Wetland Classification and Habitats at Risk in British Columbia

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ABSTRACT

The British Columbia Ministry of Forests is developing a practical classification system for British Columbia's wetland and riparian ecosystems. The project has identified a diversity of wetland and riparian ecosystem types, in terms of environmental profiles, regional distribution, and habitat values. Urbanization, agricultural development, hydrological modification, livestock grazing, intensive forestry, and introduction of invasive species pose the gravest threats to wetland and riparian ecosystems by outright destruction, habitat simplification, or isolation from important adjacent habitats. However, some wetland types are more sensitive to these disturbances or provide greater habitat values than others. The classification recognizes this variability in ecosystem function and can be used to identify and quantify ecosystem types of greatest concern. Given the importance of wetland and riparian ecosystems to overall ecosystem integrity, a wetland management policy that relies on the best available scientific information to protect these habitats is crucial. This classification project provides one such body of scientific knowledge that could form the foundation of a site- or region-specific policy for wetland and riparian conservation and management.

Key words: classification, ecology, hydrogeomorphic, riparian, wetlands.

Wetlands and riparian areas provide wildlife, fisheries, biodiversity, water quality, and aesthetic values that are disproportionately large compared with their limited extent in the landscape (Forman and Godron 1981, Naiman and Decamps 1990, Pinay et al. 1990, Gregory et al. 1991, Malanson 1993, Mitsch and Gosselink 1993). Recognition of the special nature of these habitats by researchers and managers of natural resources has led to conservation legislation and regulations in many jurisdictions. In British Columbia, the Forest Practices Code provides special management protection of riparian and wetland ecosystems. Guidelines for riparian management in the *Riparian Management Area Guidebook* (RMAG) (B.C. Ministry of Forests and BC Environment 1995) use an administratively and operationally simple classification system. However, the RMAG does little to address ecological differences between specific wetland and riparian types. Recognition of these differences is required to achieve "best management practice" of wetland and riparian areas or to make informed interpretations for other tasks such as risk ranking or wildlife habitat evaluation.

An ecologically based classification system is one of the most important tools for understanding ecosystems and applying ecosystem management principles. Classifications allow for ordering, comparison, synthesis, mapping, and inventory of information and give resource workers a common language to communicate results (Lotspeich and Platts 1982). Biogeoclimatic ecosystem classification (BEC) of forested sites is well developed in British Columbia (Pojar et al. 1987) and is used extensively in many aspects of natural resource management. To date, this classification has been applied primarily to forested ecosystems of the province. To fill the information gap surrounding wetlands and non-forested riparian ecosystems, British Columbia's Ministries of Forests, and Environment, Lands and Parks, through Forest Renewal BC funding, began the Wetland and Riparian Ecosystem Classification (WREC) project.

British Columbia has a high diversity of wetland ecosystems and landscapes. The WREC project has described >100 distinct wetland and related ecosystems, each with unique ecological functions and distributions. Some of these wetland and "riparian" ecosystems may be at risk in British Columbia. The WREC project will provide tools for recognizing, evaluating, and mitigating risk to these ecosystems. The following discussion outlines the range of risks to wetlands, the major attributes of the classification, some observed risks to wetlands by wetland regions, and the ways that the classification could be applied to risk assessment and management.

WETLANDS AS HABITATS AT RISK

Wetland and flood ecosystems have high wildlife values particularly in arid climates where the distinction from upland ecosystems is most pronounced. These habitats are vital for wetland-dependent species, such as amphibians and water birds, and important for upland species that use wetlands and their associated riparian areas for food, water, and cover. Some features that may influence a wetland's wildlife habitat value are water, structural diversity and cover, abundant forage, high prey densities, and unique habitat. Land management activities that affect these attributes will impact the use of the site by wildlife.

What Is Risk?

The Concise Oxford Dictionary (1995) defines risk as a chance or possibility of danger, loss, injury, or other adverse consequences. Historically, wetlands have been exposed to high levels of risk due to poor public perception and valuation. Since early European settlement, the perception of wetlands as wastelands, available for conversion to more productive uses, has caused millions of hectares of wetlands across Canada to be drained or filled (Lands Directorate 1986). For this paper, we address risk as it applies to wetland and riparian habitats. We define risk to habitat as a function of sensitivity to disturbance, potential for exploitation, and loss of core habitat values. The 2 distinct types of habitat risk are risk of change or destruction (e.g, conversion to agricultural land) and risk of degradation or loss of value (e.g., reduce wildlife habitat capability). Habitat degradation can change ecosystem composition and structure fundamental to wildlife use without complete ecosystem destruction.

Risks to Wetlands

Our discussion will focus on habitat destruction and degradation, habitat fragmentation, and management policy as major contributors of risk.

Habitat Destruction and Degradation

In Canada, wetland area has decreased by 15% since European settlement (Lovett Doust and Lovett Doust 1995). Likewise, human activities such as urban development and resource extraction have resulted in wetland loss and degradation throughout British Columbia.

In general, scientists agree that habitat destruction is currently the primary threat to species diversity worldwide (Ehrlich 1988, Wilson 1992 cited in Wilcove et al. 1998). In British Columbia, wetlands are at risk from hydroelectric initiatives, urban development, agriculture, forestry, ranching, transportation networks, mining, and outdoor recreation.

Hydroelectric development has caused losses of wetland and riparian ecosystems throughout the province. Impoundment of reservoirs as well as downstream impacts can present a serious risk to wetland and riparian ecosystems and the species they support. The most significant impoundment impact is the flooding of valley-bottom ecosystems after dam construction. Large-scale projects such as those on the Columbia and Peace rivers in the 1960s resulted in flooding of huge tracts of valley-bottom ecosystems including important wetland and riparian habitats (Sandborn and Penfold 1996). Although impoundment impacts can be substantial, downstream ecosystems are also at risk (Poff et al. 1997). Fluctuating water levels causing changes in flood regimes can destroy communities such as cottonwood *(Populus balsamifera)* floodplain sites that provide important wildlife habitat (Rood et al. 1995). The search for energy alternatives has introduced new threats to wetland ecosystems including the harnessing of tidal power and the extraction of peat to generate electrical energy (National Wetlands Working Group 1997).

Urban developments can pose a wide range of threats to wetlands. The most obvious threat comes from draining wetlands to accommodate commercial, housing development, and infrastructure (National Wetlands Working Group 1997). In British Columbia, this is especially common in the Fraser Valley and south Okanagan where population pressures are high. Sandborn and Penfold (1996) estimate that 30% of all land converted for urban development between 1967 and 1982 was natural wetlands. Additional impacts associated with urban development such as nutrient loading, introduction of toxic materials, and interruption of local hydrologic patterns can damage or destroy remaining wetlands (Bunnell et al. 1995). These problems are also associated with mining and transportation activities. Two impacts of transportation networks, in-filling and damming, are evident along many of British Columbia's highways.

Agriculture has been a primary cause of wetland and riparian habitat destruction in Canada. The Lands Directorate (1986) claims that 80% of the Fraser River Delta has been lost, largely to agriculture. One such example is the draining and filling of the 11,700 ha Sumas Lake wetland in the 1920s (Sandborn and Penfold 1995). Clearing, however, is not the only threat. Wetlands beside agricultural fields can also experience nutrient loading, reduced water flows, and pesticide accumulation. Wetland conversion of fens, meadows, and swamps to hay fields significantly threatens wetland and riparian habitats in the southern and central Interior. Willow swamps, for example, are often converted to reed canarygrass (*Phalaris arundinacea*) to provide winter forage for livestock. Livestock grazing in riparian areas can limit or exclude use by wildlife thereby decreasing their available habitat. Bunnell et al. (1995) cite Green and Kauffman's (1989) observations of effects of cattle grazing in riparian areas:

- direct vegetation damage caused by browsing or trampling;
- changes in plant communities through selective browsing;

- soil compaction and disturbance that increase erosion and decrease water availability to plants;
- changes in fluvial process, which lower water tables or decrease available sites for invasion of woody species; and
- changes to aquatic ecosystems through sedimentation and fluvial process, as well as changes to water quality due to fecal inputs.

Harvesting of swamp forest and alteration of existing wetlands through road building has reduced wetlands in some areas. Marginally productive swamp forest are commonly drained to improve tree growth in the boreal forest outside British Columbia and may become more important here as timber reserves diminish.

Although outdoor recreation is often associated with habitat protection, certain activities and development practices can destroy wetland and riparian habitats. Destructive uses of wetlands can include developing boating facilities, creating bathing beaches, and using off-road vehicles. In the United States, recreation activities are implicated in the demise of 27% of all endangered species—13% of all endangered species are threatened by off-road vehicles (Wilcove et al. 1998).

Invasive species may also threaten some wetland ecosystems. Shallow open water and marsh communities in southern British Columbia, for example, are threatened by nonnative species such as purple loosestrife (*Lythrum salicaria*) and Eurasian water-milfoil (*Myriophyllum spicatum*). Degraded habitats can become susceptible to invasions of nonnative species, which can displace critical species upon which wildlife depend, thereby reducing habitat value.

Climate change is anticipated to directly impact the range, composition, and viability of ecosystems and individual species alike. Some climate models predict a 0.9–3.5°C increase in global mean temperature over the next century (Houghton et al. 1995 cited in Wilcove et al. 1998). The resulting rise in temperatures and sea levels may drastically affect habitat viability, composition, and distribution. Rapidly increasing sea levels may destroy critical estuary habitats used by migrating waterfowl and other resident animals.

Habitat Fragmentation

The cumulative effects of resource extraction, urban development, and transportation networks have resulted in a disconnected landscape. Noss (1994) cites Shaffer's (1992) assertions that long-term viability of large carnivores in North America is being compromised by the fragmentation of the original wilderness into small refugia. This phenomenon may be occurring at smaller scales for less mobile wetland animals, as wetlands become isolated from each other by development activities and resource extraction. Semlitsch and Bodie (1998) argue that small wetlands are extremely valuable for maintaining diversity in a number of plant, invertebrate, and vertebrate taxa (e.g., amphibians). The continuing disappearance of small wetlands will cause a dire reduction in the ecological connectivity among remaining species populations.

Policy Initiatives

Despite improvements in recent years, wetland and riparian ecosystems continue to be under-protected in Canada. In fact, many policies have actually encouraged wetland conversion. For example, in Ontario, until 1988, wetlands were taxed twice as heavily when left in a natural state than if they were drained and planted in crops (Lovett Doust and Lovett Doust 1995). This example illustrates the need for additional wetland policies that emphasize their ecological value and mitigate the threats discussed here. Often, however, there is an equally strong need to better understand existing policies.

In 1986, the Canadian Fisheries Protection Act imposed a "no net loss of fish spawning habitat" policy. This policy requires developers to create an equivalent area of wetland to that destroyed by the project (Lovett Doust and Lovett Doust 1995). The United States has implemented similar wetland mitigation policies. However, the regulations do not specify what kind of wetland. Therefore, complex wetlands are frequently replaced by less complex types that are easier to establish. This policy does little to deter development (Roberts 1993 cited in Mitsch et al. 1998).

Semlitsch and Bodie (1998) have shown that current and proposed legislation in the United States inadequately maintains regional wetland diversity in amphibians. They further suggest that such legislation is inadequate for some taxa of plants, micro-crustaceans, and insects that use small wetlands. To protect the ecological connectivity and source–sink dynamics of species populations, they strongly advocate that wetland legislation focus not just on size but also on local and regional wetland distribution (Semlitsch and Bodie 1998).

WETLAND CLASSIFICATION

The Wetland and Riparian Ecosystem Classification (WREC) Project

The Wetland and Riparian Ecosystem Classification (WREC) is a British Columbia Ministry of Forests initiative to improve ecological understanding of wetland ecosystems and riparian areas. The project has 3 principal objectives:

1. to develop a wetland classification framework that parallels biogeoclimatic ecological classification (BEC) and recognizes some of the unique hydrological attributes of wetland ecosystems;
2. to classify and describe provincial site associations for wetland and riparian ecosystems and propose management interpretations; and
3. to develop supporting materials such as botanical identification keys and standardized terminology.

The scope of WREC encompasses all true wetlands as well as related ecosystems (Fig. 1). These include non-forested "riparian" or flood ecosystems, vegetated estuarine ecosystems, and transitional non-wetland ecosystems (i.e., the shrub–carrs and wet meadows described by Runka and Lewis [1981]) that occur with wetlands but do not meet the criteria for wetland designation. This program will produce a complete description of the classification framework (MacKenzie and Banner in prep.), description of provincial wetland site associations, a hydrophyte species list (MacKenzie 1998), and standardized terminology and methods for wetland description.

WREC Field Sampling and Observations on Wetlands at Risk in British Columbia

Extensive wetland sampling following standard field methods (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1998) has been ongoing since 1995 as part of the WREC project. Sampling was primarily on Crown lands of the Interior and North Coast. This data, combined with existing wetland and riparian plots from BEC sampling in the 1970s and 80s, various academic theses, and terrestrial ecosystem mapping projects, sum to approximately 3,000 wetland and riparian ecosystem plots. From this data, WREC has identified approximately 100 distinct wetland, flood, and estuarine site associations. Each of these community types has distinct ecological functions, habitat values, and sensitivities.

Our sampling focused on areas with (relatively) high wetland densities that remain comparatively undisturbed. At the landscape level, wetlands are generally scarce and the number of high density areas is limited.

Our observations suggest that the most prevalent disturbances to wetlands on forested Crown lands are from poor road building and culvert placement. Impoundment of small seeps by roads transforms ecosystems to wetter types, converting swamps to shallow water or marsh habitats. In addition to road building, harvesting in and around wetlands can have obvious impacts. For example, we have noticed small

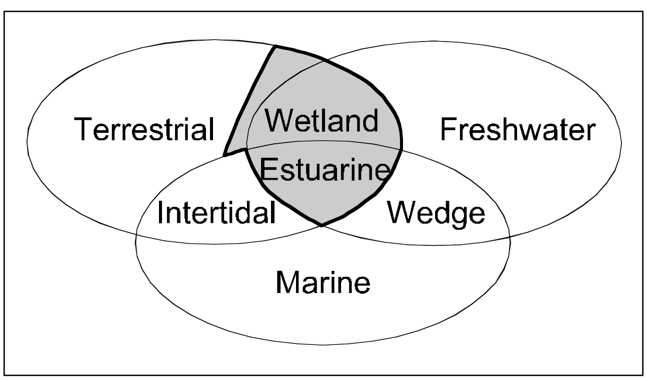

Figure 1. Ecosystem realms addressed by the Wetland and Riaprian Ecosystem Classification (WREC).

wetlands in clearcuts have dried up after their drainage patterns were altered by vegetation removal and topography alteration. However, whether this is entirely due to harvesting is unclear. Forest harvesting is now restricted around larger wetlands, but small wetlands, which are more likely to experience negative impacts from riparian harvesting, remain unprotected (B.C. Ministry of Forests and B.C. Environment 1995). Impacts to wetlands from riparian harvesting are the topic of many unanswered research questions.

The most striking examples of wetland and riparian degradation we encountered during field sampling were on private land. Wetland conversion to agriculture, draining and ditching projects, and overgrazing were all observed. The extent of wetland loss from these activities is unknown. The distribution of these activities, however, suggests they have contributed to the decline in overall wetland area as well as the relative rarity of communities such as Bebb's willow (*Salix bebbiana*)–bluejoint (*Calamagrostis canadensis*) in the Chilcotin and southern Interior.

We recognize several informal wetland regions distinguished by patterns of occurrence in the landscape and the types of wetland and related ecosystems found there. We describe each of these regions (the biogeoclimatic zones they encompass in parentheses) and some risks to the wetlands of each.

Hyperoceanic Lowlands (CWHvh, vm}

This is a 30-km wide band of low rolling terrain along the North Coast. This wetland region experiences a hypermaritime climate characterized by extreme rainfall and moderate annual temperatures. The geology is primarily granite pluton, poor in minerals with little or no glacial till. We estimate that wetlands cover almost one-half of the land base in this area. Wetland types are primarily blanket bogs and bog woodlands of shore pine (*Pinus contorta* var. *contorta*) and yellow-cedar (*Chamaecyparis nootkatensis*) on gently to strongly sloping terrain. These community types and this wetland-dominated landscape are unique in British Columbia and globally. Because of poor growing conditions and difficult access, there has been little pressure to harvest the forested wetlands of the outer coast. Fjord estuaries with extremely high wildlife values are also found in this region. While upland bogs are not generally at risk in this region, North Coast estuaries have experienced relatively high levels of disturbance from log handling activities. More critically, rapid rises in sea levels generated by global warming could destroy a major portion of these estuaries.

Temperate South Coast (CDF, dry CWH)

The southeast corner of Vancouver Island, the Gulf Islands, and part of the adjacent mainland have a Mediterranean climate. Wetlands are somewhat common. The northern range limit of many plant species is within this region and this, combined with the mild climate, produces ecosystems not found elsewhere in British Columbia. Estuarine ecosystems are distinct from those on the North Coast. Urban and agricultural development pressures are extreme throughout most of this region, and large holdings of private land and strong development pressure have placed many wetlands at risk. Two striking examples are Burns Bog in Burnaby and Rithet's Bog north of Victoria.

Arid Interior (BG, PP, IDF, MS)

The dry Interior of the province is a mix of grasslands and dry forest types. The climate is hot and dry with little growing season precipitation or snowfall. Wetlands are uncommon and are usually marshes or swamps; peatlands occur only at higher elevations (IDF and MS). Saline meadows and some marsh types such as woolly sedge (*Carex lanuginosa*) and spangle-top (*Scolochloa festucacea*) are most common (possibly unique) to these dry regions. Because water sources are fewer and wetlands are markedly different from adjacent upland habitats in structure and species composition, these ecosystems provide critical wildlife habitat. Larger wetlands in this region such as the Columbia marshes have extremely high levels of wildlife use. In addition, certain wetland-dependent wildlife species at risk, such as the Great Basin spadefoot (*Spea intermontana*) and tiger salamander (*Ambystoma tigrinum*), occur in this region. Urban development and agriculture present high threats to wetlands in this region.

Sub-boreal/Boreal Interior (BWBSdk, SBPS, SBS)

Wetlands are relatively common in the sub-boreal and boreal regions. Short cool growing seasons promote formation of peatland in most wet depressions. Consequently, subdued terrain may be covered by large expanses of peatland. Marshes and swamps are commonly associated with lake and river systems. Risks to wetlands are generally few except in areas of agricultural development such as valley bottoms like the Bulkley Valley, or the Peace River Valley around Fort St. John. Unfortunately, these areas of higher risk often correspond with prime moose winter habitat and water bird nesting habitat.

Interior Rainforest (ICH, wet SBS)

The Interior wet-belt has wetland ecosystems that blend interior and coastal qualities. Though the cool, wet climatic conditions are conducive to wetland formation, the primarily mountainous terrain results in smaller numbers than expected. Large peatlands or swamps complexes are found in a few drainages such as the Seymour, Adams, Torpy, and Hominka rivers. Unfortunately, in most other drainages, the wetlands are few and share valley bottoms with road networks and agricultural development. Although we cannot suggest specific wetland communities at risk in this region, we can suggest that their natural scarcity combined with increasing development pressures may place most of these habitats and their dependents at risk.

Taiga Plains (BWBSmw)

The northeast corner of the province is subarctic and underlain by poorly drained, glaciolacustrine deposits. Consequently, this region has some of the highest concentrations of wetlands (largely peatland) in the province. Bogs predominate though fens and swamps occur along the sluggish streams that drain the region. Oil and gas exploration and development impact on wetlands but affect a relatively small percentage of the total wetland area. Forest harvesting of the most productive habitats, riparian white spruce (*Picea glauca*) and balsam poplar (*Populus balsamifera*) alluvial forest sites, may be of greatest concern as these provide very important wildlife habitat.

Interior Mountains (ESSF)

The mountain region has relatively few wetlands because of steep terrain. However, wetlands do occur in depressions and occasionally at slope breaks where springs or snow seepage keeps sites permanently saturated. Communities in these cold continental climates are often unique and do not occur at lower elevations. Risks are not high in this region though increased forestry activities at higher elevations may impact some areas.

Windward Coast Mountains (MH)

Like the hyperoceanic lowlands, the windward Coast Mountains are mineral-poor granite and experience extreme precipitation. These higher elevation wetlands have similar species as their lower elevation counter parts but form distinct assemblages. These sites are remote and exhibit little or no resource development potential so risks to wetlands are rare.

Northern Plateaus (SWB)

Some of the northern, subalpine plateaus of the northwest, such as the Kawdy Plateau, have a high concentration of wetlands. These sites provide important waterfowl nesting habitat for species such as lesser scaup (*Aythya affinis*) and northern pintail (*Anas acuta*) (Hawkings and Majiski 1991). At this time, mostly because of their remote location, risks to these wetlands are few.

What Is a Wetland?

Clearly defining the ecosystems is one of the tasks of the wetland classification program. The program has adopted the wetland definition used in the *Riparian Management Area Guidebook* (B.C. Ministry of Forests and BC Environment 1995). The guidebook recognizes that wetlands occur where soils are water-saturated for a sufficient length of time such that excess water and resulting low soil-oxygen levels are principal determinants of vegetation and soil development. Specifically, "wetlands" must have both:

- plant communities characterized by species that normally grow in soils water-saturated for a major portion of the growing season ("hydrophytes"); and
- soils with surface peat ("O") horizons or gleyed mineral horizons (Bg or Cg) within 30 cm of the soil surface.

The term "riparian" is used in WREC as a general description of adjacency and not as a specific type of ecosystem. The term only means that the ecosystem, regardless of it composition, occurs next to a water body or wetland. Therefore, any type of ecosystem may be "riparian." In WREC, ecosystems that are ecologically distinct because of flooding, erosion/sedimentation, or subirrigation from an adjacent water body are called "flood ecosystems."

"Flood ecosystems" are sites flooded for short duration during the growing season where soils are freely drained and anoxic conditions (if they occur) are quickly relieved after subsidence of floodwaters. Plant species tolerant of brief flooding events but not prolonged soil saturation are typical. Flood ecosystems occur specifically where:

- water bodies periodically flood their banks depositing or eroding fluvial or lacustrine materials; and
- water tables are within the rooting zone during part of the growing season, but not for sufficient duration to cause gleying within 30 cm of the soil surface.

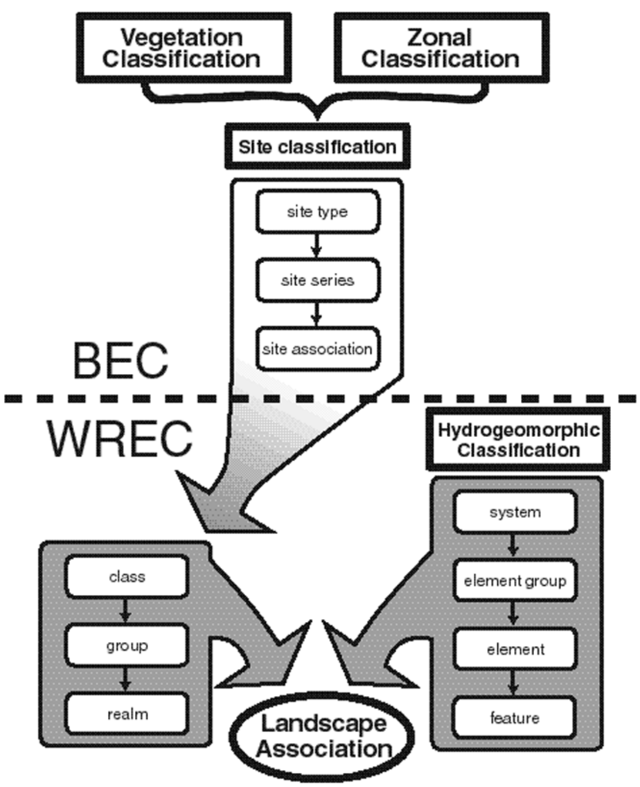

Figure 2. The Wetland and Riparian Ecosystem Classification (WREC) framework.

Classification Approach

The approach of WREC proposes a framework that places wetland ecosystems and riparian areas into a system that reflects the importance of landscape context, hydrological processes, and biological structure and composition. To this end, WREC incorporates 3 components arranged in a hierarchical structure (Fig. 2):

- an ecosystem component that describes site potential for biological communities;
- a hydrogeomorphic component that describes broad hydrological processes and concurrent geomorphic forms; and
- an integration component that unites the ecosystem and hydrogeomorphic components into associations at the landscape scale.

The basis of WREC is the biogeoclimatic ecosystem classification (BEC) of Pojar et al. (1987). The working framework uses BEC's zonal and site classification as its template. However, wetland and riparian ecosystems differ from the upland ecosystems described by BEC in 3 significant ways:

- hydrology and hydrodynamics are major site factors;
- sites are intimately connected to "upstream" landscape processes through hydrology; and
- sites are rarely homogenous except at fine spatial scales (<1:5,000) due to dynamic hydrological processes or internal environmental mosaics.

To accommodate these differences, several modifications have been made to BEC for its application to wetland and riparian ecosystems. Units broader than the site association are added to bring the site concept in line with the widely used Wetland Class unit of the National Wetlands Working Group (NWWG 1997). Hydrological criteria are also proposed as basic defining environmental site factors and as a component of a broader landscape unit classification (MacKenzie and Banner in prep.).

Ecosystem Classification

In WREC, specific ecosystems are successively grouped into more broadly affiliated units based on biologically relevant site characteristics (e.g., similar site associations placed in a single class). Functional units are defined by site potential and characterized by certain guilds of biota. Units emphasize similarities in basic underlying processes and provide a means of relating ecosystems at multiple scales. Each of these levels can have different applications (Table 1). For example, the site association defines site potential using climax communities. These units are specific and require a certain level of botanical knowledge to be applied successfully. For some applications such as mapping at a broad scale, evaluating initial habitat, establishing comparative research trials,

Table 1. Interpretive characteristics for each ecosystem of the Wetland and Riparian Ecosystem Classification (WREC).

Ecosystem Unit	Possible uses of the level	Example of the Unit	Characteristics of the example
Realm	Identification of appropriate classification structure to use, important environmental factors and broad biotic groups.	Terrestrial	Site is likely dominated by upland vascular plants typical in the climatic region and is on relatively well-drained soils.
Group	Identification of ecosystems with a common dominant ecological factor that will influence management and research. Blocking variable in research design and management interpretations	Flood	Site is riparian and is at least periodically flooded. Community dominated by non-wetland plants tolerant of flood events. Possible high wildlife capability and productivity sites.
Class	Broad management interpretations based on known characteristics. Prioritizing sites for habitat protection. Extension and communication of results to untrained users.	Low Bench	Shrub community with a sparse understory occurring directly adjacent to flowing water. The site is not a wetland but experiences long periods of flooding with pronounced erosion and deposition. Commercial tree growth not possible. Prolonged spring flood render sites unsuitable for ground-nesters and burrowers.
Site Association	Identification of rare or sensitive ecosystems. Specific wildlife or fisheries habitat capability interpretation. Specific management interpretations based on known controlling site factors. Distribution.	Drummond's Willow – Bluejoint	Tall shrub community of Drummond's willow, and erosion resistant graminoids and annuals. Site likely on sandy/silty levees beside slow moving, interior streams.

and communicating results to users with little botanical knowledge, broader ecosystem groupings may be preferred.

The classification's higher ecosystem levels (class, group, and realm) provide a consistent means of grouping site associations with similar underlying features, emphasizing similarities between ecosystems. Table 1 outlines information that can be derived from each level of this ecosystem hierarchy.

In BEC, site series are related to site conditions within a climate area (subzone or variant) using an edatopic grid. The grid illustrates the relationship of the site series to soil moisture and nutrient regime. However, the influence of hydrology in wetland ecosystems is not well represented in this model, making placement of these ecosystems problematic. For this reason, WREC introduces a modified edatopic grid, which includes hydrological variables in the subhydric and hydric moisture regime position of BEC's edatopic grid (Fig. 3). The hydrological variables considered are pH (as an indicator of base cation availability) and "hydrodynamic" index (degree and influence of water movements on the site).

Hydrogeomorphic Classification

The hydrogeomorphic component is a classification of hydrological and geomorphic features, which are fundamental features controlling ecosystem structure and composition in wetland and flood ecosystems. Historically, hydrogeomorphic classification has not been used in British Columbia but is the central concept of wetland identification and management in the United States (Cowardin et al. 1979, Brinson 1993, Bedford 1996). Most of these units rely on knowledge of landscape properties rather than specific hydrological variables and are therefore easily assessed (Bedford 1996). For purposes such as monitoring water quality or fisheries value, the hydrogeomorphic classification may be more appropriate than the ecosystem classification (Brinson 1993).

The WREC outlines a hierarchy then defines hydrological systems (as the broadest unit) and their associated geomorphological forms (Fig. 2). The system describes broad patterns of hydrology, water source, and topography. Wetland and related ecosystems occur within 4 different hydrological systems (Table 2).

The hydrogeomorphic component of WREC puts sites within a larger hydrological context. For example, the Drummond's willow (*Salix drummondiana*)–Bluejoint (*Calamagrostis canadensis*) site association described in Table 1 frequently occurs within the hydrological template described in Table 3. Depending on the hydrogeomorphic unit considered, one to many ecosystems may occur within it. The element level of the hydrogeomorphic classification describes an entire wetland or riparian landscape unit and would typically include several distinct site associations.

Ecosystems that are repeatedly associated within a hydrological template are termed a landscape association in WREC (MacKenzie and Banner in prep.).

Other hydrological features of importance in wetlands such as period of inundation, duration of soil saturation, pH, hydrodynamic index, and salinity are not directly part of the hydrogeomorphic classification but are used to define site associations.

CLASSIFICATION AS A TOOL FOR MANAGING HABITATS AT RISK

Noss (1994) observes a lack of understanding regarding the relationship between human activities and loss of diversity. Over the last 2 decades, scientists have begun to identify the critical role wetlands play for wildlife populations such as ducks and fish. However, the tools to study and understand

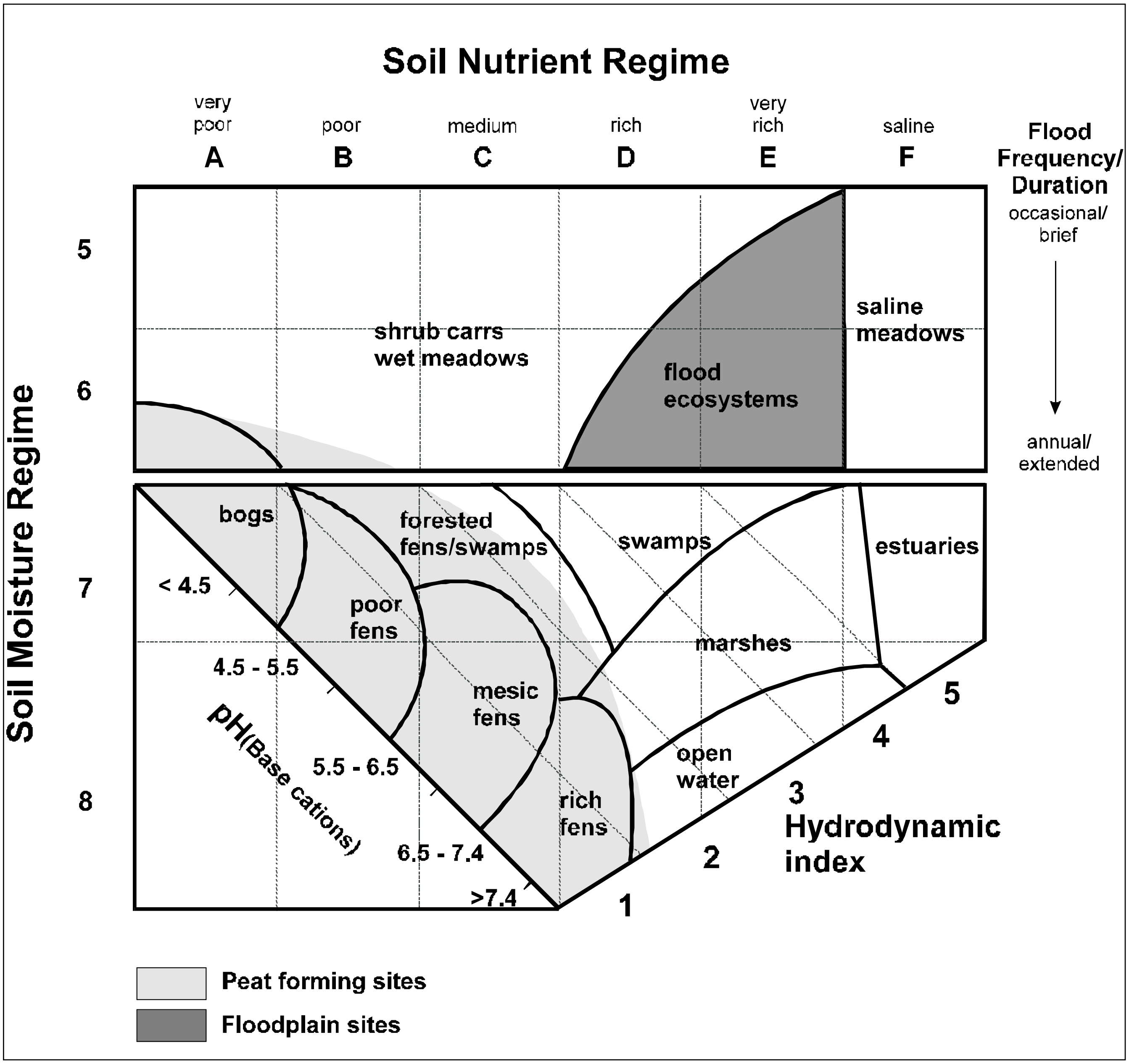

Figure 3. Relationship of wetland classes on a modified edatopic grid.

Table 2. Characteristics of 3 hydrogeomorphic systems of the Wetland and Riparian Ecosystem Classification (WREC) framework.

System	Topographic position	System Hydrology	Currently described Element Groups
Estuary	Confluence of freshwater inflow into marine environment	Subject to diurnal or periodic flooding and brackish water	Enclosed, Constrained, Extruded
Lacustrine	Adjacent to large, deep lakes	Subject to flooding by wave action; fed by circulating lake waters	Anthropogenic, Littoral, Deepwater, Peatland
Fluvial	Adjacent to flowing water course	Subject to annual stream flooding and erosion/ deposition forces; stream-fed	Alluvial, Transport, Headwater
Palustrine	Depressions or receiving sites; small shallow lakes, basins, and seepage slopes	Low energy flooding or groundwater-fed	Closed Basin, Overflow Basin, Linked Basin, Terminal Basin, Overflow Hollow, Linked Hollow, Toe Slope, Delta slope, Blanket Slope

wetlands have been scarce. One helpful tool is a comprehensive classification of wetland and riparian ecosystems. We identify several areas where WREC could be used for managing wetlands as habitats at risk.

- **Identification of natural plant communities.** The site associations of WREC are natural plant communities. Disturbed wetland sites were not used in the classification. The site association can therefore be used as a benchmark for restoration efforts or for assessing and recognizing impacts from land use practices.
- **Reference sites and hydrogeomorphic profiles.** A hydrogeomorphic profile for "fully functioning" environments provides the basic template to which potentially impacted wetlands can be compared (Brinson 1993, Bedford 1996). Brinson and Rheinhardt (1996) have promoted the use of reference wetlands for monitoring and researching potential impacts and mitigation. In addition, monitoring vegetation changes over time and comparing them with known site associations can indicate the success of restoration efforts
- **Identification of habitat value.** Known wildlife preferences for wetland plant species, structure, or hydrological form could be used to rank habitat values of different wetland types.
- **Identification of appropriate management techniques.** An understanding of sensitivities, functions, and values of different wetland types can identify appropriate and inappropriate management strategies. Risk and value of different wetland types could be ranked to help guide planning.

Table 3. Some characteristics and interpretations made for different levels of the hydrogeomorphic classification of the Wetland and Riparian Ecosystem Classification (WREC).

Hydrogeomorphic Unit	Example	Characteristics of example	Possible uses and interpretations
System	Fluvial	Site is associated with a river or stream. Water flow is unidirectional and likely seasonally or periodically variable (flood-pulse)	Special riparian management practices Possible high fisheries and wildlife habitat values.
Element group	Alluvial	Site is of low gradient and is a sediment deposition area. Likely with a well developed floodplain.	Flooding of riparian zone likely. Special development guidelines and wildlife values
Element	Tortuous Meander	Site very low gradient and has pronounced meanders and low width to depth ratio. May have oxbows, back channels, and back levee depressions. Very well developed floodplain.	System stable under normal conditions but sensitive to disturbance. Vegetation control of channel high and erosion potential high.
Feature	Levee	Raised ridge of fluvium usually directly adjacent to slow moving sediment laden stream coarse. Often downstream of higher gradient reaches	Specific environmental conditions for vegetation communities.

- **Inventory.** The classification provides a comprehensive system of recognized site associations and hydrological templates known to occur in the province. An inventory using wetland classification units can provide more accurate information regarding distribution, rarity, and landscape-scale impacts of land management practices
- **Gap analysis and coarse-filter protection for species at risk.** Certain wildlife or plant species of concern are likely associated with specific wetland types. Identification of this relationship could allow selective protection of those wetlands providing the best habitat. This approach has been demonstrated as an effective coarse-filter approach to protecting species at risk (e.g., Panzer and Schwartz 1998).
- **Direct further research.** Ecosystem classification is valuable in ecological research. Experimental design incorporating ecosystem units allows research to address the influence of different ecological attributes and to transfer knowledge from one location to others with similar attributes. Adaptive management approaches also require classification to direct management practice to appropriate site types.

CONCLUSIONS

Classifications, like any sound management tool, must be able to address varying levels of detail, from global and continental scales to regional and local scales. In British Columbia, we have been developing a hierarchical classification framework to create a comprehensive provincial wetland and riparian ecosystem classification. At present, British Columbia's wetland management policies are based on ecologically simple units, largely due to a lack of sound baseline ecological knowledge of these sites. The classification aims to assist researchers, managers, students, and resource workers to understand these ecosystems. Where development and resource extraction threaten to disturb wetlands, the classification can be used to help improve management and planning strategies.

Several major directions now await the Wetland And Riparian Ecosystem Classification program:

1. Completing landscape associations that recognize repeating complexes of site associations in relation to hydrogeomorphic form.
2. Applying WREC to management and wildlife habitat issues.
3. Using WREC with existing forest cover, TRIM database, and TEM mapping (where available) to create a preliminary provincial wetland inventory.

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