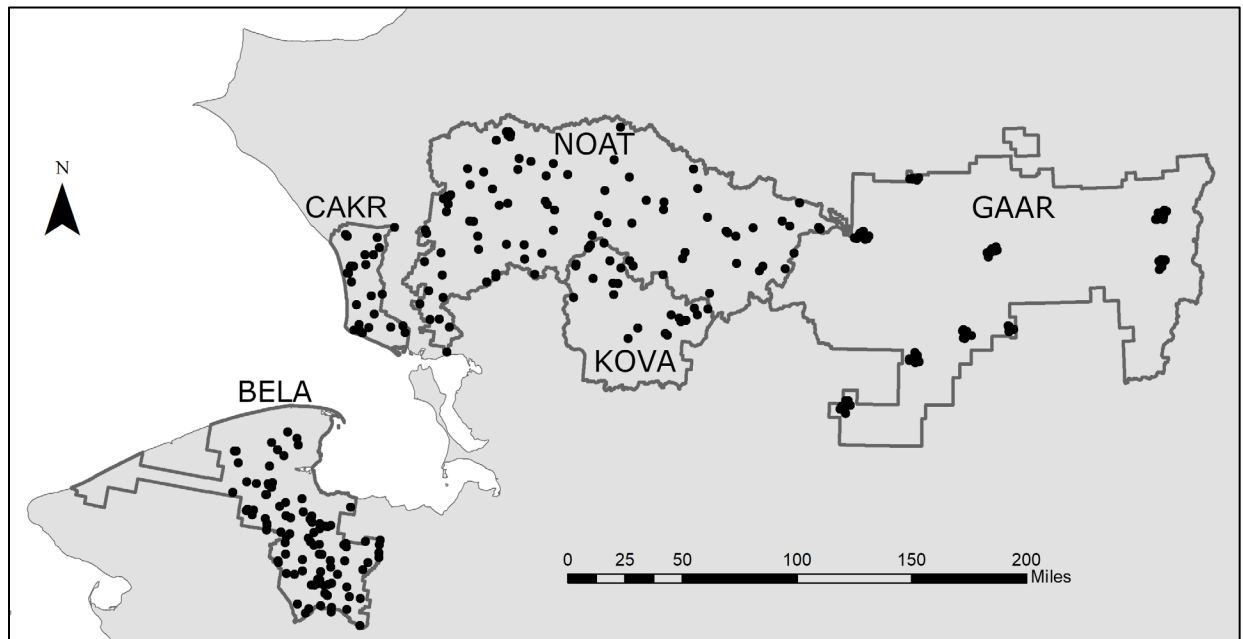


Figure 1. ARCN-wide lichen community composition long-term monitoring plot locations, 2003–2007 in WEAR and 2012 in GAAR.

Methods

These plots were sampled according to a modification of an established national monitoring protocol (USFS 2011). The modifications are described in section 3.3 of Swanson and Neitlich (2016) and consist mainly of a modified abundance scale to accommodate the dominantly ground-dwelling lichens of arctic environments (Table 1). The lichen monitoring plots, as described in the FIA protocols, cover an acre (0.37 ha). Plot searches are time-limited (2 hours) with the goal of recording as many macrolichen species as possible. Species not identifiable in the field are collected for later lab identification.

Table 1. Abundance categories.

Cover category	Abundance
1	1–3 thalli
2	3–10 thalli
3	<1% cover
4	1–5% cover
5	5–25% cover
6	>25% cover

Original plot locations were recorded with a Garmin GPS with an estimated < 15 m accuracy. These plots were installed prior to the ARCN monitoring program and were designed for a range management study on reindeer grazing in BELA (Holt 2008). It was not known whether they would be revisited. In 2019, plots were relocated using a Trimble GEO7x GPS unit. A magnet was buried at plot center and coordinates remeasured in order to be able to permanently relocate the plot.

Cover was visually estimated to the nearest percent for 10 functional group categories, along with 5 abiotic categories (Table 2). In 2003, shrubs were recorded in the categories of shrub (above knee height) and subshrub (below knee height), with dwarf shrubs such as *Dryas* recorded as forbs. In 2019, shrubs were recorded in two schemas, to better match other ARCN projects and facilitate comparison to the 2003 data.

Environmental characteristics recorded or calculated in 2003 (slope, aspect, heat load and incident radiation) were not re-recorded. Additional environmental features such as microfeatures, horizontal & vertical shape and the level IV Alaska Vegetation Classification (Viereck et al. 1992) class were recorded (Swanson and Neitlich 2016).

Table 2. Functional groups recorded.

Category	Description	Years recorded
Tree	Spruce, tree birch, aspen, or cottonwood, any size class	2019, 2003
Tall Shrub	Shrub birch, alder, or willow, > 1.5 m tall	2019
Low Shrub	Shrubs 0.2 to 1.5 m tall	2019
Dwarf Shrub	Shrubs < 0.2 m tall	2019
Gram	Graminoids	2019, 2003
Forb	Forbs	2019
Bryo	Bryophytes	2019, 2003
Lichen	Lichens (including both macrolichens and crustose lichens on all substrates)	2019, 2003
Macrolichen	Macrolichens	2019
Soil	Bare mineral soil plus gravel, particles up to 75 mm diameter	2019, 2003
Duff	Bare organic soil (duff)	2019, 2003
Rock	Exposed bedrock, boulders, and cobbles (down to 75 mm diameter)	2019, 2003
Water	Standing water	2019, 2003
Shrubs	Shrubs above knee height	2019, 2003
Sub Shrubs	Shrubs below knee height	2019, 2003
Other	Forbs, Dryas, and other dwarf shrubs	2019, 2003

Results

Species richness

Overall, species richness between the two measurements was similar (Figure 2). However, the correspondence between species richness is lower than we may have anticipated. It should be noted that (consistent with FIA protocols) previous species lists were not used during the plot searches, an approach that likely would have led to much greater correspondence given the high presence of taxonomically challenging *Cladonia* species.

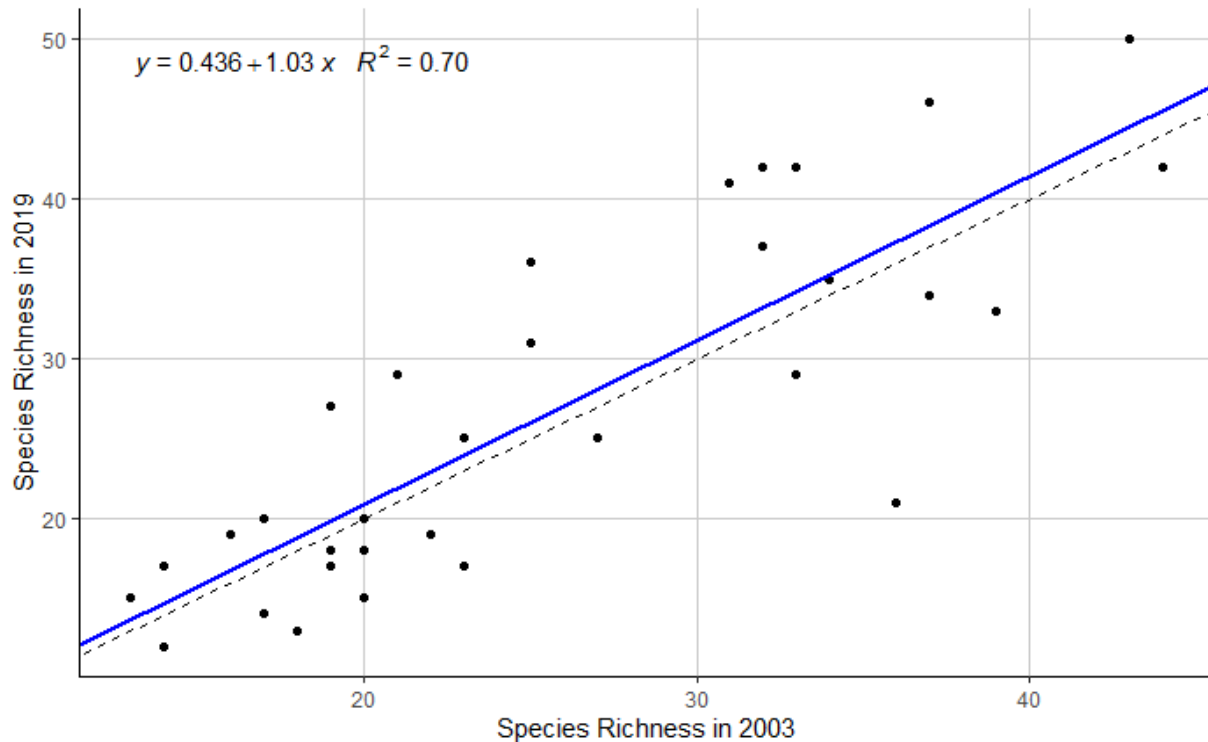


Figure 2. Correlation between number of species in a given plot over the two measurements. Linear regression in solid blue line, equation in the upper left, $x = y$ dashed line.

Abundance

There is a noted difference in the distribution of abundances recorded between iterations. Both 2019 observers (CJHM & PNN) had the highest number of observations recorded as '3' (<1%, Table 1), whereas Emily Holt (EAH) in 2003 had an a left-skewed distribution of abundances (Figure 3).

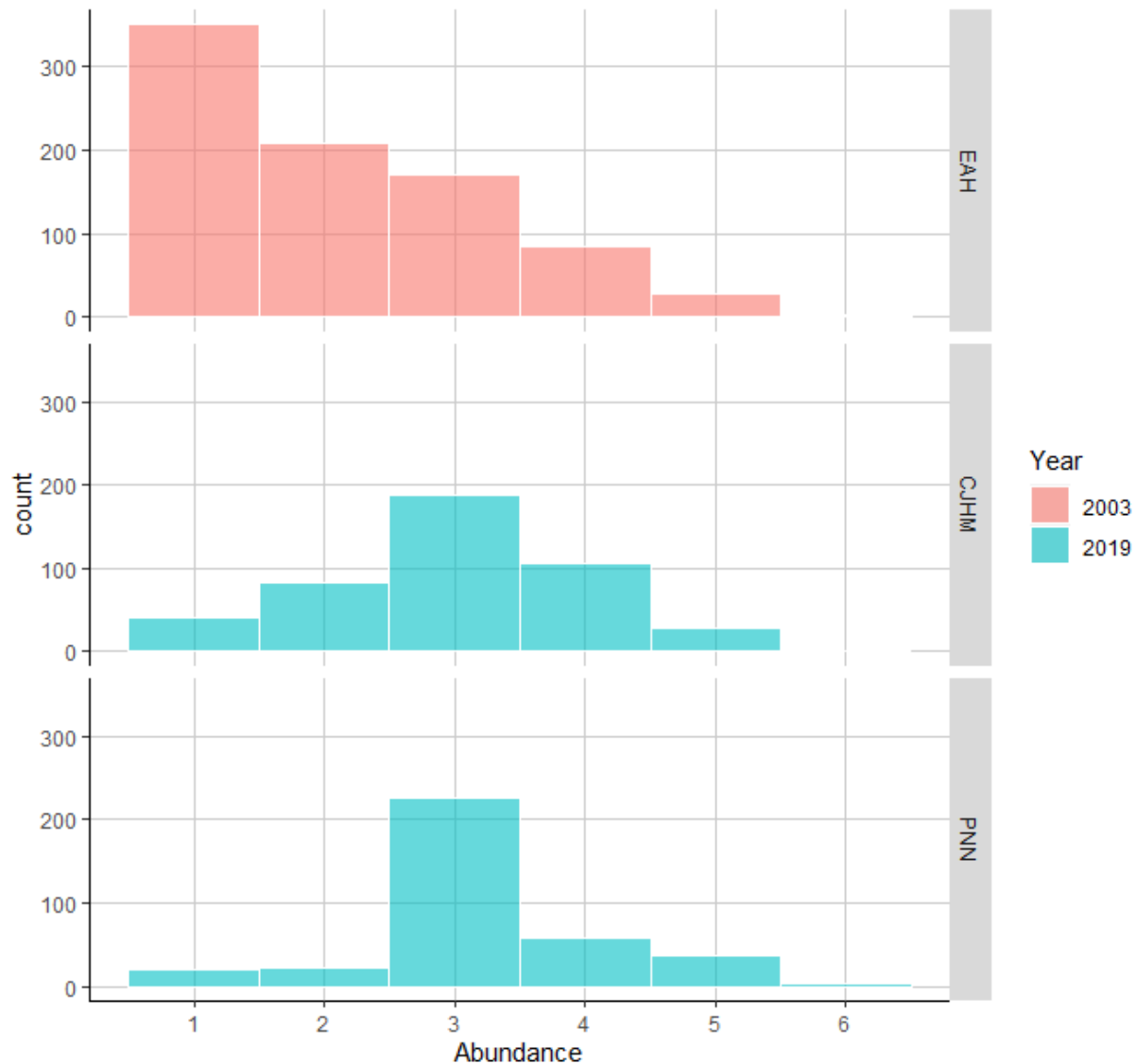


Figure 3. Distribution of recorded abundances by each observer.

Observer bias inevitably comes into effect with estimating cover visually, which is likely exacerbated by how large the plots are. The distribution of observations between observers in 2019 were fairly similar. Typically, plant abundance distributions are strongly left-skewed, but <1% cover would be the lowest end of the scale for these distributions. It may be worth comparing other ARCN lichen plot observer's records for these types of data to ascertain bias.

Species pool similarity

One of the most important metrics we were interested in for this remeasures is how many species found by Holt in 2003 were noted in the 2019 re-measure. We found surprisingly poor correspondence in species pools between measurements (Fig 4.), in spite of typically having similar species richness.

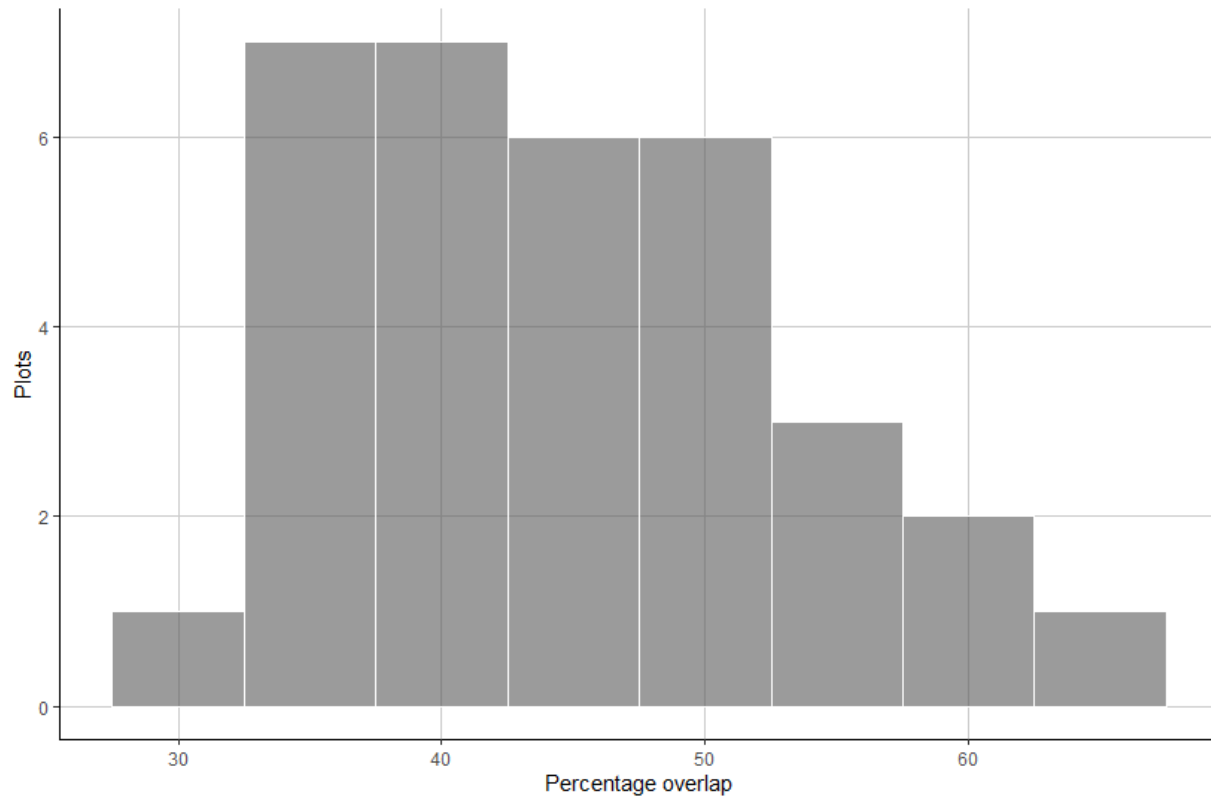


Figure 4. Histogram of percentage of species in common between re-measures.

A preliminary review of the species list led us to believe that this may be an artifact of identification. Lichens have notoriously difficult taxonomy. The 2003 collections were identified by graduate student Emily Holt working out of the McCune lab in Oregon State University. The 2019 collections were identified by the authors and Trevor Goward, noted lichen expert in Clearwater, British Columbia. Taxonomic concepts have changed in the intervening 16 years, and observers could have made mistakes in either iteration.

Indicator species analysis

We used an indicator species analysis (De Caceres et al. 2010, via R package ‘indicspecies’) to look for species strongly associated with year. This revealed a whole suite of species found almost exclusively in one measurement or another, with clear parallels in the other year (Table 3).

Table 3. Indicator species for each measurement year.

Year	Species	statistic	p-value
2003	<i>Cladonia coccifera</i>	0.633	0.001***
	<i>Cladonia subfurcata</i>	0.605	0.001***
	<i>Cladonia macroceras</i>	0.55	0.001***
	<i>Peltigera leucophlebia</i>	0.492	0.005**
	<i>Parmelia sulcata</i>	0.461	0.014*
	<i>Cetraria muricata</i>	0.426	0.035*
2019	<i>Cladonia borealis</i>	0.594	0.020*
	<i>Cladonia crispata</i>	0.608	0.014*
	<i>Cladonia gracilis</i> subsp. <i>vulnerata</i>	0.584	0.004**
	<i>Cladonia gracilis</i> subsp. <i>gracilis</i>	0.853	0.001***
	<i>Peltigera britannica</i>	0.522	0.005**
	<i>Parmelia omphalodes</i>	0.531	0.016*
	<i>Cetraria sepincola</i>	0.522	0.003**
	<i>Melanohalea septentrionalis</i>	0.461	0.011*
	<i>Cladonia chlorophaea</i>	0.461	0.013*
	<i>Allantoparmelia alpicola</i>	0.461	0.015*
	<i>Arctocetraria incurva</i>	0.426	0.033*
	<i>Allantoparmelia almquistii</i>	0.389	0.049*

* Significant at p-value ≤ 0.05 , ** significant at p-value ≤ 0.01 , *** significant at p-value ≤ 0.001

In summary, in 2003 *Cladonia coccifera* was used instead of *C. borealis*, *Cladonia subfurcata* was used instead of *C. crispata*. Almost no *Cladonia gracilis* (of any subspecies) was recorded in 2003, instead there were many instances of *Cladonia macroceras* (a highly similar species). *Peltigera leucophlebia* was recorded instead of *P. britannica*, *Parmelia sulcata* instead of *P. omphalodes*, and *Cetraria muricata* instead of *C. aculeata*. Additionally, no instances of the twig-dwelling *Cetraria sepincola*, *Melanohalea septentrionalis* or either of the small, rock-dwelling species of *Allantoparmelia* were recorded in 2003 (primarily because searching was focused more on terrestrial than epiphytic or saxicolous species for this reindeer grazing study). Some of these are updates to understandings of the flora, e.g., *Cladonia borealis* is now recognized as the predominant North American species (Goward 1999; McCune & Geiser 2009). Others are potentially errors in identification (e.g., *Parmelia sulcata*).

Because of the clear one-to-one correspondence between these taxa in the data, we created a new, temporary data set to reduce these errors, and facilitate better comparison. The above-mentioned

species pairs were synonymized to the 2003 species codes, and species not recorded in 2003 were removed from the data set.

Species overlap increased by an average 8% after synonymization (Figure 5).

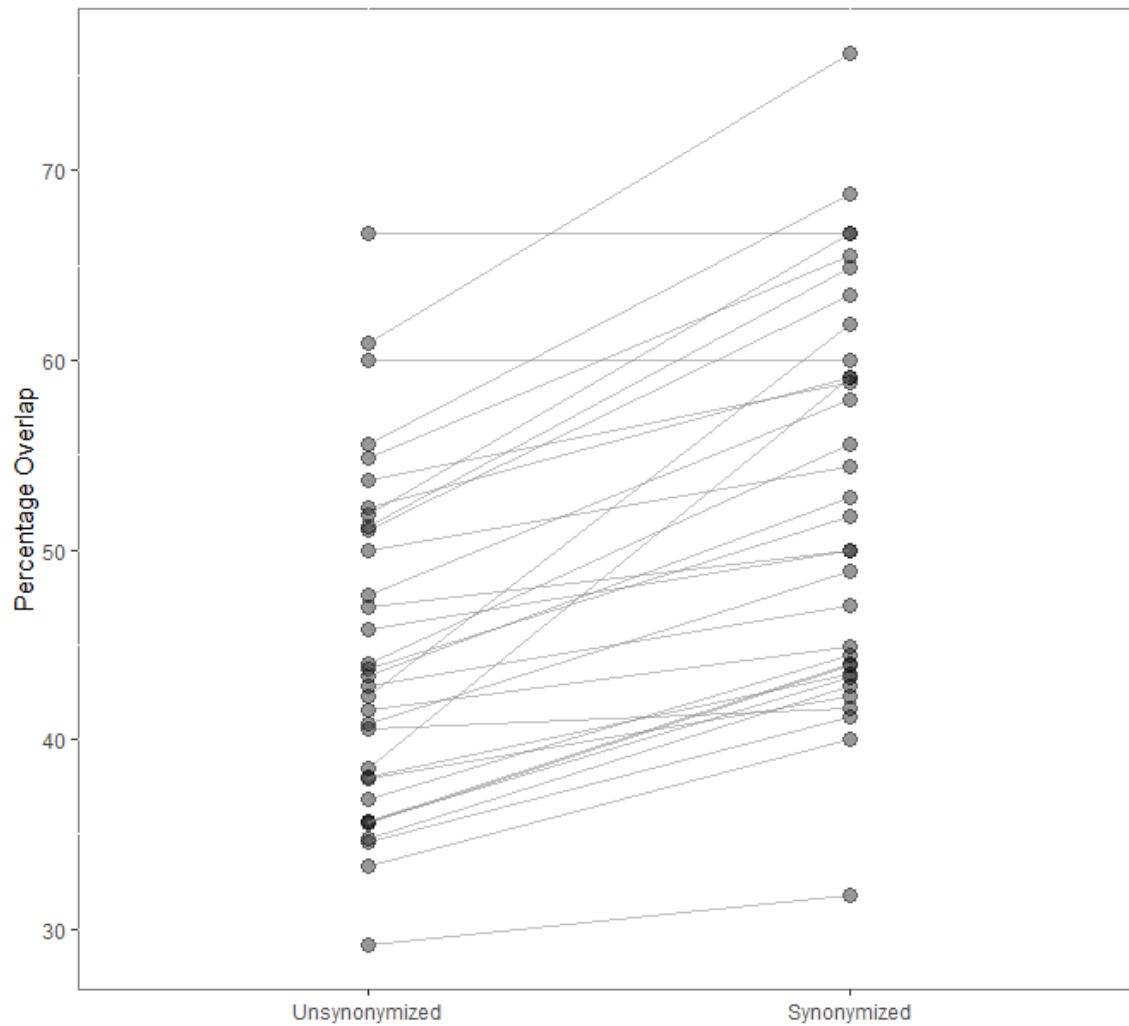


Figure 5. Shift in percentage overlap of species pools between the unsynonymized and synonymized datasets.

Similarity indices showed similar results (Figure 6).

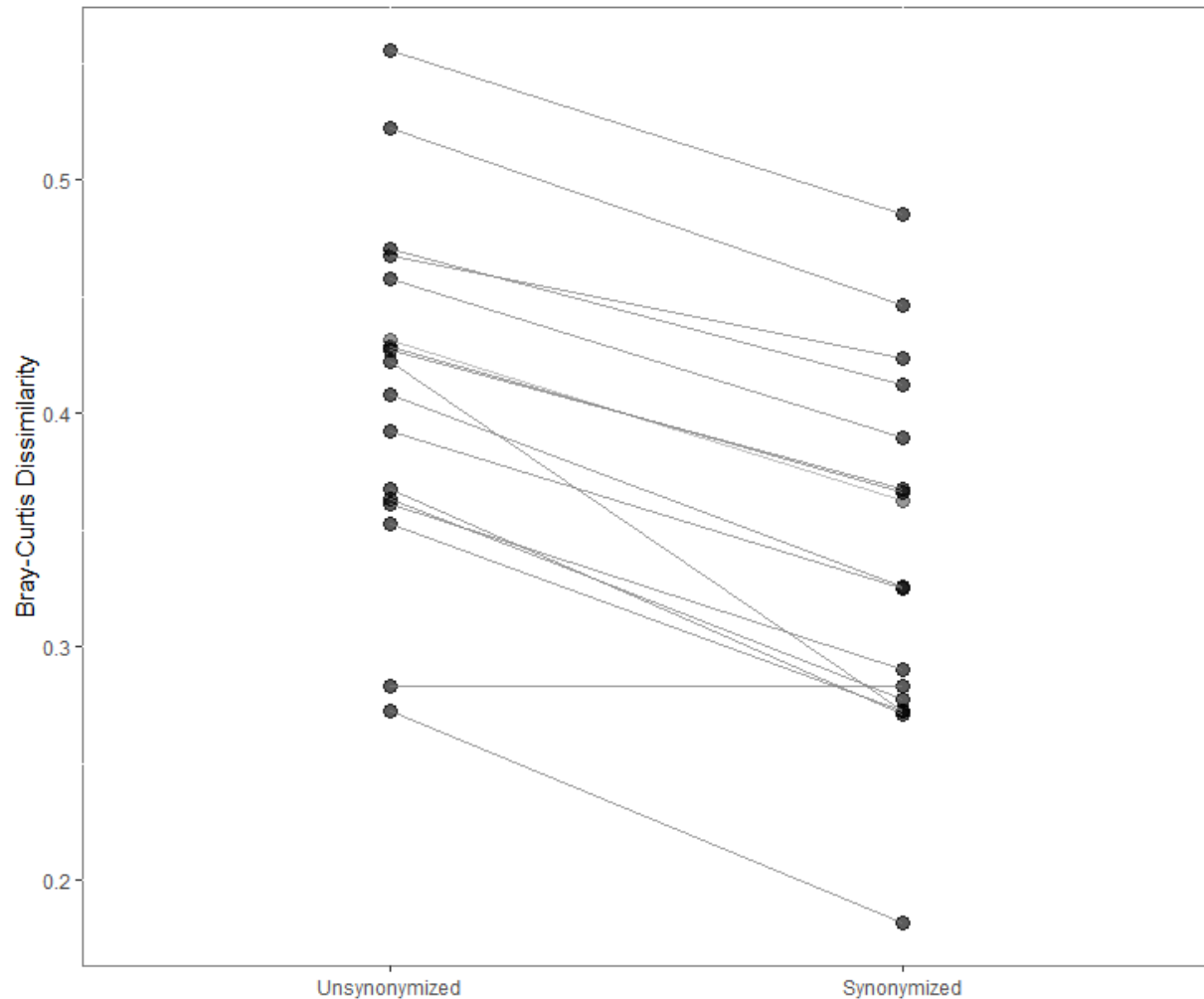


Figure 6. Change in Bray-Curtis dissimilarity between the unsynonymized and synonymized datasets.

Ordination

Using the synonymized species data, we used non-metric dimensional scaling (NMDS) ordination to explore changes in species space. We tried ordination tests using the following data transformations:

- all abundance data transformed into binary presence-absence data,
- the abundance data untransformed, and
- the abundance data changed such that all cover categories <4 were combined.

For each approach, ordinations were run with all species, species with at least 2 occurrences, and species with at least 3 occurrences. Removing rare species had little impact on the ordination, so we present ordinations for the binary & combined abundance data, both with species < 3 occurrences removed (Figures 5 & 6). Remeasures are connected by vector arrows, the head of the arrow pointing to the 2019 plot.

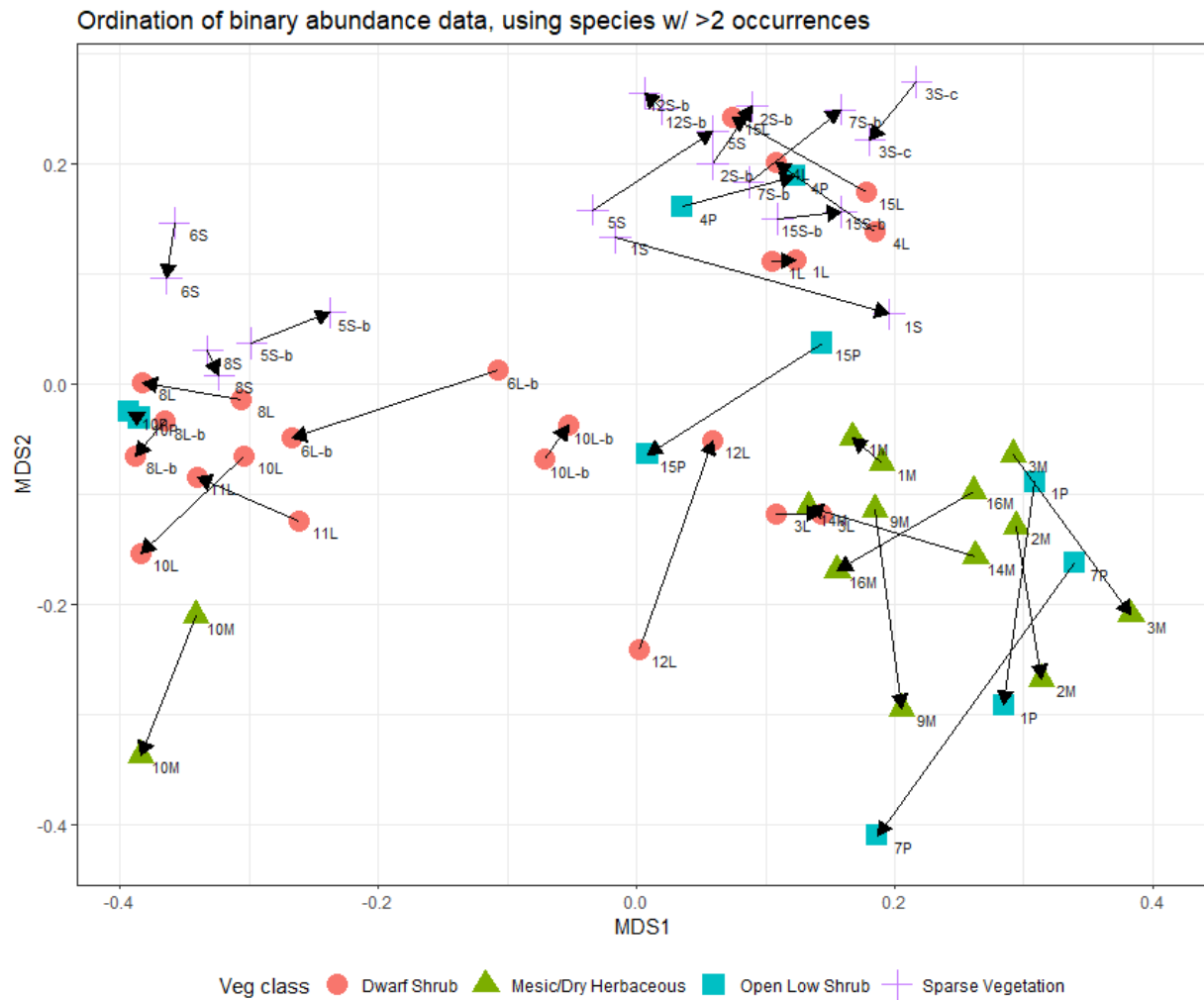


Figure 7. Ordination with binary presence-absence data.

Table 4. Paired t-tests between estimates of plot cover in 2003 and 2019.

Cover group	statistic	mean difference	p-value
Subshrub	0.10	0.18	0.9246
Shrub	4.90	4.41	0.0000
Forb & dwarf shrubs	-3.64	-12.95	0.0010
Graminoids	3.14	9.42	0.0036
Bryophytes	0.75	2.08	0.4604
Lichen	-1.26	-3.00	0.2181
Soil	-0.36	-0.44	0.7190
Duff	-7.08	-14.56	0.0000
Rock	2.24	6.24	0.0318
Water	2.65	1.85	0.0123

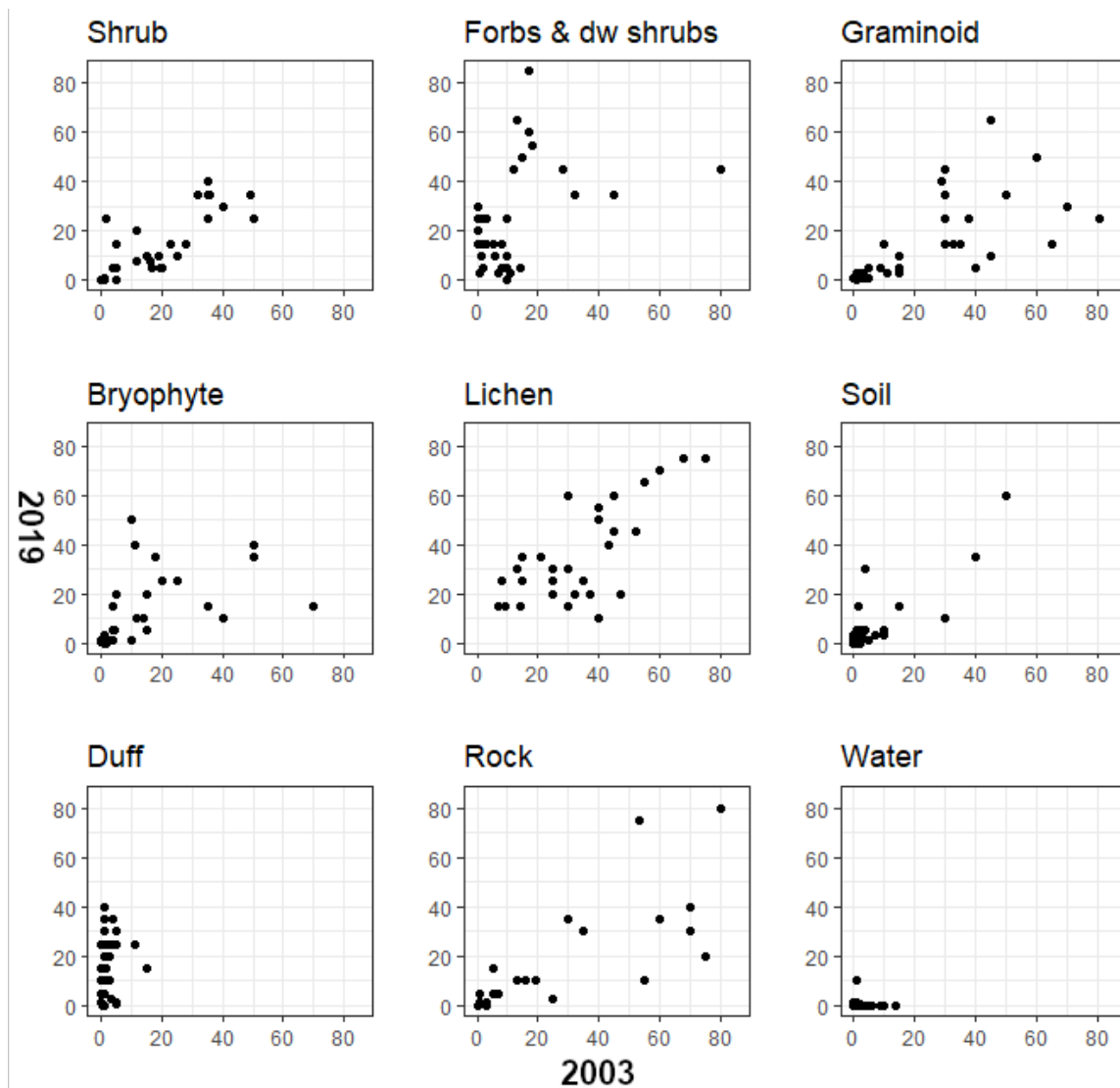


Figure 9. Scatterplots comparing all cover estimates measured between iterations.

Overall, there is a poor correspondence between estimates in 2003 and 2019, even for categories such as rock and bryophytes, which are unlikely to change rapidly.

A major metric of interest is shrub increase, given the ongoing shrubification of the arctic (Sturm et al. 2003; Tape et 2006; Myers-Smith et al. 2011). Shrubs were recorded in two categories in 2003: shrub (above knee height) and subshrub (below knee height). In 2019, shrub cover was recorded in this schema, as well as another more fine-grained set used in other ARCN projects. Relationship between shrub estimates is weak at best. There does not seem to be a clear pattern of increase—in fact, on average shrub cover went slightly down (Figure 10).

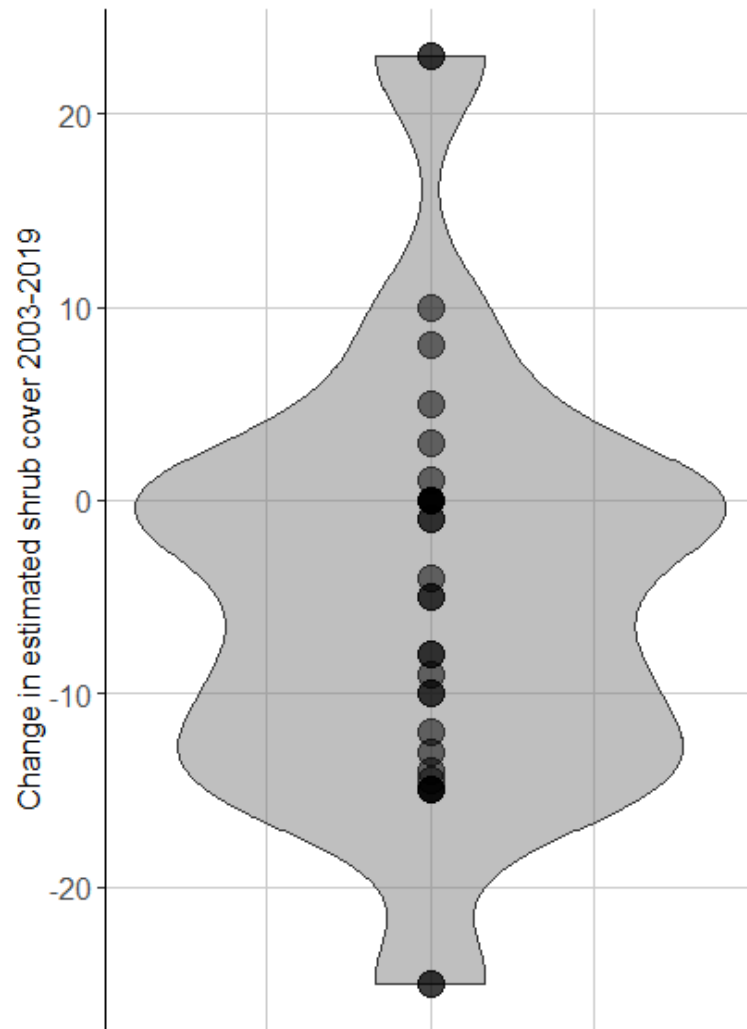


Figure 10. Violin plot of changes in estimated shrub cover between 2003 and 2019. Width is proportional to the count of plots.

Discussion

The BELA lichen remeasurement yielded less repeatable data than expected. The main factors driving the differences in data sets were:

- Different taxonomic treatments on the plot and changing taxonomy over time. This is especially problematic in BELA where such a high proportion of the diversity comes in *Cladonia*, which is an especially difficult and taxonomically complex genus. This issue may lessen in areas with forested habitat, as the proportion of *Cladonia* of the plot diversity decreases (and taxonomic repeatability presumably increases).
- Observer bias. The original purpose of this study was to look at grazing effects, thus epiphytes and saxicolous taxa were undersampled in 2003.
- Interannual variation. Variations in weather led to issues such as one plot being largely snow covered on resample.
- Drift in abundance concepts. Ocular estimation is especially subject to observer differences, and the large 0.37 ha plot can make abundance repeatability more challenging. The coarse abundance scale was designed to mitigate these differences, but they persisted nonetheless. Abundance distributions of other years need to be evaluated to determine if revisions should be made for greater repeatability.

In spite of these data issues, the ordinations do not depict large wholesale changes; most remeasured plots are close in species space to the 2003 plots. In BELA, change in lichen communities over a 16 year interval is likely to be modest unless a major disturbance occurs (e.g., fire, grazing, thermokarst). It is therefore possible that in spite of the noisy data, the ordinations correctly diagnosed the lack of significant change. Better data match between the two years would have allowed for greater confidence of this assessment.

One of the major questions we posed in this remeasure was whether our 33-plot subset of the original panel of 79 plots would be adequate to detect change. Our subset was designed to capture a fairly balanced proportion of plots in all areas of known gradients (e.g., vegetation, geology, climate). Given the high correspondence of remeasured plots to original plots in species space (in spite even of the high noise from data issues), we feel confident that subsetting is a good approach to save effort and money. If anything, doubling the number of plots would probably lead to even noisier ordinations, thus compounding the data issues already enumerated.

Future Directions

There are multiple possibilities for considering how to use these data. First, it is worth considering that the BELA plots predated the ARCN lichen monitoring protocol, and probably has the highest potential for data comparability problems between remeasurements for study design reasons addressed above. Baseline surveys in the other 4 parks occurred after the protocol was finalized to include twig- and rock-dwelling lichens; habitats in those parks are also far more diverse and rich in non-*Cladonia* taxa that are more stable and easier to confidently identify in the field. It is likely that data issues would be proportionally fewer in other parks.

There are a number of choices we could make going forward:

- 1) Treat these plots as non-repeating surveys that are appropriate for training/ground-truthing remote sensing imagery and large-scale assessments such as Environment Canada's use of these data in an assessment of lichens of boreal North America. As the cost of imagery falls and resolution increases, opportunities to use these plots in that way may become important. The Terrestrial Vegetation and Soils vital sign does have another protocol (vegetation nodes, Swanson and Neitlich 2016) that measures lichens more quantitatively, but with less taxonomic discrimination. The taxonomic lumping in that protocol could potentially be a positive for repeatability, though it does miss most of the diversity and the potential to detect changes in diversity.
- 2) Plan to remeasure a subset of the plots of other parks but with:
 - a) Special attention to taxonomic correspondence prior to going into the field. Using the many specimens collected in earlier measurements could help resolve differences. Future measurements could also use the species list of prior samples, in order to focus the search effort and lead to fewer missed species.
 - b) Examination of the abundance distribution of the first measurement as a guide to standardizing the remeasurement. If the abundance distribution doesn't skew far left as the 2003 BELA measurement did, this may not be necessary.

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