A group of field biologists and naturalists shares ecological observations and findings while on a botanical field tour, Grande Plaine, Miscou Island.

Chapter 5

Ecological Gradients

The work of poets and painters is successful when they find simple yet eloquent ways to give meaning to complex ideas or objects. Ecologists are engaged in a similar creative process when they synthesize diverse knowledge about land and vegetation into a simple expression that captures something essential about the distribution of plants and animals. With their well-rehearsed stories about flora and fauna, our park naturalists and museum curators are essentially play the role of ecological storytellers. When ecologists talk or write about relationships between vegetation and ecological gradients, they are developing stories and analogies to capture their listeners' or readers' imaginations. An ecologist invokes a level of detail appropriate to the scale of the phenomenon being described, much as certain paintings can portray the essence of a spruce, pine, and birch forest, or a few written words can evoke the image of an entire landscape.

What are Ecological Gradients?

The distribution patterns of species and ecosystems are not only a function of post-glacial migrations and human influences, but also a present-day response to ecological gradients. Ecological gradients are measures of the physical environment that explain the distribution of organisms and ecosystems in terms of environmental tolerances. Commonly used ecological gradients include air temperature, precipitation, soil fertility, soil acidity, moisture regime, and frequency of natural disturbances such as fire, wind, or infestations. The major challenge for ecologists is to explain the distributions of organisms with simple models that describe vegetation change relative to a small number of important gradients.

The most obvious and well-documented ecological narratives of this type describe very broad, continental-scale factors. For example, a traveler driving south on I-95 toward Florida may notice the transition of vegetation cover from a predominantly mixed-hardwood-spruce-fir forest of Maine, to a hardwood forest of Maryland, to a southern pine and hardwood forest as one continues through the Carolinas. These changes of forest type is related to the climatic differences well known to most travelers seeking sun in wintertime. At a finer scale in New Brunswick, different cities and towns are known to be situated with respect to several environmental gradients of temperature and precipitation. We attempt in this chapter to add to and refine these narratives by focussing on increasingly fine-scale characteristics and their relationships to vegetation differences.

Why Study and Map Ecological Gradients?

In spite of the best efforts of biologists, foresters and naturalists, we really don't know where all the populations of various plants and animals are located. Gradient analysis helps us to understand the geographic distribution of species and ecosystems. Gradient analysis enables us to use the varied abiotic, or non-living, aspects of our surroundings that explains much about the geographic distribution of species and ecosystems. When applied to natural resource inventories of timberlands or wetlands, gradient analysis enables biologists to develop a broad focus on ecosystems and the species within them, and to better understand their critical ecological and economic benefits. Gradient analysis also helps us to avoid some of the limitations associated with managing for only one or a limited number of resources or values. Ecological land classification (ELC) is designed to capture intervals in these gradients.

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Species and Traits

Many ecological gradients can be detected by observing vegetation differences that are visible at fairly broad geographic scales. Orbiting the earth, for example, an astronaut can detect different vegetation zones on the North American continent. However, those distribution patterns represent the sum of interactions that take place at the scale of the individual plant or animal. Interactions at the scale of the of a species that has certain traits, determines whether it will flourish or perish in a given environment.

It is easy to recognize differences between tree species on the basis of leaf shape, bark texture and colour, or the “shape” or profile of the tree. These morphological traits describe a plant’s physical appearance. Physiological traits include photosynthesis, transpiration, and respiration rates. Phenological traits relate to the timing of various plant processes, such as leaf emergence in spring, leaf fall in autumn, the timing of flowering and seed dispersal. Seed number and size, germination requirements, and time to reproductive maturity are important traits describing the reproductive biology of a species. Morphological, physiological and phenological traits determine a plant’s shade and moisture requirements for establishment and growth, its ability to tolerate or withstand various types of environmental stresses, and its ability to grow and compete with other species for resources, such as light, moisture, and nutrients.

Certain traits, or suites of traits, may be advantageous in some environments and disadvantageous in others. Some species have suites of traits that facilitate rapid growth and reproduction under conditions of ample light, moisture and nutrients, allowing successful competition against other plants. Other species, with different traits, are able to grow and reproduce under environmentally stressful circumstances, such as low moisture or poor nutrient conditions, dense shade, or high salinit. Some species are found over a wide range of environmental conditions; others are very specific in their requirements. However, there does not appear to be any universally adapted species that is able to thrive under all conditions. Thus, both within and among plant communities, one finds a variety of traits, resulting in a range of possible responses to environmental changes, both along environmental gradients and over time.

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Major Gradients Affecting Forest Composition

In forests, three useful environmental gradients operating at fine geographic scales are topoclimate, soil nutrient regime, and soil moisture regime.

Topoclimate

Topoclimate is the climatic regime conferred on a site by its landform shape, its slope position, and aspect. One of the primary effects associated with topoclimate is cold air drainage.

Cold air drainage refers to the tendency of cold air to settle in lower landscape positions at night forming ‘frost pockets’ or ‘frost hollows’. During cold nights in spring and fall, the valleys affected by cold air drainage are the first places to be touched by frost. In narrow, V-shaped valleys, the lower slope positions receive smaller amounts of solar radiation than do the hilltops and consequently are better places for northern coniferous species to grow.

In areas close to larger lakes, coasts, and the broader, U-shaped valleys more typical of the three lowland ecoregions, late spring and early fall frosts are less frequent than in the uplands and highlands where narrow valleys are more common. In these lowland areas, cold air drains at night from higher ground and becomes mixed with heat released by the relatively large volumes of water carried in lowland rivers, thus preventing frost. Over time since glaciation, this has led to greater predominance in the broad lowland valleys of tree species with southern continental distributions such as the maples and ashes.

The frost hollow effect is demonstrated here by pine, spruce, and fir lining lining the valleys, and sugar maple and birch on the hilltops along a tributary of the Upsalquitch River.

An interesting exception to this general pattern of tolerant hardwood trees on the summits with softwood trees in the narrow valleys occurs at Mount Sagamook in northern New Brunswick. On the north slope of the mountain (see photogrph on facing page), tolerant hardwood stands at the base of the mountain (the red and orange band) gradually give way to fir-spruce stands (first dark green band) followed farther upslope by mixed stands of black spruce and white birch (alternating yellow and dark green bands). The summit is capped with a subalpine ecosystem dominated by Laborador-tea, mountain cranberry, and stunted black spruce.

There are two main reasons for this anomalous pattern on Mount Sagamook. The first is the great size of the mountain in comparison with otherNew Brunswick landforms. Mount Sagamook rises more than 500 m above Nictau Lake and, therefore, reflects regional climatic gradients associated with a decrease in temperature with elevation. The increase in elevation is, thus, equivalent to traveling farther north. A second factor that explains the vegetation pattern on Mount Sagamook is the soil fertility gradient from lakeshore to summit. Soils along the lakeshore are enriched with calcareous sedimentary rock fragments and contain relatively base-rich minerals that have higher nutrient content, while the summit is predominantly bare rhyolitic bedrock, littered with frost-shattered stones and boulders and covered, in some parts, with a thick organic mat of detritus and roots.

A northward view from near the summit of Mount Sagamook, Mount Carleton Provincial Park.

Aspect

Aspect is the orientation of a slope with regard to the four points of the compass and is another factor contributing to topoclimate. As a general rule, slopes with a southerly aspect in the northern hemisphere tend to receive more sun exposure than do north-facing slopes. Ecological differences due to aspect are difficult to correlate with plant and animal distributions in New Brunswick. A possible explanation for this lack of correlation may be the region's high frequency of cloud cover, which diffuses light and heat and mutes the effect of aspect as an environmental gradient, in comparison to parts of the continent that are more arid or are more strongly sloping. However, some associations with aspect do stand out, such as the tendency for eastern hemlock to be abundant in the lowland ecoregions on north-facing slopes in areas where it is otherwise relatively scarce.

Soil Nutrient Regime

The ecological gradient of nutrient availability is correlated with a gradient of decreasing acidity and increasing weatherability of the rocks and rock fragments that make up the bulk of mineral soil (see Chapter 3). Acidic igneous rocks occupy the poor end of this nutrient gradient and grade into richer, non-calcareous sedimentary rocks, mafic igneous rocks, calcareous rocks, and limestone. In forest soils, low soil acidity is often associated with higher nitrogen content and ratios of carbon to nitrogen that are correlated with high plant nutrient concentration. These factors enable high rates of activity by soil micro-organisms, leading to high rates of plant growth, decomposition, and nutrient cycling.

Plant species composition also reflects soil nutrient regime. On rich sites, for example, understorey plant species such as the small enchanter's-nightshade, naked mitrewort, bristly currant and alternate-leaf dogwood are more likely to be found. In the overstorey, sugar maple, yellow birch, white spruce and eastern white cedar also have greater representation. In warmer ecoregions, white ash, ironwood and butternut are often present on such rich sites. Rich soils harbour more rare plant species, and places where these soils are found are also favourite areas for naturalists to explore.

On poor soils, many plants share adaptations that help them to conserve nutrients. Among these strategies is a tendency to be evergreen. Sheep laurel, Labrador-tea, and wintergreen are among the understorey species typical of nutrient-poor sites. In these species, the small quantity leaf litter dropped in a given year is typically low in nutrient elements because the plants reabsorb a high percentage of nutrients into the living biomass as a nutrient conservation measure. In contrast, species adapted to rich sites tend to conserve nutrients less and drop larger quantities of litter. Sugar maple, yellow birch, and ash are among the species that tend to be more abundant on sites that represent the high end of the nutrient gradient.

There is an important nutrient gradient affecting wet sites that spans differences in oxygen concentration. Oxygenated water occurs where water is not stagnant, but seeps laterally through the soil profile. While oxygen-starved soils typically are associated with level or flat ground, soil water oxygenation may occur with as little as two degrees of slope. Under oxygenated conditions, micro-organisms are able to thrive and decomposition of dead organic matter

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proceeds. Other names applied to sites where oxygenated water appears at the surface include ‘seep’ or ‘spring’. Where oxygen is lacking, conditions favour the accumulation of thick surface layers of organic matter due to the relative inactivity of soil organisms. In this way, oxygen status on wet sites is an important determinant of soil nutrient regime.

In all climate regions throughout New Brunswick, forests on wet, low-oxygen soils tend to have a boreal “look”. The soil effects are so strong that they overwhelm climatic influences. Black spruce, tamarack and shrubs (including speckled alder, Labrador-tea and rhodora) usually dominate such sites, while sphagnum mosses dominate the understorey. These sites are also very acidic, and the species there tend to reinforce soil acidity because of the acidic nature of their leaf litter and other dead plant parts. The most extreme expression of the effect of low soil oxygen under wet conditions is the formation of peat bogs (discussed later in this chapter).

Soil Moisture Regime

Three factors are primary influences on soil moisture regime: bedrock permeability, landform position, and a suite of soil attributes including texture, stoniness, organic matter content, and the presence of a constricting or compact layer. These factors influence a site’s water supply and also the drainage rate of water within the soil’s upper layers where most tree roots are found.

Bedrock permeability

Bedrock permeability describes how moisture travels through bedrock. Many bedrock areas contain cracks and fissures that allow moisture to infiltrate through to groundwater. As well, some rock types are more porous than others. In New Brunswick, volcanic and granitic rocks tend to be impermeable, whereas meta-sedimentary rocks are typically quite permeable. Where bedrock is permeable, good drainage and moderate soil moisture conditions are predominant. Where bedrock is impermeable, the soil moisture regime is more variable due to pooling of water in bedrock

The Kennedy Lakes formed where glacial deposits block drainage pathways, and impermeable bed-rock, in this case granite, prevents percolation of water to deeper levels.

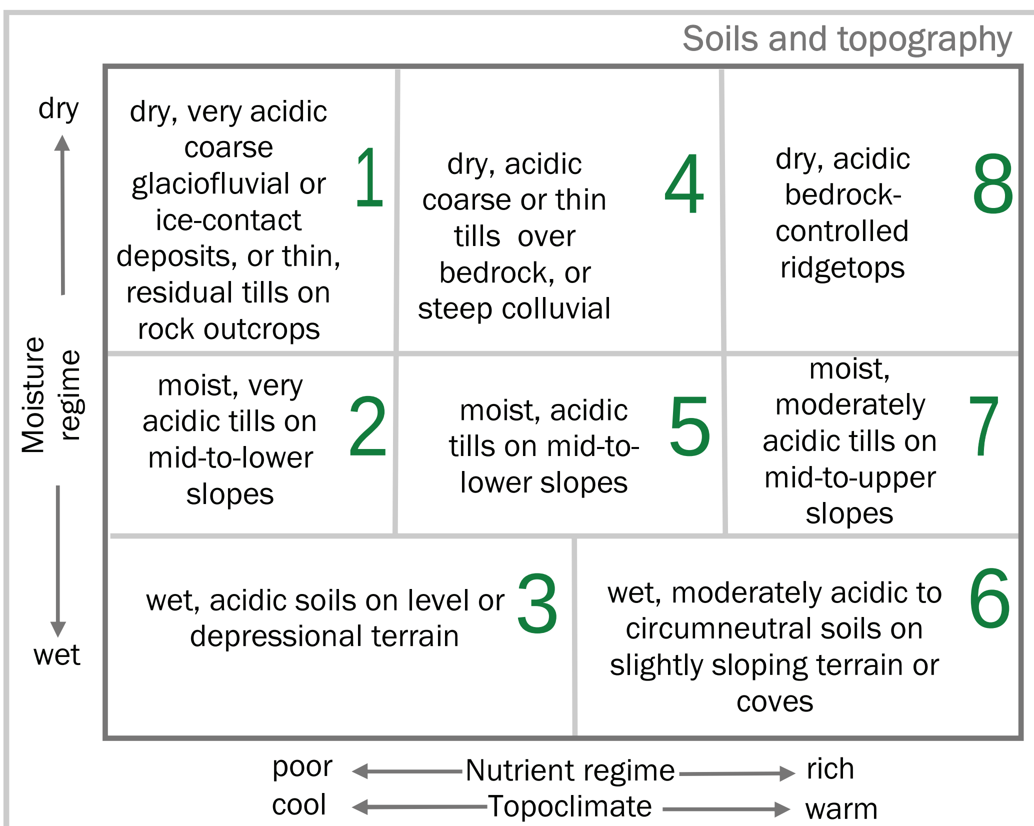
depressions; here, the composition of vegetation can reflect restricted drainage. Lakes and ponds tend to be more numerous where rocks are impermeable, which is why a disproportionately large number of lakes and ponds in New Brunswick occur on granitic bedrock.

Landform position

Sites are either moisture-shedding and receive water input primarily from precipitation, or they are moisture-receiving and are recipients of laterally-flowing seepage water. Whether a sites sheds or receives moisture depends on where it is situated on the landform. Coves are broadly concave, sloping parts of a landform where seepage water collects due to landform shape. Other moisture-receiving sites include flat areas or depressions, where surface water collects or where groundwater comes close enough to the surface to influence vegetation. Moisture-shedding sites are the high points and ridges from which moisture drains away.

Soil attributes

The presence of impermeable or highly compact layers in the soil will tend to slow soil drainage and contribute to a wetter moisture regime. In eastern New Brunswick, soil attributes are the primary



The edatopic grid for New Brunswick uplands. The grid to the right describes ecological site types, or *ecoelements,* in terms of their soils and topographic character. The grid on the facing page identifies associated typical forest vegetation .

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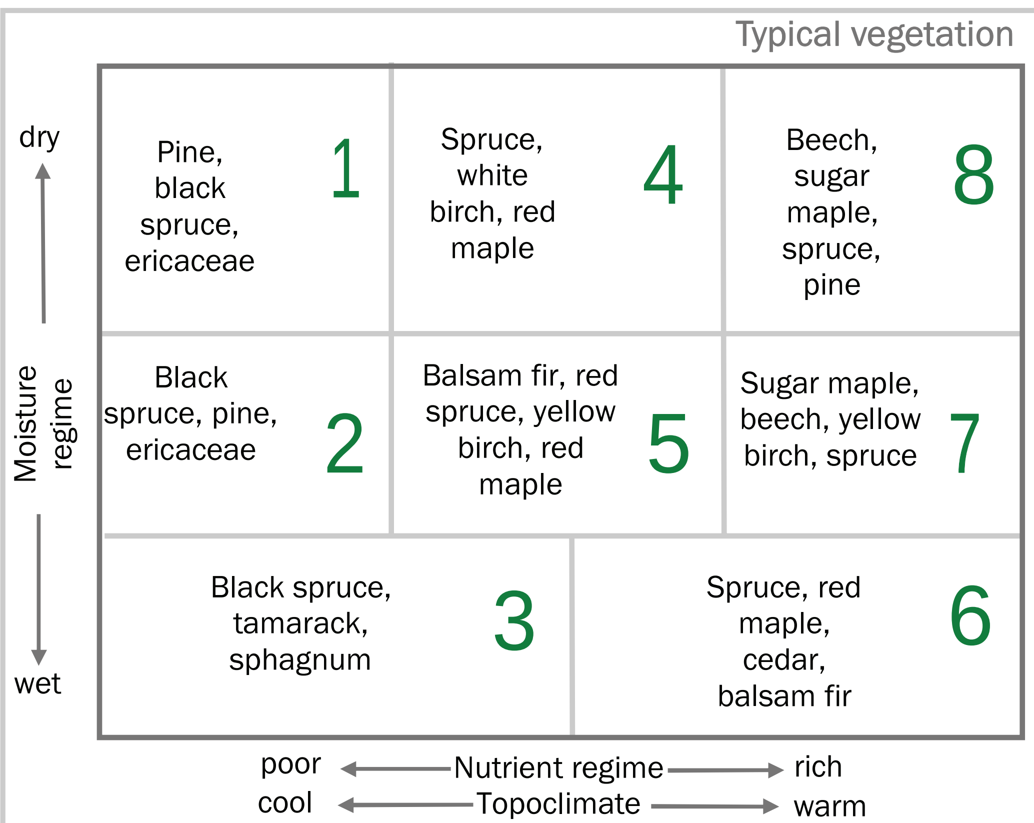
determinants of soil moisture regime. Over much of the area, a reddish, clay-rich soil horizon greatly slows infiltration of water to the bedrock. These soil conditions have contributed to the formation of large areas dominated by bog and swamp forest. In contrast, where soils are stony, gravelly, or sandy, and freely draining, lack of moisture can limit tree growth.

Dry or droughty conditions prevail where bedrock comes close to the soil surface in moisture-shedding situations. Alternatively, where sites shed moisture and the soil contains high volumes of rock or stones, the effective rooting space and moisture storage capacity of soil is restricted. Pine, blueberries and spruce are typical plant species on such sites.

Moving along the soil moisture gradient from moist to saturated or flooded conditions, one encounters forested wetlands, such as silver maple swamps, and treeless wetlands, such as marshes and peatlands.

The Edatopic Grid

After an ecologist has studied how topoclimatic, moisture, and nutritional gradients interact, it is a short step to categorizing this information in terms of fine scale ecological site-types, or ecoelements.



The edatopic grid for New Brunswick uplands. The grid on the facing page describes ecological site types, or *ecoelements,* in terms of their soils and topographic character. The grid to the left identifies associated typical forest vegetation .

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For practical purposes, ecologists subdivide the continuous gradients in topoclimate, soil nutrient regime and soil moisture regime individually into discrete classes or sections. Ecological units, or elements, emerge with the study of the diverse possible combinations of sections of the topoclimatic, moisture, and nutrient gradients. The present ecological land classification uses eight basic physical soil and landform templates based on the soil moisture, nutrient, and topoclimate gradients. These templates are later used to build a set of ecosite maps for the ecoregions of the province. The two-dimensional edatopic grid presents a convenient and simple representation of topoclimate, soil moisture, and soil nutrients described above. Because nutrient regime and topoclimate are correlated, these two gradients appear together along the horizontal axis of the edatopic grid.

Keys and tables useful for identifying ecoelements in the field are provided in Appendix 1.

Large, flat areas of eastern New Brunswick have low relief and are underlain by clay-rich, impermeable soils (top) that lead to the formation of extensive peatlands, such as the Canaan Bog area (bottom).

Major Gradients affecting Wetlands and Other Non-forested Elements

So far, we have focussed on the major gradients affecting forest composition in New Brunswick. Complementing our forested landscape is a rich array of other features and ecosystems. At higher elevations, rock outcrops and even a few subalpine barrens interrupt the forest cover, while along the coasts, sand dunes, gravel shores and mud flats are common features.

The wetlands of the province encompass the most extensive and diverse of the non-forested ecosystems. Wetland ecosystems, by definition, occur where the water table lies at or near the surface, or where shallow water – either fresh or marine – covers the land at some time during the growing season. They occupy that mysterious, transitional world between land and water. In some wetlands, the full variety of species may be partly hidden below the surface of water that nonetheless is shallow enough to give tantalizing glimpses of the life below. Few people who have ventured across a peatland on foot will forget the experience of walking on soft, soggy, spongy ground, especially if they fell through a layer of peat to take an unexpected bath! Wetlands include bogs, fens, swamps, marshes, and shallow open waters that dot the New Brunswick landscape and provide a textural contrast to our primarily forested terrain.

Wetland Gradients

The complex set of factors that shapes the character of wetlands in the Maritimes can best be summarized by describing two gradients: disturbance and flooding.

Disturbance

The disturbance gradient of a wetland is evaluated on the basis of the energy of the water that affects it, whether through wave or tidal action, ice scour, or rainfall.

Disturbance may have a profound impact on a wetland through the sorting, removal, or deposition of sand, silt or partly-decomposed organic matter. Steady flow, strong currents, wave action, and dramatic water fluctuations all prevent the accumulation of organic matter and fine particles, thus lowering the levels of nutrients available to plants. The plant species in such unprotected sites tend to be small and adapted to a high-energy environment: shrubs instead of trees, narrow spike rushes instead of robust cattails, and submerged plants with ribbon-like leaves instead of plants with large floating leaves. Where disturbance is extreme, the vegetative cover may be sparse or non-existent. Hence, the vegetation typical of gravelly shores is scattered herbaceous species.

In contrast, minimal disturbance allows the accumulation of organic material and fine sediment. This occurs in protected coves or embayments, in ponds, and along the shores of small lakes. In these situations, the associated wetland vegetation forms a thick cover of lush plants such as cattails, pickerelweed, or water-lilies. Historically, the combination of low or no disturbance, appropriate (acidic) substrate, and a cool, humid climate has been sufficient for organic matter to accumulate to impressive depths in the form of peatlands. The raised bogs common in our coastal regions have been in the making since the retreat of the last glacial seas.

Flooding

While disturbance is important, it is the ‘wet’ in wetland that defines the ecosystem. The flood regime can range from occasional or short floods to permanent flooding to various depths. This is, in effect, a continuation of the moisture gradient described for forest ecology. As already noted for forest soils, one of the primary

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Broad, floating leaves of the bullhead-lily capture sunlight, but this morphological adaptation restricts the plant to low energy, quiet backwaters.

ecological effects of prolonged flooding is the depletion of oxygen in the soil. The oxygen is consumed by microbial activity and is normally replenished through aeration or exchange with the atmosphere. Flooding slows the rate of replenishment because oxygen diffuses much more slowly through water than through air. Shallow, moving water may be well aerated and, thus, replenish oxygen somewhat, but stagnant or slow-moving water may effectively act as a barrier to the diffusion of oxygen from the atmosphere to the soil.

The lowered oxygen levels present problems for living plants, literally drowning the roots and, in deeper flooding, the shoots of the plants. Thus, species that are typical of wetlands show a number of adaptive traits that help them cope with periods of reduced oxygen availability. An example of this kind of adaptation is the formation in aquatic plants of an especially porous plant tissue called *aerenchyma*. This kind of tissue has air spaces between cells. Scientists believe these air spaces facilitate the passage of oxygen and other gases from shoot to root. A second kind of adaptation is the formation of new roots to replace those damaged by prolonged flooding. While these two examples are morphological adaptations, other adaptations may be part of the plant's life history, such as the timing of seed release or seed germination requirements. For example, many of the wetland species in our region release their seeds in autumn, to be carried about by wind and water currents, with germination occurring the following spring as flood waters recede.

Pickerelweed can withstand slow to moderate currents.

The combination and effectiveness of these adaptations vary between species, with the result that different species display different levels of flood tolerance. Among the least tolerant are woody plants, to the extent that they are restricted to the highest portions of the wetlands where flooding is of shortest duration.

The non-woody plants cover a wide range of forms and flood tolerances, from the species that resemble terrestrial plants at the upper edge of the wetland, to the emergent species in the middle, to the floating-leafed species, or even completely submerged species in the deepest areas. It is the emergent species that most of us picture when we hear the word wetland. These are the cattails, bulrushes, and smaller plants with erect stems that often have some part of their stem or shoot in the water. They are found in the middle to lower portions of the wetland where they literally 'emerge' from shallow water. The most flood-tolerant emergents are tall, reed-like species that are able to survive prolonged periods of flooding at depths exceeding 1 m.

Some wetland sites display the full span of flood gradient from high shoreline, with only brief flooding, to areas that are flooded for much of the year. With this range in flooding comes the associated zonation of plant types, from trees and shrubs, to upper marsh species, emergents and, finally, floating-leafed and submerged species. Other wetlands are more homogenous in nature. These sites receive essentially the same depth and duration of flooding throughout and thus display less zonation of vegetation across the site.

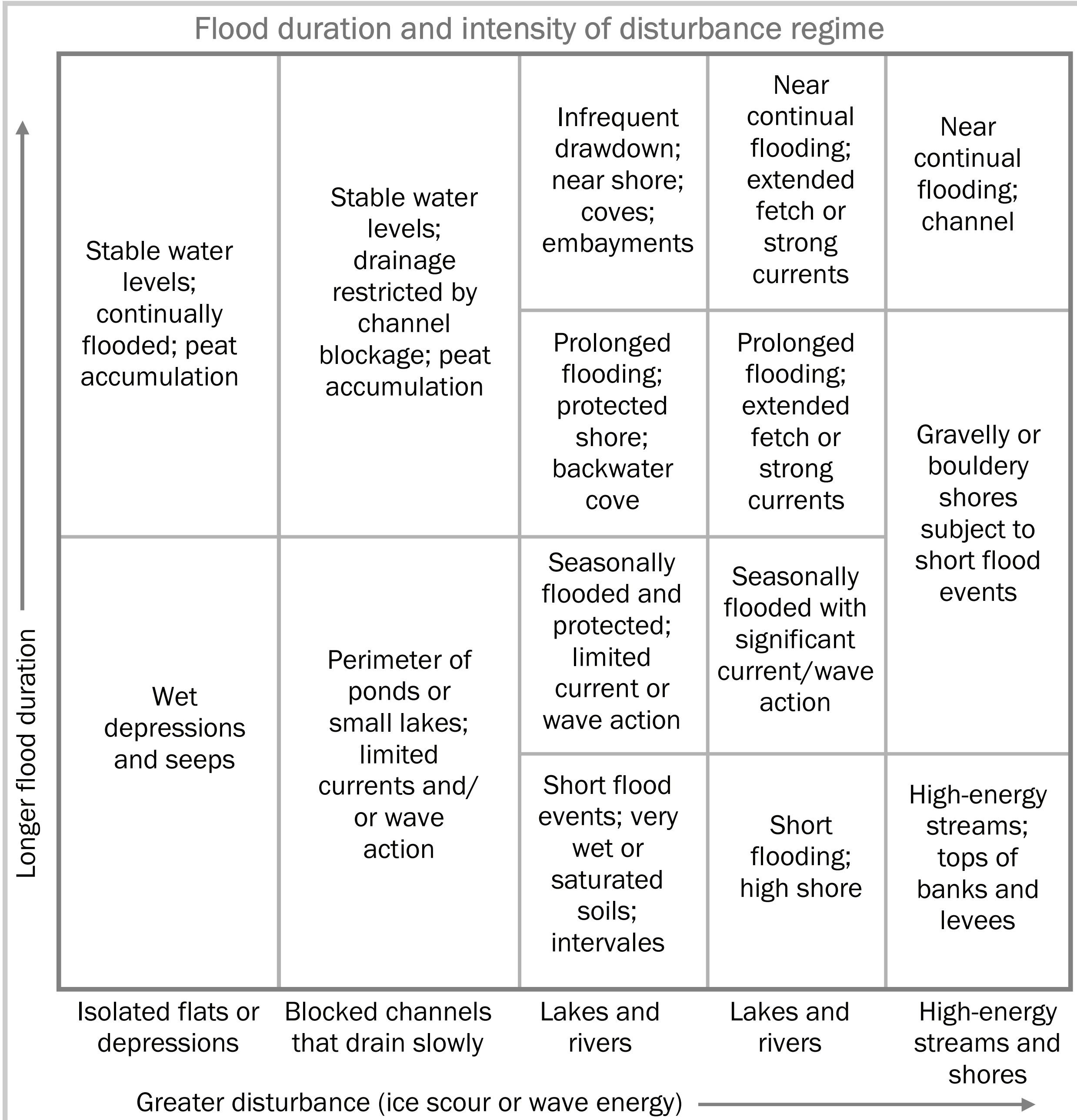
A vegetation gradient reflecting the transition from high to low flooding and disturbance environments is depicted in the vegetation in this scene from the Eastern Lowlands Ecoregion. Low grasses and sedges line the water's edge, followed in sequence by more robust grasses and ferns, and speckled alders (tall shrubs).

Diversity of Wetland Types

The interaction of flooding and disturbance events translates into a diversity of wetland forms and vegetation, from raised bogs with their stunted shrubs to floodplains with imposing stands of silver maple. There have been many approaches to distinguishing between wetland types, some emphasizing the position of the wetland in the landscape, others the water chemistry, and still others the major vegetation types. One of the more comprehensive and practical schemes is the Canadian Wetland Classification System (CWCS) as described by the National Wetland Working Group. It is based on five major classes that capture a range of hydrology, with accompanying changes in nutrient availability, rates of decomposition, and characteristic vegetation. These are bog, fen, swamp, marsh, and shallow open water.

Sandy beaches with a broad fetch (distance over water where wind may effect wave action) are high-energy environments that typically support sparse vegetation.

A simple way of distinguishing among these five classes or wetland types is to consider two broad categories: peatlands and mineral wetlands. Peatlands, defined by their thick layer of organic matter, or peat,



The edatopic grid for wetlands in New Brunswick. The illustration above describes ecological site types in terms of their flood duration and disturbance regime intensity. The grid on the following page identifies the typical vegetation associated with those conditions.

form in areas of blocked or restricted drainage such as small depressions or where glacial or other deposits have restricted the flow of surface water. Peatlands are further divided into bog or fen, depending on the extent of peat accumulation and the nature of ground water influence. Wetlands with discernable water flow or fluctuation tend not to develop appreciable layers of peat and are, therefore, on mineral soils, hence the term mineral wetlands. Mineral wetlands are generally in the form of swamps, marshes

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Typical vegetation

<table>
<tr><td>Bog ponds or shallow open water</td><td colspan="2">Shallow open water
-floating-leaved species including pond lilies</td><td>Shallow open water
-submerged species</td><td>Limited vascular plants</td></tr>
<tr><td rowspan="2">Bogs
-Sphagnum
-ericaceous shrubs
-stunted spruce</td><td rowspan="2">Fens
-Sphagnum
-ericaceous shrubs
-spruce and tamarack
-sedges
-on calcareous sites: sedges and grasses</td><td>Low marsh
-robust emergents; cattails</td><td>Low marsh
-reeds and plants with basal rosettes or creeping stems</td><td rowspan="2">Patchy vegetation
-mat-forming plants with creeping stems</td></tr>
<tr><td>Shrubs
-alder
-meadow sweet</td><td>Shrubs
-sweet gale
-meadow sweet
-willow</td></tr>
<tr><td rowspan="2">Wooded conifer swamp
-spruce
-cedar
-moss understory</td><td rowspan="2">Shrubs and meadows
-alders
-ericaceous shrubs
-grasses and sedges</td><td>High marsh
-robust leafy emergents</td><td>High marsh
-sedges, grasses, and dicots</td><td>Shrubs and patchy vegetation</td></tr>
<tr><td>Silver maple swamp</td><td>Poplar, willow, and red ash</td><td>Balsam poplar and willow</td></tr>
<tr><td>Isolated flats or depressions</td><td>Blocked channels that drain slowly</td><td>Lakes and rivers</td><td>Lakes and rivers</td><td>High-energy streams and shores</td></tr>
</table>

Longer flood duration

Greater disturbance (ice scour or wave energy)

The edatopic grid for New Brunswick wetlands. The illustration above describes the typical vegetation makeup for the flooding duration and intensity of disturbance regime described by the grid on the facing page.

(either coastal or freshwater), or shallow open water. We shall examine each wetland type in turn, beginning with the two peatland types.

Peatlands

Peatlands are essentially living carpets of mosses and other plants overlying layers of older, partly decayed organic material. Their development results from the gradual accumulation of these older plant materials, whose decomposition rate is slowed by acidic

A true bog with stunted black spruce trees. The shrub layer is dominated by species of the family *ericaceae*, which includes blueberry and lambkill.

conditions, cool temperatures, and the low oxygen levels that result from saturation or standing water. At a continental scale, New Brunswick is in a zone where the surface vegetation and the partially decayed plant material are composed mostly of *Sphagnum* mosses. Peatlands have been developing in New Brunswick since the most recent glacial retreat 11,000 years ago, and in places the depth of accumulated peat has reached 9m above the underlying mineral soil.

The visual appearance of peatlands varies markedly from one region to another. They may be dome-shaped or relatively flat. They can be surrounded by a well defined depression called a lagg, or by shrub swamp or marsh, to form a wetland complex. Pools on their surface can appear in varied sizes and may be arranged either linearly or randomly. Some surfaces are undulating, with hummocks and depressions, whereas others display a virtual lawn of colourful mosses and sedges.

Bogs

As organic matter accumulates in a peatland, its living surface gradually rises above the influence of the groundwater table. If the surface vegetation reaches the point of being isolated from groundwater, then rainfall and other atmospheric deposition become the only sources of nutrient input. Such peatlands are called ombrogenous (nourished only by rain) systems and, by definition, are true bogs. The low nutrient availability explains the nature of the vegetation: small or relatively slow-growing species that are capable of storing resources over long periods. These include mosses, lichens, low evergreen shrubs (such as leather-leaf and Labrador-tea), and stunted spruce or tamarack.

In addition to ericaceous shrubs, fens typically support grasses and sedges in greater abundance than do bogs.

Fens

If the surface vegetation of a peatland maintains at least some contact with flowing water that has contacted mineral substrates, it receives nutrients from those substrates. These peatlands are called fens. Fens contrast with bogs, where the only water input to the surface vegetation layers comes from precipitation. In fens, lateral flow and contact with mineral substrates tend to reduce acidity of the water and to increase oxygenation. Whether a peatland develops into a bog or remains a fen is determined by the extent of water flow and fluctuation, and by water chemistry.

A peatland composed of two domed bogs separated by an alder swamp growing alongside a low energy stream (flowing left to right). Lying between the green bog and the stream is the fen zone (yellow-brown colour).

Fens cover a wide range of nutrient conditions and their vegetation varies accordingly. Where mineral nutrients are in short supply, many of the species characteristic of bogs are present. On sites with rich ground water input, distinctive plant assemblages are found. Some features of these rare and rich sites include the presence of brown mosses, in addition to *Sphagnum*, and also more nutrient-demanding plants: shrubby cinquefoil, sedges (such as livid sedge), and some stunning orchid species, including grass-pink and swamp-pink (dragon's mouth). Most New Brunswick peatlands may be subdivided into true bogs and nutrient-poor fens. Raised bogs often exist side by side with sections of fen that merge into shrub swamp or some other non peat-forming system.

Mineral Wetlands

The environment of wetlands along active streams, rivers, or large lakes is not conducive to peat formation and, instead, gives rise to non-peat-forming systems. These fall into any of three wetland types: swamp, marsh, or shallow open waters, the last of which represents small bodies of standing water that are transitional to ponds or lakes. Swamp occurs on the highest portion of the shore, while shallow open waters may be scattered throughout or at the edge of the deepest marsh.

Swamps

Swamps are recognized by the dominance of woody vegetation and include both shrub-covered and forested wetlands. The range in cover type reflects a gradient from the brief, high-energy episodes of runoff along streams to the extended periods of flooding or soil saturation in the floodplains of large rivers. Shrub swamps often occur along meanders of streams or small rivers, sometimes consisting of only a narrow band of alder with meadow-sweet, dogwood, or other shrubs. Where the substrate remains moist for longer periods, alder swamps often support a rich understorey of

This silver maple swamp has a dense understorey of sensitive fern and the ostrich fern, more commonly known as the popular wild food, the fiddlehead.

ferns, sedges, violets, and other species. Along lakeshores, extensive cover by sweet gale is more common.

The abundance of streams and small rivers in the province creates a large number of areas suitable for the development of shrub swamps. However, the collection of streams over large distances necessarily creates rivers, and it is along the shores of major watercourses that we are more likely to find the distinctive treed swamps dominated by silver maple. Imposing stands of silver maple are found along the lower Saint John River and Oromocto River floodplains, as well as along other waterways that roll into the Grand Lake Lowlands. These silver maple swamps are perhaps the most regionally significant wetland type in the province. Although they are characteristic of floodplains in the southern parts of Ontario and Québec, they are absent elsewhere in the Maritimes. Away from the lowland river valleys, treed swamps also occur in uplands where soil drainage is poor. On acidic and oxygen-poor sites, these swamps are typically dominated by tamarack or black spruce and bog-like understorey vegetation; where the soils are less acidic and relatively well oxygenated, they may be dominated by various combinations of eastern white cedar, white spruce, red maple, and black ash.

Freshwater Marsh

Marshes are perhaps the most commonly recognized type of wetland. Home to fish, waterfowl, frogs, and muskrat, they are transitional in flooding duration and depth between the less inundated swamps and the more submerged shallow water wetlands. The so-called high marsh, or meadow, experiences intermittent or seasonal flooding, whereas low marsh undergoes prolonged or permanent flooding. Some of the largest wetland complexes in the province are marsh, with dominant vegetation consisting of robust emergent species such as cattail, river bulrush and soft-stem bulrush.

Cedar swamps have a relatively short period of flooding compared with silver maple swamps.

Coastal Marsh

Freshwater marsh dominated by cattails. *Photograph courtesy of Ducks Unlimited Canada.*

Coastal marshes are found in saline, coastal settlings that are sufficiently protected from wave action to allow for the accumulation of sediment and organic matter. They are characterized by species known as *halophytes* that are adapted to periodically flooded, saltwater environments.

As with their freshwater equivalents, saltwater marshes are divided into high and low marsh. High salt marsh generally lies above the mean high tide and is flooded only during the highest tides. Low salt marsh sits below the mean high tide and receives the daily tides. Low marsh, in particular, is an uncommon and vulnerable habitat, subject to reshaping by ice, storm, and wave action. In low marsh, the number of vascular plants species is generally low. Salt-water cordgrass is most often the dominant vegetation. Salt-meadow grass is common in high marsh where it is often the major element in a mosaic with arrow-grass, glasswort, sea-milkwort, sea-lavender, seaside plantain and other salt and flood tolerant plants.

A coastal marsh, near Cocagne, Eastern Lowlands Ecoregion.

Much of New Brunswick's salt marsh no longer exists, having been protected from flooding by earthen dikes to make the land available for agriculture. In other places, salt marshes have been filled in to make the land suitable for buildings. Some of the largest remaining salt marsh complexes lie at the head of the Bay of Fundy and along the Northumberland oast, where they are a favourite haunt of birdwatchers eager for sightings of uncommon and migrating bird species.

Shallow Open Water

Shallow open water wetland type, Valley Lowlands Ecoregion. On average, waters here are less than 1 m deep.

It may seem unusual to refer to shallow open water as a wetland type. The definition best fits relatively small bodies of standing water, where the vegetation consists of floating-leafed or submerged species, with only limited presence of emergent species. In our context, the term *shallow open water* may be extended to areas along lakes or rivers that fit this description and, thus, includes both isolated depressions and elements of larger wetland complexes. Shallow open water generally occurs where flooding is of a depth or duration that precludes cover by emergent species; that is, flooding for 70% to 100% of the growing season, to summer depths of up to two metres.

The End of Our Ecological Story

The ecological gradients described in this chapter provide the basis for recognizing and, to some extent, explaining the ecological variation that may be seen when looking over a landscape from a good vantage point or flying over it at a low altitude. We have reviewed some examples of how species and ecosystems are distributed across the landscape, in terms of their underlying biotic and abiotic processes, and why in New Brunswick these patterns may be important in adapting forest and wetland management to address conservation of biological diversity.

The physical landform-soil template, or edatopic grid, is the basis for variation in forest composition and rates of ecological processes at the ecosite level of classification. Wetland types have been described in this chapter in some detail to show their variation with respect to gradients of disturbance and flooding.

In the next chapter, we will build on the discussion presented here, moving from general patterns to specific instances as we further examine the distribution patterns of forest species, forest types, and wetland types as they relate to the physical attributes of New Brunswick's ecoregions.

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