Introduction to PNW Ecosystems

I. Physical & Chemical (Abiotic) Environment of WA
1. Where are we?: global / continental position
2. An overview of our place: regional geography & landforms
3. How are landforms created?
4. The importance of geology at multiple scales
5. Climate

II. Ecological Zones of WA
1. Ecoregions
2. Ecoregions: a virtual field trip
3. Environmental determinants of ecoregions

The Ecology of Washington

I. Abiotic Environment of WA

1. Global / Continental Position
2. Regional Geography & Landforms
3. Forces Behind Landforms
4. Geology
5. Climate

Global / Continental Position

1. A) Where are we?
   - Latitude:

   It affects our

   I. Present-day Climate
   1) Precipitation & Temperature
   2) Daily & Seasonal Changes

   II. Past Environment
   1) Past Climate
   2) Geological history
      (and hence present day geology)
Global / Continental Position

B) What are the ecological implications of our position?

It affects our

I. Present-day Climate
   1) Precipitation & Temperature
      A. Atmospheric circulation
      B. Oceanic circulation
      C. Maritime influences
   2) Daily & Seasonal Changes

II. Past Environment
   1) Past Climate
      2) Geological history

Atmospheric Circulation is a major determinant of global precipitation & temperature patterns

1. Sunlight energy greatest near equator

2. Results in warm, rising air at low latitudes

Atmospheric Circulation is a major determinant of global precipitation & temperature patterns

3. Rising air cools & rain falls abundantly at low latitudes

Atmospheric Circulation is a major determinant of global precipitation & temperature patterns

4. Rising air leaves low pressure area behind.
   Surface air from N and S flow into area.
   Results in large-scale circular flow of air masses (Hadley Cells)

Atmospheric Circulation is a major determinant of global precipitation & temperature patterns

5. Hadley Cells create dry latitudes of descending air at about 30° N & S
   WA sits at the edge of another rising air mass region – hence the tendency for higher levels of precipitation.

Oceanic Circulation can be a major determinant of regional precipitation & temperature patterns

Ocean currents determine the temperature of surface waters.
This has large influences on coastal climates

Campbell (2001)
ENSO: El Nino – Southern Oscillation Events

**ENSO Events**
- **El Niño** (warm phase)
  - Warm surface water in the central & eastern Pacific
- **La Niña** (cool phase)
  - Cool surface water in the central & eastern Pacific

**ENSO PNW Climate Impacts**
- **El Niño** (warm phase)
  - Warmer & drier winter
- **La Niña** (cool phase)
  - Cooler & wetter winter

PDO: Pacific Decadal Oscillations

**PDO**
- But PDO Oscillations are decades – long; rather than the annual variations of ENSO
- Monthly values for the PDO index: 1900 – May 2006

Our coastal position results in strong maritime influences on our regional precipitation & temperature patterns

Our coastal location allows large water body to moderate temperature extremes — a maritime climate

Locations further from large water bodies experience larger seasonal temperature fluctuations — continental climates

Global / Continental Position

**B) What are the ecological implications of our position?**

**It affects our**

I. Present-day Climate
- 1) Precipitation & Temperature
- 2) Daily & Seasonal Changes

II. Past Environment
- 1) Past Climate
- 2) Geological history

Daylength & Seasonality

July: 17 hours of light

Oct: 12 hours of light

Ecological implications of seasonal variation in daylength
Global / Continental Position

B) What are the ecological implications of our position?

It affects our

I. Present-day Climate
   1) Precipitation & Temperature
   2) Daily & Seasonal Changes

II. Past Environment
   1) Past Climate
   2) Geological history

The Ecology of Washington

I. Abiotic Environment of WA
   1. Global / Continental Position
   2. Regional Geography & Landforms
   3. Forces Behind Landforms
   4. Geology
   5. Climate
I. Abiotic Environment of WA

1. WA Geography & Features

B) Landscape Units:

Watersheds

WHAT IS A WATERSHED?

Murdoch & Cheo (1999)

Major Watersheds of Washington
- Columbia
- Chehalis
- Willapa & Naselle
- Nisqually
- Puyallup
- Cedar / Green
- Snohomish
- Stillaguamish
- Skagit
- Nooksack
- Skokomish

Note: These are arbitrary physiographic divisions for use in our class. Many different schemes exist.
Physiographic Regions of WA

1. Abiotic Environment of WA
   1. Global / Continental Position
   2. Regional Geography & Landforms
   3. Forces Behind Landforms
   4. Geology
   5. Climate

3. Forces Behind Landforms
   1. Building the Landscape: Tectonic Processes
      A) Terrane accretion
      B) Folding & uplift
      C) Volcanism
   2. Processes Reshaping the Landscape
      A) Continental Ice
      B) Mountain Glaciers
      C) Water
      D) Wind

Forces That Shape our Land

1. Tectonic Processes
   Subduction – the Pacific Plate is being forced down under the North American plate as it pushes eastward
   Protruding pieces of crust on the Pacific Plate are scraped off and accrete onto the shoreline (“terranes”)
1. **Tectonic Processes**
   (B) Creating Landforms: folding & uplift
   - North American Plate
   - Pacific Plate
   - Juan de Fuca Plate

2. **Processes Reshaping the Land**
   (A) Continental Ice
   - Glacier 18,000 YBP
   - Seattle
   - Olympia
   - Kruckenberg (1991)

   - Mountain carving
   - Moraines

3. **Processes Reshaping the Land**
   (C) Water
   - 1) Hill & valley local topography
   - 2) Mountain valley topography
   - Water & Ice interact with geology to create unique landscapes

4. **Processes Reshaping the Land**
   (B) Mountain Glaciers
   - Old Basin & Range Basalt Flows: 13 - 16 MYBP
   - Modern Cascade Volcanoes: 3 – 500,000 YBP
   - All & Hyndman (1994)

5. **Processes Reshaping the Land**
   - 1) Hill & valley local topography
   - Water & Ice interact with geology to create unique landscapes

   - 2) Mountain valley topography

6. **Processes Reshaping the Land**
   (C) Water
   - Erosional forces interact with geology to define habitat diversity
   - Olympic Peninsula
   - Core Sedimentary Rocks
     - Easily erodable
     - Siltstones & shales eroded away leaving gently angled sandstones to dominate. Topography gentle – low habitat complexity
   - Volcanic Crescent Formation
     - Resistant to erosion
     - Steeply angled basalts result in more rugged topography – different habitats & habitat complexity

   - McNulty (1996)
Forces that Shape our Land

2. Processes Reshaping the Land
(C) Water
1) Hill & valley local topography
2) Mountain valley topography
3) Eastern WA scablands & coulees

2. Processes Reshaping the Land
(C) Water
Great Floods reshaping the lands of Eastern WA

Lake Missoula Floods
15,000 YBP

Alt & Hyndman (1995)

4. Columbia River gorge
5) River deltas (estuaries):
   - rivers bring in and take away sediment
   - tides take away sediment

2. Processes Reshaping the Land
(D) Wind
Wind-blown deposits (loess) & the Palouse Prairie

Rolling prairie from loess deposition over old basalt flows

Loess

Forces that Shape our Land

I. Abiotic Environment of WA

1. Global / Continental Position
2. Regional Geography & Landforms
3. Forces Behind Landforms
4. Geology: influences ecological systems at different spatial scales
   4.1 Large scale: Tectonics
      - Landform creation
   4.2 Medium scale: Regional
      - Groundwater – surface water connections
      - Surface rock diversity
      - Weathers into diverse soils
   4.3 Small scale: microhabitats
      - Boulders create unique microsites
      - Influences on erosion
      - Soil chemistry

Modified from Montgomery (1997)
I. Abiotic Environment of WA

1. Global / Continental Position
2. Regional Geography & Landforms
3. Forces Behind Landforms
4. Geology
5. Climate

1) Climate diagrams

- Temperature
- Precipitation
- Drought

Temp > Precip

January - December

Washington Climate

2) Climate patterns

WA State: Mediterranean Climate

Temporal and Spatial patterns in precipitation across WA State

Western WA: Maritime Climate
Eastern WA: Continental Climate

Why are these different?

Kruckeberg (1991)

Prevailing Storm Track in Fall, Winter & Spring

Inches of annual precipitation

Kruckeberg (1991)
2) Climate patterns

**Rainshadow Rainshadow**

Washington Climate

2) Climate patterns

**Precipitation Patterns are actually highly complex across mountains**

Washington Climate

2) Climate patterns

**What causes these rainshadows?**

Prevailing winds pick up moisture over water bodies.

On the windward side of the mountain, air rises and cools, releasing moisture in the form of rain or snow.

On the leeward side of the mountain, air descends, warms, and picks up moisture, which results in little rain.

Washington Climate

3) Local variations in climate patterns

**Bottom Line: beware of using general weather station for specific sites, especially in mountainous terrain**

Washington Climate

3) Local variations in climate patterns

Olympic Mountain Study – Andrea Woodward

*Summer precipitation at 6 meteorological stations (1993)*

South: 61 mm, 100 mm, 168 mm

North: 1520 m, 1523 m, 1404 m

1503 m, 1453 m, 1404 m

Washington Climate

The Ecology of Washington

I. Physical & Chemical (Abiotic) Environment of WA

1. Where are we? : Global / Continental Position
2. An Overview of our Place: Regional Geography & Landforms
3. How are Landforms Created?
4. The Importance of Geology at Multiple Scales
5. Climate

II. Ecological Zones of WA
II. Ecological Zones of WA

1. Ecoregions

2. Ecoregions: a virtual field trip

3. Environmental Determinants of Ecoregions

II. Ecosystems of WA

1. Ecoregions

II Ecoregions of Washington State

1. Marine Shoreline  7. Alpine
3. Western Hemlock 9. Ponderosa Pine
4. Silver Fir 10. Shrub Steppe
5. Mountain Hemlock 11. Palouse Prairie
6. Subalpine Fir

Washington State Ecoregions

West-side Montane – Alpine: Silver fir; Mountain hemlock; Subalpine fir; Alpine

Washington State Natural Regions

Similar scheme to that we are using.
Note some prominent differences:
- Eastern WA prairie / shrub-steppe distribution
- Distinction of prairie woodland mosaic in western WA
- Discontinuity of high elevation forests/alpine

WA Dept. of Natural Resources 1998
I. Physical & Chemical (Abiotic) Environment of WA
1. Where are we?: Global / Continental Position
2. An Overview of our Place: Regional Geography & Landforms
3. How are Landforms Created?
4. The Importance of Geology at Multiple Scales
5. Climate

II. Ecological Zones of WA
1. Ecoregions
2. Ecoregions: a virtual field trip

II. Ecosystems of WA
3. Environmental Determinants of Terrestrial Ecoregions

Bottom Line
Major determinants of ecoregion distribution:

I. Precipitation
• Amount
• Timing

II. Temperature
• Direct effects

BEWARE OF MEAN VALUES!

3. Environmental Determinants of Terrestrial Ecoregions

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Elevation Range (ft)</th>
<th>Avg. Annual Temp (°F)</th>
<th>Avg. Annual Precip (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Seattle) for reference</td>
<td>0 - 50</td>
<td>53</td>
<td>86</td>
</tr>
<tr>
<td>Sitka Spruce</td>
<td>0 – 500</td>
<td>52</td>
<td>200 – 300</td>
</tr>
<tr>
<td>Western Hemlock</td>
<td>0 – 2500</td>
<td>47</td>
<td>70 – 300</td>
</tr>
<tr>
<td>Silver Fir</td>
<td>1900 – 2400</td>
<td>42</td>
<td>220 – 280</td>
</tr>
<tr>
<td>Mountain Hemlock</td>
<td>4200 – 5900</td>
<td>39</td>
<td>160 – 280</td>
</tr>
<tr>
<td>Subalpine Fir</td>
<td>4200 – 5800</td>
<td>39</td>
<td>100 – 150</td>
</tr>
<tr>
<td>Alpine</td>
<td>&gt;5000 – &gt;7000</td>
<td>37.5*</td>
<td>46*</td>
</tr>
<tr>
<td>Douglas-fir/Grand Fir</td>
<td>2000 – 5000</td>
<td>46</td>
<td>60 – 110</td>
</tr>
<tr>
<td>Ponderosa Pine</td>
<td>2000 – 4000</td>
<td>47</td>
<td>40 – 70</td>
</tr>
<tr>
<td>Shrub Steppe</td>
<td>150 – 2000</td>
<td>50</td>
<td>15 – 25</td>
</tr>
<tr>
<td>Palouse Prairie</td>
<td>&lt; 3000</td>
<td>48</td>
<td>40 – 70</td>
</tr>
</tbody>
</table>

* Data from Paradise R.S. on Mt. Rainier (subalpine zone) / precip includes average snowfall of 256 cm
### II. Ecosystems of WA

#### 2. Environmental Determinants of Terrestrial Ecoregions

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Elevation Range (ft.)</th>
<th>Avg. Annual Temp (°F)</th>
<th>Avg annual precip (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Seattle) for reference</td>
<td>0</td>
<td>53</td>
<td>86</td>
</tr>
<tr>
<td>Sitka Spruce</td>
<td>0 – 500</td>
<td>52</td>
<td>200 – 300</td>
</tr>
<tr>
<td>Western Hemlock</td>
<td>0 – 2500</td>
<td>47</td>
<td>70 – 300</td>
</tr>
<tr>
<td>Silver Fir</td>
<td>1900 – 4200</td>
<td>42</td>
<td>220 – 280</td>
</tr>
<tr>
<td>Mountain Hemlock</td>
<td>4200 – 5900</td>
<td>39</td>
<td>160 – 280</td>
</tr>
<tr>
<td>Subalpine Fir</td>
<td>4200 – 5800</td>
<td>39</td>
<td>100 – 150</td>
</tr>
<tr>
<td>Alpine</td>
<td>&gt;5000 – &gt;7000</td>
<td>37.5*</td>
<td>46*</td>
</tr>
<tr>
<td>Douglas-fir/Grand Fir</td>
<td>2000 – 5000</td>
<td>46</td>
<td>60 – 110</td>
</tr>
<tr>
<td>Ponderosa Pine</td>
<td>2000 – 4000</td>
<td>47</td>
<td>40 – 70</td>
</tr>
<tr>
<td>Shrub Steppe</td>
<td>150 – 2000</td>
<td>50</td>
<td>15 – 25</td>
</tr>
<tr>
<td>Palouse Prairie</td>
<td>&lt; 3000</td>
<td>48</td>
<td>40 – 70</td>
</tr>
</tbody>
</table>

* Data from Paradise R.S. on Mt. Rainier (subalpine zone) / precip includes average snowfall of 256 cm

---

**Bottom Line**

Major determinants of ecoregion distribution:

**I. Precipitation**
- Amount
- Timing

**II. Temperature**
- Direct effects

**III. Interactive Effects of Temperature & Moisture**
- Moisture effects ability to cope with temperature

---

### II. Ecosystems of WA

#### 3. Environmental Determinants of Terrestrial Ecoregions

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Elevation Range (ft.)</th>
<th>Avg. Annual Temp (°F)</th>
<th>Avg annual precip (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Seattle) for reference</td>
<td>0</td>
<td>53</td>
<td>86</td>
</tr>
<tr>
<td>Sitka Spruce</td>
<td>0 – 500</td>
<td>52</td>
<td>200 – 300</td>
</tr>
<tr>
<td>Western Hemlock</td>
<td>0 – 2500</td>
<td>47</td>
<td>70 – 300</td>
</tr>
<tr>
<td>Silver Fir</td>
<td>1900 – 4200</td>
<td>42</td>
<td>220 – 280</td>
</tr>
<tr>
<td>Mountain Hemlock</td>
<td>4200 – 5900</td>
<td>39</td>
<td>160 – 280</td>
</tr>
<tr>
<td>Subalpine Fir</td>
<td>4200 – 5800</td>
<td>39</td>
<td>100 – 150</td>
</tr>
<tr>
<td>Alpine</td>
<td>&gt;5000 – &gt;7000</td>
<td>37.5*</td>
<td>46*</td>
</tr>
<tr>
<td>Douglas-fir/Grand Fir</td>
<td>2000 – 5000</td>
<td>46</td>
<td>60 – 110</td>
</tr>
<tr>
<td>Ponderosa Pine</td>
<td>2000 – 4000</td>
<td>47</td>
<td>40 – 70</td>
</tr>
<tr>
<td>Shrub Steppe</td>
<td>150 – 2000</td>
<td>50</td>
<td>15 – 25</td>
</tr>
<tr>
<td>Palouse Prairie</td>
<td>&lt; 3000</td>
<td>48</td>
<td>40 – 70</td>
</tr>
</tbody>
</table>

* Data from Paradise R.S. on Mt. Rainier (subalpine zone) / precip includes average snowfall of 256 cm
II. Ecosystems of WA

3. Environmental Determinants of Terrestrial Ecoregions

Major determinants of ecoregion distribution:

I. Precipitation
   • Amount
   • Timing

II. Temperature
   • Direct effects

III. Interactive Effects of Temperature & Moisture
   • Moisture effects ability to cope with temperature

Interactive Effects:

- Moisture effects ability to cope with temperature
- Temperature effects moisture availability
  - \( \uparrow \text{temp} \rightarrow \uparrow \text{water use} \rightarrow \downarrow \text{water available} \)
  - \( \uparrow \text{temp} \rightarrow \uparrow \text{evaporation from soil} \rightarrow \downarrow \text{water available} \)

\( \downarrow \text{temp} \rightarrow \uparrow \text{precip as snow} \rightarrow \downarrow \text{water available} \)

<table>
<thead>
<tr>
<th>Ecoregion</th>
<th>Elevation Range (ft.)</th>
<th>Avg. Annual Temp (°F)</th>
<th>Avg. Annual Precip (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitka Spruce</td>
<td>0 – 500</td>
<td>52</td>
<td>200 – 300</td>
</tr>
<tr>
<td>Western Hemlock</td>
<td>0 – 2500</td>
<td>47</td>
<td>70 – 300</td>
</tr>
<tr>
<td>Silver Fir</td>
<td>1000 – 4200</td>
<td>42</td>
<td>220 – 280</td>
</tr>
<tr>
<td>Mountain Hemlock</td>
<td>4200 – 5900</td>
<td>39</td>
<td>180 – 280</td>
</tr>
<tr>
<td>Subalpine Fir</td>
<td>4200 – 5800</td>
<td>39</td>
<td>100 – 150</td>
</tr>
<tr>
<td>Alpine</td>
<td>&gt;5000 – &gt;7000</td>
<td>37.5*</td>
<td>46*</td>
</tr>
<tr>
<td>Douglas-fir/Grand Fir</td>
<td>2000 – 5000</td>
<td>46</td>
<td>60 – 110</td>
</tr>
<tr>
<td>Ponderosa Pine</td>
<td>2000 – 4000</td>
<td>47</td>
<td>40 – 70</td>
</tr>
<tr>
<td>Shrub Steppe</td>
<td>150 – 2000</td>
<td>50</td>
<td>15 – 25</td>
</tr>
<tr>
<td>Palouse Prairie</td>
<td>&lt; 3000</td>
<td>48</td>
<td>40 – 70</td>
</tr>
</tbody>
</table>

* Data from Paradise R.S. on Mt. Rainier (subalpine zone) / precip includes average snowfall of 356 cm