Improving Our Understanding of Climate and Weather on Wildfires: Considerations for Fisheries and Water Quality in the Klamath-Siskiyou Mountains

- Frank K. Lake
  - USFS-PSW, Research Ecologist, Fire and Fuels Program
  - Ph.D, Oregon State University 2007
  - Fisheries 1994-1999
  - B.S., U.C. Davis 1995

Orleans Complex-Somes Fire 10 August 2006, Orleans, Ca. View of Perch Creek/Klamath River
Klamath River Basin

Issues to be covered:
- Salmon stock status
- Historical and contemporary wildfire effects
- Climate and wildfires
- Linkages of wildfires to forests, riparian zones and fisheries

* Unique features-Inverted basin, geology-vegetation from the convergence of coast ranges, Cascades, Sierra Nevada mountains.

Map: NMFS-NOAA 2007:3
Klamath-Siskiyou Fish Stocks At Risk: Coho and Chinook Salmon

Fixed life history pattern

Variable life history pattern
Scientific Knowledge of the Effects of Forestry and Fires on Fisheries

- Physical
- Bio-geo Chemical
- Biological/Ecological
- Scale of magnitude or processes
- Complexity of components
- Synthesis vs. Statistical rigor-Types of research
- Scope of influence for observational vs. manipulative studies.
Factors influencing Fire and Fish

- Climate/weather
- Fire frequency, vegetation response, and landscape condition
- Direct/Indirect Effects
- Spatial and temporal scales


Figure 1.—Factors influencing fire and the effects of fire on terrestrial and aquatic ecosystems.
Synergistic Interactions: Climate-Forest-Fire-Hydrology-Fish

Fisheries and Aquatic Conditions Influenced by Forestry/Fuels Reduction and Wildfires

• Direct
  – Heating/Vegetation removal
  – Smoke/Temperature
  – Nutrient and debris inputs

• Indirect
  – Erosion: Nutrients, sediment and woody material inputs
  – Hydrology: Increased water yield
  – Population changes linked to fire severity and extent
  – Species and runs influenced differently due to life histories and disturbance adaptations

Fire suppression and repair activities?
Biophysical Changes Over Time

- Chemical/Nutrients
- Organic inputs
- Invertebrate community response
- Food web dynamics
- Fish productivity and resilience

– Gresswell 1999

Figure 3.—Hypothetical changes in physical, chemical, and biological characteristics of fluvial systems following fire. The letters F, W, S, and S indicate fall, winter, spring and summer, respectively. ( Adapted from G. W. Minshall et al. 1989.)
Paleoclimate: Holocene-Fires and Fish Adaptive Response

• Ocean sediment cores: Sancetta et al. 1992, Winds, Up-welling, seasonal production of the Nor. Cal. Current. etc. “The absence of these taxa during the glacial interval therefore implies a climate cooler than present and lacking summer coastal fogs produced by up welling”

“Evidence of atmospheric warming combined with summer fogs first appears about 13,000 yr. B.P. Studies from continental sites indicate that summer atmospheric temperatures increased throughout the PNW at this time.”
Paleoclimate and Fires: Millennia, Centuries, and Decadal Patterns

- Briles and Whitlock 2005: Bolan Lake Charcoal and Pollen Data
Paleoclimate and Fires: Patterns of Centuries, and Decades

- Whitlock et al. 2004: Comparison of charcoal and tree ring records
Historical Fires of the Western Klamath Mountains:
Clearview, near Clear Creek

Fire Interval Analyses, All Scarred, 1700-1998.
Part 1: Summary Information, > 2 scars/sample

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- **Fire Frequency**
  - Presettlement (1600s-1850s) MFRI 8 years (Skinner unpublished)
- **Seasonality of fires**
  - Majority Late Summer/Early Fall 59% (Latewood). ~14% Late earlywood, ~10% Mid-earlywood, ~16% Dormant.
Cultural and Natural Fire Regimes of the Klamath-Siskiyou Mountains

- Ethnographic and archaeological data about tribal burning practices and villages
- Paleoclimate and fire history data
- Integrated studies to examine Climate-Weather-Fire-Forests-Fish interactions

Photo: Kroeber Karuk Village

Figure: Briles 2005
Testing for Cultural Fire Regimes

- Debate about the extent of indigenous ignitions: Local or Landscape?

- Evidence:
  - Paleoclimatic
  - Fire History Reconstruction
  - Archaeology-tribal land use patterns
  - Vegetation-Ignition Simulation Models

Univ. of Nv.-Reno and USFS-PSW: Crawford and Mensing & Lake and Skinner *NSF funding provided
Wildfire behavior, severities, and frequencies: Then and Now?

- **Historical:**
  - Understory surface lower to moderate intensities
  - Low and moderate severity dominated, high severity areas patchy
  - Frequent/short to intermediate (10-50 years) fire return intervals
  - Topography, aspect, slope position, and soil-substrate influenced

- **Contemporary:**
  - More ground/duff, individual torching, and continuous crown fires in denser forests
  - Greater proportion of moderate and high severity
  - Due to fire suppression and exclusion, longer fire rotations and fire return intervals for circa 1910-1987
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  – Topography, aspect, slope position, and soil type influenced

• Contemporary:
  – More ground/duff, individual torching, and continuous crown fires in denser forests
  – Greater extent of area burnt/fire, and proportion of moderate and high severity
  – Due to fire suppression and exclusion, longer fire rotations and fire return intervals for circa 1910-1987
  – Bio-physical control factors
Fire Regime Condition Class: How does departure affect fish?

- Proportion of the landscape in class 2-3
- Changes in forest density and increased fuel load
- Prioritization of fuels treatments
- Little consideration for fisheries or hydrology
Weather to Fires to Fish: Models and research design to be developed

• Phase I:
  – MODIS: satellite imagery
  – RAWS: Temp., Precip., Rel.Humidity., Wind, Solar radiation, etc.
  – Stream temperature data from CA and PNW

• Phase II:
  – Smoke particulate readings from air quality monitoring
  – Fire progression mapping
  – Fire severity mapping
  – Fish migration/telemetry

Wildfires: Aug. 3, 2002
The hypothesized process: Climate & Weather Effects

- Climate drives longer scale weather patterns and fire events
- Seasonal weather influences fire behavior, hydrology, and fish response
- Fish respond to atmospheric-landscape scale processes
Summer coastal weather: Fire Behavior and Fish Responses-Foehn Winds and Fog

• Mass et al. 1995. “A day earlier reveals substantial warming (increasing 5-10° C) and drying in the layer of offshore flow
Elevated smoke layers produced daytime cooling but had no nighttime effects. **Inversion** strengthened by cooling. For the first two weeks, other than a cold front, a **High pressure system** prevailed over the region.
Linking salmon life history migration, thermal refugia, and wildfire research

Movement of juvenile coho within the mainstem river corridor

- **1** fry emerge
- **2** juvenile residency
- **3** winter/spring residency
- **4** Smolt emigration

**Dispersal**

- High temperatures
- Spring runoff
- Reduced Evapo.Trans

**Redistribution**

- Peak flows
- Spring runoff

**Smoke**

- Low flows

**Temperature**

Graph: Karuk Tribe,
Top Photo: MODIS, Collaborative ideas and data sharing

Burn severity: Vegetation comparison and active burning

Vegetation/fuel burning and smoke distribution
Agness, Rogue River, Or. RAWS and USGS temperature data
August 2002 during Biscuit Wildfire

Aug. 14, 02
Dillon Fire 1994: Weather, Fire/Smoke, Water Temp, & Fish

- The maximum daily water temperature of Dillon Creek 300 feet upstream of its mouth in 1993 and 1994. Temperature ranges exceeded stressful levels for salmon or steelhead in June and July 1994. Ironically, a major fire in the Dillon Creek watershed in 1994 is probably responsible for the cooling trend in the latter half of the summer of 1994. *Data source KNF stream temps/KRIS-P.Higgins.

Incorporating stream temperature monitoring and modeling data

- USFS, USGS, Watershed Councils, Tribal, NCRWQCB data
- Mid-lower Klamath River Basin TMDL-Water Quality Models
  - (Flint and Flint 2008-USGS)
- Cross reference with MODIS image of smoke and RAWS stations (air, % relative humidity, wind)
- Solar radiation-Short wave important to stream temperature

*USFS data and Flint and Flint 2008-USGS
Limiting and/or Critical Factors for Klamath Basin Salmonids: Thermal Thresholds and Risks

- **Chronic**: Reduced growth rate, increased susceptibility to disease
- **Acute**: Juvenile mortality rates begin to increase

- Chronic > 15°C and Acute > 20°C for salmonids

- Juv. Salmonids stressed > 16°C chronic and > 22°C acute
  - (Campbell et al. 2001)
Salmonids: Thermal tolerances and habitat preferences

• Species and age cohorts
  – Habitat selection varies
  – Spp. Specific biological needs within range of thermal tolerance

• 14-18°C for optimal growth (Sullivan et al. 2000).

Chinook: Hottest time of day, middle, edge w/ velocity shear line, greater distribution along refugia

Steelhead: Hottest time of day, middle, edge w/ velocity shear line

Coho: Slow water, ground seep, rooted aquatic vegetation/cover

*Sutton et al. 2007: Beaver Creek Thermal Refuge*
Salmonids: Thermal Thresholds and Risks con’t.

- Mid to upper basin summer max. not to exceed 16°C for 7 day avg. of daily max. values (USEPA 2003)
- Daily max. temp. maintained < 20-21°C for juv. Coho and Chinook, < 21-23°C Steelhead to protect from acute lethality (Hicks 2000)
- < 16-17°C water temp. salmonids are more resistant to Ceratomyxosis disease (Foott et al. 1999)
- > 20°C water temp. and D.O. below 7mg/L increase bacterial infections in juvenile Salmonids (Williamson and Foott 1998).
Integrating MODIS, RAWS, & Air Quality Data: Aug. 13, 2008 at 3pm

- Junction City [3pm: 0.033 vs. 5pm: 0.134 (mg/m³)]
- Big Bar [3pm: 0.265 vs. 5pm: 0.099 (mg/m³)]
  - *Aug. 14, 11am (1.353mg/m³)
- Orleans [3pm 0.067 vs. 5pm 0.058 (mg/m³)]

Smoke coverage, density, air temperature, % relative humidity, and stream temperature can be directly “real time” correlated!
Air Temperatures: Above and Below the Inversion-Smoke Layer

- Robock 1988: Data comparison using over 70 stations.
- Smoke has higher albedo than wooded surfaces.
- Only a strong synoptic scale front was able to disrupt the amplifying cycle of smoke induced cooling/reduced solar radiation.
Fire severity and weather (inversion layer) 2006

![Fire severity and weather graph](image)

Reasons:
- Stable air, low winds, little upward motion
- Trapped smoke reduces solar radiation, decreases temp., increases RH

*Data: Knapp and Estes: USFS-PSW*
Species or runs of fish affected by forestry/fuels reduction practices and wildfire

- Coho-low/moderate
- Chinook
  - Spring-high/moderate
  - Fall-low/moderate
- Steelhead
  - Summer-high/moderate
  - Winter-low
- Resident trout: Rainbow and cutthroat-moderate
- Sturgeon-low
- Lamprey eels-low/moderate
- Suckers, dace, sculpin, etc.-unknown/low?

- Extent and proportion of severity, and geology of watershed affected by fire
  - Example Wooley Creek tributary to the Salmon River: Multiple wildfires occurring, DG erosive soils, stocks at risk.
- Future climate-fire-vegetation and related watershed processes on fisheries
Wildfire severity, frequency, fisheries and watershed condition: Wooley Creek

Proportion of fire severity types (low-high) across watershed in relation to fish distribution
Fire Progression and Severity with Smoke

- Ukonom Fire spread July 22-24, 2008 around edge of Hancock Fire-Uncles Complex 2006 and Wooley 2005

- Weather frontal events influence fire behavior and resultant effects
  - Pre Frontal
  - Post Frontal
  - Sub Tropical Aloft (inversions and elevation)
  - Cold Fronts
  - Canyon inversion duration
Effects of Canyon Inversions on Air and Water Temperature

- July 21, 2008 at 2pm
  - Somes RAWS Air temp.: 84.0°F
  - Solar Radiation: 815.0 W/m²
  - 30% Relative Humidity
  - Salmon RM 1.0 Water Temp.: 66.47°F

- July 24, 2008 at 2pm
  - Somes RAWS Air temp.: 82.0°F
  - Solar Radiation: 703.0 W/m²
  - 35% Relative Humidity
  - Salmon RM 1.0 Water Temp.: 64.59°F
Climate influences fire weather and behavior leading to severity

Ignition probability, extent and severity can vary from year to year-
So how does this relate to stream temperature and fish?

Photo: Aug. 1, 2006 afternoon
Siskiyou Fire Severity and Progression

MODIS July 7, 2008, SE View from Kelsey Springs trail

July 7-11, 2008 Severe Fire Weather and Behavior
2008 Klamath Mountain Fires: Southern region

Composite Burn Index Categories:
- Green: Unchanged
- Light Green: Low severity
- Yellow: Moderate severity
- Red: High severity

Data/Slide: Knapp-USFS PSW
Climate and Wildfires: Threats to Salmoninds

- **Climate change**
  - Precipitation delivery: Less snow pack—hydrologic regime change
  - Winter mean temperature to increase
  - Longer wildfire season affected by fuel moisture content

- **Wildfires: Short and long term effects/impacts?**
  - Extent and severity to increase
  - Direct and indirect effects to salmonid habitat quality
  - Fire suppression/repair activities
  - Need for sub-basin planning
  - Research to link direct and indirect effects to habitat or species populations.

MODIS Image: http://activefiremaps.fs.fed.us/fireplots/cgb2008275_1500.jpg
**Future Climate Fires, Forests, and Fish?**

**Fire:** “The combination of warmer climate with higher CO2 fertilization will likely cause more frequent and more extensive fires throughout western North America; fire responds rapidly to changes in climate and will likely overshadow the direct effects of climate change on tree species distributions and migrations. A temporal pattern of climate-driven increases in fire activity is already apparent in the western United States and modeling studies specific to California expect increased fire activity to persist and possibly accelerate under most future climate scenarios, due to increased growth of fuels under higher CO2 (and in some cases precipitation), decreased fuel moistures from warmer dry season temperatures, and possibly increased thundercell activity. By 2100, Lenihan et al.’s (2003) simulations suggest a c. 5% to 8% increase in annual burned area across California, depending on the climate scenario. The MC1 runs reported in Barr et al. (2010) project increases in annual fire area in the Klamath River Basin of 11-22% by 2100, resulting in as many as 330,000 acres (134,000 ha) burned in an average year. Increased frequencies and/or intensities of fire in coniferous forest in California will almost certainly drive changes in tree species composition”

Data: R. Butz and H. Stafford 2010 USFS Klamath NF Report
Wildland Fire Smoke: Benefits to Who and What- People vs. Salmon?

• “So long as fire researchers use as primary data agency mapped wildfire perimeters unadjusted for management initiated suppression fires your conclusions - even yours about the smoke - are meaningless. How much of that smoke was natural and why was that not a prime question to investigate? I would not trade the health of River elders for a few degrees of temporary temperature relief for fish.”

– E-mail/pers.com. 29 Mar. 2011

Discussion points or Questions?

- Thanks to Karuk, Hoopa and Yurok tribes, USFS-Rogue-Siskiyou, Klamath, Six Rivers NFs, PSW-PNW, MKWC, SRRC, NCUAQMD, KRIS, and others for data

*My favorite fire effects on fish!* - Fall Chinook Aug. 2008