NATURAL DISTURBANCE:

Wetland Fire Behaviour

Wildfires are the primary landscape disturbance in the western boreal forest, but over the past 50 years Canada's western boreal has experienced a **rise in the annual burned area, larger fire sizes, increased fire severity, and a prolonged fire season.**[1] These changes are driven by climate change, land use changes, and fire supression activities over this time frame. The boreal forest is a fire adapted ecosystem, that prior to recent decades of fire suppression, experienced high levels of fire disturbance as a part of forest life cycles.

Wetlands, particularly organic wetlands, exhibit a dual nature in their interaction with wildfires. While they can function as effective fire breaks, they are also susceptible to sustaining **high-intensity fires that can contribute to significant fire events.**[2] After several severe fire seasons in the past decade, there is increasing awareness amongst Canadians of wildfire and increasing focus amongst researchers and practitioners on how all parts of the landscape contribute to wildfire. Understanding wetland fire behaviour and patterns of natural disturbance is critical for a whole landscape approach to ecosystem based management.

Wetland Fire Behaviour

While all wetland types can experience wildfire, **treed organic wetlands with deep peat soils are particularly susceptible to ignition and severe and prolonged burning because of the significant amounts of subsurface fuels compared to uplands and the higher likelihood of dry conditions compared to other wetland types.** Treed organic wetlands have been a focus of much of the wetland-fire research, and there is limited information on fire behaviour in other wetland types.

Fire behaviour in organic wetlands is characterized by **below ground burning through smoldering combustion.** Organic wetlands that are sparsely vegetated tend to not be prone to severe burning (e.g., graminoid fens); however, treed organic wetlands can accumulate surface fuel loads similar to upland stands.[1] When surface or crown fire passes through these wetlands, it ignites surface mosses and peat soils, and can smolder deep into the soil profile, sometimes sustaining through the winter and reigniting in the next fire season, making fires extremely difficult to detect and suppress.[1]

Wetland fires can be described by their:

- **Intensity:** The rate of heat energy released during a fire, impacting the amount of biomass burned and area burned by a fire.
- **Severity:** How deep and how long a fire burns in the soil profile.[3] The deeper a fire burns, the greater likeliness of a fire smouldering through the winter and reigniting in the spring, the more carbon loss to the atmosphere, and the greater impacts to landscape hydrology, biochemistry and hydrological connectivity.[1] At the site level fire severity is influenced by:
    - **Moisture Conditions:** Drier peat soils are more flammable and susceptible to deeper and longer burns than wet peat soils.

- **Fuel Load:** Above ground fuel loads can impact the flammability of a peatland. Treed wetlands are more susceptible than non-treed wetlands to fire.[1] Moss species composition can also impact the severity of combustion, with different mosses having different water holding capabilities.[1]
- **Peat Bulk Density:** Higher peat bulk density corresponds to greater burn depth (i.e., more severe fires), while lower peat bulk density results in shallower burners (i.e. less severe fires).[3]

Without interventions, climate change, land use change, and continued fire suppression are expected to continue to interact to result in drier wetland systems and increased fire intensity and severity in these sysems.[1,4]

Wetland Vegetation and Fire Behaviour

In treed wetlands, particularly those dominated by black spruce (*Picea mariana*), above-ground fuel loads can accumulate to levels similar to those found in upland forests. Climate-induced wetland drying can further intensify crown cover in these environments.[1] Black spruce, being a fire-adapted species, can sustain high-intensity crown fires and spread fire via "spotting", or by throwing embers.[1] The fire behaviour in black spruce can lead to the spread to other fire-prone ecosystems, resulting in wetlands shifting from their historical role as fire breaks to contributing to fire spread.[1,4]

Wetland mosses, particularly the *Sphagnum* mosses that dominate organic wetlands, influence fire behavior. *Sphagnum* mosses provide high water-holding capacities and drought tolerance while reducing water loss through evapotranspiration.[5,6,7] However, prolonged drying periods can diminish these protective mechanisms and result in these mosses acting as fire wicks, leading to:

- Enhanced soil and organic matter drying,
- Increased fuel availability, and
- Increased fire vulnerability.[8,9]

Canopy closure also affects wildfire behaviour. Greater canopy closure provides shade, favouring feather mosses which have poorer water retention than *Sphagnum* mosses.[1] Therefore, **feather mosses are more flammable than *Sphagnum* mosses**, and the shift from *Sphagnum* dominated to feather moss dominated contributes to increased fuel availability and fire vulnerability.[2]

More spatially and ecologically diverse wetland complexes are more likely to limit fire spread. For example, Markle et al. (2022) found that wetlands with mostly continuous vegetation cover showed higher fire severity than wetlands interspersed with shallow open water areas. Wetlands with more tree cover, a larger proportion of transition areas, or that become periodically disconnected from groundwater systems (wetlands that have drier soils or are more susceptible to periodicly dry soils) tend to be most vulnerable to high burn severity.[3,10]

Wetland Hydrology and Fire Behaviour

Moisture content in wetland ecosystems is regulated in part by the moisture retention properties of moss and peat, exhibiting variations across different peatland moss species.[11] This regulation of moisture content is crucial in understanding the vulnerability of these ecosystems to wildfires, as highlighted by hydrological feedback processes involving moss growth, peat formation, and evaporation.[12,13] These processes, in conjunction with factors such as thick wet soils, low evapotranspiration rates, and the water retention capabilities of mosses, collectively serve to mitigate wildfire frequency and restrict deep burning under most fire weather conditions.[13]

Hydrological connectivity within organic wetlands, along with water table fluctuations, significantly influence fire behavior within and between other ecosystems. When water demand from upland forests is greater than precipitation inputs, upland forests rely on organic wetlands as water sources which exacerbates water table fluctuations along the margins of organic wetlands, making them more susceptible to hydrologic changes compared to the central areas. This fluctuation leads to increased bulk density at the margins, resulting in deeper burning during fires.[3]

Additionally, surficial geology plays a crucial role in determining peatland susceptibility to fires by influencing groundwater connectivity.[3] This connectivity affects the degree of compaction and rates of decomposition within the peatland, ultimately shaping its bulk density and susceptibility to deep burning. Peatlands characterized by greater water table fluctuations and lower groundwater connectivity are at heightened risk of experiencing deep burns.

THE FIRE WEATHER INDEX SYSTEM AND WETLANDS

The Canadian Fire Weather Index (FWI) system is a widely utilized tool for assessing fire danger across various environments globally. Originally developed and calibrated for upland Jack pine (*Pinus banksiana*) forests, the FWI integrates three moisture codes — Fine Fuel Moisture (FFMC), Duff Moisture (DMC), and Drought (DC) — each reflecting the moisture content of different fuels based on meteorological data.[14]

However, wetlands, often perceived as consistently saturated throughout much of the year, have been **excluded from many wildfire models.[16]**

To help address this gap, Mortelmans et al. (2024) introduced an organic wetland-specific adaptation of the FWI system, termed FWI_{peat}. This modified model replaces the original moisture codes with hydrological estimates tailored to organic wetlands, aiming to enhance the monitoring of fire risk in organic wetlands. Mortelmans et al., (2024) found that adapting the FWI with hydrological information is beneficial in estimating the presence of organic wetland fires. However, the FWI was originally not designed to predict fire presence but rather to estimate fire danger.[14]

Resources:

- Canadian Forest Fire Behaviour Prediction (FBP) System
- Canadian Forest Fire Weather Index (FWI) System
- Mortelmans, J., Felsberg, A., De Lannoy, G. J., Veraverbeke, S., Field, R. D., Andela, N., & Bechtold, M. (2024). Improving the fire weather index system for peatlands using peat-specific hydrological input data. Natural Hazards and Earth System Sciences, 24(2), 445-464.
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