The influence of vegetation structure on the geomorphic evolution of thermokarst lakes, Old Crow Flats, Yukon

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Abstract

This paper examines the effects of vegetation structure on the geomorphic evolution of thermokarst lakes in Old Crow Flats, YT, and discusses potential implications of increased shrubbiness and tree density on thermokarst lake geomorphology near treeline. For lakes in tundra and taiga, aerial photographs from 1951 and 1996 were used to estimate rates of shore recession and lake geometry in ArcGIS. In the field, bank characteristics were monitored to determine dominant mechanisms of erosion. Lakes surrounded by taiga or tundra had similar rates of shore erosion but geometry and dominant shore erosion mechanisms differed. Climate-driven changes to the vegetation structure could lead to a decrease in the effectiveness of thermo-erosional action due to increased guarding of shorelines by tall shrubs and trees, fewer rectilinear shorelines, more lakes with irregular shapes, and, in the long term, fewer drained basins with depressed margins and raised centres after permafrost recovery.

Keywords: Thermokarst lakes, geomorphology, forest-tundra transition, vegetation structure, environmental change.

Introduction

The evolution of thermokarst lakes and how they respond to climatic trends differs based on local conditions such as permafrost, ground ice distribution, cryostratigraphy, sediment texture, and vegetation structure (e.g. Jones *et al.*, 2011; Lantz & Turner, 2015). The latter is changing rapidly in response to climatic warming, as tundra shrubbiness and tree density in the forest-tundra transition increase. The effects of such shifts in vegetation structure on the geomorphology of thermokarstic lacustrine landscapes is scarcely studied. This paper examines the effects of vegetation structure on the geomorphic evolution of thermokarst lakes in Old Crow Flats, YT, and discusses potential implications of increased shrubbiness and tree density on thermokarst lake geomorphology near treeline.

Study Area

Old Crow Flats is a 5600 km² wetland located in the continuous permafrost zone of northern Yukon. The area is within the forest-tundra transition, and the vegetation cover is a heterogeneous mosaic of woodlands, tall shrubs, low shrubs, and herbaceous communities (Lantz & Turner, 2015).

Thousands of thermokarst lakes and ponds are distributed through this vegetation mosaic. These water bodies cover approximately 35% of the surface area of OCF and exhibit clear signs of expansion by thermokarst processes. Some of these lakes have rectilinear shorelines oriented either NE-SW or NW-SE (Roy-Leveillee & Burn, 2015).

Methods

The distribution of lakes with irregular and rectilinear shores was examined on a vegetation map of OCF (Lantz & Turner, 2015) with land cover grouped as either tundra, including low shrubs, herbaceous vegetation, bryophytes and barren ground, or taiga, including tall shrubs, woodlands and coniferous forest. Lake geometry was analyzed in ArcGIS on two sets of 230 lakes, one from taiga and one from tundra areas. Aerial photographs from 1951 and 1996 were used to estimate rates of shore recession on a subset of representative lakes. Lakes with irregular and rectilinear shores were visited in the field to examine bank characteristics, and were monitored during ice break-up and the open water season in 2008, 2009, and 2010 to assess dominant patterns and mechanisms of shore erosion.

Results

Lakes with rectilinear shores abound in parts of OCF dominated by tundra. In areas where taiga dominates, lakes generally have irregular shapes with an average ratio of shore length to lake area five times greater than in tundra areas.

Tundra vegetation on shore banks is easily broken and removed by wave action, exposing frozen bank material to thermal erosion and unconsolidated sediment to transport by wave action and longshore currents. Trees and tall shrubs, however, can remain anchored in the sediment after subsidence of the shore banks beneath water level, and form a barrier guarding the shore from wave action and ice push. Without effective thermo-erosional action at the bank foot, heat conduction from the lake into the bank becomes the dominant process for permafrost thaw and lake expansion.

Despite differences in dominant erosion mechanisms, rates of shore recession were comparable in tundra and taiga areas. In polygonal tundra, however, rates of lake expansion increased exponentially with lake size, indicating the importance of wave action for lakes of all sizes. No clear relation was found between lake size and erosion rates in taiga lakes, indicating that other factors control rates of lake expansion.

Implications

The observed influence of vegetation structure on lake shore erosion suggests that a continued increase in the abundance of tall shrubs and trees near the forest-tundra transition may lead to a decrease in the effectiveness of thermo-erosion associated with wave action, as the 'guarding' effect of taller vegetation persisting at the bank foot increases. Consequently, oriented lakes with rectilinear shores may be progressively replaced by lakes with irregular shapes. In the long term, there may be fewer drained lake basins with depressed margins and a raised centre after permafrost recovery, as such relief also requires the redistribution of unconsolidated sediment through resuspension in the nearshore zone (Roy-Leveillee and Burn, 2016).

Acknowledgments

The research was supported by the Government of Canada IPY program, NSERC, PCSP, and NSTP. Essential logistical support was provided by the Vuntut Gwitchin First Nation Government and the Aurora Research Institute, Inuvik. Thanks to A. J. Jarvo, A.L. Frost, B. Brown, D. Charlie, E. Tizya-Tramm, K. Tetlichi, L. Nagwan, M. Frost Jr., S. Njoutli, S. Frost, and C.Z. Braul for field assistance.

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