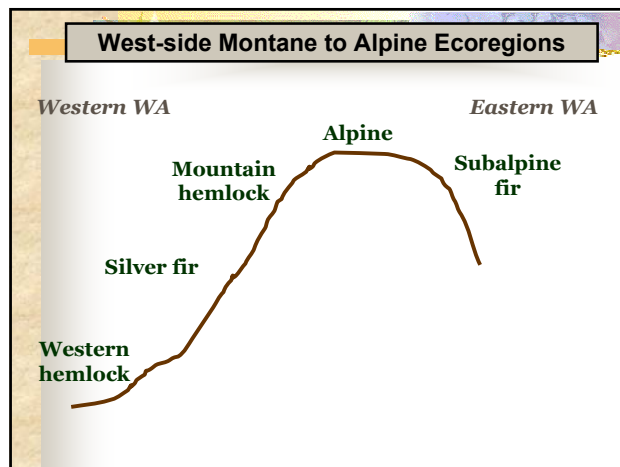
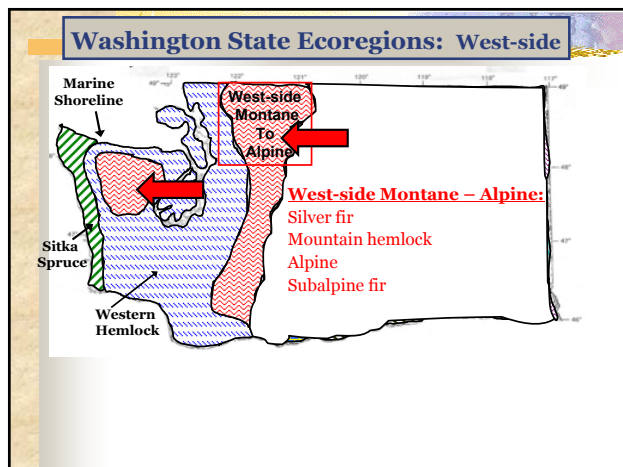
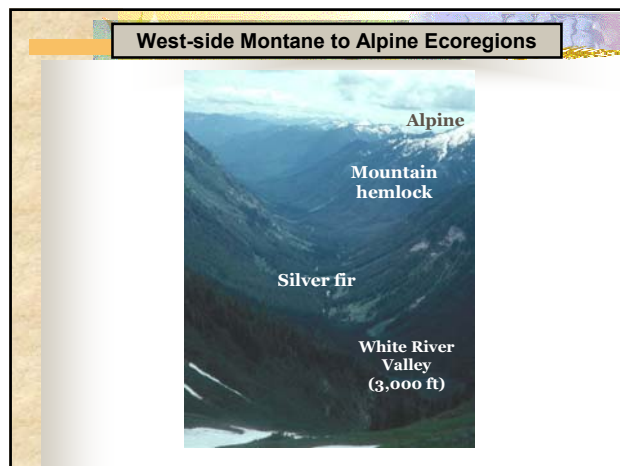




Environment of the west-side Mountain Ecoregions

Changes in temperature & precipitation with elevation

Ecoregion	Elevation Range (ft.)	Avg. Annual Temp (°F)	Avg annual precip (cm)
(Seattle) for reference	0	53	86
Sitka Spruce	0 – 500	52	200 – 300
Western Hemlock	0 – 2500	47	150 – 300
Silver Fir	1900 – 4200	42	220 – 280
Mountain Hemlock	4200 – 5900	39	160 – 280
Subalpine Fir	4200 – 5800	39	100 – 150
Alpine	>5000 – >7000	37.5*	46*



Environment of the Silver Fir Ecoregion

Mountain environment: wet & cool

Ecoregion	Elevation Range (ft.)	Avg. Annual Temp (°F)	Avg annual precip (cm)
(Seattle) for reference	0	53	86
Sitka Spruce	0 – 500	52	200 – 300
Western Hemlock	0 – 2500	47	150 – 300
Silver Fir	1900 – 4200	42	220 – 280
Mountain Hemlock	4200 – 5900	39	160 – 280
Subalpine Fir	4200 – 5800	39	100 – 150
Alpine	>5000 – >7000	37.5*	46*

Silver Fir Forests

Mountain valley bottoms from 2 – 4,000 feet



Silver Fir Forests



- Tree diameter:
- Woody debris:
- Fire return interval:

Pacific Silver Fir (*Abies amabilis*)



Up to 150 -200 ft tall
3 – 4 ft diameter
Life span ~ 300 – 500 years
Comes in later in ecosystem development; shade tolerant (more so than noble fir)



Silver Fir Forests

- Soils:
- Temperatures:
- Snow accumulation:
- Mechanically-fragile Western hemlock seedlings do not tolerate snow as well as silver fir seedlings

Silver Fir Forest Ecosystem Productivity

Silver Fir forests vary in productivity from low to high:

$\text{g C} / \text{m}^2 / \text{yr}$

Much less than Western Hemlock forests:

2,000 -3,200

$\text{g C} / \text{m}^2 / \text{yr}$

Lassoie et al. 1985

Annual Net Primary Productivity of Ecosystems

Ecosystem Type	Mean NPP $\text{g C} / \text{m}^2 / \text{yr}$	Range of NPP $\text{g C} / \text{m}^2 / \text{yr}$
Terrestrial Uplands		
Tropical rain forest	2,200	1,000 - 3,500
Temperate evergreen forest	1,320	600 - 2,500
Temperate deciduous forest	1,200	600 - 2,500
Boreal forest	800	400 - 2,000
Woodland & shrubland	700	250 - 1,200
Temperate grassland	600	200 - 1,500
Tundra and alpine	140	10 - 400
Desert & semidesert scrub	90	10 - 250
Freshwater Wetlands		
Swamp & marsh	2,000	800 - 6,000
Lake and stream	250	100 - 1,500
Marine		
Algal beds and reefs	2,500	500 - 4,000
Estuaries	1,800	500 - 4,000
Open Ocean	125	2 - 400

Silver Fir Forests

Lakes & streams provide important sites of ecosystem variation within a sea of evergreen forest

Ecosystems of the Mountain Hemlock Ecoregion

Ecosystems

Mountain Hemlock forests

Subalpine meadows

Wetlands

Streams

Lakes

Avalanche gullies



Environment of the Mountain Hemlock Ecoregion

Severe mountain environment: heavy snow & cold

Ecoregion	Elevation Range (ft.)	Avg. Annual Temp (°F)	Avg annual precip (cm)
(Seattle) for reference	0	53	86
Sitka Spruce	0 – 500	52	200 – 300
Western Hemlock	0 – 2500	47	150 – 300
Silver Fir	1900 – 4200	42	220 – 280
Mountain Hemlock	4200 – 5900	39	160 – 280
Subalpine Fir	4200 – 5800	39	100 – 150
Alpine	>5000 - >7000	37.5*	46*

Snow accumulation appears critical to dynamics of tree & ecosystem function in mountain hemlock subalpine ecosystems

Deep snow limits growing season length (climate change may alter this)

Mountain Hemlock Forests



Forest – meadow mosaics at high end

Closed canopy forests at lower end

Mountain Hemlock Forests

High elevation snowy subalpine forests



Subalpine meadows

Heathers
Huckleberries
Tall, lush forbs

Avg annual snowfall:

Mountain hemlock forests:

Mountain hemlock
Subalpine fir
Alaska yellow cedar
Silver fir

Mountain Hemlock Forests

Mountain hemlock (*Tsuga mertensiana*)



Typically 75 -100 ft tall; 2 – 3.5 ft diameter

Life span ~ 800+ years

Slow growth – 20 – 90 feet at 100 years



Mountain Hemlock Forests

Mountain hemlock (*Tsuga mertensiana*)



In very favorable sites (<4,000 ft):
3-4 ft diameter; 150 ft tall

Layers into clumps at high elevations



Alaskan yellow cedar

Mountain Hemlock Subalpine Meadows



Lush herb community

Highly variable meadow communities – depending upon:



Rich soils of lush herb community



Red heather



Mountain blueberry

Mountain Hemlock Subalpine Meadows



These meadows change through time – trees can invade



Cascade subalpine meadow invasion rapid in past century (peaked in mid 1900s)

Climate change may have a big influence on:

Fires are infrequent (800 – 1,500 yr return interval) but severe in effect

Mountain Hemlock Avalanche Track Ecosystems



Snow avalanches are an important ecological feature



Climate change effects on snow accumulation may influence:

Mountain Hemlock Avalanche Track Ecosystems

Snow avalanches create distinct community patterns



Ecosystems of the Subalpine Fir Ecoregion

Ecosystems

Subalpine Fir forests

Subalpine meadows

Wetlands

Streams

Lakes

Avalanche gullies

Environment of the Subalpine Fir Ecoregion

Severe mountain environment: moderate snow & very cold

Ecoregion	Elevation Range (ft.)	Avg. Annual Temp (°F)	Avg annual precip (cm)
(Seattle) for reference	0	53	86
Sitka Spruce	0 – 500	52	200 – 300
Western Hemlock	0 – 2500	47	150 – 300
Silver Fir	1900 – 4200	42	220 – 280
Mountain Hemlock	4200 – 5900	39	160 – 280
Subalpine Fir	4200 - 5800	39	100 - 150
Alpine	>5000 - >7000	37.5*	46*

Snow accumulation appears critical to dynamics of tree & ecosystem function in subalpine fir ecosystems

Deep snow limits growing season length & moisture availability (climate change may alter this)

Subalpine Fir (*Abies lasiocarpa*)

Typically up to 140 ft tall
Life span ~ 200 years
Slow growth – can be 5 - 6 in diameter at 100 years



Subalpine Fir

Trees at the edge



Tree Skirts



Flag Form Trees

Subalpine Fir Meadow Ecosystems



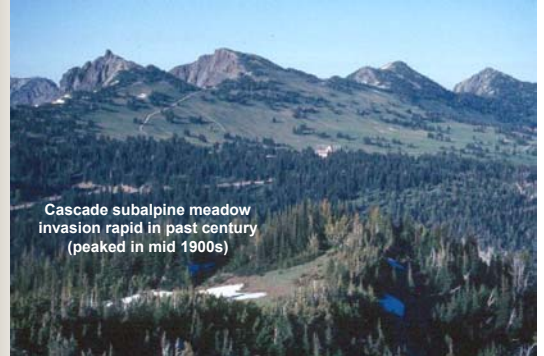
Showy subalpine meadows

Fire may be important in the establishment of tree – meadow mosaics



Subalpine Fir Forests

Subalpine parkland at Sunrise, Mount Rainier National Park



Cascade subalpine meadow invasion rapid in past century (peaked in mid 1900s)

Subalpine Fir Meadow Ecosystems

Some unique critters to subalpine / alpine ecosystems

Pikas depend upon specific vegetation



Subalpine Fir Meadow Ecosystems

High elevation critters on the decline



Olympic Marmots – on the decline



Cascade mountain goats – on the decline



FISH & WILDLIFE SCIENCE
An Online Science Magazine / from the Washington Department of Fish & Wildlife

SalmonScapes
Research Briefs
SalmonScapes
Research Briefs
SalmonScapes
Research Briefs

Article Archives
Scientists seek clues to mountain goat decline



Mountain goats are native to the Cascade Range in Washington state. Photo courtesy of USFS

Alpine Ecoregion: LAND ABOVE THE TREES

Environment of the Alpine Ecoregion

Severe mountain environment: low snow & very cold

Ecoregion	Elevation Range (ft.)	Avg. Annual Temp (°F)	Avg annual precip (cm)
(Seattle) for reference	0	53	86
Sitka Spruce	0 – 500	52	200 – 300
Western Hemlock	0 – 2500	47	150 – 300
Silver Fir	1900 – 4200	42	220 – 280
Mountain Hemlock	4200 – 5900	39	160 – 280
Subalpine Fir	4200 – 5800	39	100 – 150
Alpine	>5000 – >7000	37.5*	46*

Snow accumulation & topography are critical to dynamics of ecosystem function (climate change may alter this)

Alpine Ecosystem Productivity

Alpine ecosystems generally low in productivity :

10 – 400
g C / m² / yr

Variation due to different types of ecosystems

Annual Net Primary Productivity of Ecosystems

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

Boundaries of the Alpine Ecoregion

Aeolian Zone

Alpine Zone

Subalpine Zone

Boundaries of the Alpine Ecoregion

Why don't trees grow higher?



Timberline Winter Drought Theory

- Growing upright:
- Growing upright:
- Water loss from needles in winter:
- The higher you go, the more severe the effects of winter drought on trees

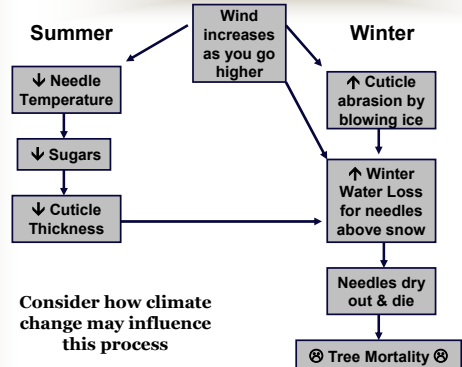


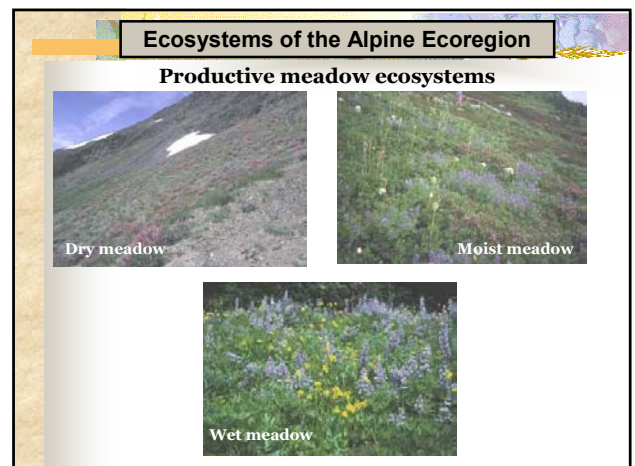
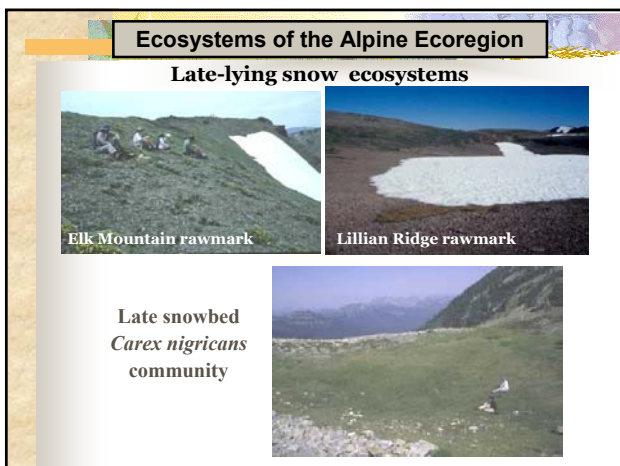
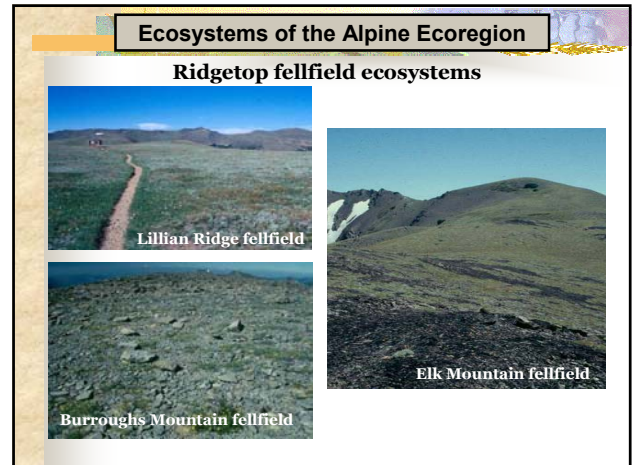
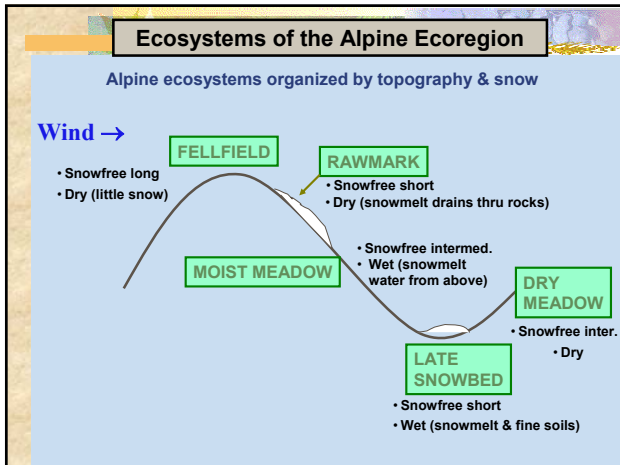
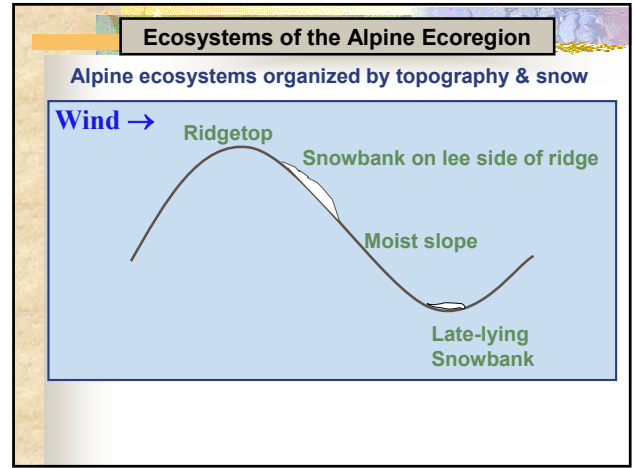
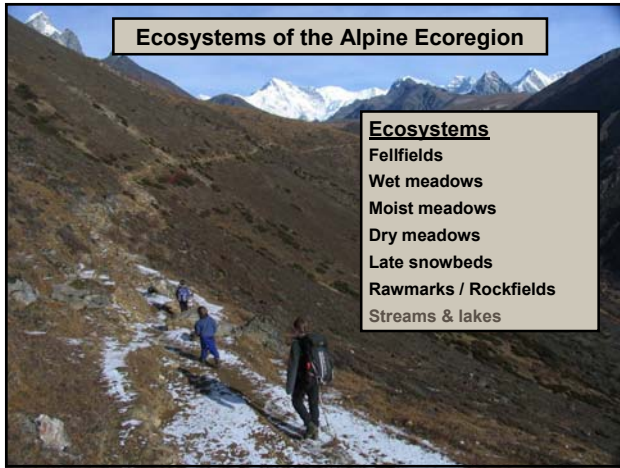
Subalpine fir foliage prolific under the snowline



Winter desiccation of Whitebark pine

Timberline Winter Drought Theory





Ecosystems of the Alpine Ecoregion

Many plants are uniquely adapted & restricted to the alpine



Juncus mertensiana



Oxyria digyna



Penstemon davidsonii



Eriogonum pyralifolium



Saxifraga caespitosa



Douglasia laevigata



Claytonia megarhiza

Ecosystems of the Alpine Ecoregion

Abiotic Factors are generally harsh –
and thus they control primary production

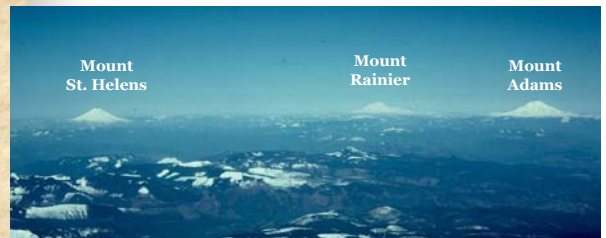
- Growing season:
- Temperatures:
- Summer moisture:
- Nutrients:
- Wind:
- Other soil attributes:

Solifluction terraces; 7,600 ft Mt Rainier

Freeze-thaw disturbances important in the alpine –
susceptible to climate change?

Ecosystems of the Alpine Ecoregion

Alpine habitats as ecological islands in WA



Ecosystems of the Alpine Ecoregion

Soil Crusts of lichens & mosses

Crustose lichen dominated Crust



Crust of Loose Fruticose Lichens



Moss / Fungi Dominated
Black Crust



Crust Effects

-
-
-

They're fragile & response to climate change is unknown

Human Impacts in the Alpine Ecoregion

- Grazing
- Mining
- Recreation
- Research / Study
- Road building
- Introduced species
- Atmospheric pollution



Restoring heavily degraded
alpine areas is a difficult
process!

