Bryophytes: Messengers from the Past; Builders of the Future

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Boreal Peatlands

- Some definitions
- Why is there peat, ecosystem function
- Classifying peatlands – a history lesson
- The importance of bryophytes in peatlands
Peatlands –
Ecosystems that accumulate peat

A peatland is an area covered by peat to a minimal depth of 40 cm. Or another definition is: An area with or without vegetation with a naturally accumulated peat layer at the surface.

Functionally, peatlands are ecosystems wherein plant production exceeds decomposition that over the long term accumulate organic matter as a deposit of peat.
Let’s consider an alternative term: Mire

• A Mire is a wet area dominated by living, peat-forming plants.

• Fens and Bogs are peatlands and also Mires: Reclaiming to Mires takes 3-4 years, reclaiming to peatlands takes longer.
Peatlands: Why do we care?

- Abundant on the Alberta landscape
- Carbon/nitrogen stores
- Habitat for rare and endangered species
- Sensitive to disturbances
- Priority areas for First Nations Peoples
- Natural environmental filters
Important??

• In Britain, 45% of public water comes from watersheds draining peatlands.

• Historically, peat was used as litter for cavalry: One of Napoleon’s armies had 13,500 horses and needed 22,000 tonnes of peat in a year.

• Surgical dressings were made from *Sphagnum* in the Franco-Prussian War; by the Japanese in the 1904-05 war with Russia; and in World War I by both sides.

• And of course the peaty flavor of Scotch whisky is imparted by slowly drying ‘green malt’ over a smoldering peat fire.
Total peatland area = 365,160 km² or 21% land base

Vitt et al. (2000)
STRUCTURAL ELEMENTS

- Trees
- Shrubs
- Herbs
- Gramioids

- Brown Mosses
  - *Sphagnum*

- Roots:
  - Ectomycorrhizal
  - Ericoid
  - Non-infected

- Moss and Peat
  - Roots

- Above Ground Vascular Plant Production
- Vascular Plant Litter Ground Layer Annual NPP
- Acrotelm with Roots
- Catotelm
Global Carbon Accumulation of Peatlands Today

Atmospheric CO$_2$
- NPP: 307 g C m$^{-2}$ yr$^{-1}$
- Decomposition: 284 g C m$^{-2}$ yr$^{-1}$

Atmospheric CH$_4$
- Decomposition: 0.14 g m$^{-2}$ yr$^{-1}$

Pool = 133,000 g m$^{-2}$ of C

Accumulating C at 23 g m$^{-2}$ yr$^{-1}$
Global sink is 76 Tg yr$^{-1}$

Why is there peat?

- **Acidity** but rich fens are not acid
- **Cold climate** but there are large peatlands in the tropics
- **Oceanic climate** but continental Siberia and Canada have large peatlands
- **Mosses** but some tropical peatlands are dominated by woody plants
- **Sphagnum** but rich fens have little or none
- **Anaerobic conditions** TRUE for all peatlands
Anaerobic conditions

- Acrotelm – aerobic upper layer (surface to 50 cm)
- Catotelm – Anaerobic peat column (from 5-50 cm to bottom of peat column)
- The amount of time spent in the acrotelm determines the quality of material that the catotelm receives.
- Estimated that catotelm receives 5-10% of plant material after decomposition in acrotelm.
Peat Core Section

Acrotelm

Rooting depth

Catotelm
Peat: Mostly composed of bryophytes

Slide courtesy of Rose Bloise
Peat-Age curve for Alberta fens: Convex
So:

Peatlands are important on the Alberta landscape.
They accumulate peat.
The structure of the peat column is important.

Are all peatlands the same?
And how do bryophytes fit in?
Peatland (Mire) Site-types

• Historically peatlands were divided into
  – Hochmoore (bogs) and Niedermoorre (fens) by C.A. Weber in 1906.
  – Heinar DuRietz in the 1940’s observed that fens could be dominated by either *Sphagnum* or by true mosses. He called these poor fens and rich fens, but why????
  – Then Hugo Sjors, in the 1950’s, related chemistry to flora – and further recognized two types of rich fens (moderate and extreme) – but why these words???
Since then people have thought:

Poor vs. Rich: could mean –

• Poor or rich in nutrients
• Poor or rich in base cations
• Poor or rich in species richness
• But DuRietz and Sjors meant none of these things – they defined fens meaning poor and rich ‘in species with high fidelity’ to the fen type and secondly by chemistry (moderate vs. extreme).
Let’s look at species richness and at species with ‘high fidelity’.

*Paludella squarrosa*
Comparison of distribution of Sphagnaceae and Amblystegiaceae along pH gradient
Peatland Gamma Diversity

<table>
<thead>
<tr>
<th>Type of Peatland</th>
<th>n</th>
<th>Number of Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP = Permafrost Peatland</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>CB = Continental Bog</td>
<td>35</td>
<td>110</td>
</tr>
<tr>
<td>PF = Poor Fen</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>MRF = Moderate Rich Fen</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>ERF = Extreme Rich Fen</td>
<td>15</td>
<td></td>
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</tbody>
</table>

**Sphagnum**
- Total Species = 20

**Bryophytes**
- Total Species = 110
Indicators: Species that have high fidelity to particular site types

— Fens: “Bog Birch” [*Betula glandulosa*]

— Rich (circumneutral and alkaline) Fens: True mosses, *Larix laricina*

— Poor (acid) Fen: ‘wet’ *Sphagnum, Picea mariana*

— Bog: Cloudberry [*Rubus chamaemorus*], ‘hummock’ *Sphagnum [S. fuscum]* and lack of sedges
The Current View: Criteria for classifying peatlands
C.A. Weber’s view still holds: There are two fundamental types of peatlands based on source of the water: **Bogs and Fens**

Additionally, fens can have a number of water sources----
Flow
Source of Water

- Minerogenous (Fens)
  - Topogenous
  - Soligenous
  - Limnogenous
- Ombrogenous (Bogs)
Other criteria are found in

—Porewater Chemistry
Chemistry

Acidity       H^+
Alkalinity    HCO_3^-
Base Cations  Na^+, K^+, Ca^{2+}, Mg^{2+}
Nutrients     N, P
Relationship of Calcium to pH in Peatland Surface Water

[Graph showing the relationship between pH and calcium concentration (Ca) in peatland surface water, with data points indicating different peatland types: Rich Fens, Poor Fens, and Bogs.]
Canadian Wetland site-types:

**Peatlands:**
- Bogs
  - Continental bogs
  - Peat plateaus
  - Bogs with internal lawns
- Fens
  - Poor fens (= acid fens)
  - Rich fens (= circumneutral and alkaline fens)
    - Moderate (or transitional) -rich fens = circumneutral fens
    - Extreme-rich fens = alkaline fens
- Saline wetlands

**Non-peat-forming wetlands**
- Marshes
- Swamps
- Shallow open waters
Functional Attributes of Wetlands

- Mesotrophic
- Oligotrophic
- Eutrophic
- Total nutrient availability
- Production
- Decomposition
- Swamp
- Bog
- Poor Fen
- Moderate-Rich Fen
- Extreme-Rich Fen
- Fresh Water Marsh
- Tidal Marsh
- Saline Wetland
- Fresh Water
- Marsh
- Tidal Marsh
- Saline Wetland

- Base Cations, pH, Alkalinity
- Water Flow
- Water
- Shallow
- Open
- N, P, Water Level Fluctuation

- Wooded
- Sphagnum
- True Moss
- Open Water
The Importance of Mosses

- Sequester nearly all atmospheric deposition (N,P) – “’gatekeepers’”
- Resistant to decomposition
- Maintain water levels
- Form the base topography of the site
- Form majority of the peat column
- *Sphagnum*: inorganic acidity

Decomposition differences
True mosses – or the peristomate mosses

often called ‘brown mosses” due to dark reddish-brown color.

Historically placed in the family Amblystegiaceae, but currently considered to be largely a group of unrelated species.

*Sphagnum* – or the peat mosses

Unique class of mosses with two genera and about 200 species worldwide (21 in Alberta).

So what’s so unique about *Sphagnum*----
Morphology of *Sphagnum*

Alternating dead hyaline and living green cells.

Efficient water-holding capacity and wicking capacity – provides the base for water levels in peatlands
Water levels

- Pools
- Carpets
- Lawns
- Hummocks
Cell Walls of *Sphagnum*

Corollaries:
Decomposing *Sphagnum* peat releases previously sequestered cations downstream including Hg, Pb, Al, Ca, Na, Mg

*Sphagnum* yields efficient biofiltration systems
Acidification

*Sphagnum* and inorganic acidity

Let’s do an experiment. . .

Result

Take a handful of *Sphagnum* and place in distilled water (pH 5.5). Wait 5 min and measure pH--

pH 5.5

Add pinch of NaCl. Wait 5 min and measure pH--

pH 3.0-3.5
Dated peat profiles from long cores
The succession to fens and bogs

The Importance of *Sphagnum*

![Bar chart showing the pH distribution of Bogs, Poor Fens, and Rich Fens.](chart.png)
Questions and Comments
Peat Macrofossils

[Graph showing the percentage of various macrofossils over time, with age (cal year BP) on the y-axis and various taxa on the x-axis, including Sphagnum warnstorffii, Toleration nitens, Calliergon, Meesia, Cyperaceae, Picea needles, Charcoal, Scorpidium dominated fen, and Broad leaves.]
Vegetation: 4 layers

- Tree layer: single-stem woody plants
- Shrub layer: multiple-stemmed woody plants
- Field layer: herbaceous sedges/grasses
- Ground layer: bryophytes - pools / carpets / lawns / hummocks
Initiation

- Key to reclamation of disturbed sites is to base reclamation strategies on natural occurring events.

So how did peatlands in Alberta form in the past?

Initiation

Succession
Initiation

- Terrestrialization
- Paludification
- Primary Peat Formation
Terrestrialization

- Mineral Soil
- Lake Sediments
- Gyttja
- Moss Peat
- Sedge
- Bog/fen

Sample soil core
Sharp transition to mineral soil
Paludification

- Mineral Soil
- Woody Peat
- Moss Peat
- Bog/fen

Layers:
- Upland deposits
- Woody Peat
- Moss Peat
- Bog/fen

Sample soil core

Water Table
Conversion to carbon accumulation

**Fig. 11.** Physicochemical data, La Ronge bog. (Analysis by Linda Halsey.)

FROM P. KUHRY, L. HALSEY, S. BAYLEY, & D. VITT. 1992
Oligotrophic - Bog
Mesotrophic – Alkaline Fen
Secondary Bog and water track development
**SPHAGNUM-DOMINATED PEATLAND RESPONSE SURFACE**

From Gignac, Halsey & Vitt 2000
Fig. 4. Mire bryophyte species response surfaces in climatic space for western Canada; temperature = mean annual temperature; precipitation = precipitation during the growing season. A third climatic axis, length of the growing season, is not shown. Data from Gignac et al. 1991b.
Mean indicator values and tolerance ranges of macrofossil taxa for depth to water table, pH, and conductivity corrected for hydrogen ions ($K_{corr}$). *Limprichtia/Hamatocaulis* = *L. revolvens* (*Drepanoclados revolvens*) / *H. vernicosus* (*D. vernicosus*).