EXPLORING WASHINGTON’S PEATLAND DIVERSITY: ENVIRONMENTAL GRADIENTS & ASSOCIATED VEGETATION PATTERNS

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Seattle, WA
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Presentation Overview

• Introduction
  – peatland definition
  – bogs vs fens

• Environmental Gradients
  – regional gradients
    • climate
    • geology
    • biogeography
  – local gradients
    • hydrology
    • pH
    • nutrients
Presentation Overview

- **Introduction**
  - peatland definition
  - bogs vs fens

- **Environmental Gradients**
  - regional gradients
    - climate
    - geology
    - biogeography
  - local gradients
    - hydrology
    - pH
    - nutrients

- **General Vegetation Patterns**
  - dominant species vs. environmental gradients

- **WA Peatland Classification**
  - general peatland types
  - specific peatland types

- **WA Peatland Types**
  - review of Subgroups
What Are Peatlands?

- **Peat**
  - an accumulation of OM due to incomplete decomposition
  - forms *in situ*
What Are Peatlands?

- Peat
  - an accumulation of OM due to incomplete decomposition
  - forms *in situ*

- Peatland
  - peat-covered terrain
  - minimum peat depth criteria
    - 40 cm in USA/Canada
    - 30 cm in other countries
  - term for ‘bogs and fens’
  - distinctive vegetation
**Bogs vs. Fens**

Hydrological Criteria

- bogs are rain-fed (ombrotrophic)
Bogs vs. Fens

Hydrological Criteria

– bogs are rain-fed (ombrotrophic)
– fens are groundwater/surface-water fed (minerotrophic)
Bogs vs. Fens

Vegetation Criteria

Bogs

• **broad definition**: dominated by acid-loving plants & *Sphagnum* spp.
• **strict definition**: bogs *lack* minerotrophic species
Bogs vs. Fens

Vegetation Criteria

Bogs

- **broad definition**: dominated by acid-loving plants & *Sphagnum* spp.
- **strict definition**: bogs lack minerotrophic species

Fens

- dominated by sedges, various shrubs, various *Sphagnum* spp., brown mosses, etc.
Climate
Precipitation > Evapotranspiration

Mean Annual Precipitation (inches)
- 5 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 35
- 36 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- 71 - 80
- 81 - 90
- 91 - 100
- 101 - 110
- 111 - 120
- 121 - 140
- 141 - 150
- 151 - 170
- 171 - 180
- 181 - 200
- 201 - 240

Peatlands
Unique Geology
Phytogeography

- regional species pools
- embedded in the USNVC

- Vancouverian Province*
  - North Pacific

- Rocky Mountain Province*
  - Columbia Plateau
  - Rocky Mountain

Local Environmental Gradients

Cation Concentration / Soil Nutrients

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<th>Moist</th>
<th>Very Moist</th>
<th>Wet</th>
<th>Very Wet</th>
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*Wetland edatopic grid adapted from MacKenzie and Moran (2014) Wetlands of British Columbia*
Local Environmental Gradients

Cation Concentration / Soil Nutrients

Moist

Very Moist

Wet

Very Wet

Soil Moisture Regime

Hydrodynamics

pH

Stagnant

Sluggish

Mobile

Dynamic

Soil Moisture Regime

Very Poor

Poor

Medium

Rich

Very Rich

Hyper

Local Environmental Gradients

Cation Concentration / Soil Nutrients

Soil Moisture Regime

Moist

Very Moist

Wet

Very Wet

pH

Very Acidic

Acidic

Slightly Acidic

Neutral

Alkaline

Hydrodynamics

Stagnant

Sluggish

Mobile

Dynamic

Very Dynamic

*Bwearland edatopic grid adapted from MacKenzie and Moran (2014) Wetlands of British Columbia
General Vegetation Patterns

Abundance vs. pH

- Sphagnum spp.
- Ericaceous shrubs
General Vegetation Patterns

Abundance vs pH

- Sphagnum spp.
- Ericaceous shrubs
- Brown mosses
- Cyperaceae
- Deciduous shrubs
WA *Sphagnum* Distribution

**Relation to Water Level**

- Hollow
- Intermediate
- Hummock

**pH / nutrients**

- Ombrotrophic
- Oligotrophic
- Mesotrophic
- Eutrophic

- *S. capillifolium*
- *S. fuscum*
- *S. austinii*
- *S. rubellum*
- *S. russowii*
- *S. palustre*
- *S. magellanicum*
- *S. angustifolium*
- *S. alaskense*
- *S. papillosum*
- *S. subnitens*
- *S. pacificum*
- *S. mendocinum*
- *S. miyabeum*
- *S. girgensohnii*
- *S. squarrosum*
- *S. teres*
- *S. warnstorffii*
- *S. riparium*
- *S. teres*
- *S. squarrosum*
## General Patterns & Peatland Types

<table>
<thead>
<tr>
<th>Colloquial</th>
<th>Technical</th>
<th>Types</th>
<th>Mosses</th>
<th>Plants</th>
<th>Water source</th>
<th>pH</th>
<th>Base cations</th>
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<td><em>Sphagnum</em> (oligotrophic)</td>
<td>Ericaceous shrubs, few herbaceous</td>
<td>precipitation</td>
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<td><strong>Bog</strong></td>
<td><strong>Fen</strong></td>
<td>Poor Fens</td>
<td><em>Sphagnum</em> (oligotrophic)</td>
<td>Sedges, Ericaceous shrubs, stunted trees</td>
<td>surface / groundwater</td>
<td>4.0-5.5</td>
<td>low</td>
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<td>Intermediate Fens</td>
<td><em>Sphagnum</em> (minerotrophic) to “brown mosses”</td>
<td>Graminoids; short willows, bog birch</td>
<td>surface / groundwater</td>
<td>5.5-7.0</td>
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<td><strong>Fen</strong></td>
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<td>Shrub Carrs</td>
<td><em>Sphagnum</em> (minerotrophic) to “brown mosses”</td>
<td>Tall willows, alder, graminoids;</td>
<td>surface / groundwater</td>
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<td>moderate</td>
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<td><strong>Various</strong></td>
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<td>Extremely Rich Fens</td>
<td>“Brown mosses”</td>
<td>Calciophiles; graminoids, shrubs</td>
<td>surface / groundwater from ultramafic/basic bedrock</td>
<td>&gt;6.8</td>
<td>high</td>
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WA Peatland Classification

- **Framework**
  - U.S. National Vegetation Classification
  - general peatland types

- **Supervised / expert-based classification**
  - literature / field experience
  - primary ecological drivers and vegetation diversity

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WA Peatland Classification

- Supervised / expert-based classification

- Collect vegetation, pH, and EC data to refine units
  - 306 vegetation plots at 148 sites
  - classify plots to peatland type & Subgroup in field

- NMS ordination to discern vegetation patterns

- Descriptive statistics to summarize pH & EC
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pH of Peatland Types

- Open Bogs: n = 12
- Bog Woodlands: n = 11
- Poor Fens: n = 35
- Intermediate Fens: n = 29
- Shrub Carrs: n = 25
- Extremely Rich Fens: n = 5

The pH values range from 3 to 9, with each peatland type exhibiting a distinct distribution.
pH of Subgroups

Peatland Type
- Open Bogs
- Bog Woodlands
- Poor Fens
- Intermediate Fens
- Shrub Carrs
- Extremely Rich Fens

Subgroup

n = 5
n = 6
n = 11
n = 5
n = 11
n = 12
n = 17
n = 5
n = 12
n = 7
n = 5
n = 17
n = 5
n = 12
n = 3
n = 10
n = 5
n = 6
n = 1
n = 5
n = 5
n = 1
Electrical Conductivity of Peatland Types

Electrical Conductivity (uS/cm)

- Open Bogs: n = 4
- Bog Woodlands: n = 5
- Poor Fens: n = 17
- Intermediate Fens: n = 24
- Shrub Carrs: n = 4
- Extremely Rich Fens: n = 25
Electrical Conductivity of Peatland Types

Electrical Conductivity (µS/cm)

Peatland Type
- Open Bogs
- Bog Woodlands
- Poor Fens
- Intermediate Fens
- Shrub Carr
- Extremely Rich Fens

Subgroup

n = 1
n = 2
n = 3
n = 4
n = 5
n = 6
n = 7
n = 10
n = 12
n = 16
n = 3
n = 4
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<th>Peatland Type</th>
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| Open Bogs            | North Pacific Open Raised Bog  
|                      | North Pacific Open Flat Bog  
|                      | North Pacific Open Transitional Bog                                           |
| Bog Woodlands        | North Pacific Raised Bog Woodland  
|                      | North Pacific Bog Woodland  
|                      | North Pacific Coastal Bog Woodland                                           |
| Poor Fens            | North Pacific Lowland Open Poor Fen  
|                      | North Pacific Montane Poor Fen  
|                      | North Pacific Open Transitional Poor Fen  
|                      | Rocky Mountain Poor Fen  
|                      | Rocky Mountain Patterned Fen                                                  |
| Intermediate Fens    | North Pacific Lowland Intermediate Fen  
|                      | North Pacific Montane Intermediate Fen  
|                      | Rocky Mountain Intermediate Fen                                               |
| Shrub Carr           | Rocky Mountain Shrub Carr                                                    |
| Extremely Rich Fens  | North Pacific Serpentine Fen  
|                      | Columbia Plateau Alkaline Fen & Seep  
|                      | Rocky Mountain Calcareous Fen                                                 |
Open Bogs
(Beal’s smoothing applied)

Subgroups
- North Pacific Open Flat Bog
- North Pacific Open Transitional Bog
- North Pacific Raised Open Bog

Original Subgroups NOT Significantly Different
- NP Coastal Open Flat Bog ~ NP Open Flat Bog
- NP Coastal Open Flat Bog ~ NP Open Raised Bog
North Pacific Open Raised Bog Subgroup

- short-statured Ericaceous shrubs >60%
- *Sphagnum* > 80%
- *Carex* <1%; deciduous shrubs <5%
- conspicuously raised surface
- summer fog likely critical

http://www.josephrocchiophotography.com/p133163904/h84171e47#h84171e47
North Pacific Open Flat Bog Subgroup

- Ericaceous shrubs >75%
- *Sphagnum* > 40%; *Carex* <5%
- deciduous shrubs <5%
- ombrotrophic / semi-ombrotrophic

North Pacific Open Transitional Bog Subgroup

- Ericaceous shrubs >40%
- *Sphagnum* > 40%
- deciduous shrubs + *Carex* >15%
- semi-ombrotrophic
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Bog Woodlands

Subgroups
- North Pacific Bog Woodland
- North Pacific Coastal Bog Woodland
- North Pacific Raised Bog Woodland

Original Subgroups NOT Significantly Different
- NP Bog Woodland ~ NP Poor Treed Fen
- NP Coastal Bog Woodland ~ NP Coastal Poor Treed Fen
North Pacific Raised Bog Woodland Subgroup

- stunted shore pine / western hemlock
- Ericaceous shrubs >25%
- *Sphagnum* > 75%
- *Carex* <1%
- conspicuously raised surface
- ombrotrophic
North Pacific Bog Woodland Subgroup

- Ericaceous shrubs >75%
- *Sphagnum* < 20%
- *Carex* <5%
- dense shrub understory
- ombrotrophic / semi-ombrotrophic

North Pacific Coastal Bog Woodland Subgroup

- Ericaceous shrubs >25%
- *Sphagnum* > 20%
- *Carex* >10%
- open shrub understory
- ombrotrophic / semi-ombrotrophic
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Poor Fens
(Beal’s smoothing applied)
North Pacific Lowland Poor Fen

- Carex > 25%
- Ericaceous shrubs <10%
- Sphagnum > 40%
- low elevation species
- pH < 5.5

North Pacific Montane Poor Fen

- Carex > 25%
- Ericaceous shrubs <10%
- Sphagnum > 40%
- high elevation species
- pH < 5.5
North Pacific Transitional Poor Fen

- Carex > 50%
- Ericaceous shrubs < 10%
- Sphagnum < 10%
- pH < 5.5

Rocky Mountain Poor Fen

- Kalmia microphylla, Drosera rotundifolia, Scheuchzeria palustris ssp. americana
- Sphagnum > 75%
- pH 5.0 – 6.0
Rocky Mountain Patterned Fen

- no vegetation indicators
- unique ribbed pattern
- strings & flarks
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<td></td>
<td>North Pacific Open Transitional Poor Fen</td>
</tr>
<tr>
<td></td>
<td>Rocky Mountain Poor Fen</td>
</tr>
<tr>
<td></td>
<td>Rocky Mountain Patterned Fen</td>
</tr>
<tr>
<td>Intermediate Fens</td>
<td>North Pacific Lowland Intermediate Fen</td>
</tr>
<tr>
<td></td>
<td>North Pacific Montane Intermediate Fen</td>
</tr>
<tr>
<td></td>
<td>Rocky Mountain Intermediate Fen</td>
</tr>
<tr>
<td>Shrub Carr</td>
<td>Rocky Mountain Shrub Carr</td>
</tr>
<tr>
<td>Extremely Rich Fens</td>
<td>North Pacific Serpentine Fen</td>
</tr>
<tr>
<td></td>
<td>Columbia Plateau Alkaline Fen &amp; Seep</td>
</tr>
<tr>
<td></td>
<td>Rocky Mountain Calcareous Fen</td>
</tr>
</tbody>
</table>
Intermediate Fens & Shrub Carrs

Subgroups
- North Pacific Lowland Intermediate Fen
- North Pacific Montane Intermediate Fen
- Rocky Mountain Intermediate Fen
- Rocky Mountain Shrub Carr

Axis 1
Axis 2
Axis 3
Western WA
Eastern WA
Shrubland
Herbaceous
North Pacific Lowland Intermediate Fen

- deciduous shrubs + *Carex* > 50%
- Ericaceous shrubs <10%
- *Sphagnum* <10% (minerotrophic spp.)
- pH > 5.5

North Pacific Montane Intermediate Fen

- deciduous shrubs + *Carex* > 50%
- Ericaceous shrubs <10%
- *Sphagnum* <10% (minerotrophic spp.)
- *high elevation species*
- pH > 5.5
Rocky Mountain Intermediate Fen

- Carex dominated
- short Salix (S. farriae, S. planifolia) Betula glandulosa, Eleocharis quinqueflora
- minerotrophic Sphagnum <10%
- pH 5.5 – 6.0

Rocky Mountain Shrub Carr

- tall Salix (S. drummondiana, S. geyeriana)
- Alnus (A. incana, A. viridis)
- floristically similar to fens & shrub swamps
- hydrologically most similar to fens
- pH > 6.5
<table>
<thead>
<tr>
<th>Peatland Type</th>
<th>WA Subgroups</th>
</tr>
</thead>
</table>
| Open Bogs           | North Pacific Open Raised Bog  
                       | North Pacific Open Flat Bog  
                       | North Pacific Open Transitional Bog |
| Bog Woodlands       | North Pacific Raised Bog Woodland  
                       | North Pacific Bog Woodland  
                       | North Pacific Coastal Bog Woodland |
| Poor Fens           | North Pacific Lowland Open Poor Fen  
                       | North Pacific Montane Poor Fen  
                       | North Pacific Open Transitional Poor Fen  
                       | Rocky Mountain Poor Fen  
                       | Rocky Mountain Patterned Fen |
| Intermediate Fens   | North Pacific Lowland Intermediate Fen  
                       | North Pacific Montane Intermediate Fen  
                       | Rocky Mountain Intermediate Fen |
| Shrub Carr          | Rocky Mountain Shrub Carr |
| Extremely Rich Fens | North Pacific Serpentine Fen  
                       | Columbia Plateau Alkaline Fen & Seep  
                       | Rocky Mountain Calcareous Fen |
Extremely Rich Fens

Subgroups
- North Pacific Serpentine Fen
- Rocky Mountain Calcareous Fen
- Columbia Plateau Alkaline Fen and Seep

Axes:
- Axis 1: Eastern WA
- Axis 2: Western WA
- Axis 3

Markings:
- Minimal moss cover
- Brown moss dominated
North Pacific Serpentine Fen

- *Triglochin maritima, Argentina egedii*
- *Carex viridula, C. interior*
- pH > 6.5; EC > 350 uS/cm
Columbia Plateau Alkaline Fen & Seep

- *Carex hystericina, C. diandra*
- shallow peat
- at or below lower treeline
- pH > 7.0; EC > 150 uS/cm

Rocky Mountain Calcareous Fen

- *Carex flava, C. gynocrates, Salix brachycarpa, S. candida, Symphyotrichum boreale*
- pH > 6.8; EC > 200 uS/cm
- calcareous bedrock
# Peatlands & Rare Plants

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>Total Numbers</th>
<th>% of Wetland Rare Plants (147)</th>
<th>% of All Rare Plants (328)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Peatland Types</td>
<td>43</td>
<td>29%</td>
<td>13%</td>
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<tr>
<td>Bogs and Poor Fens</td>
<td>22</td>
<td>15%</td>
<td>7%</td>
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<tr>
<td>Intermediate Fens</td>
<td>9</td>
<td>6%</td>
<td>3%</td>
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<tr>
<td>Extremely Rich Fens</td>
<td>12</td>
<td>8%</td>
<td>4%</td>
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<tr>
<td>Marsh</td>
<td>16</td>
<td>11%</td>
<td>5%</td>
</tr>
<tr>
<td>Marsh</td>
<td>16</td>
<td>11%</td>
<td>5%</td>
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<tr>
<td>Wet Meadow/Seasonal Wetlands</td>
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<td>29%</td>
<td>13%</td>
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<tr>
<td>Wet Prairie</td>
<td>6</td>
<td>4%</td>
<td>2%</td>
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<tr>
<td>Vernal Pool</td>
<td>18</td>
<td>12%</td>
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<tr>
<td>Swamps</td>
<td>16</td>
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<td>5%</td>
</tr>
<tr>
<td>Riparian</td>
<td>34</td>
<td>23%</td>
<td>10%</td>
</tr>
<tr>
<td>Alkaline</td>
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<td>5%</td>
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</tr>
<tr>
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<td>1%</td>
<td>0%</td>
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<tr>
<td>Wet Cliffs/Spray Zones</td>
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<td>8%</td>
<td>4%</td>
</tr>
<tr>
<td>Seep/Springs</td>
<td>16</td>
<td>11%</td>
<td>5%</td>
</tr>
<tr>
<td>Salt Marsh/Tidal</td>
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<td>1%</td>
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</tr>
</tbody>
</table>
Conclusions

WA Peatland Types

- 18 Subgroups
- reflect vegetation patterns
- reflect ecological gradients
  - more effectively assess threats / restoration goals
  - effective conservation targets
Conclusions

Peatlands are important for rare plant conservation
Acknowledgements

- EPA, Region 10 Wetland Program Development Grants
- Rex Crawford (former WNHP vegetation ecologist)
- Linda Kunze (former WNHP wetland ecologist)
- Sarah Howie (Corporation of Delta, BC)
- Judy Harpel (Curator of Bryophytes, UBC Herbarium)
- Miles Berkey (bryologist)
Peatland Types

Peatland Type
- Open Bogs
- Bog Woodlands
- Poor Fens
- Intermediate Fens
- Shrub Carrs