Estimating ecosystem transitions in the North Yukon Planning Region associated with climate warming

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Transitions

Please see the associated spreadsheet (*ny_biophysical_transition_table.xls*) for details of estimated transitions. The transitions suggested represent a first cut at estimating ecosystem changes in response to climate change in the North Yukon planning region.

Climate change scenario

Climate in the North Yukon and surrounding areas has undergone detectable warming over the past 3-4 decades. Estimates for the period of 1966-1995 are for an annual average of ~0.5 °C annual warming per decade (Serreze et al. 2000). Although current and predicted rates of warming are believed to be highest in winter, analyses of temperature trends at individual climate stations in the North Yukon indicate a significant summer warming trend of about 0.3-0.5 °C per decade (Arctic Borderlands Ecological Knowledge Co-op website). An annual warming rate of 0.5 °C per decade corresponds to a warming of 5 °C in annual temperatures between 1970 and 2070. This scenario lies within the temperature envelopes predicted for northern regions with a doubling of atmospheric CO_2. On the basis of current trends and predicted outcomes from general circulation models, I have chosen to use a 0.5 °C warming per decade scenario as the basis for estimating ecosystem responses.

Ecosystem classification

The transitions that have been estimated for different ecosystem types are subject to my personal understanding of the ecosystem classification system used. This understanding has been developed from a suite of 1-3 representative photos for each class, and a short description of the classes used. I have not had access to detailed information on soils or vegetation composition. I have used the information provided to me to relate the ecosystem classes to circumpolar arctic (Walker 2000, Gould et al. 2003) or boreal forest (Hollingsworth 2004) vegetation classes currently in use, and estimates of the dominant vegetation species. These interpolated relations should be double-checked against the actual data, as errors in my understanding of the ecosystem classes will translate to errors in predicted transitions.

Sources of data

There are relatively few sources of empirical data on ecosystem transitions in relation to climate for the circumpolar region, and virtually none that deal with the North Yukon Planning Region. Several studies are underway that have the potential to provide information in the future on ecosystem change in this area, such as ongoing monitoring of vegetation composition and soil temperatures at plots in Old Crow (J. Johnstone, unpublished data), remote sensing of water levels in the Old Crow Flats (J. Hawkins, unpublished data), and recording of local knowledge and observations (i.e. with the Arctic Borderlands Ecological Knowledge Co-op). However, due to the low availability of current information, most of the estimates listed in the transition table derive from other locations in the North. I have given particular emphasis to studies from Alaska, which are a) most abundant, and b) likely to be reasonably comparable to the North Yukon.

There are four sources of data that we can draw on to estimate ecosystem transitions in response to climate change: 1) experimental studies, 2) observations of recent change, 3) paleoecological studies of past change (centuries-millenia), and 4) ecological modeling. Experimental studies are useful to determine the mechanisms of vegetation and soil responses to climate change, but are often limited spatial or temporal extent and are relatively poor at mimicking 'realistic' patterns of climate change. Observations of recent change provide direct evidence of responses to recent climate warming, but are relatively rare and often site-specific. Paleoecological studies can provide information on past ecosystem responses to climate change, but are often limited by poor temporal resolution and a lack of independent estimates of climate change. Finally, modeling studies provide to possibility to estimate future changes, but the quality or validity of a given model is difficult to assess and inappropriate application of model results can lead to incorrect conclusions. Where experimental data or direct observations are not available, biogeographical patterns often provide us with the best information on equilibrium vegetation responses to climate (Whittaker 1975). However, extrapolating from biogeographical patterns leaves much uncertainty regarding the rate and pathway of transitions over decadal or century timescales (Davis 1989, Chapin and Starfield 1997). This is particularly true when the modeling exercises (such as with ALCES) are not built around mechanistic responses to changing environmental conditions (Kittel et al. 2000). It is important that these limitations be recognized when applying the model. **Due to poor spatial data coverage and gaps in our understanding of the mechanisms driving ecosystem transitions, most of the transitions predicted in this report are associated with substantial levels of uncertainty. Uncertainty is particularly high with respect to estimating the rate of a given transition.**

Overview of responses

There is the strong evidence for expansion of shrubs into surrounding tundra and increasing shrub size in association with recent warming (Silapaswan et al. 2001, Sturm et al. 2001, Sturm et al. 2005). There is also accumulating evidence for a slower rate of tree expansion into surrounding shrub tundra, with treeline forests increasing in density

and a spread of low-density forests into the tundra (Szeicz and Macdonald 1995, Lloyd and Fastie 2002, Lloyd and Fastie 2003). Expansion of treeline forests appears to be limited by a variety of lags associated with dispersal (Lloyd et al. 2003), competition with tundra vegetation (Hobbie and Chapin 1998), and variable responses of trees in different regions to warming trends (Lloyd and Fastie 2003, Wilmking et al. 2004). There is also accumulating evidence to suggest that the extent of several northern basin wetlands may be declining (K. Walters, unpublished data; J. Hawkings, unpublished data).

In general, we expect the rate and direction of ecosystem responses will be affected by several key factors: a) the nature of the climate change, including rate, seasonal patterns, and balance between temperature and precipitation change; b) the current structure of ecosystem transitions (abrupt or gradual gradients); c) dispersal distances and barriers to dispersal; d) persistent effects of substrate or other physical factors (Rupp et al. 2001, Lloyd et al. 2003, Dullinger et al. 2004, Epstein et al. 2004). I have attempted to take these factors into account in generating predictions for transitions. For example, I have included few transitions between acidic and non-acidic ecosystem types, as substrate effects appear to constrain switching between these types (Oswald et al. 2003, Epstein et al. 2004). Likewise, rates of change are implicitly higher where ecosystems are believed to occur in adjacent areas or to intergrade. I have followed a general sequence of ecosystem transitions that mimics those found along latitudinal gradients, namely, increasing plant cover and stature with increasing mean temperatures (Walker 2000, Gould et al. 2003). This translates into a general pattern of transitions from prostrate vegetation, to low shrubs, to tall shrubs, and finally to forested ecosystems.

Future Steps

Time constraints have limited the scope of this project in estimating future transitions of ecosystems in association with climate change. There is a need to refine the projected transitions based on additional information gathered from published resources, unpublished data, and expert opinion. Ecosystem definitions should also be checked against available soil and vegetation data. It would also be valuable to make an assessment of the key data gaps that limit certainty in estimating transitions, and assess possible ways in which these gaps could be assessed. This work should form part of the ongoing development of the North Yukon planning assessment.

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