

# Climate Change & the Freshwater Habitat of Pink and Chum Salmon



Gordon H. Reeves

David D'Amore

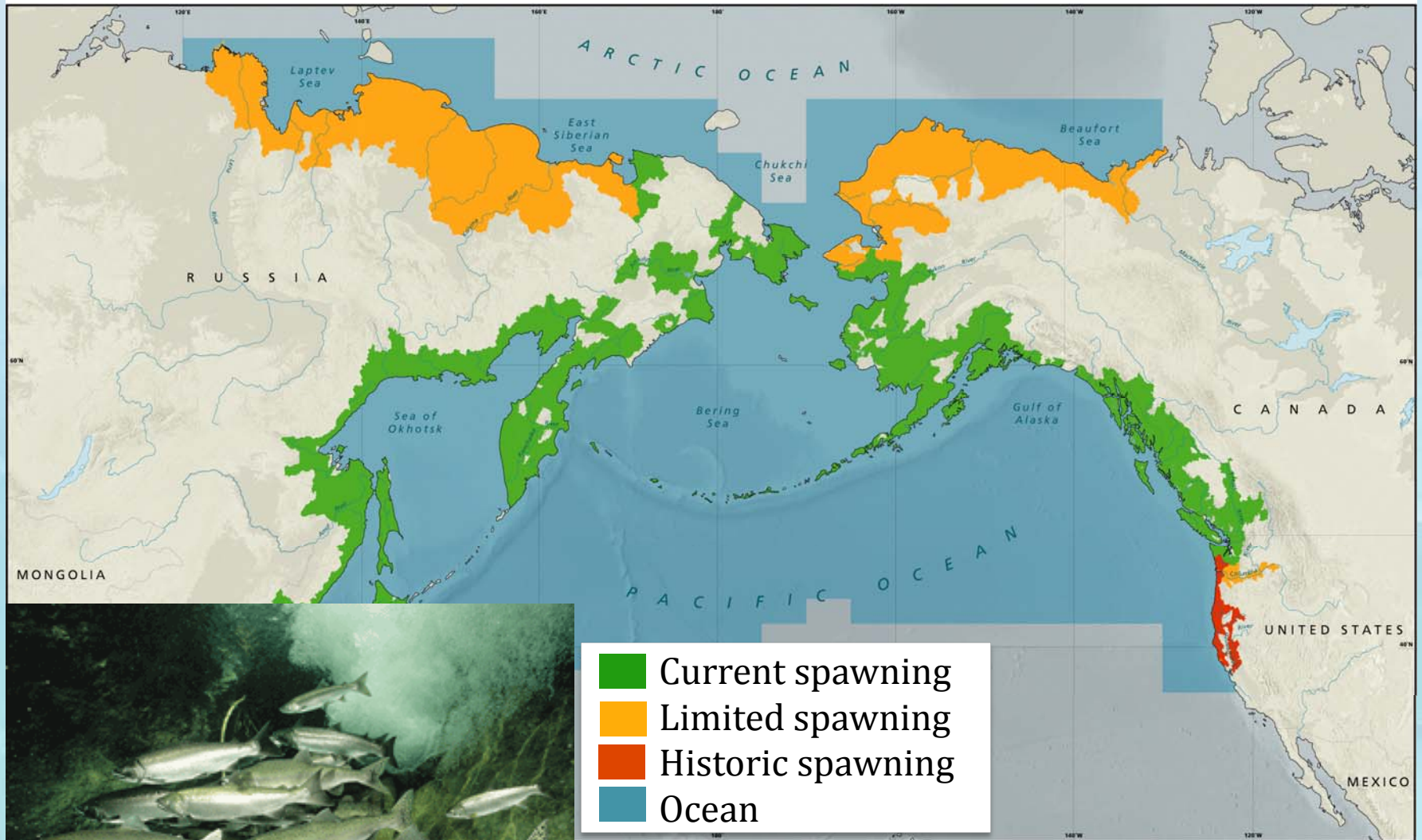
Richard T. Edwards

*US Forest Service*

*PNW Research Station*

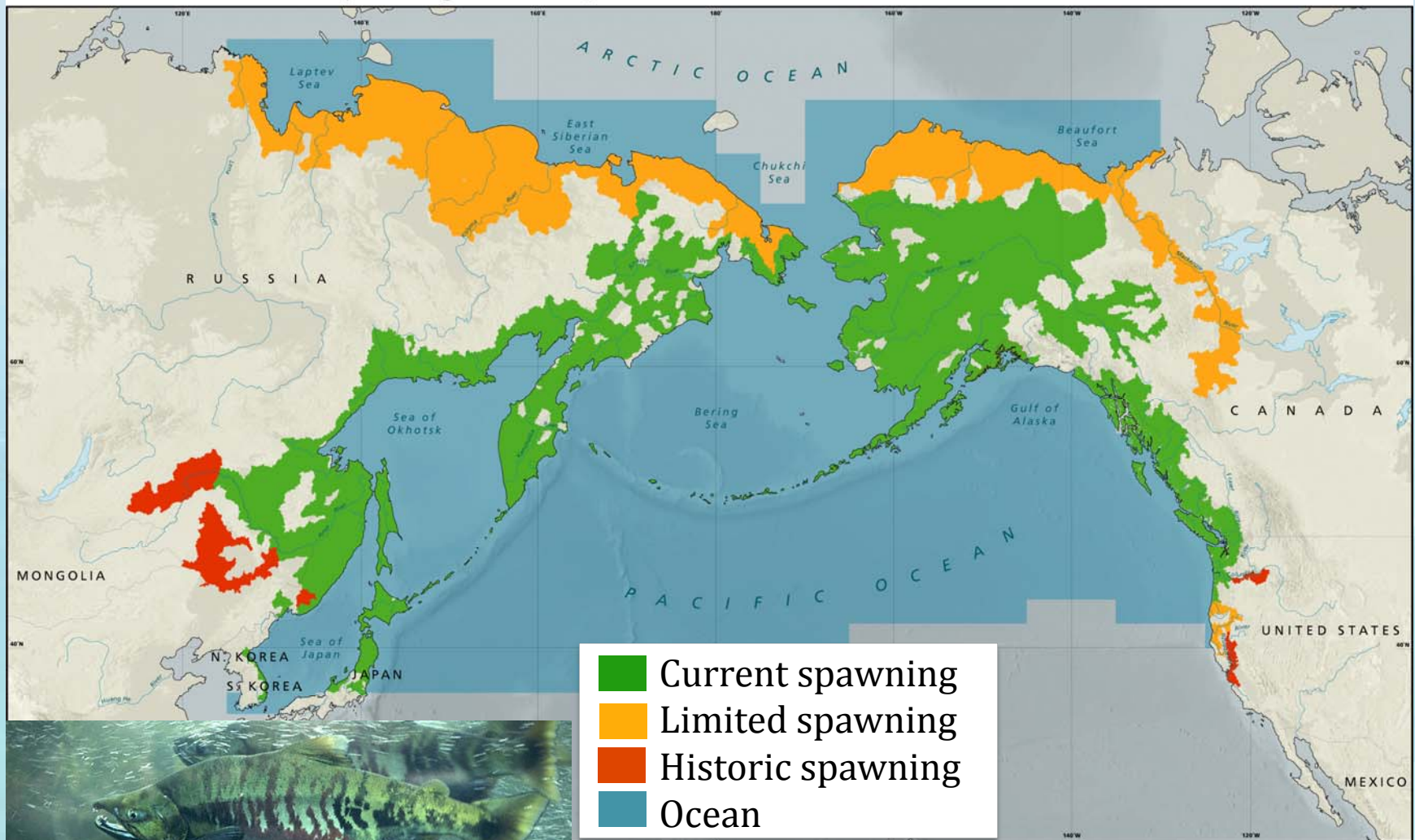
# Pink Distribution

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# Distribution of Chum (*Oncorhynchus keta*)

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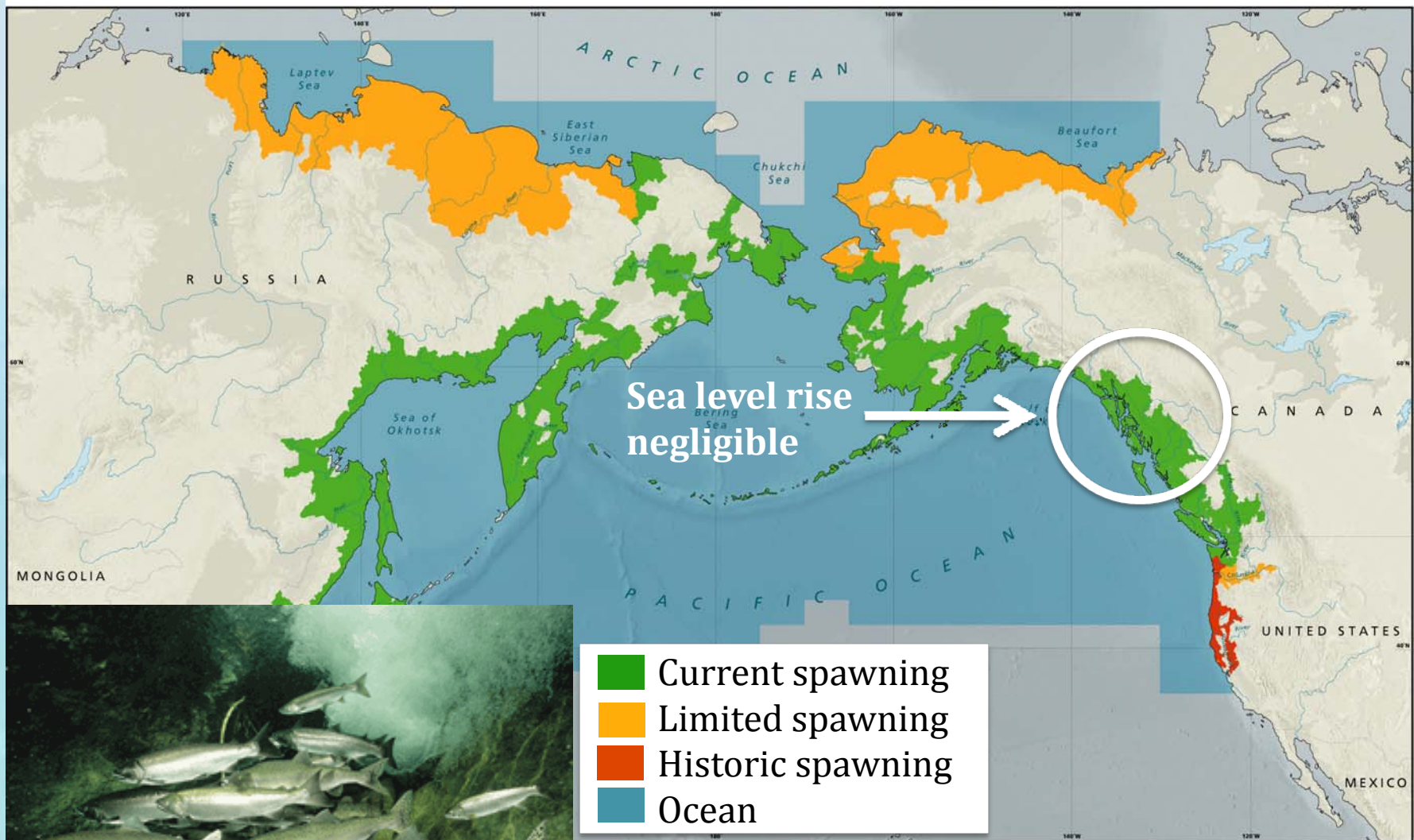
# Expected Effects of Climate Change

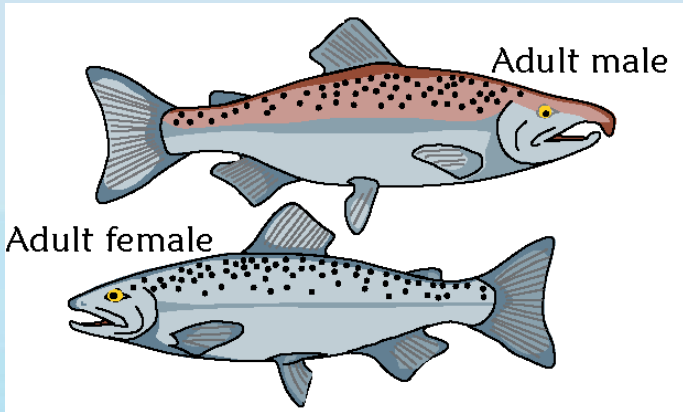
## ◆ Ocean

- Increased temperatures
- Change in pH (acidification)
- Elevated sea level
- Change in nearshore environments

# Pink Distribution

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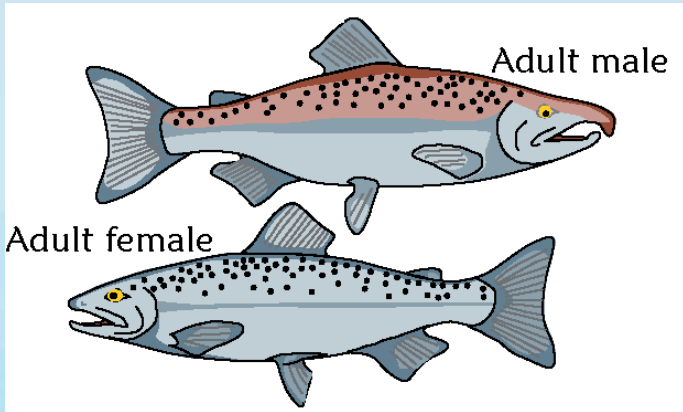


# Adults: Ocean

◆ Water temp ↑  
◆ pH ▲

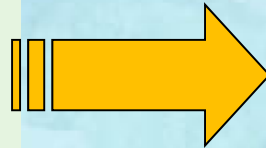


- Decreased food supplies
- Decreased growth and survival in marine environment
- Smaller size at return to freshwater



# Adults: Freshwater

◆ Water temp ↑  
◆ Flows ↓



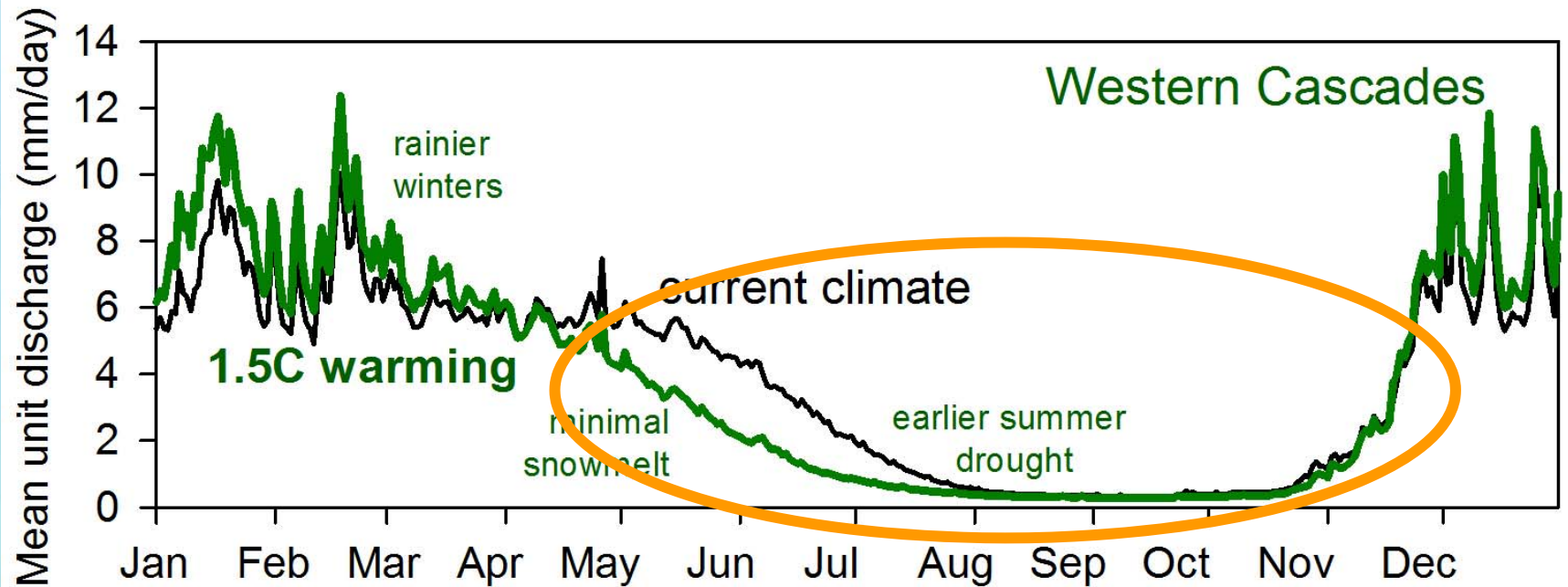
- Reduced size & fecundity
- Increased energetic costs of migration
- Increased disease susceptibility
- Altered habitat availability (quantity and quality)

# Expected Effects of Climate Change

## ◆ Freshwater

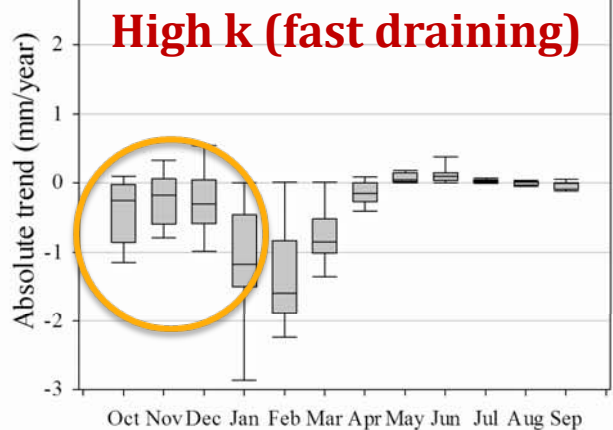
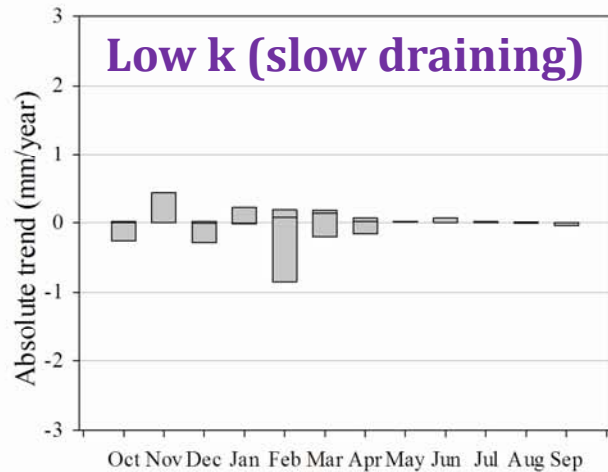
- Change in the hydrograph
- Increased water temperatures
  - Summer and winter

# Potential Changes in Hydrograph



From: Tague and Grant 2009

# Historical Trends in Monthly Streamflow (1950-2010)

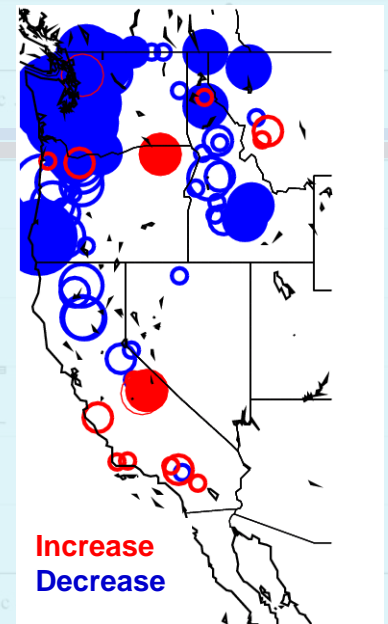


For Rain-Dominated Basins  
(Snow <10%)

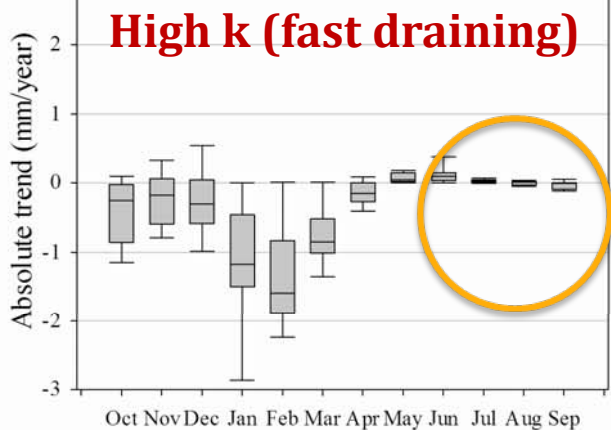
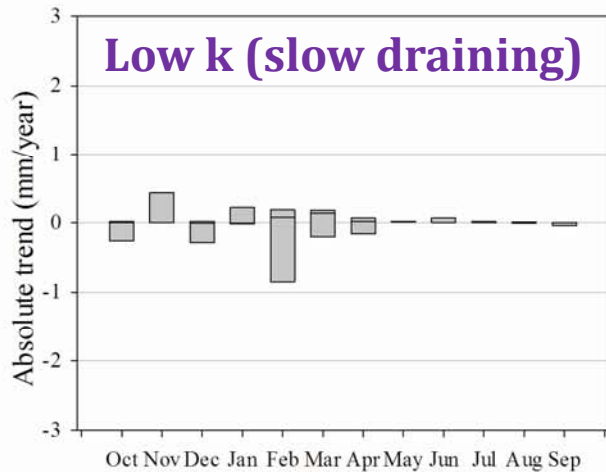
- ◆ Greatest declines in fall and winter

- Due to change in ppt

- ◆ Small difference between low and high k



# Historical Trends in Monthly Streamflow (1950-2010)

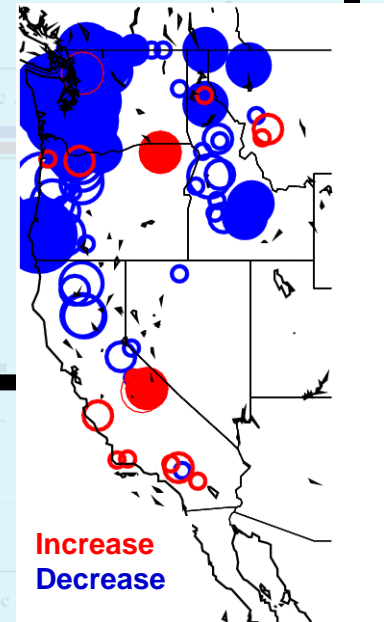


## For Rain-Dominated Basins (Snow <10%)

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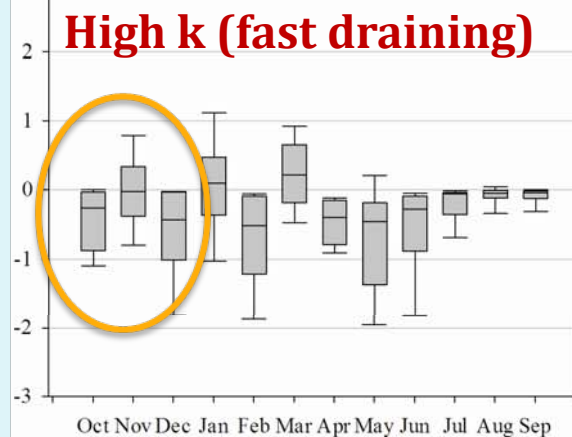
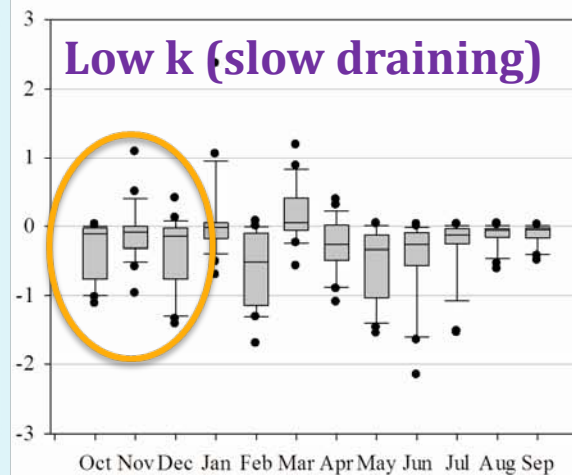


# Historical Trends in Monthly Streamflow (1950-2010)

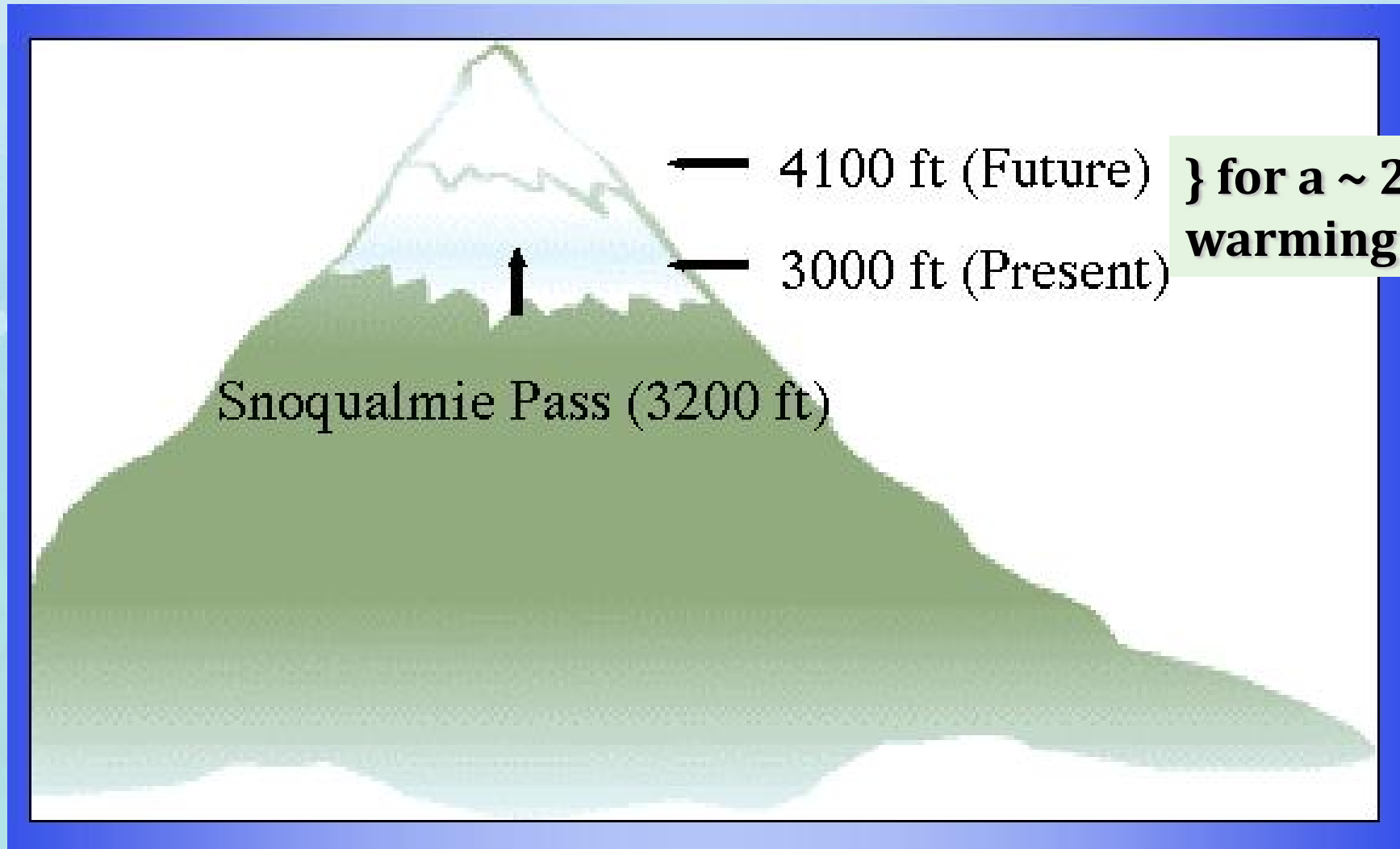
For mixed  
basins:  
(10 to 45% snow)

◆ Overall trend  
declining but  
variable

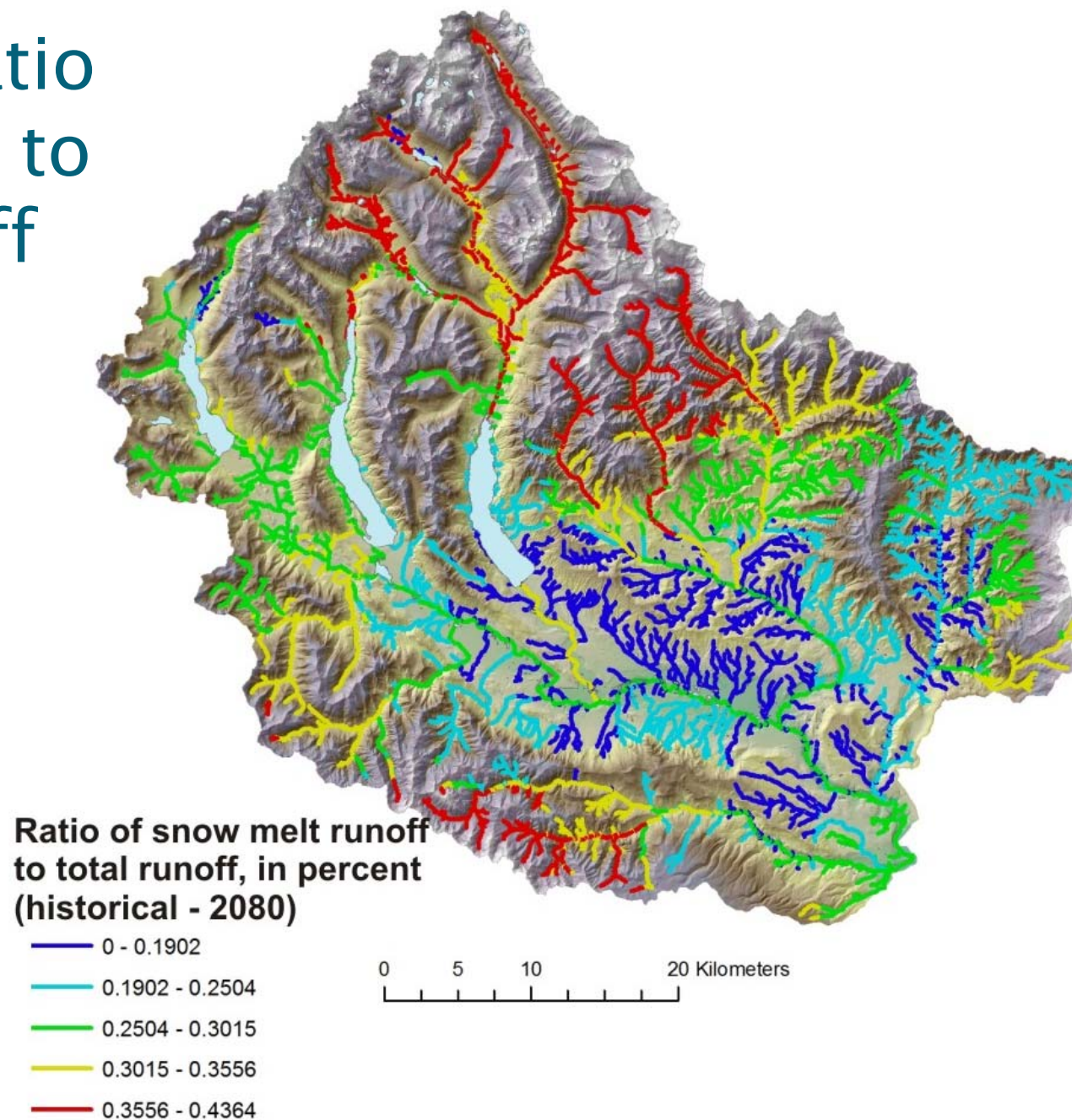
- Most sensitive to  
rain/snow  
threshold



# Snow to Rain Transition



# Change in Ratio of Snow Melt to Total Runoff



# Historical Trends in Monthly Streamflow (1950-2010)

## For Snow-Dominated Basins:

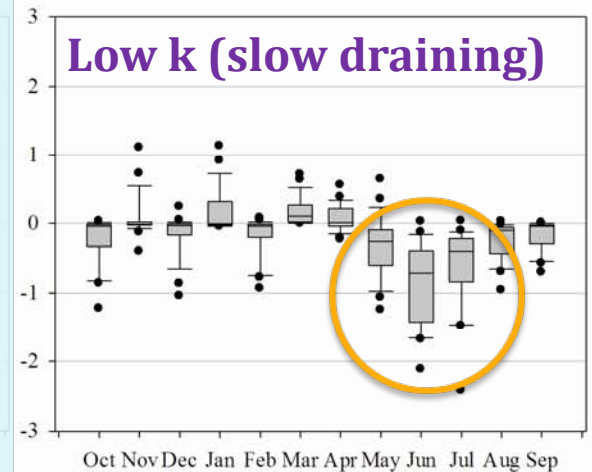
(Snow >45%)

◆ Greatest declines in late spring and summer

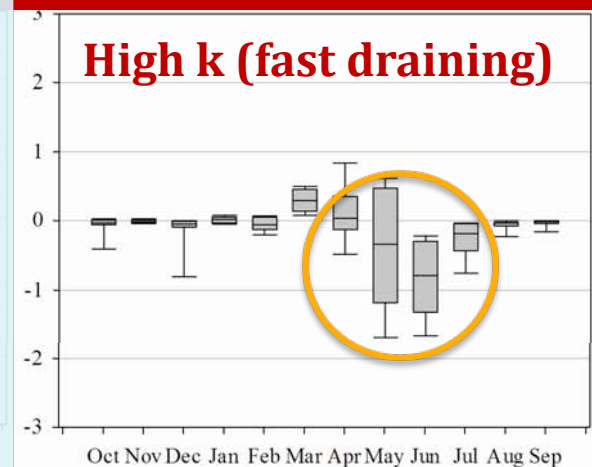
■ Diminished snowpack and/or earlier snowmelt

◆ Greater late summer decline in low k basins

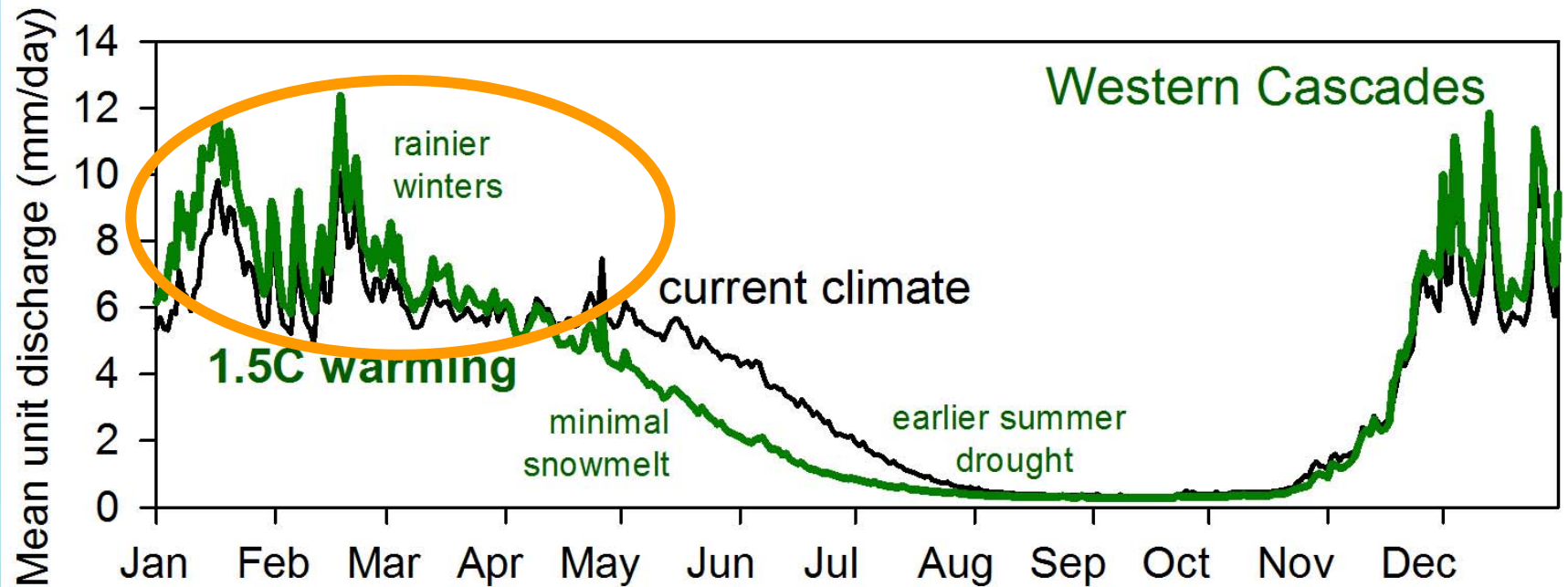
**Low k (slow draining)**



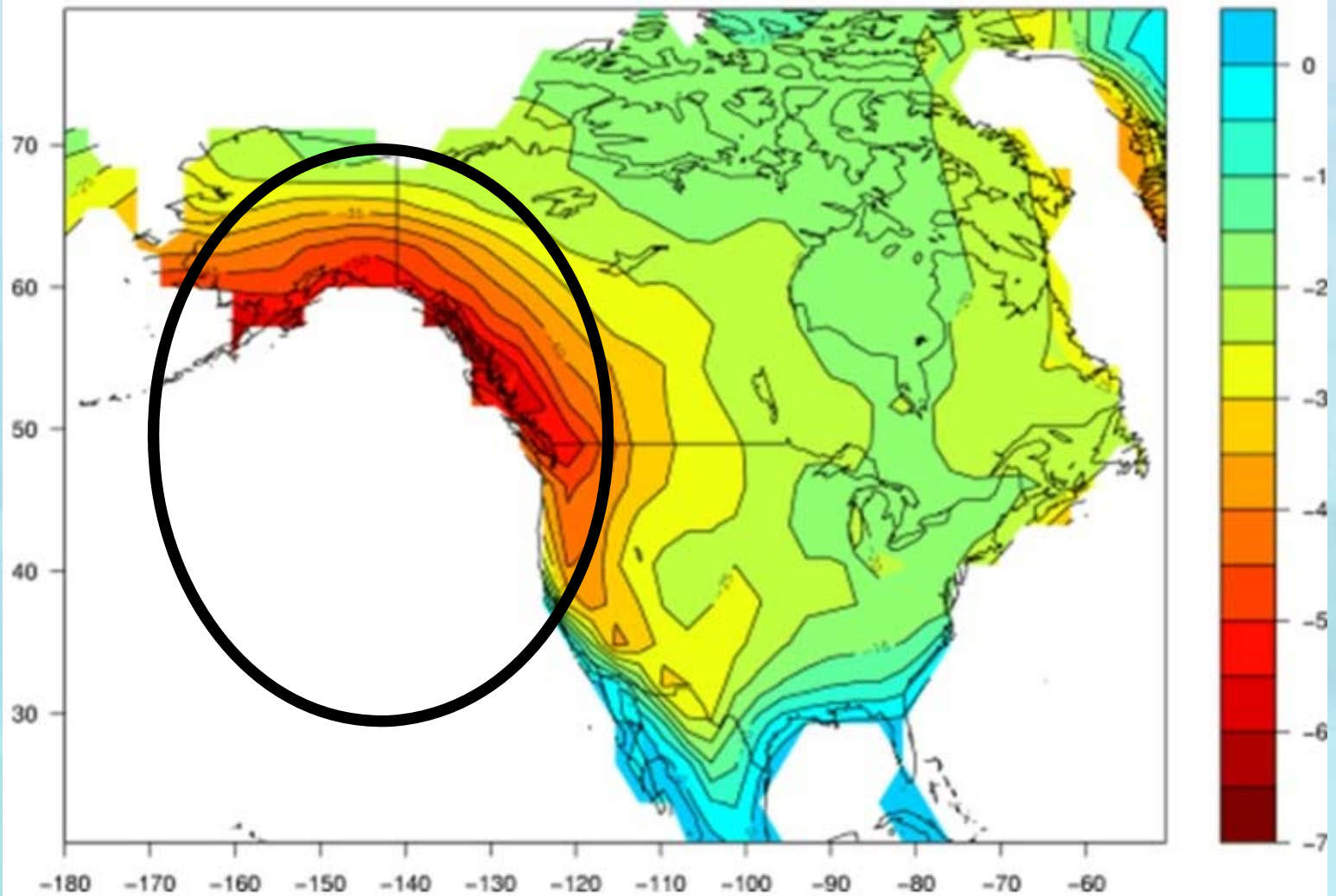
**High k (fast draining)**



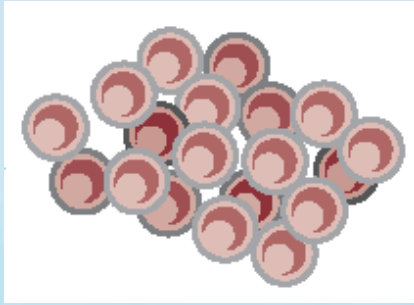
# Potential Changes in Hydrograph



From: Tague and Grant 2009

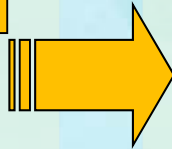


Predicted change in the number of days with frost by the end of the century (Meehl 2011).

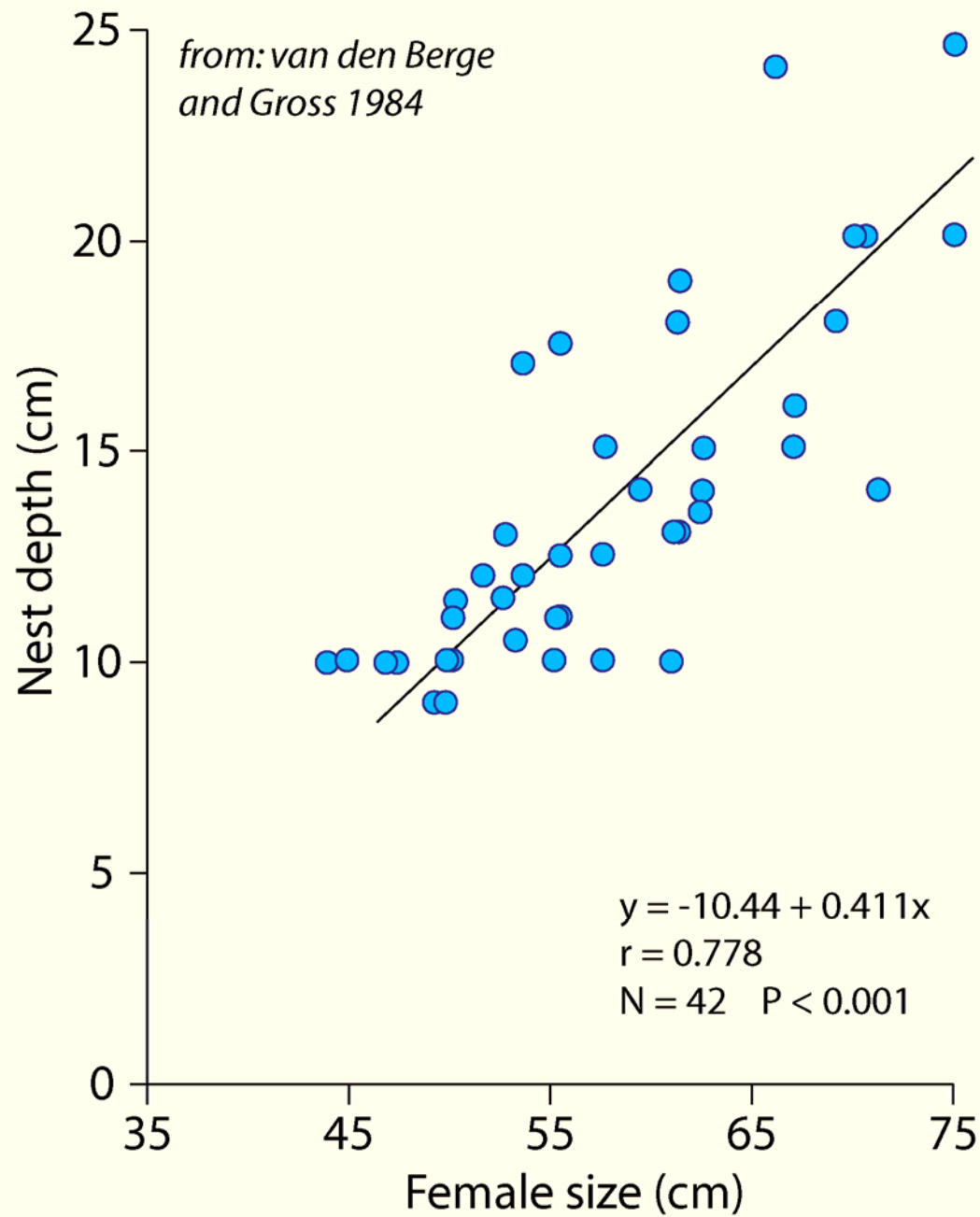


# Eggs & Developing Embryos

◆ Water temp ↑  
◆ Flows ↑

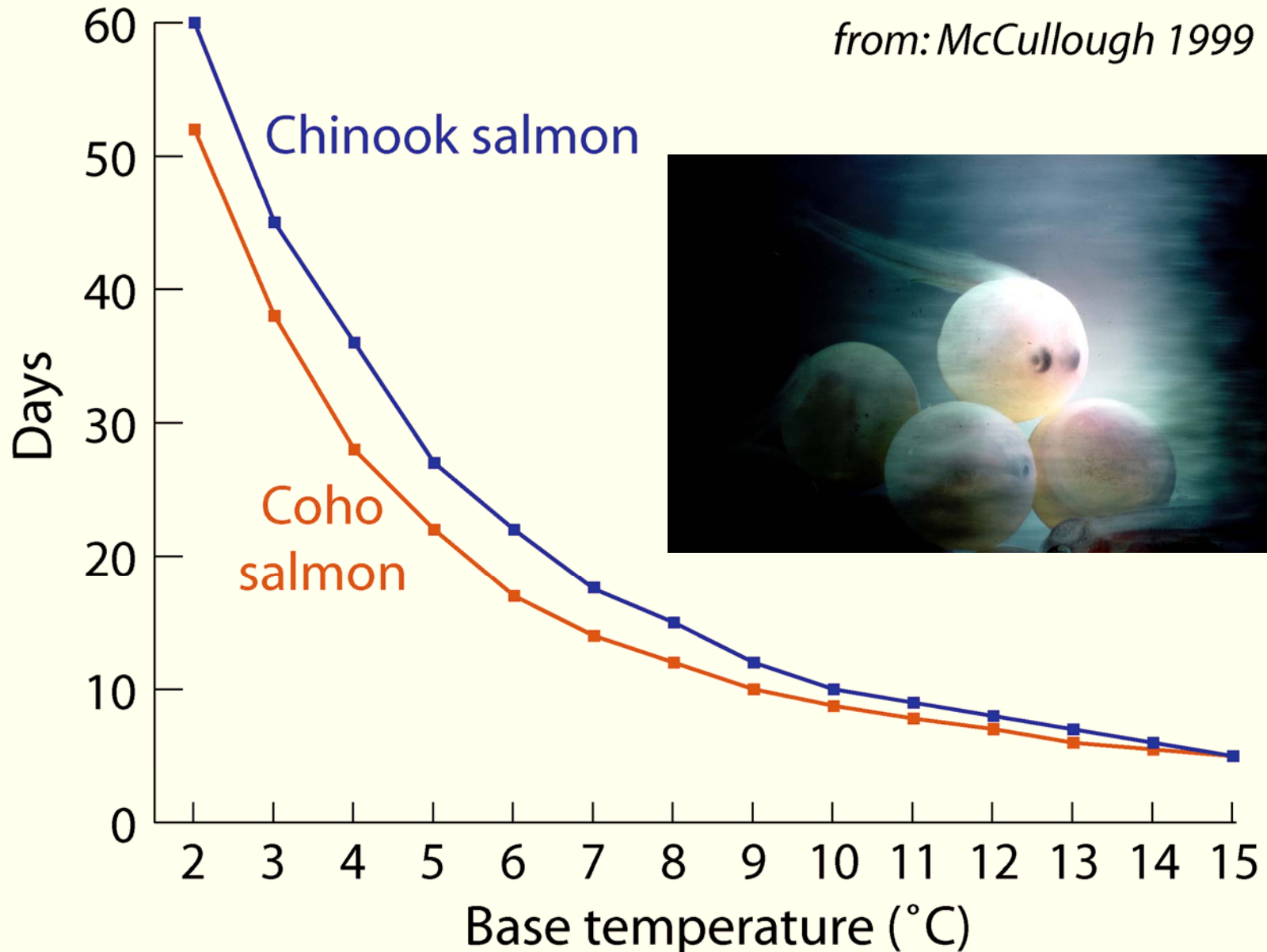


- Increased susceptibility to scour
- Increased rate of development



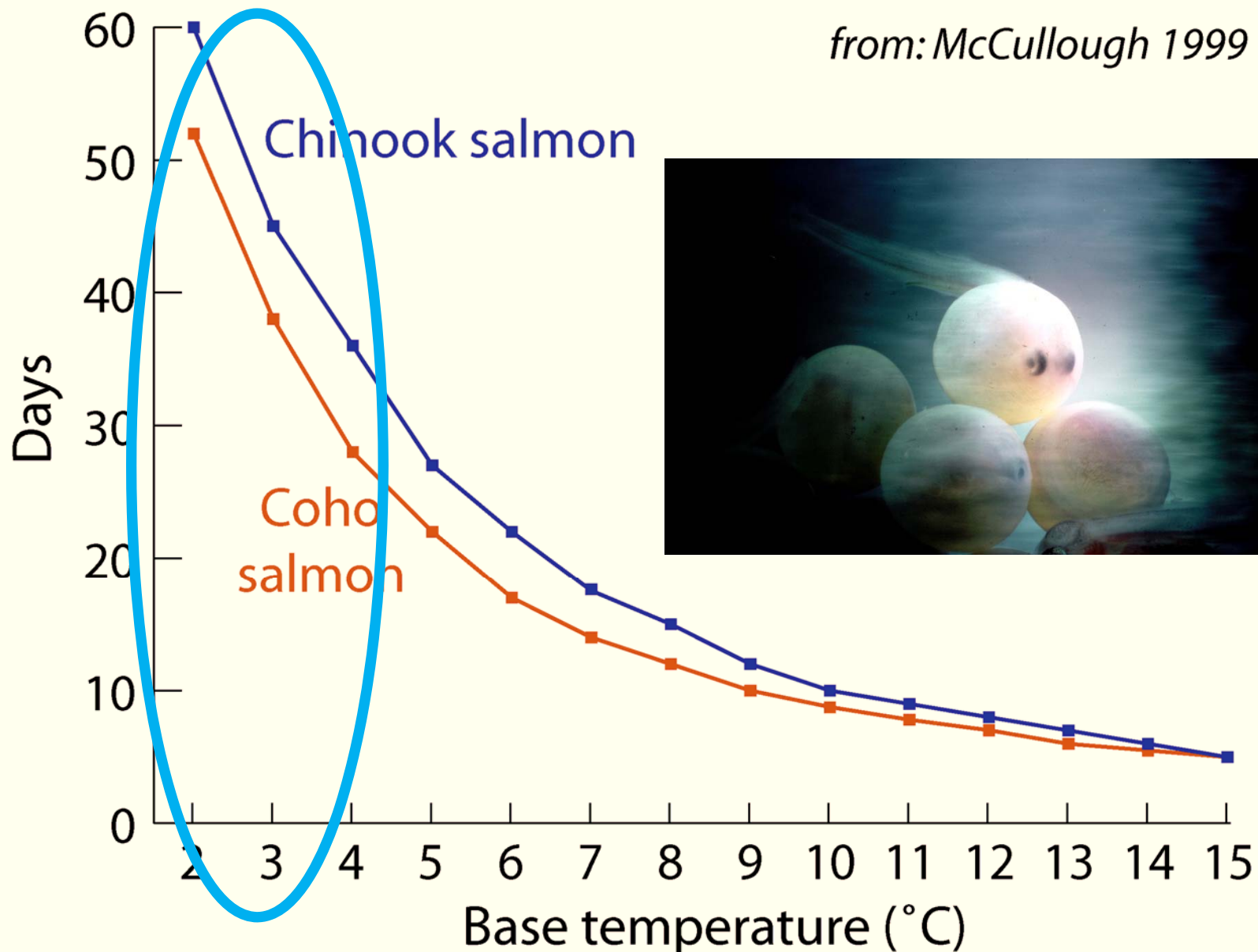
# Reduced Number of Days to Emergence from Each 1°C Increase in Water Temperature from Base

*from: McCullough 1999*

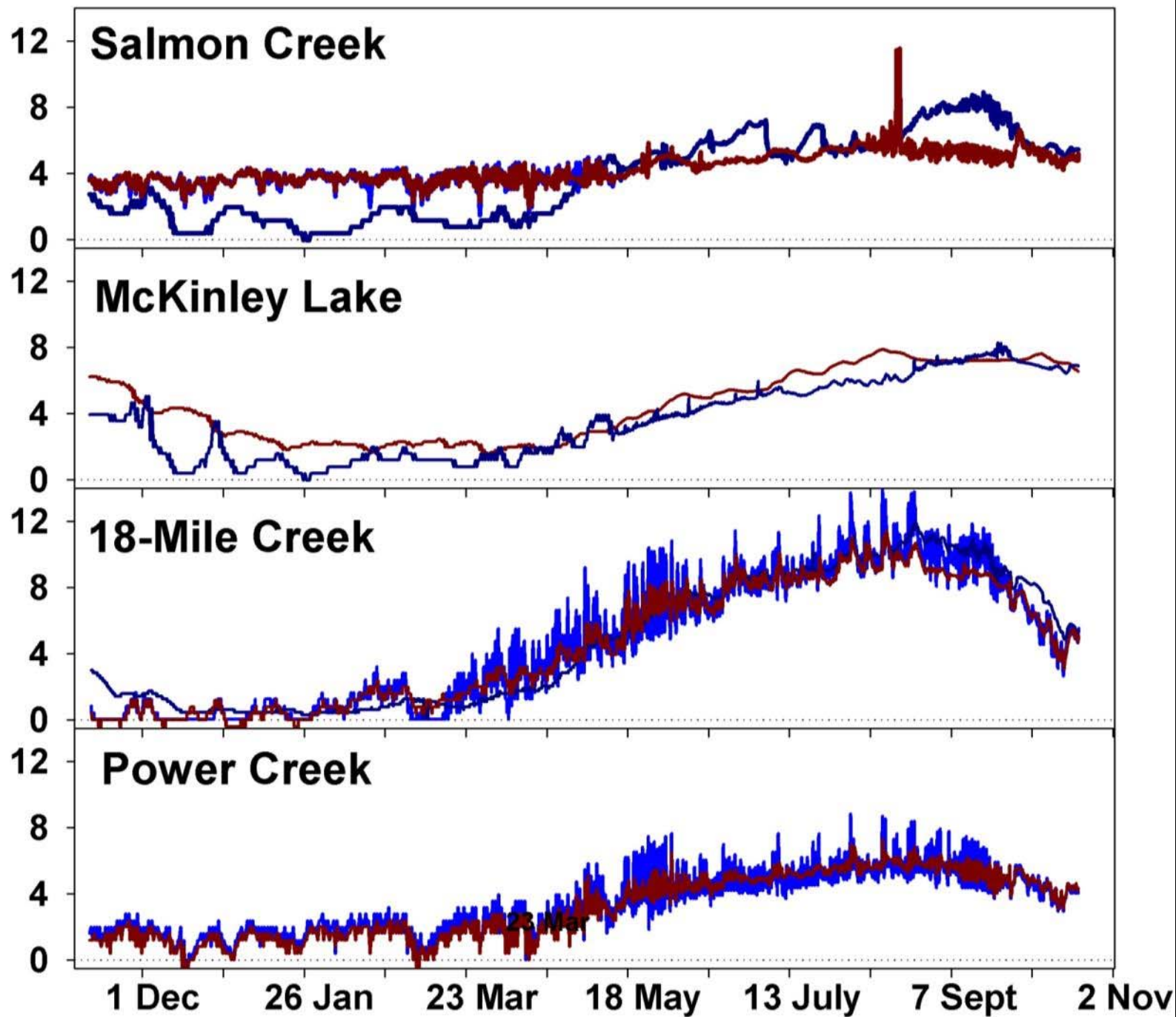


# Reduced Number of Days to Emergence from Each 1°C Increase in Water Temperature from Base

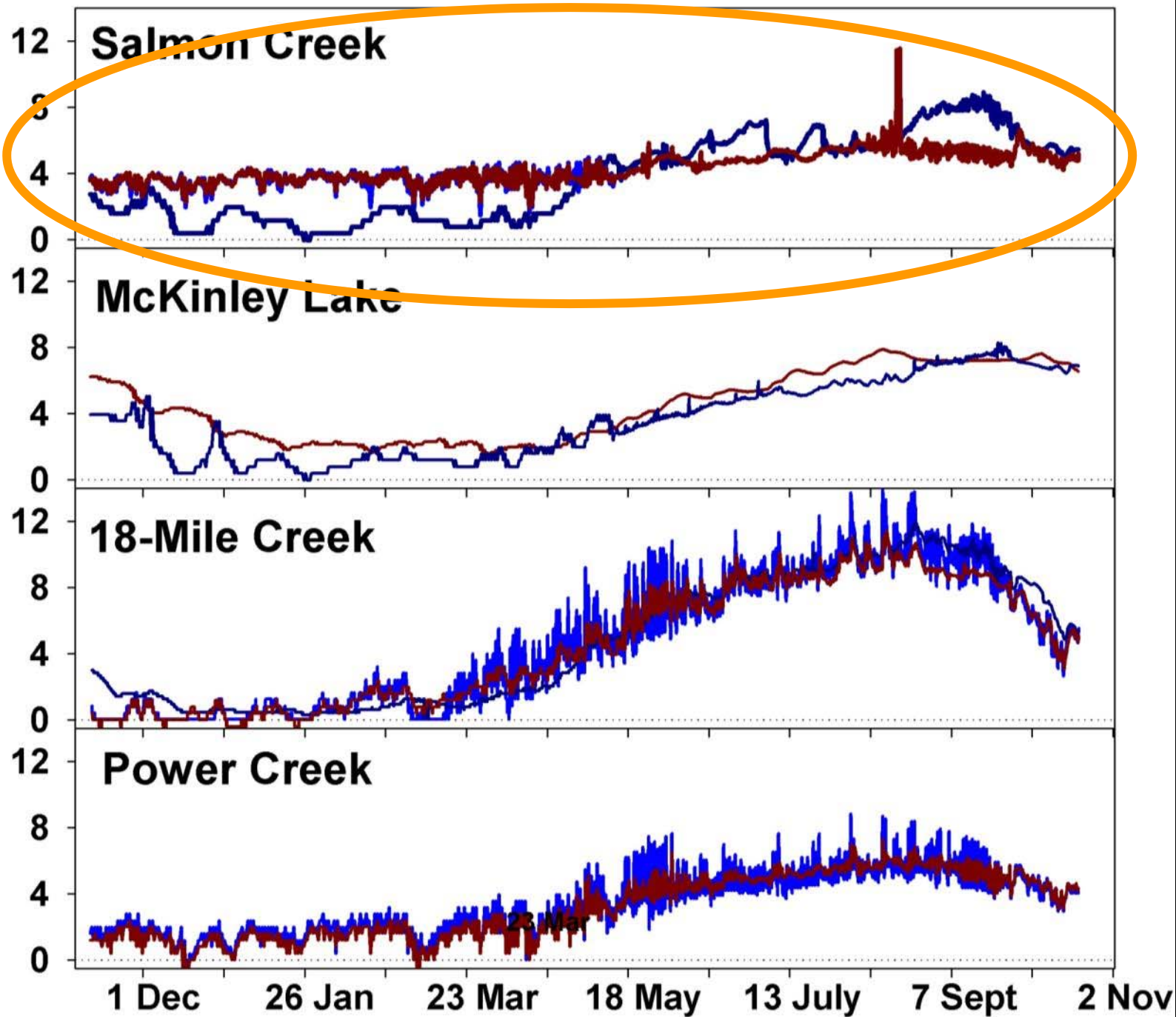
*from: McCullough 1999*



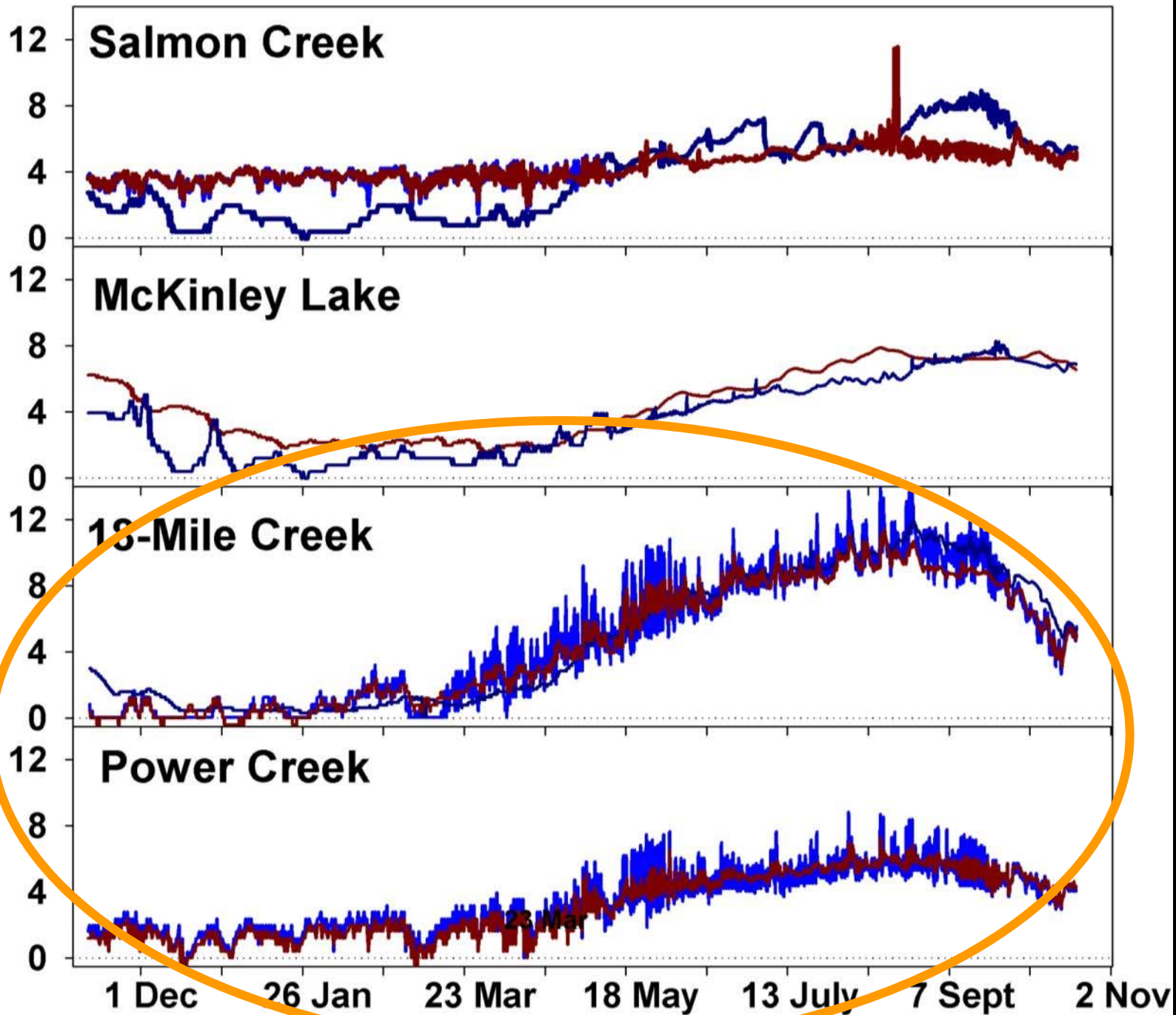
Water temperature (daily max / min in °C)

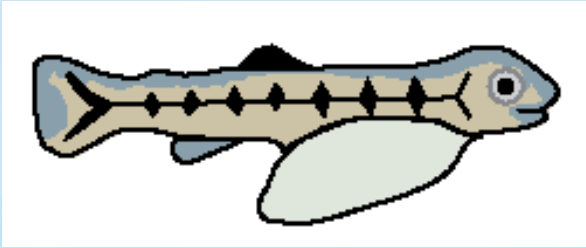


Water temperature (daily max / min in °C)



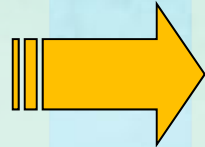
Water temperature (daily max / min in °C)





# Fry

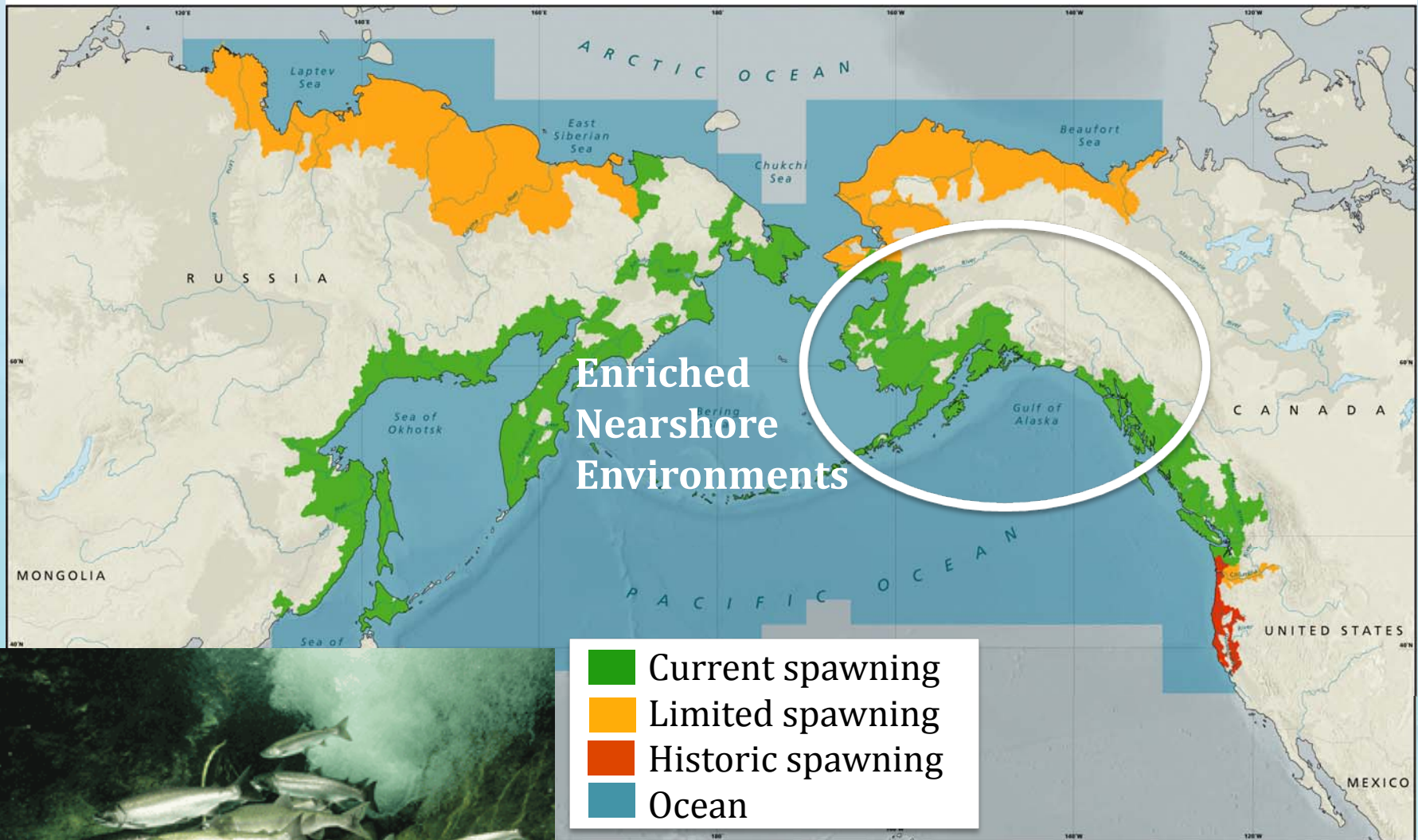
- ◆ Water temp ↑
- ◆ Flows ↑



- Positive effects
  - early emergence
  - increased habitat availability
- Negative effects
  - displacement
  - altered time of ocean entry

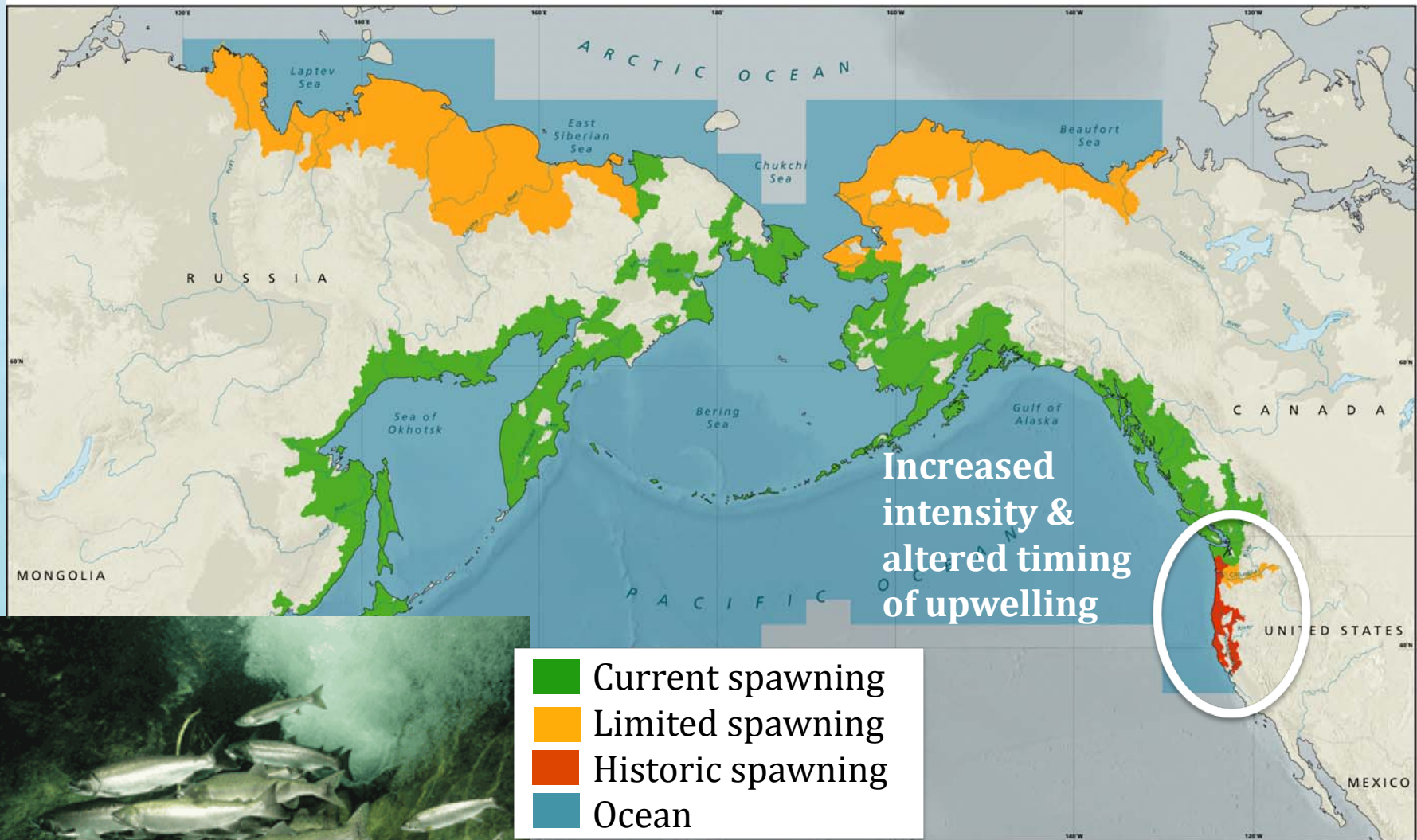
# Pink Distribution

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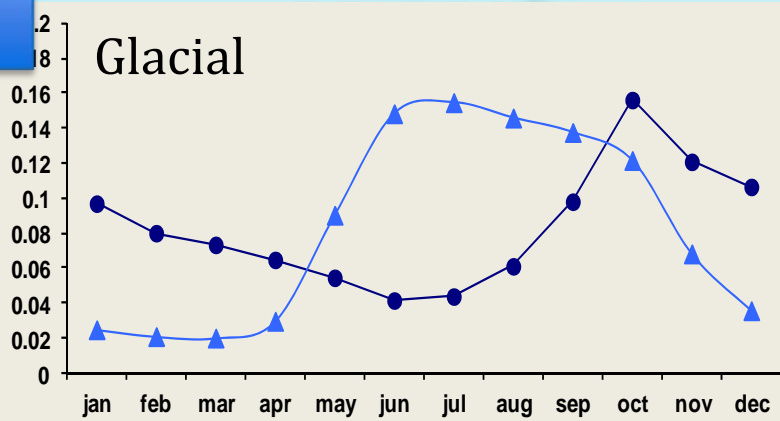
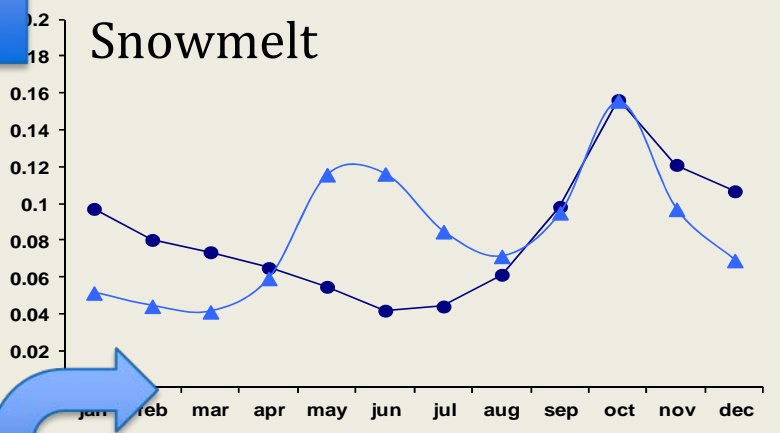
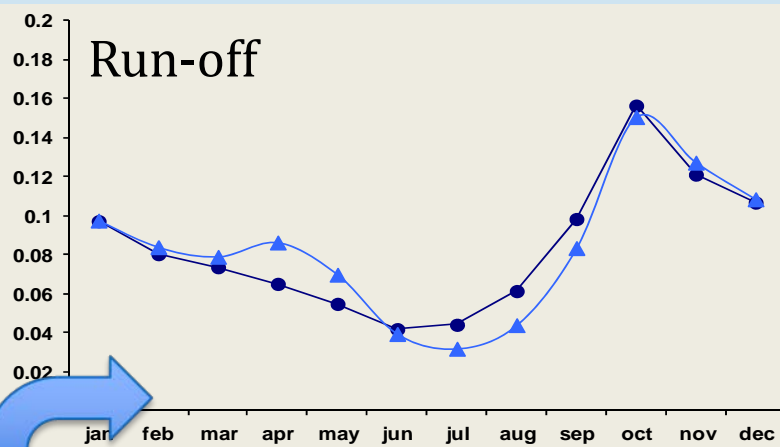
# Pink Distribution

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% of annual  
precipitation

% of annual  
hydrograph



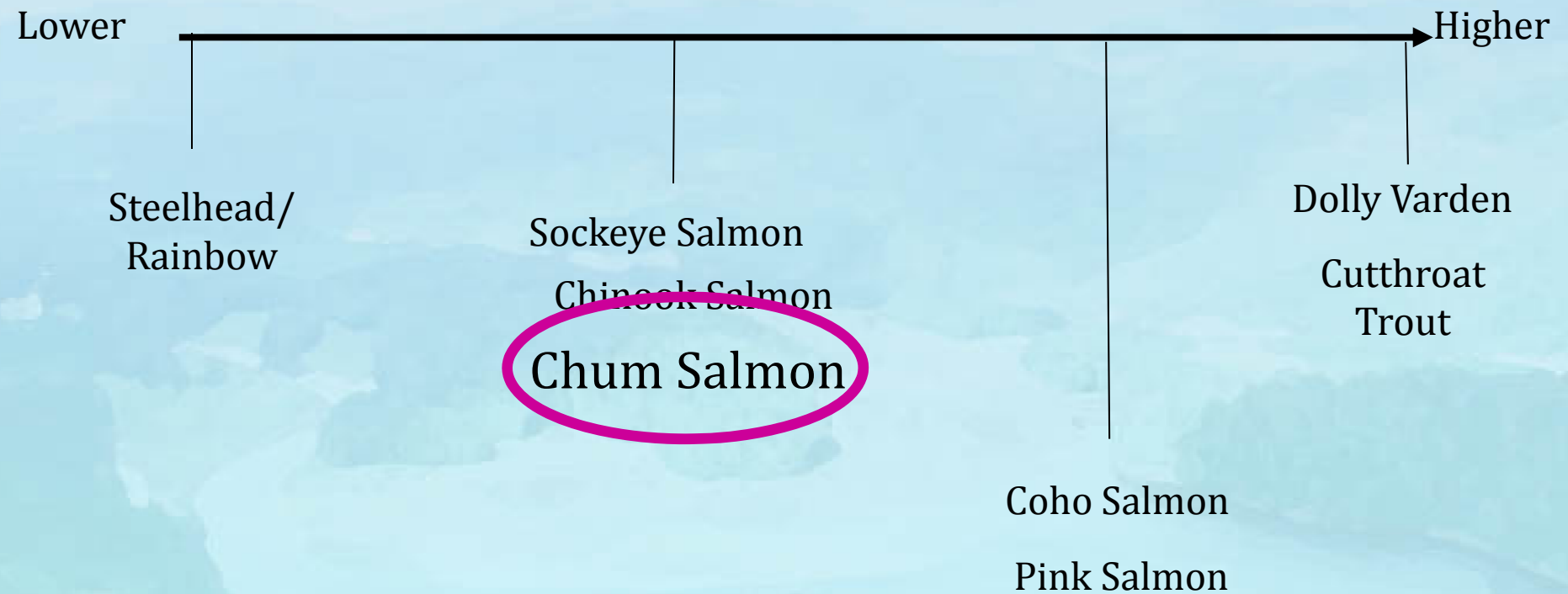
# Potential of Anadromous Salmonids to Respond to Climate Change

- ◆ Life-history & phenotypic variability
  - immediate response
- ◆ Genetic adaptability
  - longer-term response

# Vulnerability to Potential Climate Change Effects

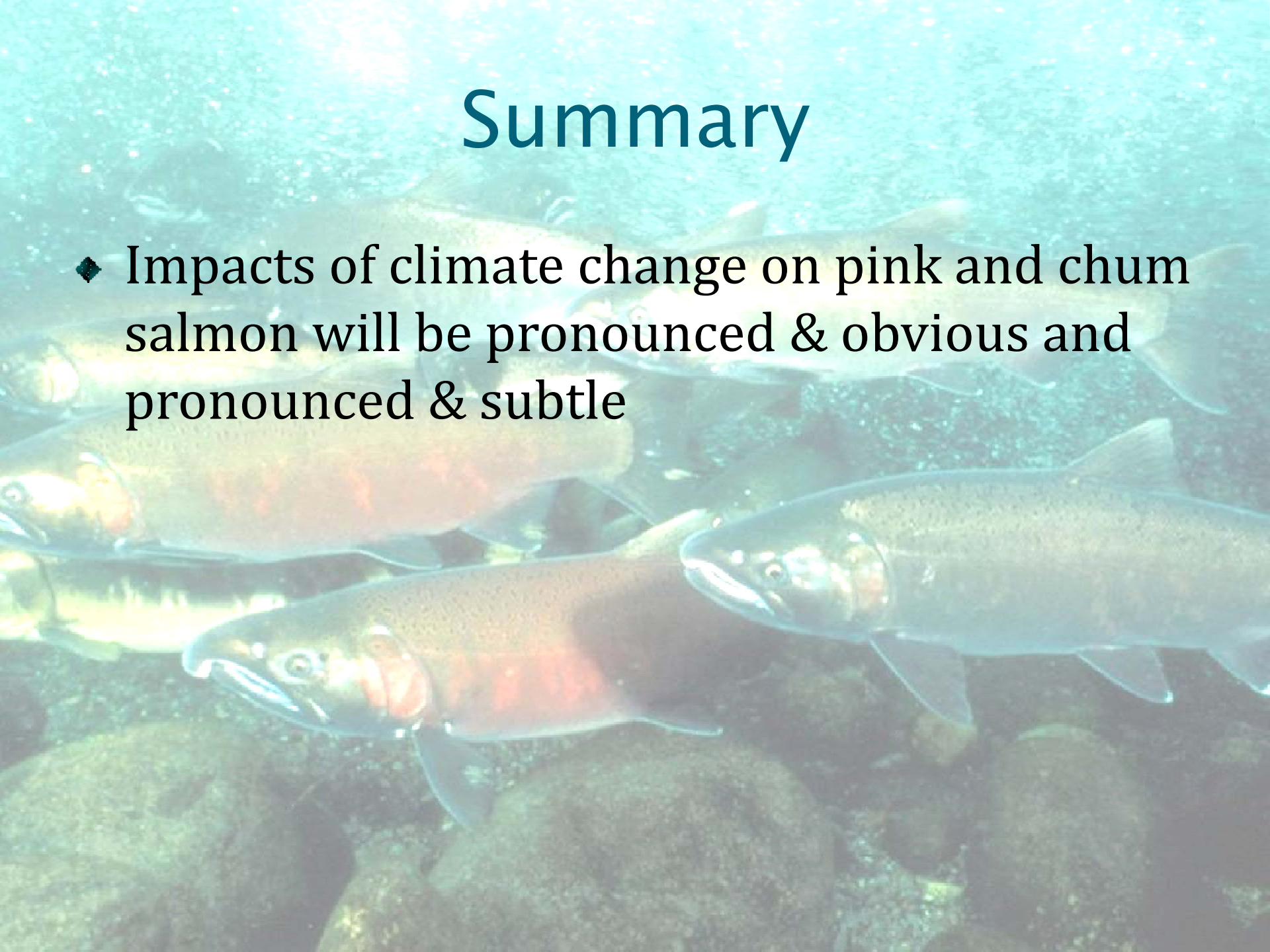


# Vulnerability to Potential Climate Change Effects



# Summary

- ◆ Impacts of climate change on pink and chum salmon will be pronounced & obvious and pronounced & subtle



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- ◆ Magnitude of impacts likely to vary

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- ◆ Impacts of climate change on pink and chum salmon will be pronounced & obvious and pronounced & subtle
- ◆ Magnitude of impacts likely to vary
- ◆ Anadromous salmonids have inherent capacity to respond to climate change

***“The significant problems we face today cannot be solved with the same level of thinking that were at when we created them.”***

**Albert Einstein**



THE FISH ARE CALLING

# Winter Temperatures

ECHAM5

surface air temperature

+40°

F

0°F

-50°F

January 1990

ECHAM5

surface air temperature

+40

+30

+20

+10

0

-10

-20

-30

-40

-50

January 2099

From: <http://igloo.atmos.uiuc.edu/SNAP/>



# Potential impacts of climate change on terrestrial and marine interactions in the coastal temperate rainforest

Eran Hood,  
Frances Biles, Erik Norberg, Jason Fellman



## Background

- The Coastal Temperature Rainforest (CTR) of British Columbia and Alaska contain the largest remaining intact temperate rainforest in the world.(Fig 1).
- The North American coastal watersheds of the Gulf of Alaska discharge 410 Km<sup>3</sup> of water per year, equal to the discharge of the Mississippi river (Fig 2).
- The flux of water and materials from the terrestrial margin is huge, and influences circulation patterns and productivity within the estuaries of the Alexander Archipelago and the pelagic food webs of the GOA. (Figs 3 and 4, Table 1).
- Watersheds in the rainforest ecosystem fall into three main hydrologic and biogeochemical classes, with distinct differences in the seasonality and composition of discharge and material flux (Fig 5)
- Predicted increases in temperature are centered on the GOA (Fig. 6) and will result in a significant increase in the elevation of the rain-snow transition zone.
- As the snow line increases, watersheds will receive less precipitation as snow and more as rain. The hydrology of watersheds will change as less precipitation is stored as ice and snow and more is discharged in synchrony with annual precipitation patterns.
- The change in seasonal discharge of water and nutrients will have potentially major impacts on the productivity of freshwater habitats, estuaries and nearshore coastal waters and the Gulf of Alaska.
- All watersheds are not created equal. The vulnerability of watersheds to climate induced changes in water and nutrient fluxes varies with their physical characteristics such as slope, mean elevation, percent glacial ice and geology. These factors, which control the present pattern of annual runoff, will also influence when, and to what degree, watershed properties change in response to warming.

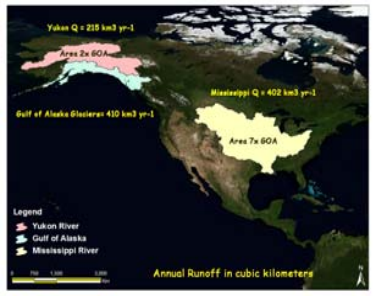
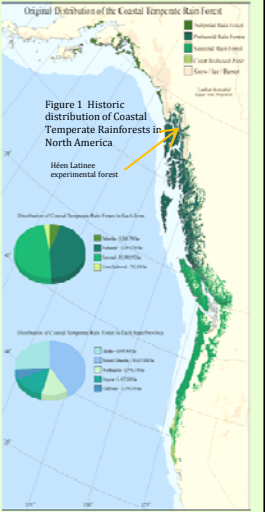


Figure 2 Comparison of freshwater discharge from major basins into coastal waters.

Table 1. Magnitude of carbon, nitrogen and phosphorus fluxes between terrestrial and marine ecosystems in SE Alaska.

	Carbon (metric tons)	Nitrogen (metric tons)	Phosphorus (metric tons)
Salmon inputs	7,900	1,931	281
Terrestrial outputs	790,000	46,078	6,200
Ratio salmon/terrestrial	0.01	0.04	0.04

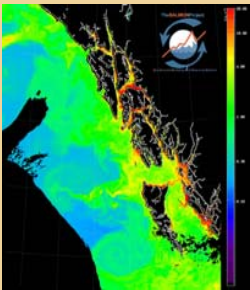


Figure 3 Surface water chlorophyll concentrations in the Alexander Archipelago and near shore waters of SE Alaska illustrating the effect of runoff on productivity.

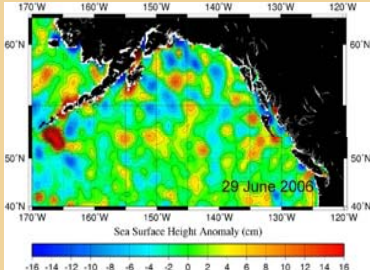


Figure 4 Sea surface height map showing the train of eddies containing freshwater, chlorophyll, and nutrients moving from the coastal waters west into the Gulf of Alaska. Eddies cover about 10% of the GOA and contain 50% of the Gulf's chlorophyll.

Brownwater

Clearwater

Glacial

Figure 5 Three dominant watershed types based on mean annual hydrograph. Dark blue lines are the percent of annual precipitation falling in a given month, the light blue lines are the percent of annual runoff in each month. Data are from USGS long term discharge records. There are obvious differences in when precipitation is delivered from watersheds to the marine system.

Figure 6 Along with differences in hydrology, the different watersheds also exhibit distinct differences in temperature and the concentration and seasonality of carbon, and other nutrient dynamics.

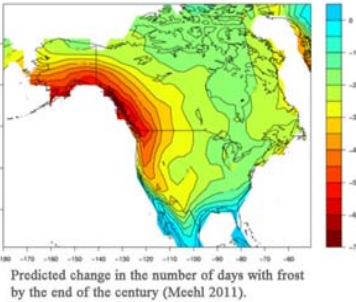


Figure 7 Warming in the region is centered in the Gulf of Alaska and along the temperate rainforest continental fringe.

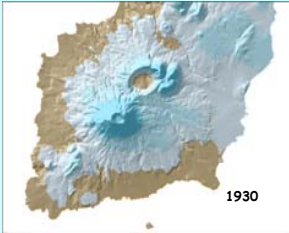


Figure 8 Snow model of the change in snow cover from 1930 to 2080 on Mt Edgecumbe near Sitka, AK demonstrating the retreat of the snow line up the mountain.

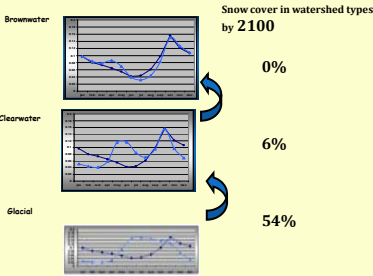
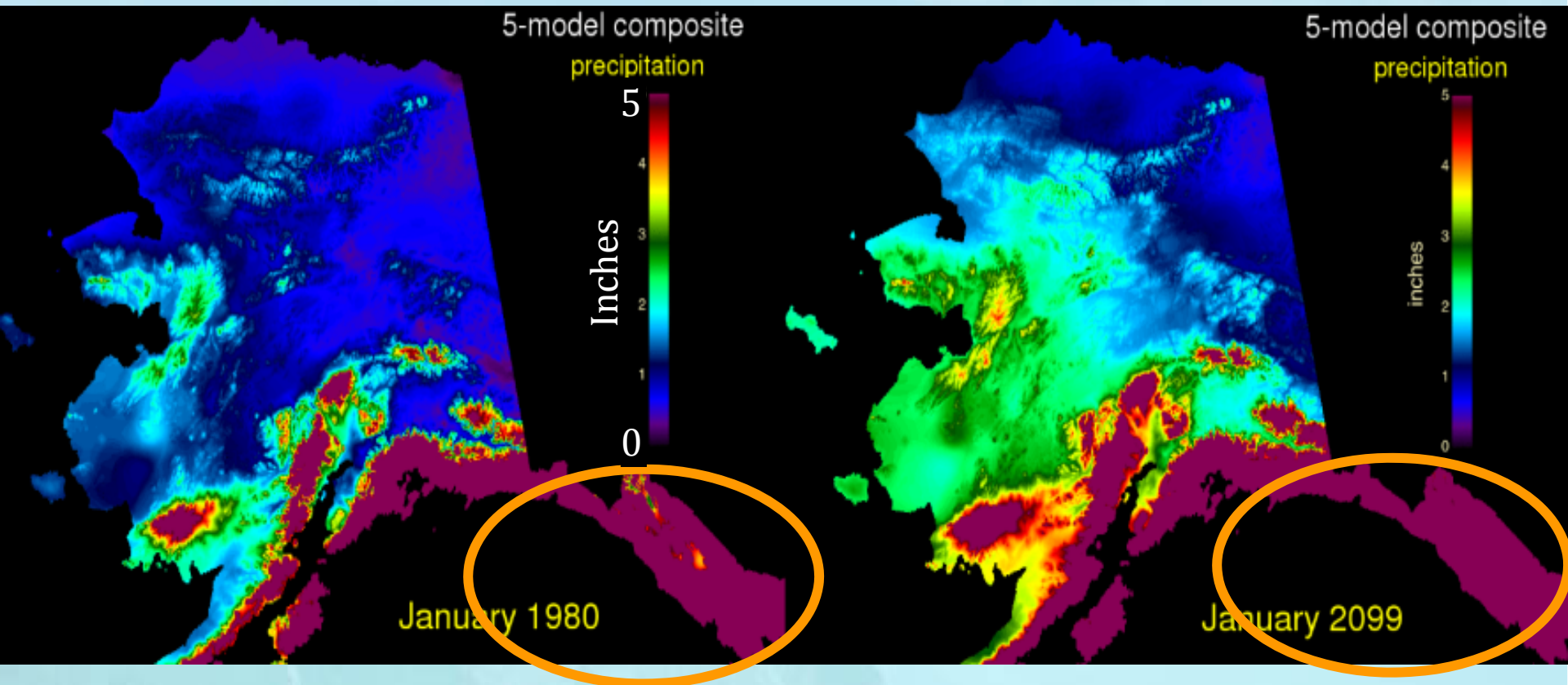


Figure 9 Preliminary predictions are that watersheds will lose much or all significant snow cover by the end of the century, shifting the hydrological regime toward that of the lower elevation types.

## Conclusions

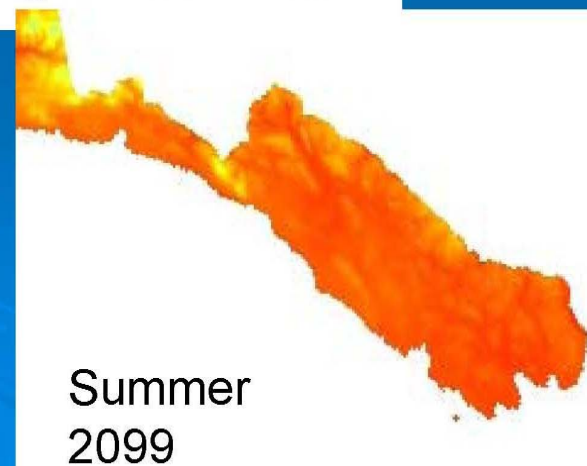
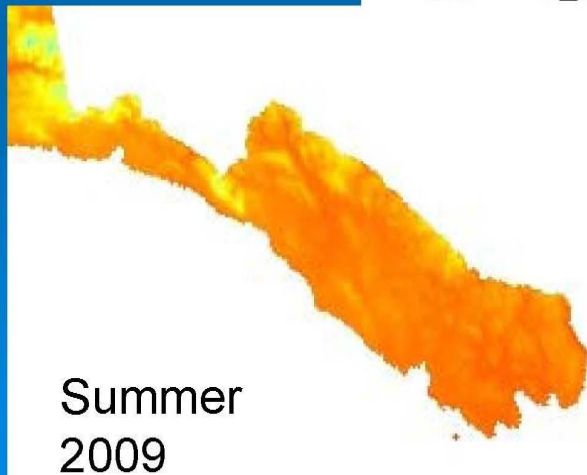
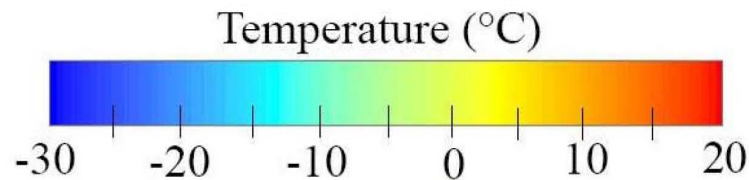
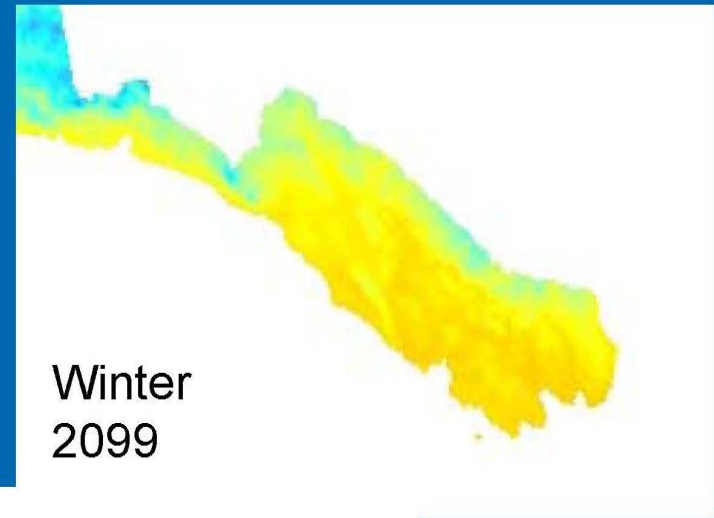
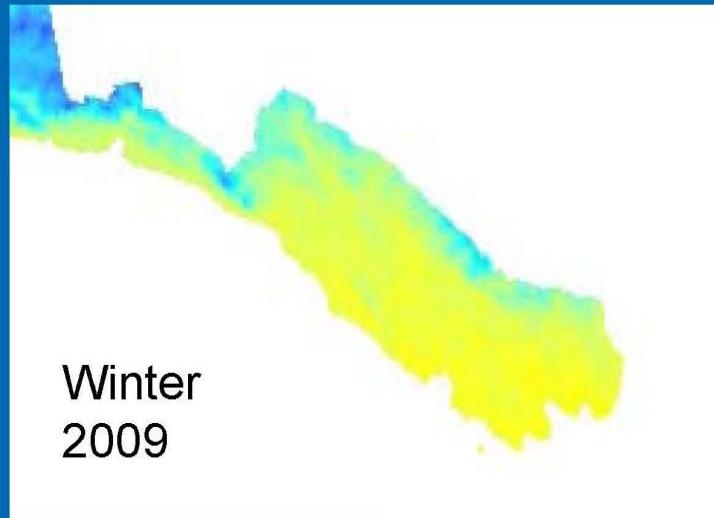
- Present patterns of freshwater discharge suggest that the coastal margin and Gulf of Alaska are highly influenced by riverine inputs.
- Predicted changes in the magnitude and timing of water and nutrient fluxes suggest that significant changes could occur in estuarine, coastal and Gulf circulation and nutrient cycling with potentially serious impacts on productivity.
- To better predict the impact of warming on hydrology, material fluxes and productivity we need more precise models coupling climate to hydrology and biochemistry at multiple scales from regional to watershed.
- An understanding of hydrology alone is not sufficient to predict change. Watersheds exhibit distinct personalities based on geomorphology, underlying geology, small scale climate and the history of post-glacial development of vegetation and soil influenced by those factors.

# Changes in Precipitation









From: <http://igloo.atmos.uiuc.edu/SNAP/>

# Climate change in SE Alaska



# Classification of Study Basins

-  LR (Low k - Rain)
-  LM (Low k- Mixture of rain and snow)
-  LS (Low k - Snow)
-  HR (High k - Rain)
-  HM (High k - Mixture of rain and snow)
-  HS (High k - Snow)

