Riverbank erosion and its consequences in the Yukon River Basin

Overview: River and floodplains are particularly susceptible to a warmer climate due to permafrost thaw that can lead to accelerated erosion. This erosion threatens critical infrastructure and disrupts community life. Here, we summarize objectives and early findings from a new NIA project to understand riverbank erosion and its impact on contaminants including heavy metals, such as mercury, along with carbon, nutrients, and pathogens. In tandem, we are working to understand regional adaptive capacity and how actionable plans and policies can be used to meet local challenges presented by riverbank erosion. The project involves a collaboration of natural and social sciences, the Yukon River Inter-Tribal Watershed Council, and with three partner communities in the Yukon River basin.

Field Campaign: This project involves field campaigns at three locations centered around three Alaskan communities within the Yukon River basin. Each location offers a different substrate and geomorphic setting.
1. Beaver – Yukon River: Gravel-beded, Anabranching channel
3. Alakanuk – Yukon River: Deltaic environment, Silt-beded

Organic Carbon
New permafrost contains approximately 1300×10^15 Mt of organic carbon (OC), accounting for almost 50% of global soil carbon in organic only 15% of land area and more than two times the size of the global pre-industrial atmospheric carbon (1, 2). Eroded solids are transported in the form of suspended particulate matter (SPM) in the fluvial system, carrying terrestrial OC in the form of particulate organic carbon (POC), redistributing eroded OC to varying geomorphic units and leading to different rates. In this project, we seek to quantify the effects of permafrost riverbank erosion on transport, fluxes, and fates of OC.

Community Engagement: This project has been developed with support of the Beaver Village Council, the Huslia Tribal Council, and the Alaskanak Traditional Council to enhance their communities’ climate-change adaptive capacity. In September, the project team hosted community meetings in Huslia and Beaver to build community capacity and to engage in discussion about their research objectives and activities. The meetings also gave the opportunity to listen and learn from community members about the environmental observations and erosion impacts in their region. The knowledge shared with the team will further inform the physical and socio data collection. The meetings gave the opportunity to discuss the establishment of the Erosion Action Group, an advisory group consisting of community members, with the goal to serve as a project bridge between community concerns, and to support the Yukon River Inter-Tribal Council efforts in building a community-driven Erosion Action Plan. The team research engaged with the local schools and teachers to explore additional outreach opportunities for the upcoming field season.

Geology: During the field campaigns in both June and September 2022, we collected samples of river bed sediment and suspended sediment (via water filtration) for microbial community analysis. We will connect microbial abundance, community composition, and activity measurements to geochemical, hydrological, sedimentological, and geomorphic metadata to construct landscape-scale maps and estimates of geochemical and microbial processes associated with bank erosion and evaluate how these change throughout the season and year-to-year. We are particularly interested in the potential role of microbes in water quality—particularly their role(s) in mobilizing/immobilizing mercury and other heavy metals in the environment, as well as transformations involving the sediment and carbon liberated from bank erosion. We will also investigate whether or not there is evidence for mobilization of pathogenic microbes in these ecosystems. Sampling sites include bars and banks on the main rivers (Koyukuk and Yukon), depth profiles of the main river channel (for suspended sediment), and suspended sediment collected from a variety of adjacent clearwater sloughs, oxbow lakes, ponds, and tributary streams within the watershed.

Adaptive Capacity, Institutional Barriers, and Policy Priorities
Watershed communities are facing multiple stressors in addition to riverbank erosion that include: a severe collapse in salmon fisheries, water quality problems, housing shortages, and a lack of opportunities for youth. The UAA team is focused on the social vulnerability index with the Yukon River Inter-Tribal Watershed Council (YRTWC). Understanding opportunities for and institutional barriers to adaptation using a Critical Institutional Analysis and Development framework. Identifying policy priorities through structured interviews with stakeholders, community leaders, and policymakers.

The vulnerability approach is important for applying climate risk assessments to planning efforts and policy strategies because it focuses the analyses on people and communities most affected by these risks. The broader goal is to collaborate with the YRTWC and project partner communities in efforts to draft, adopt, and implement Erosion Action Plans. Bank Erosion: Rapid warming in cold regions has been hypothesized to lead to the destabilization of riverbanks and drive more rapid rates of bank erosion and fluvial morphodynamic activity. The accelerated thawing of permafrost (8, 9). To determine how rates of bank erosion and lateral river channel migration might be affected by warming, the climate change, we are actively monitoring the erosion of riverbanks and the water flow at each of these three sites over the current and future summers. By exploring the relationships between water temperature, discharge, fluvial stress, and bank erosion, we are investigating the driving mechanism behind permafrost riverbank erosion in order to understand how riverine activity in cold regions may change under the changing climate.

Mercury: Arctic permafrost contains many emergent pollutants like viruses, bacteria (10, 11, 12), anthropogenic (13, 14) contaminants, and biogeochemical cycles that may pose threats but are not well studied. The project will study water quality specifically looking at the release of mercury (Hg) from permafrost into Arctic rivers and how microbial response may change mercury methylation rates.

Remote Sensing: Remotely sensed imagery allows for the quantification of erosion, deposition, and water temperature through change detection over meters to 100s of kilometers of river reaches. We have developed an integrated workflow that extracts pixel-scale measurements of riverbank dynamics using SREAM software (7) which has been widely applied to river systems across the Arctic. This approach of topographic change is being coupled with remote sensing of water temperature to understand how changing water temperature under the warming climate affects rates of riverbank erosion theory and model development through other aspects of this project.

1. Scharf et al., 2015, Nature
2. Scharf and others, 2018, Environmental Research Letters
3. Hughes et al., 2018, Biosciences
4. Rowland et al., 2020, Geophysical Research Letters
5. Rowland et al., 2020, Remote Sensing of Environment
7. 7. Huslia, E. et al., 2018, Ecological Applications
8. 8. Huslia, E. et al., 2018, Ecological Applications