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The changing contribution of peatlands to burned area in Alberta's Boreal Plains

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Abstract

Fire regimes are changing globally in response to climate change, with burned area increasing across nearly all Canadian ecozones. The strongest trends are occurring in western Canada, including the peatland-dominated Boreal Plains (BP) ecozone. Until recently, land cover classification and fire perimeter resolution and accuracy have limited understanding of which ecosystem types contribute to burned area, in particular, the role of peatlands in the boreal wildfire regime. Here, we use a high-resolution wetland subtype map along with burned area perimeters and ignition point data to evaluate peatland burn rates and ignition conditions. We show that the contribution of coniferous treed peatlands to the total area burned in Alberta's BP ecozone increased between 1985 and 2019 and with total area burned. Coniferous peatlands burned at approximately twice the rate (percent of peatland type area/year) of deciduous peatlands over the study period and that deciduous treed peatlands have the greatest number of human-caused ignitions, affecting both ignition seasonality and peatland area burned. These new insights into the boreal fire regime help reveal drivers of change and have implications for land use planning, fire management, and carbon accounting as changes to ecosystem conditions and fire weather combine to produce shifts in fire regimes.

Key words: wildfire, peatlands, coniferous, fire regime, burned area, climate change

Introduction

Northern regions are experiencing the impacts of climate change at a greater rate than other geographical areas (Bush et al. 2022). This is pertinent for Canada which encompasses important northern ecosystems, including the second largest remaining contiguous area of forest that contains 1.136 million km^2 of peatlands (Tarnocai 2009). Peatlands are wetland ecosystems with >0.4 m of organic soil (peat) accumulation (NWWG 1997). These carbon-rich ecosystems are concentrated in the boreal zone but also exist in temperate and subarctic regions in Canada (Tarnocai 2009). An average of 12% of Canada's landbase is covered by peatlands, but some ecozones have a much higher coverage (e.g., the Boreal Plains is ∼30% wetland with the majority being peatlands, Ducks Unlimited Canada 2014; Pontone et al. 2024). Throughout the Holocene, peatlands have regulated the climate by limiting organic soil decomposition and sequestering carbon; however, these typically wet ecosystems may be especially susceptible to the impacts of climate change, such as evapotranspiration-driven drying (Helbig et al. 2020), leading to changes in their interactions with fire. These changes are likely to decrease the strength of their carbon sink capacity through greater oxic layer depth and associated increases in decomposition rate, as well as greater depth of burn and carbon combustion losses (Wilkinson et al. 2018, 2023).

Across Canada, climate change is driving increased evapotranspiration, greater drought frequency and severity, reduced snowpacks, permafrost thaw, and greater variability in precipitation (Helbig et al. 2020; Bush et al. 2022). These changes to climatic variables contribute to a higher potential for fire on the landscape through the drying of vegetation and soils creating more available above- and belowground wildfire fuels (Ellis et al. 2022). The impact of climate change on wildfire regimes is evidenced by the trends of increasing area burned across the majority of the landbase including in 13 of the 16 homogenous fire regime zones across Canada (Hanes et al. 2019). Further, there have been significant increases in the length of the fire season (Jain et al. 2017) and the size of large fires over the last 50 years (Hanes et al. 2019). These trends are expected to continue into the future with area burned projected to increase by ∼100% by 2100 (Flannigan et al. 2005) and the fire season to lengthen further (Wotton and Flannigan 1993). The effects of changing fire regimes could result in an alteration of peatland's role in the global carbon cycle; hence, it is critical to understand the extent to which their fire frequency (burn rate) is changing over time (Wilkinson et al. 2023). Further, to better understand the drivers and impacts of changes in landscape fire regimes it is important to identify what peatland types are burning and under what conditions.

Peatlands have historically been considered fire breaks on the landscape and under some conditions can act as fire- and climate-refugia (Tekatch et al. 2025). However, some studies suggest that changes in the hydrological status of peatlands, driven by drying, can lead peatlands to become more prone to combustion (Wilkinson et al. 2018; Thompson et al. 2019; Bourgeau-Chavez et al. 2020). In some regions of boreal Canada, peatlands have been found to burn at similar rates to uplands (Turetsky et al. 2004), or even preferentially under dry early-season conditions (Bourgeau-Chavez et al. 2020). Further, greater peatland proportion on the landscape has been correlated with larger fire sizes (Turetsky et al. 2004), suggesting that peatlands may, under certain hydrological conditions, connect landscape fuels and contribute to fire spread. However, such thresholds are likely to differ based on peatland type (Turetsky et al. 2002; Thompson et al. 2019).

Peatland type is predominantly based on hydrological characterization and vegetation community (National Wetlands Working Group [NWWG] 1997), though all peatlands are spatially complex, multi-layered systems, often with abundant above-ground fuels in stands of dense black spruce (*Picea mariana)* with some larch (*Larix* spp.; bog and poor-fens; Johnston et al. 2015) or more wet-adapted sedges, willows (*Salix* spp.), and birch (*Betula* spp.; moderate- and rich-fens; Schiks et al. 2016), sitting atop thick (>0.4 m) below-ground fuels in the form of carbon-rich peat deposits (Vitt 2006). If fire propagates into the peat deposits, smouldering combustion can last for weeks to months, including throughout winter (Scholten et al. 2021), causing suppression and mop-up challenges for firefighters (Rein and Huang 2021). Because of the high carbon content of peat, the majority of carbon emissions in peatland fires tend to originate from peat, rather than above-ground vegetation combustion (Wilkinson et al. 2018, 2021). However, above-ground fuels are critical for the ignition likelihood of peat (Thompson et al. 2017), potential smouldering severity (Wilkinson et al. 2018, 2021), and the spread of fire across peatlands (Johnston et al. 2015; Schiks et al. 2016). Critical distinctions for peatland types when defining wildfire behaviour can be summarized as: the predominance of a tree canopy, as opposed to shrub or grass/sedge dominance, and whether the canopy is coniferous-dominated or deciduous-dominated, as trees increase fuel loading and energy input into surface layers (Thompson et al. 2017) and deciduous trees are inherently less vulnerable to fire due to their structure and high leaf moisture content (Park et al. 2024).

Peatlands are typically slow to recover following wildfire disturbance, only reestablishing their carbon-accumulating functions after 20–30 years (Wieder et al. 2009). However, most research on peatland burn severity and recovery has focused on treed bogs and poor-fens i.e., black spruce dominated peatlands (e.g., Wieder et al. 2009; Ingram et al. 2019) with some work also comparing to treed fens (e.g., Turetsky et al. 2004; Bourgeau-Chavez et al. 2020). Less research has been done on moderate and rich (open) fens (but see Guêné-Nanchen et al. 2022) and open blanket bogs (Davies et al. 2016). Further, there is a scarcity of research comparing the burn rates or conditions for successful ignition in these varying peatland types, where peatland type is categorized based on the hydrological conditions that affect vegetation assemblages and therefore also wildfire interactions.

Here, we use a high-resolution (30 m) wetland sub-type map (Enhanced Wetland Classification [EWC]; Ducks Unlimited Canada [DUC] 2014) and burned area perimeters and ignition data from the National Fire Database (NFDB; Canadian Forest Service n.d.) to determine the contribution of three major peatland types to total annual area burned in Alberta's Boreal Plains (BP) ecozone. Our dataset spans 1985–2019 as this period contains reliable fire perimeters (polygons) and ignitions (points). We use these 35 years of data to assess changes over time in area burned in peatlands and per peatland type as well as analyze trends in ignition and the fire weather conditions under which different peatland types experience successful ignitions.

Since fire weather is increasing in intensity across the boreal (Wang et al. 2015), there is the potential for peatlands to increasingly contribute to area burned and landscape fire dynamics across peatland-dominated regions. To investigate this concern, we highlight Alberta's BP ecozone due to its high coverage of peatlands (up to ∼40% in some sub-regions), the availability of a high-resolution wetland type map (DUC 2014) and its high density of weather stations. Utilizing fire perimeters and ignition data from 1985 to 2019 our specific research questions are:

(i) Are peatlands contributing more to the burned area in Alberta's BP over time?
(ii) When and what types of peatlands are burning in Alberta's BP?
(iii) Under what fire weather conditions are successful peatland ignitions occurring?

Methods

Study area

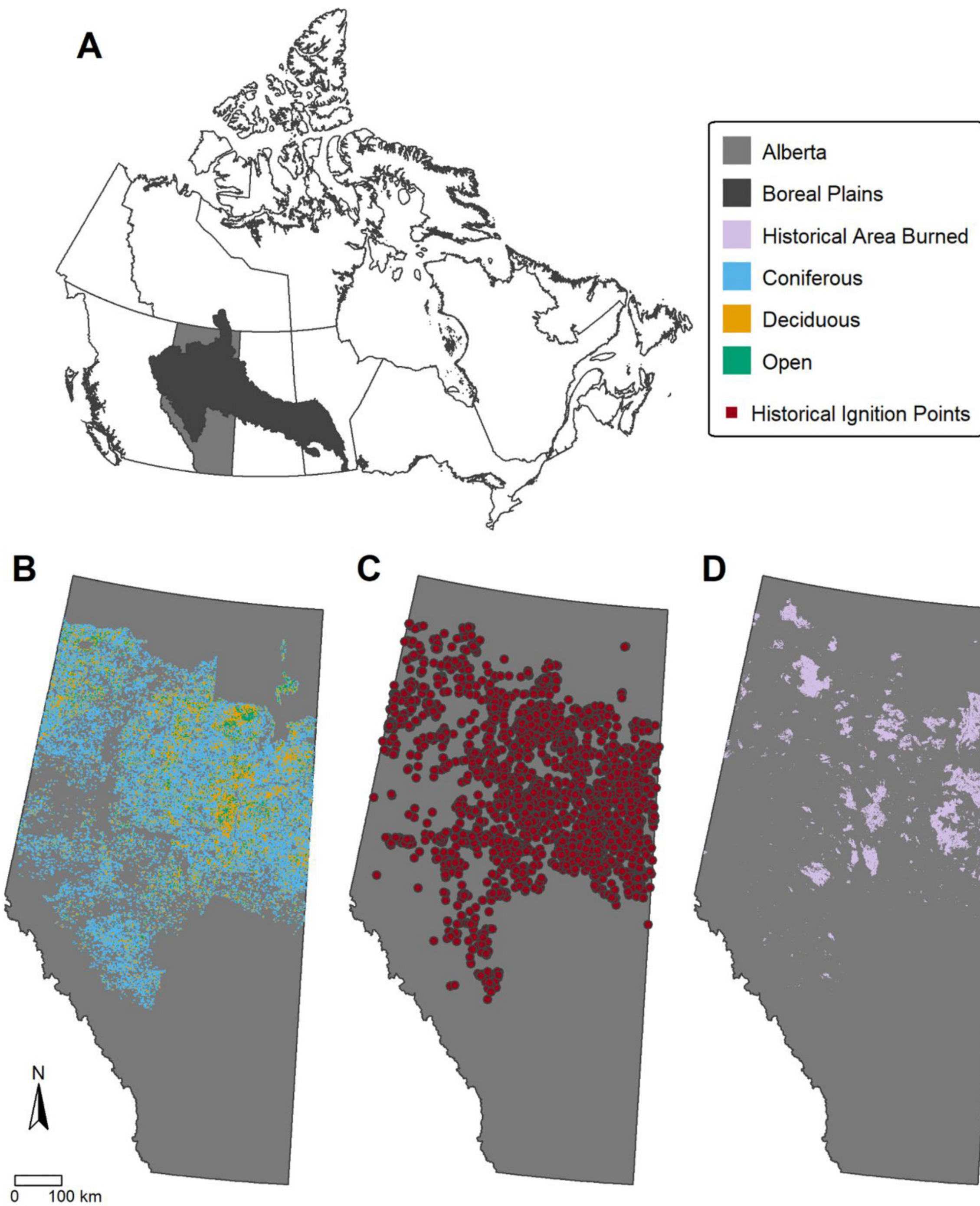
The BP is Alberta's largest ecozone, making up 57% of the province's area (Fig. 1A). The BP is comprised of deciduous, mixedwood, and coniferous forests, with wetland complexes in low-lying areas (Fig. 1B; Albert et al. 2006). Alberta's BP has a sub-humid continental climate, characterized by short summers and long cold winters (Albert et al. 2006). It follows a summer-high continental precipitation pattern, with 60%–70% of precipitation falling between the months of April–August and an average of 480 mm of precipitation falling annually (Albert et al. 2006). Forestry is the predominant land use, but the BP also contains the Athabasca and Peace River oil sands mining regions (San Miguel et al. 2020), and a number of population centres including Fort McMurray and Grande Prairie.

This study focuses on the Alberta BP, using the footprint of the EWC dataset as study area perimeter, which represents 10 798 506 ha of peatlands (DUC 2014). Minor (sub-type) wetland classes present within the study area include conifer swamp, graminoid poor fen, graminoid rich fen, hardwood swamp, mixedwood swamp, open bog, shrubby swamp, shrubby bog, shrubby poor fen, shrubby rich fen, tamarack swamp, treed bog, treed poor fen, and treed rich

Fig. 1. Spatial data used in analysis (A) Canada with Boreal Plains ecozone indicated in dark grey, Alberta in light grey. (B) Enhanced Wetland Classification grouped into category by peatland type (Coniferous, Deciduous, and Open). (C) Canadian National Fire Database ignitions occurring in peatlands, 1985–2019. (D) Historical area burned in peatlands, 1985–2019.
The map was created using R 4.1, using an Albers Equal Area projection and assembled from the following data sources:

- Provinces/Territories, Cartographic Boundary File—2016 Census (Source: Government of Canada): https://open.canada.ca/data/en/dataset/a883eb14-0c0e-45c4-b8c4-b54c4a819edb
- Terrestrial Ecozones of Canada (Source: Government of Canada): https://open.canada.ca/data/en/dataset/7ad7ea01-eb23-4824-bccc-66adb7c5bdf8
- Enhanced Wetland Classification (Source: Ducks Unlimited Canada): https://www.ducks.ca/resources/industry/enhanced-wetland-classification-inferred-products-user-guide/
- National Fire Database—Agency provided fire locations (point data; Source: Natural Resources Canada): https://cwfis.cfs.nrcan.gc.ca/datamart/metadata/nfdbpnt

National Fire Database—Agency Provided Fire Perimeters (v2021; Source: Natural Resources Canada): https://cwfis.cfs.nrcan.gc.ca/datamart/metadata/nfdbpoly



fen. Our study excluded the open water (aquatic bed, open water) and marsh (emergent marsh, meadow marsh) wetland types from the study because of the focus on peatland wildfire disturbance, and these classes do not accumulate a significant amount of peat (NWWG 1997).

Wildfire is the largest natural disturbance in the BP, but insects, disease and windthrow events are also present (Brandt 2009). The entire BP (not AB specific) has a 0.30% annual area burned, with a fire return interval of 369 years (Coops et al. 2018; San Miguel et al. 2019). Homogeneous fire regime zones within the Alberta BP study area are the Southern Cordillera (SC), Southern Prairie (SP), Great Slave Lake (GSL), and a small amount of the Lake Athabasca (LA) (Boulanger et al. 2014). The majority of the ecozone falls within the managed forest boundary and active wildfire suppression occurs regularly.

Data

Peatland data

Mapped wetland data for the study area were obtained from the EWC dataset produced by Ducks Unlimited Canada (2014). This dataset classifies satellite imagery and field data based on spectral signatures that use object-based supervised classification methods, resulting in a 30 m resolution raster dataset (DUC 2011) with an overall accuracy of 90% for distinguishing wetland versus upland and 80% for wetland class specifically. The EWC dataset was chosen for its breakdown of minor Canadian Wetland inventory classes, allowing for sorting into coniferous, deciduous, and open peatland types (Fig. 1*b*).

Wildfire data

Fire data were obtained from the Canadian National Fire Database (Canadian Forest Service N.d.). This dataset was chosen over other fire databases since it contains both corresponding points (Fig. 1*c*; representing fire ignitions) and polygon perimeters (Fig. 1*d*; depicting fire area), as well as other variables such as cause and size. Fires that occurred between May to October 1985–2019 with burned area overlapping peatlands were included in analysis ($n = 2312$ fires). Ignitions were isolated to those occurring within peatland-identified area, for a total of 3432 ignitions.

Fire weather indices

Daily historical fire weather data from 1985 to 2019 were provided directly by the Canadian Forest Service. This was collected by 489 weather stations across the province and contains collection date, weather station ID, latitude, longitude, wind speed, precipitation, and calculated daily Fire Weather Index System outputs, including Initial Spread Index (ISI), Fine Fuel Moisture Code (FFMC), Build-up Index (BUI), and the Fire Weather Index (FWI) using the national standardised Canadian Forest Fire Danger Rating System calculations (Van Wagner 1987).

Analysis

ArcGIS Pro 2.7.0 was used for all spatial analyses. First we merged minor peatland sub-types into peatland types based on the following logic: treed coniferous (treed bog, treed poor fen, treed rich fen, tamarack swamp, and conifer swamp), treed deciduous (hardwood swamp, mixedwood swamp), and open (shrubby rich fen, shrubby poor fen, shrub swamp, graminoid rich fen, graminoid poor fen, and shrubby bog). Treed coniferous and treed deciduous are hereafter referred to as coniferous and deciduous, respectively.

Overlapping area between peatland types and fire polygons were cross-tabulated in ArcGIS Pro. Area burned in each peatland type and in each year between 1985 and 2019 was calculated. Linear regression analyses were used to quantify the temporal trends in the proportion of area burned in peatlands. Theil-Sen regression was applied to assess the relationship between the proportion of area burned in peatlands and total annual area burned in the study area, using the *mblm* package (version 0.12.1; Komsta 2019). Theil-Sen provides the median trend and was used due to the prevalence of outliers and non-normally distributed residuals in total annual area burned that do not adhere to the assumptions of regular linear regression. Significance of Theil-Sen slopes were then tested with a Mann–Kendall test.

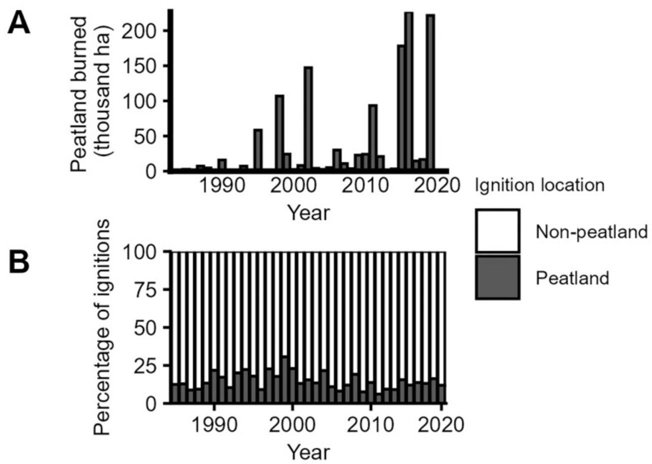
Next, we selected NFDB ignition points occurring within peatland boundaries. A thin plate spline was performed in R (version 4.1.1) using the *fields* package (version 16.3.1; Nychka et al. 2021) to interpolate fire weather conditions at the time of ignition based on proximity to fire weather stations. Non-normality of fire weather system variables was confirmed using the Shapiro–Wilk test, nonparametric tests were used throughout. To isolate the effect of peatland on ignition conditions Kruskal–Wallis tests (non-parametric equivalent to the one-way ANOVA) were employed. Significant results were followed by Dunn's post hoc pairwise comparisons to identify which types differed (R Core Team 2024). Note that all analyses were also calculated for each peatland sub-type (Figs. S1 and S2; Tables S2 and S3).

Results

Ignitions in peatlands accounted for an average (±StD) of 14.6% ± 5.46 of all ignitions. This proportion showed no distinct trend over time despite the total area burned increasing (Figs. 2*a* and 2*b*). Inter-annual variability in ignitions was present with a minimum of 6% and a maximum of 30% of ignitions occurring in peatlands. The absolute area of peatland burned per year in the BP varied considerably between years, with the largest area of peatland burning in 2016 at >226 000 ha, closely followed by 2019 where ~221 000 ha of peatlands burned.

Peatlands supporting coniferous trees dominate the land cover, accounting for 69% of all peatlands by area. Comparatively, non-treed (open) peatlands account for 23% and deciduous peatlands for 7% (Fig. 3*a*). When evaluating the patterns of ignitions in each peatland type we find similar trends to type area where the number of ignitions is greatest in coniferous, followed by open, and then deciduous (Fig. 3*b*). However, there are distinct differences in the patterns of ignition cause between peatland types. Ignitions in coniferous peatlands are predominantly caused by lightning (86%), whereas ignitions in deciduous peatlands are predominantly caused

Fig. 2. (A) Peatland area burned within study area, in hectares. (B) Percentage of ignitions in study area occurring in peatland versus non-peatland.



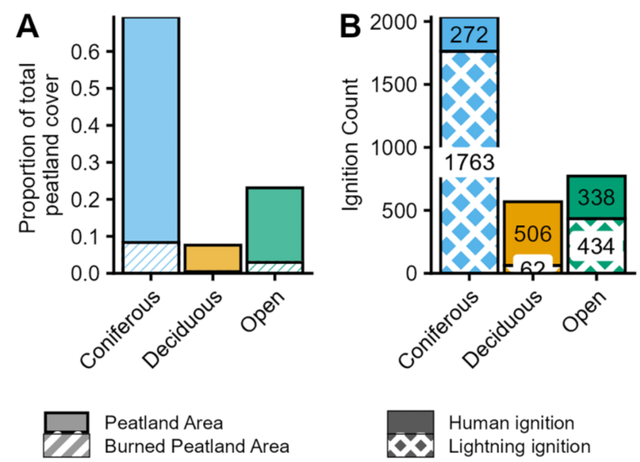
by humans (89%). In contrast, lightning and human caused ignitions in open peatlands are similar (lightning 56% vs. human 44%).

Coniferous peatlands dominate absolute peatland area burned in most years, burning an average (±StD) of 26 000 ± 49 000 ha/year. Over the entire study period (1985–2019; 35 years), when accounting for the differences in peatland type area, coniferous and open peatlands burn an average of 0.35% of their area per year, twice as much as deciduous peatlands (0.17%/year). This equates to fire return intervals (mean ± StD) of 283 ± 153 years for coniferous, 267 ± 161 years for open and 569 ± 306 years for deciduous peatlands. The average annual contribution to total burned area for the three peatland classes over the study period is as follows: coniferous peatlands contribute 13 ± 10.8% of total annual area burned, open peatlands contribute 8 ± 8.1%, and deciduous peatlands contribute 1 ± 0.9%. The highest contribution to area burned in a year is coniferous peatlands representing 38% of total area burned in 2016.

Temporally, there is a significant increasing trend in peatland area burned between 1985 and 2019 despite the large interannual variation. Overall, total peatland burned area increased by an average of ~3000 ha/year (0.03% of total peatland area per year) over the study period. The largest contribution of the increase in burned area is coniferous treed peatlands (Fig. 4*a*). The ratio of coniferous peatland burned area to total area burned increases significantly over the study period (slope = 0.00434, $p = 0.015$) and also increases as area burned increases (Theil Sen $\tau = 0.25$, $p = 0.035$; Fig. 4*b*). Conversely, the amount of open peatland burning per year decreases significantly (slope = −0.0045, $p = 0.0004$), and the open peatland burn proportions decrease significantly with increasing total area burned ($\tau = -0.36$, $p = 0.002$). There is a non-significant decreasing trend in deciduous peatland area burned with total area burned ($\tau = -0.072$, $p = 0.550$).

There is no significant increase in peatland ignitions over the study period, yet there are distinct temporal patterns to

Fig. 3. (A) Solid colour indicates total peatland cover grouped by peatland type (coniferous, deciduous, and open). Striped bars represents the portion of each peatland type that has burned between 1985 and 2019. (B) Number of fire ignitions by peatland type and ignition source. Bars are divided by ignition cause, with human-caused ignitions shown in solid and lighting-caused ignitions patterned. Numbers within bars indicate total ignition counts per category.



peatland ignitions throughout the fire season (May–October; Fig. 5). The spring (May–June) is dominated by ignitions in deciduous peatlands which then decrease considerably throughout the rest of the season, with a slight increase in late season (October). Ignitions in open peatlands are relatively steady May through August before decreasing slightly in September and October. Conversely, ignitions in coniferous peatlands increase through May and June to a sustained peak, where they dominate peatland ignitions throughout summer (July and August) before decreasing into the fall (September and October). Each peatland class shows a seasonal trend in ignition source, with human-caused ignitions concentrated in the spring and lightning ignitions increasing during the summer, when fire weather conditions are typically more severe (Fig. S3).

The fire weather conditions associated with these ignitions corroborate temporal trends and human versus lightning ignition causes. In general, deciduous peatland ignitions occur under the lowest fire weather conditions, and this is consistent for the BUI, FFMC, FWI, and ISI (Fig. 6). Successful ignitions in open peatlands tend to be associated with a wide variability of fire weather conditions, similar to coniferous peatlands, owing to their relatively even distribution across the fire season. Coniferous peatland ignitions appear to occur under the highest fire weather conditions (significantly higher BUI), correlating with their peak occurrence in summer months. All fire weather system variables were found to be non-normally distributed as assessed by the Shapiro–Wilk test. The Kruskal–Wallis test indicated significant differences among peatland type ignition conditions. Dunn's post hoc pairwise comparison tests found all peatland types differed significantly from each other for BUI ($p < 0.001$; Table S1). For FFMC, FWI, and ISI, deciduous peatlands differed from

Fig. 4. (A) Proportion of total study area burned that occurred in peatlands, shown by peatland type (coniferous, deciduous, and open) across years. Coniferous and open peatlands show significant trends over time (linear slopes, $p < 0.05$). (B) Proportion of burned area in peatlands relative to annual total area burned in study area. Theil-Sen regression slopes shown.

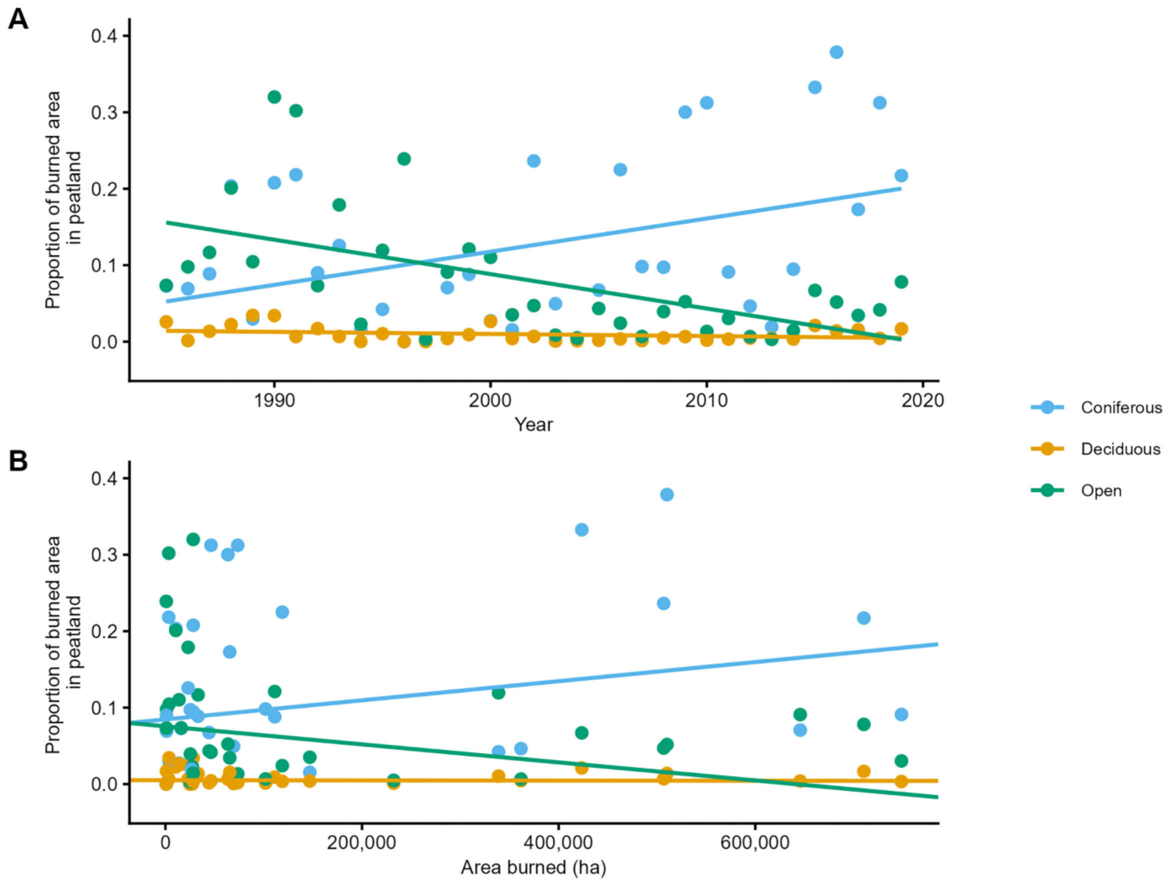
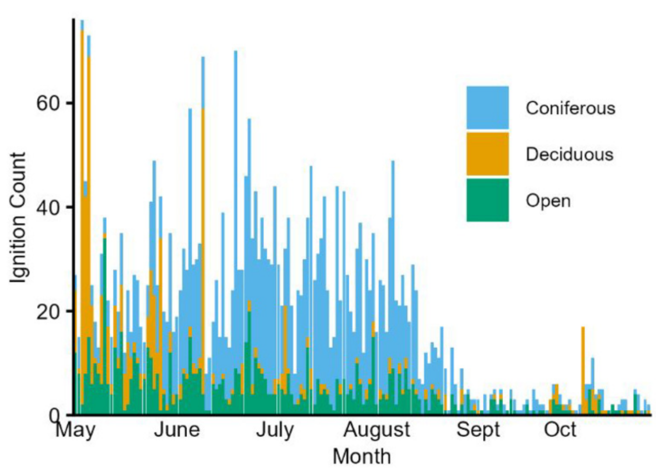


Fig. 5. Ignitions in peatlands by date, with colour indicating peatland type (coniferous, deciduous, and open).



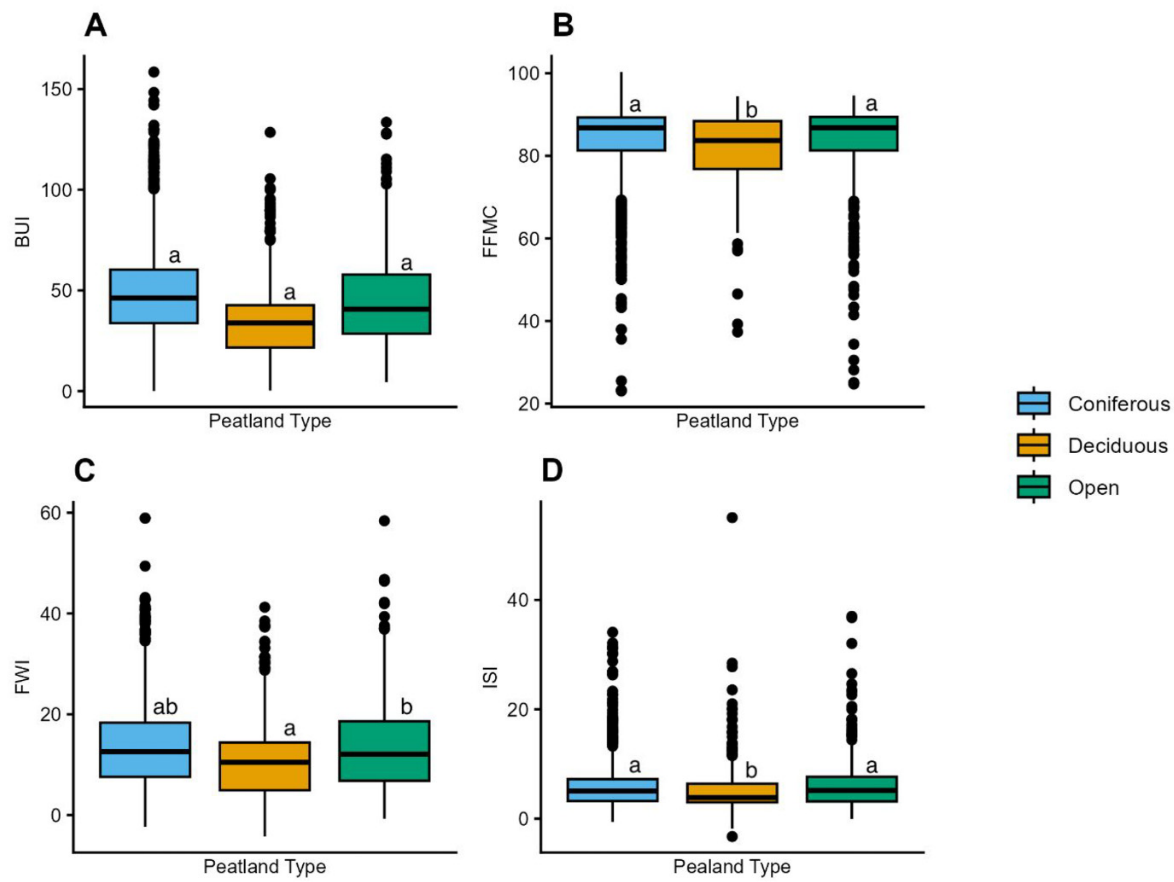
both coniferous and open peatlands ($p < 0.05$), while coniferous and open peatlands did not significantly differ from one another ($p > 0.1$).

Linear regression analyses showed no significant trends in burned area for peatland subtypes (bog, fen, and swamp) over the study period (Fig. S2a; Table S2). However, Theil–Sen analysis indicated a significant increasing trend for bogs only (Fig. S2b; Table S3).

Discussion

Across Canada, area burned is increasing (Hanes et al. 2019) and fire weather is projected to increase in intensity (Wang et al. 2015; Hanes et al. 2025), driving drier fuels (Ellis et al. 2022) and more days of active fire spread (Wang et al. 2017). Despite the immense socio-ecological costs of an intensifying wildfire regime (Jain et al. 2024) and the differences in impacts between peatland fires and non-peatland fires (Rein and Huang 2021), it has proven challenging to disentangle the specifics regarding which ecosystem types are burning, and when, across diverse landscapes. This has mainly been attributed to the limitations of high-resolution land cover maps, especially wetland and peatland maps (Amani et al. 2020). Here, we used a high resolution (30 m × 30 m pixel) EWC map (DUC 2014), to map three major peatland types (coniferous, deciduous, and open) based on minor sub-type peatland classifications, across the BP ecozone in Alberta. We intersected this map with fire perimeters and ignitions from the NFDB from 1985 to 2019 to assess trends in peatland area burned and ignition conditions.

Fig. 6. Fire weather indices conditions for peatland ignitions in coniferous, deciduous, and open peatlands. Letters indicate peatland types that are significantly different from each other ($p < 0.05$) based on Dunn's pairwise comparisons. (A) Build Up Index (BUI). (B) Fine Fuel Moisture Code (FFMC). (C) Fire Weather Index (FWI). (D) Initial Spread Index (ISI).



Here, we show that treed coniferous peatlands and open peatlands burn at similar rates (~0.4%/year). This supports findings that treed coniferous peatlands are vulnerable to fire (Wilkinson et al. 2018; Bougeau-Chavez et al. 2020) and challenges the assumption that open (here including shrubby) peatlands do not burn (Turetsky et al. 2002). Across the boreal region, peatlands have been shown to burn at similar rates to uplands, and at similar rates to their expected burn rate based on their proportional cover on the landscape. Turetsky et al. (2004) found that uplands did not burn preferentially to peatlands in a 1.2 million ha (Mha) study area in central Alberta (within our study area), and in the Taiga Plains, Bourgeau-Chavez et al. (2022) found that treed peatlands burned as expected relative to their proportion on the landscape. Further, increasing peatland cover on the landscape does not appear to reduce landscape level burn rate as Wilkinson et al. (2023) found that there was no significant relationship between burn rate (annual area burned/total area) and proportional peatland cover across the northern hemisphere. This work suggests that peatlands do not play a static fire break role on the landscape. However, as fire weather increases (warmer, drier, and windier conditions) it is hypothesized that peatland burn area will increase (Thompson et al. 2019). Our results offer support of this hypothesis as coniferous peatlands contribute more to area burned in higher area burned years.

We found that the absolute area of peatlands burning in the BP increased throughout the study period of 1985–2019. Similar to Turetsky et al. (2004), we found large interannual variations in the area of peatland burned, and the contribution of peatlands to total area burned. However, we found that coniferous peatlands have contributed a significant increasing amount to total annual area burned over the study period. Overall, we estimate that treed peatland area burned is increasing by ~3000 ha/year. These findings are supported by studies that have reported increasing area burned in the region over the last few decades (e.g., Kasischke and Turetsky 2006; Coops et al. 2018; Hanes et al. 2019; Jones et al. 2022). Given the large area burned in 2021, 2022, 2024, and the record breaking 2023 fires (~15 Mha burned; Jain et al. 2024), and the dominance of fires in northern forests, in these years, it is likely that the amount of peatland burning has continued to increase over time.

As area burned increases, our suppression resources will be tested, and perhaps reach a critical point of overwhelm, especially in northern forests (Wotton et al. 2017). Importantly, Wotton et al. (2017) used the Canadian Fire Behaviour Prediction System, which does not account for peatland fuels, to draw these conclusions, although peatland fuels are expected to dry disproportionately more compared to other forests due to climate change (Helbig et al. 2020). Due to their sensitivity to water table conditions and potential for positive (self-reinforcing) feedbacks (Waddington et al. 2015), coniferous (black spruce-dominated) peatlands have been highlighted as a concern for increasing fire severity and carbon loss as climatic drying occurs (Wilkinson et al. 2018) and for the dangers they pose to infrastructure and values in the wildland–human interface in the BP (Wilkinson et al. 2021). These feedbacks may become critical for fire management operations as we found that coniferous peatlands contribute more to area burned in large fire years.

We found significant differences in the successful ignition conditions associated with each peatland type. The BUI combines the Drought Code and Duff Moisture Code which are fuel moisture indices for deep (>18 cm) duff and large downed woody debris and shallow (<10 cm) duff fuel beds, respectively (Van Wagner 1987). Successful ignition BUI was significantly different for each peatland type where BUI was highest for coniferous peatlands, followed by open and then deciduous. Similarly, ignitions in coniferous and open peatlands had higher FFMC, ISI (a combination of FFMC and wind speed), and FWI (a combination of the ISI and BUI) values than deciduous, although absolute effect sizes were small. These variables represent the fire weather and fuel moisture conditions under which ignitions occur. Here, we find that the differences in peatland ignition fire weather conditions appear to generally reflect the seasonal patterns of ignitions in each peatland type, where early season fire weather values are typically lower than those in the mid-season. Deciduous peatland ignitions have the lowest number of ignitions and they predominantly occur in the spring, driven by human-caused ignitions. Boreal Alberta has a conducive spring-time wildfire regime tied strongly to snow melt and green up characteristics of a given year, where pre-green up conditions (i.e., the presence of cured fuels) in deciduous stands enhances ignition risk (Parisien et al. 2023). Accordingly, deciduous peatlands have significantly lower fire weather ignition conditions than coniferous or open peatlands, where ignitions tend to occur throughout the season.

To remove the influence of phenology or ground ice effects we evaluated the ignition conditions across peatland types during peak summer months only (July and August). Here, we found that there was no significant difference in BUI across peatland types; however, ignitions in deciduous peatlands had significantly lower FFMC and ISI, similar to the year-round trends (Table S4). FWI for open peatland ignitions was significantly higher than deciduous, but not coniferous (Fig. S4). The relatively small differences between median fire weather ignition conditions, and the wide ranges of each class (e.g., ignitions occurring in FWI values of 1 to >40) demonstrates the vulnerability of peatlands to fire across a variety of fire weather conditions. Further, it highlights the need for a peat-specific fuel moisture code, to enable deeper understanding of peatland ignition and fire dynamics, especially across different peatland types.

In conclusion, peatlands are playing an active and integrated role in the wildfire regime of Alberta's BP ecozone. The proportion of total area burned in peatlands is variable year to year, depicting the complex interactions of fuel conditions, fire weather, and ignition locations. However, in some years, peatlands contribute up to 40% of the total area burned, matching or exceeding their coverage on the landscape. Peatlands dominated by coniferous trees dominate area burned and ignition counts compared to deciduous treed and open peatlands, mirroring their abundance on the landscape. Coniferous peatland burned area increased over the study period (1985–2019) and also increases with total area burned per year, while open peatland burned area decreases. Deciduous peatland area burned shows no trend over time and ignitions are driven by spring conditions and human-causes. This knowledge is critical for developing our understanding of the roles of peatlands in regional wildfire regimes, especially as they are disproportionately impacted by climate change. As fire weather increases in severity and wildfire management capacity is stretched, there is a pressing need for peatland-specific fuel moisture modelling to better capture ignition potential and fire dynamics in these ecosystems and in landscapes with an abundance of peatlands.

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Data availability

Fire data analyzed during this study are available in the following repositories: CWFIS/NRCan Datamart; https://cwfis.cfs.nrcan.gc.ca/datamart/download/nfdbpoly; https://cwfis.cfs.nrcan.gc.ca/datamart/download/nfdbpnt. Fire Weather and EWC data used during this study were not publicly available during the time of research, but Wetland classification data will be available soon through the Canadian National Wetlands Inventory, https://open.canada.ca/data/en/dataset/d5af4ac5-ebdb-4645-bb0a-8ec5cac5e29f.

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Competing interests

The authors declare there are no competing interests.

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Supplementary material

Supplementary data are available with the article at https://doi.org/10.1139/cjfr-2025-0292.

References

Albert, A., Pettapiece, W.W., and Downing, D.J. 2006. Natural regions and subregions of Alberta. *In* Natural Regions Committee. Edmonton, AB, Canada.
Amani, M., Brisco, B., Mahdavi, S., Ghorbanian, A., Moghimi, A., DeLancey, E.R., et al. 2020. Evaluation of the Landsat-based Canadian wetland inventory map using multiple sources: challenges of large-scale wetland classification using remote sensing. IEEE J. Selected Topics Appl. Earth Observ. Remote Sens. **14**: 32–52. doi:10.1109/JSTARS.2020.3036802.
Boulanger, Y., Gauthier, S., and Burton, P.J. 2014. A refinement of models projecting future Canadian fire regimes using homogeneous fire regime zones. Can. J. For. Res. **44**(4): 365–376. doi:10.1139/cjfr-2013-0372.
Bourgeau-Chavez, L.L., Graham, J.A., Vander Bilt, D.J., and Battaglia, M.J. 2022. Assessing the broadscale effects of wildfire under extreme drought conditions to boreal peatlands. Front. For. Glob. Change **5**: 965605.
Bourgeau-Chavez, L.L., Grelik, S.L., Billmire, M., Jenkins, L.K., Kasischke, E.S., and Turetsky, M.R. 2020. Assessing boreal peat fire severity and vulnerability of peatlands to early season wildland fire. Front. For. Global Change, **3**: 20. doi:10.3389/ffgc.2020.00020.
Brandt, J.P. 2009. The extent of the North American boreal zone. Environ. Rev. **17**(NA): 101–161. doi:10.1139/A09-004.
Bush, E., Bonsal, B., Derksen, C., Flato, G., Fyfe, J., Gillett, N., et al. 2022. Canada's changing climate report in light of the latest global science assessment. Government of Canada. Ottawa, ON. **37**p.
Canadian Forest Service. N.d. Canadian National Fire Database–Agency Fire data [Spatial dataset]. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre. Available from http://cwfis.cfs.nrcan.gc.ca/en_CA/nfdb [accessed 14 October 2024].
Coops, N.C., Hermosilla, T., Wulder, M.A., White, J.C., and Bolton, D.K. 2018. A thirty year, fine-scale, characterization of area burned in Canadian forests shows evidence of regionally increasing trends in the last decade. PLoS One, **13**(5): e0197218. doi:10.1371/journal.pone.0197218.
Core, R. 2024. R: a language and environment for statistical computing (Version 4.2) [Computer software]. R Foundation for Statistical Computing. Available from https://www.r-project.org/ [accessed March 2025].
Davies, G.M., Kettridge, N., Stoof, C.R., Gray, A., Ascoli, D., Fernandes, P.M., and Vandvik, V. 2016. The role of fire in UK peatland and moorland management: the need for informed, unbiased debate. Philos. Trans. R. Soc. B Biol. Sci. **371**(1696): 20150342. doi:10.1098/rstb.2015.0342.
Ducks Unlimited Canada (DUC). 2011. Enhanced wetland classification (EWC) inferred products user guide. Available from https://www.ducks.ca/resources/industry/enhanced-wetland-classification-inferred-products-user-guide/ [accessed March 2025].
Ducks Unlimited Canada(DUC). 2014. Boreal wetland classes in the Boreal Plains ecozone of Canada. [Spatial dataset]. Ducks Unlimited Canada, Western Boreal Office, Edmonton, AB.
Ellis, T.M., Bowman, D.M., Jain, P., Flannigan, M.D., and Williamson, G.J. 2022. Global increase in wildfire risk due to climate-driven declines in fuel moisture. Global Change Biol. **28**(4): 1544–1559. doi:10.1111/gcb.16006.
Flannigan, M.D., Logan, K.A., Amiro, B.D., Skinner, W.R., and Stocks, B.J. 2005. Future area burned in Canada. Clim. Change, **72**(1): 1–16. doi:10.1007/s10584-005-5935-y.
Guêné-Nanchen, M., LeBlanc, M.C., and Rochefort, L. 2022. Post-fire peatland vegetation recovery: a case study in open rich fens of the Canadian boreal forest. Botany, **100**(5): 435–447. doi:10.1139/cjb-2021-0194.
Hanes, C.C., Jain, P., Wang, W., Wang, X., Parisien, M.A., Little, J.M., and Flannigan, M.D. 2025. Fire regime changes in Canada: an update. Can. J. For. Res. **55**: 1–11.
Hanes, C.C., Wang, X., Jain, P., Parisien, M.A., Little, J.M., and Flannigan, M.D. 2019. Fire-regime changes in Canada over the last half century. Can. J. For. Res. **49**(3): 256–269. doi:10.1139/cjfr-2018-0293.
Helbig, M., Waddington, J.M., Alekseychik, P., Amiro, B.D., Aurela, M., Barr, A.G., and Zyrianov, V. 2020. Increasing contribution of peatlands to boreal evapotranspiration in a warming climate. Nat. Clim. Change, **10**(6): 555–560. doi:10.1038/s41558-020-0763-7.
Ingram, R.C., Moore, P.A., Wilkinson, S., Petrone, R.M., and Waddington, J.M. 2019. Postfire soil carbon accumulation does not recover boreal peatland combustion loss in some hydrogeological settings. J. Geophys. Res.: Biogeosci. **124**(4): 775–788. doi:10.1029/2018JG004716.
Jain, P., Barber, Q.E., Taylor, S.W., Whitman, E., Acuna, D.C., Boulanger, Y., et al. 2024. Drivers and impacts of the record-breaking 2023 wildfire season in Canada. Nat. Commun. **15**(1): 6764. doi:10.1038/s41467-024-51154-7.
Jain, P., Wang, X., and Flannigan, M.D. 2017. Trend analysis of fire season length and extreme fire weather in North America between 1979 and 2015. Int. J. Wildland Fire, **26**(12): 1009–1020. doi:10.1071/WF17008.
Johnston, D.C., Turetsky, M.R., Benscoter, B.W., and Wotton, B.M. 2015. Fuel load, structure, and potential fire behaviour in black spruce bogs. Can. J. For. Res. **45**(7): 888–899. doi:10.1139/cjfr-2014-0334.
Jones, E., Chasmer, L., Devito, K., Rood, S., and Hopkinson, C. 2022. Ecological impacts of shortening fire return intervals on boreal peatlands and transition zones using integrated in situ field sampling and lidar approaches. Ecohydrology, **15**(3): e2403. doi:10.1002/eco.2403.
Kasischke, E.S., and Turetsky, M.R. 2006. Recent changes in the fire regime across the North American boreal region—spatial and temporal patterns of burning across Canada and Alaska. Geophys. Res. Lett., **33**(9). doi:10.1029/2006GL025677.
Komsta, Ł. 2019. mblm: median-based linear models (R package version 0.12.1) [Computer software]. The Comprehensive R Archive Network (CRAN). Available from https://CRAN.R-project.org/package=mblm [accessed January 2025].
National Wetlands Working Group. 1997. The Canadian wetland classification system. University of Waterloo. pp. vii–vii.
Nychka, D., Furrer, R., Paige, J., and Sain, S. 2021. fields: tools for spatial data (Version 16.3.1) [R package]. GitHub. Available from https://github.com/dnychka/fieldsRPackage [accessed January 2025].
Parisien, M.A., Barber, Q.E., Flannigan, M.D., and Jain, P. 2023. Broadleaf tree phenology and springtime wildfire occurrence in boreal Canada. Global Change Biol. **29**(21): 6106–6119. doi:10.1111/gcb.16820.

Park, J., Moon, M., Green, T., Kang, M., Cho, S., Lim, J., and Kim, S.J. 2024. Impact of tree species composition on fire resistance in temperate forest stands. For. Ecol. Manage. **572**: 122279. doi:10.1016/j.foreco.2024.122279.

Pontone, N., Millard, K., Thompson, D.K., Guindon, L., and Beaudoin, A. 2024. A hierarchical, multi-sensor framework for peatland sub-class and vegetation mapping throughout the Canadian boreal forest. Remote Sens. Ecol. Conserv. **10**(4): 500–516. doi:10.1002/rse2.384.

Rein, G., and Huang, X. 2021. Smouldering wildfires in peatlands, forests and the Arctic: challenges and perspectives. Curr. Opin. Environ. Sci. Health, **24**: 100296. doi:10.1016/j.coesh.2021.100296.

San-Miguel, I., Andison, D.W., and Coops, N.C. 2019. Quantifying local fire regimes using the Landsat data-archive: a conceptual framework to derive detailed fire pattern metrics from pixel-level information. Int. J. Digital Earth, **12**(5): 544–565. doi:10.1080/17538947.2018.1464072.

San-Miguel, I., Coops, N.C., Chavardès, R.D., Andison, D.W., and Pickell, P.D. 2020. What controls fire spatial patterns? Predictability of fire characteristics in the Canadian boreal plains ecozone. Ecosphere, **11**(1): e02985. doi:10.1002/ecs2.2985.

Schiks, T.J., Wotton, B.M., Turetsky, M.R., and Benscoter, B.W. 2016. Variation in fuel structure of boreal fens. Can. J. For. Res. **46**(5): 683–695. doi:10.1139/cjfr-2015-0445.

Scholten, R.C., Jandt, R., Miller, E.A., Rogers, B.M., and Veraverbeke, S. 2021. Overwintering fires in boreal forests. Nature, **593**(7859): 399–404. doi:10.1038/s41586-021-03437-y. PMID: 34012083.

Tarnocai, C. 2009. The impact of climate change on Canadian peatlands. Can. Water Resour. J. **34**(4): 453–466. doi:10.4296/cwrj3404453.

Tekatch, A.M., Markle, C.E., Wilkinson, S.L., McCarter, C.P., Moore, P.A., and Waddington, J.M. 2025. Ecohydrological drivers of boreal shield Peatland fire refugia. Ecohydrology, **18**(5): e70075. doi:10.1002/eco.70075.

Thompson, D.K., Parisien, M.A., Morin, J., Millard, K., Larsen, C.P., and Simpson, B.N. 2017. Fuel accumulation in a high-frequency boreal wildfire regime: from wetland to upland. Can. J. For. Res. **47**(7): 957–964. doi:10.1139/cjfr-2016-0475.

Thompson, D.K., Simpson, B.N., Whitman, E., Barber, Q.E., and Parisien, M.A. 2019. Peatland hydrological dynamics as a driver of landscape connectivity and fire activity in the boreal plain of Canada. Forests, **10**(7): 534. doi:10.3390/f10070534.

Turetsky, M., Wieder, K., Halsey, L., and Vitt, D. 2002. Current disturbance and the diminishing peatland carbon sink. Geophys. Res. Lett. **29**(11): 21–21. doi:10.1029/2001GL014000.

Turetsky, M.R., Amiro, B.D., Bosch, E., and Bhatti, J.S. 2004. Historical burn area in western Canadian peatlands and its relationship to fire weather indices. Global Biogeochem. Cycles, **18**(4). doi:10.1029/2004GB002222.

Van Wagner, C.E. 1987. Development and structure of the Canadian forest fire weather index system forestry. 35.

Vitt, D.H. and Wieder, R.K. (*Editors*). 2006. Functional characteristics and indicators of boreal peatlands. *In* Boreal peatland ecosystems, Ecological studies, **Vol. 188**, Springer. pp. 9–24. doi:10.1007/978-3-540-31913-9.

Waddington, J.M., Morris, P.J., Kettridge, N., Granath, G., Thompson, D.K., and Moore, P.A. 2015. Hydrological feedbacks in northern peatlands. Ecohydrology, **8**(1): 113–127. doi:10.1002/eco.1493.

Wang, X., Parisien, M.A., Taylor, S.W., Candau, J.N., Stralberg, D., Marshall, G.A., et al. 2017. Projected changes in daily fire spread across Canada over the next century. Environ. Res. Lett. **12(2)**: 025005.

Wang, X., Thompson, D.K., Marshall, G.A., Tymstra, C., Carr, R., and Flannigan, M.D. 2015. Increasing frequency of extreme fire weather in Canada with climate change. Clim. Change, **130**: 573–586. doi:10.1007/s10584-015-1375-5.

Wieder, R.K., Scott, K.D., Kamminga, K., Vile, M.A., Vitt, D.H., Bone, T., et al. 2009. Postfire carbon balance in boreal bogs of Alberta, Canada. Global Change Biol. **15**(1): 63–81. doi:10.1111/j.1365-2486.2008.01756.x.

Wilkinson, S.L., Andersen, R., Moore, P.A., Davidson, S.J., Granath, G., and Waddington, J.M. 2023. Wildfire and degradation accelerate northern peatland carbon release. Nat. Clim. Change, **13**(5): 456–461. doi:10.1038/s41558-023-01657-w.

Wilkinson, S.L., Furukawa, A.K., Wotton, B.M., and Waddington, J.M. 2021. Mapping smouldering fire potential in boreal peatlands and assessing interactions with the wildland–human interface in Alberta, Canada. Int. J. Wildland Fire, **30**(7): 552–563. doi:10.1071/WF21001.

Wilkinson, S.L., Moore, P.A., Thompson, D.K., Wotton, B.M., Hvenegaard, S., Schroeder, D., and Waddington, J.M. 2018. The effects of black spruce fuel management on surface fuel condition and peat burn severity in an experimental fire. Can. J. For. Res. **48**(12): 1433–1440. doi:10.1139/cjfr-2018-0217.

Wotton, B.M., and Flannigan, M.D. 1993. Length of the fire season in a changing climate. For. Chron. **69**(2): 187–192. doi:10.5558/tfc69187-2.

Wotton, B.M., Flannigan, M.D., and Marshall, G.A. 2017. Potential climate change impacts on fire intensity and key wildfire suppression thresholds in Canada. Environ. Res. Lett. **12**(9): 095003. doi:10.1088/1748-9326/aa7e6e.