Influence of Fog and Overcast on Stream Temperatures across Several Scales, North Coastal California

Mary Ann Madej, USGS

Motivation for this study:

Water temperature influences:

- Fish metabolism
  - Appetite and digestion rates
- Growth rates
- Developmental rates of embryos and alevins
- Timing of life-history events:
  - Migration
  - Fry emergence
  - Smoltification
- Competitor and predator-prey interactions
- Disease-host and parasite-host relationships

And…….

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Fish kills due to high temperatures

Klamath River, 2002, (65,000 dead salmon))

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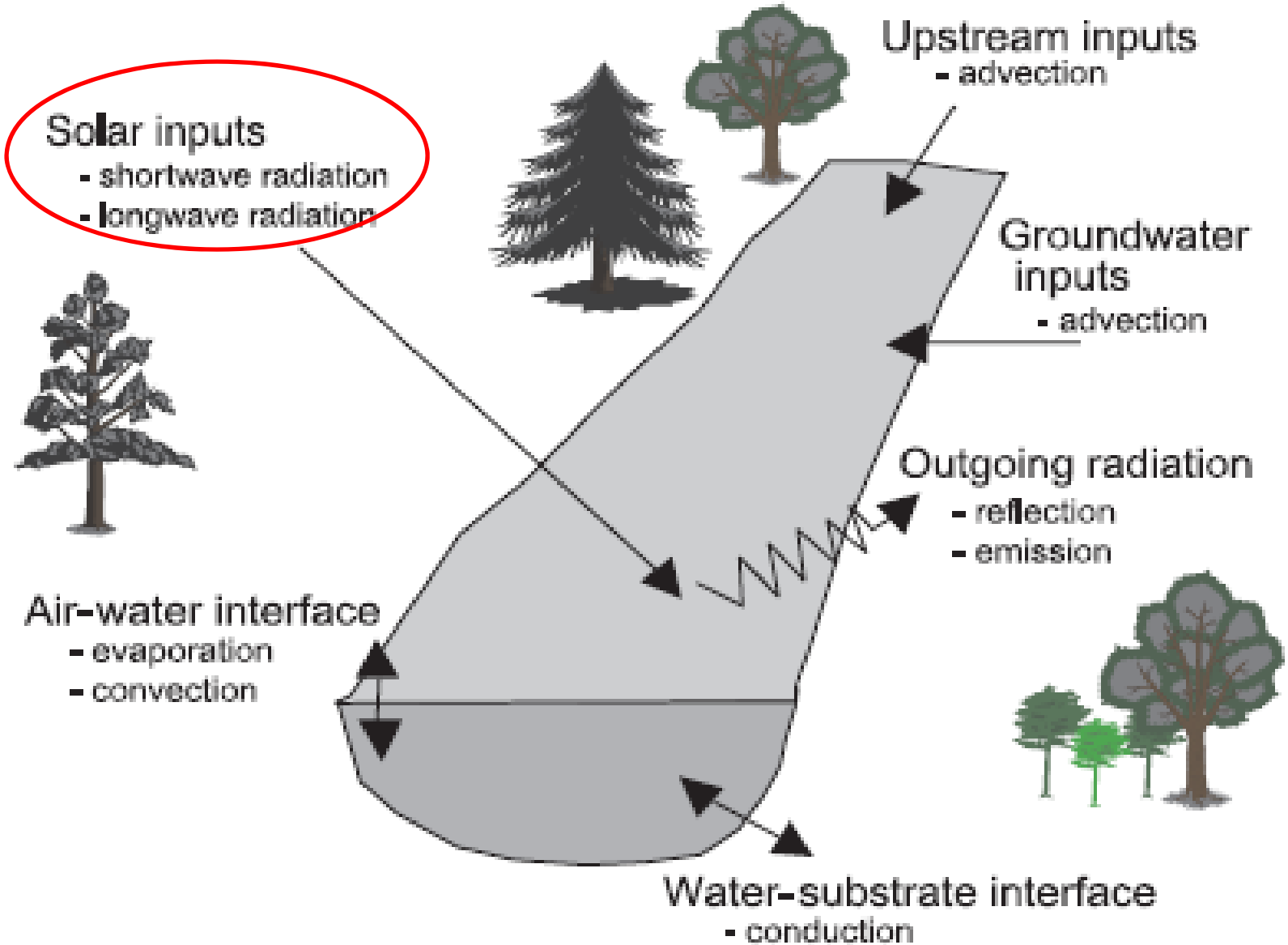

From Johnson and Jones, 2000

Fog along the coast, but not upvalley

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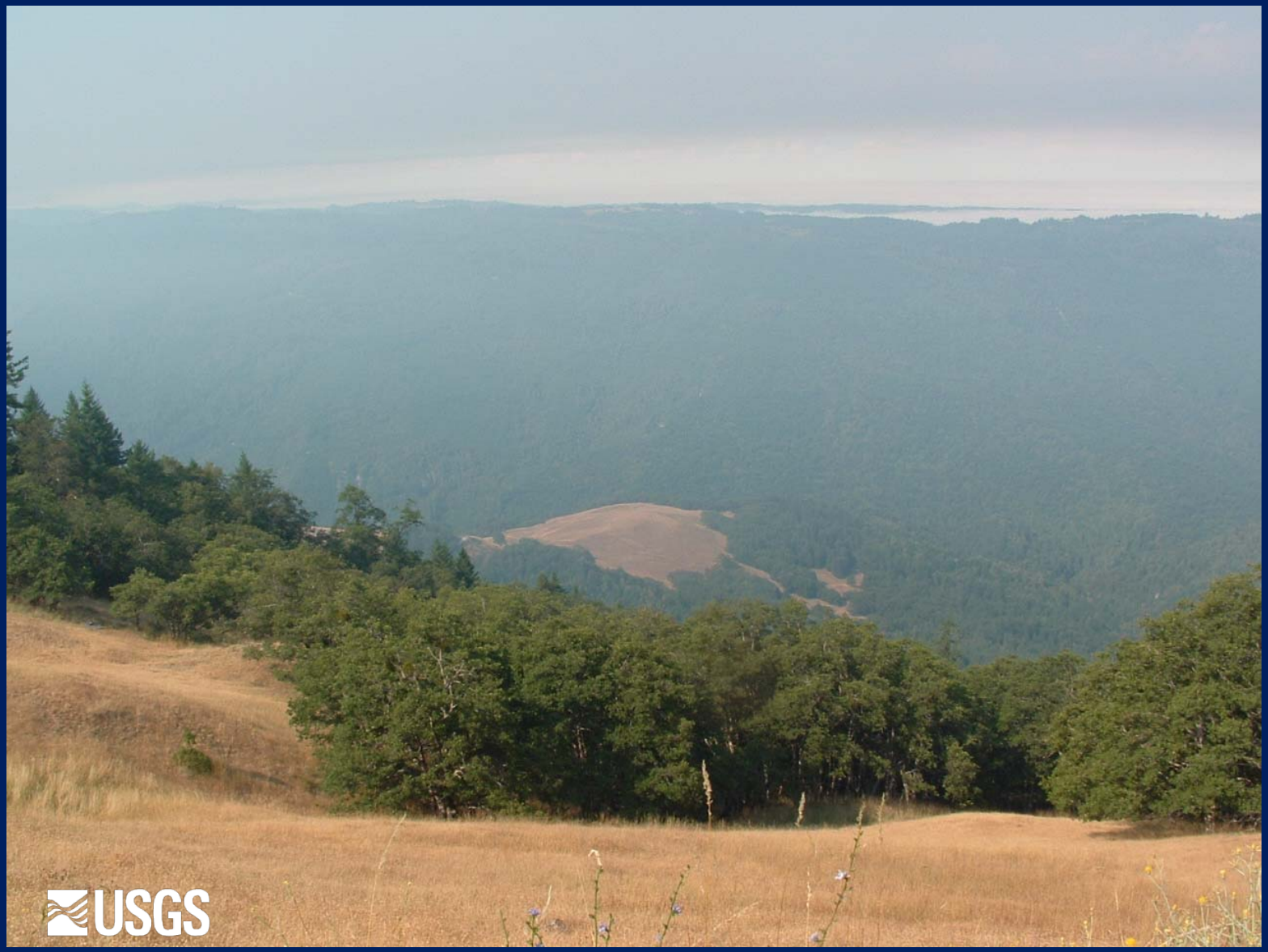
Fog in the Redwood Creek Valley

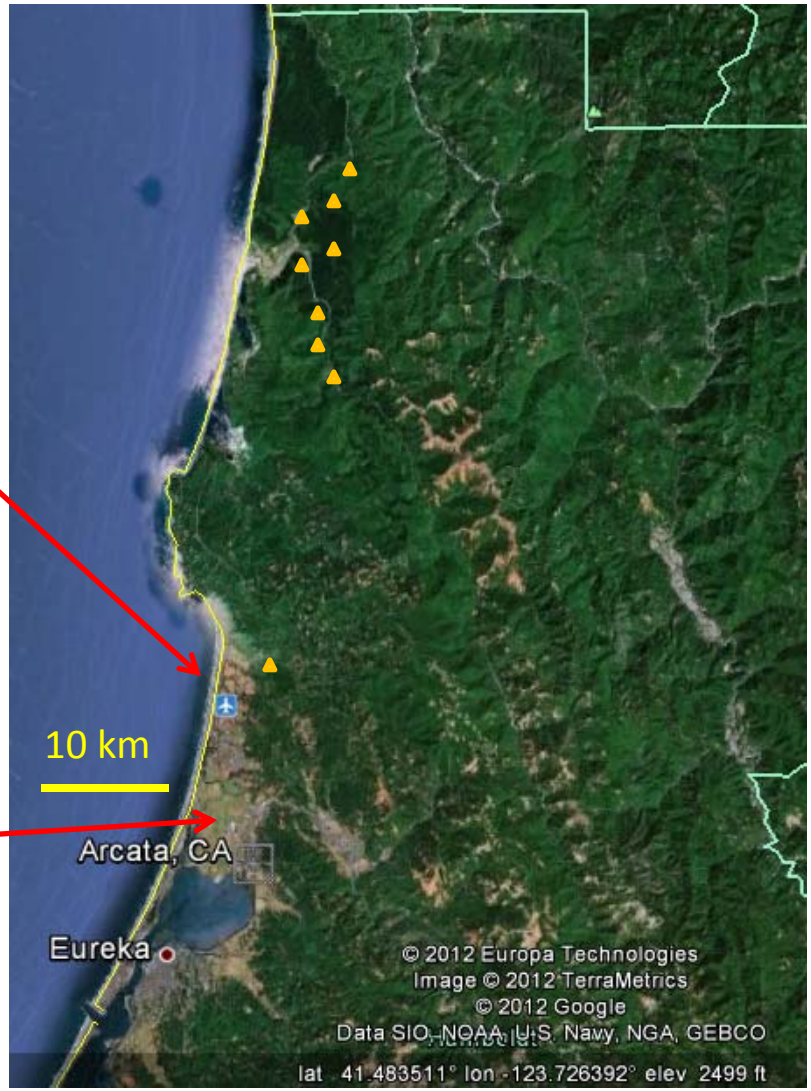
Wildfire haze also decreases incoming solar radiation



Sources of Fog Data

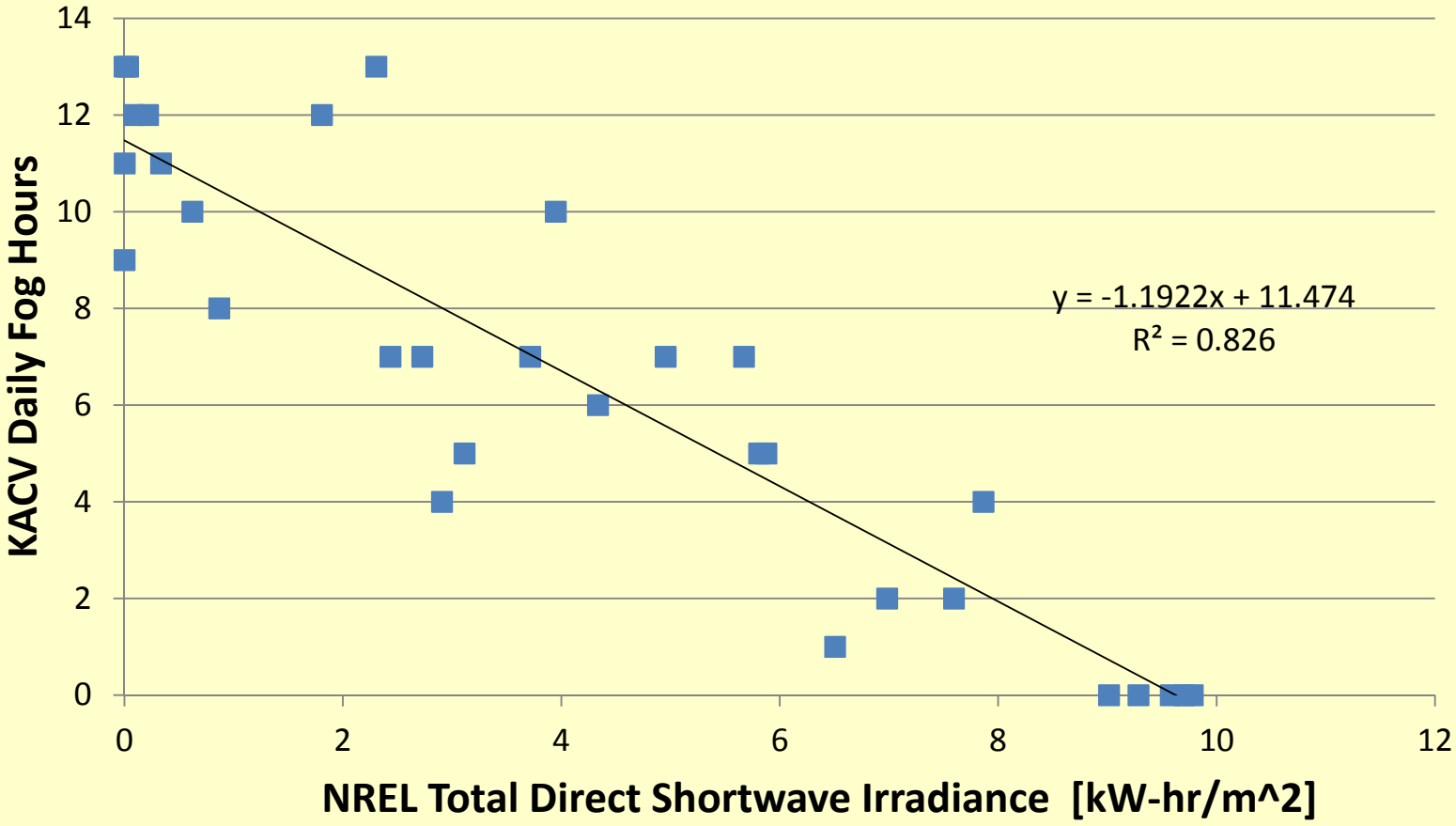
Hourly Observations
Arcata Airport
(KACV), McKinleyville, CA

National Renewable Energy Lab,
Humboldt State University,
Arcata, CA



Total Hemispheric shortwave irradiance as measured by an Eppley Laboratory, Inc. Model PSP (Precision Spectral Pyranometer)

Total Daytime Fog Hours (Airport) vs. Total Direct Normal Irradiance (HSU) August 2008



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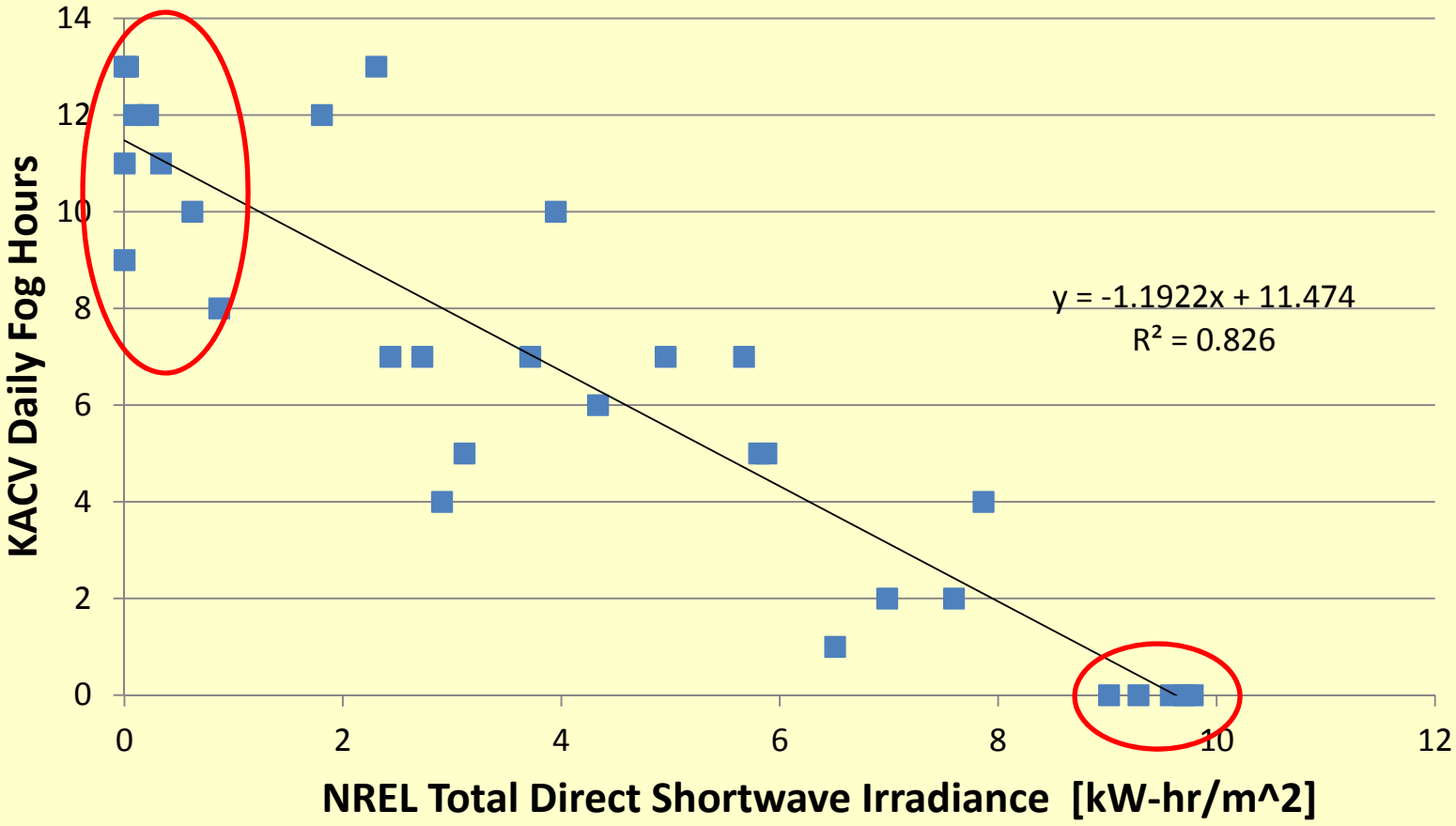

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Scales of Analysis

Temporal Scales

- Hourly
- Daily
- Seasonal
- Annual
- Decadal

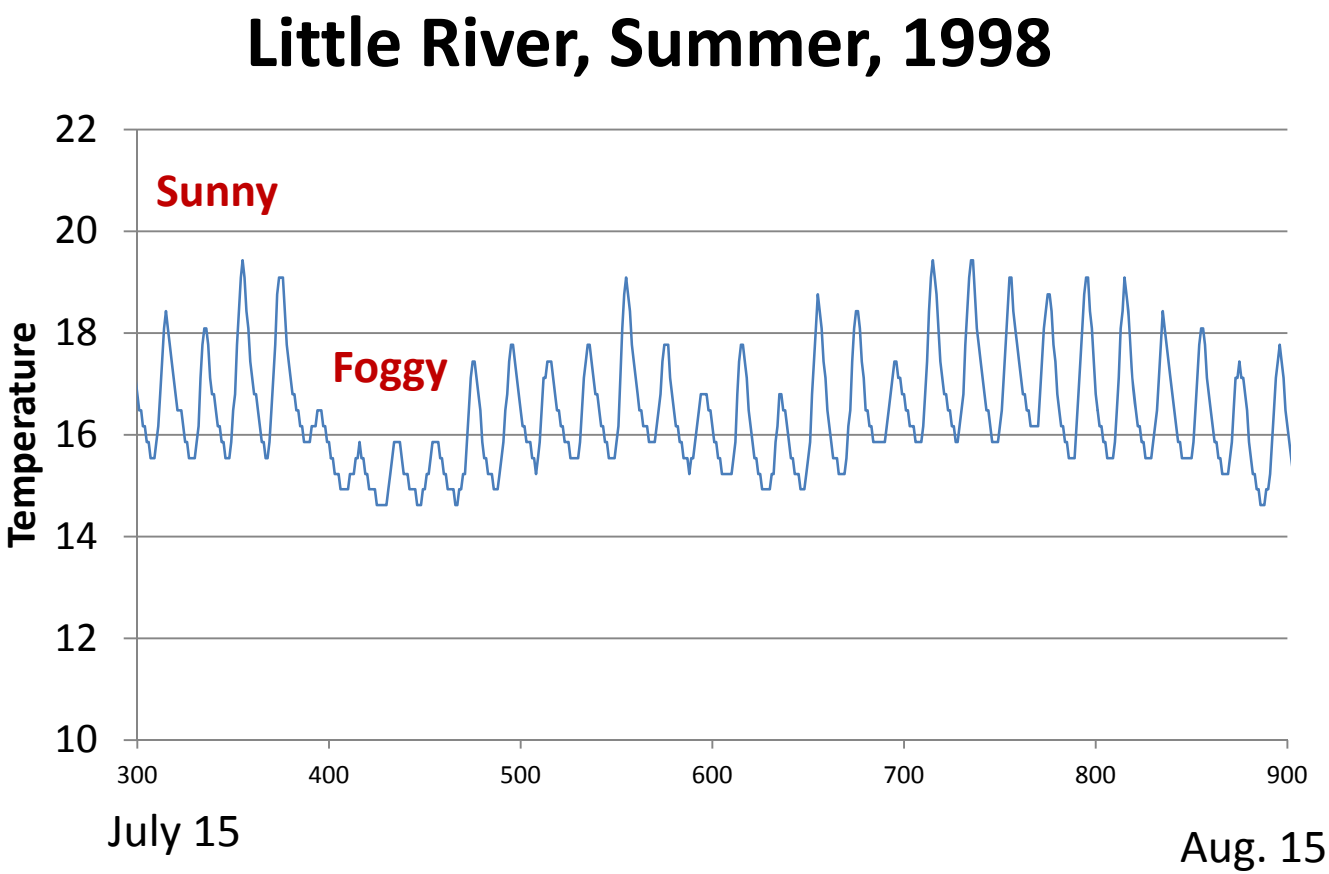
Spatial Scales

- Size of watershed
- Distance from ocean

Other influences

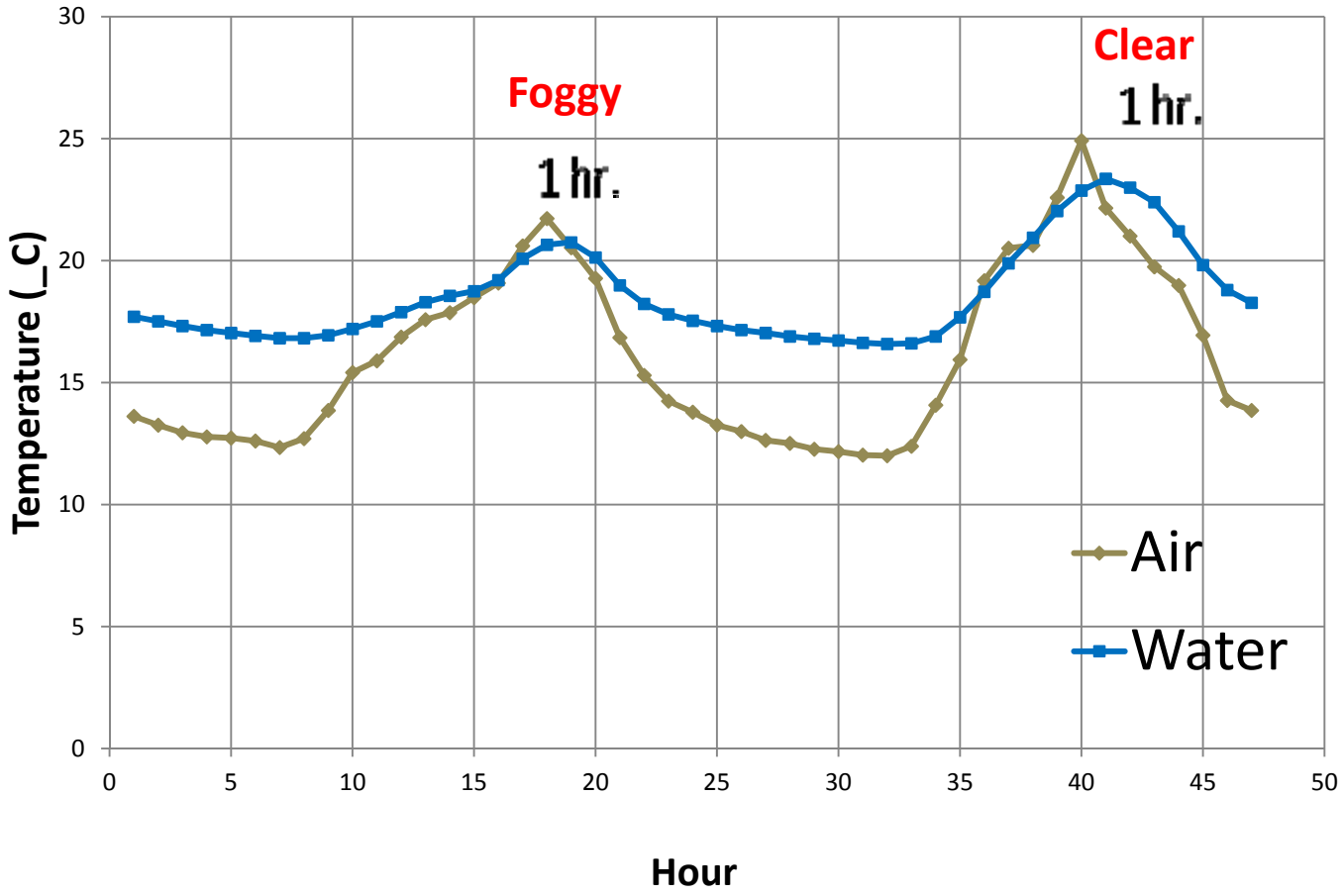
- Channel orientation
- Canopy closure
- Elevation
- Streamflow

Daily scale:
Higher maximum and diurnal variability on sunny days than on foggy days.

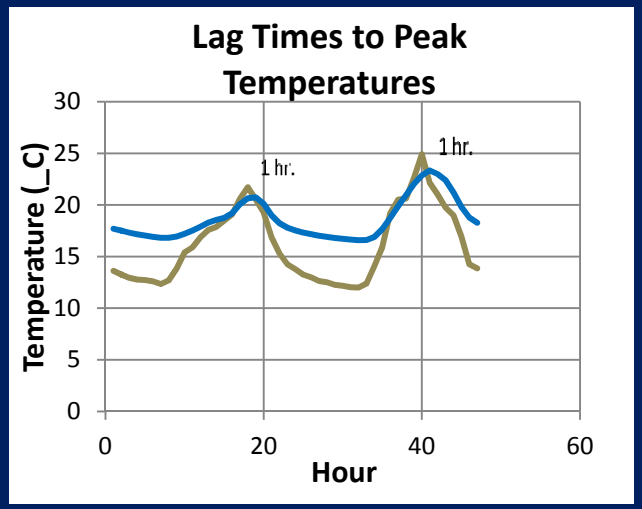


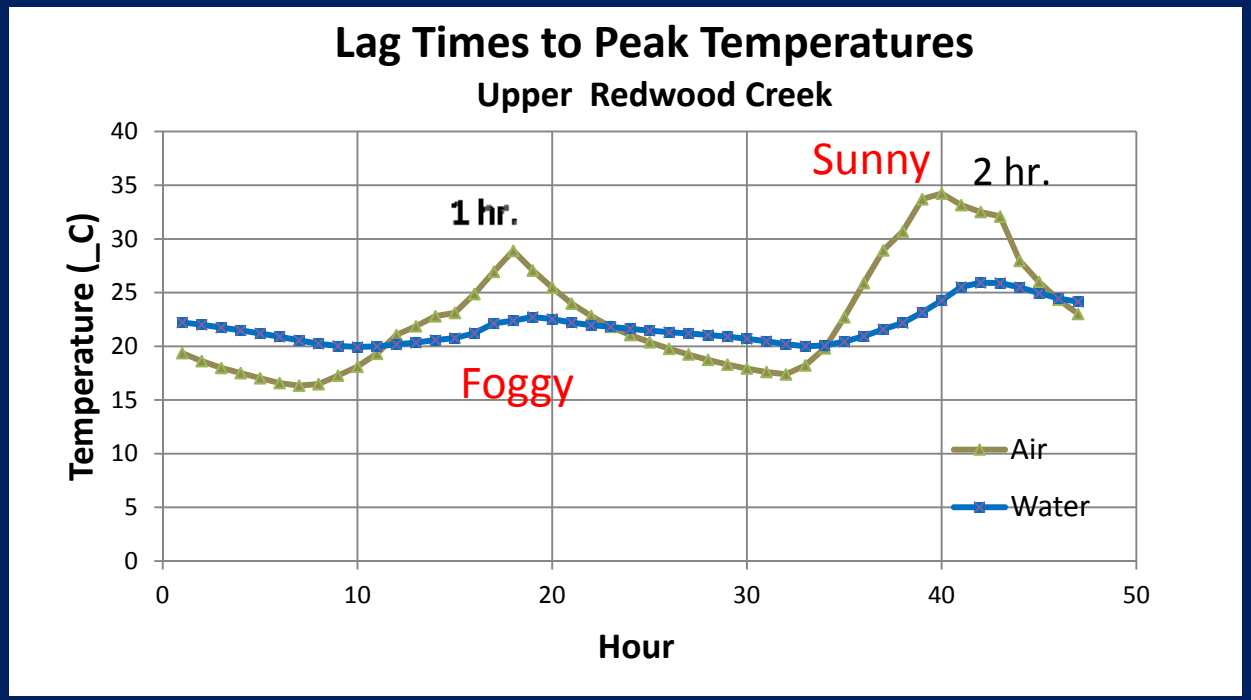
Lag Times to Peak Temperatures

Lower Redwood Creek



No difference in timing of maximum temperature, just magnitude of peak


Lag Times to Peak Temperatures
Temperature (_C)
Hour
1 hr.
1 hr.
0
5
10
15
20
25
30
0
20
40
60


Lag Times to Peak Temperatures
Upper Redwood Creek
Temperature (_C)
Hour
1 hr.
Sunny
2 hr.
Foggy
Air
Water
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50

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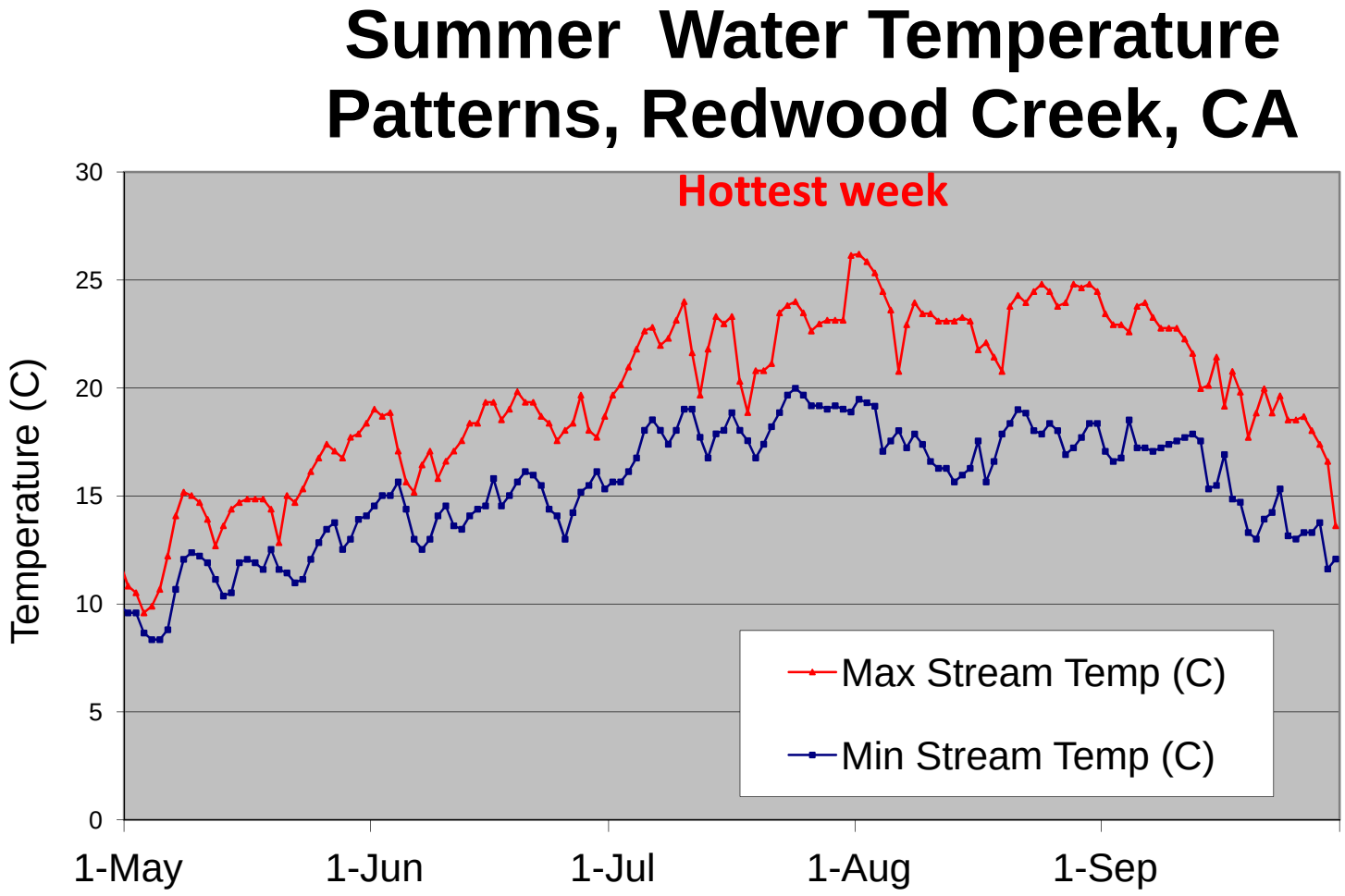
Seasonal Patterns



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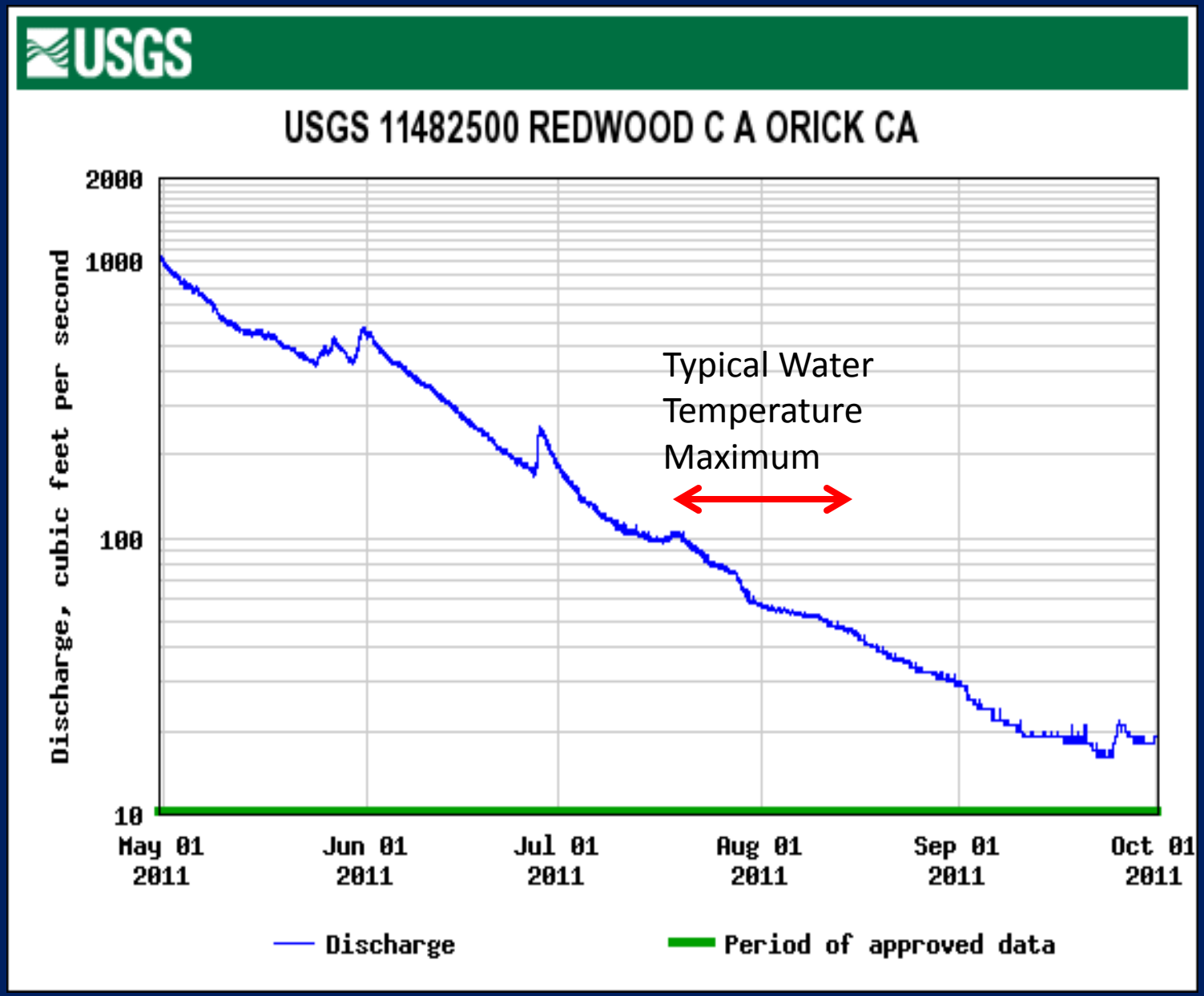
Seasonal Patterns: Decreasing streamflow during summer months



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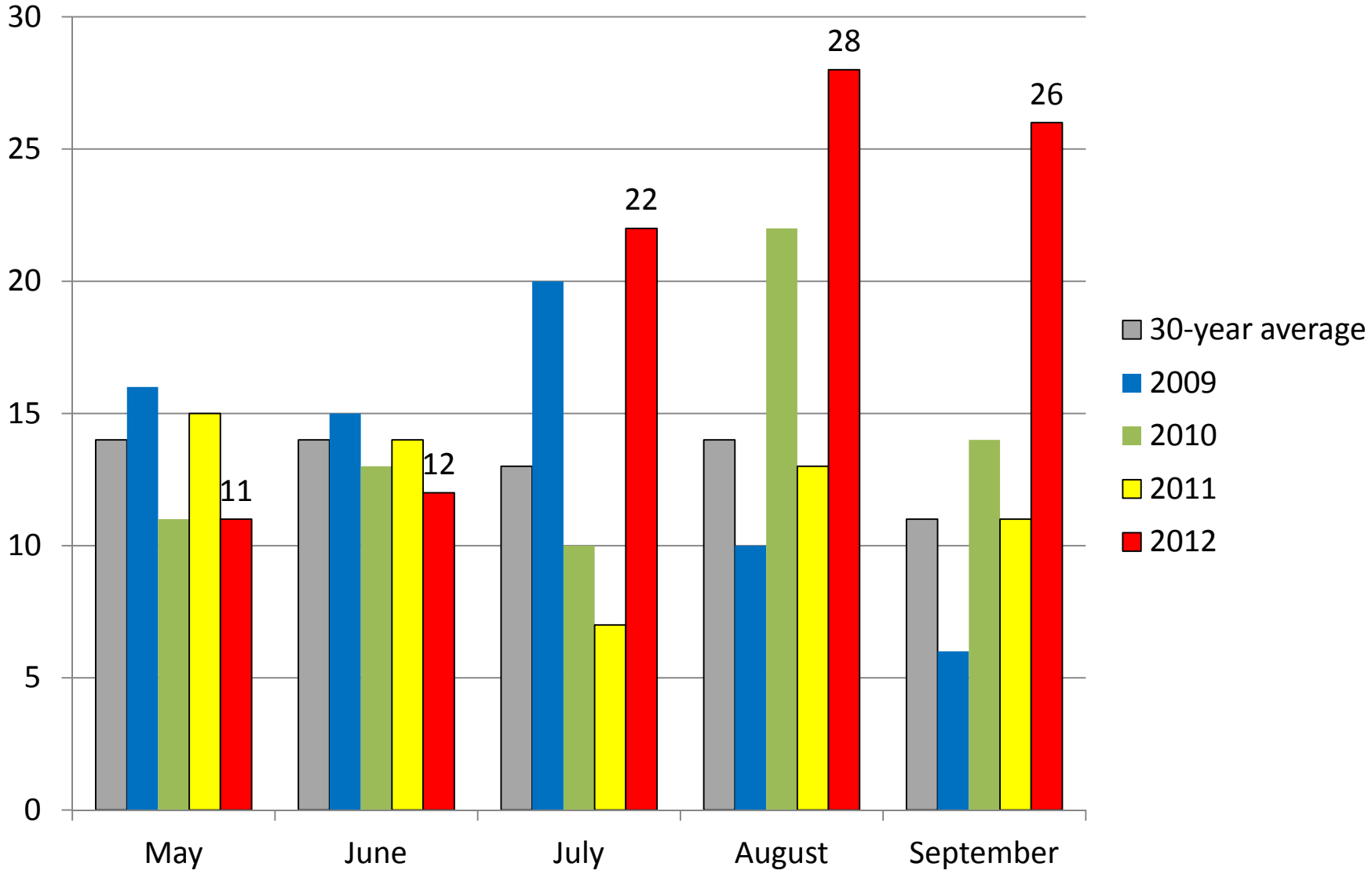
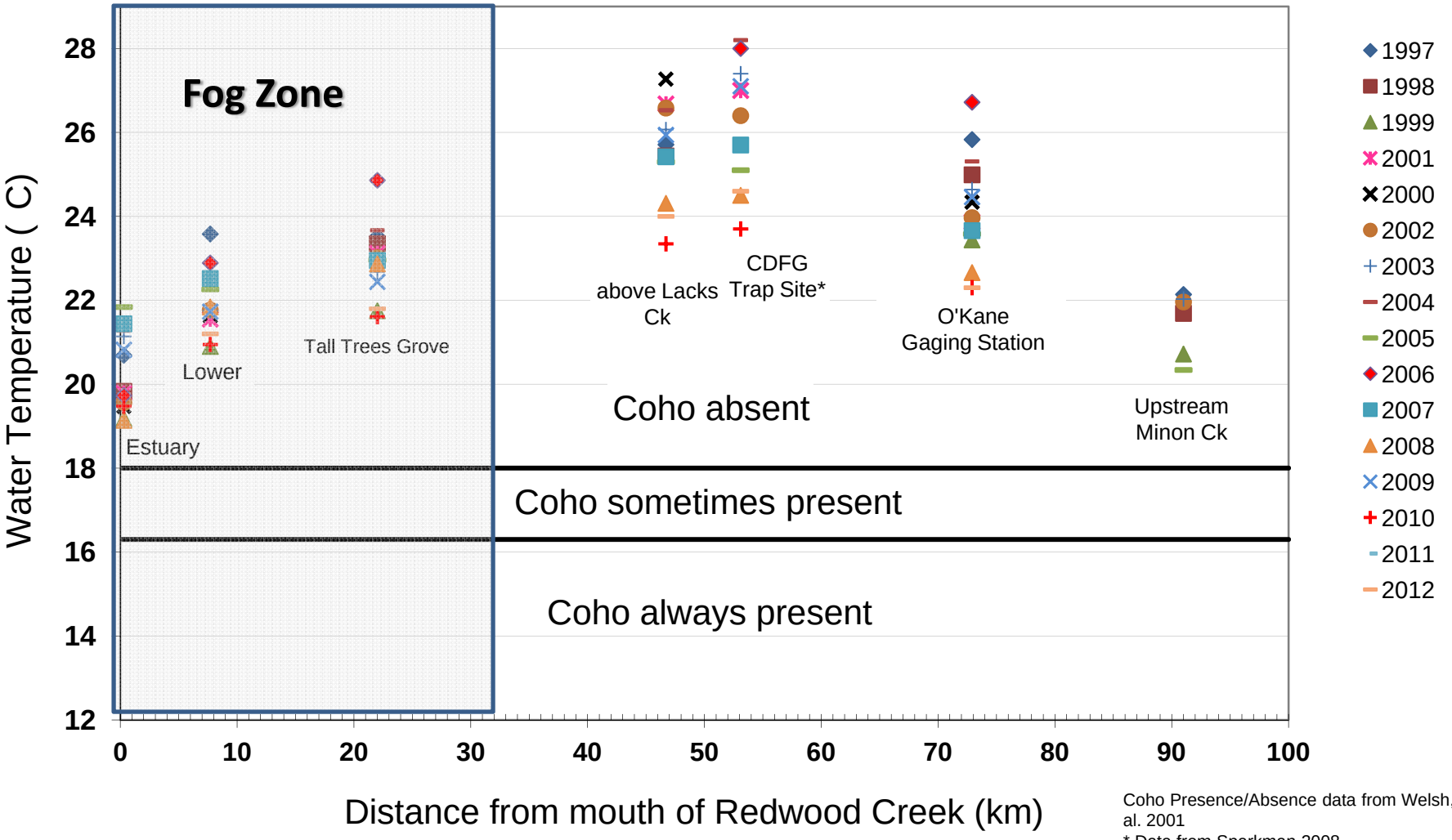
Cloudy Days per Month for Eureka, CA



Maximum 7-Day Water Temperature
Redwood Creek, CA



Coho Presence/Absence data from Welsh, et al. 2001
* Data from Sparkman 2008

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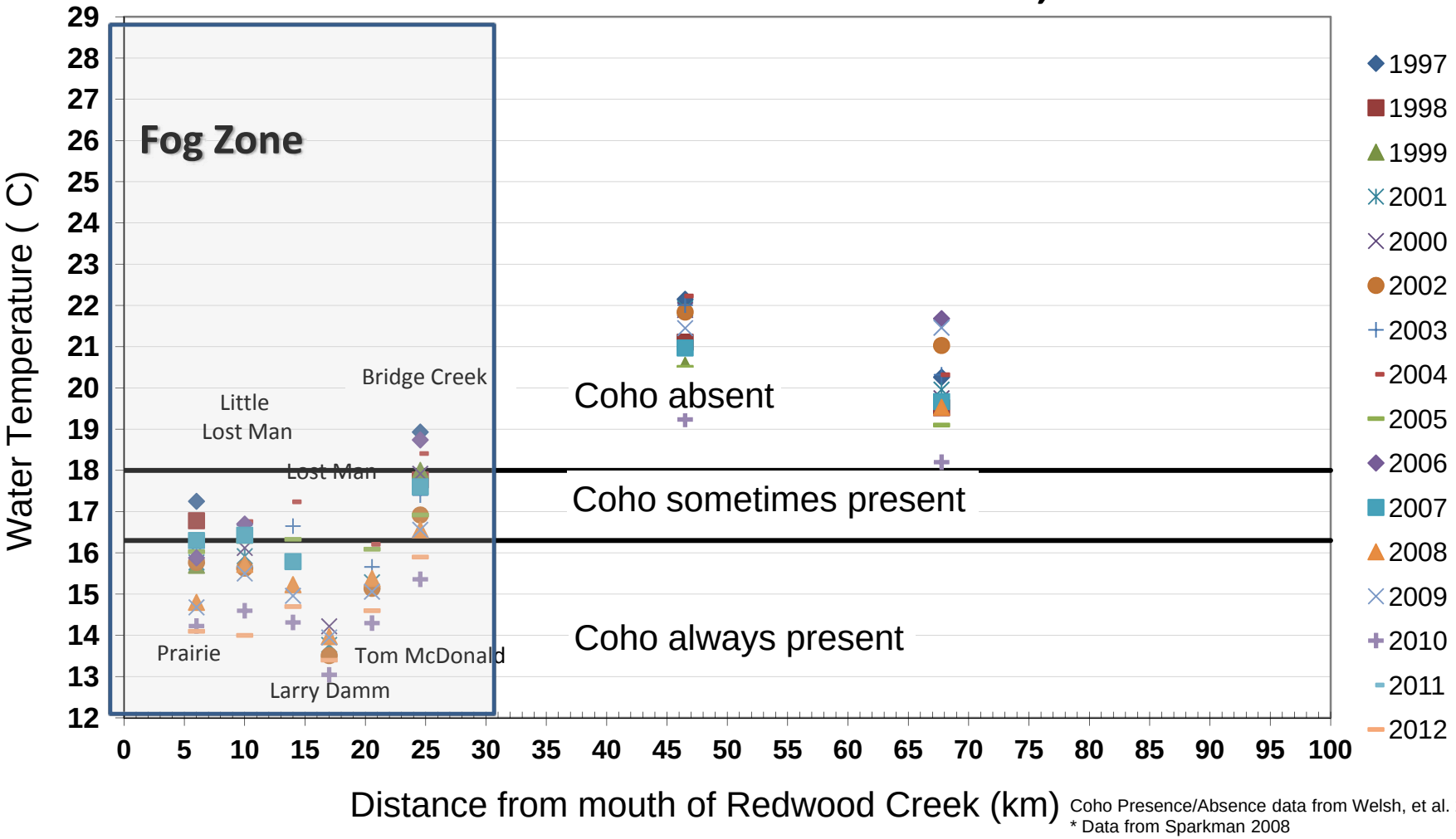
Maximum 7-Day Water Temperature
Tributaries of Redwood Creek, CA



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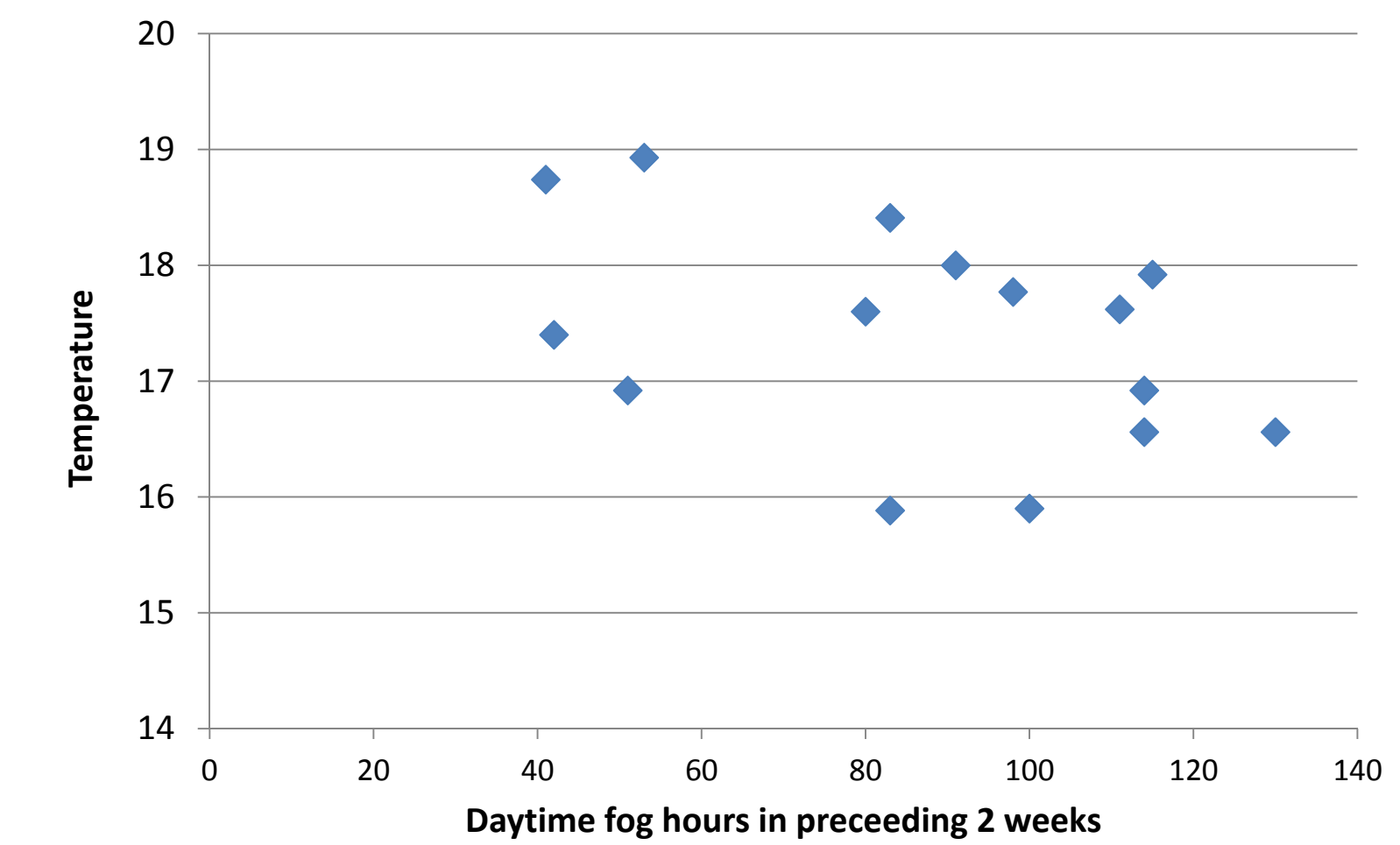
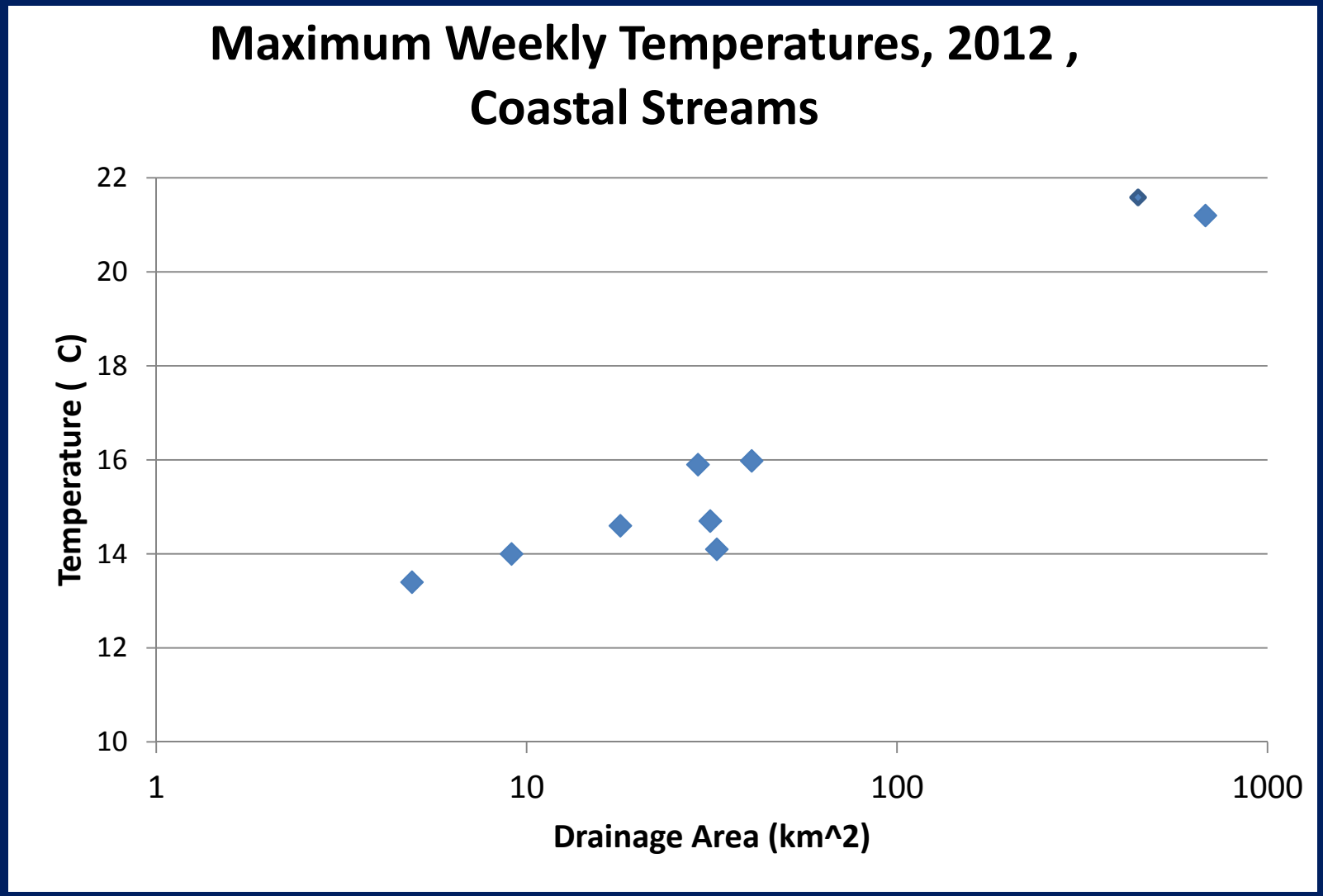
Maximum Weekly Temperature in Bridge Creek vs. Daytime Fog Hours



Spatial Scale and Stream Temperatures



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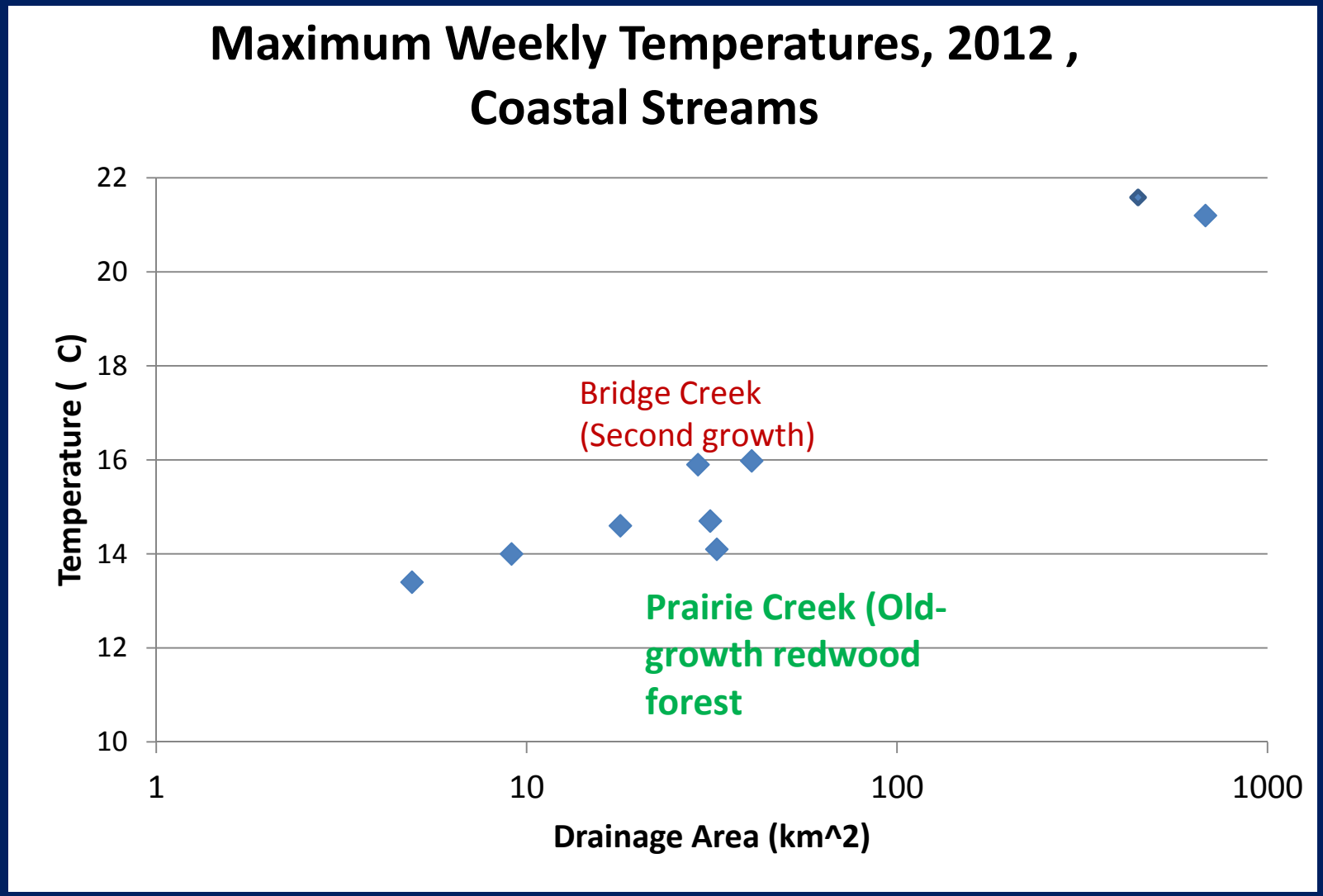
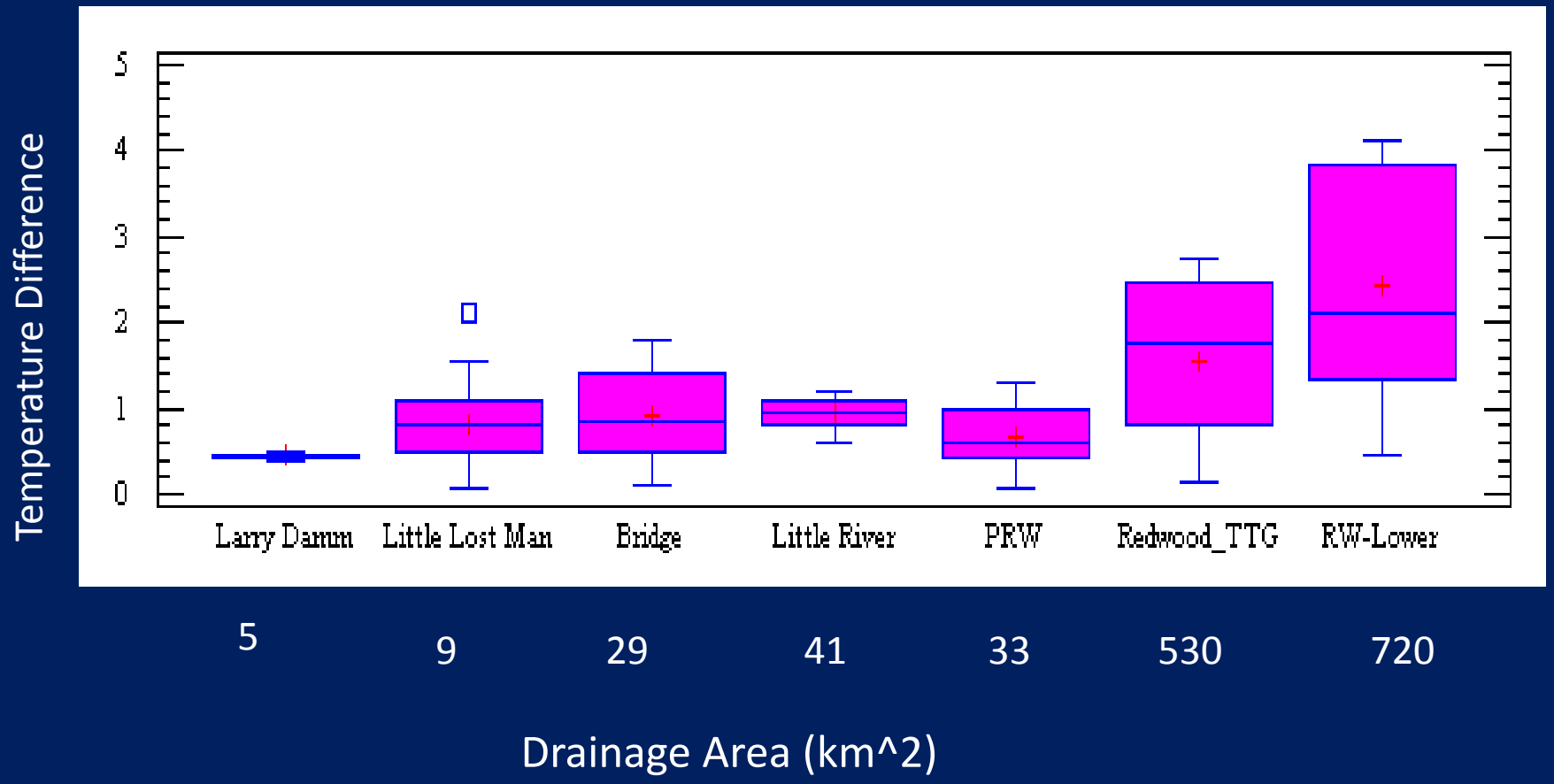


Sensitivity of Streams to Fog Events

Difference in Daily Maximum Temperatures

Foggy vs. Sunny Days



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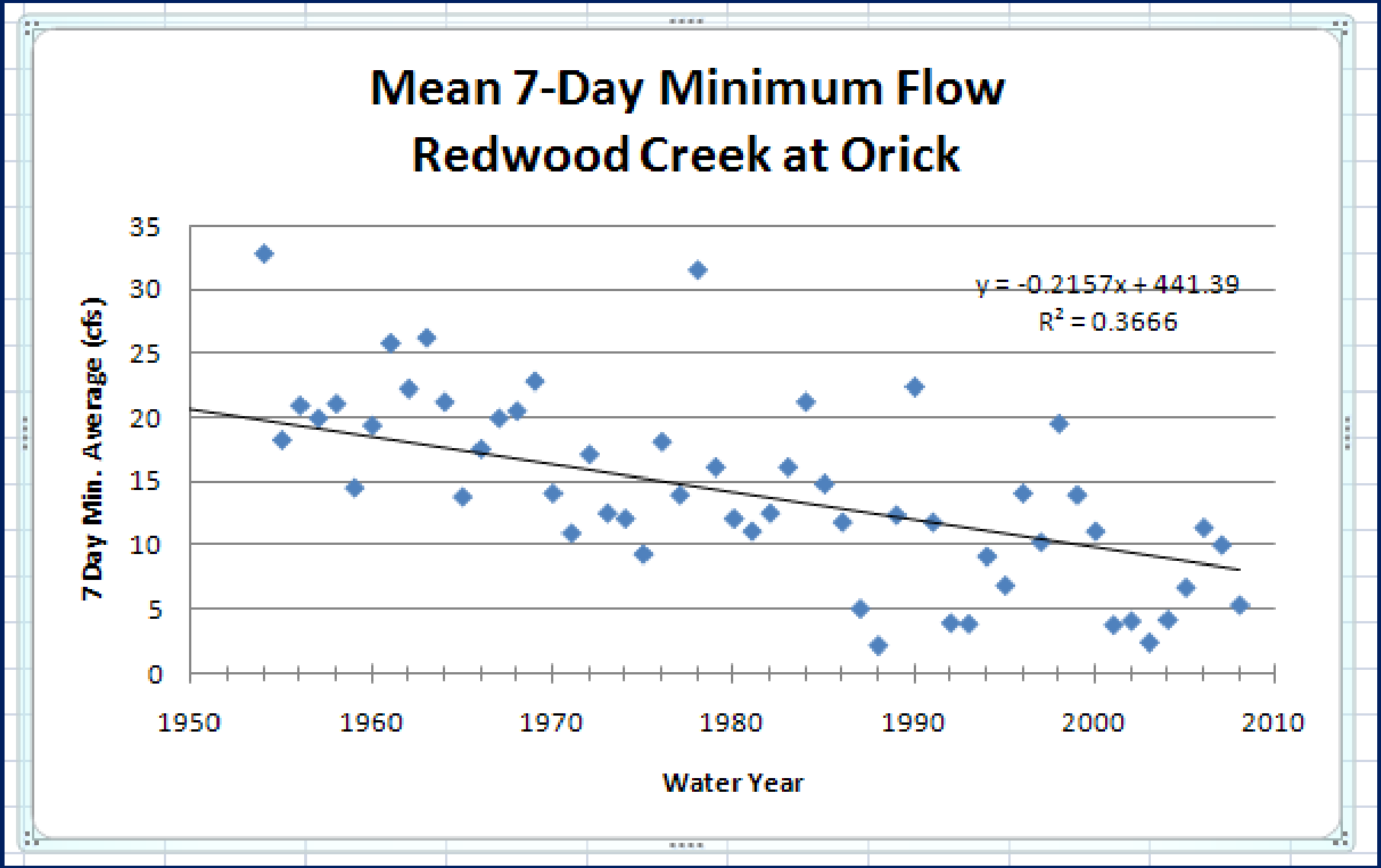

Long-term decrease in summer low flows exacerbates temperature problems

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A change in fog frequency (solar irradiance) may have cascading food web effects:

Algae
Periphyton
Benthic macroinvertebrates
Amphibians
Fish

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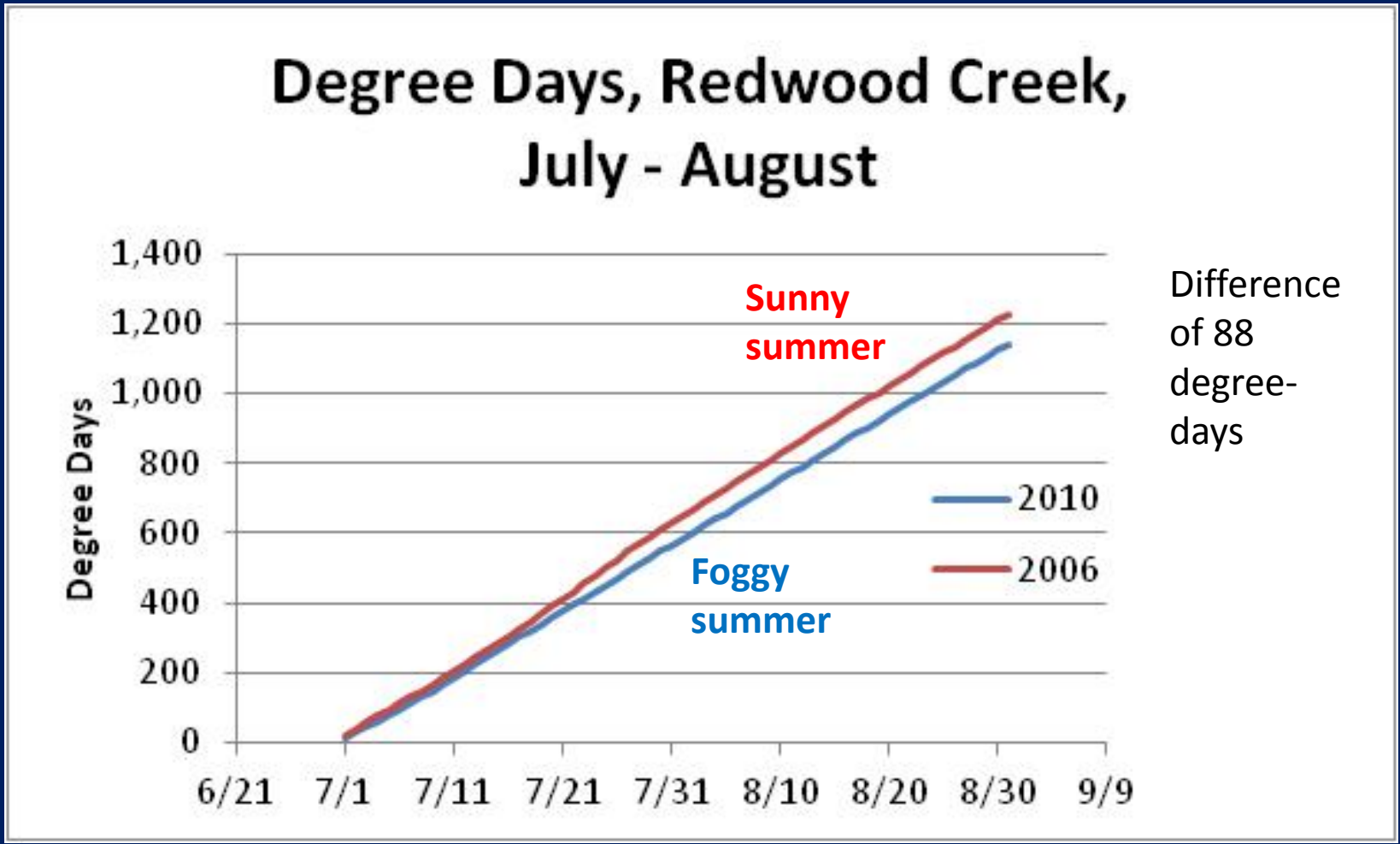

Difference of 88 degree-days

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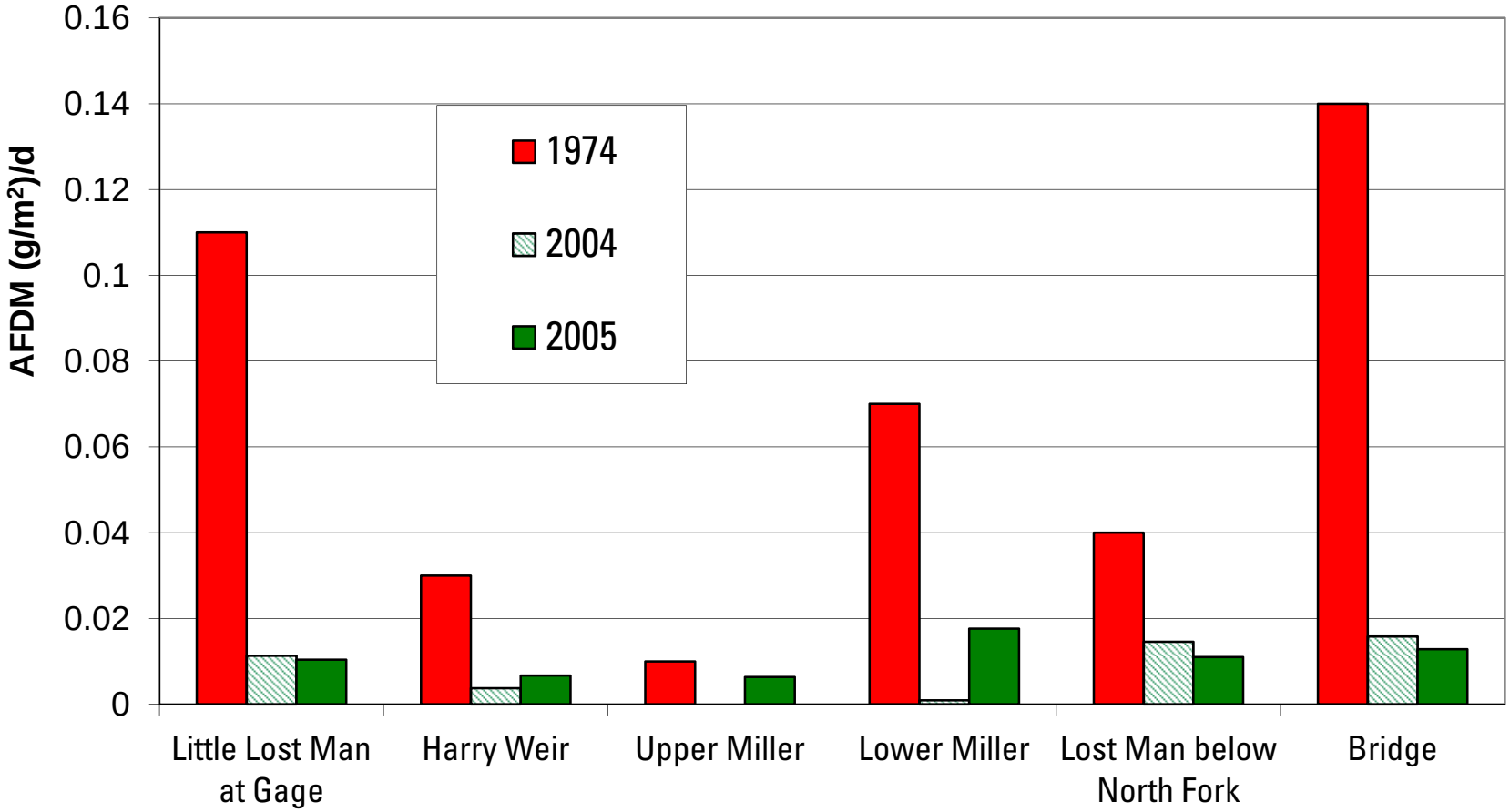
Sampling Periphyton

Periphyton Growth in Tributaries of Redwood Creek

Open canopy (1974) vs. Semi-closed canopy (2004-2005)



Sensitivity of streams to fog events:

Daily:

Fog had minimal effect (0.5 ^{o} C) on small streams (< 10 km^2)
More shade, Large groundwater contributions

Large streams (> 500 km^2) exhibited 2 to 3 ^{o} C water temperature increases on sunny days, but these streams are already above preferred temperatures for salmonids. Wide channels, open canopy.

Medium-scale rivers (20- 200 km^2) exhibited 1 to 2° C temperature increases on sunny days. These are the streams that are currently near the threshold for fish tolerance and a small increase in temperature may have large effects on salmon.

Annual:

Foggier summers result in lower maximum summer water temperatures.

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We rowed into fog . . .
and out through fog. . . . Oh how blue,
how bright the wide sea!

SHIKI