**Freshwater Ecosystems**

I. Freshwater Ecosystem Types
   1. Definition & classification

II. Freshwater Wetland Ecology
   1. Wetland productivity
      2. Wetland environments
      3. Ecological functions

III. Freshwater Wetlands of the Puget Sound Region
   1. Wetland Organisms
      2. Wetland Communities

IV. Stream Ecology: Riverine and Riparian Wetlands

V. Lakes & Ponds

---

**What are WETLANDS?**

Wetlands definitions from a LEGAL standpoint

Those areas that are saturated or inundated by surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, & similar areas. (US Army Corps of Engineers 1987)

"Wetlands" or "wetland areas" means areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from nonwetland areas to mitigate the conversion of wetlands. (Washington Administrative Code 173-22-030.)

---

**What are WETLANDS?**

Wetlands are distinguished by:

1. WETLAND HYDROLOGY

2. WETLAND VEGETATION

3. WETLAND SOILS

![Image: "Gleyed" soils]

---

**Simple wetland classification schemes**

I. Water chemistry (salinity)
   - ...

II. Water depth & source
   1. Surface water wetlands
      A. Shallow water – margins
      B. Deepwater wetlands (> 2 meters in depth)

   2. Groundwater wetlands
      Soil saturation / inundation maintained by subsurface water flow
1. Cowardin classification (1979)

Classifying wetlands hierarchically based upon

- Hydrology & Geomorphology (Wetland System & Subsystem)
  - Riparian, riverine, lakeshore, marine
- Vegetation Physiognomy (Wetland class)
  - Forested, shrubland, grassland
- Biological Characteristics (Wetland subclass)
  - Dominant species

Alder-hemlock forested riparian wetland

2. British classification system (Rieley & Page)

Major initial wetland categories based upon

- Dominant form of water source
- Hydrodynamics
- Nutrient status

**Minerotrophic Wetlands**
- Water source: surface or groundwater
- Hydrodynamics: strong - moderate
- Nutrient Status: high - moderate
- Riparian & lakeshore wetlands

**Ombrotrophic Wetlands**
- Water source: precipitation
- Hydrodynamics: weak
- Nutrient Status: poor

Bogs & fens

3. Hydrogeomorphic (HGM) classification

Major wetland categories based upon

- Hydrological characteristics of the wetland
- Landscape position (“geomorphology”)

Used increasingly commonly in wetland regulatory applications
Not covered in this course – see wetland ecology course

---

**Freshwater Wetland Classification for Class**

Wetland Types & Classification Categories

**Physiognomy**

1. 
2. 
3. 
4. 

**Forested wetlands**: woody vegetation at least 6 m tall on at least 30% of the site

---

**Alder-hemlock forested riparian wetland**
Freshwater Wetland Classification for Class

1. Physiognomic classification

- **Scrub-Shrub wetlands**: woody vegetation < 6 m tall on at least 30% of site.
- **Emergent wetlands**: dominated by herbaceous vegetation (growing up & out of the water).

**Drawing from Yates (1993)**

Freshwater Wetland Classification for Class

**Physiognomic classification**

- **Aquatic bed wetlands**: dominated by floating or submerged vegetation.

**Drawing from Yates (1993)**

Vegetation Structure & the wetland environment

**Mitsch & Gosselink (2001)**

What is responsible for this pattern of adaptation?

1. 
2. 

**Mitsch & Gosselink (2003)**

Wetland Types & Classification Categories

<table>
<thead>
<tr>
<th>Physiognomy</th>
<th>Location</th>
<th>Hydrology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Forested</td>
<td>1.</td>
<td>1.</td>
</tr>
<tr>
<td>2. Scrub-shrub</td>
<td>2.</td>
<td>2.</td>
</tr>
<tr>
<td>3. Emergent</td>
<td>3.</td>
<td>3.</td>
</tr>
<tr>
<td>4. Aquatic bed</td>
<td>4.</td>
<td>4.</td>
</tr>
</tbody>
</table>
Wetlands characterized by hydrology

- Surface flow in
- Evaporation
- Drainage
- Surface flow out

Marsh
Wet meadow
Fen
Bog

1. Wetland Types & Classification

<table>
<thead>
<tr>
<th>Physiognomy</th>
<th>Location</th>
<th>Hydrology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forested</td>
<td>Riparian</td>
<td>1. Marsh / Swamp</td>
</tr>
<tr>
<td>Scrub-shrub</td>
<td>Lakeshore</td>
<td>2. Wet meadow</td>
</tr>
<tr>
<td>Emergent</td>
<td>Pothole</td>
<td>3. Fen</td>
</tr>
<tr>
<td>Aquatic bed</td>
<td>Hillslope</td>
<td>4. Bog</td>
</tr>
</tbody>
</table>

We will use various combinations: e.g.,
- Forested riparian bog
- Emergent hillslope wetland

Freshwater Wetland Environments

1) Abundant supply (exceptions?)
2) Variation in water availability
   (depth of inundation / degree of saturation: the “hydroperiod”)
   a) Hydrographs show the hydroperiod

Streamside wetland (rain-fed)

A streamside wetland that is both rain-fed and snowmelt-fed will have a similar pattern but offset timing.

Freshwater Wetland Environments

1. Riparian
2. Lakeshore
3. Pothole
4. Hillslope

Freshwater Wetlands are among the most productive ecosystems

Even higher than old growth forests per unit area

Annual Net Primary Productivity of Ecosystems

<table>
<thead>
<tr>
<th>Ecosystem Type</th>
<th>Mean NPP g C/m²/yr</th>
<th>Range of NPP g C/m²/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial Uplands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical rain forest</td>
<td>2,200</td>
<td>1,000 - 3,500</td>
</tr>
<tr>
<td>Temperate evergreen forest</td>
<td>1,320</td>
<td>600 - 2,500</td>
</tr>
<tr>
<td>Temperate deciduous forest</td>
<td>1,200</td>
<td>600 - 2,500</td>
</tr>
<tr>
<td>Boreal forest</td>
<td>800</td>
<td>400 - 2,000</td>
</tr>
<tr>
<td>Woodland &amp; shrubland</td>
<td>700</td>
<td>250 - 1,200</td>
</tr>
<tr>
<td>Temperate grassland</td>
<td>600</td>
<td>200 - 1,500</td>
</tr>
<tr>
<td>Tundra and alpine</td>
<td>140</td>
<td>10 - 400</td>
</tr>
<tr>
<td>Desert &amp; semidesert scrub</td>
<td>90</td>
<td>10 - 250</td>
</tr>
<tr>
<td>Freshwater Wetlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swamp &amp; marsh</td>
<td>2,000</td>
<td>800 - 6,000</td>
</tr>
<tr>
<td>Lake and stream</td>
<td>250</td>
<td>100 - 1,500</td>
</tr>
<tr>
<td>Marine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algal beds and reefs</td>
<td>2,500</td>
<td>500 - 4,000</td>
</tr>
<tr>
<td>Estuaries</td>
<td>1,800</td>
<td>500 - 4,000</td>
</tr>
<tr>
<td>Open Ocean</td>
<td>125</td>
<td>2 - 400</td>
</tr>
</tbody>
</table>

Freshwater Wetland Ecology

Freshwater Wetlands are highly productive ecosystems

Even higher than old growth forests per unit area

Even higher than old growth forests per unit area

Annual Net Primary Productivity of Ecosystems
A) Water – the defining feature of wetlands
   1) Abundant supply (exceptions?)
   2) Variation in water availability
      (depth of inundation / degree of saturation: the “hydroperiod”)
      a) Hydrographs show the hydroperiod
      b) Hydroperiod Classification (Cowardin et al. 1979)
         Characterizing (categorize) environments with different hydroperiods

Hydroperiod Classification (Cowardin et al. 1979)

<table>
<thead>
<tr>
<th>Hydroperiod Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanently flooded</td>
<td>Inundated throughout year</td>
</tr>
<tr>
<td>Intermittently exposed</td>
<td>Permanently flooded, except in years of extreme drought</td>
</tr>
<tr>
<td>Semi-permanently flooded</td>
<td>Flooded during growing season (GS) in most years</td>
</tr>
<tr>
<td>Seasonally flooded</td>
<td>Flooded for extended periods during GS (but no standing water at end)</td>
</tr>
<tr>
<td>Saturated</td>
<td>No standing water but saturated soils for extended periods during GS</td>
</tr>
<tr>
<td>Temporarily flooded</td>
<td>Flooded for brief periods during GS but otherwise water table well below surface</td>
</tr>
<tr>
<td>Intermittently flooded</td>
<td>Surface water present unpredictably (without seasonal pattern)</td>
</tr>
</tbody>
</table>

3) Water Level Fluctuations & Biodiversity

What effects do these water level fluctuations have on ecological systems?

Ability of individuals to grow, survive & reproduce
Community & ecosystem properties

What is responsible for high WLF – where biodiversity is low?
Freshwater Wetland Environments

What is responsible for high WLF – where biodiversity is low?

Impervious Surface Area

Water Level Fluctuation

Freshwater Wetland Environments

Water Level Fluctuations & Plant Biodiversity (Cooke & Azous 2001)

Low WLF:
What is responsible for different levels of diversity at low WLF?

Freshwater Wetland Environments

Water Level Fluctuations & Plant Biodiversity (Cooke & Azous 2001)

What is responsible for different levels of diversity at low WLF?

Impervious surfaces may be a driver for understanding low diversity in high WLF wetlands.

BUT

What is responsible for different levels of diversity at low WLF?

Water Level Fluctuations & Plant Biodiversity

Low WLF:

Low WLF (moist soil)

Low WLF (flooded)

What is responsible for different levels of diversity at low WLF?

A) Water
1) Abundant Supply
2) Hydroperiod
   a) Typical Hydrographs
   b) Hydroperiod Classification
3) Water Level Fluctuations & Biodiversity

The Bottom Line

Fluctuating water levels also have effects on wetland animals

Example: amphibians
Water Level Fluctuations & the success of native amphibians

Urbanized watersheds with high WLF tend to be more dominated by non-native amphibian species.

(Richter & Azous 2001)

1) Abundant Supply
2) Depth / Hydroperiod
   a) Typical Hydrographs
   b) Hydroperiod Classification (Cowardin et al. 1979)
3) Water Level Fluctuations & Biodiversity
4) Water Source & hydrodynamics
   Balance of water input sources is a strong ecological determinant
   (precipitation, groundwater, stream flow, surface flow)
   Speed of flow through is also a strong ecological determinant
   (disturbance, chemistry)

B) Temperatures
   • Moderate & stable
C) Nutrients
   • Large organic supply
   • Inorganic availability variable (sometimes very limited)
     • Limited availability: Slow nutrient cycling slows replenishment
     • Limited availability: Reduced root function slows soil exploration
D) Acidity
   • pH variable in space & time – can be quite low (e.g., acidic bogs)
E) Light
   • Often high (varies) but considerable seasonal competition
F) Gases
   • No aerial limitation on CO₂ or O₂
   • Limited O₂ in soils can limit plant function & productivity

III. Freshwater Wetlands of the Puget Sound Region

TWO References for Washington Wetland Science:
1. Freshwater Wetlands in Washington State
   Volume 1: A Synthesis of the Science
   Washington State Dept. of Ecology
   Publication #03-06-016 (2003)
2. Wetlands and Urbanization: Implications for the Future
   by A. Azous & R. Horner (CRC Press 2001)
   UWB Library (on reserve): QH105.W2 W38 2001
III. Freshwater Wetlands of the Puget Sound Region

1. Wetland Organisms
   2. Wetland communities

Puget Sound Freshwater Wetlands

1. Wetland Organisms
   A) King County Wetland Inventory Species List
      (optional lists available as a handout)
      • Appendix 1: Full species list
      • Appendix 2: Priority species & habitats (part D below)
   B) Wetland Plants
      Using plants as wetland indicators

Puget Sound Freshwater Wetlands

1. Wetland Organisms
   B) Wetland Plants

Table 3.1. Indicator status categories for wetland plant species.

<table>
<thead>
<tr>
<th>Code</th>
<th>Designation</th>
<th>Wetlands Probability</th>
<th>1 Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>QBL</td>
<td>Obligate wetland</td>
<td>&gt; 99</td>
<td></td>
</tr>
<tr>
<td>FACW</td>
<td>Facultative wetland</td>
<td>67 to 99</td>
<td></td>
</tr>
<tr>
<td>FAC</td>
<td>Facultative</td>
<td>34 to 66</td>
<td></td>
</tr>
<tr>
<td>FACU</td>
<td>Facultative upland</td>
<td>1 to 33</td>
<td></td>
</tr>
<tr>
<td>UPL</td>
<td>Obligate upland</td>
<td>&lt; 1</td>
<td></td>
</tr>
<tr>
<td>NI</td>
<td>No indicator status</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Percent occurrence of plant found in a wetland

Puget Sound Freshwater Wetlands

1. Wetland Organisms
   A) King County Wetland Inventory Species List
      • Appendix 1: Full species list
      • Appendix 2: Priority species & habitats
   B) Wetland Plants
      1) Wetland Indicator Lists
      2) Common Puget Lowland Wetland Plants

Field Guides mentioned previously plus

Plants of the Pacific Northwest Coast
1. Wetland Organisms

Common Puget Sound Lowland Wetland Plants

2 most common species:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Cover Dominance Category</th>
<th>Species</th>
<th>Puget Sound Freshwater Wetlands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (1-10%)</td>
<td>High (5-10%)</td>
<td>Phalaris arundinacea</td>
<td>Spirea douglasii</td>
</tr>
<tr>
<td>Medium (11-15%)</td>
<td>Low (10-15%)</td>
<td>Anemone xiphium</td>
<td>Monochoria vaginalis</td>
</tr>
</tbody>
</table>

Cooke & Azous (2001)

Puget Sound Freshwater Wetland Plants

TREES

- Red alder
- Cascara (Pacific willow)
- (Oregon ash)
- (Cottonwood)

SHRUBS

- Hardhack
- Twinberry
- Salmonberry
- Blackberries
- Red huckleberry
- Willows

HERBACEOUS

- Reed Canarygrass
- Lady, sword, bracken ferns
- Creeping buttercup (sedges & rushes)
- (many herbs)

Cooke & Azous (2001)

Puget Sound Freshwater Wetlands

1. Wetland Organisms

D) Protected / Declining Species

King County 1991 Wetland Inventory Priority Species & Habitats

Priority species: species of concern due to vegetation status and/or habitat manipulation

Includes federal & state listed species as well as species of special concern and game species

Birds
- Plants
- Fish
- Insects
- Amphibians
- Reptiles

Puget Sound Freshwater Wetlands

1. Wetland Organisms

C) Consumers

1) Herbivores

- Invertebrates:
  - Insects (caddis flies, midges, beetles, etc.) many omnivorous
  - Crustaceans (crayfish, fairy shrimp) often indiscriminate filter feeders
  - Molusks (freshwater snails & clams)

- Vertebrates:
  - Birds
  - Mammals (rodents, beaver, muskrat)
  - Amphibians
  - Fish

2) Carnivores

- Birds, mammals, fish, insects, amphibians, etc.

3) Detritivores

- Insects, annelid worms, crustaceans, microbes, etc.

Puget Sound Freshwater Wetlands

2. Wetland Communities

Puget Sound Freshwater Wetlands

It is not necessary to “know” these specific communities.

Optional handout available

Summarized from Kunze’s 37 Plant Community Types of the Puget Trough Lowland (Kunze 1994)

What I would like you to “know” is this distilled version:

- Herb Dominated
- Shrub Dominated
- Tree Dominated

This should give you a sense for array of freshwater wetland communities in our region in terms of their

- Vegetation structure
- Hydrology

It does not indicate relative abundance

This scheme was created from the 37 communities in Kunze (1994).

2. Wetland Communities

A) Sphagnum Bogs

Lodgepole pine (Pinus contorta) growing on floating mat of Sphagnum moss (Anacortes City Forest)

Predominance of Sphagnum moss

- stress tolerant species (with inherently slow growth) adapted to low nutrient conditions
- Lodgepole & western white pines (also in dry, nutrient-poor sites)
- Evergreen-leaved shrubs: an important strategy for nutrient conservation
- Carnivorous plants (sundew, pitcher plant): nutrient acquisition

2. Wetland Communities

A) Sphagnum Bogs

Evergreen shrubs: evergreen leaves an important strategy for nutrient conservation

Ledum groenlandicum Labrador tea

Kalmia polifolia Bog laurel

• 10
2. Wetland Communities

A) Sphagnum Bogs

Carnivorous plants (e.g., sundews): nutrient acquisition

Drosera rotundifolia
Drosera intermedia

B) Flowing (Minerotrophic) Wetlands

1) Locations
Surface water impounded by topography or beavers
All parts of drainages (both inflow & outflow)
Degree of water flow through highly variable across types

2) Environmental Characteristics
Mosaics of varying environmental gradients
Secondary substrates form crucial microenvironmental heterogeneity

Water input dominated by both precipitation and flow
Natural disturbances from physical (flooding) and biological (beavers) environments have important influences (diversity)
2. Wetland Communities

B) Flowing Wetlands

3) Plants

- Vegetation correlated with:
  - Water depth
  - Hydroperiod / fluctuation
  - Flow energy

- Riverside wetlands: dynamic vegetation with high diversity

- Red alder floodplain forest
- Black cottonwood floodplain forest

- AQUATIC HERBS (Aquatic bed vegetation)

- Nuphar polysepalum
- Potomageton natans
- Lemna minor
- Polygonum hydropiperoides
- Smart Weed
- Duck Weed

- HERBS

- Veronica americana
- Oenanthe sarmentosa
- Sparganium emersum
- Lysichiton americanum

- GRASSES, SEDGES & RUSHES

- Carex obnupta
- Carex comosa
- Juncus effusus
- Typha latifolia
- Scirpus microcarpus

- SHRUBS

- Spirea douglasii
- Coriunus sericea
- Rubus spectabilis
- Lonicera involucrata

- Some Evil Doers: exotic species

- Creeping buttercup
- Purple loosestrife
- Reed canarygrass
IV. Stream Ecology: Riverine and Riparian Wetlands

1) Streams in a Landscape
2) Structure of Stream Habitats
3) Salmon & Streams
4) Stream Environments
5) Stream Organisms

Streams in a Landscape: Streams exist within a watershed

A) Watersheds as Landscape Units

B) Streams as Ecological Corridors
   1) Conduits of movement
   2) Sites of ecological complexity
      - Rapid lateral habitat transitions
      - Atypical habitat attributes
      - High light
      - Summer water availability

Structure of Stream Habitats

The Riparian Zone: what is it?

The Riparian Zone: where is it?

Note: some definitions do NOT include the stream channel

Riparian & Riverine Wetlands

Riverine Wetlands

Riparian Wetlands
Five species of salmon in our region

- Chinook (King)
- Silver
- Chum
- Sockeye
- Pink

Plus (not pictured):
- Steelhead (freshwater only)
- Sea-run cutthroat trout

Illustrations from USFWS brochure 1998

Salmon are ANADROMOUS fish
This means they use both FRESH & SALT water during their life cycle

Salmon Lifecyle

Use of Estuaries

Different species of salmon spawn in different portions of the watershed
Salmon & Streams

Some Key Environmental Requirements

- Streamflow for migration, OK obstacles, good water quality
- Fry
- Estuaries for acclimation to salt water
- Cool ocean temperatures, food supply, minimal predators
- Clean gravels, O₂, for spawning, egg development
- Estuaries for acclimation to freshwater
- Streamflow to migrate, OK obstacles, resting & hiding places in stream, cool H₂O

Stream Environments

Understanding the features of stream channels important to salmon (and other critters!)

Stream Environments

What does a stream channel look like?

- Cut Banks & Point Bars
- Water flows fast
- Water flows slow
- Pools are created in cut banks
- What good are pools?
- Other important features
  - Woody debris

Drawings from Murdoch & Cheo (1999)
Wood in streams is very important – WHY?

Stream Environments

What happens with a meandering stream channel?
Cut Banks & Point Bars

Water flows fast
Water flows slow

Cut Bank
Point Bar

Pools are created in cut banks
What good are pools?
Other important features
  • Woody debris
  • Succession

Streams are DYNAMIC systems!

What do we do to stream channels?

What are the effects of removing meanders on habitat?

Drawings from Murdoch & Cheo (1999)
Stream Environments

We can also alter how stream channels form and change without a backhoe.

Geology

Precipitation

Hydrology (stream flow)

Stream Channel Form

Soils

Vegetation

Climate Change

Remove vegetation

Pavement

Topography

Webspace

Why is this important?

silt sand gravel cobble boulders

Why is this important?

Stream Environments

Water Quality is Important

Streams FLOOD

Precipitation / snowmelt

Topography

Wetlands (retention ponds) vs. slopes

Surface runoff

Pavement vs. plants

Flooding

Erosion (can smother eggs or scour out streambed gravels)

Soil building

Nutrient exchange

Stream Environments

Stream Channel Form

Stream Environments

Stream Environments

Stream Environments

Stream Organisms

A) Primary Producers

- Algae
- Obligate wetland plants
- Facultative wetland plants
- Plants tolerant of saturated soils & flooding

B) Herbivores

- Aquatic: Various invertebrates
- Terrestrial: Mammals (e.g., beavers)

C) Carnivores

- Aquatic: Various invertebrates; Fish (e.g., salmon)
- Terrestrial: Mammals (e.g., river otters)

D) Detritivores

- Aquatic insects
- Fungi
- Bacteria

Marine-derived nutrients support forest ecosystems

Young salmon migrate out to ocean

Salmon feed in ocean, gathering nutrients from the marine environment and incorporating them into their bodies

Predators transport nutrients in salmon into forest ecosystem

After spawning the salmon die (if not taken by predators earlier)

After a few years they return to migrate upstream

Photos from Lewis (1994)
V. Lakes & Ponds

Lacustrine ecosystems described on pp. 247 – 270 in textbook