Indirect Changes in Fish Assemblages Due to Increases in Arctic River Discharge

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Introduction

Global climate warming has impacted nearshore systems in nearly all areas of the Earth, but most notably in the Arctic basin. This ecosystem has seen massive changes over the past few decades that can be attributed to elevated temperatures. As the Earth's oceans increase in temperature, sea ice is receding at a faster pace in polar regions while also increasing freshwater outflow due to higher amounts of rain and glacial runoff. The combination of these two climate change driven events is having an indirect effect on nearshore fish assemblages (Frainer et al. 2017).

The Arctic Ocean system has very little swell and is mainly driven by winds and the land masses that border its edges. During the winter months, ice occupies much of the basin thereby deterring any waves or water movement. In recent years this ice has receded much earlier giving added space for river discharge to impact the nearshore ecosystem. River discharge into the Arctic ocean basin has been incrementally increasing in Eurasian countries over the past three decades (Peterson et al. 2002). This outflow carries with it organic and inorganic nutrients in the base forms of carbon, nitrogen, and phosphorous (among other essential elements). Freshwater nutrient input into nearshore systems has been shown to increase primary production by up to two-fold (Wikner & Andersson 2012).

Increases in primary production bring an influx in opportunistic consumer species that tend to cause pulses in top level trophic species. While some of these increases in consumer species (e.g. fishes) might seem like a benefit to coastal ecosystems, they are drastically changing the dynamics of the nearshore environments. Shifts in fish assemblages have been seen all across the Arctic basin and have had varying effects on the predators that inhabit these regions (e.g., birds, fishes, and humans). Native villages have relied on certain species for decades and with this recent shift they have been forced to adapt to fishing for less appealing species.

The north slope of Alaska has recently been seen to be a newly impacted area in the Arctic Ocean in terms of the freshwater output (McClelland et al. 2014). This region is dominated by areas of high terrestrial rugosity that lead into major river outflows, but has largely been unexamined in reference to how those inputs might affect the floral and faunal communities in the surrounding marine environment. Many watersheds in the north slope of Alaska are fed from the Brooks Range, which is a far-reaching mountain range that houses dozens of glacial pockets. These areas of freshwater accumulation have a vast impact on the regions they touch due to their high concentrations of organic and inorganic nutrients. These nutrients are derived of eroded vegetation and sediment that help supplement nearshore autotrophs for their growth period after the sea ice has receded.

The purpose of this study was to examine the areas of high freshwater discharge and correlate them with the fish species that inhabit that area. The resulting information was to be used in predicting fish migration through the Alaskan Arctic coastline by attaching the most opportunistic fish species to the areas where the highest amount of primary production occurred and seeing how those trends varied over time given the current climate models.

Methods

Study site

This project examined three areas of interest in the north slope of Alaska (Fig. 1). These three areas encompassed three separate watersheds, the lower Colville, Kuparuk, Sagavanirktok (Sag) rivers. These watersheds deposit massive amounts of soluble nutrients into their respective nearshore environments. Each is located in an area of high rain deposition and have glacial input in some respect along their path.

ArcGIS Techniques

A 30m digital elevation model (DEM) was obtained from the USGS GIS website (agdc.usgs.gov) in order to determine river outflow. This was attempted using the flow direction, flow accumulation, and stream delineation tools in each watershed. These tools were used to estimate how much discharge would pile into the nearshore environment by possibly looking at drainage areas and stream lengths. This study attempted to use these calculations to help understand what amount of nutrients would be deposited in these nearshore systems by correlating the value produced in the aforementioned ArcGIS analysis tools with known values of dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) from McClelland et al. (2014). An inference can be made using this correlation as to where areas of high primary productivity are and thus where areas of high amounts of fish abundance would follow. Shapefiles containing the location of streams with known anadromous fish population and regions along each watershed that had glaciers were added to the original map for a visual reference.

Results & Discussion

Results

The results of this study were inconclusive due to technical issues. All of the compiled data, maps, and analysis obtained or performed for the purpose of this project were lost and there was an insufficient amount of time to be able to reconstruct what was lost. Stream gage data was used to help visualize (Fig. 2) what the outcome of this study might have been in terms of flow estimation out of the watershed.

Discussion

Flow accumulation analysis was showing a trend of water piling up in the Sag river much more so than in either the Colville or Kuparuk. This is the opposite of what was seen by USGS gage data (Fig. 2), but could possibly be due to the exclusion of the Upper Colville watershed in this study. Looking at the nutrients being deposited by each of these rivers (Fig. 3), although the Sag river might be releasing much more water than the other two rivers does not necessarily mean that it would be contributing the most to nearshore primary production. The Colville river discharge rate in conjunction with the DOC and DON values seen would make the environment much more of a productive area.

The goal of this study was to try and find a predictive technique for shifts in the fish assemblages using GIS and combining it with known or modeled nutrient values. While the project was ultimately a failure due to unforeseen circumstances, I still believe future work can be done using hydrographic methods in GIS and coupling them with sensor data and water sample analyses to create a reliable predictive model, similar to what has been seen in other studies (Joy & Death 2004). If this model is combined with fish catch data taken by the USGS over the next 5 years, a highly refined mode of assessing climate change impacts on the nearshore Arctic ecosystem could be developed.

Because the Arctic is such a remote area, but there are many native villages that rely on fishing for their nutrition, developing a model that could be used to inform the native people once a year one of the trends in fish movement could have lasting positive impacts. It would help strengthen the relationship between the native people and researchers and allow for a mutually benefitted future.

Literature Cited

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Peterson, Bruce J, Robert M Holmes, James W McClelland, Charles J Vörösmarty, Richard B Lammers, Alexander I Shiklomanov, Igor A Shiklomanov, and Stefan Rahmstorf. "Increasing River Discharge to the Arctic Ocean." *Science* 298, no. 5601 (December 13, 2002): 2171 LP-2173. http://science.sciencemag.org/content/298/5601/2171.abstract.

Figures & Tables

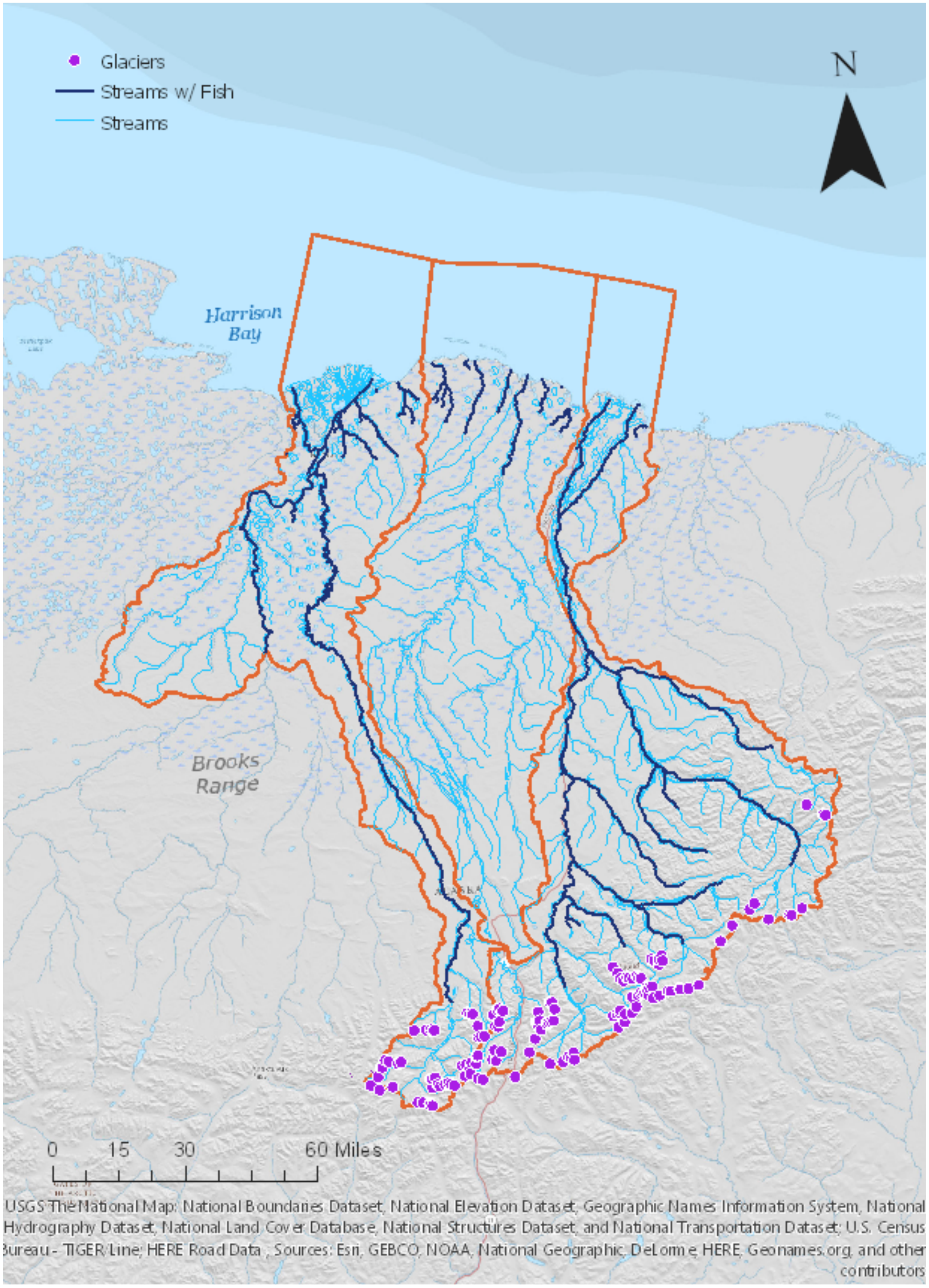

Figure 1. The lower Colville watershed, Kuparuk watershed, and Sagavanirktok watersheds (from left to right) showing the river and stream input (in light blue) while streams that have recorded anadromous fish data are denoted by dark blue. Areas with known glaciers are marked by purple dots.

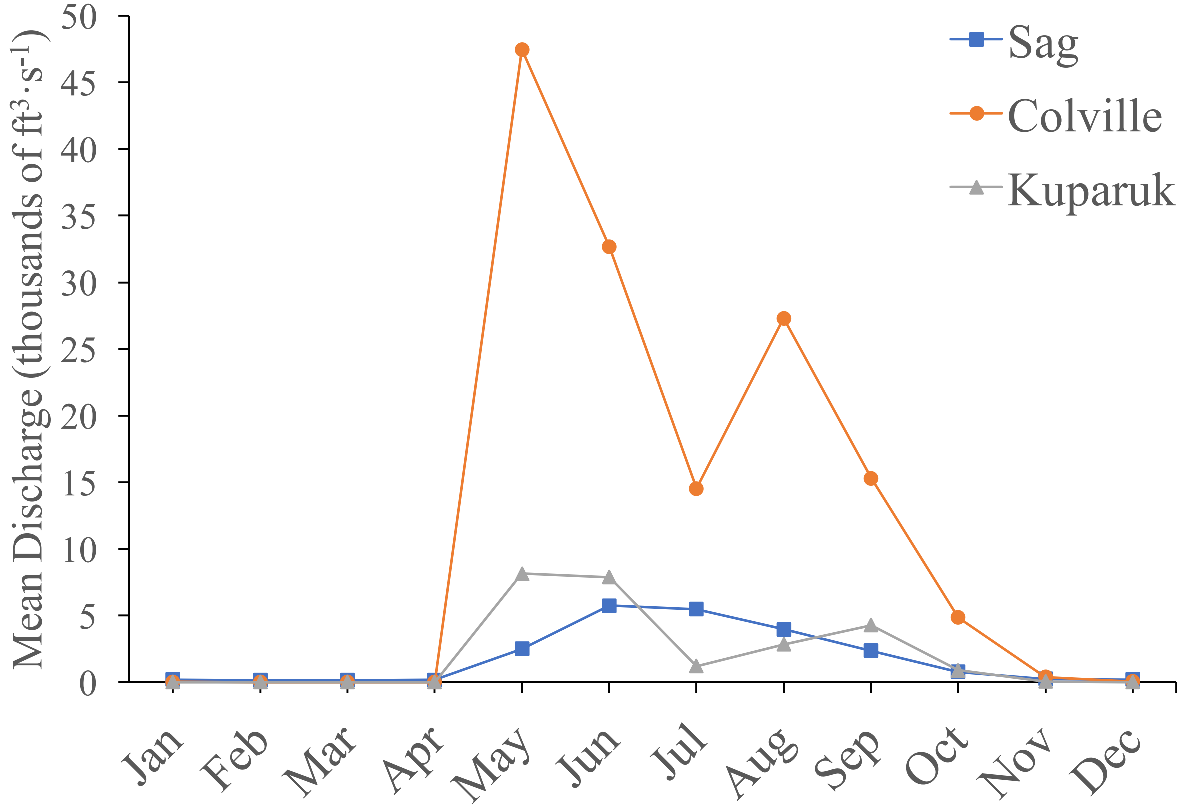

Figure 2. Discharge of the Colville, Kuparuk, and Sag rivers in 2016 as recorded by USGS stream gages. Peaks seen in late spring and early summer are thought to be correlated with nearshore nutrient deposition.

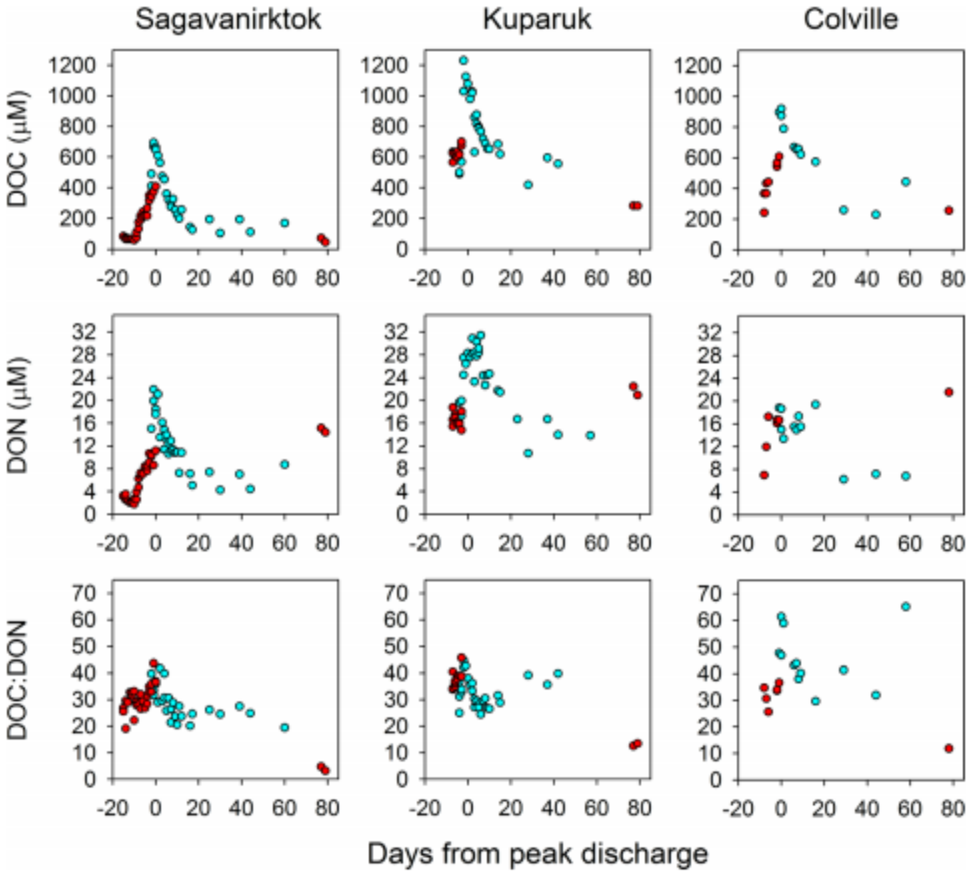

Figure 3. Temporal variations in dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) in micromoles (μM) for each of the three rivers for 2006 (blue) and 2007 (red) are plotted against relative to the timing of peak discharge (taken from McClelland et al. 2014)