

# Disrupted ecosystem and human phenology at the climate frontline in Gwich'in First Nation territory

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In the Arctic, the dynamic nature of climate change is directly affecting ecosystems and human communities (Bush & Lemmen 2019). Climatic changes are often reported as regional trends, but impacts differ between and within ecosystems and are ultimately experienced locally (Byg & Salick 2009). Additionally, directional trends in environmental conditions do not fully represent impacts because increased variability within and across years may also drive significant change. We considered multiple changes occurring in the Gwich'in Settlement Area (GSA) in northwestern Canada to highlight how Arctic residents are dealing with global change at local scales and why local experiences are relevant to global audiences.

We are a group of Gwich'in First Nation land users and researchers collaborating on a community-based monitoring program and other research related to an important subsistence fish in the Mackenzie River watershed: *luk dagaii* (broad whitefish [*Coregonus nasus*]) (Hovel et al. 2020; Proverbs et al. 2020). The ongoing monitoring program is a partnership between Gwich'in community members, the Gwich'in Renewable Resources Board ([www.grrb.nt.ca](http://www.grrb.nt.ca)), community Renewable Resource Councils, and academic researchers. Authors A.S., A.V., and E.V. are Gwich'in land users involved in the monitoring program. They sample a subset of their subsistence harvest to document information about *luk dagaii* populations (Hovel et al. 2020; Hodgson et al. 2020). In our experience, identifying local impacts of environmental change is key to understanding their varied effects and developing adaptive strategies.

Indigenous people around the world are intricately connected to the ecosystems where they live and hold deep knowledge of seasonal changes in biological and environmental conditions. This traditional knowledge (TK) is passed through generations and informs historical and present-day land use (Turner et al. 2000; Eira et al. 2018). Like other Indigenous people, the ancestors of A.S., A.V., and E.V. monitored the land, noting patterns and unusual events (Gill et al. 2014). This tradition continues today. Throughout the GSA, residents are witnessing unprecedented changes to the land, rivers, and lakes (Gill et al. 2014). Until recently, interactions between the Gwich'in and the seasons, land, and animals operated in a predictable cycle (Fig. 1). This seasonal rhythm, however, is changing rapidly.

As landscapes change, Gwich'in land users frequently observe novel conditions and can no longer consistently rely on knowledge of seasonal patterns. For instance, community members noted an unseasonably warm March in 2019, when it rained instead of snowed. This had not happened in living memory, and reflects increasing March temperatures (Fig. 2). A.S. noticed unusual seasonal temperatures for the rest of 2019. He wore winter clothing in July, but a t-shirt in September, when conditions are typically frosty. These seasonal shifts have resulted in uncertainty, and A.V. was unsure whether it would stay cold or warm up amidst these unpredictable changes. Other unusual conditions contribute to uncertainty, including changing river hydrology and flow phenology (Yang et al. 2015). Near Fort McPherson, Northwest Territories, average monthly discharge of the Peel

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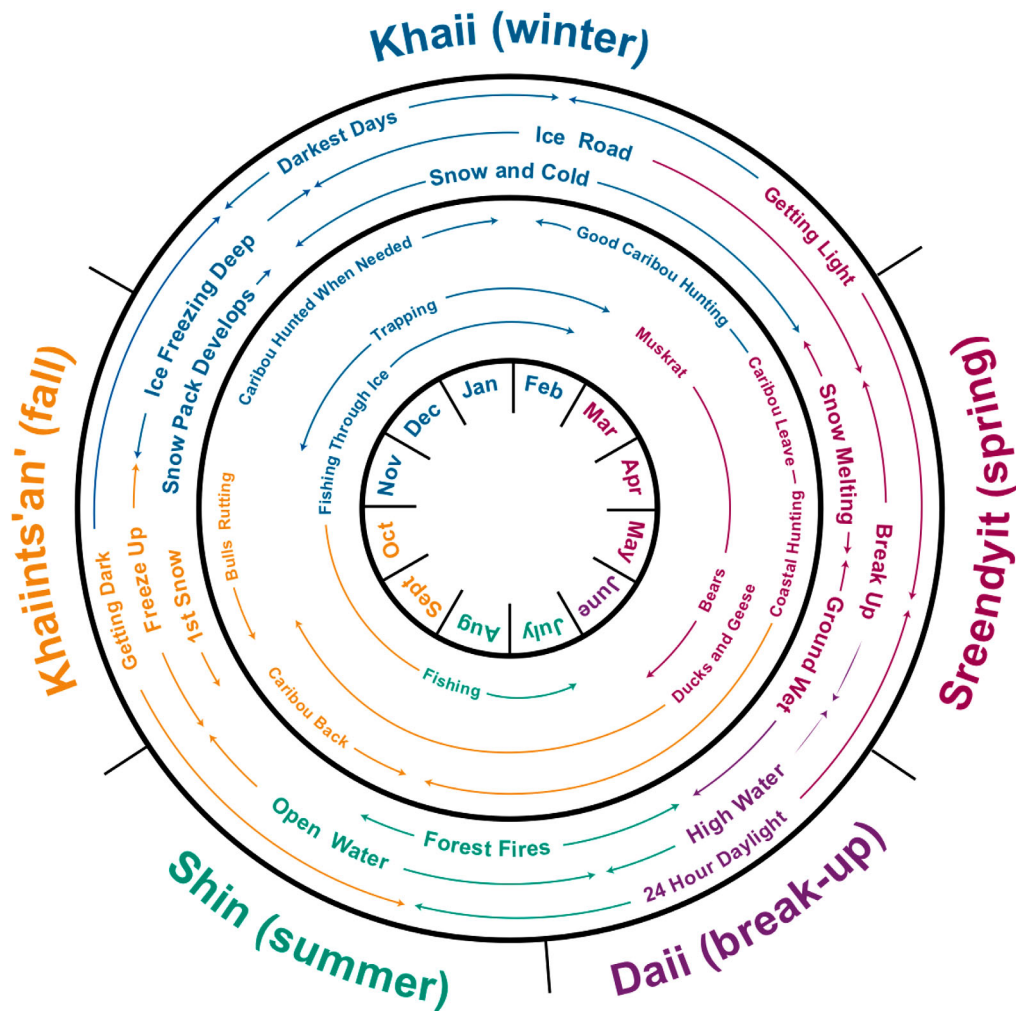
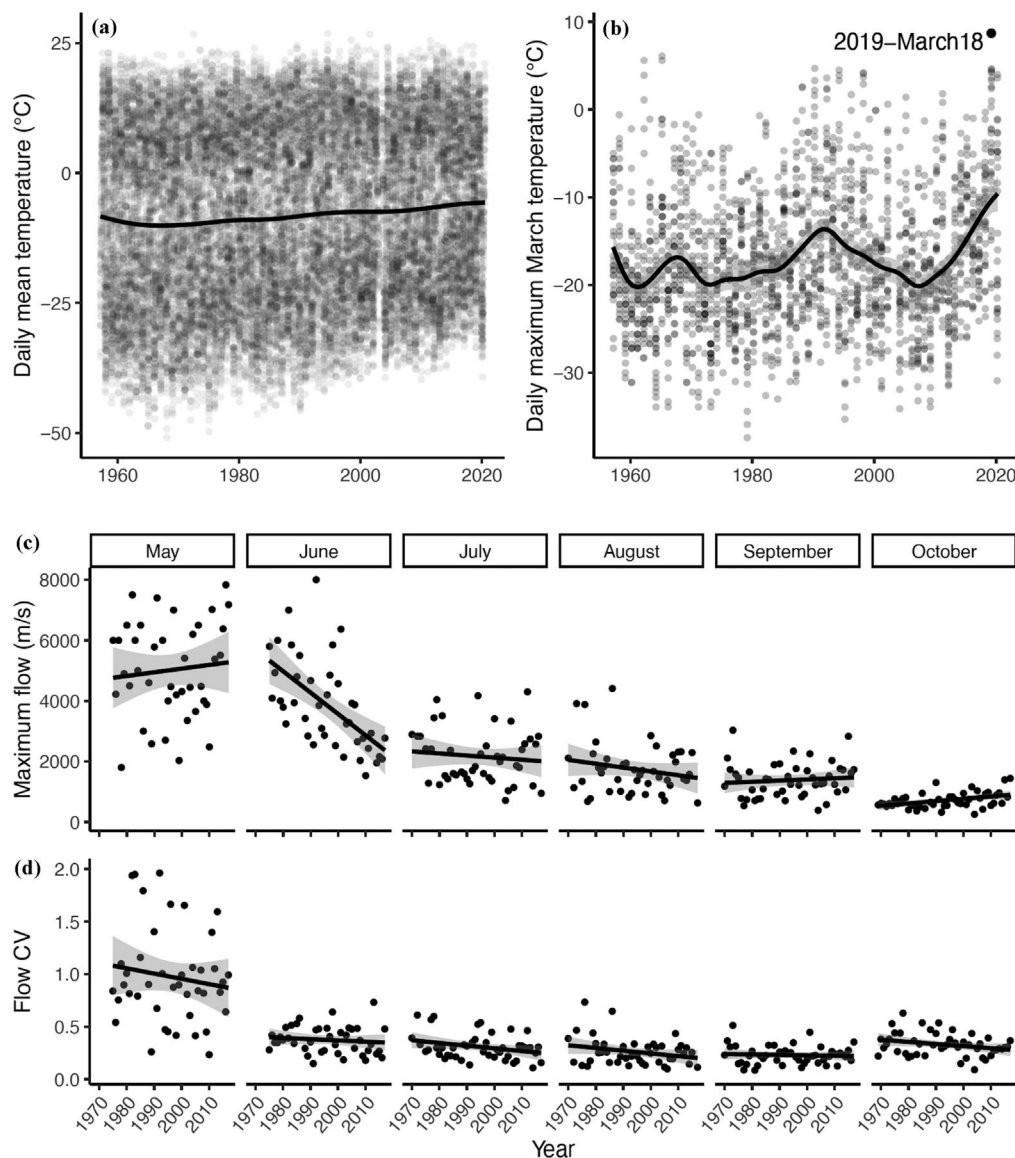


Figure 1. The Gwich'in Seasons Calendar: outer circle, the 5 Gwich'in seasons; second circle, environmental conditions in each season; third circle, land-use activities (i.e., trapping muskrats [*Ondatra zibethicus*]) and animal behaviors (e.g., caribou [*Rangifer tarandus*] rutting) in each season; innermost circle, Julian months that correspond with each season, environmental condition, and land use; matching colors illustrate the correspondence between environmental conditions and land uses and seasons and months. Several Gwich'in seasonal land uses are represented that are a part of the Gwich'in traditional economy, including the harvesting (trapping, hunting, fishing, gathering) of animals and plants every year. Plants are not described, but harvesting plants is an important Gwich'in land use. Permission to include this figure was granted by the Gwich'in Tribal Council.

River is changing, with trends varying among months (Fig. 2). August flow has been decreasing through time (Fig. 2), similar to elsewhere in the Mackenzie River Basin (Bawden et al. 2014). These and other unusual conditions affect harvesters' access to the river. In autumn 2019, A.S. witnessed rapidly changing water levels on the Peel River, including the lowest flows he had ever witnessed at his camp. In 1 day, water levels dropped so quickly that he could not repeat his boat route in the same day, a highly unusual occurrence.

Uncertainties and unpredictability in environmental conditions affect Gwich'in land use. For instance, climate variability compromises harvest predictability (Fig. 1),

and changing river phenology affects fishing practices. Gwich'in ancestors knew when to set nets, and taught A.S. to start fishing around 26 June. In 2019, he set a net on 10 June—over 2 weeks ahead of the traditional schedule—and caught many fish. A.S. had never experienced this, associating it with warmer temperatures and early ice breakup. These changes have land users concerned about fish migration, spawning, and competition from new species. In the last few years, A.S. has caught fish with mature eggs in November, something typically seen in October. Additionally, A.V. noted rapidly increasing numbers of Pacific salmon in Gwich'in territory. All 5 Pacific salmon species have now been caught



**Figure 2.** Historic trends in air temperature and river discharge. Results of generalized additive models for 1957–2020 data on (a) daily mean air temperatures and (b) daily maximum air temperatures in March for Inuvik, Northwest Territories. The 2019–March 18 point in panel b indicates the only date in the record on which the maximum temperature was  $>8^{\circ}\text{C}$  in March. Results of linear models of monthly maximum discharge in (c) the open water season and (d) within-month coefficient of variation for 1969–2017 in the Peel River near Fort McPherson, Northwest Territories. Additional information on this figure including data sources and model fits are provided in Appendix S1.

in the Arctic, and community members are concerned they will compete with subsistence fishes (Dunmall 2018).

In response to shifting and unpredictable phenology, Gwich'in land users combine TK with an innovative mindset. Researchers increasingly cite Indigenous Peoples' relationships to the land and TK as factors that enhance responses to social-ecological changes (i.e., adaptive capacity [Ford 2012]). Gwich'in community members are adapting in multiple ways, including mod-

ifying fishing techniques. For example, changing hydrology has changed river morphology. During low water in 2019, E.V. could not fish in his traditional eddy, so he set his net near a recently formed sand bar and successfully caught fish. Additionally, A.V. determined how to dry fish in damp, unexpectedly cool summer weather: keep a woodstove burning in the drying house to prevent mold. In a third example, A.S. prepared to fish ahead of schedule in 2020. Although water levels were too high, he will remain flexible in the future. By devising new

fishing techniques in response to change, E.V. and A.V. are adapting to uncertain conditions.

Gwich'in community members are passing on this new knowledge by teaching youth land-based skills. Teaching about both traditional environmental conditions and new, variable conditions creates a strong foundation of traditional and adaptive practices. With his sons, A.S. plans to teach land-based skills to youth who have not had the opportunity to learn. It is important to him that local youth, in a time when they see younger generations protesting climate change globally, know they can learn to survive. A.V. and E.V. also teach youth, and A.V. shares similar feelings, quoting another community member who said: "Eventually, we're going to have to go back on the land." She strongly feels that youth need to know their traditional ways of life alongside how the land is changing. E.V. says teaching youth is important to protect people's lifestyles and put food on the table. A.S. emphasizes that they have to teach TK differently because of unpredictability: He feels that he has to find new ways to survive by continuing to utilize everything the Elders taught him and also adapting some of these practices.

Gwich'in community members are also sharing knowledge outside of their community, including with researchers. Like many community members, AS., A.V., and E.V. wonder what unpredictable conditions mean for the animals they harvest. This has driven their involvement in research. A.V. hopes her observations will inspire ideas for addressing changing landscapes and lifestyles. A.V. and E.V. stress the importance of including youth in research, to provide training, exposure to biology and other disciplines, and time on the land (Hovel et al. 2020). For E.V., knowledge coproduction instills hope that fish will not be neglected. The projects described here coproduce knowledge by centering community priorities around adaptation to changing phenology, providing opportunities for youth and combining TK and Western science to understand the impacts of changing environments.

It is increasingly recognized that collaboration with Indigenous communities is essential to doing meaningful scientific research about environmental change (Ban et al. 2018). When conducted in a way that respects multiple approaches and recognizes the validity of different knowledge systems, incorporating both TK and Western science can strengthen project design and implementation and provide unique insights (Pearce 2018). The mutually beneficial projects described here were motivated by the importance of *luk dagaii* to Gwich'in ways of life. We adapted scientific methods based on Gwich'in knowledge to answer questions and implement methods relevant to all parties. Gwich'in knowledge is central to study design (e.g., when, where, and how to sample fish without compromising fish drying techniques), and

Gwich'in adaptive strategies have ensured fishing success despite fluctuating water levels and uncertainty in migration phenology.

Gwich'in observations of environmental change and adaptive responses highlight research areas that require further attention across the north. For instance, substantial scientific knowledge gaps remain for northern fish species (Dey et al. 2018). In Gwich'in territory, life history patterns and habitat requirements are uncertain for many species, although scientific research in the region has occurred for decades (Reist 1989; Harris et al. 2012). Gwich'in knowledge can help fill these knowledge gaps, and Gwich'in observations of changing seasonal phenology have prompted additional questions of interest to community members and researchers. These include questions about fish spawning, migration, phenology, abundance, and interactions with new species and safety concerns over accessing the river. Complementary scientific tools can address questions that cannot be answered fully with TK, such as tracking life-long fish movements (Hodgson et al. 2020).

Detailed observations and adaptive strategies make Indigenous land users powerful players in research on global ecological change. Indigenous groups around the world possess longstanding TK about their territories, foster high amounts of biodiversity, and have significant adaptive capacities (Ford 2012; Schuster et al. 2019). We believe that focusing on these experiences at local scales lends numerous benefits, including the following: local voices highlight the impacts of global climate change at scales relevant to social-ecological systems; local experiences showcase innovative adaptive strategies that are effective within or across regions; and collaborations between communities and researchers extend local experiences with environmental change and adaptation to broader audiences.

In these ways, collaborative work addresses pressing questions on social-ecological change relevant to local communities and global audiences. This comprehensive approach informs understandings of patterns of climate change and adaptations at the spatial and temporal scales at which they are expressed.

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## Supporting Information

Additional information is available online in the Supporting Information section at the end of the online article. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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