The 2014 NWT Fires – Returning results and determining next steps

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Photo credit: Environment and Natural Resources – Government of the Northwest Territories

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The fire season of 2014 saw 2.85 million ha of forested lands impacted by wildfires in the Northwest Territories (NWT), which made this the largest fire season in the NWT's history. The fires were concentrated in the region around Great Slave Lake (Figure 1) and thus affected the majority of NWT residents. Direct impacts to people living in the NWT included dramatic reductions in air quality, closures and damage to roads and power transmission infrastructure, and risks to community safety. In addition, the fires impacted a wide range of ecosystems across several distinct ecoregions and over large wildland areas. The 2014 fires presented a unique opportunity to address important knowledge gaps across a diverse range of ecological conditions and levels of burn severity in the southern NWT. To this end, participants from the Government of Northwest Territories (GNWT) gathered in January 2015 with researchers from universities and federal government agencies from across Canada and USA to discuss the research needs arising from the 2014 fire. For full details of the 2015 workshop, please see Baltzer and Johnstone (2015).

Since the original workshop, several major research projects were initiated throughout the areas affected by the 2014 wildfires (Figure 1) offering the opportunity to reconvene with the following goals:

1) Have researchers report back on research outcomes to date and develop syntheses to integrate newly acquired knowledge of fire in the NWT
2) Develop plain language messages of the key results arising from the research
3) Discuss opportunities for integration of new fire science into the curriculum of schools and colleges in the NWT
4) Identify next steps in the NWT fire research program based on priorities that were identified in the 2014 workshop but were not completed or new questions that have arisen through research or community-identified needs.

At the original workshop, researchers were broken into five themes and this structure was maintained in the 2019 workshop. Research results are summarized by these themes and the 2015 workshop outcomes below.

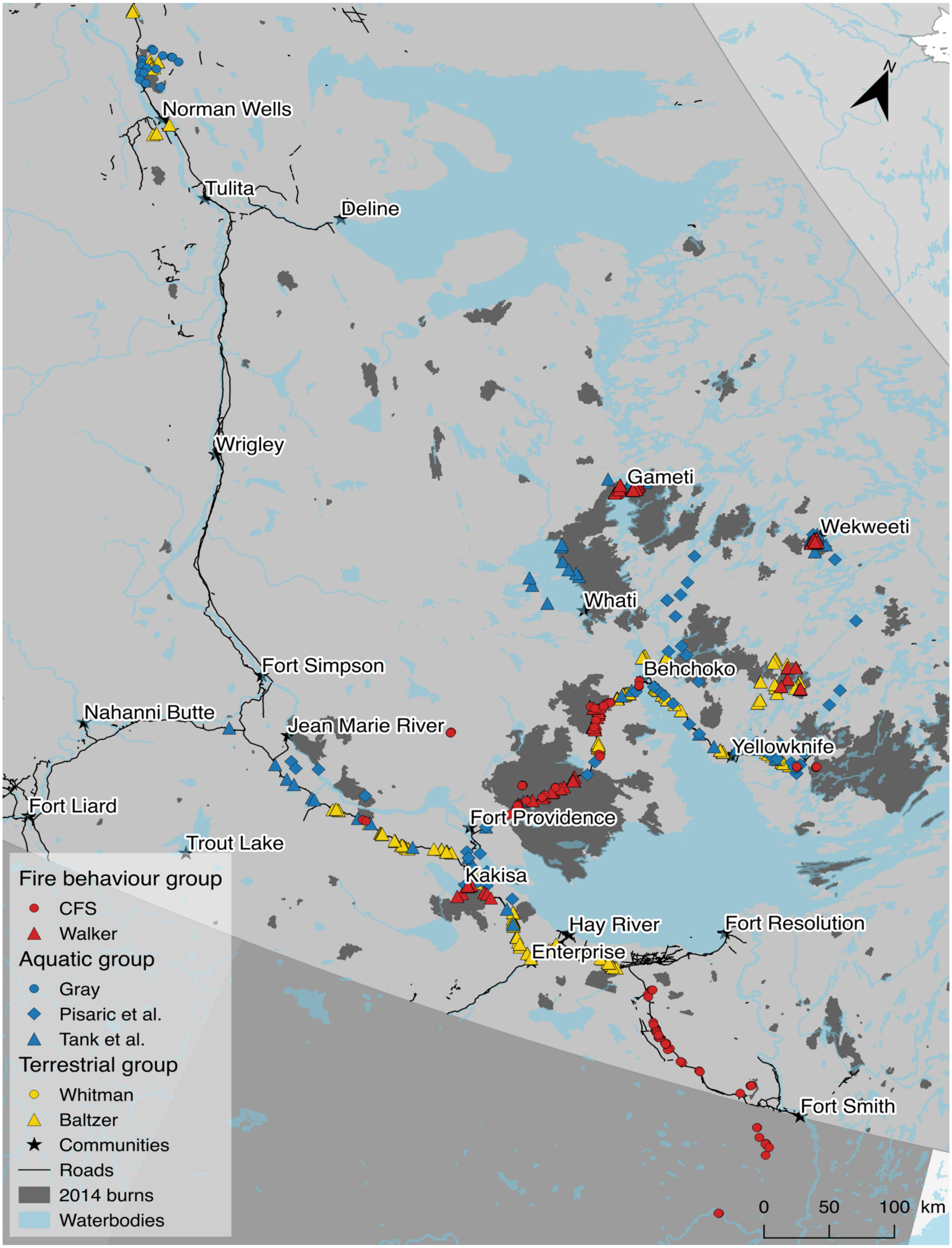


Figure 1. Locations of field sampling efforts by theme.2014 fire perimeters are indicated in dark grey. Map prepared by G. Degré-Timmons.

Terrestrial Working Group
Working group leads: Ellen Whitman and Carolyn Gibson

The health and renewal of the boreal forest relies on regular wildfire and over the past several thousand years, wildfire has led to self-replacement of boreal forests due to the adaptions that many boreal plants and trees have for rapid recovery following fire. However, warming and drying of boreal systems is leading to more extreme fire conditions which have been shown to result in changes in how forests recover following fire. For example, in Alaska, severe fire has been shown to cause self-replacing black spruce stands to convert to aspen forests. These changes alter the composition, structure and function of the forest with substantial implications for ecosystem services. Research carried out in this theme focused largely on whether this unprecedented fire event drove changes in vegetation recovery and what the drivers of these changes were, much of which informs wildfire impacts on wildlife habitat. A second area of research in this theme related to the impact of wildfire on rates of permafrost thaw. In the southern part of the NWT permafrost thaw and loss is occurring rapidly and fire has the potential to greatly accelerate this.

Table 1. Terrestrial research priorities identified during the 2015 Yellowknife Fire Workshop (Key Questions) and the status of our knowledge of these issues in 2019. Key results and their sources are provided.

Key questions identified in 2015 workshop	Level of assessment	Key results and insights	Source
How do pre-existing conditions and fire severity influence patterns of vegetation succession after fire?	Fully assessed	•Broadleaf (Taiga Shield) and jack pine and aspen (Taiga Plains) abundance increased at the cost of black spruce following the 2014 fires, particularly in drier sites where soil combustion was severe •Short interval fires increased the likelihood of post-fire regeneration failure •Severe canopy combustion reduced total and viable seed rain of black spruce •Except in the driest sites where organic soil burning was most complete, the majority of ground vegetation recovered from rhizome suggesting burning was not deep enough to affect these belowground structures •Deep burning reduced the species richness and abundance of beneficial fungi which corresponded with decreases in plant community richness •Heat-resistant fungi were common in the newly burned landscape and commonly reduced seedling growth	Whitman et al. 2018 Day et al. 2019 Whitman et al. 2019 Day, White et al. 2020 Day et al. 2020 Day et al. in review Reid et al. in review
Under what conditions do we see vegetation recovering to its pre-fire	Fully assessed	•Resilience was greatest in poorly drained landscape positions where thick residual organic layer was maintained even after fire.	Whitman et al. 2018 Day et al. 2019

composition vs. shifting to a new state?			Day, White et al. 2020 Day et al. in review
What factors controlled C emissions during the 2014 fires?	Fully assessed	•Across ecosystems, 3.4 kg C/m^2 was combusted on average. Combustion was insensitive to moisture class in jack pine stands. Black spruce forests lost proportionally less carbon with increasing soil moisture •Despite smaller depth of burn relative to Alaska, regional C losses from the NWT fires remained high. 94.3 Tg C was released from the 2014 NWT fires. •Legacy carbon (i.e., carbon that has escaped burning in previous fire cycles) was present across the landscape, particularly in wetter landscape positions. There was evidence of legacy carbon combustion, particularly in drier sites and where fire return interval was <70 years.	Walker et al. 2018a,b Walker et al. 2019
How does permafrost vulnerability to thaw influence patterns of vegetation succession?	Partially assessed	•Surface permafrost under thin organic layers is most vulnerable to thaw under with thin organic layers meaning that thick peat layers add resilience to permafrost. •Fire increases expansion rates of thermokarst bogs at three times the rate of climate warming-related thaw •Viable fungal spores are found throughout the permafrost profile. When seedlings were inoculated with these fungi that will be released during thaw, growth was negatively impacted or showed no response	Gibson et al. 2018 Holloway et al., 2020 Holloway et al. in prep. Day et al. in prep

Table 2. Hierarchical rules defining resiliency of forests and wetlands to the 2014 NWT wildfires. Results summarize the findings of Day (2019, 2020), Walker (2018a,b; 2019), Whitman (2018, 2019) papers listed in the references.

Forest type	**Key consequences (who cares?)**
Proportion of soil organic layer combusted (cm): •xeric > mesic > hydric •jack pine > black spruce[3]	Drives patterns of vegetation recovery and permafrost stability
Carbon combustion/m^2: •mesic = hydric > xeric •For proportional combustion xeric > mesic > hydric	Climate feedbacks

Loss of legacy (old) carbon: •xeric > mesic > hydric •young xeric stands>older xeric stands	Climate feedbacks
Vegetation resilience (recovery of forests and ground vegetation): •jack pine > black spruce •hydric, mesic > xeric	Climate feedbacks, wildlife

It is noteworthy that the impacts of the 2014 NWT wildfires have now been put into a broader context. Syntheses resulting from a NASA ABoVE workshop led by M. Mack have resulted in two soil carbon combustion syntheses that include northwestern North America (Walker et al. 2020; Walker et al. accepted) and a North America-wide post-fire regeneration synthesis (Baltzer et al. in review). It is clear from these syntheses that there are both commonalities and regional specificity in the drivers of combustion and regeneration and the post-fire outcomes of tree regeneration.

Needs for Future Research and Recommendations

- Improved understanding of post-fire permafrost change as a driver of vegetation dynamics. Key recommendation: Establish additional plots for improved monitoring of permafrost stability in burned and unburned sites. *Status*: *CIMP funding is in place to support this effort beginning in 2020 (Dieleman, Baltzer and Turetsky leads).*
- Moving beyond a case study, put 2014 in context of other years to better understand and predict future forest health and conditions. Key recommendation: continue to monitor ecosystem responses to a range of fire conditions. *Status: UK Natural Environment Research Council funding in place to evaluate drivers of regeneration failure; PKC funded project focused on evaluating the frequency of post-fire vegetation state changes through time (Baltzer, Turetsky and Cumming leads; UK collaborator Baxter from University of Durham).*
- Enhanced understanding of ecological thresholds, their impacts for community well-being, and the consequences of surpassing them. Key recommendation: Work toward understanding what ecological tipping points, and surpassing them, mean for community well-being and the associated impacts on land use and livelihoods. *Status: This forms a focus of C. Gibson's PhD research.*
- Improved understanding of what lagged effects of changes to the aboveground condition mean for belowground conditions. Key recommendation: continued monitoring of regeneration plots across a range of depth of burn. Continued monitoring of permafrost plots. *Status: CIMP, PKC, and UK NERC funding sources in place to support re-measurement of 2014 burn sites when COVID situation permits (Baltzer, Turetsky, Cumming leads).*
- Improved understanding of cascading effects and multiple linkages between aquatic and terrestrial ecosystems. Key recommendation: establish a working group of NWT researchers interested in co-locating terrestrial and aquatic measurements. Task this working group with developing conceptual models of change that can be tested using these measurements. *Status: GWF-funded Northern Water Futures project working toward some of these goals and could spearhead this working group (Baltzer and Swanson leads).*
- Enhance community-based monitoring opportunities in unburned sites to support pre-burn and post-burn studies, as opposed to paired burn, unburned sites. *Status: Training opportunities possible through GWF-funded Water Knowledge Camps and NSERC Promoscience-funded on-the-land events (Baltzer and Spring leads).*
- Improved understanding of NWT fires in climate feedbacks. Key recommendation: initiate study to compare climate feedbacks from changing snow, vegetation, and biomass burning. Where do fires

lead to net warming versus cooling? *Update: GWF-funded modelling project may support some of these activities (Baltzer and Clark leads).*

- Improved linkages between post-fire ecosystem monitoring and measurement of ecosystem services. Similarly, we need to enhance our knowledge of changes in social systems post-fire to strengthen our understanding of post-fire socio-ecological system. For example, burning of thick peat layers through smouldering does not lead to the greatest carbon emissions, but increases CH_4 and CO emissions, and also has the biggest impacts on people's health. Recommendation: Establish a committee to identify key metrics of change that matter from ecological and social frameworks. Task this committee with designing a socio-ecological monitoring program that links changes in the ecological environment to changes in the social environment.
- Improved understanding of combustion versus ecosystem recovery. Analysis of plant and soil recovery with time-following-fire in the NWT are ongoing, but results to date suggest that forested stands will recover their pre-fire carbon stocks within 50 years. Key recommendation: design field measurements to understand how recovery rates are impacted by fire return interval and fire-thaw interactions. *Status: 2019 field work in support of fire-permafrost interactions completed (Turetsky and Baltzer, leads)*

Aquatic and Hydrology Working Group
Working ground leads: Suzanne Tank and Chris Spence

Fire disturbance may be expected to lead to considerable changes in both runoff and water quality in the short-term as particulate from the fire is deposited on or drains into water bodies or in the medium- to longer-term in response to fire-induced permafrost thaw. Northern communities are reliant on healthy aquatic communities meaning an improved understanding of impacts of severe wildfire is critical.

Table 3. Water quality research priorities identified during the 2015 Yellowknife Fire Workshop and the status of our knowledge of these issues in 2019. Key results and their sources are provided.

Key questions identified in 2015 workshop	Level of assessment	Key results and insights	Source
What are the consequences of fire for hydrological processes and water quality?	Hydrology mostly assessed using several paired burned/unburned catchments; Water quality assessed using synoptic sampling across sites	•Preliminary studies of paired burned/unburned watersheds suggest the following hydrologic responses following fire: deepening of active layer, increased net radiation and snow water equivalents, loss of preferential flow and change in seasonality of runoff; increased runoff in Taiga Shield •Cross-site sampling suggests no strong or long-term effects of fire on water quality in streams, though there is evidence of fire-related differences in dissolved organic carbon quality. •In contrast to stream systems, the longer residence time of lakes may enable a fire associated-effect in aquatic communities	Burd et al. 2018 Tank et al. 2018 Hutchins et al. 2019 Burd et al. 2020 Pretty et al. in revision Spence et al. in review
How do fire effects vary with proportion of catchment burned or fire severity?	Partially assessed and studies continue in the Dehcho and Sahtu regions	•Catchments with fewer lakes, less exposed bedrock and higher forest cover are less hydrologically resilient to forest fire. The more forest before the fire, the more that must burn in order for there to be a change the catchment hydrological function. However, wet conditions reduce this threshold burn fraction.	Spence et al. in review Baker, Bill, Swanson, Baltzer, Turetsky, Gibson, in progress
How do fire effects vary across different ecological	Partially assessed	•Little effect was found of ecological region in evaluations of post-fire water quality	Tank et al. 2018 Hutchins et al. 2019

regions and permafrost conditions?			

Needs for Future Research and Recommendations

- Are there effects of wildfire on fish populations and food supply? Key recommendations: Incorporate a fish specialist into future network efforts. Community collection of fish alongside populations surveys – analysis for toxin load?
- Improved community level monitoring in response to fire and other key stressors. Key recommendation: Extend assessment of benthic effects to stream systems, coupled with community assessment of freshwater quality and invertebrate communities. This could serve as a great outreach project for school groups. Curriculum could be designed for communities including resources for collection and taxonomic ID guide, water quality testing, etc. To what extent does this duplicate CMBP and CABIN work? Focus on headwater streams and lakes would be useful for understanding landscape effects
- Conduct synchronicity studies across landscapes. Key recommendation: Use remote sensing products to understand lake or other hydrological responses (chlorophyll a; turbidity). *Status: in progress through funded Northern Water Futures project (Swanson, Baltzer, leads)*
- Improved mechanistic understanding of what's happening between pore waters and stream waters; why do we see a response in one and not the other?
- Identify community-relevant ecosystem services and locations of interest/importance. Key recommendation: Building community capacity for monitoring to enable long-term efforts. See also key recommendations for Terrestrial WG.
- Examination of co-occurring stressors and the importance of fire in the context of long-term change *Status: in progress through modelling work being undertaken by C. Spence.*

Wildlife Working Group Summary
Working group leads: James Hodson and Steve Cumming

Food security and traditional livelihoods in the NWT depend on the availability and quality of wildlife habitat. While wildfire has supported forest renewal and health in the boreal for millennia, large fire years like 2014 have the potential to alter wildlife habitat. Communities and wildlife managers have well-founded concerns about the implications of climate warming induced increases in wildfire activity on the long-term health of wildlife populations in the NWT. Summarized below are the key related findings relating to wildlife arising since the 2014 wildfires and next steps in the research agenda.

Table 4. Wildlife research priorities identified during the 2015 Yellowknife Fire Workshop (Key Questions) and the status of our knowledge of these issues in 2019. Key results and their sources are provided.

Key Questions	**Status**	**Key Results**	**Source**
How do wildlife species change their habitat use in response to fire?	Partially Assessed	Traditional knowledge of caribou habitat indicates that large amounts of caribou habitat have burned recently Boreal caribou are using new fires (spatial analysis of collar data)[2] Boreal songbirds are resilient to fire. Only at very high burn severity was either songbird species richness or functional diversity reduced	Jean Marie First Nation/Yukon College GNWT-ENR M Knaggs, S Hache, S Nielsen, R Pankratz, E Bayne (ECCC, UofA)
What is the rate and pattern of habitat recovery after fire for different wildlife species (caribou, bison, fur-bearers, non-game species)?	Partially addressed	Lichen takes 40-50 years to recover to levels comparable to pre-fire. Traditional knowledge and western science[4] agree on this	Gruel, Degré-Timmons et al. in review
What are the patterns of caribou habitat quality within burned areas?	Not addressed but work ongoing		J Cook, R Cook, A Kelly, N Larter Deninu Kue First Nation
What is the natural range of variability in fire impacts on wildlife habitat based on historic conditions?	Not addressed but work ongoing[7]		D Andison, E McIntire, A Chubaty
What do we expect wildlife habitat suitability and availability to look like with increased fire activity?	Partially addressed	Spatial modelling indicates that boreal caribou habitat disturbance increases under climate warming induced increases in fire frequency	Sahtu Renewable Resources Board

Needs for Future Research and Recommendations

- Ask communities! Key recommendations: Make use of existing processes for setting research priorities
- Why do caribou use recent burns and what are they eating/doing there? Key recommendations: Continued efforts to understand habitat quality within burned areas including better land cover data; Evaluate the importance of summer browse for caribou diet; Evaluate how caribou post-fire habitat use depends on fire characteristics; Evaluate the duration of use of fires by caribou; Determine the transferability of findings from one herd to another; Use of new remote sensing products to extend field-measures over broader areas. *Status: Ongoing efforts by Cook, Kelly et al focus on forage quality and quantity across a fire chronosequence in the South Slave; Baltzer, Cumming and Turetsky have a PKC-funded project focused on remote mapping of lichen biomass including development of ecological forecasting tools.*
- Are there umbrella species that can be used to characterize broader wildlife responses to fire? Key recommendations: Require broad surveys of wildlife to address this; Pre- and post-fire surveys to evaluate the range of responses; Spatial modelling of these attributes to understand overlap/similarities. *Status: Ongoing efforts on this front by Cumming and the Boreal Avian Monitoring Project.*
- Limited knowledge of impacts of fire on many species or post-fire interactions between species. Key recommendations: Work with communities to identify other wildlife that require detailed study of wildfire impacts; Characterize the post-fire successional responses of wildlife based on available forage species; Need better land cover data; Ecological forecasting efforts can provide a framework to connect different parts. *Status: Funded project evaluating the recovery of key forage species for wildlife species of interest to communities (Baltzer, Cumming leads).*
- Link TK and western science understanding of recovery of wildlife habitat for different species. Key recommendations: Evaluate congruence between the time the community says it takes to come back vs. the time we see our measured values beginning to recover; Several existing indigenous led-caribou/fire projects that could/should connect with western science projects.

Fire regime mapping and modelling group summary
Working group leads: Nancy French and Dan Thompson

The 2014 fire season led to the largest area burned in a single year on record for the NWT. Reports from fire managers and communities of the 2014 wildfires suggested that the fire behavior during 2014 was unusual and that the impacts were more widespread in terms of the landscape positions that burned. There is a need to better understand fire behavior and controls on burning during these large fire years that are expected to become more common with climate warming.

Table 5. Wildfire regime research priorities identified during the 2015 Yellowknife Fire Workshop (Key Questions) and the status of our knowledge of these issues in 2019. Key results and their sources are provided.

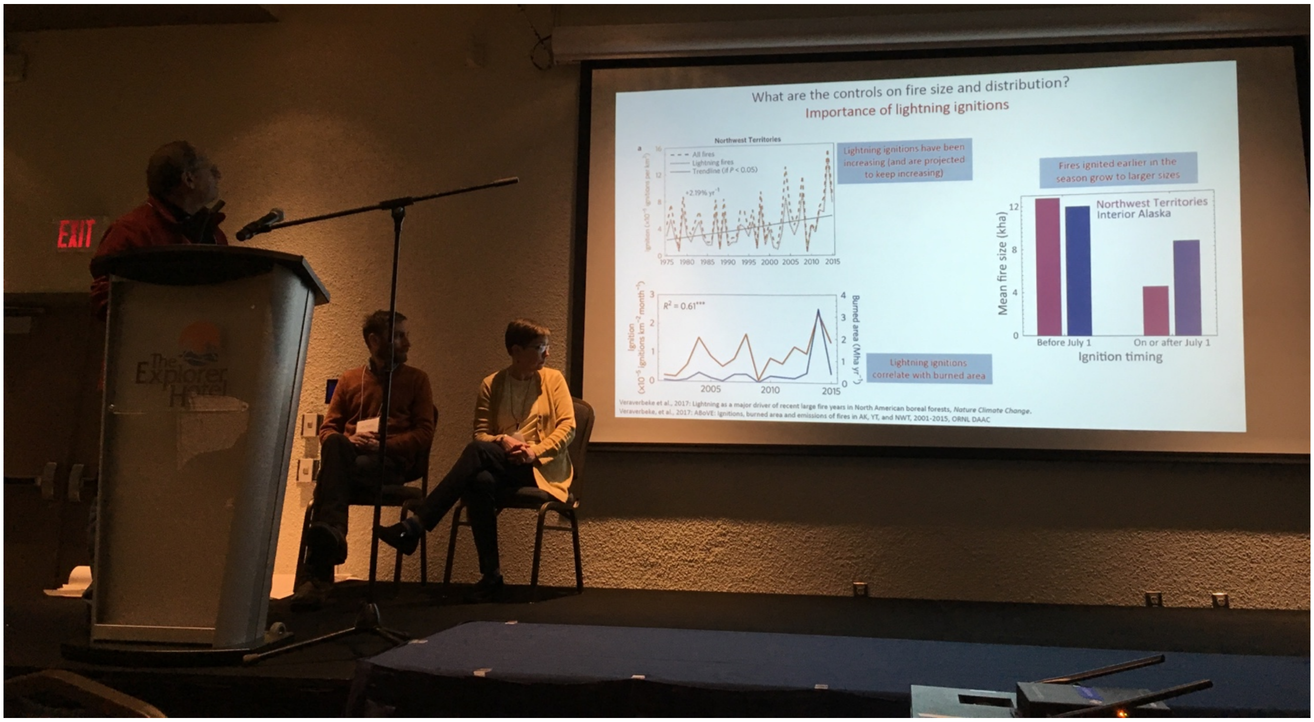
Key questions identified in 2015 workshop	Level of assessment	Key results and insights	Source
Are there reliable pre-season indicators of extreme fire years?	Partially assessed	• The winter and spring leading into summer 2014 were very dry, pre-conditioning forest fuels for fires	Kochtubajda et al. 2019
What are the controls on fire size and distribution?	Partially assessed	• Lightning ignitions have been increasing (and are projected to keep increasing) • Lightning ignitions correlate with burned area • Lightning activity was the main driver of fire activity; fire weather was dry but not unusual • Young forest was most resistant to burning but this break is less effective during drought • Drier parts of the landscape had both more spatially extensive and more severe burning	Veraverbeke et al. 2017 Parks et al. 2018 Kochtubajda et al. 2019 Walker et al. 2018a,b French, Bourgeau-Chavez et al. 2020 Bourgeau-Chavez et al., in prep
What are the controls on spatial and temporal variations in fire severity?	Assessed	• Fires ignited earlier in the season grew to larger sizes • Most severe to moderate burning occurred in coniferous forest but light burning was widespread in wetlands and deciduous forests, particularly on the Taiga Shield. • A quarter of the area was unburned or lightly burned • Drier parts of the landscape were more likely to experience complete combustion of the organic layer but mesic landscape positions have greatest total combustion	Veraverbeke et al. 2017 French, Bourgeau-Chavez et al. 2020 Walker et al. 2018a,b Whitman et al. 2018a Bourgeau-Chavez et al., in prep

How can we improve models of both flaming and smoldering combustion?	Not assessed		

Take home messages:
The next dry year won't result in another 2014 without extra lightning.
We are moving in a "new" fire regime (lightning; younger, more deciduous forest; new land-use).
Younger forest slows but does not stop a large fire.
There are some fires we can't put out and some we choose not to.

Needs for Future Research and Recommendations

- More rapid mapping of fire location and severity would help communities recover and adapt to new landscapes.
- How do we manage/prioritize initial attack under "2014 conditions"? Key recommendations: evaluate drivers and patterns of fire spread in the NWT landscape in "extreme years" to improve fire behavior models under these unusual conditions.
- Work on understanding fuel treatment maintenance. How are fuel breaks effectively and economically maintained? Key recommendations: work with communities to implement and maintain fuel breaks; modelling studies using information from previous bullet to evaluate spread under different fuel break scenarios. *Status: Ongoing work with the community of Kakisa to grow food in firebreaks, thereby supporting firebreak maintenance (A. Spring lead)*
- Work on education for young students on the fire regime "facts" for their communities and the boreal forest more generally. Key recommendations: update curriculum relating to fire ecology and behavior. Status: *On-the-land learning activities were developed and implemented in the community of Kakisa and could serve as a template for fire ecology activities (Spring et al. 2019)*
- Look at holdover fires. Recommendations: Evaluate how common holdover fires and in what type of vegetation are they supported. *Status: Remote sensing studies of holdover fires (Lead: S. Veraverbeke). Holdover fires from 2014 were detected in 2015 and Turetsky, Baltzer and Veraverbeke are working to access funds to evaluate the ecological impacts of these holdover fires.*
- Better understand the possibility of another extreme year. How do we know when an extreme year is going to happen? What can we do?



EXIT
The Explorer Hotel
What are the controls on fire size and distribution?
Importance of lightning ignitions
Northwest Territories
All fires
Lightning fires
Trendline (if P < 0.05)
+2.19% yr⁻¹
Lightning ignitions have been increasing (and are projected to keep increasing)
Fires ignited earlier in the season grow to larger sizes
Northwest Territories
Interior Alaska
Mean fire size (kha)
Before July 1
On or after July 1
Ignition timing
R² = 0.61***
Burned area (Mha yr⁻¹)
Lightning ignitions correlate with burned area
Veraverbeke et al., 2017: Lightning as a major driver of recent large fire years in North American boreal forests, Nature Climate Change.
Veraverbeke, et al., 2017: ABoVE: Ignitions, burned area and emissions of fires in AK, YT, and NWT, 2001-2015, ORNL DAAC

Human Dimensions
Working group leads: Craig Scott and Andrew Spring

The 2014 wildfires were focused around many NWT communities meaning that there were immediate impacts of fire and smoke that directly affected many communities. The various changes to the lands and waters described above have longer-term impacts on the well-being and livelihoods of northern communities.

Table 6. Human dimensions research priorities identified during the 2015 Yellowknife Fire Workshop and the status of our knowledge of these issues in 2019. Key results and their sources are provided.

Key questions identified in 2015 workshop	Level of assessment	Key results and insights	Source
How should we prioritize allocation of human resources during large fire years	Not assessed		
What are best practices for dealing with air quality problems?	Partially assessed	•Summer of smoke research showed acute impacts of fire on human health: increased inhaler use, more clinic visits for respiratory issues, doubled ER visits for asthma and pneumonia •Respiratory health impacts were short-lived but mental health impacts were longer lived with heightened anxiety and issues relating to separation from the land and traditional activities •Perception that the summer of smoke was part of a broader issue of widespread environmental change. •Evidence of adaptation to severe smoke conditions	Dodd et al. 2018a,b
What is the effect of large fire years on food security in northern regions?	Partially assessed	•Many impacts were identified by communities including road closures, loss of access to the land, concerns about water and by extension fish health, impacts on gathering. •Concerns about post-fire regeneration and longer term impacts of such a big fire year •These impacts/concerns led to discussions about adaptations that could benefit communities including firebreak farming and morel harvesting •On-the-land learning opportunities were also developed.	Spring et al. 2019

Needs for Future Research and Recommendations

- Ask the community
- What are the implications of fire from a whole system perspective? Recommendations: integration of studies of fire impacts on permafrost, water quality, wildlife, contaminants, food access; Include community observation of change and impacts of fire in research efforts (e.g., when things come back, needed infrastructure)
- What are the community metrics of ecosystem health (i.e., when does it come back to original state)? Key recommendations: work toward knowledge co-creation (on-the-land knowledge exchange is needed to better understand impacts); Improve knowledge mobilization and sharing practices.
- Evaluate when species return to burned area. This should include a range of species (i.e., fish, caribou, muskox, berries, rabbit, birds, benthos etc.) and should incorporate both TK and western science methods and observations
- Are there changes to the quality/safety of wild food resources following fire? Key recommendations: Identify concerns about fire and contaminants impacts on food taste and preference and evaluate potential mechanisms; improve understanding of mechanisms and transformations (e.g., mercury methylation processes in water quality and fish health)
- What are the gendered impacts of fire on community food systems? Key recommendation: Work with fire-impacted communities to evaluate these differences and the implications for community resilience. *Status: Ongoing initiatives in Kakisa (Spring, lead)*
- What are the longer-term impacts of fire seasons like 2014? Key recommendations: long-term tracking of health impacts (follow up from 2014 impacts)

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