Understanding Documented Vegetation Change in Northern Alaska

Robert D. Hollister & the Arctic Ecology Program

Biology Department, Grand Valley State University (GVSU)
hollistr@gvsu.edu

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The Arctic Ecology Program at GVSU (led by Robert Hollister) is monitoring change in tundra vegetation in relation to climate change at sites in northern Alaska. The research incorporates a warming experiment to forecast vegetation change due to climate change at four study sites established in the mid 90's as part of the International Tundra Experiment (ITEX) network. The larger project links findings from automated sensor platforms that measure a suite of vegetation surface properties at a near daily frequency (led by Steve Oberbauer) with medium-scale aerial imagery, using Kite Aerial Photography acquired throughout the growing season and satellite imagery (led by Craig Tweedie) to scale observed changes to the regional level **[PART A]**. The primary goal of the GVSU component of the project is to understand dynamics of vegetation change happening at the species level. Thus far we have shown major changes major changes in vegetation cover over time; however only some of these changes can be explained by regional warming trends. The weather in a given year can result in very large changes in vegetation cover which makes patterns of response due directly to warming difficult to detect. The observed changes in cover are due to both an increase in size of plants and a change in the number of individuals **[PART B]**. Plant growth is also shown to respond to many different abiotic patterns within a given year and a prior year. The complexity described above illustrate the importance of long-term observations necessary to document directional changes due to warming given the great variability between years **[PART C]**. These observations provide much more explanatory power because they are linked with an embedded experiment and a network of sites making similar measurements **[PART D]**. These findings provide the foundation for observations obtained by automated sensor platforms and remote sensing **[PART A]**.

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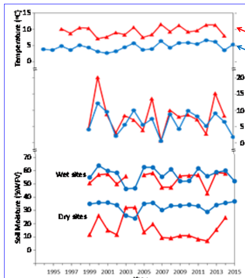

FIG 8. Mean temperature (top), total precipitation (middle), and mean soil moisture (bottom) at the sites in Atqasuk (red triangles) and Barrow (blue circles) in July during the years of the study. No precipitation or soil moisture information was available before 1999.[4]

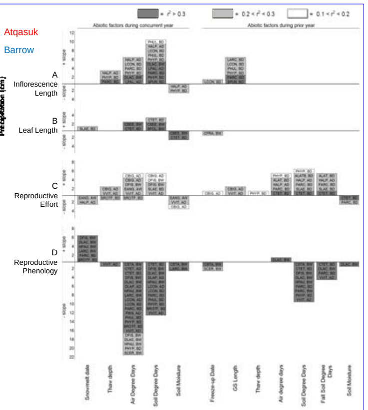

FIG 9. Relationships between plant traits and abiotic factors. The following plant traits were included: (A) Inflorescence height, (B) Leaf length, (C) Reproductive effort, and (D) Reproductive phenology. Each bar represents a species from a site that showed a significant linear mixed model where abiotic factors were considered fixed effects while plot and year were treated as random effects. The letters in the box represent the genus (first letter) and species (next three letters) at a site (last two letters) from a possible 27-40 species at a site combinations. While relationships varied greatly by species, phenology and growth showed the strongest relationship with abiotic factors from the current year and reproductive effort showed the strongest relationship with factors from the previous year.[1]

PART C.

The climate at the sites has varied over time, however there has been a trend toward warmer summers (**FIG 8**). There are many abiotic factors that correlate strongly with plant performance and these factors vary greatly by plant species (**FIG 9**). Therefore long-term monitoring is necessary to understand the causes of community change and to make meaningful predictions.

FIG 1. Photograph of one of the four ITEX sites taken from a kite showing the boardwalk, warming chambers and control plots of the dry site in Atqasuk. It also shows the tent and the transect where automated measurements are made and the matted trail to it.

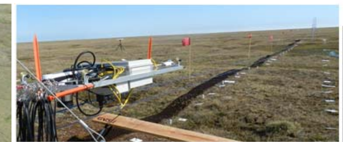

FIG 2. Photograph of the transect at Barrow where automated measurements of ecosystem properties are collected almost daily. The sensors are mounted on a platform which runs along cables to standardize the footprint of measurements and minimize disturbance due to researchers.[8]

PART A.

The overarching project is documenting change in terrestrial ecosystems at the landscape level in Barrow and Atqasuk, Alaska (**FIG 3**). Similar measurements are also made at Toolik Lake, Alaska and Thule, Greenland. The measurements collected in Barrow and Atqasuk are done collaboratively with Steve Oberbauer at FIU and Craig Tweedie at UTEP. The FIU group is using automated sensor platforms to document seasonal and annual changes in ecosystem parameters (**FIG 2**) which are correlated with visual observations made by the GVSU group (**FIG 9**). We then scale up our results from manual (~1 m^2 scale) and automated (100 m^2) observations to larger spatial scales (>1000 m^2) using medium-scale aerial photography (**FIG 1**) and high resolution remote sensing under the leadership of the UTEP group. The goal is to not only to document vegetation change, but also to understand the causes and consequences of vegetation change.

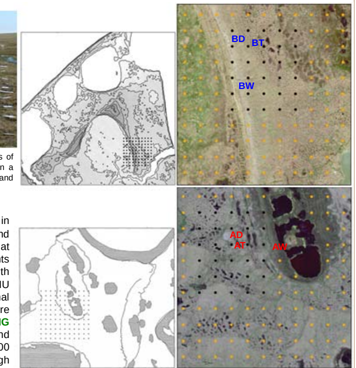

FIG 3. Images of the research locations at Barrow (top) and Atqasuk (bottom). Shown are both the general region and the grid established in the early 1990's to assist with long-term monitoring. The boardwalks associated with the ITEX warming experiments are denoted as following: AD- Atqasuk Dry, AW- Atqasuk Wet, BD- Barrow Dry, and BW- Barrow Wet. The location of the transect is denoted at AT- Atqasuk Transect and BT- Barrow Transect (**FIG 2**).

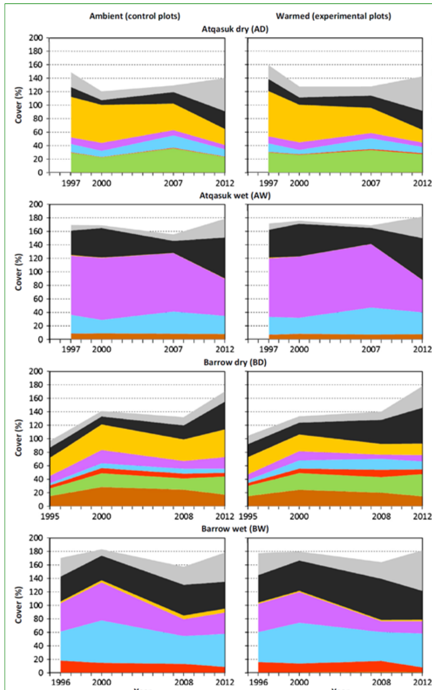

FIG 4. Change in cover over time in the ambient environment and with experimental warming at the four ITEX sites. The year measured is listed on the x-axis; vegetation sampling began the year after site establishment.[4]

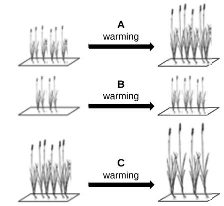

FIG 5. A schematic diagram illustrating three possible relationships between growth and density in graminoids that may correspond to increased cover with warming. Scenario (A), increased size of plants leads to greater cover. Scenario (B), increased density of plants leads to greater cover. Both scenarios (A) and (B) show a positive relationship with cover and both are possible if there is little to no competition. Scenario (C) represents an inverse relationship between growth and density, where an increased size of larger plants results in lower density due to competition. There is evidence of all three scenarios are occurring at the sites.[6]

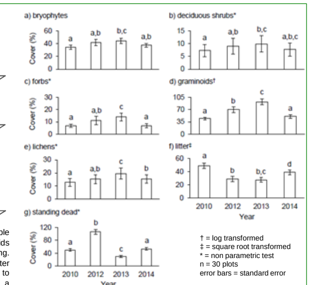

FIG 6. Mean cover of a) bryophytes, b) deciduous shrubs, c) forbs, d) graminoids, e) lichens, f) litter and g) standing dead over time at the Barrow grid (this is a subset of 30 plots denoted in black in **FIG 3**). Different letters indicate statistical significance between individual years determined by a 1-way repeated measures ANOVA or Friedman test.[3]

PART B.

There are major changes in vegetation cover that can be observed annually (**FIG 6, FIG 7**). This is especially true for graminoids (**FIG 5, FIG 6**). These changes have been shown to strongly correlate with climate factors other than temperature.[3,1] Therefore cautious is necessary when interpreting the vegetation changes occurring at the sites over the long-term (**FIG 8**). By comparing observed changes over time with those from the warming experiment we can clearly attribute only a few changes to regional warming; these include increased graminoids, decreased lichens, and taller plants.[4] These responses to warming are consistent with findings from analysis of the ITEX network[14,15] (**FIG 11**). As the project continues the focus is on meaningful prediction of future change and understanding the consequences of vegetation change on ecosystem processes.[12]

FIG 7. Photograph of vegetation sampling using a point frame.

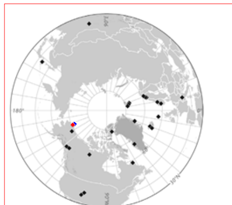

FIG 10. Map of the ITEX (International Tundra Experiment) sites included in recent synthesis activities. The blue box is Barrow and the red is Atqasuk.[15]

PART D.

The project is part of a network of collaborating researchers that are examining the response of tundra vegetation to warming known as the International Tundra Experiment (ITEX)(**FIG 10**, also see the ITEX logo under the poster title). By comparing the vegetation changes observed with those resulting from a warming experiment, we are able to better understand the causes for change.[4]

ITEX was originally designed, in the early 1990's, to examine plant response to warming by incorporating a warming experiment using open top chambers (OTC, seen in **FIG 1** and **FIG 7**) and a common measurement protocols that allowed for results from experiments conducted across the tundra biome to be analyzed together. The sites at Barrow and Atqasuk have been a major contributor to every ITEX synthesis effort (**FIG 11**).[7,9,10,14,15,21,23,29]

The focus of the ITEX network has recently expanded to become a powerful monitoring platform. The coupling of monitoring and experimentation allows for a much greater understanding of the causes of vegetation change. ITEX is widely considered one of the most successful research networks in the Arctic.

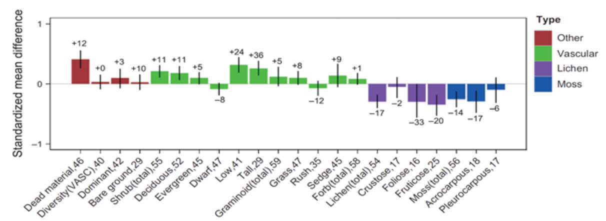

FIG 11. Average effects of warming on community attributes and growth form abundance from a synthesis of experimental warming studies conducted across the ITEX network.[2] Bars show the weighted mean effect size (standardized mean difference) based on intercept-only weighted linear mixed models of all studies and sampling years. Error bars show 95% credible intervals. Median per cent change recorded over all studies and years is inset above or below the corresponding bar. The x-axis labels show response variable and number of studies included in the analysis.[15]