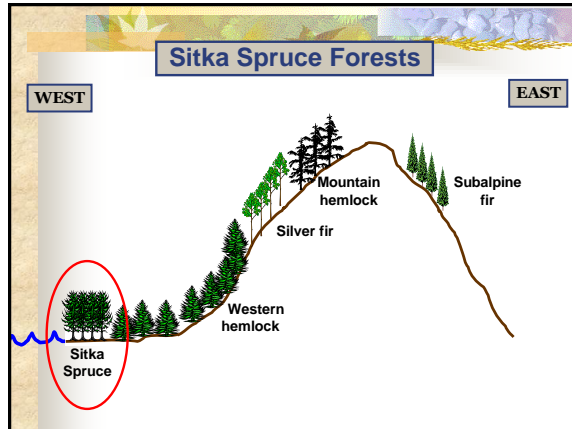


Forests of the Northwest

Forest Ecosystems

- Sitka Spruce Forests
- Western Hemlock Forests
- Silver Fir Forests
- Subalpine Forests
 - Mountain hemlock forests
 - Subalpine fir forests
- Grand fir / Douglas-fir Forests
- Ponderosa Pine Forests



Forest Environments

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	80 – 300
Silver Fir	1900 – 4200	42	220 – 280
Mountain Hemlock	4200 – 5900	39	160 - 280
Subalpine Fir	4200 - 5800	39	100 - 150





Sitka Spruce Forests

Sitka spruce (*Picea sitchensis*) Dominant coastal tree: Oregon to Alaska

Among the 3 largest trees in WA

- 175 – 200+ feet tall
- 8 – 16 feet in diameter

Sitka Spruce Forests

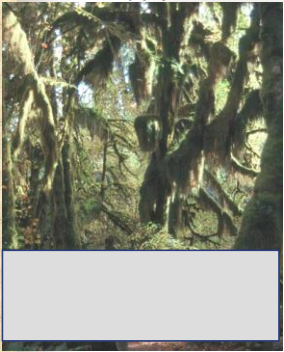
Washington's largest Sitka Spruce




WORLD'S LARGEST
SPRUCE TREE
191 FEET
96' SPREAD
58' AROUND
ABOUT 1000
YEARS OLD

Sitka Spruce Forests

Epiphytes



Towering trees



Sitka Spruce Forests

Animal Species

Greatest vertebrate species diversity in the US except subtropical coastal areas (S California & Florida)

- 225 native vertebrates
- But only ____% restricted to coastal rain forest ("endemic")
 - 2% bird species mostly endemic
 - 14% mammals endemic
 - 72% amphibians endemic

Canopy complexity → _____

Many vertebrate species are strongly tied to _____
(exploiting managed forests as remnant populations)

- 56 vertebrate species use cavities of large trees
- 42 vertebrate species use woody debris




Data: NAS (2000); Bunnell & Chan-McLeod (1997); Johnson & O'Neil (2001)

Sitka Spruce Forests

Some Representative Animal Species

Northern flying squirrel





Northern spotted owl



Black-tailed deer



Roosevelt Elk



Marbled Murrelet

Sitka Spruce Forests

Some Representative Animal Species

Marten



Kirk & Franklin (1992)

Fisher



Mathews (1988)

Vaux's swift



Mathews (1988)

Other mammals not pictured: cougar, Douglas squirrel, raccoon, black bear, etc.

Other birds not pictured: chestnut-backed chickadee, grey jay, dark-eyed junco, American dipper, etc.

Salamanders



Disturbance in Sitka Spruce Forests

Fires infrequent: _____

Fire consequences severe

-
-



Photo: John McColgan (USPWS) Bitterroot Mts; Aug 2000

Disturbance in Sitka Spruce Forests

Hurricane-force winds hit WA coast about every 20 years (over last century)


Over last 100 years, major wind storms:

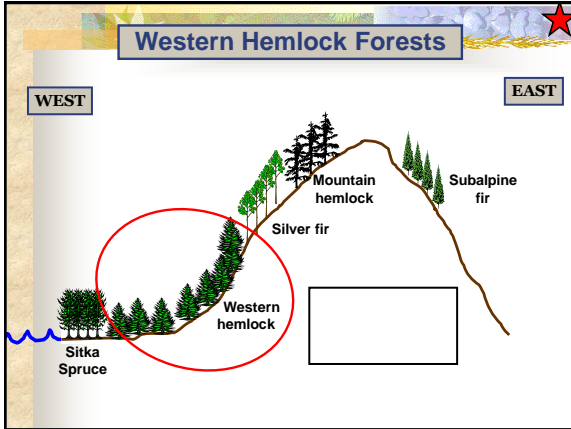
- 1921 • 1955 • 1979 • 2006
- 1923 • 1961 • 1981
- 1934 • 1962 • 1995

Columbus Day windstorm in 1962

- Peak winds > 100 mph
- 11 billion board feet timber blown down in WA & OR
- Enough to frame 845,000 homes

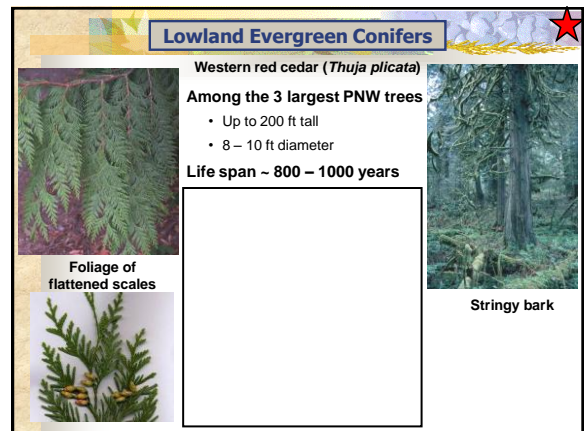
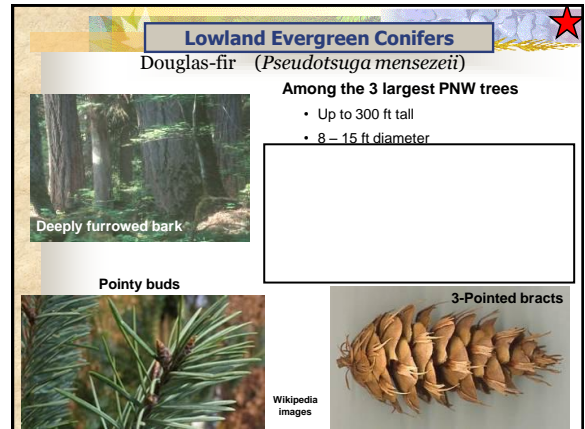
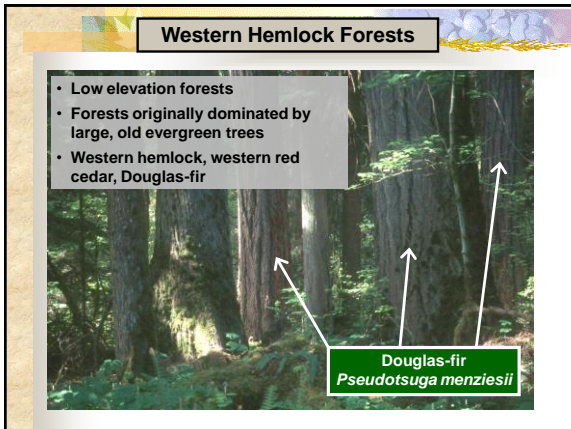
Long Island, WA 1962
Columbus Day Windstorm aftermath






Forest Environments

Ecoregion	Elevation Range (ft.)	Avg. Annual Temp (°F)	Avg annual precip (cm)
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Mountain Hemlock	4200 – 5900	39	160 – 280
Subalpine Fir	4200 – 5800	39	100 – 150



Lowland Evergreen Conifers




Western hemlock (*Tsuga heterophylla*)


"Moderate" size

- Up to 200 ft tall
- 4 – 5 ft diameter

Life span up to 500 yrs



Small, delicate cones



Flattened needles of varying lengths

Platy bark

Drooping leader

Coastforest.org

Western Hemlock Forest Ecosystem Productivity

WA WH Forests are HIGHLY productive:

$g C / m^2 / yr$

Lassoie et al. 1985


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

Western Hemlock Forests


Conditions on the forest floor

- Chronic shade
- Cool
- Moist / humid
- Little wind



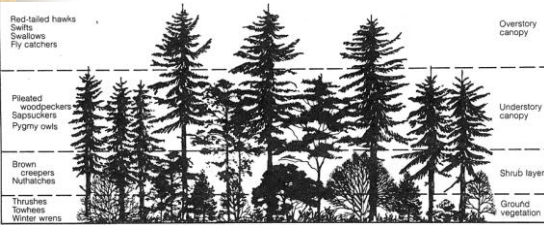
Understory plants adapted to stressful conditions

Some things are stressful



Western Hemlock Forests

Complex vertical structure promotes habitat diversity in mature forests



Overstory canopy: Red-tailed hawks, Swifts, Swallows, Fly catchers





Understory canopy: Pileated woodpeckers, Sapwoodpeckers, Pygmy owls

Shrub layer: Brown creepers, Nuthatches

Ground vegetation: Thrushes, Towhees, Winter wrens


Western Hemlock Forests

Within overall forest structure there are four key structural elements

- 
- 
-  Nurse Log
- 

Western Hemlock Forests

Pileated woodpeckers use snags & create further habitat (ecological engineers)



Holes used by:

- Owls
- Bats
- Martens
- Flying squirrels
- Vaux's swifts and other birds

Western Hemlock Forests

Animal Species


Nearly as diverse as coastal Sitka Spruce forests

~ _____ native vertebrates


Animals strongly tied to mature forest conditions – overall structure & habitat elements

- 56 vertebrate species use cavities of large trees
- 42 vertebrate species use woody debris


Other species similar to Sitka Spruce forests




Northern spotted owl



Douglas squirrel (*Tamiasciurus douglasii*)



Marbled Murrelet



Photos from Mathews (1988)

Data: NAS (2000); Bunnell & Chan-McLeod (1997); Johnson & O'Neil (2001)

Western Hemlock Forests

Animal Species

Forests support very high animal diversity for nation

WA + OR

- % US Conifer Forest Lands:
- % US Breeding Birds:
- % US Cavity Nesters:
- % US Mammals:
- % US Mammals (> 1 kg):

Data: NAS (2000); Bunnell & Chan-McLeod (1997); Johnson & O'Neil (2001)

Western Hemlock Forests

What is an "Old Growth Forest" ?

Age – how old does it have to be?

1) Definitions vary

Variation often tied to:

- Basis for definition (species composition, structure)
- Political / social agenda

2) Class definition

- 175 years without a major disturbance – *for Western Hemlock Ecoregion*
- Based upon known patterns of the accumulation of key structural elements (that have critical functional importance)


Disturbance in Western Hemlock Forests

Fires return interval of _____ years is much more frequent than Sitka Spruce forests (1,146 years)

- Data possibly inflated by Native American burning

Fire consequences severe

-
-



Wind disturbance
significant but not nearly as often or intense as Sitka Spruce forests

Western Hemlock Forests: Human Impacts & Management

Most of our lowland forests are heavily managed for production




Forest harvest
Wishkah Valley

Western Hemlock Forests: Human Impacts & Management


Less than _____ of original forests remain at **low elevations** in western WA

Estimated Potential Extent of Forest Cover (including old-growth) in Western Washington, Pre-settlement



Potential Forest Cover

Extent of Late-Serial Forests More Than 100 Years Old in Western Washington in 1997



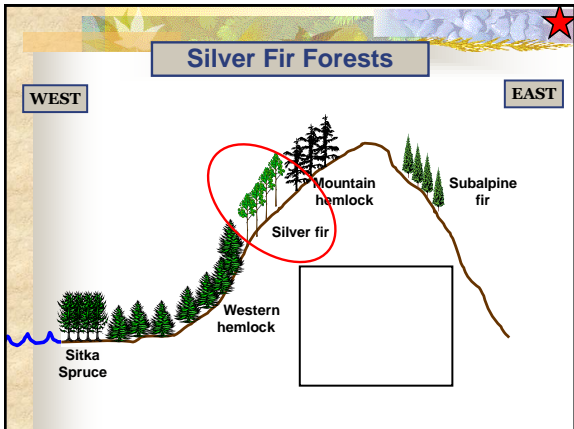
WA DNR 1998

Western Hemlock Forests: Human Impacts & Management

The landscape patterns of harvest are critical for understanding ecological impacts

Western Hemlock Forests: Human Impacts & Management

Plantation forests are not the same ecologically



Forest Environments

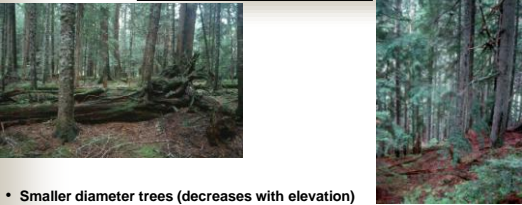
Silver fir forests: mountain environment - wet & cool

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	80 – 300
Silver Fir	1900 – 4200	42	220 – 280
Mountain Hemlock	4200 – 5900	39	160 - 280
Subalpine Fir	4200 - 5800	39	100 - 150

Silver Fir Forests

In addition to slopes, these dominate

Silver Fir Forests



- Smaller diameter trees (decreases with elevation)
- Woody debris common (cold & snow limits decomposition)
- Fire return interval of :

Pacific Silver Fir (*Abies amabilis*)



Up to 150 -200 ft tall
3 – 4 ft diameter
Life span ~ 300 – 500 years



Silver, smooth bark



Silver Fir Forests



- Thin soils
- Cool temperatures
- Heavy snow accumulations:

• Western hemlock seedlings don't survive as well here because:

Silver Fir Forest Ecosystem Productivity

Silver Fir forests vary in productivity from low to high:

$g C / m^2 / yr$

Much less than Western Hemlock forests:
2,000 -3,200
 $g C / m^2 / yr$

Lassoie et al. 1985

Annual Net Primary Productivity of Ecosystems

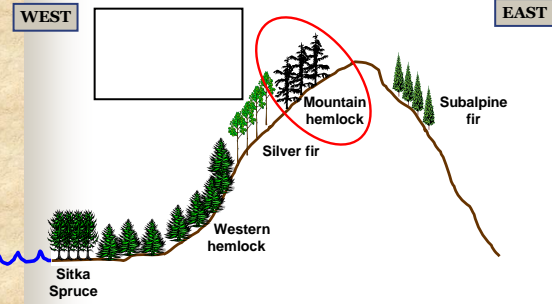
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Tundra and alpine	140	10 - 400
Desert & semidesert scrub	90	10 - 250
Freshwater Wetlands		
Swamp & marsh	2,000	800 - 6,000
Lake and stream	250	100 - 1,500
Marine		
Algal beds and reefs	2,500	500 - 4,000
Estuaries	1,800	500 - 4,000
Open Ocean	125	2 - 400

Silver Fir Forests

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



Mountain Hemlock Forests



WEST

EAST

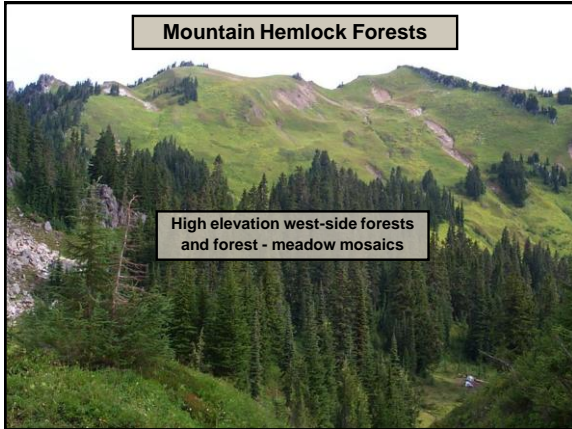
Sitka Spruce

Western hemlock

Silver fir

Mountain hemlock

Subalpine fir



Mountain Hemlock Forests

High elevation west-side forests and forest - meadow mosaics

Environment of Mountain Hemlock Forests

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
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Silver Fir	1900 - 4200	42	220 - 280
Mountain Hemlock	4200 - 5900	39	160 - 280
Subalpine Fir	4200 - 5800	39	100 - 150

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

Deep snow limits _____

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

"tree islands"

Alaskan yellow cedar


Mountain Hemlock Subalpine Meadows




Lush herb community

Highly variable meadow communities – depending upon


- 1.
- 2.
- 3.
- 4.



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 tree invasion of meadows or disturbance rates, such as fire frequency

Fires:

Mountain Hemlock Avalanche Track Ecosystems

Snow avalanches are an important ecological feature





Avalanches are a spatially-limited but important agent of disturbance


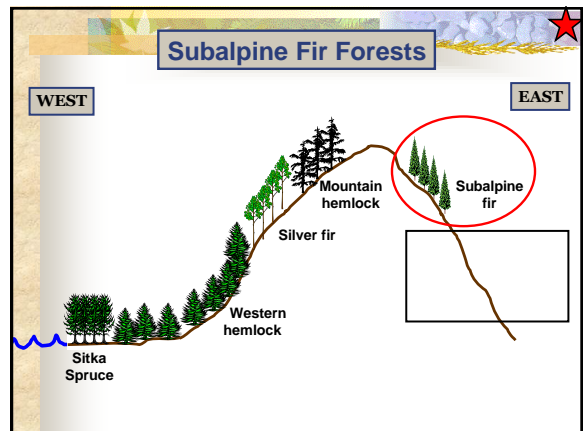
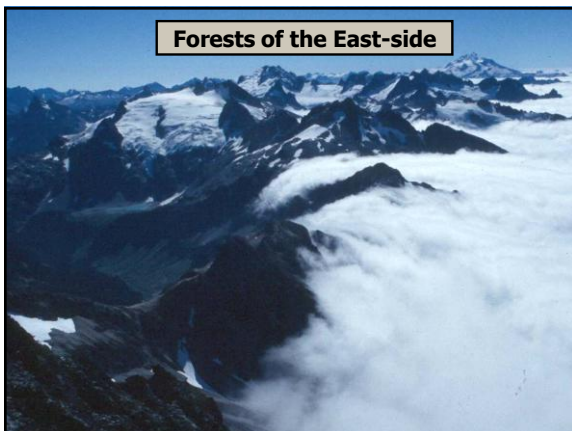


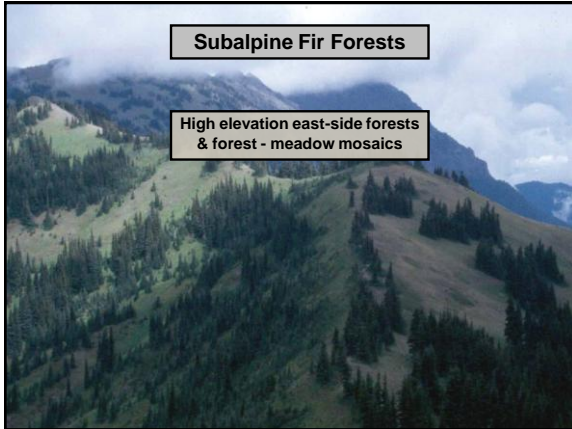
Mountain Hemlock Avalanche Track Ecosystems

Snow avalanches create distinct community patterns – and habitats



Edge habitat are important for ungulates



Environment of Subalpine Fir Forests ★

Severe mountain environment: moderate snow & very cold


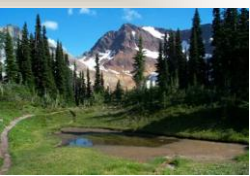

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Subalpine Fir	4200 – 5800	39	100 – 150

Snow accumulation appears critical to dynamics of tree & ecosystem function in subalpine fir ecosystems
 Deep snow limits growing season length & moisture availability

BUT:

Subalpine Fir (*Abies lasiocarpa*) ★

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


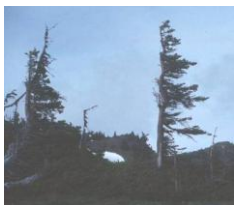




Spire-like growth form




Needles silvery, whitish on both sides

Subalpine Fir ★

Trees at the edge: subalpine fir forms classic growth patterns of trees at timberline

Subalpine Fir Meadow Ecosystems ★

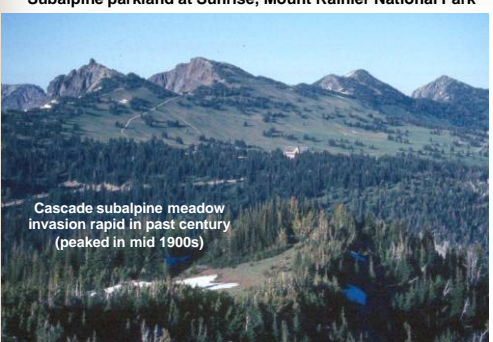




Showy subalpine meadows

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



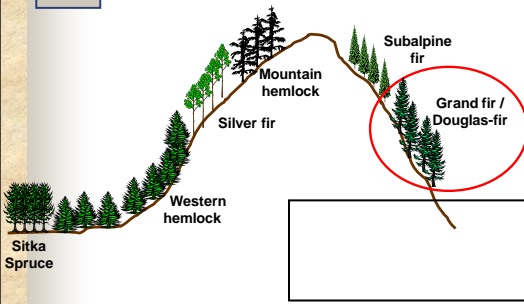
Scientists seek clues to mountain goat decline



Grand fir / Douglas-fir Forests

WEST

EAST

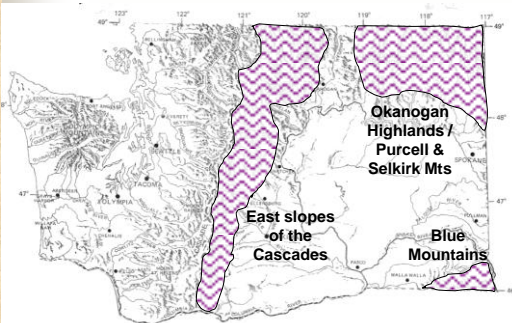


Grand fir / Douglas-fir Forest Environment

General Environment : warm & relatively dry

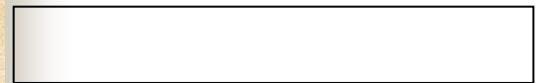
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Subalpine Fir	4200 - 5800	39	100 - 150
Douglas-fir/Grand Fir	2000 – 5000	46	60 – 110

Grand fir / Douglas-fir Forests



Grand fir / Douglas-fir Forest Climate

This east-side forest ecoregion is more continental in climate:



Air Temperature

Station	Ecoregion	Elevation (ft)	Mean annual (°F)	Mean Jan min (°F)	Mean Jul max (°F)
Tonasket	Doug-fir / Grand fir	960	49.4	22.7	87.2
Darrington	Western Hemlock	550	49.1	27.7	77.3

Similar avg. annual temperature

Data from the Western Regional Climate Center <http://www.wrcc.dri.edu/>

Grand fir / Douglas-fir Forest Climate

This east-side forest ecoregion is more continental in climate

Air Temperature

Station	Ecoregion	Elevation (ft)	Mean annual (°F)	Mean Jan min (°F)	Mean Jul max (°F)
Tonasket	Doug-fir / Grand fir	960	49.4	22.7	87.2
Darrington	Western Hemlock	550	49.1	27.7	77.3
Republic	Doug-fir / Grand fir	2,600	43.2	15.1	81.4
Greenwater	Western Hemlock	1,700	45.6	26.0	73.1

What are the effects of this difference in temperature extremes on precipitation?

Data from the Western Regional Climate Center <http://www.wrcc.dri.edu/>

Grand fir / Douglas-fir Forests

Diverse mid-elevation east-side forest ecosystems

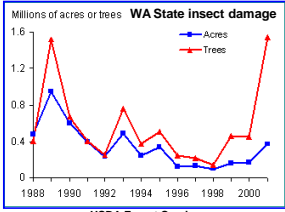
Most diverse forests in Northwest (in tree species)

- Grand fir
- Douglas-fir
- Engelmann spruce
- Subalpine fir
- Ponderosa pine
- Lodgepole pine
- Western white pine
- Whitebark pine
- Western larch
- Alpine larch

Okanogan Highlands

Disturbance in Grand fir / Douglas-fir Forests: Pests

Insect damage to WA forests can be intense and

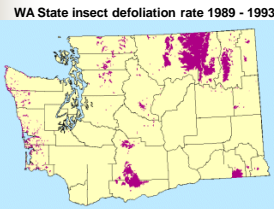


USDA Forest Service <http://www.fs.fed.us/r6/nr/fid/health/2001highlights-wa.shtml>



Disturbance in Grand fir / Douglas-fir Forests: Pests

Insect damage to east-side forests is common and most intense in THIS ecoregion

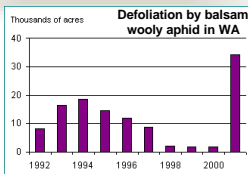


Mtn pine beetle infestation, British Columbia <http://www.for.gov.bc.ca/hre/bcmpt/>

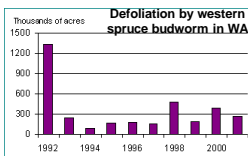
USDA Forest Service <http://www.fs.fed.us/r6/nr/fid/health/2001highlights-wa.shtml>

Disturbance in Grand fir / Douglas-fir Forests: Pests

Insect damage by certain species varies through time



Specific conditions (climate, biological) for outbreaks vary for each different pest through time



USDA Forest Service <http://www.fs.fed.us/r6/nr/fid/health/2001highlights-wa.shtml>

Disturbance in Grand fir / Douglas-fir Forests: Pests

- Recent massive outbreak of the mountain pine beetle in BC has killed 100 billion board feet (~ 9 yrs of harvest)
- low temperatures (< -10 °F) limit beetle activity
- recent lack of extreme cold, killing temperatures has allowed the beetle to thrive



Info courtesy of A Snover, UW Climate Impacts Group Photos from <http://www.for.gov.bc.ca>

Disturbance in Grand fir / Douglas-fir Forests: Fire

Fire is also frequent and extensive (and interacts with insect damage)

Fire return interval: _____

(Western hemlock 230 yrs; Sitka spruce 1140 yrs; Silver fir 3 – 500 yrs)

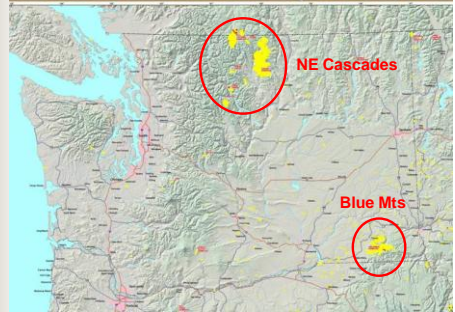


Data: Agco 1993

Disturbance in Grand fir / Douglas-fir Forests: Fire

This ecoregion is disproportionately affected by fire

MODIS Active Fire Detections - September 11, 2006



USDA Forest Service <http://activefiremaps.fs.fed.us/activefiremaps.php>

North American Lynx in Grand fir / Douglas-fir Forests



NPS

Lynx canadensis

Small predator common in lodgepole pine-dominated forests
(30 - 40 inches long; 10 - 40 lbs)

Status

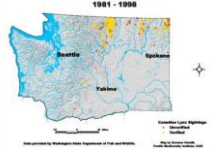
State:

Federal:

Challenges

-
-
-

Canadian Lynx Sightings 1981 - 1996

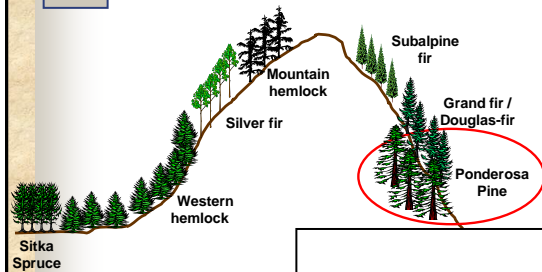


Map from Pacific Biodiversity Institute

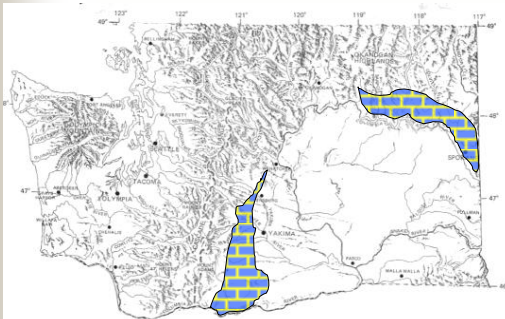
Ponderosa Pine Forests

WEST

EAST



Ponderosa Pine Forests




Ponderosa Pine Forest Environment

General Environment : warm & quite dry

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
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Subalpine Fir	4200 – 5800	39	100 - 150
Douglas-fir/Grand Fir	2000 – 5000	46	60 – 110
Ponderosa Pine	2000 – 4000	47	40 – 70

What mean values do not reveal is **VARIABILITY** or **EXTREMES**
(similar pattern of continental climate as Grand fir / Douglas-fir forests)


Ponderosa Pine Forests ★



Dry, mid-elevation fire-dependent forests
 Open understory indicates frequent fires
 Mean fire return interval for PNW: _____

Ponderosa Pine Forests ★

Ponderosa Pine is well adapted for fire (and drought)



Acidic litter deters tall undergrowth, promoting low intensity ground fires


No lower branches to carry fire upward

Thick, fire-resistant bark

Pinus ponderosa

Ponderosa Pine Ecoregion ★

Insect damage



Data: USDA Forest Service <http://www.fs.fed.us/r6/nr/rid/health/2001highlights-wa.shtml>

Ponderosa Pine Forests ★

Relatively few grazers & carnivores:
 simple food webs

- 1.
- 2.
- 3.
- 4.

