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LAGGS OF RAISED BOGS IN COASTAL BRITISH COLUMBIA, CANADA: HYDROLOGY, HYDROCHEMISTRY, AND VEGETATION AT THE MIRE MARGIN

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SUMMARY

We studied water levels, hydrochemistry, vegetation, and peat characteristics of 17 lagg transects in coastal British Columbia, Canada. Based on field observations, the laggs were classified into two hydrotopographic lagg forms: [1] marginal depression, and [2] flat transition. We split these forms into four vegetative types: [a] *Spiraea* thicket, [b] *Carex* fen, [c] peaty forest, and [d] direct transition to forest (without an ecotone). Greater understanding of regional lagg types contributes to better management, helps identify conservation sites, and allows for improvement of restoration plans for raised bogs in coastal British Columbia.

KEY WORDS: raised bog, lagg, classification, hydrology, conservation

INTRODUCTION

The lagg is an integral part of the hydrological system of a bog because it sustains a high water level in the peat mass (Schouwenaars, 1995). The traditional definition of lagg is usually limited to an ecotone plant community that develops at the edge of a bog where waters from the bog and adjacent mineral landscape mix, but this ecotone is not evident in all cases. For the purposes of this study, a lagg zone is defined as the hydrologic and vegetative transition zone at the margin of a bog, regardless of whether an ecotone is present.

Bogs are common along the coast of British Columbia (BC), in some areas covering up to 75% of the terrain (National Wetlands Working Group (NWWG), 1988). Many bogs in coastal BC, particularly those near urban areas, such as Vancouver, have been subject to disturbance and drainage. Often, the lagg zone at the bog margins is the first part lost (or degraded), usually to agricultural use, because it is drier and more physically stable than the peat mound of the bog. Thus, restoration or conservation programs need to incorporate the lagg zone to ensure bog hydrology is maintained (Schouwenaars, 1995; Howie and Tromp-van Meerveld, 2011).

To develop a better understanding of the laggs of raised bogs in coastal BC, we studied seventeen lagg zones in the region, specifically looking at summer water levels, hydrochemistry, vegetation, and peat characteristics. Annual precipitation ranges from <1000 mm to >3000 mm amongst the different coastal areas studied (NWWG, 1988), leading to a variety of peatland types. In this paper, we describe the results of our lagg studies, particularly how varying hydrotopography of the lagg zone relates to hydrochemistry, tree basal area, and vegetation forms. We also discuss how hydrochemistry, and ash content and humification of peat, varied across the lagg transects.

METHODS

Thirteen bogs were studied in the coastal BC area. The bogs were located in Haida Gwaii (Graham Island), the Prince Rupert area, the east and west coasts of Vancouver Island, and the Greater Vancouver area. For each bog, we located one or more lagg zones, such as a transition to an upland forest or to a riparian area. Transects were installed perpendicular to the lagg zone, starting in the bog and ending in the forest adjacent to the bog. The five sampling locations along transects were as follows: 1) inside the bog, 2) between bog and lagg (closer to bog), 3) between bog and lagg (closer to lagg), 4) approximate centre of the lagg, and 5) outside the bog. For each transect, these five locations were determined in the field based on broad vegetative characteristics that indicated the position along the lagg transition. All locations were recorded with an Oregon 300 handheld GPS unit, accurate to 5 metres, and the entire transect was surveyed with a rod and level.

At each of the locations along the transect, peat samples were collected at 5, 50, and 100 cm below the surface with an Eijkelkamp flag corer. For each of the peat core depths, the von Post level of humification was determined in the field using the method described by Rydin and Jeglum (2006). Peat samples from the three depths were then wrapped in plastic wrap and sealed in plastic freezer bags for laboratory analysis. Core samples were transported in a cooler and kept refrigerated up to one month, or frozen, until laboratory analysis was possible. In the lab, each 5-cm sample was weighed, oven-dried at 105 ºC for 24 hours and weighed again, and then dry-ashed in a 550 ºC oven for 24 hours and weighed a final time to determine the amount of mineral (i.e. non-organic) material in the sample. The depth of peat was recorded at each coring location as well. Using this depth information and the topographic survey, it was possible to draw a scaled profile of the lagg transition for each transect.

Piezometers were installed at each of the five peat coring locations to determine depth to water table. The piezometers were 1.5 m long, 25 mm diameter PVC pipe with a 0.40 m slotted length at the bottom. The piezometers were evacuated twice using a low-flow peristaltic pump prior to sampling. After recharge, depth to water table was measured with an electronic water level meter (Heron Instruments “Little Dipper”). A WTW Multiline P4 water quality meter, which was suitable for field measurements of bog water, was used to measure pH, electrical conductivity, temperature, redox, and dissolved oxygen. To minimize contact of sample water with the air, these field parameters were measured by inserting probes directly into the piezometers at a depth of 10-15 cm below the water table. Electrical conductivity readings were corrected for hydrogen ion concentrations using the formula: $EC_{corr} = EC_{measured} - EC_{H^+}$ (Rydin and Jeglum, 2006).

A low-flow peristaltic pump with plastic tubing was used to collect water samples, which were field-filtered with a 0.45 micron filter (Waterra FHT-45). The water samples for cation analysis were preserved with nitric acid. The water samples were analyzed for calcium, magnesium, sodium, potassium, acidity, and dissolved organic carbon at the Pacific Environmental Science Centre (North Vancouver).

At each of the five hydrology/chemistry study sites along each transect, a 5x5 m vegetation plot was sampled. In addition, in an extended 10x10 m plot, only the trees were sampled. Every tree in the 10x10 m plot (except seedlings shorter than 20 cm) was measured for height and diameter. A second, parallel transect of 5x5 m plots at a distance of 20 m from the first transect was also sampled. Cover and abundance of each species was recorded according to the Braun-Blanquet scale (Mueller-Dombois and Ellenberg, 1974).

RESULTS

Two general hydrotopographic lagg forms were identified from topographic surveys of the lagg transects: 1) marginal depression and 2) flat transition (Fig. 1). The marginal depression form consisted of a topographic low point at the edge of the bog where the water table was high due to pooling water. Using the conventional definition of lagg: a transition zone at the margin of a (usually raised) bog receiving water from both the bog and surrounding mineral ground (Damman and French, 1987; Howie and Tromp-van Meerveld, 2011). This form would be considered a "true lagg". In the flat transition form, the topographic gradient from bog to forest was relatively smooth, and the water table gradually declined across the bog margin (Fig. 1).

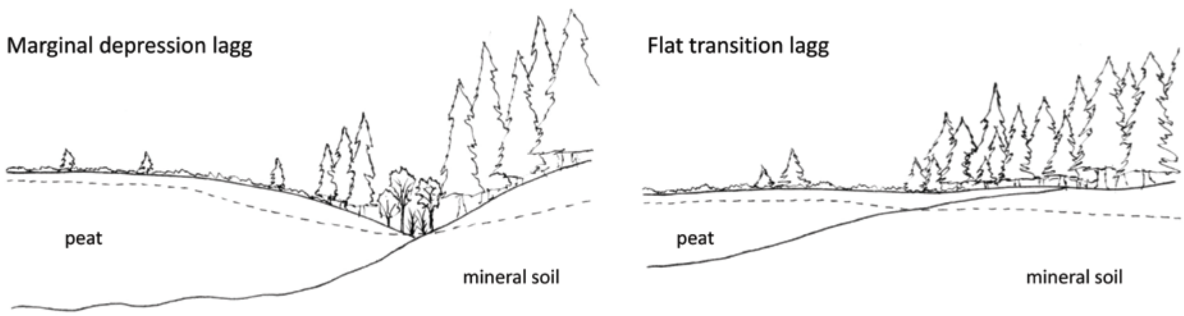

Figure 1: Two hydrotopographic lagg forms found in bogs of coastal British Columbia. The dashed line represents depth of the water table. The solid line represents the boundary between peat and mineral soil.

Tree basal area was a clear indicator of the hydrotopographic lagg forms. In the marginal depression form, pooling water inhibits tree growth, and resulted in a low basal area (0.0 – 7.2 m^2/ha in the lagg). For the flat transition form, the increasing depth to water table across the transect resulted in a gradual increase in basal area from bog to forest (9.6 – 67.2 m^2/ha in the lagg) (Table 1).

Within the nine marginal depression laggs, there were two broad vegetation types: *Carex* fen and *Spiraea* thicket. The *Carex* fen lagg type was characterized by a meadow of *Carex* species and (usually) *Sphagnum*. At two sites, *Myrica gale* grew with the *Carex*, reaching >75% cover in three of four plots. In the *Spiraea* thicket lagg type, a dense thicket of *Spiraea douglasii* dominated, with few other species present (mostly mosses, including *Sphagnum*). In half of the *Spiraea* thicket sites, *Carex* was present, with cover ranging from sparse (<5%) to abundant (>75%) depending on the openness of the *Spiraea* canopy. In British Columbia, a dense cover of *Spiraea douglasii* is generally associated with a swamp environment (MacKenzie and Moran, 2004).

The flat transition lagg category can be divided into two types: peaty forest and direct transition to forest (without an ecotone). These two lagg types had generally similar vegetation. Flat transition lagg plots contained mostly ericaceous shrubs (e.g. *Gaultheria shallon, Ledum groenlandicum, Empetrum nigrum, Vaccinium spp.)* and stunted trees (e.g. *Thuja plicata, Picea sitchensis, Tsuga heterophylla*). The main difference in vegetation was average *Sphagnum* cover (peaty forest: 2.5%; direct transition: 47.3%). The peaty forest sites in the Greater Vancouver area contained tall trees (20-30 m). In the peaty forest lagg type, peat samples from the lagg and adjacent forest contained low levels of mineral material (<6% ash content; avg. 2.6%). In contrast, where the bog transitioned directly to forest, 77% of the peat samples from the lagg and forest contained more mineral material (2 - 92% ash content; avg. 39%) than the peaty forest samples. Ash content of peat samples generally increased from bog to lagg, and this parameter was often a good indicator of the location of the lagg zone, except in the peaty forest laggs where ash content was low even in the forest sites.

Acidity, pH, dissolved organic carbon, and dissolved oxygen were similar in both hydrotopographic lagg forms. Concentrations of Ca^{2+}, Na^{+}, K^{+}, and Mg^{2+} (and, consequently, electrical conductivity) were generally higher across the flat transition laggs. Redox was also somewhat higher in the flat transition laggs (avg.: 147 mV; s.d.: 64) compared to the marginal depression lagg types (avg.: 96 mV: s.d.: 45). On average, calcium concentrations and pH of water increased across the transition from bog to forest for all lagg types. However, calcium concentrations did not increase consistently from bog to forest in 71% of the sites, but rather fluctuated along the transect, and pH increased gradually across the transition with no clear shift in pH from bog to lagg. The von Post values of the degree of humification for the peat samples varied widely at all three sample depths but, on average, increased consistently across the transects from bog to lagg, and with depth below surface, for all lagg types.

DISCUSSION AND CONCLUSION

We found two hydrotopographic lagg forms in coastal BC bogs: marginal depression and flat transition. Tree basal area changes may be considered as a good field indicator of the two hydrotopographic lagg forms. In cases where tree growth appears to be inhibited by a high water table at the bog margin, a marginal depression lagg may be present. Where basal area gradually increases across the transition from bog to forest, a flat transition lagg form is more likely. A marginal depression lagg form is likely indicated by a dense cover of *Carex* spp. (e.g. *C. sitchensis*) and *Sphagnum* spp. (*Carex* fen type), or *Spiraea douglasii* (*Spiraea* thicket type), at the edge of a bog. Percent ash content of soil samples may be the best way to determine the difference between the two types of flat transition lagg, whereby the peaty forest lagg has a much lower ash content.

Hydrochemical parameters may also be useful to differentiate between the two hydrotopographic forms, particularly concentrations of major cations, electrical conductivity, and redox (Table 1). Since bog water is characterized by low cation concentrations, so is the lagg water in marginal depression laggs (where bog water pools). In contrast, the flat transition lagg form tends to have a lower water table in the lagg, so it is likely more influenced by the chemistry of the lagg peat and the surrounding landscape than by bog water. Also, as the depth to water table increases, the oxygen content in the peat increases. As the soil environment becomes more oxidizing, the redox potential increases (Rydin and Jeglum, 2006). Consequently, the lower water table in the flat transition lagg sites resulted in a more oxidizing environment and likely produced higher redox values compared to the wetter lagg zones in the marginal depression sites.

Table 1: Measured range of values in "lagg" study location on transect for four vegetative lagg types in coastal British Columbia. For ash content, n=10-15 for each lagg type. For all other numerical parameters, n=4-5 for each lagg type.

Parameter	**Marginal Depression**		**Flat Transition**	
	***Carex* Fen**	***Spiraea* Thicket**	**Peaty Forest**	**Direct Transition**
Water table depth below surface (m) (avg.)	-0.02 – 0.21 (0.07)	0.03 – 0.41 (0.20)	0.19 – 0.47 (0.33)	0.14 – 0.50 (0.35)
Tree basal area (m^2/ha) (avg.)	0.2 - 7.2 (3.7)	0.0 – 2.7 (1.0)	11.5 – 67.2 (36.7)	9.6 – 25.4 (15.8)
Dominant vegetation	*Carex* spp., *Sphagnum* spp.	*Spiraea douglasii*	Ericaceous shrubs, stunted trees (some tall trees in peaty forest)	
Ash content of soil (%) (avg.)	2.2 – 71.8 (21.0)	3.0 – 94.7 (30.8)	0.0 – 5.4 (2.6)	1.6 – 83.4 (25.9)
Redox (mV) (avg.)	44 – 178 (107)	47 – 127 (87)	82 – 254 (159)	83 – 189 (138)
Electrical conductivity (µS/cm, corr.) (avg.)	23 – 84 (52)	25 – 78 (48)	18 – 117 (69)	60 – 238 (111)
Calcium (mg/l) (avg.)	1.3 – 4.0 (2.6)	1.8 – 3.8 (3.0)	1.3 – 4.6 (2.7)	2.0 – 10.9 (5.6)
pH (avg.)	4.27 – 6.29 (5.11)	4.17 – 5.47 (4.67)	3.64 – 5.42 (4.56)	4.07 – 6.02 (5.15)

For most lagg transects, calcium and pH were the best hydrochemical indicators of the transition from bog to lagg. These two parameters are commonly used when assessing the poor-rich gradient in peatlands (Tahvanainen, 2004). However, neither parameter was consistently useful in locating the exact position of the lagg along the transect, i.e. the transition was gradual for pH, and calcium concentrations often fluctuated along the transect.

We propose a classification of laggs of bogs on the west coast of Canada, based upon lagg hydrotopography, hydrochemistry, and vegetation. This classification of the forms and types of laggs will assist land managers in delineating representative and functional conservation areas that include the critical lagg zone for bogs by providing a list of lagg zone indicators. These results also establish measurable parameters to guide the restoration of natural laggs in the region.

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