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Extension Note

Biodiversity
Management Concepts in Landscape Ecology

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March 2000

Wetland or riparian?
The term "wetland" refers to ecosystems dominated by water-loving plants and having wet or saturated soils. The term "riparian" refers to any land adjacent to water bodies or wetlands. These may be upland sites or periodically flooded ecosystems. The ecology of riparian areas is the subject of Research Branch Extension Note 17.

The Ecology of Wetland Ecosystems

Abstract

This extension note describes the basic ecological features of wetland ecosystems. It is a foundational document that provides important concepts and background information to be applied in future extension notes on wetland management. Major topics and concepts covered in this document are:

- definition of a wetland ecosystem and comparison of characteristics with other related ecosystems,
- recognition of the different applications of the term "wetland ecosystem" at site and landscape scales,
- major environmental factors and their effects on wetland ecosystems,
- classification of wetland ecosystems,
- successional patterns in wetland ecosystems,
- natural disturbance regimes of wetlands,
- role of reserves in protecting wetland ecosystems,
- regional variation in wetland abundance and characteristics, and
- some important management issues for wetland ecosystems in British Columbia.

Introduction

Wetlands are an important element of British Columbia's biological diversity. From the extensive "muskeg" of the outer north coast and boreal northeast to the tiny "pothole marshes" of the dry southern interior, wetland ecosystems perform essential but varied ecological and hydrological functions.

Land managers, planners, and field staff must recognize the functional diversity of wetland ecosystems in order to manage wetlands sensibly and sustainably.

Wetlands cover about 6% of the province; this number varies regionally from more than 50% (some coastal and northern areas) to less than 1% (southern interior). These ecosystems are transitional between upland and open-water aquatic environments. Wetlands provide essential habitats for many wildlife and plant species, and are focal ecosystems for many others.

Wetlands are often concentrated in valley bottoms and lowland areas, where industrial, urban, and agricultural development pressures are highest. This has led to significant wetland alteration and destruction, especially in the lower mainland and the semi-arid interior of the province (Voller 1998).

British Columbia
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Hydrophytes
The water-saturated environment of wetlands supports a unique group of plants called "hydrophytes." These plants are adapted to grow in waterlogged soils. Excessive water and the low rate at which oxygen diffuses under these conditions leads to a complex of critical conditions that require specialized adaptations (Daubenmire 1959). Adaptations, such as leathery leaves (to reduce nutrient requirements and combat "physiological drought") or specialized internal air compartments (to transport oxygen to the roots), are required for wetland plants. ***Obligate hydrophytes*** *(such as great bulrush) are restricted to wetlands and semi-aquatic sites.* ***Facultative hydrophytes*** *(such as Labrador tea and many other members of the Heather family) occur most commonly in wetlands but also appear in some upland sites.*

Wetland soils are subhydric or hydric, having one or more of the following features

1. *Peaty organic horizons greater than 40 cm thick.*
2. *Non-sandy soils with blue-grey gleying within 30 cm of the surface.*
3. *Sandy soils with prominent mottles within 30 cm of the surface or blue-grey matrix.*
4. *Hydrogen sulphide (rotten egg smell) in upper 30 cm.*

Throughout British Columbia, forestry activities have also had direct and indirect impacts on wetlands. Although only a small portion of the operable landbase consists of forested wetlands on which timber is being harvested, many non-forested wetlands are adjacent to harvested areas.

In 1995, a wetland and riparian classification program was initiated by the Research Branch of the Ministry of Forests to investigate these important ecosystems. This program was intended to extend the concepts of Biogeoclimatic Ecosystem Classification (BEC) to wetlands and to provide an alternative classification model that recognized the unique ecological characteristics of these ecosystems (MacKenzie and Banner 2000). At this time, the recently released *Riparian Management Area Guidebook* (RMAG) (B.C. Ministry of Forests 1995) of the Forest Practices Code (FPC) used a simple wetland classification system, based primarily on wetland size, to set widths for the riparian management areas around wetlands. However, this type of classification system, while administratively easy to apply, does not reflect natural variation in the sensitivity or ecological function of different wetland types that occur in British Columbia. A system that more explicitly addresses this variability would enable the development of more site-specific best management practices as well as interpretations for landscape planning, risk ranking, and wildlife habitat evaluation. An ecological classification of the province's wetlands could provide a knowledge base to incorporate ecological principles into wetland management.

This extension note provides basic ecological information as a technical contribution to the evolution of wetland management practices. We define and describe the primary environmental and ecological attributes distinguishing major wetland types, and then outline the dominant wetland management issues in British Columbia to be addressed in future extension notes.

How are Wetlands Defined?

Cattail marshes or peat bogs are common images brought to mind by the term "wetland." For many, this is self-explanatory but for scientific, practical, and (more recently) legal purposes, we need to put some descriptive bounds on the definition of a wetland.

Wetlands are:
Areas where a water table is at, near, or just above the surface and 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. Wetlands will have a relative abundance of obligate hydrophytes in the vegetation community and soils featuring "hydric" characteristics (see sidebars).

From an ecological perspective, either an abundance of hydrophytes or indicators of hydric soil conditions is generally sufficient to indicate a wetland ecosystem. The boundary of the wetland is identified by changes in vegetation structure, loss of hydrophytes, and wetland soil characteristics.

This wetland definition encompasses a wide range of ecosystems, from semi-terrestrial fens, bogs, and swamps to semi-aquatic marshes and shallow open water.

Excluded from the definition are deep water and flowing aquatic ecosystems and transitional ecosystems such as shrub-carrs, riparian low benches, and graminoid "wet" meadows, which have at various times been considered wetland ecosystems. Transitional sites are not saturated for long enough to be considered true wetland ecosystems and generally lack an abundance of hydrophytes. However, these types of ecosystems are frequently associated with wetlands. From an ecological perspective, it often makes sense to include them (and the surrounding riparian forest) with wetland sites and treat them as a larger ecological unit or wetland mosaic in the landscape (Figure 1). At a broad spatial scale, this complex of sites acts as a single ecological unit in terms of wildlife habitat.

The Wetland Environment

Wetlands can form wherever soil water is excessive. Climate, internal soil drainage, and topography all interact to create the hydrological template for wetland formation. Other factors (such as bedrock geology, soil characteristics, and hydrological system) influence specific wetland characteristics (such as plant community composition and productivity).

An interaction of hydrological factors manifests itself in the biotic and abiotic features of a wetland. The ecological features that reflect these hydrological gradients are vegetation composition, species richness, productivity, soil characteristics, organic matter accumulation rates, and nutrient cycling and availability.

Annual soil moisture regime, water table pH, and magnitude of lateral and vertical water table movements (hydrodynamics) are the primary hydrological features distinguishing biological communities. The relationship between wetland classes and these major environmental factors is diagrammatically represented in Figure 2.

Soil moisture regime (SMR): SMR describes the annual "average" water regime (Klinka et al. 1995). A Wet or Very Wet SMR is the prerequisite to wetland formation. Wet sites have a water table within 30 cm of the surface but for a least some of the year have an aerated surface layer. Very Wet sites remain saturated at the surface

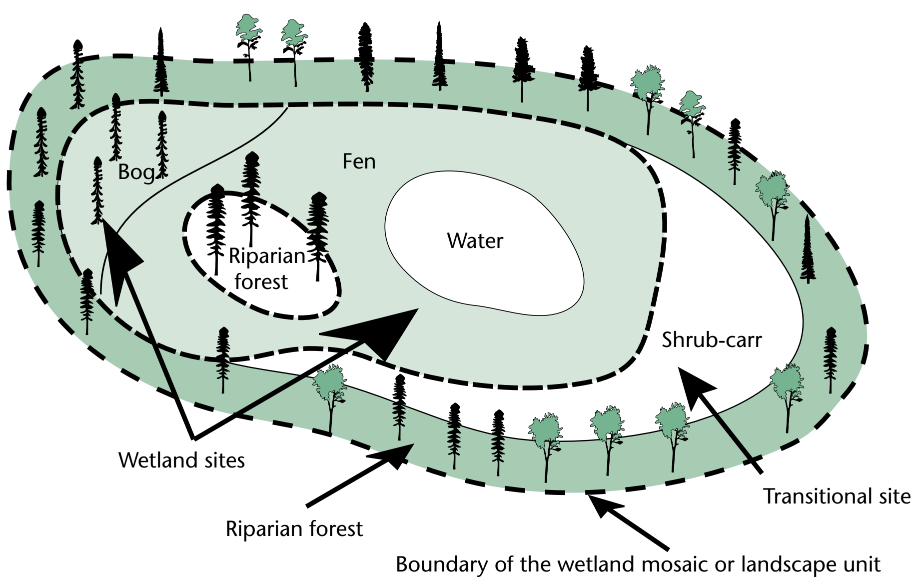


FIGURE 1 *A comparison between the boundary of wetland ecosystem sites and a wetland mosaic*

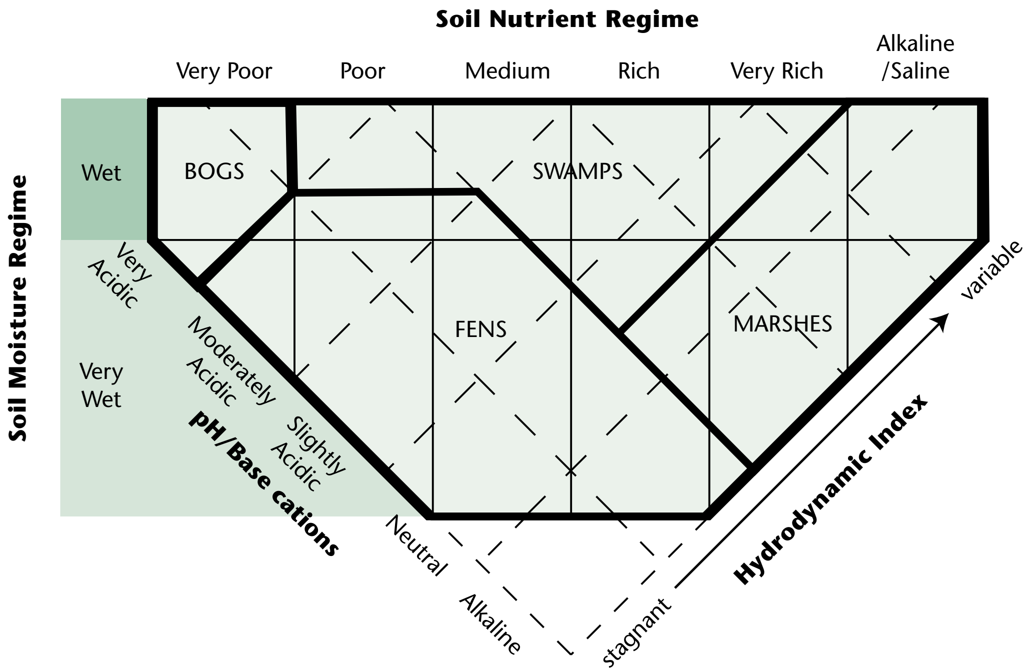


FIGURE 2 *Major environmental gradients affecting wetland ecosystems. Modified from Vitt (1994) in MacKenzie and Banner (2000).*

"Hydrology, the way in which a wetland is supplied with water, is one of the most important factors in determining the way in which a wetland will function, what plants and animals will occur within it and how the wetland should be managed"
(Welsh et al. 1995).

throughout the year and often have a water table above the soil surface.

Hydrodynamics: The degree of vertical water table fluctuation and rate of lateral groundwater flow (hydrodynamics) describe much of the functional variation in wetlands. Sites with relatively stable water regimes (bogs and fens) are peat-accumulating sites. With more active hydrodynamics (marshes and swamps), organic matter is more likely to decompose, aeration improves, and nutrients become more available.

Some interior marshes have significant drawdown during the summer and this contributes to the concentration of salts in soil horizons.

Soil acidity/alkalinity: The abundance of base cations, such as calcium, has a strong influence on wetland characteristics, especially species composition and productivity. Low mineral content yields fewer nutrients as well as lower pH. Acidic conditions inhibit the ability of most plants to take up nutrients. In peatlands, very low mineral content reflects isolation from groundwater sources and is often indicated by an abundance of *Sphagnum* mosses. *Sphagnum* actively removes basic minerals from the soil water, exchanging them with hydrogen ions, thereby increasing acidity. On other sites, soil water chemistry is a function of degree of groundwater influence and mineralogy of the adjacent terrain.

The soil nutrient regime (SNR) is mainly a function of the two gradients of base cation availability (as indicated by pH) and hydrodynamics.

Soils

While all wetlands share some common soil attributes, such as saturation and anaerobic (no oxygen) conditions, the physical, chemical, and biological properties of wetland soils are highly variable. This variability is due primarily to the hydrological gradients mentioned above.

Natural disturbance in wetlands *Wetlands, like upland ecosystems, undergo succession and periodic disturbance events. However, these disturbances are often hydrological and affect the fundamental site potential of the wetland.*

Beaver impoundment *Beavers are primary disturbance agents of wetlands. Mainly through dam building but also by removal of vegetation and creation of runs, beavers create new wetlands or modify existing ones. Flooding changes wetlands to more productive ecosystems through the release of nutrients. It also creates habitat heterogeneity, which improves overall wildlife habitat capability.*

Drought *Potholes and shallow lakes in semi-arid regions often experience dramatic water table fluctuations in response to climatic cycles. Dry years have a marked impact on the size, boundaries, and plant communities of wetlands. Major changes to the annual water budget may lead to some wetlands disappearing for several years, only to reappear when the water table is reestablished. This cycle is favourable to many marsh species.*

Wildfire *Wildfire does occur in some wetland ecosystems, though wetlands are less likely to burn than upland forests because of wet soils, low fuel loading, and sparse canopies. This often leaves forested wetlands as patch remnants in a widely burned landscape.*

Mineral soils with little or no surface accumulation of organic matter are associated with nutrient-rich wetlands having dynamic soil water regimes. Lateral groundwater seepage flow and pulsing hydroperiod promote higher plant productivity as well as more rapid decomposition and "flushing" of organic matter. More active decomposition and nutrient cycling in these soils results from higher faunal and bacterial activity.

Peatlands develop where hydrological gradients are less dynamic. The nature of the peat is also highly variable, ranging from very fibrous *Sphagnum* peats in nutrient-poor, rain-fed bogs to dense, well-decomposed sedge peat in fens influenced by groundwater. Recognizing this variation in the chemical and physical properties of peat is important in the peat mining industry. Extraction of peat deposits for fuel, agriculture, and other industrial uses has been substantial world-wide but limited in British Columbia (Rubec et al. 1988). For palynologists, peat deposits provide a record of past vegetation and climate change through the analysis of fossil pollen and spore rain preserved in these ancient soils (Moore et al. 1991).

Another aspect of wetland soils and vegetation, which has been exploited for the treatment of industrial and urban effluent, is their capacity as natural water filters. Significant amounts (up to 98%) of eutrophying nutrients such as nitrogen and phosphorus have been removed from sewage effluent filtered through wetland soils (Mitsch and Gosselink 1993). The capacity of wetlands as nutrient sources, sinks, or transformers is highly variable, however, and has been the subject of much research (Mitsch and Gosselink 1993).

Succession

Plant community succession takes place at two time scales in wetlands. Secondary succession following vegetation removal follows a pattern similar to that of upland sites, with the establishment of pioneer species followed by a "climax" species group.

However, many natural or human-caused disturbances of wetlands are hydrological (see sidebar) and they can change the site potential of the wetland. In these cases, the initial climax community changes to a new one that reflects the new environment. Conversion to the new climax plant community can be relatively rapid, occurring over the span of several years.

Longer-term primary succession occurs in wetlands as peat and sediments accumulate. Successional trends are from shallow water to marshes to swamps to upland communities in dry, temperate climates, and from shallow water to marshes to fens and bogs in cooler and wetter climates. Organic soil development results from the very slow decomposition of plant litter in a saturated, low-nutrient environment. This "autogenic" succession, occurring over thousands of years, yields peat deposits that vary in depth from less than 50 cm to more than 10 m, depending on climate, terrain, and hydrology.

A Classification of Wetlands

Taxonomists categorize organisms into species, genera, and higher taxa in a structure that facilitates our understanding of their relationship to each other. When ornithologists see a bird, they can refer to field identification manuals that will tell them (based on field characteristics) what species it is. Knowing this, they might then refer to the literature to find out what is known about that species' life history, related species, etc.

Towards a similar goal, ecologists create ecosystem classification units to represent repeating patterns of environmental conditions and associated biota in the landscape. Once defined,

Wetland Regions

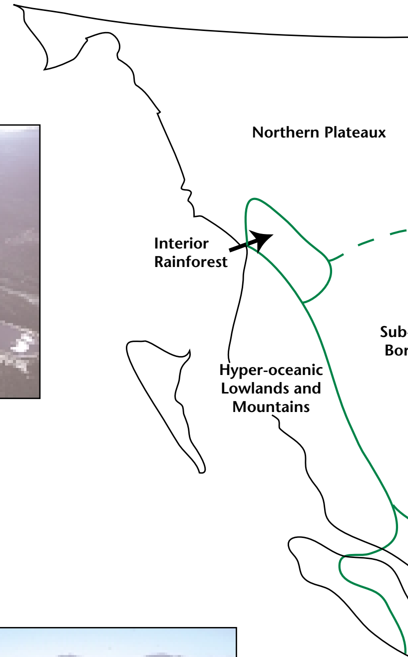
The abundance of wetlands and predominant wetland type occurring in a region is a function of climate and topography. Several informal wetland regions may be described for the province. The value of a wetland as habitat will vary between regions. Wetlands in regions of low wetland abundance and high numbers of wetland-using species will have extremely high habitat value. A similar wetland, in a region of high wetland density or with low numbers of wetland-using species, will generally be considered less important.

Climate

Variation in climate throughout the province is largely responsible for the variation in wetland extent. On the hypermaritime coast where precipitation is high, temperatures relatively cool, and evapotranspiration relatively low, soil water is retained on most sites. As a result, wetland formation is extensive, even on some steep slopes. In the boreal interior, cool annual temperatures limit decomposition rates. The resulting build-up of organic matter, combined with fine-textured soils (and, in some areas, permafrost), impedes drainage and promotes wetland formation. In drier portions of the interior, wetland formation is precluded by moisture deficits on most sites, and wetlands are limited to topographic depressions and fine-textured fluvial and lacustrine landforms.

Boreal Interior (western BWBS, SBPS, SBS, SWB)

Wetlands occur over less than 3% of the central and sub-boreal interior, though there are areas with higher concentrations. Short, cool growing seasons promote formation of peatlands in most wet depressions. Consequently, subdued terrain may be covered by large expanses of fen ecosystems. Marshes and swamps are common in association with lake and river systems. Ecosystems of these areas have been described in Roberts (1984) and MacKenzie and Shaw (2000).

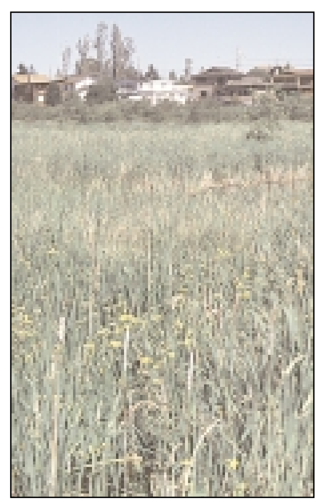


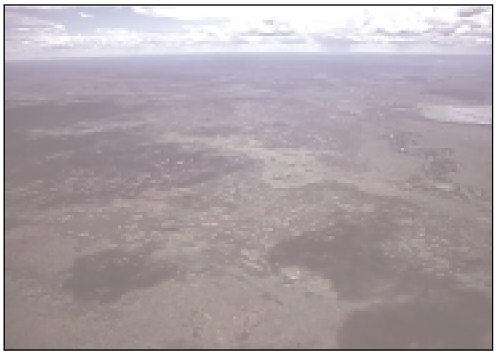
Hyper-oceanic Lowlands and Mountains (CWH, MH)

Encompassing the windward side of the Coast Mountains, this is a wetland region experiencing a hypermaritime climate characterized by extreme precipitation and mild summer and winter temperatures Wetlands may cover up to 50% of the landscape in some areas. The geology is predominantly granitic and poor in minerals, with little or no glacial till. Consequently, wetlands are primarily bogs even though most sites receive groundwater seepage. These bogs are extensive on gently to steeply sloping terrain. The community types and form of the wetland landscape in this area are globally unique. Ecosystems of these areas have been described in Banner et al. (1988).

Temperate Coast (CDF, dry CWH)

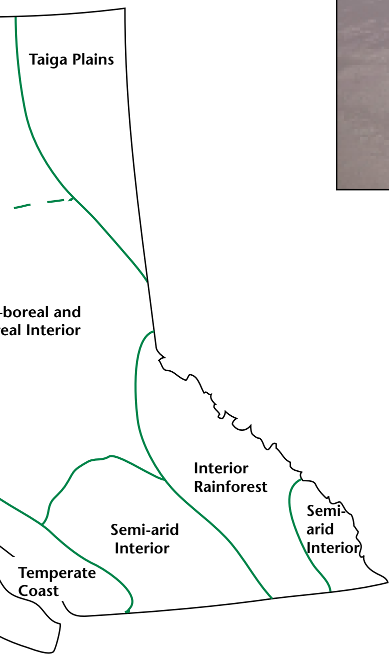
The southeast corner of Vancouver Island, the Gulf Islands, and part of the adjacent mainland experience mild winters, warm summers, and moderate precipitation. Swamps and marshes are most common in this landscape, though some extensive bog ecosystems do occur (e.g., Burns Bog on the Fraser River delta). Wetlands are not uncommon in this landscape (6% of the area), but most have been modified by human activities; some have been lost completely. The northern range limit of many plant and animal 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. Ecosystems of these areas have been described in Ward et al. (1992) and Banner et al. (1988).

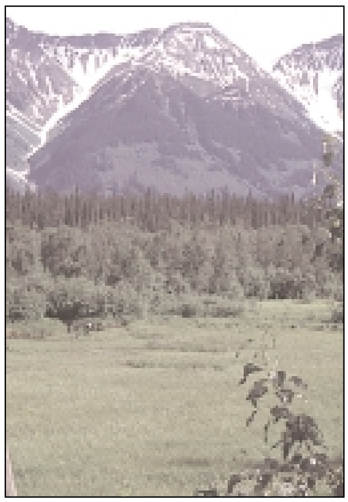




Taiga Plains (eastern BWBS)

Extensive, poorly drained, glaciolacustrine deposits underlie the northeast corner of the province. The climate is boreal to subarctic with very cold winters and warm summers. This region has some of the highest concentration of wetlands in the province (30% aerial extent). Bogs predominate, though fens and swamps occur along the sluggish streams that drain the region. Permafrost is common. Ecosystems of these areas have been described in Zoltai et al. (1988).





Interior Rainforest (ICH, wet/very wet subzones of the 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 restricts wetland abundance (<1% aerial extent). Some large peatland or swamp complexes are found in valley bottoms. Ecosystems of these areas have been described in MacKenzie and Shaw (2000).

Semi-arid Interior (BG, PP, IDF, MS)

The semi-arid interior experiences low precipitation and high summer temperatures. These conditions limit peat formation except at higher elevations; therefore, marshes and swamps are most common. Wetlands occur on less than 2% of the landscape, though some areas in the Chilcotin Plateau have much higher wetland density. Some potholes and shallow lakes may experience severe evaporation and drawdown during the summer months, resulting in the accumulation of salts and formation of distinctive ecosystems. These interior saline/alkaline sites are mostly restricted to this wetland region. Because water sources are fewer and wetlands are markedly different from adjacent upland habitats in structure and species composition, wetlands are particularly important in the semi-arid interior. 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 toad (Spea intermontana) *and tiger salamander* (Ambystoma tigrinum)*, occur only in this region. Wetlands in this region have been dramatically altered, mostly by agricultural activities such as crop production and grazing (Van Ryswyke et al. 1992). Ecosystems of these areas have been described in Steen and Roberts (1988) and MacKenzie and Shaw (2000).*

these ecological units can be identified in the field, and information and interpretations, based on the experience of others, can be accessed.

Classification of wetlands provides an important tool for understanding ecosystems and applying principles of ecosystem management. Classifications allow for the ordering, comparison, synthesis, mapping, and inventory of information and give resource workers a common language to communicate results.

In British Columbia, biogeoclimatic ecosystem classification (BEC) is the primary classification applied to forested sites. This approach uses indicator species groups to identify environmental conditions or site potential. The fundamental unit of BEC, the **site association**, provides specific and detailed information on plant species occurrence and environmental conditions. Wetland site associations have been described for some regions of the province (e.g., MacKenzie and Shaw 2000). Groups of site associations with broadly similar ecological properties of hydrology, soils, and vegetation structure are described by the **wetland class**. This level of the classification is more useful for general discussion of wetlands (National Wetlands Working Group 1997). There are five wetland classes: Bogs, Fens, Marshes, Swamps, and Shallow Open Water (see page 9). Bogs and Fens develop deep accumulations of peat and are referred to as Peatlands. Swamps and Marshes occasionally occur on deposits of well-decomposed peat, but more commonly have mineral soils.

Physical characterization of wetlands

In addition to ecological features, a wetland can be classified through a physical approach using hydrology and geomorphic form (see page 10). Several different wetland ecosystems may exist together within a single wetland mosaic but they will have a common basic hydrological environment, known as a hydrological template (Moore and Bellamy 1974). Classification of this template is useful for purposes that require an emphasis on the hydrological and geomorphic controls of wetlands.

At the broadest level, a wetland occurs within the hydrological influence of streams, lakes, or catchment basins. Geomorphic forms of these systems give an indication of factors maintaining a wetland's ecological functions (Brinson 1993).

Other Factors Affecting the Ecological Role of Wetlands

Classification serves to generalize the complexity of nature. However, additional factors not directly incorporated into the classification also perform important ecological functions, such as providing fish and wildlife habitat, flood attenuation, or biogeochemical filtration.

For example, the wildlife habitat quality of a wetland can be influenced by:

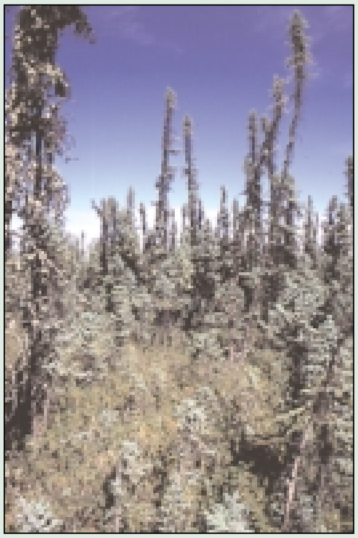
- wetland class,
- structural diversity and vegetation cover,
- diversity of site associations,
- presence of open water,
- quality of adjacent upland habitat,
- presence of adjacent wetlands,
- regional scarcity of wetlands,
- regional climate,
- presence/absence of fish,
- prey density, and
- other unique habitat features.

Flood attenuation and filtering are a function of:

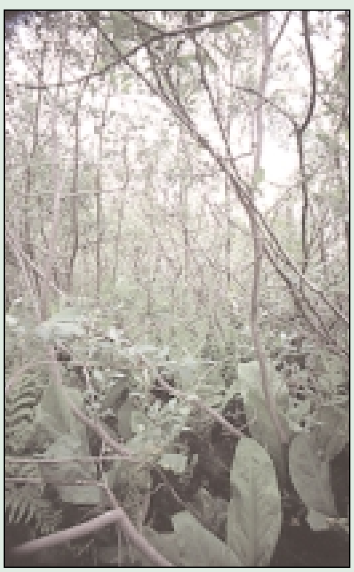
- soil characteristics,
- groundwater retention and flow rates, and
- linkages within the watershed.

Wetland ecosystem classes

An interrelated combination of hydrological conditions, soil features, vegetation structure, and species guilds differentiate the wetland classes.



***Bogs** are treed or low-shrub, nutrient-poor peatlands dominated by evergreen shrubs and* Sphagnum *mosses. The rooting zone is isolated from mineral-enriched soil waters and* Sphagnum*-derived soils are highly acid.*



***Swamps** are treed or tall-shrub mineral wetlands having significant water flow and periodic surface aeration of the substrate.*

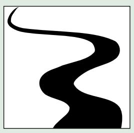
***Fens** are peatland ecosystems that receive nutrient and water inputs from groundwater. Fens have a large complement of plant species indicating mineral rich conditions.*

***Marshes** are semi-permanently to seasonally flooded mineral wetlands dominated by emergent grass-like vegetation.*

***Shallow Open Waters** are mineral wetlands with permanent shallow flooding where submerged or floating aquatic plants predominate.*

More detailed descriptions of these units can be found in MacKenzie and Banner (2000).
Sites that do not fall clearly within a single wetland class, but have characteristics of two, can occur. These sites can be described as intermediates (e.g., fen-bog, swamp-bog). These inter-grading types can result from natural peatland succession, hydrological changes, or simply intermediate environmental conditions.

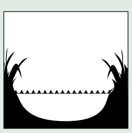
Broad hydrophysical forms of wetlands



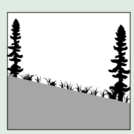
Fluvial
Sites occurring beside and influenced by streams and rivers.

Lacustrine
Sites occurring in the flooded zone of lakes.

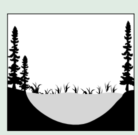
Wetlands not associated with rivers or lakes can be grouped into three major forms:



Ponds and potholes
Sites associated with small water bodies. Usually dominated by shallow open water or marsh ecosystems.



Slopes
Sites on slopes with abundant near-surface seepage derived from groundwater or precipitation.



Basins
Sites in depressions and other topographic low points that receive water mainly from groundwater and precipitation and have little standing water. Usually dominated by peatland ecosystems.

The role of reserves in wetland protection

The value of forested reserve zones around wetlands is primarily for the protection of wildlife habitat values. The wetland-riparian boundary is a natural edge that is favourable to many wildlife species. Wetlands often have high prey densities and excellent forage, making them very attractive to wildlife. However, many wetland sites do not themselves provide sufficient cover or suitable structure to satisfy the life requirements of some wildlife species. A forested riparian fringe around wetlands provides this structure, and the presence of an intact forest will enhance the value of the wetland to wildlife. The riparian reserve provides cover for mammals, nesting and foraging for songbirds, suitable trees for cavity-nesters, and cover and forage for amphibians.

To a lesser extent, reserves reduce the potential for sedimentation from uplands and modify the microclimate of the wetland edge, a factor particularly important in small wetlands.

However, riparian reserves are of limited use in protecting wetland integrity on their own where modifications are made on water inflow or outflow of a wetland. Significant impacts to the hydrological system feeding into wetland cannot be ameliorated through the use of a riparian management area alone.

Ten Management Issues for Wetlands in British Columbia

Many wetland protection measures rely solely on the establishment of reserve and management zones adjacent to wetlands. In some cases, however, activities well away from the wetland edge (e.g., road building) are of greater significance to the integrity of the wetland than are the activities immediately adjacent to it. In addition, the importance or sensitivity of some very small wetlands may be underestimated, whereas some larger wetlands, depending on their ecological characteristics, may require few management considerations.

Conservation of wetlands in British Columbia is of prime importance for landscape biodiversity and wildlife habitat planning. Based on a review of available information, the following areas represent gaps in the knowledge needed to effectively manage wetlands.

1. Determine the potential and scope of wetland change caused by forestry activities such as riparian logging and road design. Impacts may include flooding, water table depression, water table stabilization, or other changes to hydroperiod.
2. Identify and document the most significant threats to wetland conservation in British Columbia resulting from industrial, urban, and agricultural development.
3. Identify specific and unique habitat values of different wetland types.
4. Assess the impacts to wildlife habitat values of connectivity and isolation as a result of road building, clearing, and urbanization (Semlitsch and Bodie 1998).
5. Document the appropriate riparian reserve widths for different wildlife species and establish acceptable management activities in a riparian management area for each (deMaynadier and Hunter 1998; Semlitsch 1998).
6. Investigate the ecological importance of very small wetlands (<0.25 ha). Some studies suggest that very small wetlands are essential habitat components in the landscape, especially in dry climates (Semlitsch and Bodie 1998).
7. Develop a better understanding of the ecological importance of size and adjacency relationships to help designate wetland complexes.
8. Determine appropriate special management considerations for rare wetland communities or wetlands supporting rare wetland-using species (Lovett-Doust and Lovett-Doust 1995).
9. Determine the importance of wetlands for groundwater recharge in semi-arid areas (van der Kamp and Hayashi 1998).
10. Develop a science-based policy for wetland conservation and restoration in British Columbia.

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