Causes of recent (1985-2015) landcover changes in western Banks Island, Northwest Territories: A wild goose chase

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Background

Many northern ecosystems are experiencing rapid changes to vegetation, permafrost, and hydrology [*1*,*2*]. Remote sensing is an effective way to detect ecological changes across large areas [*3*,*4*,*5*]. Landsat Tasseled Cap (TC) greenness and wetness trends from 1985-2015 show there are concentrated areas of declining vegetation productivity and moisture across the Banks Island Migratory Bird Sanctuary No. 1 (BIMBS1). The lesser snow goose (*Chen caerulescens caerulescens*) population on Banks Island has almost tripled since 1976 [*6*] and may be driving observed vegetation changes. However, overlapping declines in moisture may also be contributing to vegetation changes.

Objective: Explain the declines in vegetation productivity in the BIMBS1.
Hypothesis 1: Declines in vegetation productivity are related to overgrazing by the expanding lesser snow goose population.
Hypothesis 2: Declines in vegetation productivity are related to reduced surface water and soil moisture.

Study Area

The BIMBS1 is located on Banks Island, Northwest Territories (Figure 1). There is only one permanent settlement on Banks Island, the Inuvialuit community of Sachs Harbour.

BIMBS1 provides nesting grounds for over 95% of the western Arctic lesser snow goose population [*6*,*7*]. Topography consists of gently rolling uplands, intersected by west flowing rivers and their floodplains [*7*]. The area is also extensively vegetated, relative to other areas in the northern Arctic [*6*].

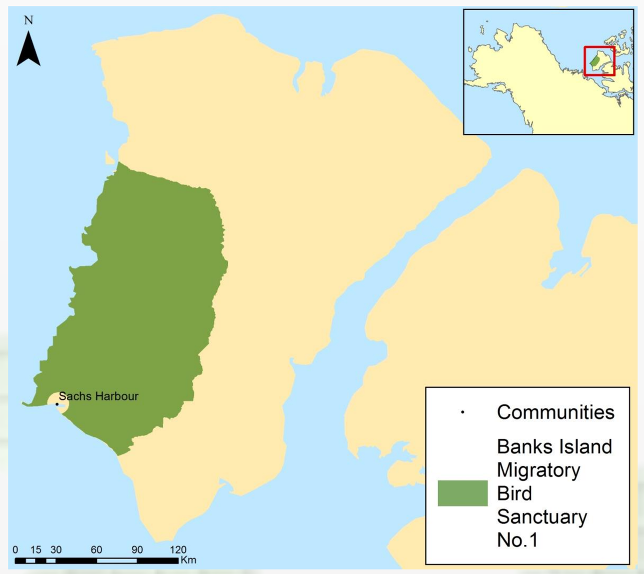


Figure 1: Banks Island and the BIMBS1. Inset map shows Banks Island as the western most island of the Canadian Arctic Archipelago.

Methods

Landsat scenes between 1985-2015 were Tasseled Cap (TC) transformed to measure trends in: brightness (TCB), greenness (TCG), and wetness (TCW) [*3*]. Field sampling was conducted at 18 sites within alluvial terraces. At each site, 11 plots were established to measure vegetation, soil, and goose habitat use. Site locations were selected using Local Indicators of Spatial Association (LISA) statistics [*8*] (Figure 2). The 18 sites were divided into 3 classes:

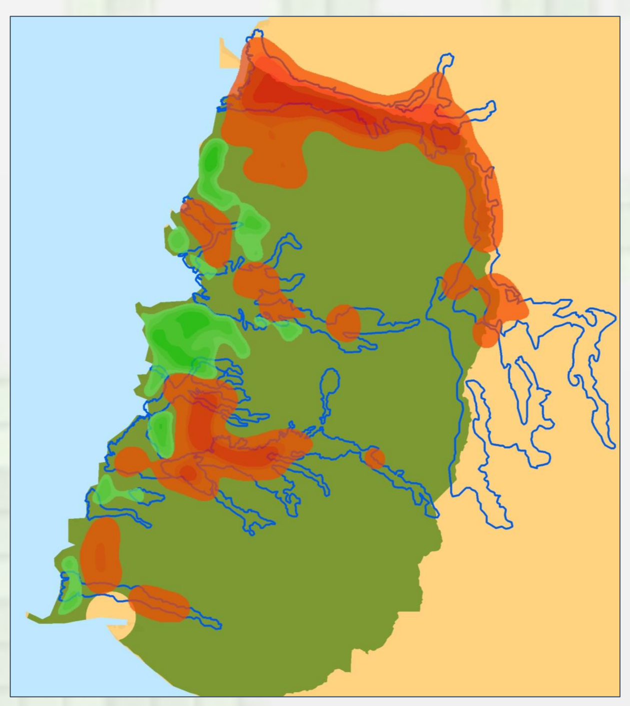
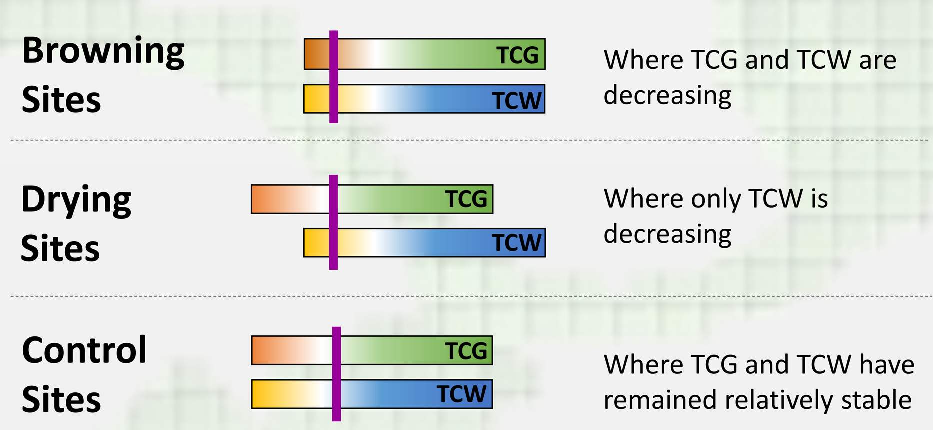


Figure 2: Clusters of low TCG trends (orange) and high TCG trends (light green), determined by LISA statistics [*8*]. River floodplains are delineated in blue.



Non-metric multidimensional scaling (NMDS) and generalized linear mixed models (GLMM) [*9*] were used to assess differences in vegetation and goose habitat use among site types (Figure 3). All plots that landed within former pond basins were removed from these analyses.

Random forest decision trees were used to assess spatial and topographic variance in TCG trends. Variables included land cover, latitude, longitude, and metrics derived from the 10m resolution ArcticDEM.

A histogram breakpoint method [*5*] was used to calculate sub-pixel water fractions from TCW data.

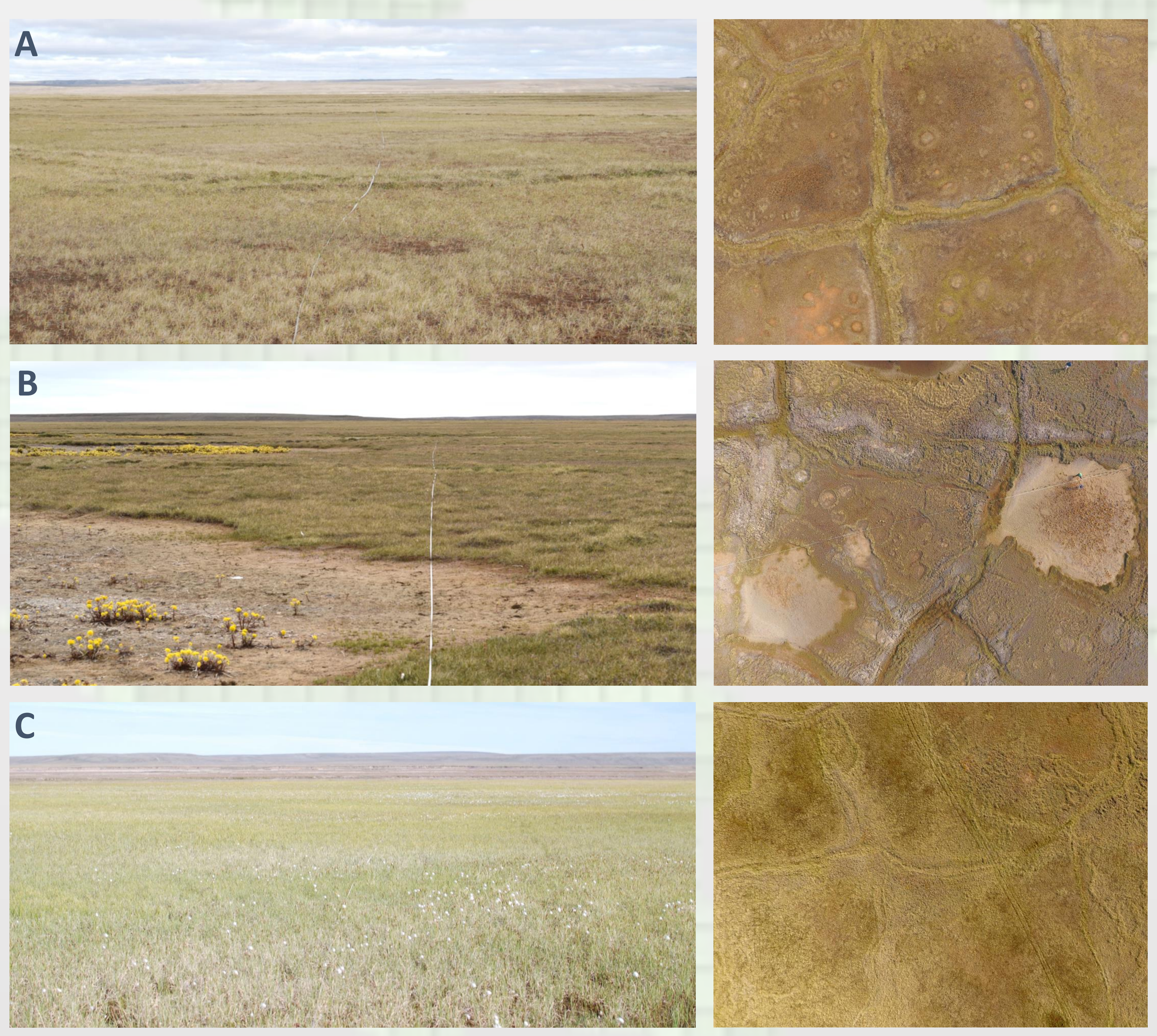


Figure 3: Oblique and aerial photographs of site types. A is the browning site type, B is the drying site type, and C is the control site type.

Theil-Sen linear regression was then used to test for per-pixel trends in surface water between 1985-2015.

Results & Discussion

Vegetation community composition was relatively similar among site types (Figure 4), without obvious differences that could produce browning TCG signals.

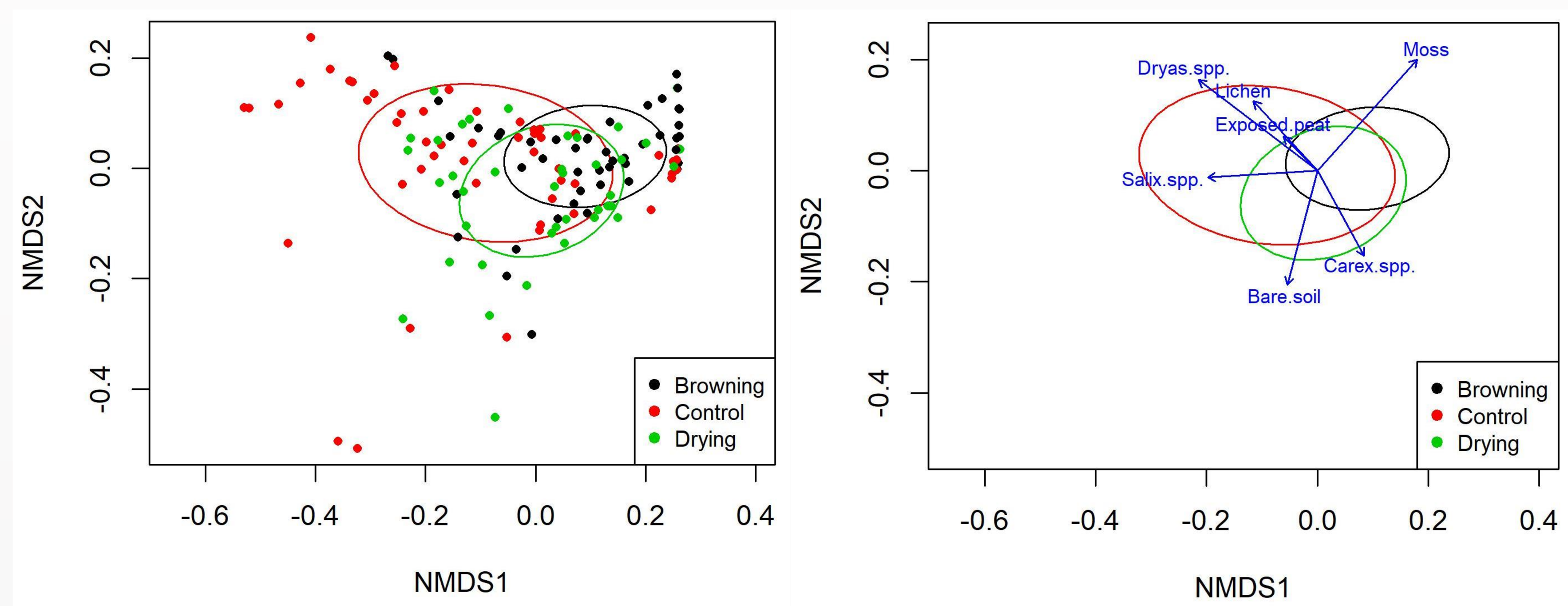


Figure 4: NMDS ordination plots showing similarity of vegetation community composition among site types. Points that are closer together are more similar in composition. Arrows show the influence of vegetation types on point placement.

Pairwise comparisons of least squares means [*9*] showed browning sites had significantly higher proportions of dry moss to moss cover ($p < 0.05$) (Figure 5), which indicates low moisture conditions. Most bryophytes are very resilient to drought conditions, but poor internal regulators of water when external conditions are unfavorable [*10*].

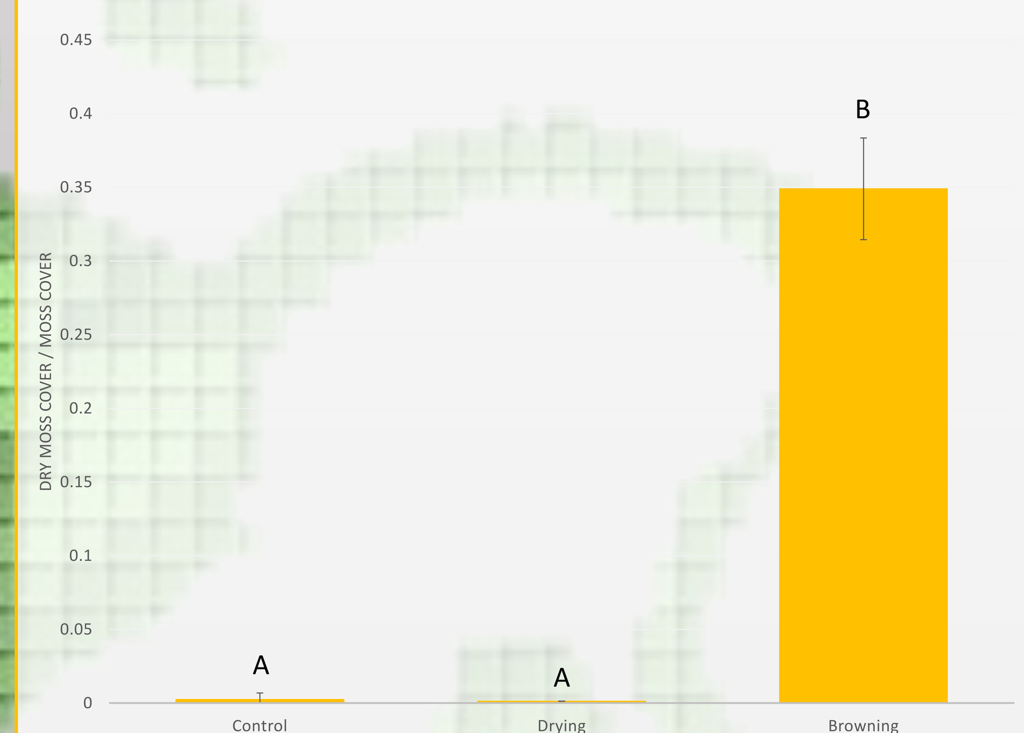


Figure 5: Proportion of dry moss to total moss among site types. Error bars are standard error. Bars with different letters are significantly different [*9*].

Increasing proportions of dry moss could be producing browning TCG signals (Figure 6). TCG is heavily influenced by the visible red wavelength [*11*]. Visible red light is reflected more by unhealthy vegetation, compared to healthy, green vegetation.

Figure 6: Photos show moss cover characteristic of control (left) and browning (right) sites.

Goose grubbing was significantly higher at browning sites ($p < 0.05$), but all other measures of goose habitat use did not suggest that geese were using browning sites more (Figure 7).

However, goose grubbing is known to increase evaporation in soils, and intensive goose foraging can lead to increased cover of dry moss and exposed peat [*12*].

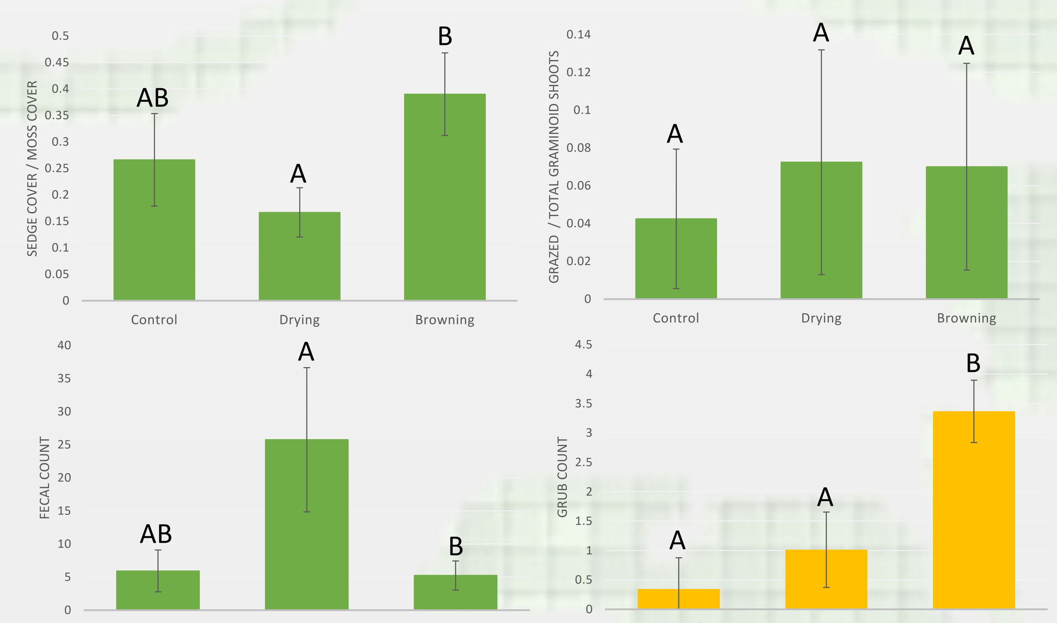


Figure 7: Lesser snow goose habitat use among site types. Error bars are standard error. Bars with different letters are significantly different [*9*].

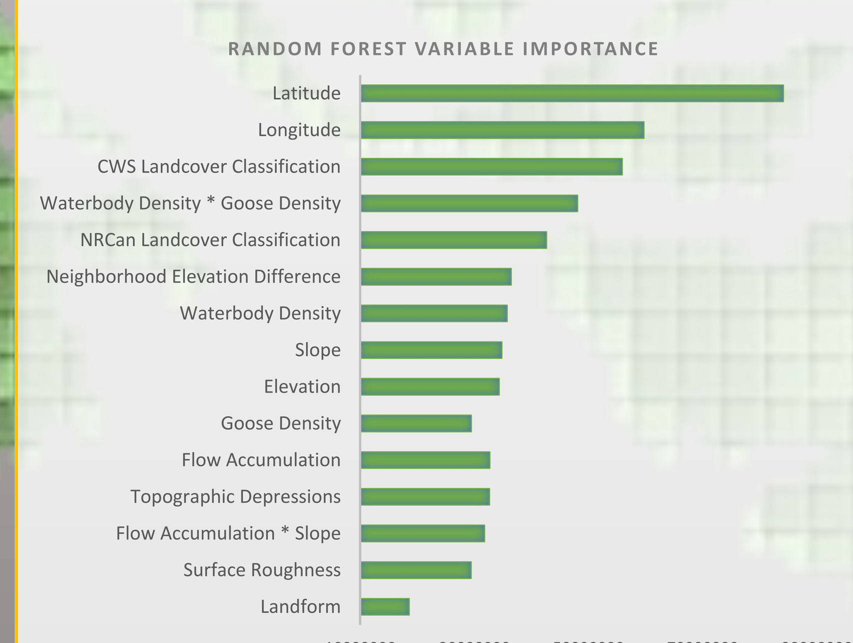


Figure 8: Variables used in random forest regression and their relative importance values.

40.98% of the variance of TCG trends across low-lying areas in the BIMBS1 were explained by random forest decision tree regression (Figure 8).

This analysis indicates that browning TCG trends are associated with northern latitudes, wetter habitat types, and wet areas with high observed goose densities.

Within the 6 major river floodplains of the BIMBS1, sub-pixel water fraction analysis suggests there has been a net loss of 11.14 km^2 of surface water (Figure 9).

Figure 9: Net change in water cover between 1985-2015 in the BIMBS1 major river floodplains. Estimates from sub-pixel water fraction analysis.

Field sampling confirmed that drying/draining of shallow tundra ponds occurred in both drying and browning sites, but not in control sites (Figure 10).

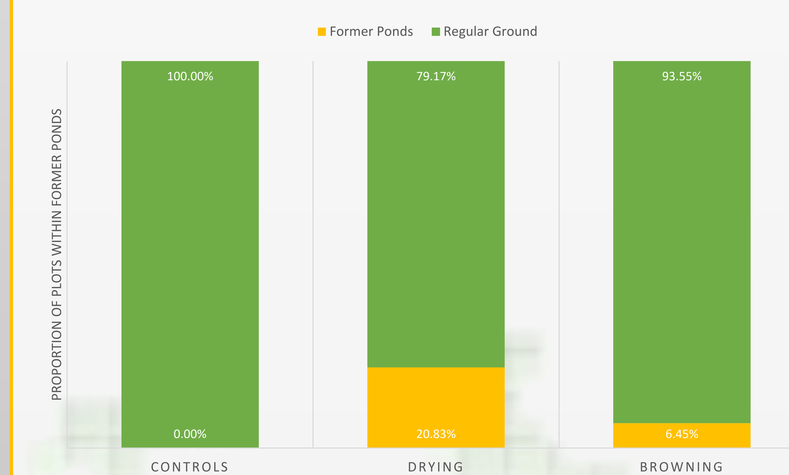


Figure 10: Percentage of plots that landed within former pond basins for each site type.

Drying/draining shallow tundra ponds are also likely contributing to increased dry moss cover and reductions in TCG.

Conclusion

Observed declines in vegetation productivity are likely related to increasing proportions of dry moss in wet sedge habitat. This shift has likely been caused by a combination of snow goose grubbing and climate induced changes to hydrology. Future studies exploring the effects of goose grubbing at different moisture levels, can help to clarify the relative contributions of these processes.

TC indices have been used here to detect drying occurring in multiple terrain types on Banks Island. Widespread overlap between declines in TCW and TCG highlight the importance of using multiple remote sensing indices to measure Arctic landscape change. These or similar remote sensing techniques can be used to continue monitoring habitat changes in the BIMBS1 and other areas of the northern Arctic.

Altered habitat in the BIMBS1 could impact the snow goose population and the other migratory bird species that use the area [*6*]. These changes are relevant to the Sachs Harbour Hunters and Trappers Committee and Canadian Wildlife Service, for appropriate management of the area.

Acknowledgements

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