BOREAL FOREST WETLANDS: A SUMMARY OF BENEFITS, THREATS, AND THE IMPORTANCE OF WETLAND CLASSIFICATION SYSTEMS

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EXECUTIVE SUMMARY

Boreal wetlands are found all around the world and are critical for the success and function of many species and neighbouring ecosystems. The boreal ecosystem is one of the largest continuous forest ecosystems in the world, covering approximately 1.9 million hectares or 33% of the Earth's forested area, and boreal wetlands are an integral part of this wide-ranging biome (Natural Resources Canada 2020). The boreal ecosystem is characterized by coniferous stands, with some mixed coniferous/deciduous stands and deciduous stands. The boreal ecosystem is well adapted to northern climatic conditions that includes short, cool summers and long, cold winters. It supports a large range of plant and animal species, both migratory and non-migratory. The boreal forest includes many different ecosystems including a diversity of wetlands (Brandt et al. 2013).

Boreal wetlands can be characterized by their hydrology (water levels and flood frequency), soil types, and vegetation communities (Cox and Cullington 2009). There are five types of wetlands that are characterized in the boreal forest: bog, fen, swamp, marsh, and shallow open water. Each of these wetland types can be identified through soil characteristics, species composition, hydrology, and location on the landscape. They each serve important functions and provide different types of benefits within the boreal forest.

A examination of resources regarding boreal forest wetlands and threats to boreal forest wetlands was conducted as part of the literature review. To understand the benefits of wetlands and the threats they face, the following types of documents were reviewed: scientific papers, wetland management guidelines, industry best practices and other relevant documents. Various wetland classification systems and related programs were reviewed to better understand the components and structures that can be used in these systems. For the Yukon case study, documents released by the Yukon Government were reviewed to understand the current state of wetland classification in the Yukon.

The wetlands of the boreal forest provide many benefits and play a vital role in the functioning of the boreal forest ecosystem. These include hydrological benefits (water storage and regulation, water temperature regulation, water quality regulation and filtration, sediment control), biophysical benefits (terrestrial and aquatic habitat, biological diversity, wildfire barriers) and chemical benefits (carbon storage, nutrient cycling). Boreal forest wetlands are currently facing several threats that limit their functions and impacts on the landscape. These threats include habitat loss and fragmentation, drainage, physical alteration, changes to water quality, invasive species, and climate change.

Wetland classification systems can be used to gather information and better understand the wetland benefits and threats. A well-developed classification system also provides definitions for the component or systems being measured, a common vocabulary, and a data structure. By describing the landscape in this way, it can help scientists, land-use managers, local stake holders, and industry better understand the extent of ecosystems, potential affects of land-use change on habitats and associated wildlife and identify ecological responses to potential disturbances. Recommendations for the development of an effective wetland classification system include incorporating appropriate consultation, developing a comparable and useful system structure, developing useful application and distribution methods, and through adapting and updating the systems when necessary.

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ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition
AB	Alberta
AWCS	Alberta Wetland Classification System
BC	British Columbia
BEC	Biogeoclimatic
CWCS	The Canadian Wetland Classification System
ELC	Ecological and Landscape Classification
EIA	Environmental Impact Assessment
GIS	Geographic Information System
TEM	Terrestrial Ecosystem Mapping
YBIS	Yukon Biophysical Information System
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environment and Socio-economic Assessment Board
YG	Yukon Government
YT	Yukon Territory
YWSP	Yukon Wetland Stewardship Policy

1 INTRODUCTION

Boreal wetlands are found all around the world and are critical for the success and function of many species and neighbouring ecosystems. The boreal ecosystem is one of the largest continuous forest ecosystems in the world, covering approximately 1.9 million hectares or 33% of the Earth's forested area and boreal wetlands are an integral part of this wide-ranging biome (Natural Resources Canada 2020). In Canada alone, wetlands cover about 13% of the country, and boreal wetlands make up approximately 85% of all Canadian wetlands (Natural Resources Canada 2016). Boreal wetlands provide many important benefits including regulating hydrological systems, providing terrestrial and aquatic habitat, maintaining biodiversity, and carbon sequestration.

Boreal wetlands are also facing many threats including physical degradation, changes in water quality, invasive species and climate change. Human activities that directly affect wetlands include oil and gas, mining, forestry, recreational activity, agricultural practices, grazing, and urban and rural development. These threats can disrupt the hydrological balance, degrade water quality, and fragment critical habitats across the boreal landscape. Some components of these threats are understood; however, the processes and systems involved are complex and far-reaching, and more information is needed in order to help understand and protect boreal wetlands.

In order to better understand boreal wetlands, their benefits, and the threats they face, it is important to create and utilize wetland classification systems. Wetland classification systems area a valuable tool that can be used to communicate knowledge, and aid in conservation, research, and landscape planning. A wetland classification system is currently being developed in the Yukon Territory, Canada, the process and system provides a case study to demonstrate the potential needs and uses of such classification systems. By describing the landscape in this way, it can help scientists, land-use managers, local stake holders, and industry better understand the extent of ecosystems, potential affects of land-use change on habitats and associated wildlife and identify ecological responses to potential disturbances.

This paper provides an overview of the benefits provided by boreal wetlands, an investigation into the threats they face, a discussion of the wetland classification in the Yukon as a case study, and recommendations for the development of a wetland classification system. This research paper has been completed in the context and framework of the Masters of Land and Water Systems (MLWS) program at the University of British Columbia (UBC), and the course LWS 548 (MLWS Major Project). The project was supervised by Dr. Les Lavkulich (UBC Land Food Systems).

2 METHODS

A examination of resources regarding boreal forest wetlands and threats to boreal forest wetlands was conducted as part of the literature review. Sources were found using the UBC library and online database searches. To understand the benefits of wetlands and the threats they face, the following types of documents were reviewed: scientific papers, wetland management guidelines, industry best practices and other relevant documents. Various wetland classification systems and related programs were reviewed to better understand the components and structures that can be used in these systems. For the Yukon case study, documents released by the Yukon Government were reviewed to understand the current state of wetland classification in the Yukon. Wetland classification systems that were reviewed include:

- Canadian Wetland Classification System (CWCS) (National Wetlands Working Group 1997)
- Alberta Wetland Classification System (AWCS) (Alberta Environment and Sustainable Resource Development 2015)
- British Columbia Terrestrial Ecosystem Mapping (TEM) (Resources Inventory Committee 1998)
- Wetlands of British Columbia: Identification Guide (MacKenzie and Moran 2004)
- Ducks Unlimited Boreal Wetland Classes in the Boreal Plains Ecozone of Canada: Field Guide (Ducks Unlimited Canada 2015)
- Yukon Ecological and Landscape Classification (ELC) (Environment Yukon 2016)
- Yukon Wetland Stewardship Policy (Government of Yukon 2022)
- Alberta Wetland Classification System (Alberta Environment and Sustainable Resource Development 2015)

The literature was synthesized and grouped into the headings found within this report. A review of wetland classification programs from other jurisdictions was also reviewed to gain insight for the recommendations outlined in this paper. All literature was reviewed for accuracy and relevance to the paper topic.

The literature reviewed and recommendations provided are limited to the documents and programs that were most easily accessed in the amount of time allotted for this paper during the summer of 2023. While boreal wetlands are found across the circumpolar north, this paper focused on the programs and information available mostly within in Canada, and some within the United States. This was due to the time available for the literature review and because documents from other regions were not readily available in English.

The intended audience of this paper is fellow MLWS students who are interested in learning more about the topic, and other people in the fields of wetlands, wetland classification, and wetland policy, and other interested stakeholders such as industry representatives and conservation groups. It is assumed that the readers will have a basic understanding of ecological systems and the related vocabulary and concepts.

3 BACKGROUND

3.1 THE BOREAL FOREST

The boreal ecosystem is one of the largest continuous forest ecosystems in the world, covering approximately 1.9 million hectares or 33% of the Earth's forested area (Natural Resources Canada 2020). The boreal is found across the northern hemisphere, including in North America, Europe and Asia. In Canada, it covers approximately 522 million hectares, which is about 28% of the Earth's boreal zone (Natural Resources Canada 2021). The Canadian boreal ecosystem ranges from the Yukon and British Columbia to Newfoundland and Labrador (Figure 1). The boreal forest serves many important functions including contributing to global biodiversity, carbon sequestration, air and water purification, regulation of regional and global climates, and nutrient cycling (Brandt 2009).

Figure 1. The extent of the boreal forest in North America (Brandt 2009).

The boreal ecosystem is characterized by coniferous stands, with some mixed coniferous/deciduous stands and deciduous stands. Upper elevation forests are dominated by fir species (*Abies species*), while lower elevation forests are dominated by white spruce (*Picea glauca*), black spruce (*Picea mariana*) and lodgepole pine (*Pinus contorta*) (Yukon Ecoregions Working Group 2004). Deciduous stands can also be found through the boreal, and contain balsam poplar (*Populus balsamifera*), trembling aspen (*Populus tremuloides*) and birch (*Betula species*). The boreal ecosystem is well adapted to northern climatic conditions that includes short, cool summers and long, cold winters. It supports a large range of plant and animal species, both migratory and non-migratory. The boreal forest includes many different ecosystems including a diversity of wetlands (Brandt et al. 2013).

The boreal forest is a dynamic ecosystem, that changes through regular cycles of disturbance. Boreal forest dynamics are driven by several types of disturbance including fire, insects, climate, diseases and the interactions between these components (Brandt et al. 2013). These natural disturbances play an important role in the cycles of productivity of the boreal forest and contribute to the variability in habitat range and size, successional stage, and species composition. In addition to natural disturbances, the boreal forest is also facing man-made disturbances which threaten the delicate balance of the many integrated systems of the boreal ecosystem. Many people live and work within the boreal zone, and the boreal forest is the source for many important resources, such as metals and lumber (Brandt 2009; Brandt et al. 2013). These disturbances, or threats, affect all parts of the boreal forest, including the boreal plant and animal species and the many diverse habitats found within the boreal, such as wetlands.

3.2 BOREAL WETLANDS

A wetland is "land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity which are adapted to a wet environment (National Wetlands Working Group 1988)." Wetlands can be distinguished from other habitat types by the characteristics of their water levels and flood frequency, soil types, and vegetation communities (Cox and Cullington 2009). Water levels are generally near, at or above the wetland surface, and the soil is saturated, for some or all parts of the day or year. Wetland vegetation communities are primarily made up of species that are hydrophytic ("water loving") which are adapted to living in water and saturated soils (MacKenzie and Moran 2004). The vegetation communities and soil types that are found in Boreal wetlands are generally the result of the low soil oxygen levels and saturated conditions.

Wetlands can be divided into two broad categories (National Wetlands Working Group 1997):

- Organic wetlands: contains more than 40 cm accumulation of organic matter (peat).
- Mineral wetlands: located where excess water collects on the surface, and where there is little or no accumulation of organic matter.

There are five types of wetlands that are characterized in the boreal forest: bog, fen, swamp, marsh, and shallow open water. Each of these wetland types can be identified through soil characteristics, species composition, hydrology, and location on the landscape. They each serve important functions and provide different types of benefits within the boreal forest.

Bogs and fens are the two types of organic wetlands. Bogs develop when large accumulations of peat become raised above the groundwater or surface water (National Wetlands Working Group 1997, MacKenzie and Moran 2004). The accumulated organic matter is most often made up of partially decomposed sphagnum mosses and shrubs. These conditions lead to poor nutrient and acidic conditions in the soil. Dominant vegetation in bogs are species adapted to these conditions and can be ground shrubs, low shrubs or stunted trees. Bogs develop in depressions in the landscape where the accumulation of peat is raised above the water table.

Fens are identified by large accumulations of peat with water flowing at the surface or subsurface (National Wetlands Working Group 1997, MacKenzie and Moran 2004). The accumulated organic matter is most often made up of partially decomposed brown mosses and graminoids. The flow of water through the fen helps maintain high nutrient availability. Dominant vegetation in fens can be graminoids and low shrubs. Fens develop in many areas of the landscape, including lake margins, basins, and seepage slopes, where the water table is at or just below the surface of peat accumulation.

Swamps, marshes and shallow open water areas are the three types of mineral wetlands. Swamps can have both mineral and/or organic soils (but less than the 40 cm of organic matter required for an organic wetland) (National Wetlands Working Group 1997, MacKenzie and Moran 2004). The water table may be permanent to semi-permanent, near-surface and flowing or fluctuating through the swamp. Nutrients are abundant leading to a diverse vegetation community. Dominant swamp vegetation can be dense tall shrubs or contain trees (coniferous or deciduous) on elevated microsites surrounded by saturated depressions. Swamps develop in depressions in the landscape, seepage areas and at the edges of ponds, rivers and lakes.

Marshes are identified by mineral soils and flooded areas with fluctuating water levels (National Wetlands Working Group 1997, MacKenzie and Moran 2004). Water fluctuations are generally seasonal and will determine the type and density of vegetation that grows at the site. Due to the changing water levels, there is little organic matter accumulation, but a thin layer can occur at the surface of the soil. Nutrient availability is high due to the water movement and oxygen availability. Dominant vegetation in marshes can be emergent aquatic vegetation including grasses, sedges, rushes, and reeds, and sometimes floating aquatic vegetation species. Marshes develop at the edges of lakes, ponds, creeks, and rivers.

Shallow open water areas are generally vegetated areas of standing water no deeper than 2m (MacKenzie and Moran 2004). These sites are generally permanently flooded, with slow moving or standing water. Water levels may fluctuate seasonally. Nutrient availability is variable depending on the conditions where the shallow open water site formed. Dominant vegetation can be floating, submerged or rooted aquatic vegetation, such as pondweeds (*Potamogeton species*). Shallow open water sites develop in depressions on the landscape or in shallow areas at the edges of deeper lakes or ponds.

3.3 ORIGINS OF BIOLOGICAL CLASSIFICATION

Biological classification has existed in our societies for hundreds of years. It is a system by which organisms and ecosystems are named and grouped together based on shared characteristics and/or common ancestry (Lomolino, Riddle & Whittaker, 2017). Classification systems have evolved over time, increasing in both complexity and scale and are an important factor in helping us understand the natural world. Determining the characteristics of ecosystems through biological classification allows for better understanding of the natural world, including the formation of ecosystems, their role in the landscape, how they are used by humans and other organisms, and how human activities may impact the landscape.

The most commonly known and earliest use of biological classification is used for classifying organisms. The first record of biological classification dates from the fourth century BC and is in the form of several volumes written by Greek natural philosophers Aristotle and Theophrastus (Killas, 2013). Aristotle's volumes on animal classification were well organized, describing and classifying over 100 animal species (Yoon, 2009). These volumes and became the basis for biological classification into the Renaissance. While Aristotle's and Theophrastus' specific reasons for developing a biological classification system are not known, it can be assumed that they, like so many other biologists that would follow in their footsteps, wanted to find order in the natural world and perhaps to get closer to understanding what life is and where it comes from.

It was quite some time before the system of biological classification became a topic of interest again. By the end of the eighteenth century, Europeans were sending out ships full of explorers, cartographers and naturalists to lay claim to the world. These expeditions led to the discovery of many new landscapes and organisms and to the creation of vast new specimen collections (Mischler, 2009). As there was no convention for naming organisms, many ended up with multiple names which were sometime also in multiple languages (Magner, 1994). The influx of so many new species and the multitude of names made it difficult and confusing for naturalists to relate to each other's work. As the specimen collections grew, so did the demand and need for a method that could put them in order.

In 1735, the Swedish botanist Carl Linnaeus published "Systema Natura." Linnaeus was driven to create a methodology to better "describe and understand the natural world as a reflection of the logic of God's creation" (Yoon, 2009). His book outlined a system for classifying and naming flora and fauna that was in line with the worldview of the era to control and create order in the natural world. Linnaean classification is based on a hierarchical system that incorporates seven levels: Kingdom, phylum, class, order, family, genus and species.

Building on the scientists before him, Alexander von Humboldt, a German naturalist and explorer, began describing and classifying ecosystems in a structured manner (Lomolino, Riddle & Whittaker, 2017). He conducted extensive field work in South America and Europe, in the late eighteenth century through to the middle of the nineteenth century. He combined the studies of meteorology, geology, geography, botany, zoology and anthropology in order to accurately understand and describe the landscape in a holistic way (Wulf, 2014). Through his research, Humboldt recognized that ecosystems were complex systems of interconnected components, including plants, animals, and their physical environments. By studying all of the components together, he could better understand the relationships and processes that shaped ecosystems.

In 1807, Humboldt published, "Essai sur la géographie des plantes" (Essay on the Geography of Plants). He introduces the concept of vegetation physiognomy, which characterizes plant communities in different regions of the world. He described how environmental factors influenced the composition and structure of vegetation communities, leading to distinct ecosystem types. Humboldt's approach to describing and classifying ecosystems is credited for laying the foundation for modern biogeography. His recognition of global ecological processes and the relationships between organisms and their environment, have led to what we use in modern ecosystem classification systems.

4 BENEFITS OF BOREAL FOREST WETLANDS

Wetlands are complex and interconnected systems that contain many components and processes, and the interactions between the components and processes. The many wetland benefits are a result of the functioning of all these components and processes, and interruptions to one or more can result in negative effects to the wetlands, and the species that rely on these wetlands. To fully understand wetland benefits, it is important to take a wholistic approach to be able to understand the full range of the elements involved and their effects on each other. Wetlands require an interdisciplinary view, including understanding environmental processes (soils, geography, hydrology, and biology), and social and economic perspectives and activities. By better understanding wetland benefits and collecting, recording and sharing this information through systems such as wetland classifications systems, we will be better able to protect wetlands and maintain their vital functions.

The wetlands of the boreal forest provide many benefits and play a vital role in the functioning of the boreal forest ecosystem. While not every wetland may provide the full range of benefits described below, collectively boreal wetlands are critical to the function and success of many species and connected ecosystems. Environmental benefits provided by wetlands include:

- hydrological benefits (water storage and regulation, water temperature regulation, water quality regulation and filtration, sediment control);
- biophysical benefits (terrestrial and aquatic habitat, biological diversity, wildfire barriers); and,
- chemical benefits (carbon storage, nutrient cycling).

Wetlands also provide numerous social and cultural benefits; however, these will not be included in the scope of this paper.

4.1 HYDROLOGICAL BENEFITS

Boreal wetlands offer a range of hydrological benefits, including water storage and regulation, temperature regulation, sediment control and water quality regulation. Water enters wetlands through surface or groundwater flows and precipitation, and leaves through surface or groundwater flows, infiltrating out through the soil, evapotranspiration and transpiration through plants (Cox and Cullington 2009). The many hydrological benefits and links to surface and groundwater flows means that boreal wetlands are critical to the functioning of ecosystems and are important for the survival of many species.

Wetland locations in low-lying or seepage areas, combined with the vegetation communities adapted to saturated soils, enable wetlands to function as natural water storage reservoirs (Krasnostein, and Oldham 2004, Cui et. al. 2021). The connection of wetlands to larger water bodies, and both surface and groundwater flows, allows them to efficiently hold and process water as it traverses through the boreal landscape. This water regulating and holding capacity means that wetlands play a crucial role in flood mitigation (Cox and Cullington 2009). During heavy rainfall or snowmelt events, wetlands can retain excess water before directing it into surface or groundwater systems, or to larger connected water bodies. This stored water is gradually filtered and released, mitigating floods that could have otherwise overwhelmed the other water bodies and upland habitats. During droughts, wetlands provide a vital source of stored water, offering a slow release that supports nearby habitats and wildlife.

Wetlands serve as natural filtration systems that play an important role in water quality management. As stormwater runoff and surface water flow through wetlands, the wetland vegetation and soils act as physical barriers that trap suspended sediments (Cox and Cullington 2009). As water enters a wetland, the water velocity slows due to the vegetation and topography. This reduced flow allows suspended sediment to settle out and accumulate within the wetland. This process prevents sediment from entering larger water bodies like rivers, creeks and lakes. By acting as a barrier against sediment transport, wetlands help maintain or reduce the amount of sediment that can travel downstream that can negatively affect other habitats and species.

In addition to sediment control, wetlands can also serve as natural filtration systems, for pollutants and excess nutrients, such as nitrogen and phosphorus (Cox and Cullington 2009, Olewiler, 2004). Similar to suspended sediments, as the water slows in wetlands, these particles can also be trapped and settle out. The root systems of wetland plants further enhance this process by promoting sediment deposition and nutrient absorption (Cox and Cullington 2009). Through a combination of physical and biological processes, wetlands effectively remove harmful substances from the water, preventing their introduction into downstream ecosystems, improving aquatic habitats and providing clean drinking water.

4.2 BIOPHYSICAL BENEFITS

Boreal wetlands provide several biophysical benefits including terrestrial and aquatic habitat, biological diversity, and wildfire mitigation. Wetlands support a large diversity of habitat types and support many species in both terrestrial and aquatic environments (Cox and Cullington 2009, Tozer et. al. 2018). A large variety of aquatic species such as amphibians, aquatic invertebrates and fish utilize boreal wetlands for all or some of their life cycle (Dixneuf et. al. 202, Cox and Cullington 2009). These species rely on the unique characteristics of wetlands for food, breeding, and their various life stages.

Terrestrial species, including birds, mammals, and insects, rely on wetlands for food, shelter, breeding areas and migratory stopovers. For example, moose (*Alces alces*) rely heavily on the emergent and floating aquatic vegetation found in boreal wetlands. Boreal wetlands provide critical stopover and breeding habitat for migratory birds (Blancher and Wells 2005). It is estimated that the Canadian boreal forests support 1-3 million breeding per year, and approximately 3-5 billion migratory bird species a year, and most of these species rely heavily on wetlands (Cheskey et al. 2011).

Wetlands are also unique in that they are also transitional zones between aquatic and terrestrial habitats (Cheskey et al. 2011, Tozer et. al. 2018). These transition zones facilitate interactions between terrestrial and aquatic species, and also provide transition zones for some species as they move between aquatic and terrestrial life stages. For example, amphibians rely on aquatic habitats for breeding and their early stages as tadpoles, and then move between terrestrial and aquatic habitats during their adult life (Tozer et. al. 2018).

Wetlands are critical sites for biodiversity in the boreal ecosystem (Cox and Cullington 2009, Tozer et al. 2018, Blancher and Wells 2005). Wetlands provide specialized habitat for many species, some that are only adapted to the particular conditions offered by different wetland types (Cox and Cullington 2009, Gingras 2018). They can be unique microsites found in an otherwise somewhat homogenous forested landscape in the boreal ecosystem. For example, the moist and acidic soil conditions of bogs provide a unique habitat for plant species such sundews (*Drosera species*) that would not be able to grow in the more neutral and dry soils of the forested ecosystems. The many migratory species that use boreal wetlands each year also vastly increase biodiversity for the region (Blancher and Wells 2005).

Boreal wetlands also play an important role in wildfire mitigation, as wildfire barriers and by aiding in ecosystem recovery after wildfires (Neary et al. 2005). Wetland vegetation and saturated soils can act as natural fire breaks in the boreal landscape. The high moisture content limits the spread of fire and can impede or slow the progression of fires between adjacent forested areas, reducing the overall fire risk of a region. Boreal wetlands can also provide refuge or escape corridors for species during wildfires. Post-wildfire, wetlands can provide valuable habitat and sources of food to support the species negatively affected by fire in the region. Wildfires can also often result in the destabilization of soil causing issues with erosion and large amounts of sediment entering waterways. Wetlands can assist with the reduction of sedimentation and help protect downstream waterways.

4.3 CHEMICAL BENEFITS

Boreal wetlands provide important chemical benefits including carbon storage and nutrient cycling, which plays an important role in maintaining the overall health and stability of the boreal ecosystem. Boreal wetlands, particularly bogs and fens, are significant carbon sinks on a global scale (Ducks Unlimited 2017). The nutrient cycling that occurs in boreal wetlands is the driver of many of the species and processes found in wetlands and other adjacent boreal habitats (REF).

Organic boreal wetlands, often collectively referred to as peatlands, are mostly made up of sphagnum mosses, brown mosses, sedges and shrubs (Mackenzie and Moran 2004). Peatlands occur in areas where water accumulates due to high precipitation and/or poor drainage, such as areas with impermeable layers such as bedrock or permafrost (International Peatland Society 2022). Due to the saturated conditions, there is little soil oxygen content, decreasing microbial activity. In Canada, most peatlands also occur in areas with low temperatures (compared to temperate and tropical climates). The combination of saturated conditions, low soil oxygen levels, and low temperatures lead to very slow decomposition rates, and the massive build up of organic matter. As organic matter, or peat, builds up over time, bogs and fens are formed. With very low rates of decomposition, the massive amount of partially decomposed organic matter becomes a carbon sink. Decomposition rates can be further slowed if they become part of the permafrost layer in more northern parts of the boreal ecosystem.

Peatlands are the largest terrestrial carbon sink in the world, estimated at over 500 gigatons of stored carbon. Canada contains about 25%, or 1.1 million km^2 of the worlds peatlands, and most of these are within the boreal ecozone (Figure 1; Wildlife Conservation Society of Canada 2021). It is estimated that the boreal wetlands in Alberta store between 11.5-13 billion metric tons of carbon (Ducks Unlimited 2017). Other boreal wetland types can also act as carbon sinks due to do low decomposition rates in northern climates; however, the carbon stored in the mineral sediments is estimated to be considerably less than that in the organic wetlands. Carbon sequestration varies depending on conditions like wetland productivity, temperature and decomposition rates.

Wetlands also play an important role in nutrient cycling in the boreal ecosystem. Nutrients enter wetlands through various inputs including surface runoff and can contain nutrients that occur naturally in the environment, or other pollutants or contaminants, such as excess nitrogen and phosphorous from agricultural activities (Cox and Cullington 2009). Nutrients also occur internally through decomposition of organic matter, as plants and organisms die, and the nutrients contained in them are released back into the ecosystem. The balance between internal and external nutrient inputs determines the overall nutrient dynamics of a wetlands and can influence their function as regulators and filters for downstream water quality.

Nitrogen and phosphorus cycling in wetlands is a complex process and can be particularly important in areas with high levels of agriculture use (Cox and Cullington 2009). An increase in phosphorus and nitrate levels in waterways can lead to algae growth and potentially toxic conditions for aquatic species. Bacteria found in wetlands complete nitrogen fixation, which converts atmospheric nitrogen into a form that plants can utilize, and nitrification, which transforms ammonia into nitrates, which wetland plants also can uptake (Krzic et al. 2021). Phosphorus cycling involves the release of phosphate from organic matter breakdown and subsequent uptake by plants. The microorganisms and vegetation in boreal wetlands are critical for these processes to occur throughout the boreal ecosystem. While different types of wetlands will have varying rates of nutrient cycling, they are important regulators of nutrient cycling and maintaining water quality.

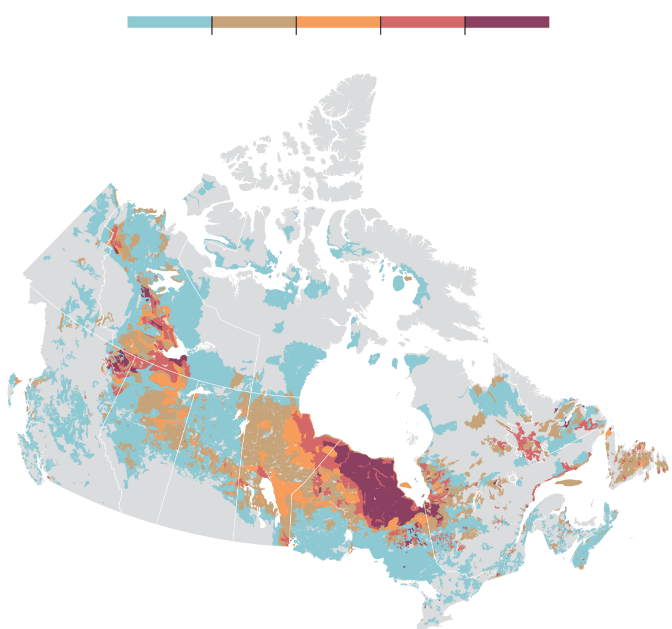

Figure 2. Peatlands of Canada (Geological Survey of Canada, 2011)

5 THREATS TO BOREAL FOREST WETLANDS

Boreal forest wetlands are currently facing several threats that limit their functions and impacts on the landscape. These threats include physical degradation, changes to water quality, invasive species, and climate change. These activities can disrupt the hydrological balance, degrade water quality, and fragment critical habitats across the boreal landscape. Climate change, with its associated impacts such as altered precipitation patterns and thawing permafrost, poses further risks to the stability and functioning of wetlands.

Human activities that directly affect wetlands include oil and gas, mining, forestry, recreational activity, agricultural practices, grazing, and urban and rural development. Some of the activities, such as resource extraction, often effect more remote areas that are otherwise unaffected by human activity. These can also happen on very large scales, potentially changing habitats across a larger part of the landscape, and over time periods of 25 to 50 years use (Cox and Cullington 2009). Activities such as urban development may affect wetlands on a more local and smaller scale and. However, the wetlands in these areas are often critical wild areas in otherwise urban landscapes. The loss or disruption of these wetlands could change the only important habitat in the area and cause the loss or reduction in important ecosystem functions.

A study in British Columbia, Canada estimated that 60% to 98% of the original wetlands in southern BC were drained or filled by 2006 (Olewiler, 2004). In BC, regions with higher human populations and agricultural areas show much more wetland degradation compared to more remote, less populated regions. This and similar patterns are being recorded throughout the boreal landscape. It is important the policy makers, governments, and land-use planners better understand the benefits and the threats faced by boreal wetlands so that decisions can be made to protect wetlands or mitigate further damage.

Boreal wetlands are widespread and complex ecosystems, and they interact with many human activities and can be affected by changes in the natural and social domains. It will be necessary to have a thorough and multi-disciplinary approach to understand wetland threats in order to decipher how the threats directly and indirectly affect boreal wetland health and function. This paper will outline the major threats faced by boreal wetlands; however, there are likely many other threats that cannot be covered in the scope of this paper.

5.1 PHYSICAL DEGRADATION

Physical degradation of wetlands includes the threat of habitat loss and fragmentation, drainage, and physical alteration. These are caused by a wide range of activities including resource extraction (forestry, mining, and oil and gas), the construction of linear infrastructure (roads, pipelines, and powerlines), urban and rural development, agriculture practices and recreational activities (Cox and Cullington 2009). These threats can reduce the capacity of wetlands to provide their many benefits, through the disruption of surface, groundwater and nutrient flows, and the destruction or reduction critical habitats and habitat functions and habitat connectivity.

Habitat loss and fragmentation is the direct loss of wetlands through the removal of the habitat, the reduction in the size of the wetlands, or the isolation or disconnection of a wetland from larger wetland complexes (Cox and Cullington 2009). This can lead to a disruption in the flow of surface and groundwater flows and interfere with the movement of nutrients. It can also lead to the loss of critical habitats and habitat connectivity, potentially interrupting migratory patterns or the movement of some species from one habitat to another during different life stages.

Human activities are one of the primary drivers of habitat loss and fragmentation. Poorly constructed roads, culverts, and drainage systems can lead to dewatering, compaction and infilling of wetlands (Cox and Cullington 2009). Livestock grazing and trampling, and the removal of vegetation for crops and livestock damage wetland vegetation and soil and, overtime, can transform wetlands into upland habitats. Major development projects, such as urban and rural develop and mining and oil and gas activities, destroy or fragment boreal wetlands through vegetation clearing and soil excavation and compaction. Linear developments have the potential to cause habitat loss and fragmentation by interrupting surface and groundwater flows and creating physical barriers for the movement of fish and wildlife species.

As was outline in biophysical wetland benefits (Section 4.1), wetlands serve as critical breeding and feeding areas for various species (Blancher and Wells 2005, Cox and Cullington 2009, Tozer et. al. 2018). Wetland habitat loss and fragmentation may in reduction in boreal biodiversity and species success. The loss of boreal wetlands in critical areas have the potential to interrupt migrations of many bird species by limiting their stopover areas and available food resources (Tozer et. al. 2018). The loss of urban wetlands could drastically decrease the potentially already low biodiversity of urban areas (Cox and Cullington 2009). While many species have been able to adapt to human activities and presence, without boreal wetlands near and through urban areas, there would be no foothold for these remaining species.

Wetlands may be drained for various purposes, including agriculture, development, recreational uses and land conversion (Cox and Cullington 2009, Chapman and Labadz 2004). Drainage changes natural surface and groundwater flow patterns and levels, leading to the loss or degradation wetlands. As water is drained from the wetland, the saturated conditions that are necessary to maintain the wetland are lost, and the area turns into an upland habitat. The loss of wetlands, particularly in areas near to human development, can mean the loss of important benefits such as wildlife and flood mitigation. Draining of boreal wetlands can also negatively impact the recharge of groundwater resources. Wetlands are connected to many other waterbodies, often through groundwater sources, and provide important base flows during dry periods.

5.2 CHANGES TO WATER QUALITY

Changes to boreal wetland water quality includes the threats of the introduction of pollutants and contaminants, and increased erosion and sedimentation (Cox and Cullington 2009). The introduction of these elements can alter the complicated and delicate balance of nutrients in boreal wetlands and alter their ability to function as habitats and water quality filters and regulators on the boreal landscape. This can directly affect the species living in the wetlands, and also neighbouring and downstream habitats and species.

The are many sources of pollutants and contaminants to boreal wetlands (Cox and Cullington 2009). Agricultural practices and livestock can contribute through the utilization of fertilizers, soil amendments, and pesticides. This can lead to imbalance in nutrient cycling and poisoning of wetland water resulting in oxygen depletion, eutrophication and algae blooms, aquatic species mortality. The development and use of roads, urban development, and other development related to resource extraction can also add pollutants and containments to wetlands. Stormwater runoff in urban areas can contain a wide variety of pollutants and contaminants, including salt, petroleum products, fertilizers, and pesticides. Improper mining techniques or abandoned mines can lead to phenomena such as acid rock drainage, where acidic water is leached into waterways at levels that are toxic to aquatic organisms and vegetation. These changes in water quality will have many negative and potentially lethal effects within the wetlands and in downstream aquatic and terrestrial ecosystems.

An increase in erosion and sedimentation can also have negative impacts on boreal wetlands (Cox and Cullington 2009). Ground disturbance due to development and construction or exposure of soil due to the removal of vegetation and livestock trampling can cause erosion and an increase in sediment entering wetlands. Sedimentation can considerably disrupt the natural processes of wetlands, reducing primary productivity, impairing feeding behaviors of aquatic and terrestrial species, reduce vegetation's ability to photosynthesize, and can cause physical stress to some species such fish.

5.3 INVASIVE SPECIES

There are many potential consequences of invasive species within boreal wetlands. Invasive species are non-native species that are able to establish quickly in new areas and have negative social, economic and environmental impacts (Government of British Columbia 2017). Invasive species can lead to environmental degradation by interrupting food webs, altering habitats, disrupting waterway (Invasive Species Council BC 2021). They can also introduce pest species and diseases and be poisonous to humans and wildlife. Since invasive species are new to the ecosystems, they do not have any predators or natural restrictions to keep their populations in check (Government of British Columbia 2017). Some species can spread quickly and widely, causing harm to native ecosystems and species by outcompeting or displacing native species.

Invasive species enter wetlands through various pathways, which are often facilitated by human activities. Recreational activities, vehicle and boat movements associated with recreational activities, development or construction projects, and the creation of new roads act as vectors for introducing invasive species (Cox and Cullington 2009). Agricultural practices can introduce invasive species through escaped crops or from livestock feed. Wetlands that have already been degraded are particularly vulnerable to invasive species, which can be the case in urban areas. Road building and vehicle transport associated with resource extraction can allow invasive species to become established in otherwise wild areas. The lack of native vegetation and increased exposed soil provides ideal conditions for invasive species to become established.

Managing invasive species presents complex challenges due to the intricate nature of ecosystems, the speed at which invasive species can spread, and the various vectors that contribute to their introduction (Government of British Columbia 2017). Maintaining up-to-date knowledge on potential threats and finding suitable control measures are key to helping reduce or prevent the spread of invasive species. Educational programs and participation from many people are necessary to help reduce the risk of invasive species and manage those that are already established.

5.4 CLIMATE CHANGE

Climate change poses many threats to wetland ecosystems, including changes in air and water temperatures, increase in precipitation events and magnitude, permafrost thaw, and an increase in flood and drought risk (Cox and Cullington 2009, Ducks Unlimited 2017). These changes can impact wetlands by disrupting many of the wetland ecosystem components and processes, resulting in a loss of wetland ecosystem functions, biodiversity, and health. These changes are already being recorded in boreal wetlands in all regions and have the potential to effect thousands of species through the boreal ecosystem and the world.

Changing precipitation patterns can dramatically impact wetlands, as storm events become more frequent and larger in magnitude (Ducks Unlimited 2017). This can overwhelm the storage capacity and water quality capacity functions of wetlands, decreasing the positive effect they can have on surrounding and downstream ecosystems. In the summer, drought conditions are becoming more frequent, reducing the water available to wetlands. Without sufficient flows, wetlands cannot support the vegetation communities that so many other species rely on for food and shelter.

The change in air temperatures and lack of water is also increasing the fire risk throughout the boreal ecosystem (Ducks Unlimited 2017, Neary et al. 2005). While boreal wetlands can provide fire mitigation, they can become overwhelmed by fires that are burning hotter and traveling faster due to the dry conditions and warmer temperatures. Fires are also occurring earlier in the season before wetland vegetation can become fully established. This loss of a potential saturated buffer of wetland vegetation allows fires to travel across areas that might have once helped prevent the spread of wildfires.

As temperatures are increasing, permafrost is melting across the northern hemisphere and affecting the characteristics and functions of many boreal wetlands, peatlands in particular (Cox and Cullington 2009, Ducks Unlimited 2017). As permafrost melts, the conditions required for carbon sequestration in the peatlands are diminishing. Warmer temperatures, result in greater saturation and an increase in microbial activity, which increase the decomposition rates of the organic matter stored in the peatlands. As this occurs, the vast amount of carbon stored in the peatlands is released into the atmosphere.

Climate change may bring about substantial changes in boreal wetlands, impacting their functions and health and associated environmental benefits. There are many potential threats and changes, many of which are still being researched and understood. Due to the broad range of climate change effects, the full range of consequences on boreal wetlands is not understood. It will be critical to continue to monitor and understand the range of changes that occur due to climate change to begin to understand how boreal wetlands will be affected and what can be done to help protect and manage them in the face of all these changes.

6 WHY CLASSIFY?

Classification systems organize data into hierarchical groups and sub-groups that are complete, connected, consistent and relevant to the users needs (Finisdore et al. 2020). A well-developed classification system also provides definitions for the component or systems being measured, a common vocabulary, and a data structure. Classification systems should be created through consultation with user groups and reviewed and updated regularly. Ecosystem classification systems, including wetland classification systems, are important because they incorporate all the components, processes and systems that make up the ecosystem. These systems provide a holistic view of the landscape, which allows for better understanding of each piece and also how they are all connected and function together.

Beyond data collection and data management, wetland classification systems can be used as a communication tool to help relay the potentially abundant amount of information on wetlands to a wide range of users. By describing the landscape in this way, it can help scientists, land-use managers, local stake holders, and industry better understand the extent of ecosystems, potential affects of land-use change on habitats and associated wildlife and identify ecological responses to potential disturbances.

Wetland classification systems can be used to gather information and better understand the wetland benefits and threats (Sections 4.0 and 5.0). The common language, tools and data frames of a classification system will assist with the multi-disciplinary approach to understanding wetlands by allowing all types of specialists to add data and analyze data. Wetland classification systems can also assist in conducting meta-analysis and tracking changes over time. This is potentially very useful for understanding threats such as climate change which are very dynamic, fast acting and still being understood.

There are several benefits associated with classification systems (Environment Yukon 2016, Finisdore et al. 2020, van Oudenhoven, 2018):

- **Common Language**: A common language can be used for all components and systems and can be utilized by all users.
- **Common Methodologies/Tools:** Specific data collection methods and management systems, tools and models can be developed for the data. The common tools help to make sure data is collected and managed in consistent manner.
- **Common Data Framework**: Creating a framework for data collection and data management that is consistent and holds all data for a region(s) will make the information more accessible and easier to use.
- **Increase Knowledge**: A better understanding of how the components and systems are interrelated and linked, how they interact on the landscape, and how they may compare to other regions or landscapes. An interdisciplinary approach to understanding wetlands allows various specialists to be able to contribute to the collective knowledge base and provide information about all aspects of wetlands.
- **Knowledge Transfer**: Common language, data practices, and systems will improve the efficiency and transparency of knowledge transfer between users, including specialists and non-specialists.

With the data contained in a uniform data frame will make it more accessible, and additions can be made by specialists of various fields.

- **Increase Efficiencies**: Reduces the chances of overlapping work being completed - one data management centre allows for multiple users to enter and access data so that users can see what work has been completed already and were there are knowledge gaps. This provides efficiencies in both time and money.
- **Track Changes**: Changes in an ecosystem can be tracked over time, all data is recorded in a consistent manner and stored in one framework. Data is more easily and accurately compared when it is recorded and managed in a consistent way.
- **Conduct Meta-analysis**: Meta-analysis can be conducted by combining information from several studies to provide insights to ecological processes and phenomena at various landscape scales. If all data is part of the same system, it is more likely that results will be more precise. There is also the potential for greater accuracy when scaling the data.
- **Improve Communication:** A common language and more comparable data will allow for better communication outside the specialist users, including with the general public (education)and with decision and policy makers, and stakeholders.
- **Specialization:** When developing the classification system, specific needs of users can be incorporated, and updates can be made systematically as they are needed.

7 CASE STUDY: YUKON WETLAND CLASSIFICATION SYSTEM

Wetland classification has been developed and used in many jurisdictions around the world. In Canada, there are existing federal and provincial systems that have been established and are designed to serve particular purposes. The Canadian Wetland Classification System (CWCS) is an example of a long-standing classification system that was developed to support wetland classification at a national scale. The aim of the CWCS is to "provide a standardized framework for identifying, classifying, and describing wetlands in Canada. It assists in understanding wetland functions, values, and ecological significance, aiding in their effective management and conservation (National Wetlands Working Group 1997)." The CWCS has been used by researchers, policy makers, conservation groups, industry and many other user groups.

In Alberta, the Alberta Wetland Classification System (AWCS) was developed to provide a standardized provincial wetland classification system. This system was designed to provide a consistent classification system for the entire province, promote understanding of wetlands, relate wetland characteristics to environmental processes, to be compatible with existing inventories and systems, is aligned with provincial legislation and policies, and can be used with other GIS databases and inventories in Canada (Alberta ESRD 2015). Currently, the AWCS is being used by industry, land-use planners, conservation groups, researchers and many other user groups.

The Yukon Territory does not currently have a Yukon-specific wetland classification system. In many situations, the CWCS is used as the default classification system. However, several projects and regions within the boreal zone of the Yukon have also created independent wetland classification systems that are more useful in describing local and/or project specific conditions. While many of these independent wetland classification systems are based on the CWCS, the lack of a central wetland classification system may lead to inconsistencies between data collection and interpretation and a loss of efficiency, knowledge, and communication.

The Yukon Government (YG) is currently developing an ecosystem classification program, Ecological and Landscape Classification (ELC), which includes boreal forest wetland ecosystems. In addition to the ELC program, the Yukon Government recently released the Yukon Wetland Stewardship Policy. This document outlines the current state and next steps required for characterizing and understanding wetlands in the Yukon. These two initiatives can help lay the foundation for the creation of a Yukon Wetland Classification System, that is specific to the Yukon and it's boreal wetlands.

The classification of wetlands is important for the future of the Yukon. It is necessary to understand the distribution and types of wetlands within the Yukon landscape so appropriate conservation and mitigation actions can be implemented when discussing land use planning, resource projects, and the needs of humans and animals. A well-developed wetland classification system can help inform decision making processes, track changes in wetlands over time, and better understand the benefits and threats that are faced by boreal wetlands in the Yukon.

7.1 ECOLOGICAL AND LANDSCAPE CLASSIFICATION

Ecological and Landscape Classification (ELC) is used to describe and identify ecosystem units based on landscape patterns, by providing information on physical and biological characteristics, collected using a combination of imagery interpretation and ground sampling (Environment Yukon 2016). The program is currently being developed to support land and resource management decisions and to provide ecosystem maps for a variety of programs and services throughout the territory (Ecological and Landscape Classification Supervisory Committee 2013).

It has become more common to include ELC mapping in project baseline studies and EIAs, and in applications to the Yukon Environment and Socio-economic Assessment Board (YESAB) (the independent body that is responsible for the assessment responsibilities of the Yukon Environmental and Socio-economic Assessment Act (YESAA) regulations and legislation) (YESAB 2022). As it becomes more standard to include ELC mapping in this type of work, a functional and well-established ELC program is needed to ensure that data is collected, analyzed, and described using a standardized and practical method. Since its initiation in 2002, the Yukon ELC program has grown and evolved; however, there are still many more components to develop and incorporate into the program before it reaches its full potential.

Environment Yukon (a branch of the Yukon Territorial Government) is responsible for coordinating, developing, and delivering the Yukon ELC program, with the Yukon Energy Mines and Resources branch working as partner and contributor. A multi-agency biophysical mapping technical working group was established in 2002 to begin developing the Yukon ELC framework (ELCSC 2013). In 2006, financial support and staff were allocated to begin developing ecosystem classifications and other technical work, and in 2010 an ELC coordinator was hired. In 2013, the *Yukon Ecological and Landscape (ELC) Program Five-Year Strategic Plan* was released, outlining the approach to development, implementation phases, and the components needed for a successful program (ELCSC 2013). Before and during these initial stages of the ELC program, other documents and projects already existed in the Territory but were not standardized and were developed on a case-by-case basis.

The Yukon was divided into nine biogeoclimatic (BEC) zones: Boreal Low, Boreal High, Boreal Subalpine, Subarctic Woodland, Subarctic Subalpine, Arctic Tundra Low Shrub, Arctic Tundra Dwarf Shrub, Pacific Maritime Glacial, and Alpine Tundra (Figure 3) (Environment Yukon 2016). Each BEC zone is further divided into various subzones, depending on their climate and their local-level ecosystems. For example, the Boreal Low Zone is divided into eight subzones that are in different regions of the Yukon (Figure 4) Each of the subzones have unique ecosystems that need to be identified and classified and described in a subzone specific field guide.

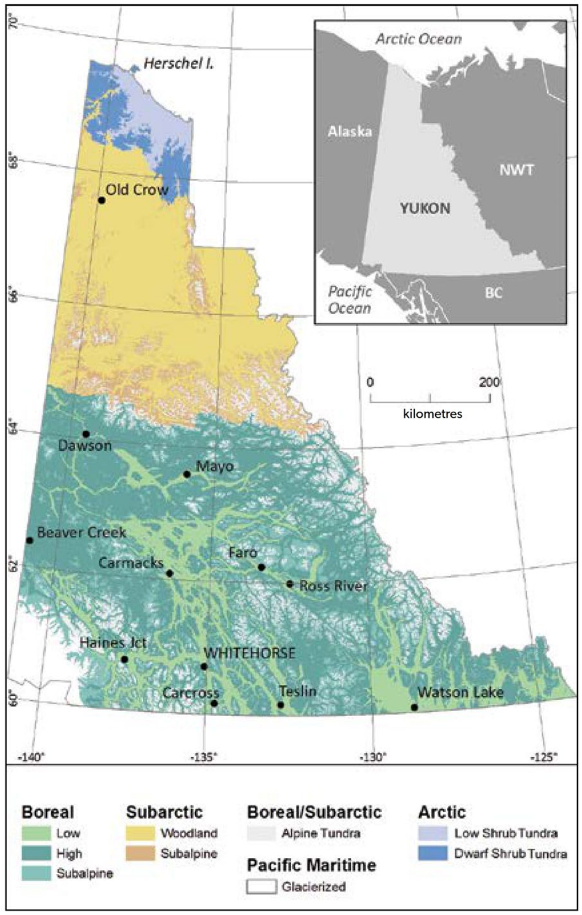

Figure 3. Bioclimatic zones of the Yukon (Environment Yukon 2017).

To develop the subzone field guides, the ecosystem units (or ecosites) need to be characterized. The ecosites are based on vegetation, soil, climate, and landscape characteristics which are learned through extensive field programs. Depending on the region, Environment Yukon may need to initiate and conduct these surveys, and/or they may use existing data or data collected by environmental consultants from various exploration or infrastructure projects. The field data is collected into a large database, the Yukon Biophysical Information System (YBIS), which is where all Yukon biophysical data is stored by the Government of the Yukon (Environment Yukon 2016). The ELC data is analyzed and reviewed, and finally drafted into an ELC Subzone Field Guide.

In the 2010s the ELC coordinator began developing the standardized ecosystem classification and identification system and the first field guides. In 2016, the first version of the Yukon Ecological and Landscape Classification and Mapping Guidelines was released (Environment Yukon 2016). This document provided initial guidelines and standards to assist with ELC mapping while the ecosystem guidebooks for various Yukon regions were still being developed. In 2017, Environment Yukon released the Field Manual for Describing Yukon Ecosystems and the associated field forms (Yukon Environment 2017). This field manual and datasheets were important steps to standardizing ELC data collection in the Yukon. In 2017, the first field guide was released followed by two others over the next few years (Table 1).

Included in the Subzone Field Guide ecosite descriptions, are descriptions of the wetlands found in the particular subzone. These wetland descriptions follow the basic groupings of wetlands that are found in the CWCS and other provincial wetland classification systems: bog, fen, swamp, marsh and shallow open water. The field guides provide a description of each wetland and its characteristics such as vegetation community, soil and moisture regimes, and location on the landscape. The Yukon Government is also currently developing an identification guide, *Wetlands of the Yukon*, which will be similar to the BC identification guide, *Wetlands of British Columbia*. The subzone field guides, and the wetland identification guide, are an important first step towards creating a Yukon Wetland Classification System. The identification of wetland ecosystems will help build the knowledgebase, methods and language required to classify wetlands in the Yukon.

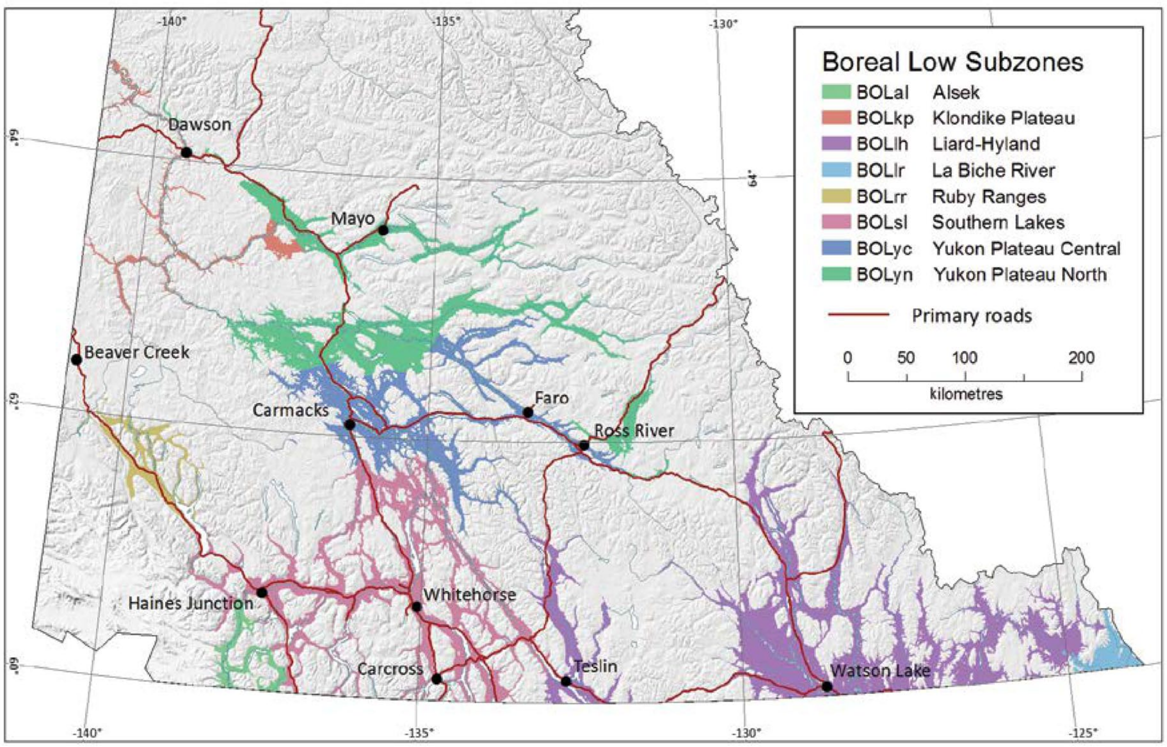

Figure 4. Map of the preliminary subzone of the Boreal Low Zone (Environment Yukon 2017).

Table 1. Published Yukon ELC field guides.

Guide	BEC Zone	BEC Subzone	Release Date	Number of Described Wetlands
Southern Lakes Boreal Low Subzone (BOLsl)	Boreal Low	Southern Lakes	2017	11
Klondike Plateau Boreal Low Subzone (BOLkp)	Boreal Low	Klondike Plateau	2019	28

Guide	BEC Zone	BEC Subzone	Release Date	Number of Described Wetlands
Ecosystems of the Yukon Arctic Region	Arctic Tundra Dwarf Shrub, Arctic Tundra Low Shrub	N/A	2022	10

There are several key next steps for the Yukon ELC program. As outlined in the Strategic Plan, Environment Yukon will continue to develop the remaining subzone guides so the there is full ELC coverage of the Yukon (ELCSC 2013). A major component of the ongoing development of the Yukon ELC program is to create these field guides. To develop the subzone field guides, the ecosystem units (or ecosites) need to be characterized. The ecosites are based on vegetation, soil, climate, and landscape characteristics which are learned through extensive field programs. Depending on the region, Environment Yukon may need to initiate and conduct these surveys, and/or they may use existing data or data collected by environmental consultants from various exploration or infrastructure projects.

If a Yukon Wetland Classification System is developed and used in parallel to data collection for the ELC program, a vast number of wetlands could be visited, identified and classified during the extensive ELC programs that are likely to occur in the future. By developing a Yukon specific wetland classification system, the potential extensive ELC data collection efforts can also collect practical, detailed and compatible data on Yukon wetlands. This data can help contribute to better understanding and utilizing the benefits of boreal wetlands in the Yukon and help safeguard them against the many threats that they face.

7.2 YUKON WETLAND STEWARDSHIP POLICY

The Yukon Wetland Stewardship Policy (YWSP) was released by the Yukon Government in January 2023. The intent of the policy is to "define a common approach to wetland stewardship in the Yukon (Government of Yukon 2022)." The Yukon Government would like to approach wetland stewardship through a regulatory framework that includes municipal and federal governments, industry representatives, non-governmental organizations, and Indigenous governments and groups. The policy goal is to ensure the benefits of the Yukon's wetlands are sustained, through the following actions:

1. "improving our knowledge and understanding of Yukon's wetlands;
2. managing the impacts of human activities on wetlands through implementation of a mitigation hierarchy; and,
3. identifying and protecting Wetlands of Special Importance through legal designation and applying specific mitigation measures to achieve no loss or reduction of benefits within these wetlands (Government of Yukon 2022)."

Five key action areas and sixteen implementation actions have been identified in the YWSP (Government of Yukon 2022):

- "Wetland Benefits:

    - Develop guidance for the evaluation of wetland benefits in the Yukon.
- Building Knowledge:
    - Update and finalize a Yukon wetland classification system.
    - Produce an accessible field guide to the wetlands of the Yukon.
    - Develop specific wetland mapping standards for regional, local, and project specific mapping applications.
    - Create a broad scale territory-wide wetland inventory, within 5 years of policy approval.
    - Support local scale wetland mapping, where needed.
    - Promote research on northern wetlands.
    - Promote public awareness of wetlands.
- Managing Human Impacts:
    - Develop guidance for the application and use of the mitigation hierarchy.
    - Update or develop proponent guidance to be used when submitting wetland impact mitigation information.
    - Update or develop Standard Operating Procedures or Preferred Management.
    - Practices for different activities impacting wetlands.
    - Update or develop general wetland reclamation guidelines, and, where required, sector specific guidelines.
    - Develop guidance for offsetting wetland impacts.
- Protection of Wetlands of Special Importance:
    - Develop specific and measurable guidance for the interpretation and application of nomination criteria.
    - Establish a process for, and regulations to support, legal designation of Wetlands of Special Importance.
    - Create a publicly accessible catalogue of Wetlands of Special Importance.
- Implementation and Evaluation:"
    - Develop an evaluation process to track the progress on the implementation actions including yearly implementation tracking, implementation review, and policy review. All levels of reporting and results will be made public.

The need for a Yukon wetland classification system is clearly identified in the YWSP as Implementation Action #2 (Government of Yukon 2022). The YWSP connects the need for improved understanding of Yukon wetlands with the ability to make informed stewardship decisions for Yukon wetlands. While there is little detail given at this stage, the YWSP states that the Yukon wetland classification system will be based on the Yukon ELC program and the CWCS.

Beyond the obvious statement of support for a Yukon wetland classification system, other actions and ideas outlined in the YWSP will be beneficial in determining the direction and content of the Yukon wetland classification system. To help understand, identify and document the range of wetland benefits, the Yukon wetland classification system could include the evaluation guidelines for wetland benefits. To help manage human impacts in wetlands, the Yukon wetland classification system could include data collection that could help with restoration efforts and determining what activities are impacting the wetlands. To aid in determining wetlands of special importance, the Yukon wetland classification system could include the guidelines for identifying wetlands of special importance. The data collection methods, data framework, and language used in the Yukon wetland classification system could consider the need to share knowledge with restoration experts, the people involved in the impacting activities, the public and other researchers.

7.3 CASE STUDY SUMMARY

The Yukon does not have a Yukon-specific wetland classification system. Small-scale project or region-specific classification systems have been developed, or the CWCS has been used, to classify Yukon wetlands. A Yukon wetland classification system would be beneficial to help better understand the diversity of, and benefits provided by Yukon wetlands. It could also be developed to help other wetland-based initiatives such as the guidelines for wetland mitigation, wetland restoration, and the protection of wetlands of special importance.

The two current initiatives in the Yukon that are most directly related to wetlands, Yukon ELC and the YWSP, are both directly supporting the development of wetland identification and classification and the need for a Yukon wetland classification system. Both also provide insight into ways the Yukon wetland classification system could be structured so that it is functional and has an impact and benefits the largest number of users possible. Thes factors should be considered when making decisions on the design, application, and distribution of the Yukon wetland classification system.

8 RECOMMENDATIONS

Wetland classification systems are an important tool to understand and protect boreal wetlands by providing a structured approach to understanding their diversity, functions, benefits and threats. These systems can inform decision making, guide conservation efforts, and facilitate the sustainable use of resources in and around these ecologically important ecosystems. Updating an existing system or developing a new wetland classification system, as is being done in the Yukon, provides an opportunity to incorporate the structure, data fields, language, tools, and application and distribution methods that are most likely to be used widely and be the most useful to all stakeholders. The development of a wetland classification system should include incorporating appropriate consultation, developing a comparable and useful system structure, developing useful application and distribution methods, and through adapting and updating the systems when necessary.

Developing a wetland classification system involves including input from various user groups and ensuring that a wide range of perspectives are considered. Engaging stakeholders such as scientists, land use planners, indigenous communities, conservation organizations, and industry representatives are crucial to understand how each of these user groups might need to use the classification system. These stakeholders offer diverse expertise and insights into wetland functions, diversity, and management needs. By involving these groups, the classification system can be designed to address the specific requirements and concerns of each stakeholder, leading to a more inclusive and effective structure and framework. The continued consultation of these groups will help anticipate future needs and allow the wetland classification system to be adaptable to changing environmental, social, and economic contexts over time.

The wetland classification system's structure should be hierarchical, replicating the structure of neighbouring classification systems. In Canada, the development of a new wetland classification system should replicate the structure of the Canadian Wetland Classification System to aid in the transfer of data between jurisdictions and the inclusion of existing data. This hierarchical approach involves categorizing wetlands into increasingly specific groups based on their ecological attributes, hydrological characteristics, and other key factors. The system should establish a common language, methods, and data framework, enabling consistent and standardized classification across different regions and disciplines. This promotes effective communication among stakeholders and helps ensure that data are comparable and applicable across various contexts and regions.

For the wetland classification system to be practical and effective, it should be user-friendly and easily accessible. The classification system's guidelines and criteria should be clear and comprehensible to both experts and non-experts. This accessibility encourages widespread use by land use planners, policy makers, researchers, and other stakeholders. Creating training and education opportunities around the system is critical for capacity building and ensuring that users understand how to correctly apply the classification tools and methods. Workshops and educational materials can empower people to use the system accurately and confidently, increasing its impact and useability.

An adaptive management approach should be incorporated in the development of a wetland classification system. This approach recognizes that environmental, social and economic systems evolve and change, and the wetland classification system should be flexible enough to accommodate these changes. Regular updates based on new scientific knowledge, emerging priorities, and evolving land use practices should be incorporated. Maintaining relevance to user needs and interests is important for the encouragement of continued use across all sectors and user groups. Regular engagement and consultation with stakeholders will help ensure that the wetland classification system remains responsive and valuable over time.

A well-developed wetland classification system involves consultation with diverse stakeholders, anticipating future needs, adopting a structure similar to those already existing in the region, establishing a common language and data framework. It should also be user-friendly and accessible, include training and education opportunities, and include an adaptive management approach to keep the system updated in alignment with user interests. By adhering to these recommendations, a wetland classification system can effectively collect data on wetland threats and benefits, inform decision making, enhance wetland protection efforts, and contribute to the sustainable management of wetlands in the boreal forest and beyond.

9 CONCLUSION

Boreal wetlands play a critical role in maintaining the health and balance of many habitats and support many species. These wetlands are found across the world and cover a significant portion of the Earth's surface. They are important in the regulation hydrological systems, offer habitat to a large diversity of terrestrial and aquatic species, sustain biodiversity, and serve as important carbon sinks. Despite their importance, these wetlands are currently under threat due to a range of human activities and environmental changes that disrupt their functions and their effects on the surrounding boreal landscape.

To address these challenges, the development and implementation of wetland classification systems are a potential tool for understanding the complexities of wetland ecosystems. The ongoing initiative in the Yukon, Canada illustrates the potential benefits of developing a wetland classification system that builds on input from various stakeholders, incorporates the future needs of wetland data users, and can be widely used. By adopting a holistic approach that spans ecological, social, and economic systems and processes, wetland classification systems can help understand the characteristics, functions, benefits and threats of boreal wetlands.

Wetland classification systems can be an important tool in understanding the various threats that face boreal wetlands, including habitat loss, degradation, and climate change impacts. These systems provide a unified language and framework for data collection, management, and analysis, allowing researchers, land-use managers, and policymakers to collaborate effectively across disciplines. The potential to conduct meta-analysis and track dynamic changes, these classification systems can potential be important in understanding and addressing complex and evolving threats such as climate change. By developing and using wetland classification systems, we can work towards understanding and protecting boreal wetlands and the critical contributions they make to our ecosystems and beyond.

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