How are fish in Gwich'in and Inuvialuit lakes responding to climate change and new road development?

Report prepared for Gwich'in Renewable Resources Board, Gwich'in Tribal Council, Tetlit Gwich'in Renewable Resources Council (RRC), Gwichya Gwich'in RRC, Nihtat Gwich'in RRC, Inuvik Hunters and Trappers Committee, and Tuktoyaktuk Hunters and Trappers Committee

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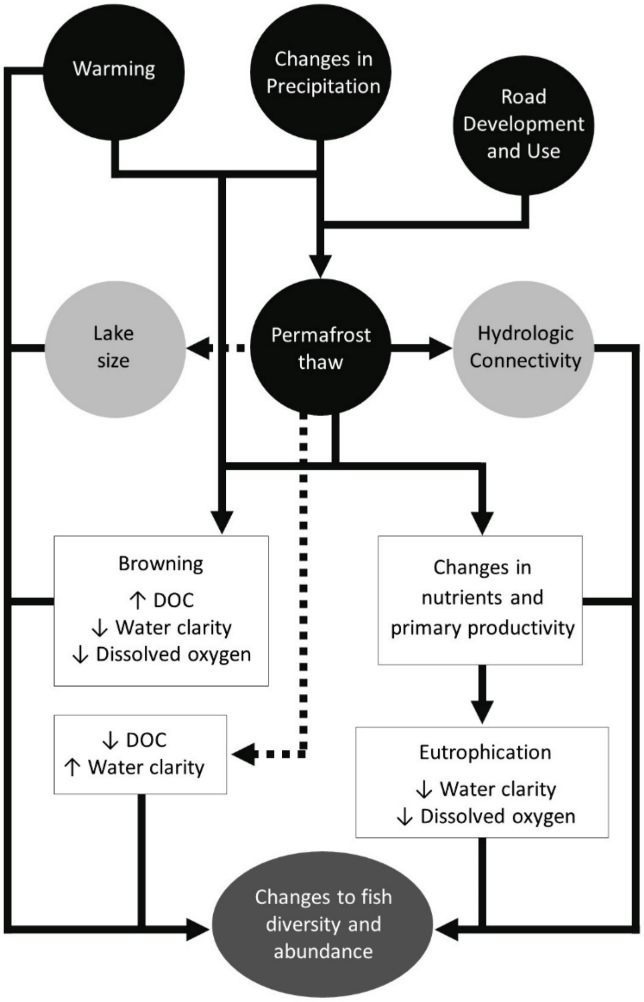
Background: Climate change is rapidly altering the north. As a result, northern Indigenous citizens continue to observe many environmental changes including shorter and warmer winters, changes in ice break-up and freeze-up timing, lake draining, warmer water temperatures, and permafrost thaw and erosion. In some cases, these environmental changes are impacting the plants and animals important for traditional food activities such as gathering, hunting, and fishing.

Our main project goal was to understand how fish in Gwich'in and Inuvialuit lakes are responding to climate change and new road development. The Gwich'in Settlement Area (GSA) and Inuvialuit Settlement Region (ISR) have experienced substantial climate warming as well as new major highway development with the construction of the Inuvik to Tuktoyaktuk Highway (ITH). Together, both climate change and new infrastructure development built on sensitive permafrost have the potential to impact local fish, sometimes in complex ways (Box 1).

Box 1. Ways that climate change and road development may combine to influence fish in Gwich'in and Inuvialuit lakes



There are many fish species that use lakes in the Gwich'in Settlement Area and Inuvialuit Settlement Region either seasonally or year-round. Some species require cold water temperatures and may be vulnerable to warming waters including lake trout, broad whitefish, lake whitefish (crookedback), inconnu (coney), and cisco (herring).

Warming, changes in precipitation, and road development may also combine to impact fish via permafrost thaw and impacts on water quality (white boxes). Thawing earth may lead to an increase in sediment and nutrient delivery to lakes. In turn, these changes can influence how clear the water is, as well as the aquatic plant habitat and food available for fish.

Permafrost thaw can also impact lake and stream levels, influencing lake size and migratory corridors for fish (light grey circles).

What we did:

To understand how fish were being impacted by climate change and road use, we sampled 50 lakes in the GSA and ISR along the Dempster and ITH corridors over a three-year period. At each lake, we collected information about the fish species present, lake size, and water quality. To better understand how warming and road use were influencing lake water quality, we compiled historical water quality data from an additional 153 lakes in the region.

Photos: Colten Gruben and Mariam Elmarsafy sampling a lake along the ITH (top left), Erika Gervais holding an adult whitefish (top right), live northern pike waiting to be measured (bottom left), Clay Steell setting a fishing gillnet (bottom middle), and Billy Conley, Clay Steell and Matt Teillet posing lakeside (bottom right). Credits: Erika Gervais, Alyssa Murdoch, Clay Steell.

What we found:

Finding #1: Rapid warming may have negatively impacted local fish

We found that warmer temperatures may have negatively impacted lake fish in the GSA and ISR. However, the negative effect of warming on fish was not straightforward. Although we expected that colder lakes may be preferred by many coldwater fish species (e.g., lake trout, whitefish, herring), we did not find any clear evidence to support this idea. Instead, lakes that had experienced more warming had *poorer water quality for fish*, including lower water clarity and higher nutrient and algal levels. These 'murky' lakes supported less fish species and lower numbers of fish overall, including less whitefish and northern pike (jackfish).

Finding #2 Some lakes along the new highway (ITH) had poorer fish habitat, but more research is needed to understand why

In addition to understanding climate change effects, we also looked at how highway development may be impacting lake fish in this region. We expected that the highway may influence lake water chemistry due to the potential influence on permafrost stability, changes in runoff, and the impact of road dust entering nearby lakes. We discovered that some lakes located along the ITH appeared to have poorer water quality for fish, possibly leading to lower numbers of fish.

However, it is important to note that more research is needed to understand why some lakes along the highway had poorer water quality for fish, and we provide more detail and suggestions below under the heading "Conservation Idea #2."

Tools for local conservation:

What we found may be useful to help local conservation and stewardship in a few ways, detailed below:

Conservation Idea #1: Protect biodiversity 'hotspots' from local stressors

We found that larger lakes and those with stream connections to even bigger lakes/rivers such as Husky Lakes were important hotspots for fish diversity – meaning that they often supported more species at higher abundances (please see "High" biodiversity values in Figure 1 and the attached Supporting Information for more detail). In addition, larger lakes often had better water quality for fish, suggesting that they may be relatively more resilient to climate change impacts. Where possible, reducing local stressors like tourism angling and nearby infrastructure development may help these hotspot lakes to maintain their valuable biodiversity despite ongoing global environmental change.

Conservation Idea #2: Increase whole-lake ecosystem monitoring for major infrastructure projects

Ideally, we would have collected fish and water quality data in lakes both before and after the ITH construction for comparison. Instead, we used the next-best thing which was to compare lakes that were either near or far away from the road to understand the potential impacts. The downside of our method is that we can’t say for sure if the road degraded water quality or if those lakes were already degraded. Based on this uncertainty, we suggest that new major construction projects follow a conservative approach and complete whole-lake ecosystem assessments both before and after construction.

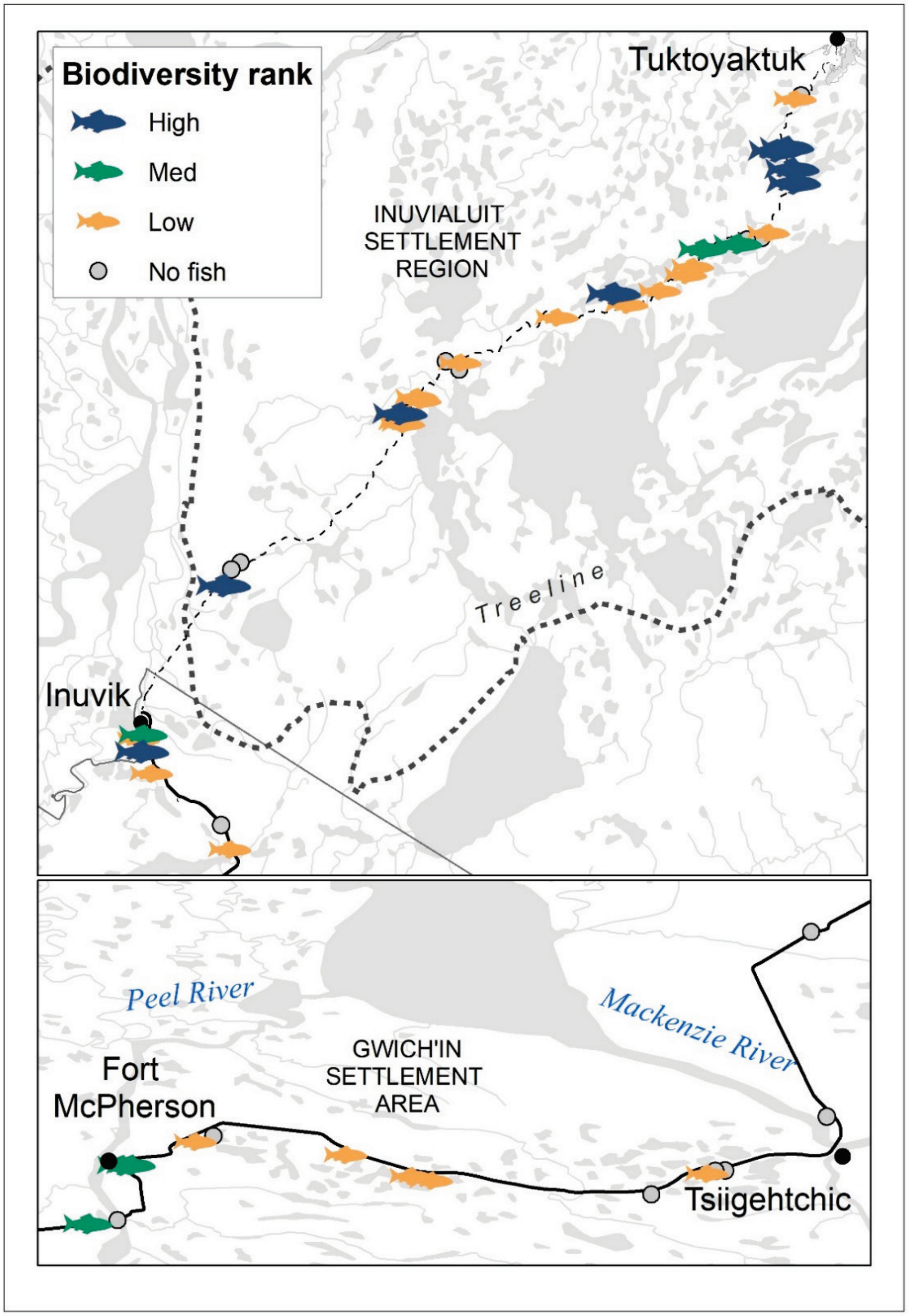


Figure 1. Map of 50 fish sampling lakes ranked according to fish biodiversity value. See attached supporting information for additional lake information and ranking methods.

Project limitations:

Although our results suggested that climate warming and road use were negatively impacting lake fish in this region, it is important to keep in mind that we only looked at a small number of lakes. In contrast, the GSA and ISR contain tens of thousands of lakes as well as major river, delta, and nearshore marine habitats for fish species. It is important to understand that climate change may be impacting fish differently depending on where they spend their time. For example, fish that migrate to the delta or out to sea during summers may actually be benefitting from warming if it means there is more food available for them.

Another thing to consider is that some permafrost thaw common in this region (known as shoreline retrogressive thaw slumps) may actually improve fish habitat by reducing nutrient levels and making the water clearer. Right now, more work is needed to understand the bigger picture for how fish in the GSA and ISR might respond to climate change in the long-term.

Summary:

We found that climate warming and new road development may have negatively impacted lake fish in the GSA and ISR. However, lowered fish diversity was related to water quality degradation and was not in response to warmer water temperatures as we had initially expected. Local communities may consider prioritizing the protection of larger and well-connected lakes that contain more fish biodiversity when making future land use and fisheries management decisions. We also suggest that lakes are sampled before and after new construction to better understand the potential impacts of new infrastructure on these important ecosystems.

Thank you to:

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Supporting Information:

Biodiversity ranking methods

Biodiversity ranking was completed based on the number of species captured and the relative abundances of large-bodied fish more suitable for harvest (Table 1). Additional information that was considered was the relevance of species to the local communities, lake size, the presence of any current stressors around the lake, and any permanent stream connections to larger lakes/rivers nearby such as Husky Lakes, the East Channel, or the Peel River floodplain. We identified eight lakes that had "High" biodiversity value which may be considered biodiversity hotspots (Table 2, shaded in grey). These hotspot lakes were typically larger lakes or lakes with strong connections to larger habitats and they did not have any substantial development in their catchments.

Table 1. General biodiversity ranking methods according to number of species and the abundance of large fish captured in each lake (measured as large mesh catch per unit effort). Where lakes didn't fit clearly into a single category we considered other details described above such as relevance to local communities.

Biodiversity rank	Number of species	Large mesh catch per unit effort (CPUE)
High	3 – 4	Greater than 1.68 fish / net-hour
Medium (Med)	2	Greater than 1.13 fish / net-hour
Low	1	Less than 1.13 fish / net-hour
No fish	0	0

Table 2. Lake size, connectivity, and fish community information for our 50 study lakes. Lakes with high biodiversity values are shaded with grey. Species captured in each lake are marked with an "X", with short-forms for species including BW = broad whitefish, CS = least cisco (herring), IN = inconnu (coney), LT = lake trout, LW = lake whitefish (crookedback), NP = northern pike (jackfish), NSB = ninespine stickleback. We provide two catch per unit measurements (CPUE), one which is a measure of abundance with larger mesh gill nets and one with smaller mesh gill nets.

Lake ID	Latitude	Longitude	Depth (m)	Area (ha)	Connected	Species captured							Number of species	Large mesh CPUE	Small mesh CPUE	Biodiversity rank
						BW	CS	IN	LT	LW	NP	NSB				
1	69.37342	-133.037	5.2	27	N	0	0	0	0	0	0	0	0	0	0	No fish
2	69.36707	-133.044	3.3	31	N	0	0	0	0	0	0	X	1	0	1.35	Low
3	69.31477	-132.983	8.9	133	N	X	X	0	X	0	X	0	4	1.22	2.73	High
4	69.30497	-133.007	8	885	N	X	X	0	0	X	X	0	4	1.69	2.89	High
5	69.29724	-132.93	9.6	1179	N	0	X	0	0	X	X	0	3	2.38	1.26	High
6	69.28471	-132.903	10.6	70	N	0	X	0	X	0	0	0	2	1.81	0.44	High
7	69.22103	-132.888	3.4	63	N	0	X	0	0	0	X	0	2	0.74	2.22	Low
8	69.21164	-132.9	2.7	26	N	0	0	0	0	0	0	0	0	0	0	No fish
9	69.20114	-132.937	2.9	31	N	0	0	0	0	0	0	0	0	0	0	No fish
10	69.19182	-132.951	3.4	830	Y	0	X	0	0	0	X	0	2	1.16	2.27	Med
11	69.16526	-133.038	10.7	67	N	0	X	0	0	0	X	0	2	1.67	1.39	Med
12	69.14185	-133.035	4.7	10	N	0	0	0	0	0	X	0	1	NC	NC	Low
13	69.13014	-133.04	3.2	27	N	0	0	0	0	0	X	0	1	NC	NC	Low
14	69.09845	-133.083	2.9	115	N	0	0	0	0	0	X	0	1	1.41	0.50	Low
15	69.06757	-133.203	11.64	1310	Y	0	X	0	0	X	X	0	3	2.60	2.38	High
16	69.06515	-133.148	4.5	27	N	0	X	0	0	0	0	0	1	0	1.54	Low
17	69.00984	-133.314	6.6	32	N	0	X	0	0	0	X	0	2	0.30	0.51	Low
18	68.90628	-133.497	4	3	N	0	0	0	0	0	0	X	1	0	33.55	Low
19	68.899	-133.491	3.3	58	N	0	0	0	0	0	0	0	0	0	0	No fish
20	68.89853	-133.54	4.2	42	N	0	0	0	0	0	0	0	0	0	0	No fish
21	68.84672	-133.555	2.4	20	N	0	0	0	0	0	X	0	1	0	0.11	Low
22	68.84546	-133.539	7.5	72	N	0	0	0	0	0	X	0	1	0.69	0.26	Low

23	68.82339	-133.56	5.2	71	N	0	0	0	0	0	0	0	0	0	0	No fish
24	68.82043	-133.57	2.5	183	N	0	X	0	0	0	X	0	2	3.82	3.33	High
25	68.8127	-133.542	4.9	14	N	0	0	0	0	0	0	X	1	0	5.35	Low
26	68.81207	-133.554	7.2	23	N	0	0	0	0	0	X	0	1	0.26	0.18	Low
27	68.57744	-133.74	2.4	113	N	0	0	0	0	0	0	0	0	0	0	No fish
28	68.56477	-133.754	0.6	58	N	0	0	0	0	0	0	0	0	0	0	No fish
29	68.54529	-133.743	13.1	153	N	0	X	0	X	X	X	0	4	3.38	2.04	High
30 (Boot Lake)*	68.3515	-133.702	5.9	21	Y	0	X	0	0	X	X	0	3	0.96	8.50	Med
31	68.34356	-133.706	5.8	14	N	0	0	0	0	0	0	X	1	0	0.19	Low
32 (Jak Lake)	68.3342	-133.676	5.2	32	Y	0	X	0	0	X	X	0	3	1.36	3.03	High
33*	68.3192	-133.616	5.5	90	N	0	X	0	0	0	X	0	2	0.78	0.01	Low
34	68.312	-133.35	5.2	1	N	0	0	0	0	0	0	0	0	0	0	No fish
35	68.2943	-133.283	2.2	9	N	0	0	0	0	0	X	0	1	0	1.32	Low
36	67.7913	-133.791	2.8	0	N	0	0	0	0	0	0	0	0	0	0	No fish
37	67.5048	-133.767	4.1	1	N	0	0	0	0	0	0	0	0	0	0	No fish
38	67.47414	-134.72	3.2	74	N	0	0	0	0	0	0	0	0	0	0	No fish
39	67.4651	-134.747	2.6	10	N	0	0	0	0	0	0	X	1	0	0.14	Low
40	67.44469	-134.513	6.7	30	N	0	0	0	0	X	X	0	2	0.69	0.37	Low
41	67.4293	-134.846	4.8	7	Y	0	0	0	0	X	X	0	2	1.56	1.00	Med
42	67.42827	-134.86	6.1	9	N	0	0	X	0	X	0	0	2	3.09	5.89	Med
43	67.421	-133.925	1.8	5	N	0	0	0	0	0	0	0	0	0	0	No fish
44	67.4202	-133.94	1.5	4	N	0	0	0	0	0	0	0	0	0	0	No fish
45	67.41566	-133.952	2.3	189	N	0	0	0	0	0	0	X	1	0	2.07	Low
46	67.4119	-134.411	1.2	41	N	0	0	0	0	0	X	X	2	0	0.43	Low
47	67.40497	-134.38	1.5	42	N	0	0	0	0	0	X	X	2	0	0.30	Low
48	67.3833	-134.04	1.8	16	N	0	0	0	0	0	0	0	0	0	0	No fish
49	67.3434	-134.868	4.5	1	N	0	0	0	0	0	0	0	0	0	0	No fish
50	67.3377	-134.913	5.3	54	Y	0	X	X	0	X	X	0	4	0.45	0.84	Med

*Sampling methods differed for these two lakes and CPUE was estimated based on the relationship between overnight gillnet sets and short sets;
NC = indicates CPUE information was not comparable and therefore not reported here