

**WCS WILDLIFE CONSERVATION SOCIETY CANADA
& UNIVERSITY OF SASKATCHEWAN**

INTERIM REPORT on project

*Cumulative effects of human disturbance and climate change on salmon habitat in
Central Yukon*

Prepared by: Dr. Daniel Yip (Post-doctoral Research Fellow)
Dr. Chrystal Mantyka-Pringle (Conservation Planning Biologist & Adjunct Professor)

Summary

In partnership with the First Nation of Na-cho Nyäk Dun (FNNND), Tr'ondëk Hwëch'in (TH), Yukon Government (YG), and Fisheries and Oceans Canada (DFO), Wildlife Conservation Society Canada (WCSC) and the University of Saskatchewan are conducting a study investigating the cumulative impact of surface disturbance and climate change stressors on water quality in salmon spawning habitat in Central Yukon. While considerable research has been conducted examining the influence of resource and climate related stressors on salmon populations, understanding how these effects interact when multiple stressors co-occur is crucial for guiding effective conservation actions or mitigation strategies. Cumulative effects are not well understood in northern ecosystems, but are important for effective implementation of land use planning, which is currently ongoing in the Dawson Regional Planning area of Yukon.

Study Area

We incorporated long-term water quality monitoring data from Yukon Government's water data catalogue for the Indian and Klondike River drainages and all associated sub-drainages from 2006-2019. A total of 89 unique sampling locations and approximately 11,000 unique water samples were included in our dataset.

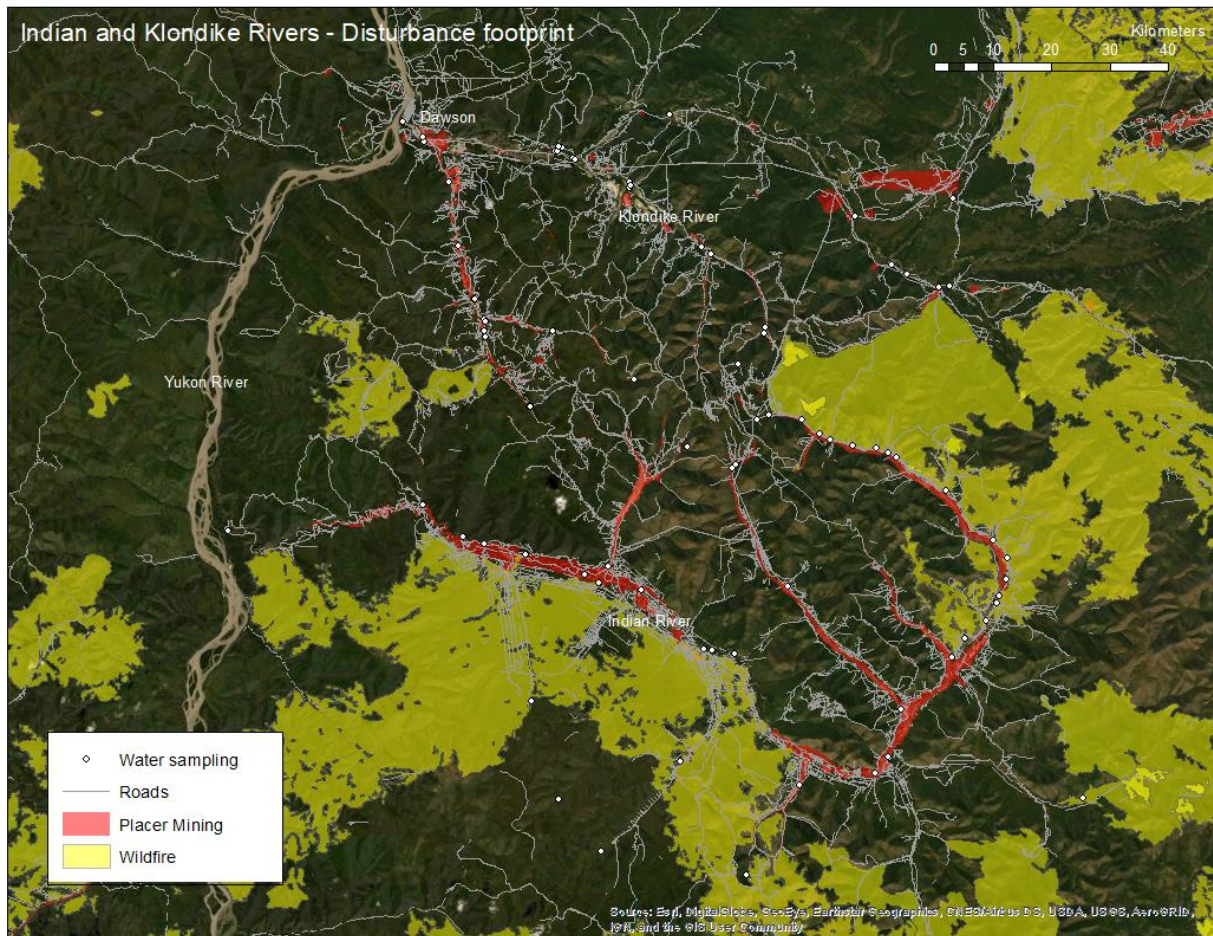


Figure 1. Study area map indicating the location of surface disturbances and long term water monitoring locations.

Key Indicators

We identified four key indicators for water quality in salmon spawning habitat. These indicators are:

- Total suspended sediments (TSS, mg/L)
- Turbidity (NTUs)
- Total organic carbon (TOC, mg/L)
- Water temperature (degrees celsius)

TSS and turbidity are indicators of the sediment content in water, which can increase mortality in eggs and juvenile salmon by smothering spawning redds. TOC and water temperature can influence the dissolved oxygen content in water, impacting salmon mortality rates.

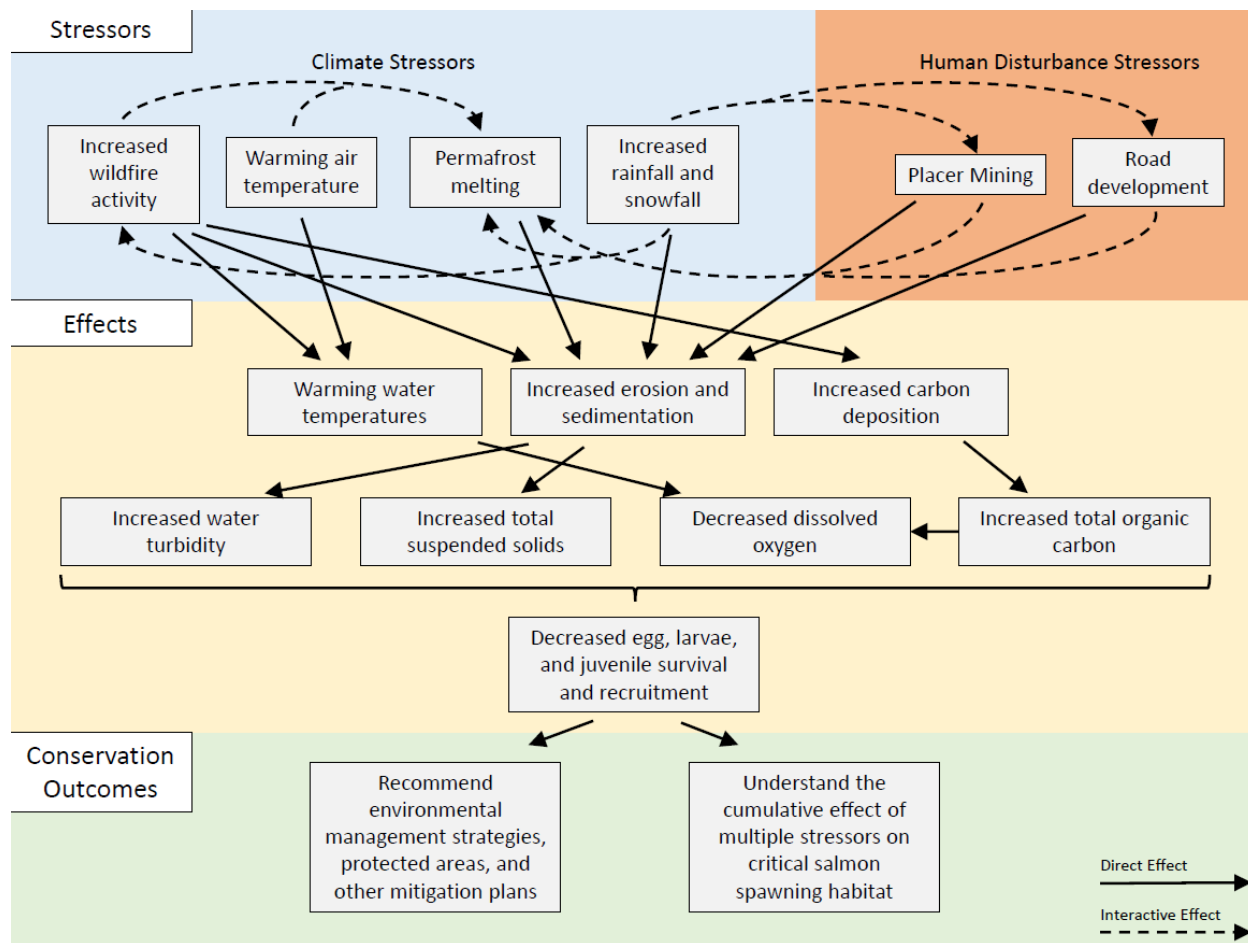


Figure 2. A conceptual model linking climate and surface disturbance stressors to key water quality indicators in salmon spawning habitat.

Stressors and Other Predictor Variables

We collated and quantified a variety of surface disturbances, climate stressors, and landscape variables that could impact water quality indicators. For surface disturbance stressors, we calculated upstream buffers at each site with a radius of 500 and 1000m. We calculated the proportion of each buffer occupied by placer mining (% disturbed), linear feature density (km/km^2) and the classification of those linear features (trails, transportation roads, mining roads, energy right of ways, and forestry roads), and forest fire extent (% disturbed) using existing spatial data (2018) and the Canadian National Burned Area Composite (NBAC).

For climate stressors, we used the ERA5-LAND hourly reanalysis product from European Centre for Medium Range Weather Forecasts (ECMWF) and Copernicus Earth Observation Programme to obtain historical climate variables and modelling synced spatially and temporally with each water sampling occurrence at a native resolution of 9km. We calculated climate variables at 1, 3, 6, and 12 month time windows for mean temperature (average degrees celsius during time window), maximum temperature (max degrees celsius during time window), surface runoff (sum of total surface runoff in meters), snow

depth (average snow depth in meters), snowfall (total snowfall accumulation in meters of water equivalent), snowmelt (snow loss in meters of water equivalent), soil temperature at four different depths (degrees celsius), and total precipitation (meters accumulated).

Finally, we extracted naturally spatial landscape variables that may impact water quality indicators to account for variation across our study area. These variables include watershed, watercourse, sampling site, elevation (meters above sea level), stream gradient (degrees), stream order, stream magnitude, and soil order. We also included sampling date and time to account for daily, seasonally, and annual variation in water quality conditions.

Preliminary Analysis

We checked for correlated climate and landscape variables to eliminate potential multi-collinearity in our dataset. In the case of correlated variables, we selected one of the variables for further consideration using a hypothesis-driven approach, or by keeping the variables with higher explanatory power (for example, stream order versus stream magnitude). We utilized a common model selection approach where we compared various candidate generalized linear models by ranking AIC. Once we had selected our final suite of climate, surface disturbance, and landscape variables, we tested models with additive and interactive variable combinations to investigate the cumulative impact of these stressors.

Findings

Our final model included stream order, date, stream gradient, and soil order as important natural landscape variables. We also controlled for watershed and sampling location by including a random effect of sampling location nested within watercourse. For surface disturbance stressors, we found linear density and proportion of disturbance from mining to be most influential at a 1km buffer radius. For both of these stressors, increases in surface disturbance upstream of sampling locations were associated with an increase in TSS in water samples. We also found surface runoff, average temperature, and total precipitation to have a significant impact on water quality. Increases in each of these variables were associated with an increase in TSS in water samples as well.

When testing for cumulative impacts of multiple stressors, we found a significant interaction between surface runoff and surface disturbances. Increased surface runoff greatly increased the impact on water quality for both linear density and mining within the 1km buffer radius. Finally, when investigating the impact of road classification on water quality, we found that mining and forestry roads, road types that are unpaved and see a high amount of activity, had the highest impact on water quality directly downstream. Details are presented visually in the attached figures.

Future research

The findings presented in this report represent preliminary analysis of a complex ecological dataset that we prepared for the draft Dawson Regional Land Use Plan. Future analyses will consider the impact of wildfire, permafrost thaw, and investigate each individual watercourse to get a better understanding of

how climate and surface disturbance stressors are impacting salmon spawning habitat now and in the future.

