Scenarios of Arctic Climate and Land-use Change as a Unifying Framework for Integrating Long-term Monitoring with Interdisciplinary Research in a Focal Watershed

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Summary

Ecosystem responses to climate change are occurring in the Fish Creek Watershed at the same time that resource development is expanding, primarily oil exploration and extraction. Because this watershed is located entirely within the National Petroleum Reserve – Alaska (NPR-A), the Bureau of Land Management (BLM) has been monitoring and studying these changes in cooperation with a wide range of stakeholders. The protection of wildlife, habitat, and water resources are key concerns to all stakeholders here and they recognize that making scientifically sound decisions in the face of uncertain climate change responses is challenging. Breaking down this complexity in terms of observations, advanced modeling techniques and scenarios analysis provides an opportunity for scientists, managers, and other stakeholders to interactively bring their expertise and interests to bear on uncertainty and future decisions. An expanding monitoring network, the Fish Creek Watershed Observatory, coupled with an interdisciplinary science project, Fish CAFÉ, is providing a test case for scenarios analysis in a focal Arctic watershed ripe for decision support.

The Fish Creek Watershed Observatory

The Fish Creek Watershed (FCW, Figure 1) is of interest to multiple Arctic stakeholders because of its valuable natural resources and vulnerability to both climate and land-use change. Located in the National Petroleum Reserve-Alaska

(NPR-A) between Prudhoe Bay and Barrow, Alaska, this hydrologic unit drains a 4500 km^2 land area that is *de facto* wilderness of the Arctic Coastal Plain. Yet petroleum exploration in the winter has occurred here since the 1940's and the first oil development in the NPR-A began in the lower FCW last year and is expected to progress deeper into the watershed during the next decade. The Native Village of Nuiqsut is located outside of FCW's North Eastern corner, making this area important for traditional subsistence harvest and also increasing tundra travel by all-terrain vehicles.

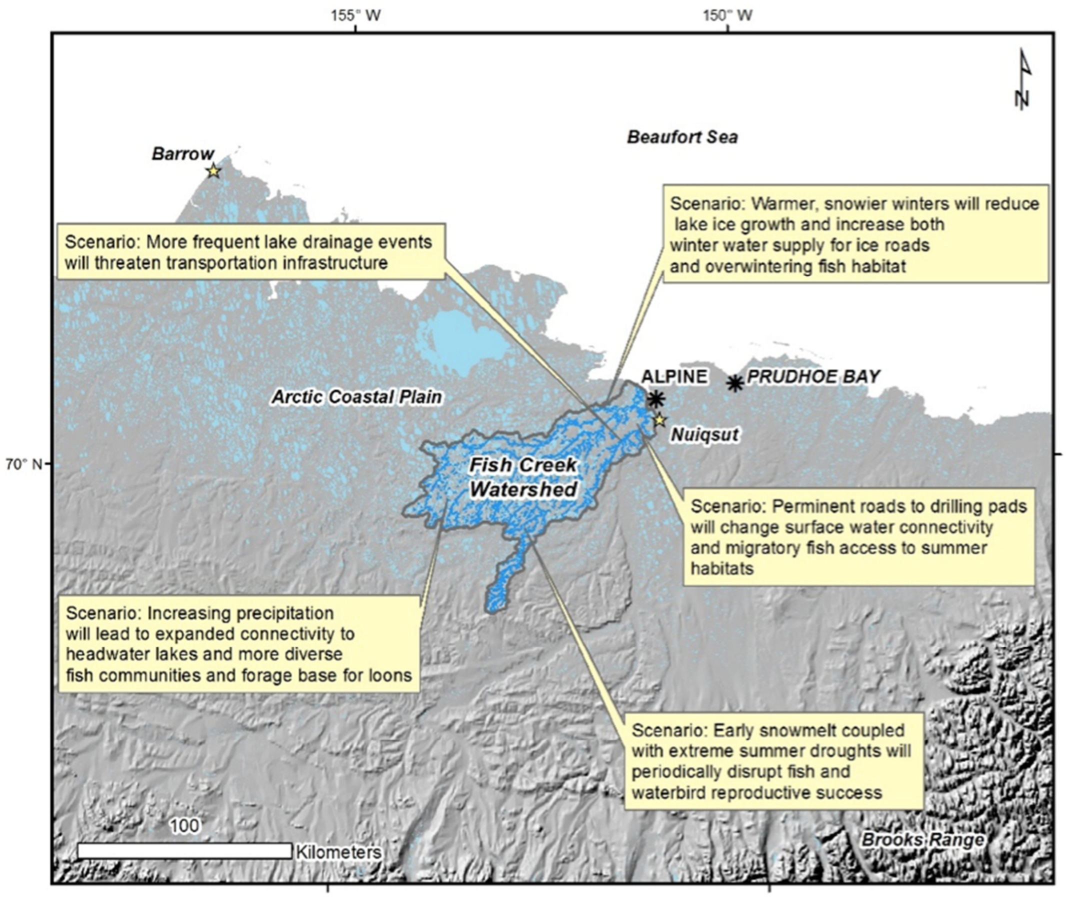

Figure 1. Location of the Fish Creek Watershed in northern Alaska, USA with example scenarios of climate and land-use change.

Accordingly, the BLM in cooperation with the UAF's Water and Environmental Research Center (WERC) initiated a stream and lake monitoring program in 2009 in catchments where petroleum development is being planned to collect baseline data [*Whitman et al., 2011*]. Data from this project is publically available (http://www.fishcreekwatershed.org/data.html) and has been used in scientific papers on Arctic hydrology [*Arp et al., 2012a*] and beaded stream habitat [*Arp et al., 2015a*]. Lakes are prevalent on the Alaskan North Slope and thus play a key role in regional hydrology. There is particular interest in lakes in the NPR-A beyond ecosystem services because they supply water for winter ice roads used for petroleum exploration. Since many Arctic lakes are shallow and ice grows thick (historically 2m or greater), seasonal ice commonly freezes to the lake bed (bedfast ice) by winter's end. Analysis shows a trend towards thinner ice that is causing more lakes to maintain floating ice regimes, which is potentially beneficial to winter water supply and overwintering fish habitat, but detrimental to sub-lake permafrost [*Arp et al., 2012b*]. Summer analysis of lakes in northern Alaska indicated that ice-out of bedfast ice lakes occurred on average 17 days earlier (22 June) than ice-out on adjacent floating ice lakes (9 July) [*Arp et al, 2015*]. This dynamic helps explain varying hydrologic response of Arctic lakes and downstream fluvial systems and their sensitivity to winter climatology.

FishCAFE project (http://www.fishcreekwatershed.org/fishcafe.html) funded by the Arctic Landscape Conservation Cooperative (Arctic LCC) links temporal aquatic habitat dynamics with spatial lake distributions and takes this several steps further by considering multiple habitat types and using models to make future predictions and explore various scenarios of environmental change. This type of approach that couples classification and mapping with process models provides managers and other stakeholders with a simple but comprehensive view of environmental change in time and space that can be applicable to both local and regional planning. Such a research framework will foster the Arctic LCC objective of providing reliable forecasts of future conditions under various climate and land use change scenarios, so that managers may incorporate these considerations into decision making processes.

Scenarios-based Interdisciplinary Science Supported by Long-term Datasets

Scenarios are hypotheses about what might take place and can provide guidance in the adaptive management process when stakeholders actively engage in scenarios development and analysis. In order understand impacts of climate change on thermokarst lakes, permafrost, and the regional ecosystems, meteorological downscaled products were created with a domain covering the central Arctic Coastal Plain (Fish Creek Watershed) and the surrounding Alaska North Slope region. Weather Research & Forecasting (WRF) model forced with ERA-Interim Reanalysis, NCEP/NCAR Reanalysis and the Community Earth System Model (CESM) model is used as a downscaling tool. The downscaled output consists of multiple climatic variables for 10 km grid spacing at three-hour intervals, covering so far 1950-2050 [Cai et al, in prep].

Our first experiments with WRF-downscaled output demonstrated the linkage between early winter ocean conditions (declining sea ice and late freeze-up) and late winter freshwater response along lake-rich Arctic lowlands. The projected future reduction in sea ice extent is expected to continue and accelerate a landscape-wide regime shift in shallow thermokarst lakes leading to sub-lake permafrost thaw and a range of habitat and biogeochemical responses [*Alexeev et al, 2016*]. WRF output is also used as a forcing for detailed permafrost/hydrology model WaSiM (http://www.wasim.ch/en/index.html). Using WaSiM, all aspects of the water cycle are simulated as well as heat processes in the subsurface. The analysis specifically addresses changes in surface water connectivity (lakes and streams) under past, present and future climate.

Discharge, snow depths, and meteorological variables have been measured since 2009. A LiDAR digital elevation model of 0.25 m horizontal resolution facilitates the representation of micro-topographic landscape features (i.e. ice wedge polygons). In addition, 1052 fish were captured and 781 fish were tagged using a half-duplex passive integrated transponder. The observations have not only allowed analysis of fish migration patterns [*Heim et al.*, 2014; *Heim et al.*, 2015], but is also be utilized as input to drive WaSiM model.

Hydrological and meteorological data collected at various FCW locations are available online: http://www.fishcreekwatershed.org/data.html. Meteorological downscaled fields are stored at the Arctic Region Supercomputing Center and the international Arctic Research Center's data server http://data.iarc.uaf.edu/. Project contributes to other data portals: Circum-Arctic Lakes Observation Network (CALON), Arctic Lake Ice Systems Science (ALISS, http://arcticlakeice.org/), also to ACADIS portal (https://www.aoncadis.org/home.html).

The analyses will ultimately provide regional stakeholders (e.g. Bureau of Land Management) with information on the hydrologic impacts of climate change within the National Petroleum Reserve Alaska to mitigate impacts on aquatic ecosystems as well as the local population. The experience gained in this study may also serve as a benchmark for future studies and developments in similar environments.

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