Northwest Power and Conservation Council

February 27, 2008

MEMORANDUM

TO: Council Members

FROM: Jim Ruff, Manager, Mainstem Passage and River Operations

SUBJECT: NOAA's Northwest Fisheries Science Center Presentations on Ocean Conditions, Snake River Spring/Summer Chinook Parr Response to Climate Change, and Incised Channels Research

At the March 11, 2008, Council meeting in Boise, Idaho, four scientists from NOAA's Northwest Fisheries Science Center in Seattle will provide briefings on the following topics. First, John Ferguson, who is the Director of the Fish Ecology Division at the Science Center, will introduce the three topics and provide an overview of current research on the potential effects of climate variability on fisheries resources in the Pacific Northwest.

Bill Peterson, an Oceanographer working out of NOAA's Newport, Oregon laboratory, will provide the Council with an update of ocean ecosystem indicators of salmon marine survival in the Northern California current off the Washington and Oregon coasts. He will show that biological indicators are directly linked to the success of salmon during their first year at sea through food-chain processes. These biological indicators, coupled with physical oceanographic data, offer new insight into the mechanisms that lead to success or failure for salmon runs.

Next up will be Rich Zabel, a Team Leader of the Quantitative Ecology Team, who will discuss differential population response to climate change indices in freshwater habitats of Salmon River Basin spring/summer Chinook salmon. His work indicates that juvenile salmon survival is related to climate indices of stream flow and water temperature during the parr life stage, and the response to freshwater climate varies across salmon populations depending on habitat characteristics.

Finally, Tim Beechie, who is a Team Leader of Ecosystem Processes Research, will present information about using beavers to restore incised streams in the interior Columbia River Basin. He will show that beaver dams and sediment retention structures help increase sediment aggradation rates and reduce the time required to reconnect incised channels to their historical floodplains. Restoring beaver populations raises the water table, creates new fish habitat and expands the extent of riparian vegetation.

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Current research on the potential effects of climate variability on fisheries resources in the Pacific NW

NOAA Fisheries
Northwest Fisheries Science Center

JOINT OCEAN COMMISSION INITIATIVE

- Commission is a collaborative effort between the US Commission on Ocean Policy and the Pew Oceans Commission (led by Adm. Watkins and Hon. Leon Panetta)

- 2007 added "Links between oceans and climate change" to their joint initiative:

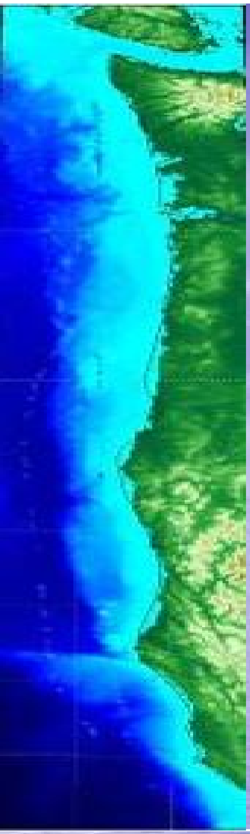
  "Given the staggering economic and ecological ramifications associated with climate change, the Joint Initiative stresses that a better understanding of ocean-related processes and their impacts will be necessary for policy makers and the public to make informed decisions on mitigation and adaptation strategies."

WEST COAST GOVERNORS' AGREEMENT on OCEAN HEALTH

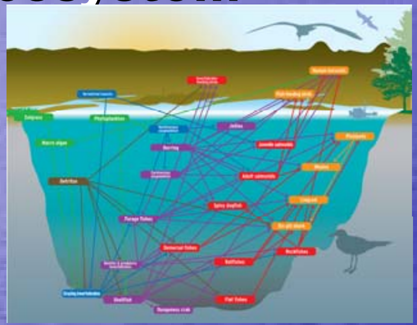
CALIFORNIA OREGON WASHINGTON

- *Seven Priority Areas*
  - Promoting the effective implementation of **ecosystem-based management** of our ocean and coastal resources
  - Expanding ocean and coastal **scientific information, research, and monitoring**
- *Draft Action Plan*
  - **Preparing for the Effects of Climate Change**

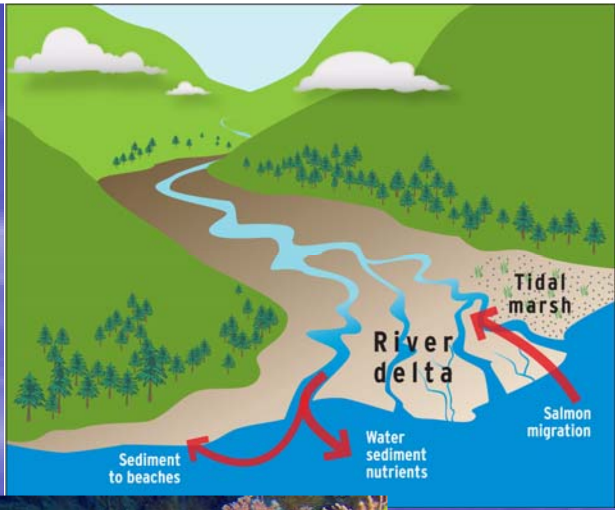
NWFSC Strategic Research Plan



Ecosystem-based Management for the California Current Large Marine Ecosystem

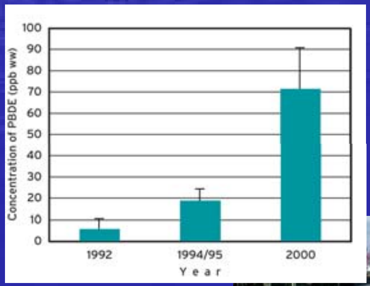


Habitats to Support Sustainable Fisheries and Recovered Populations



Recovery, Rebuilding, and Sustainability of Marine and Anadromous Species

Oceans and Human Health



Why study climate?

Freshwater Ecosystems:

- Climate directly affects water temperature and the magnitude and timing of stream flows, which affect all aspects of salmon development, rearing, and migration.
- Understanding which types of restoration actions are robust to climate change is critical for effective recovery of federally listed populations.

Why study climate?

Marine Ecosystems:

- Coastal upwelling, food chain productivity, individual growth, fish size, reproductive output, and predator distribution and abundance are all directly linked to temperature.
- For salmon – recruitment into the sub-adult life stage is directly related to the ecosystem smolts experience during the first few days, weeks, months at sea.
- Examples of recent phenomenon:
  - Harmful algal blooms (HABs) and anoxia events are increasing in scope, magnitude, and duration, and these changes have been linked to climate change.

NWFSC approach to climate research for salmon: "Summit to the Sea"

- Studies to determine the effects of river flow and water temperature on migration and survival of wild Snake River spring/summer Chinook salmon parr/smolts (today)
- Studies to determine migrational behavior of fall Chinook salmon during the summer in the lower Snake River
- A study to estimate survival through the Columbia River estuary using acoustic tags (September science-policy workshop)
- Within year timing of juvenile ocean entry and marine survival related to climate
- Modeling climate change in Puget Sound
- Forage fish and predator fish studies and climate/ocean conditions
- Climate, marine food webs and Pacific salmon in the coastal upwelling zone of the Pacific NW (today)
- Jellyfish as indicators of climate change and their role in the ecosystem?
- Effects of climate on salmon ocean feeding and bioenergetics

Today's talks

- **Bill Peterson:**
  - **Update of Ocean Ecosystem Indicators of Salmon Marine Survival in the Northern California Current – 2007**
- **Rich Zabel:**
  - **Differential population response to climate change in freshwater habitats of Salmon River basin spring/summer Chinook salmon**
- **Tim Beechie:**
  - **Using beaver to restore incised streams in the interior Columbia River basin**

- Bill Peterson:
  - Update of Ocean Ecosystem Indicators of Salmon Marine Survival in the Northern California Current – 2007

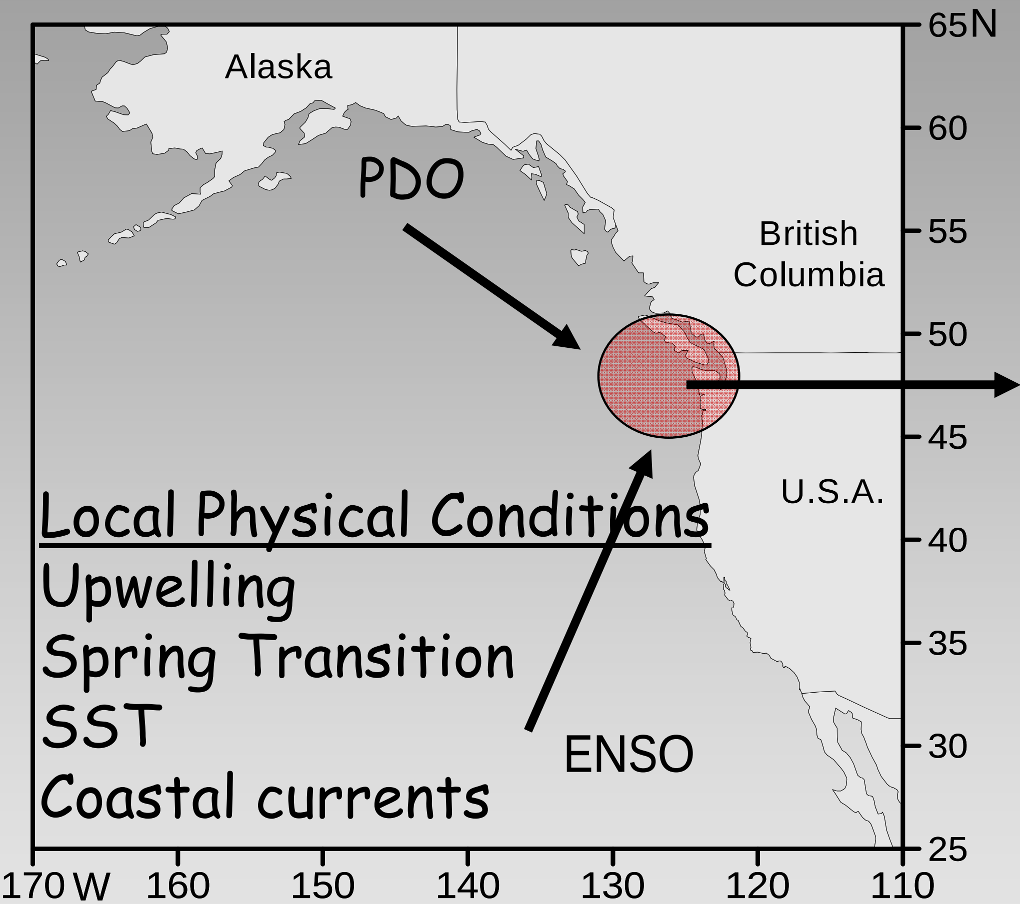
Climate, ocean conditions and salmon

Bill Peterson

NOAA Fisheries
Northwest Fisheries Science Center
Hatfield Marine Science Center
Newport Oregon

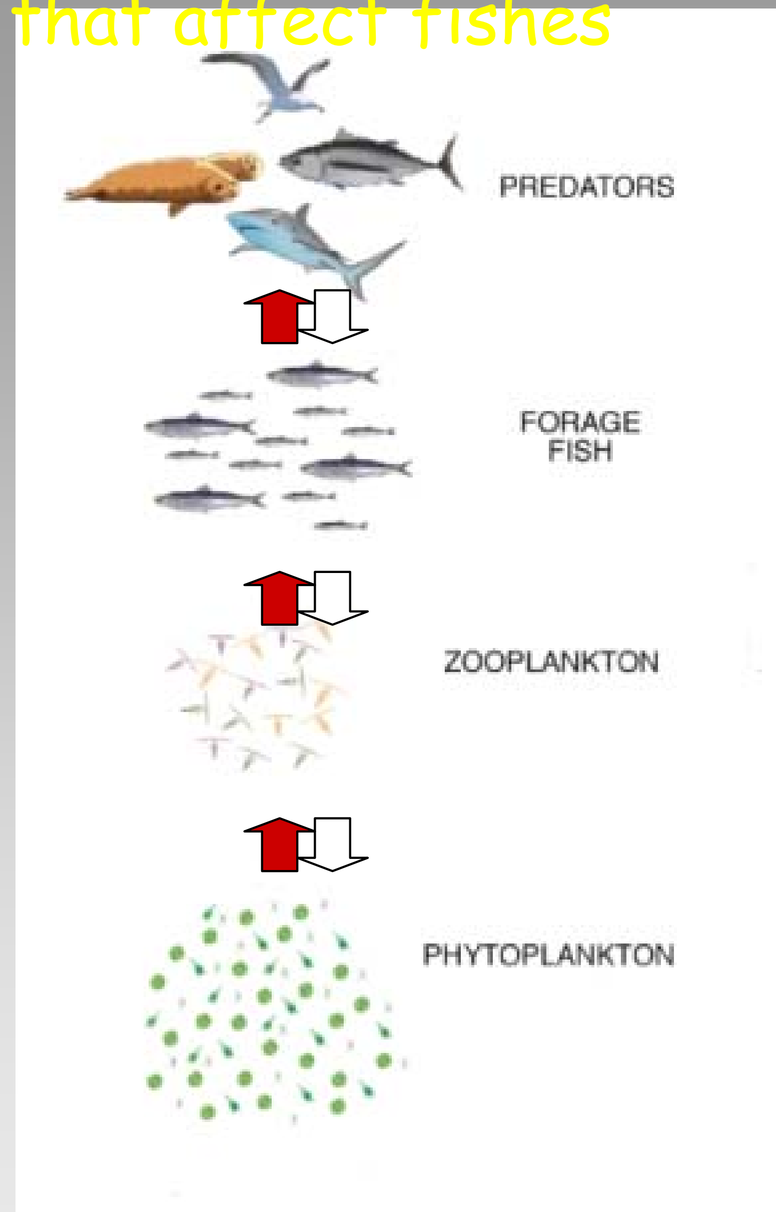
We are taking a holistic approach to development of indices and management advice by considering a suite physical and biological factors that affect fishes

Large scale forces acting at the local scale can influence biological process important for salmon

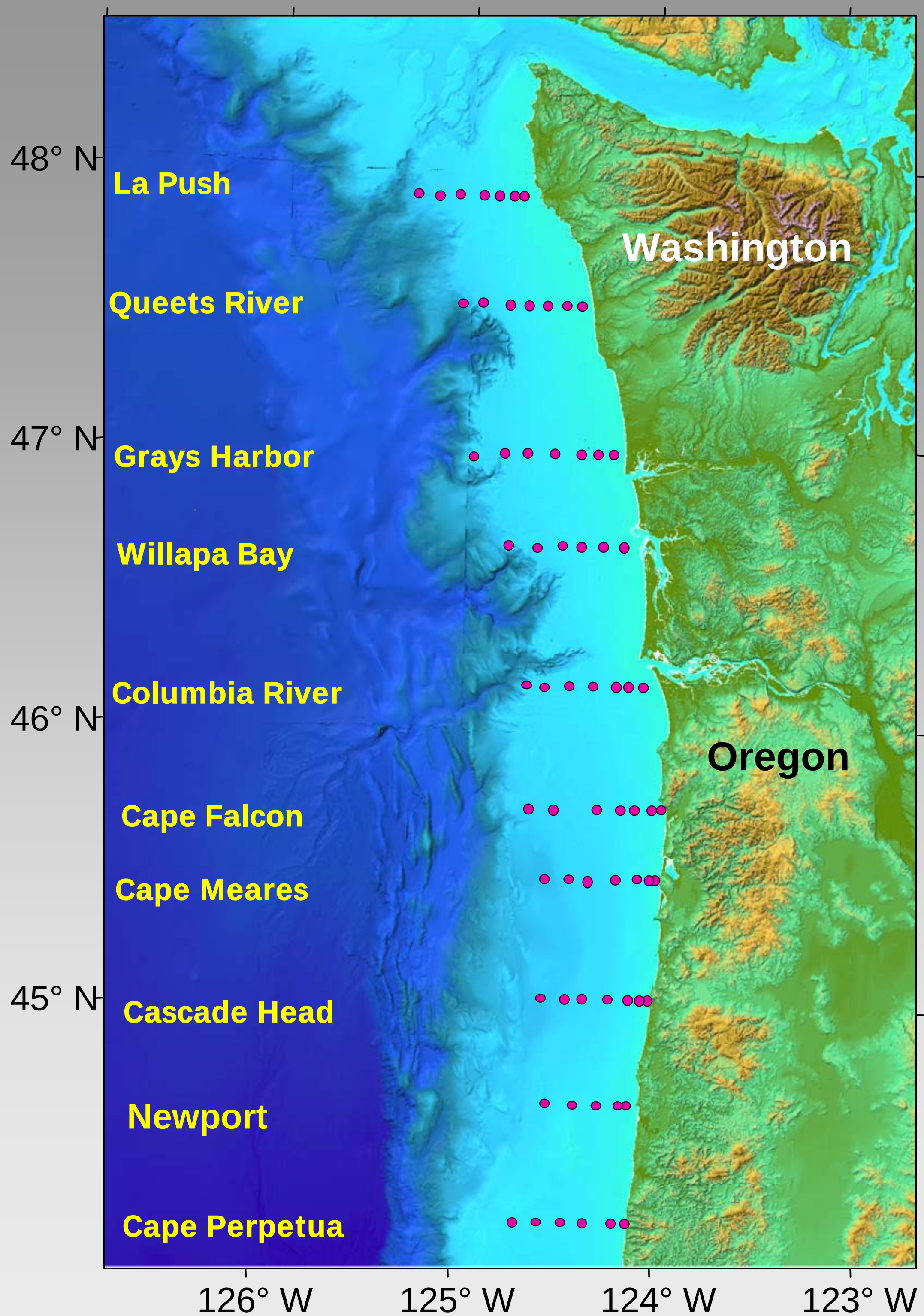


Approach

1. Develop time series
2. Relate to salmon through simple bivariate analyses



Local Biological Conditions



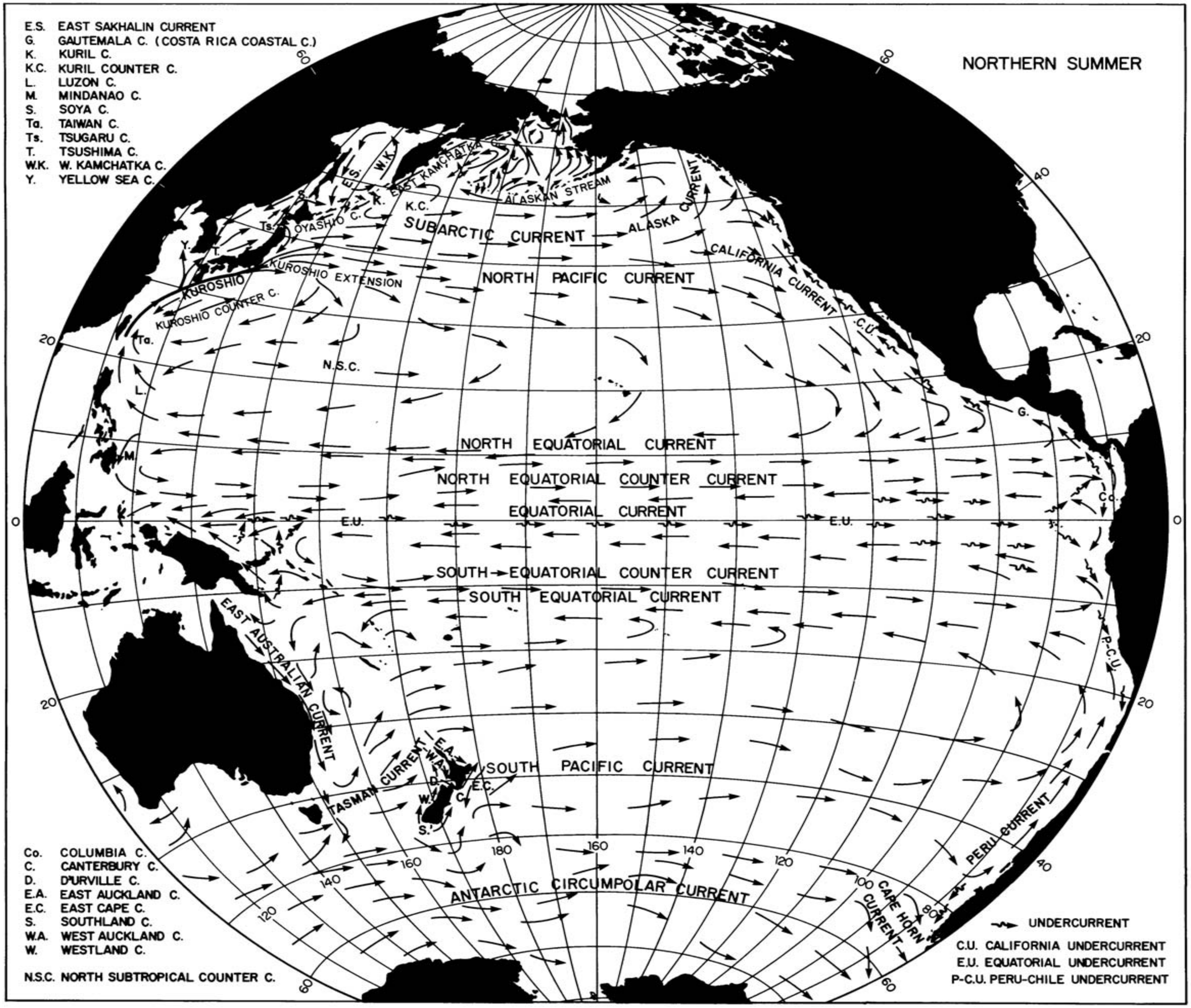
Climate, ocean conditions and salmon

- Newport Line biweekly sampling since 1996
- Juvenile salmon sampling in June and September since 1998

Three factors affect plankton, food chains, pelagic fish and salmon growth and survival in the northern California Current

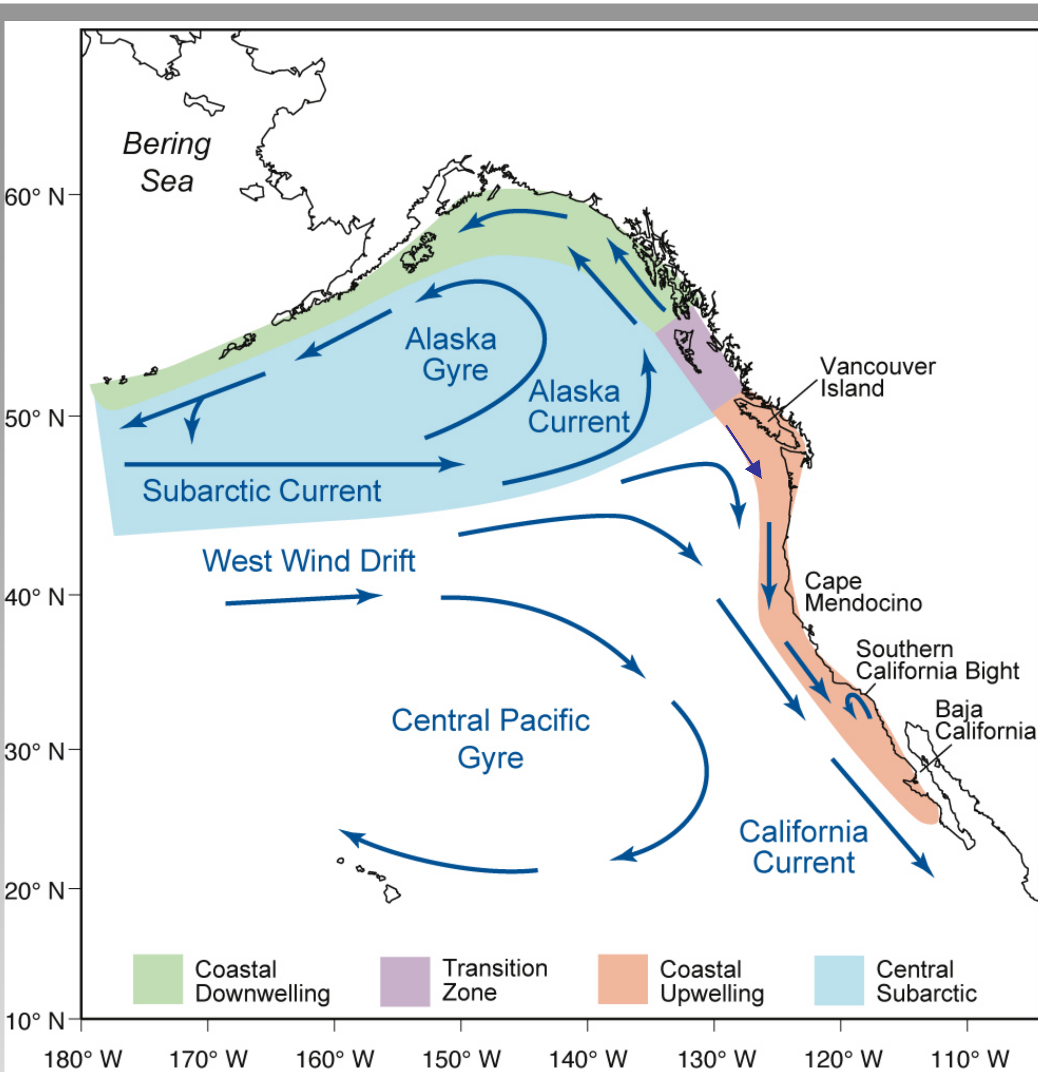
- Strength of coastal upwelling
- Seasonal reversal of coastal currents: southward in summer – northward in winter
- Phase of the Pacific Decadal Oscillation (PDO

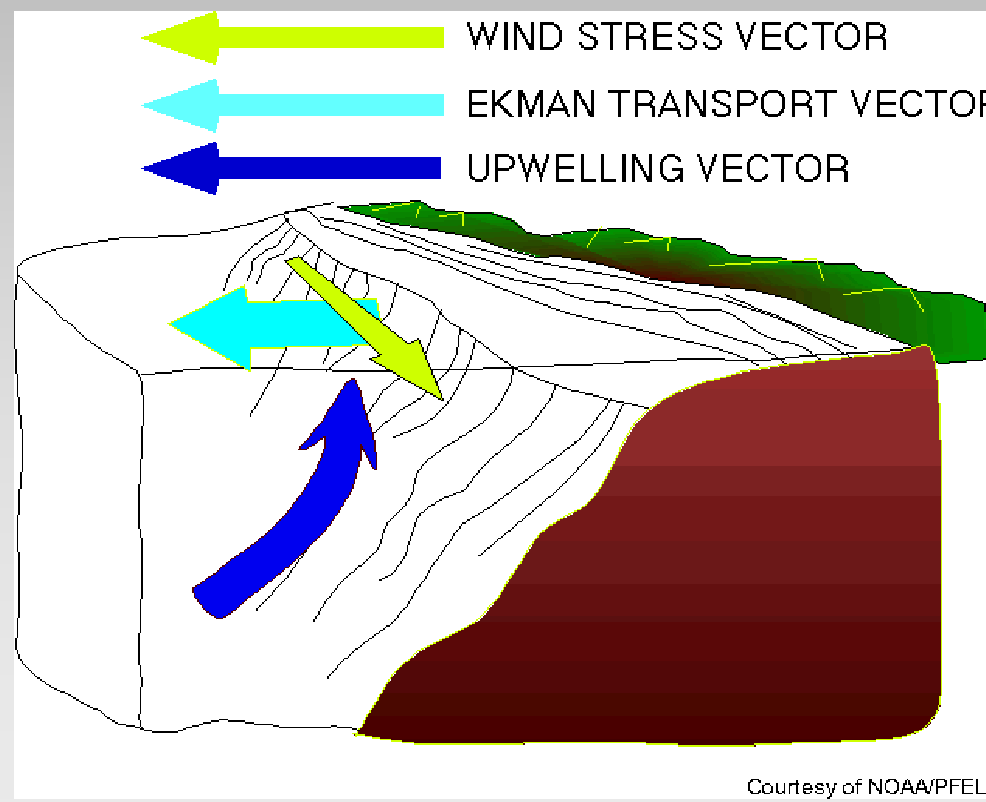
Oceanography 101



Circulation off the Pacific Northwest

Note: CC begins at ~ N end of Vancouver Island





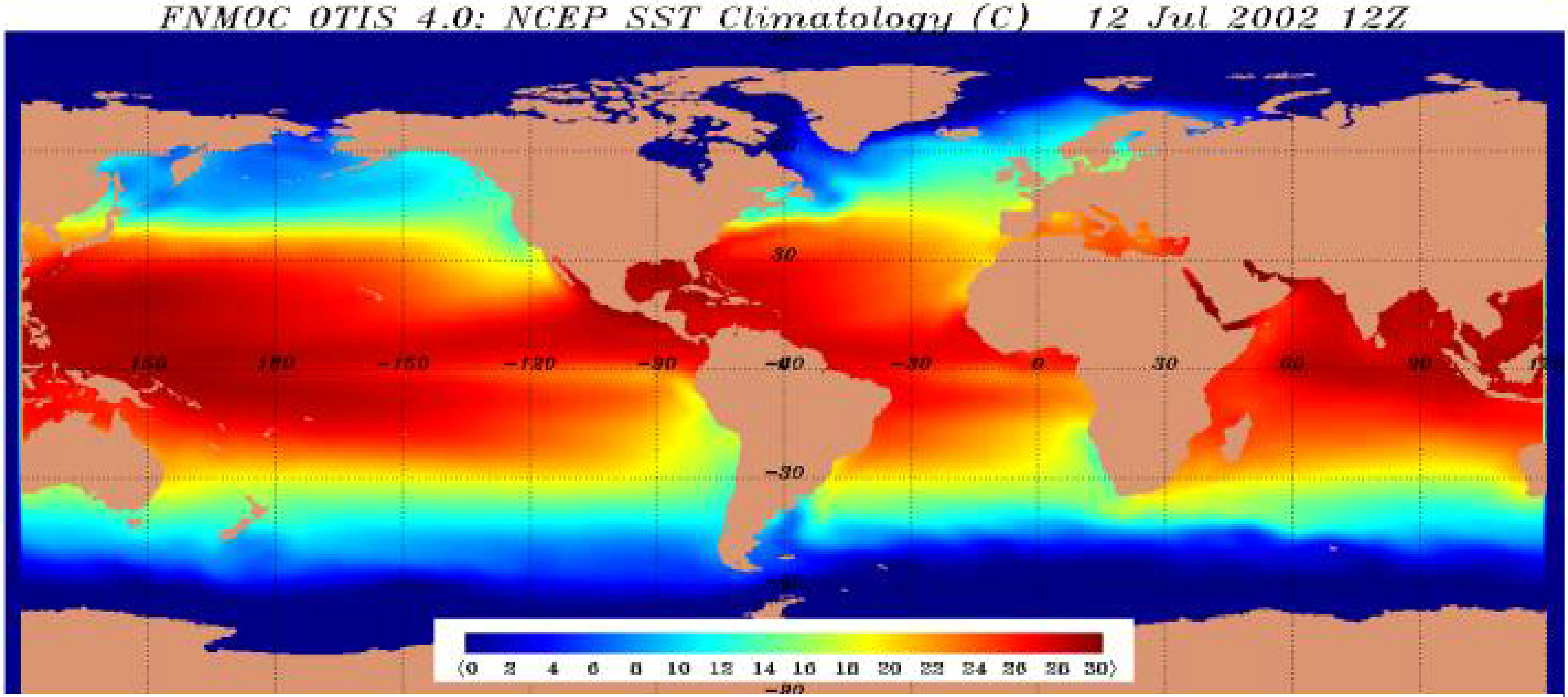


CHART OF SEA SURFACE TEMPERATURE

- Note: warm water between the equator and ~ 30 N
- Because of upwelling off North America, S. America N. Africa and S. Africa, cool water is found at the coast. Without upwelling, the coasts would be ~ 5-10°C warmer during summer because offshore waters would move shoreward.
- Without upwelling we would have no salmon off PNW

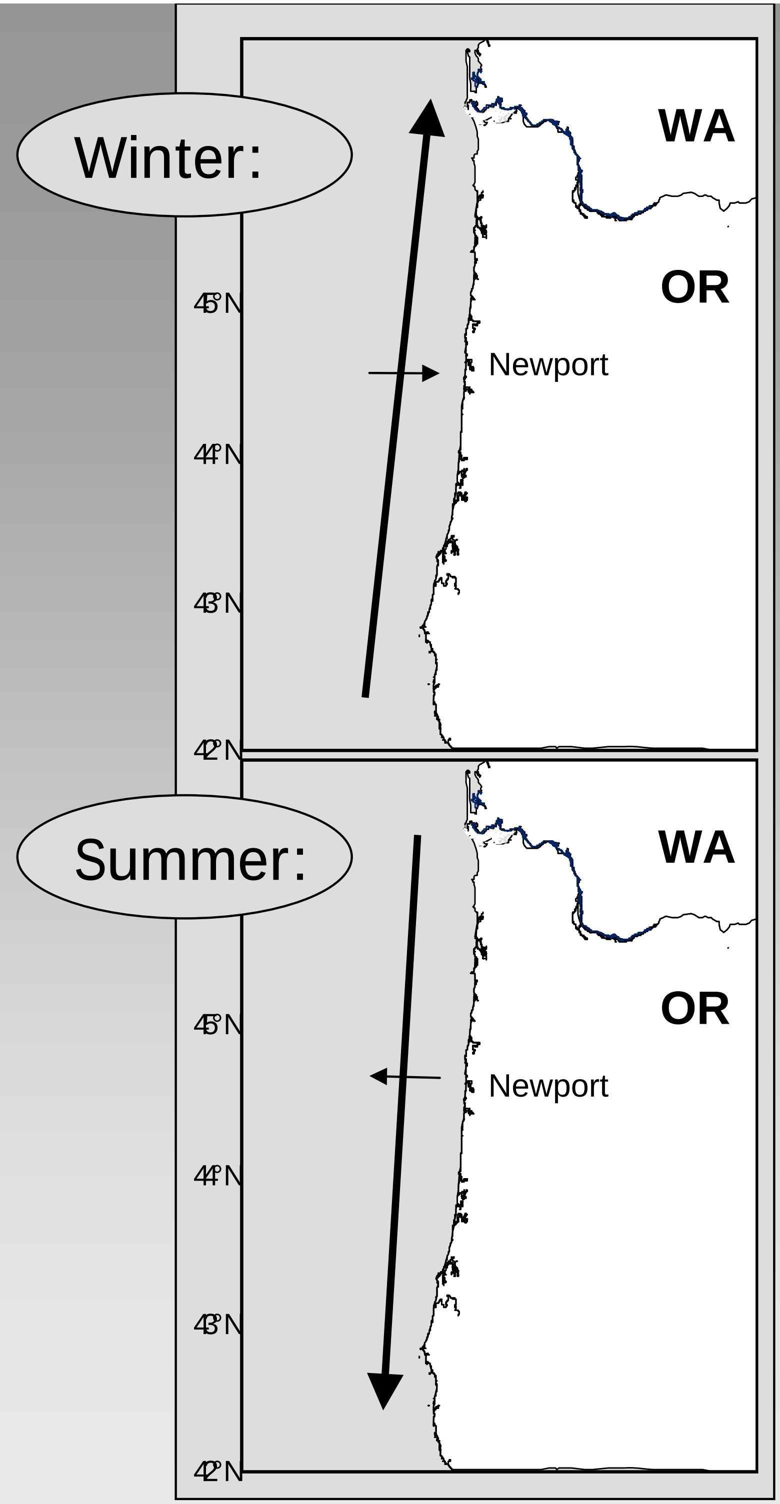
Winds and current structure off coastal Oregon:

- Winter:
  - Winds from the South
  - Downwelling
  - Poleward-flowing Davidson Current
  - Subtropical/southern species transported northward & onshore

- **Spring Transition in April/May**

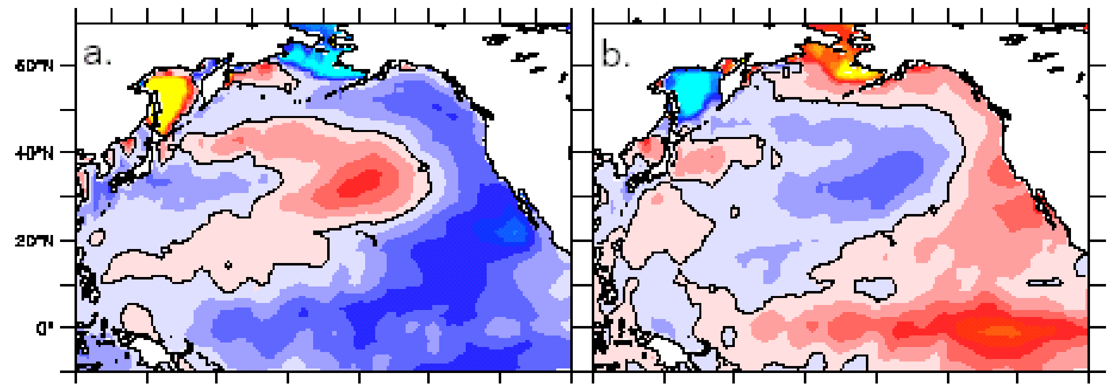
- Summer:
  - Strong winds from the North
  - Coastal upwelling
  - Equatorward alongshore transport
  - Boreal/northern species transported southward

- **Fall Transition in October**



PDO & SST

The PDO has two phases, resulting from the direction from which winds blow in winter. The SST patterns shown on the right result from basin scale winds: W'ly and NW'ly [negative phase] and SW'ly [positive phase]

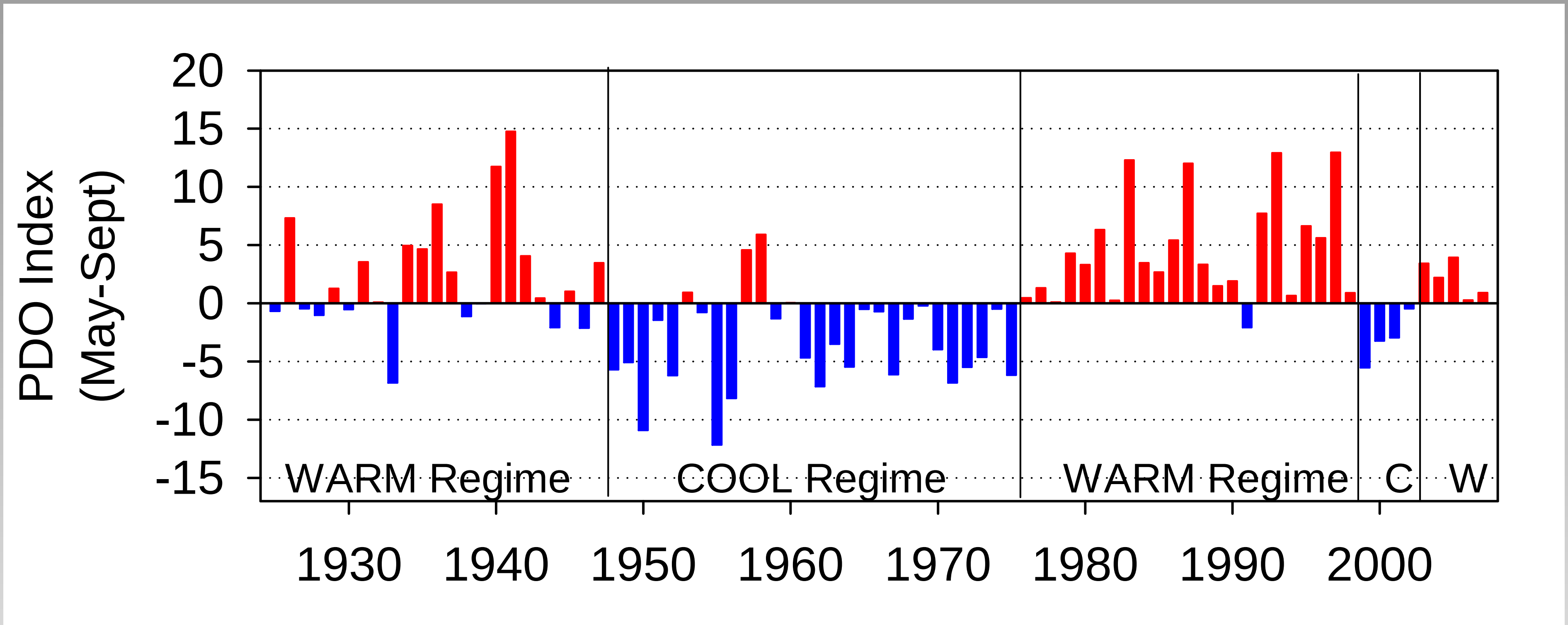


Negative Phase	Positive Phase
1947-1976	1977-1998
1999-2002	2003-2006
2007-	

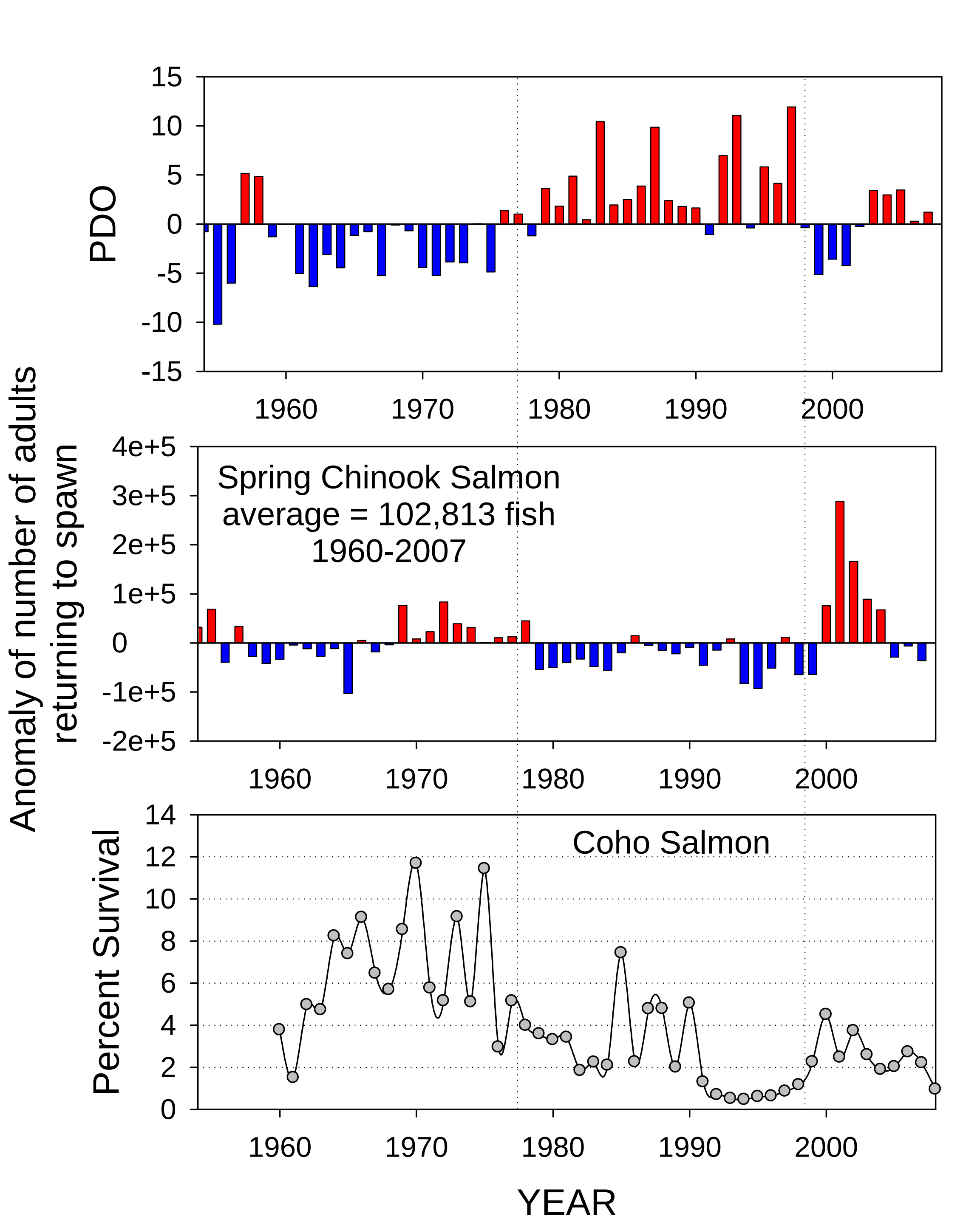
Westerlies are dominating this winter (07-08).

Blue is cold water
Red is warm water

PDO: May-Sep Average, 1925-2007



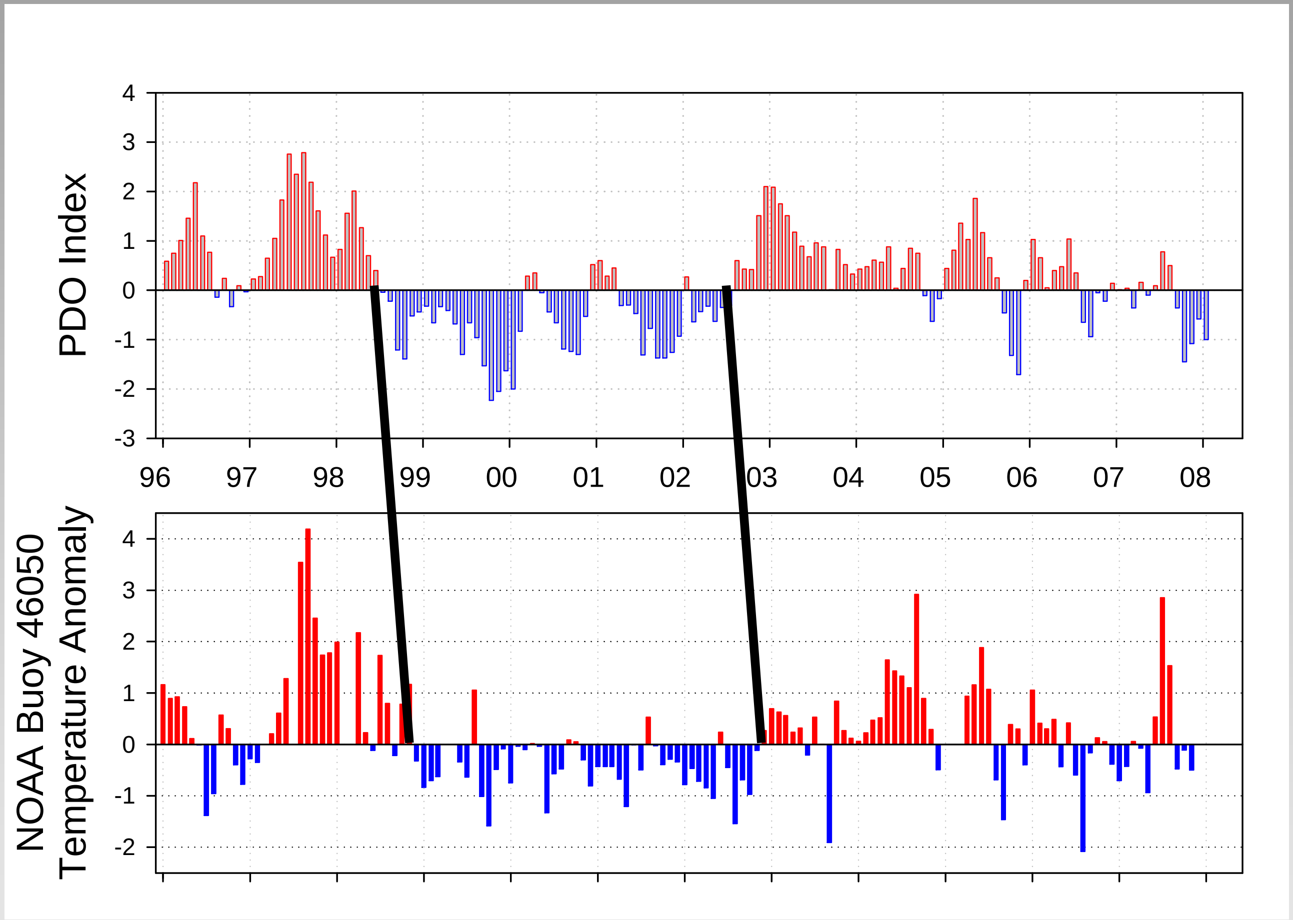
- From 1925-1998, PDO shifted every 20-30 years. Some refer to these as "salmon" regimes (cool) and "sardine" regimes (warm).
- However, we have had two shifts of four years duration recently: 1999-2002 and 2003-2006, thus we have a natural experiment to test the affects of PDO on salmon populations.



Shifting baselines: PDO and salmon

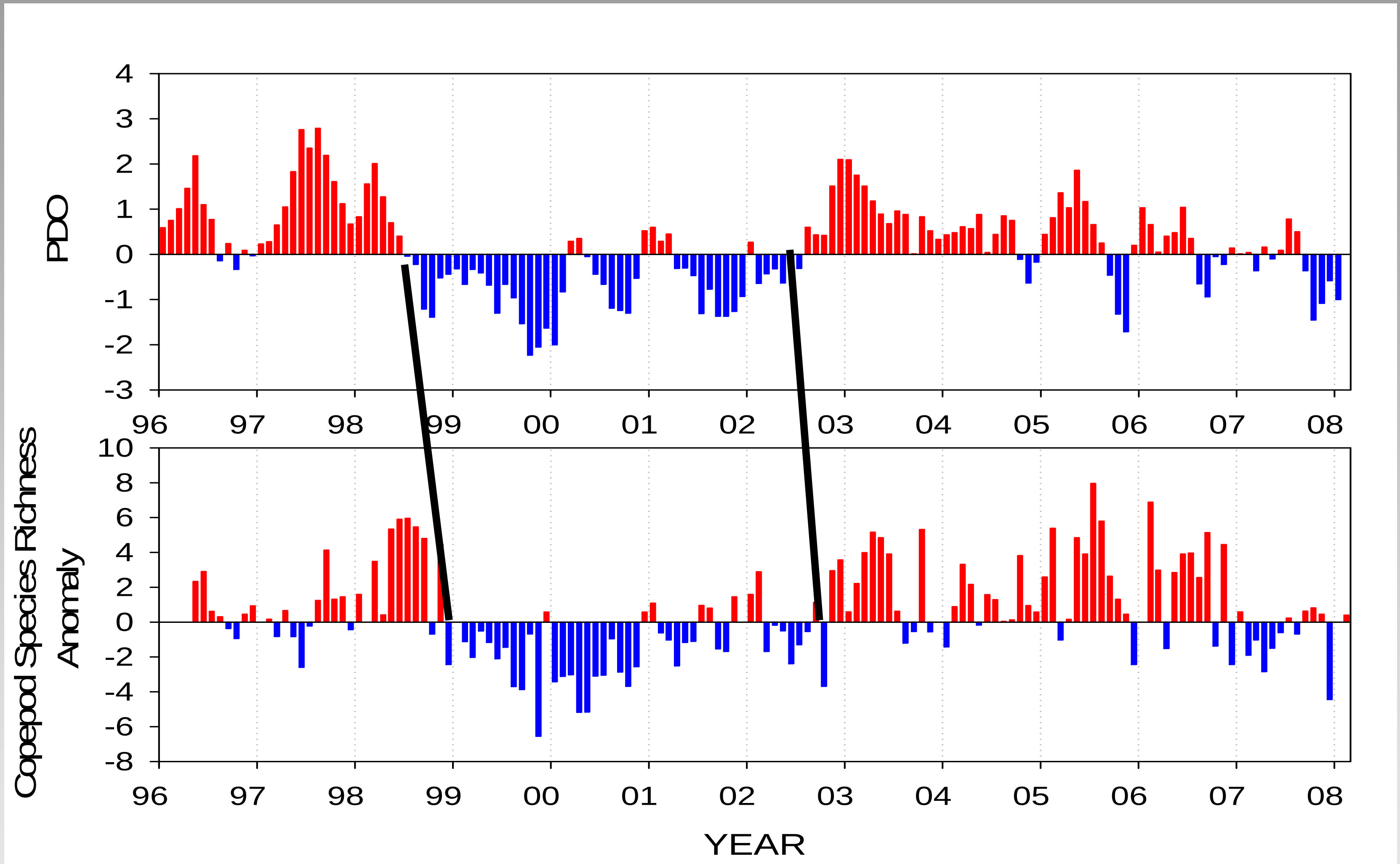
- Spring Chinook salmon counts at Bonneville Dam began to track PDO in ~ 1977; HUGE RETURNS of fish in 2001-2003 surprised everyone.
- Percent of Coho salmon that return to hatcheries track the PDO since 1960
- PROGNOSIS: negative PDO a good salmon; positive PDO not good for salmon.

12 year time series of SST off Newport shows that PDO downscales to local SST



- PDO and SST correlated, as they should be.
- However there are time lags between PDO sign change and SST response of 3-5 months.
- Suggests PDO is an advective signal along the Oregon coast

12 year time series of zooplankton sampling off Newport shows that monthly anomalies of copepod species richness are correlated with the PDO



As with SST, there are time lags of a few months between the recent 4-year "cold periods" and "warm periods". Cold periods are characterized by "cold water" copepods and vice versa.

Contrasting Communities

- **Negative PDO = low diversity and "cold-water" copepod species.** These are dominants in Bering Sea, coastal GOA, coastal northern California Current
  - *Pseudocalanus mimus, Calanus marshallae, Acartia longiremis*
- **Positive PDO = high diversity and "warm-water" copepods.** These are common in the Southern California Current neritic and offshore NCC waters
  - *Clausocalanus spp., Ctenocalanus vanus, Paracalanus parvus, Mesocalanus tenuicornis, Calocalanus styliremis*

Based on Peterson and Keister (2003)

Comparisons in size and chemical composition

- **Warm-water taxa** - (from offshore OR) are **small** in size and have limited high energy wax ester lipid depots
- **Cold-water taxa** – (boreal coastal species) are **large** and store **wax esters** as an over-wintering strategy

Therefore, significantly different food chains may result from climate shifts;

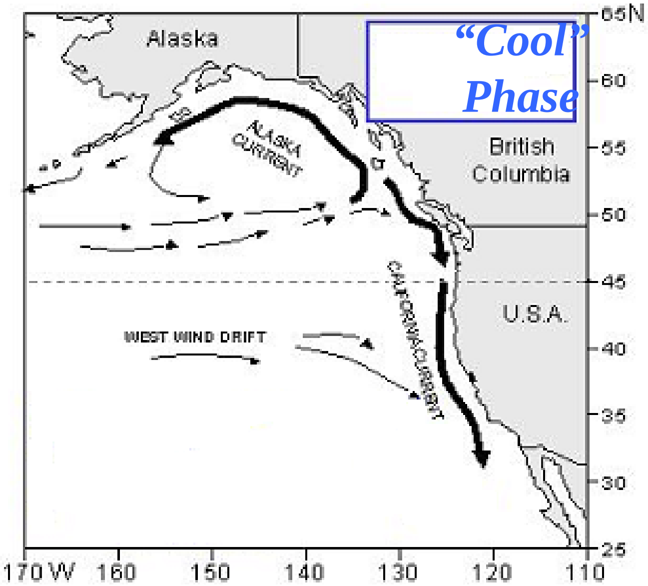
A working mechanistic hypothesis: source waters. . .

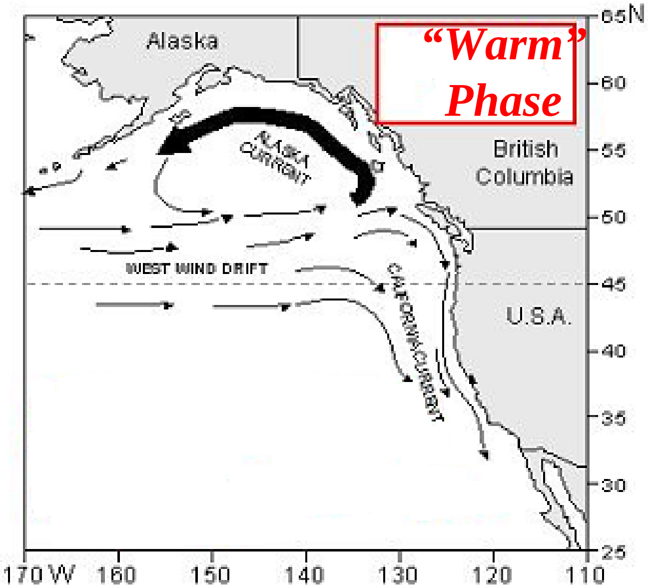
Cool Phase →

Transport of boreal coastal copepods into NCC from Gulf of Alaska

Warm Phase →

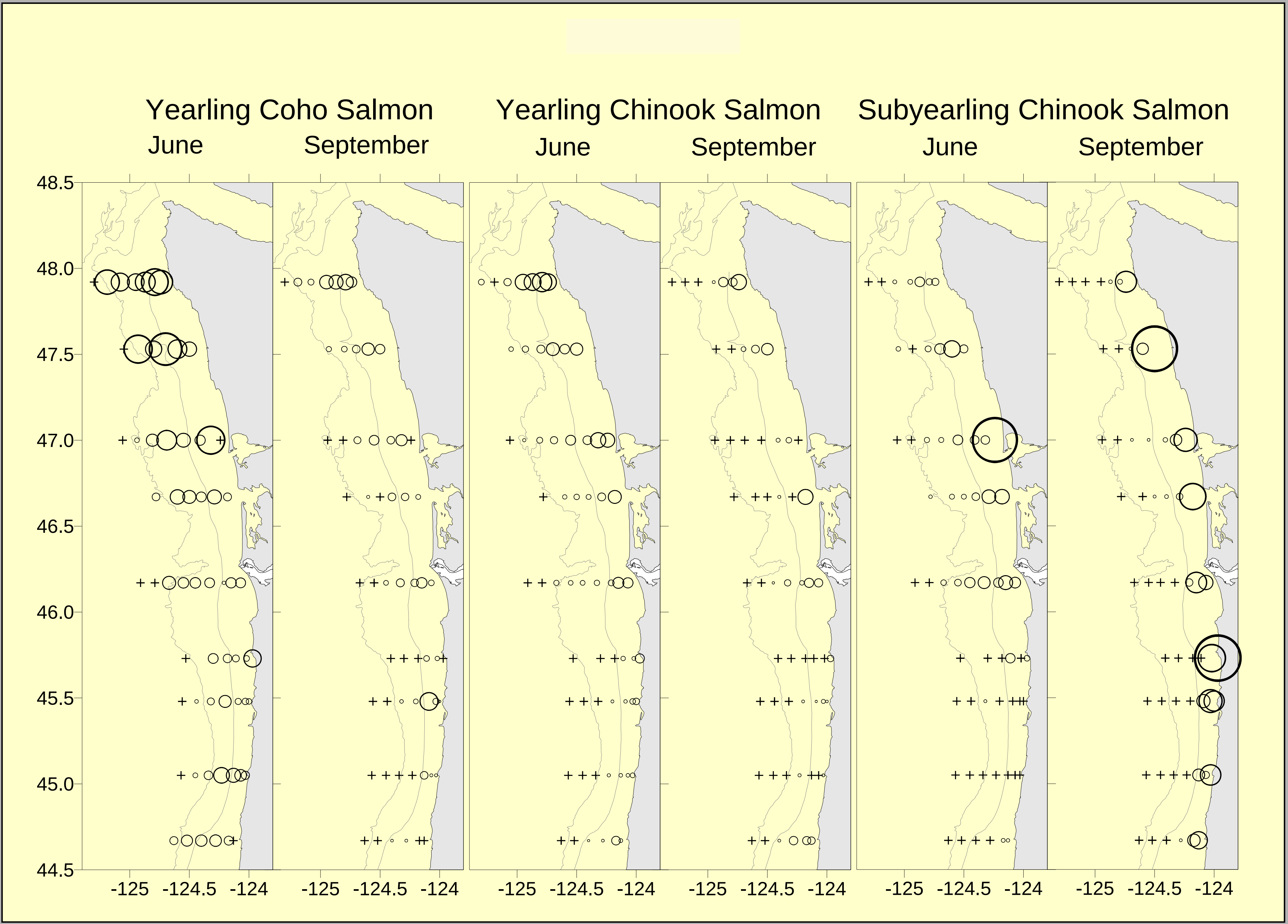
Transport of sub-tropical copepods into NCC from Transition Zone offshore





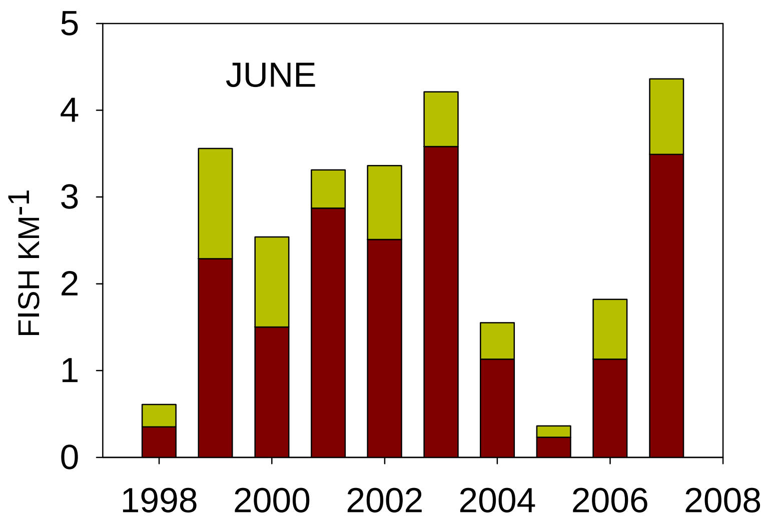
Salmon Habitat Work

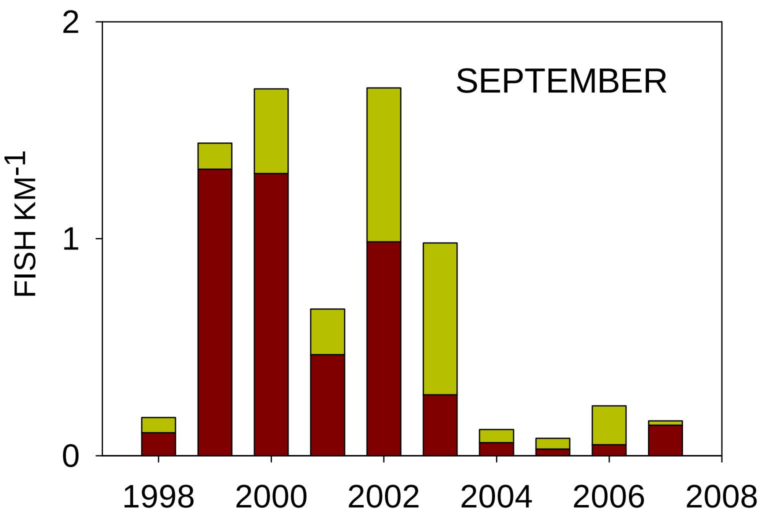
- In order to forecast returns of various salmon life history types, we must first establish where they live in the ocean.



Yearling Coho Salmon
June
September
Yearling Chinook Salmon
June
September
Subyearling Chinook Salmon
June
September
48.5
48.0
47.5
47.0
46.5
46.0
45.5
45.0
44.5
-125
-124.5
-124

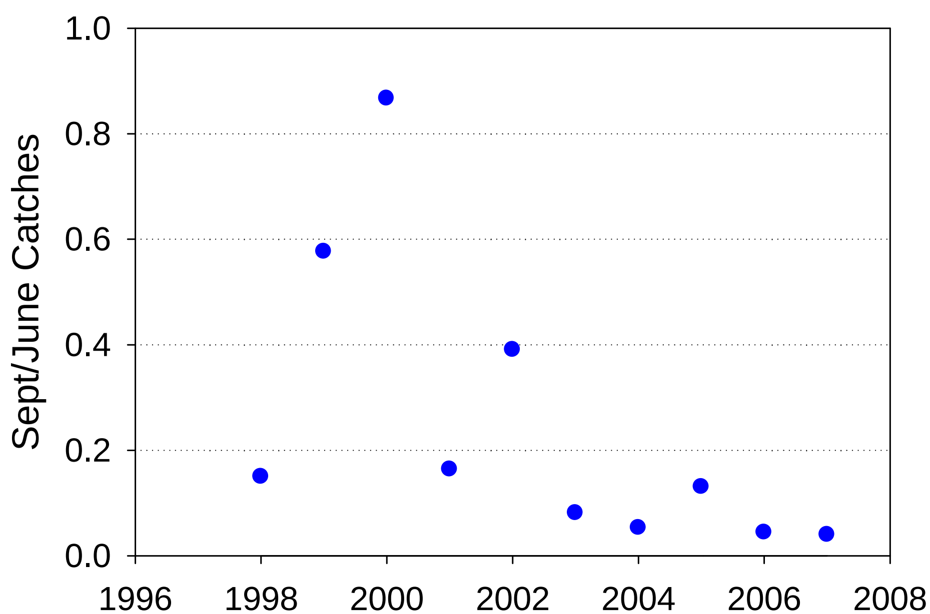
Juvenile coho salmon in trawl surveys (maroon): high in June 2007 but very low by September 2007



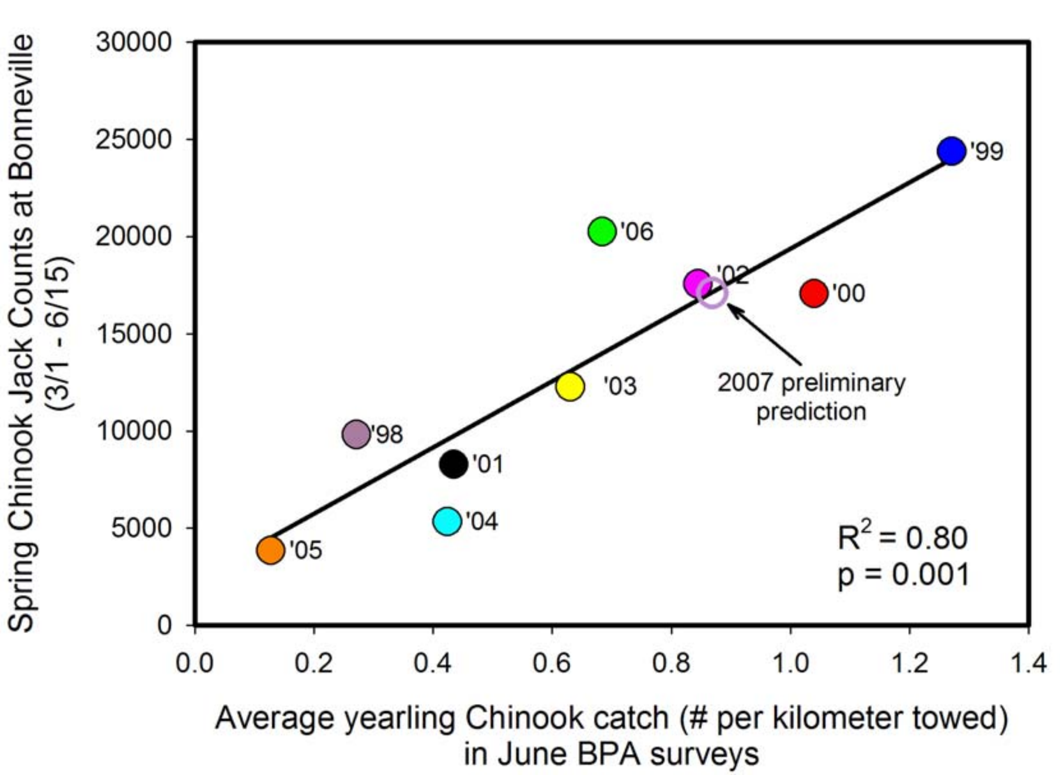


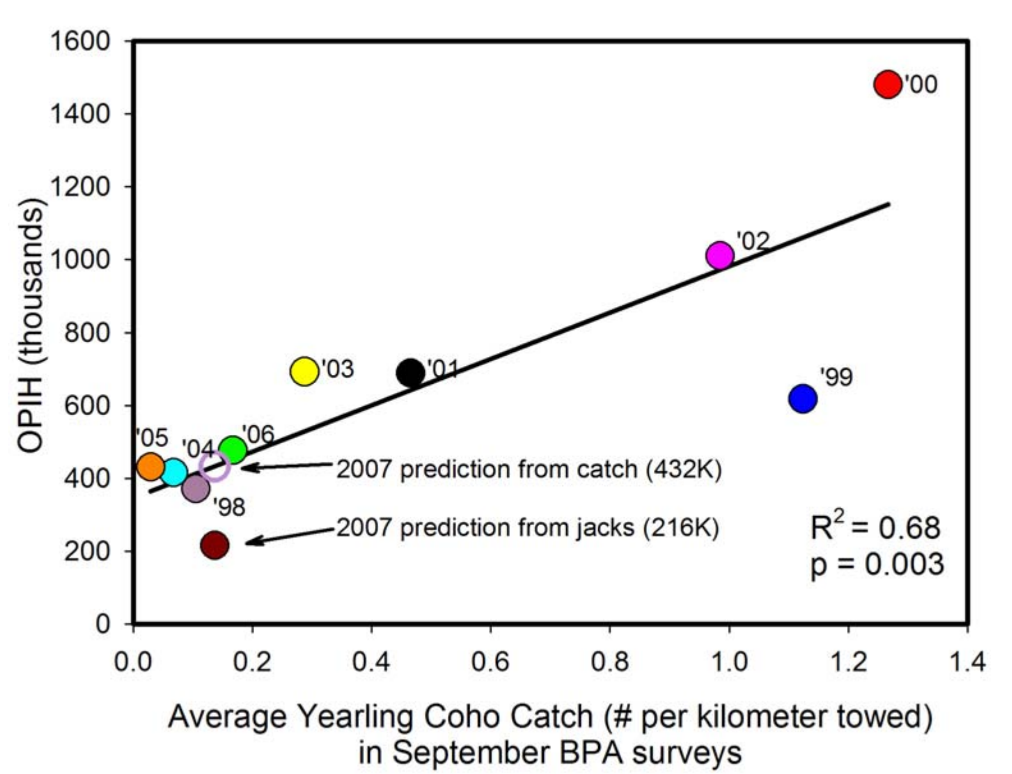
Ratio of September-to-June catches of coho may be a measure of survival over the summer.

If so, we conclude that 2007 had the lowest survival in 10 years. NOTE: summers of 2003-2006 also low, (~ 5%) due to warm ocean conditions during those years

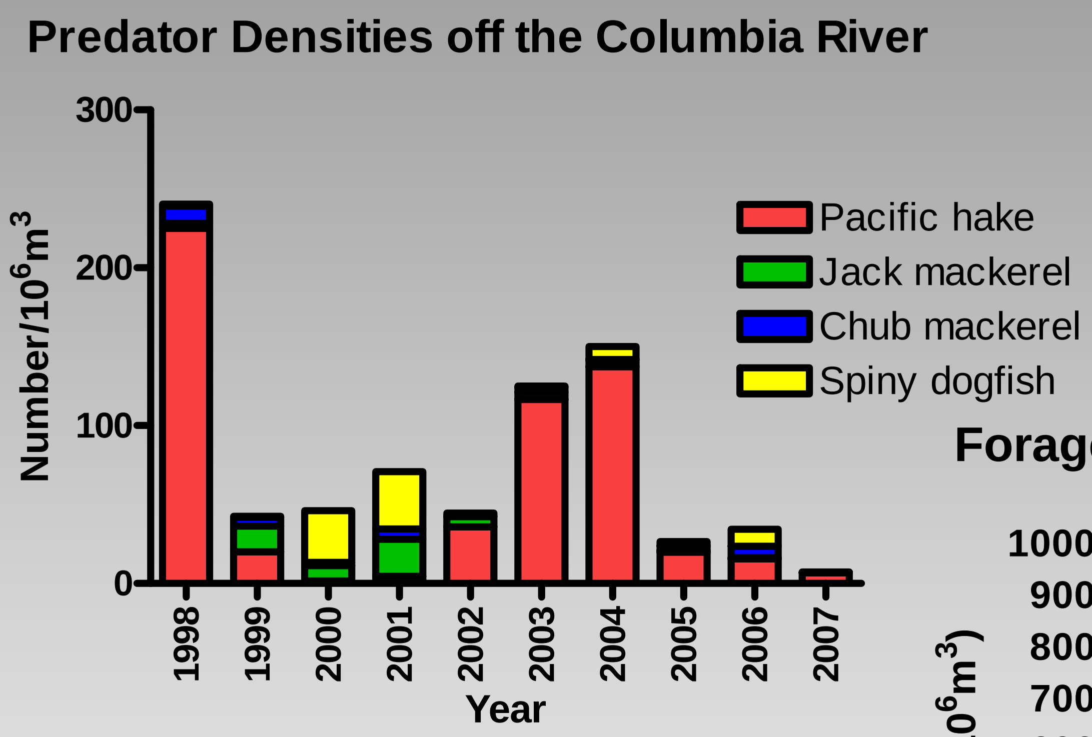


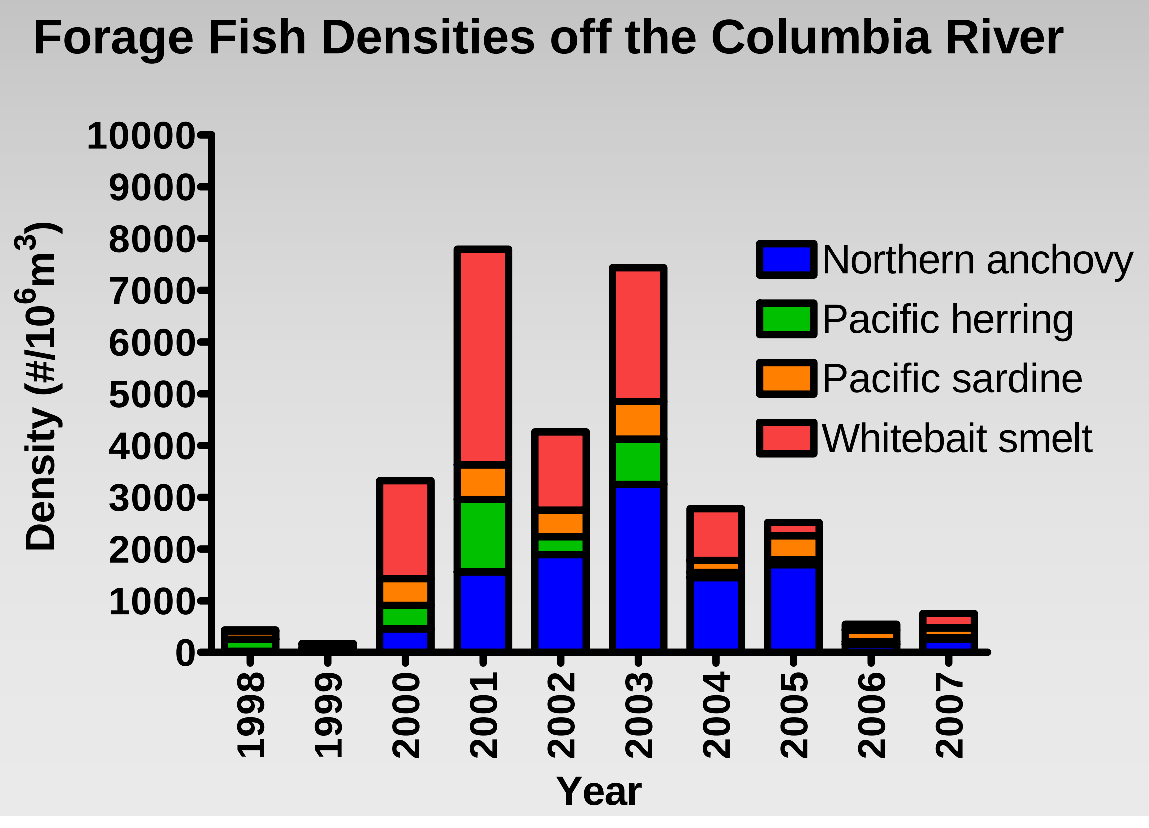
Catches of juv. salmon vs. number of returning spring Chinook jacks and OPIH coho one year later





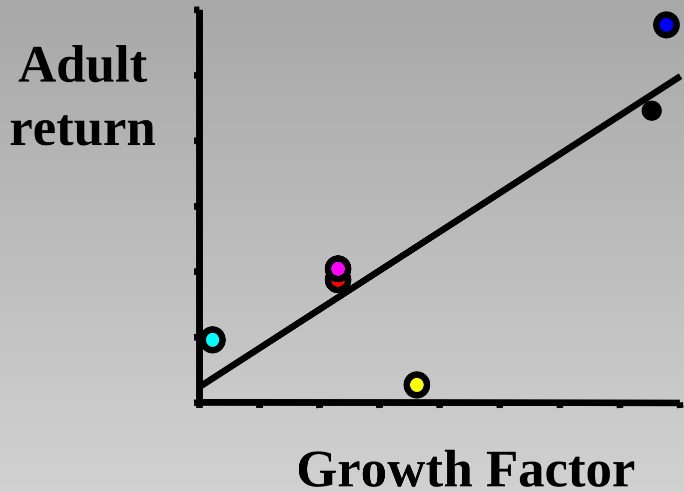
Variation in Other Biological Factors of the California Current Ecosystem During the 1998-2007 Period



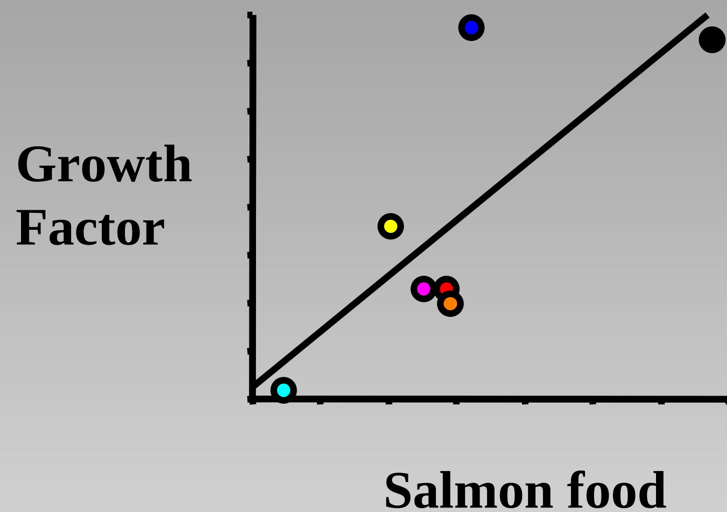


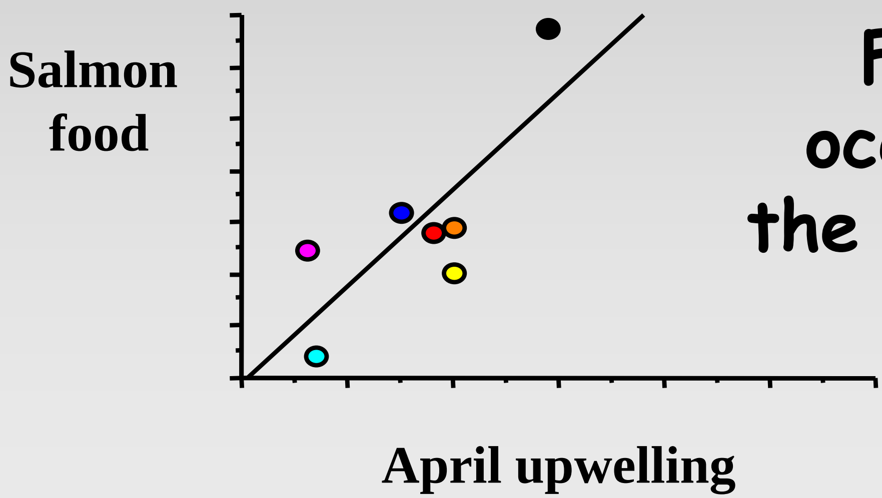
Are Growing Conditions Important To Salmon?

Survival relates to growth



Growth relates to food





Food relates to ocean conditions in the California Current Ecosystem

A chain of events

	Negative	Positive
• Changes in basin-scale winds lead to sign changes in PDO	Negative	Positive
• SST changes as do water types off Oregon	Negative Cold/salty	Positive Warm/fresh
• Spring transition	Early	Late
• Upwelling season	Long	Short
• Zooplankton production	Cold species	Warm species
• Forage Fish	Many	Few
• Juvenile salmonids	Many	Few
• Predatory fish (hake)	Few	Many

But time lags complicate interpretations!

Forecasting

- Physical and biological features of the California Current ecosystem appear to change rapidly due to phase shifts in the large scale forces reflected in the PDO
- Marine survival of salmon similarly appears to reflect rapid changes in ocean conditions of the northern California Current ecosystem
- Because global warming could affect duration and variability in large scale forcing, managers of fishery resources will need a broad variety of forecasting tools
- An example of one a set of forecasting tool documents current ocean conditions and potential impact of salmon survival 1 to 2 years ahead of their actual return (See webpage www.nwfsc.noaa.gov)

Table of qualitative indicators of ocean conditions

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
PDO		7	1	2	3	4	9	8	10	6	5
MEI		10	1	2	4	9	8	6	7	5	3
MEI Jan-June		10	1	2	4	6	8	5	9	3	7
SST at 46050		8	1	3	4	2	6	10	7	5	9
SST at NH 05		7	2	1	3	5	6	10	9	4	8
SST winter before going to sea		10	5	3	4	2	6	9	8	7	1
Upwelling		5	1	9	3	4	8	7	10	5	2
Physical Spring Transition		9	1	7	4	2	6	8	10	3	5
Deep Temperature		10	3	5	1	1	6	7	9	8	4
Deep Salinity		10	2	2	4	7	8	9	6	5	1
Copepod richness		10	2	1	4	3	7	6	9	8	5
N.Copepod Anomaly		10	7	2	4	1	8	5	9	6	3
Biological Transition		10	4	1	4	3	8	6	9	7	2
Length of upwelling season		10	2	4	2	1	7	8	9	6	5
June-Chinook Catches		9	1	2	7	4	6	8	10	5	3
Sept-Coho Catches		8	2	1	4	3	5	10	9	6	7
Mean of Ranks		8.9	2.3	2.9	3.7	3.6	7.0	7.6	8.8	5.6	4.4
RANK of the mean rank		10	1	2	4	3	7	8	9	6	5
Coho Salmon Survival (Ocean Entry Year)		9	6	1	4	2	3	8	7	5	10 **
Adult springs		4	1	2	3	5	7	6	8		
Adult Fall (Bonn)		7	5	3	1	2	4	6	8		
Adult Fall (Klamath)		1	5	3	4	7	6	8	2	9 **	

Climate change impacts. How will management strategies need to be modified?

- A lot depends on the PDO pattern. Will it continue?
- Food chain effects likely (cold --> warm water communities)
- Northerly shifts in all populations likely.
- But…given the uncertainties (especially surprises as seen recently), best to set catch quotas on the low side.
- May see a shift in fishing effort from salmon to tuna
- Shifts to less snow and more rain will change river flow patterns and may negatively impact spring-run salmon
- Warming might favor fall-run Chinook salmon
- Impacts on other fisheries very uncertain due to lack of understanding of how they respond presently to ocean variability (hake, Dungeness crabs, rockfish)

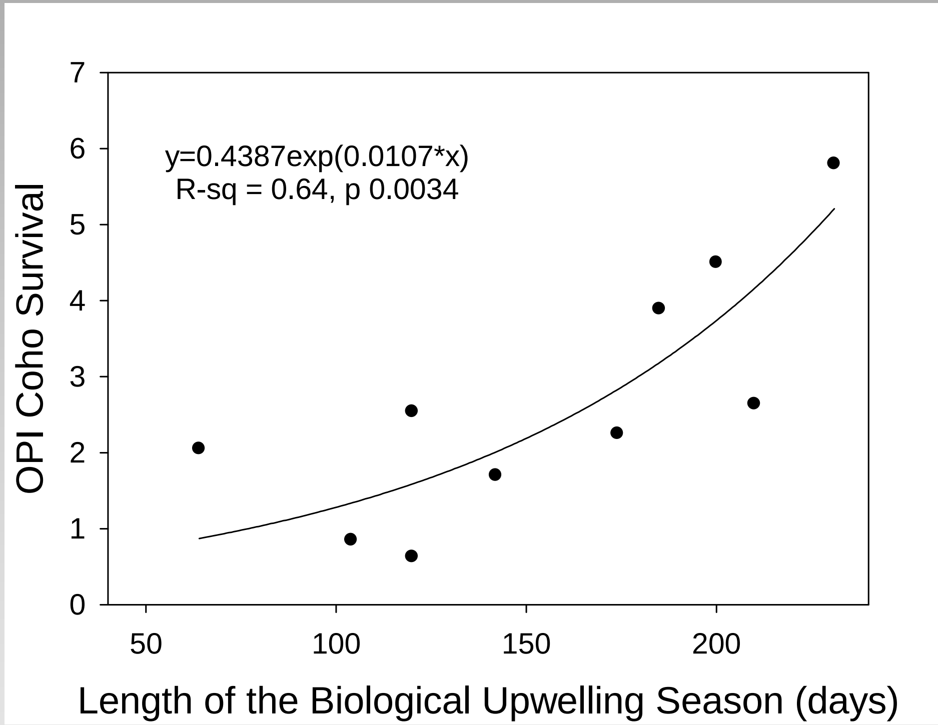
Thanks for you attention

Acknowledgements

- Bonneville Power Administration
- U.S.GLOBEC Program (NOAA/NSF)
- PaCOOS Program (NOAA)
- National Science Foundation
- Office of Naval Research

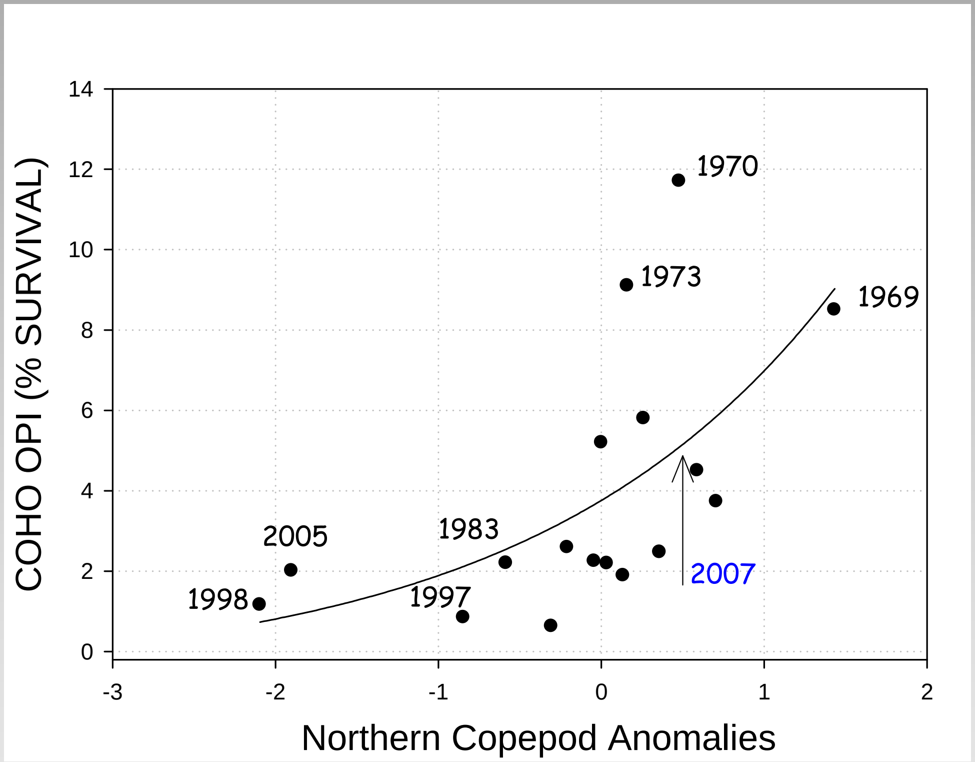
- See www.nwfsc.noaa.gov, “What’s New“

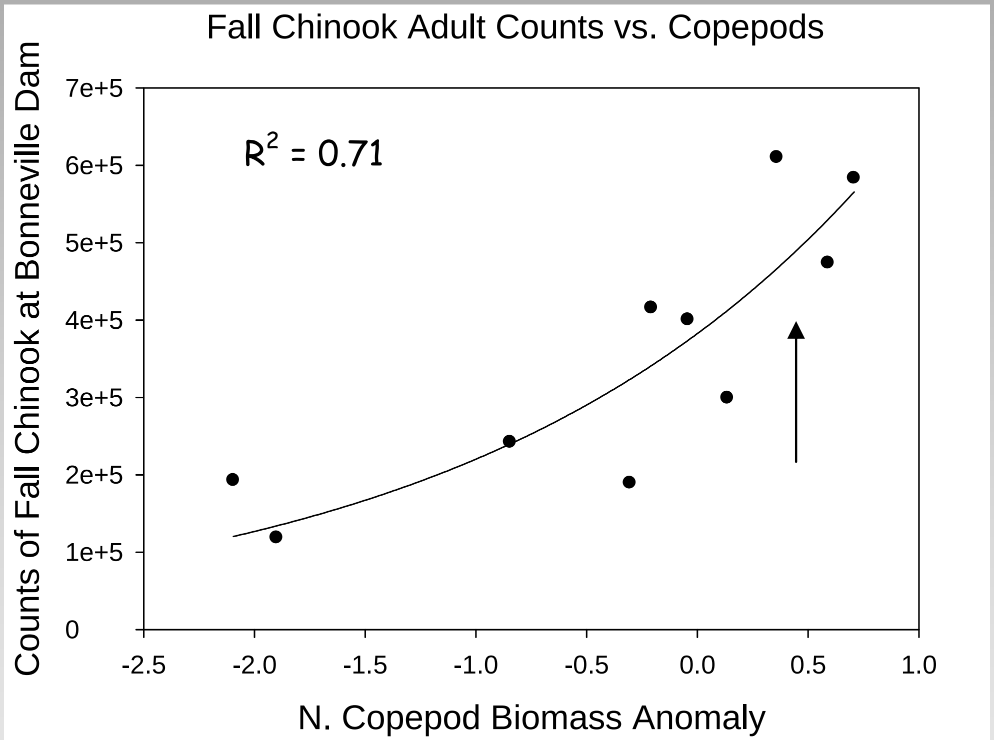
Length of upwelling season vs. coho survival

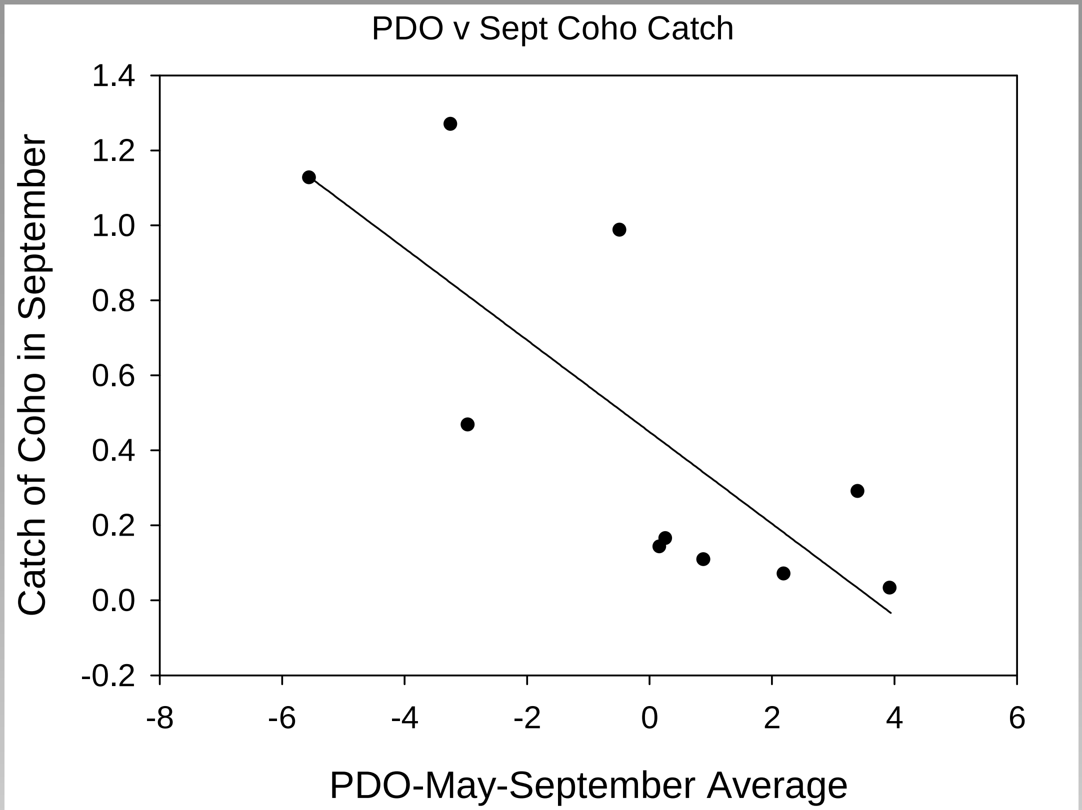


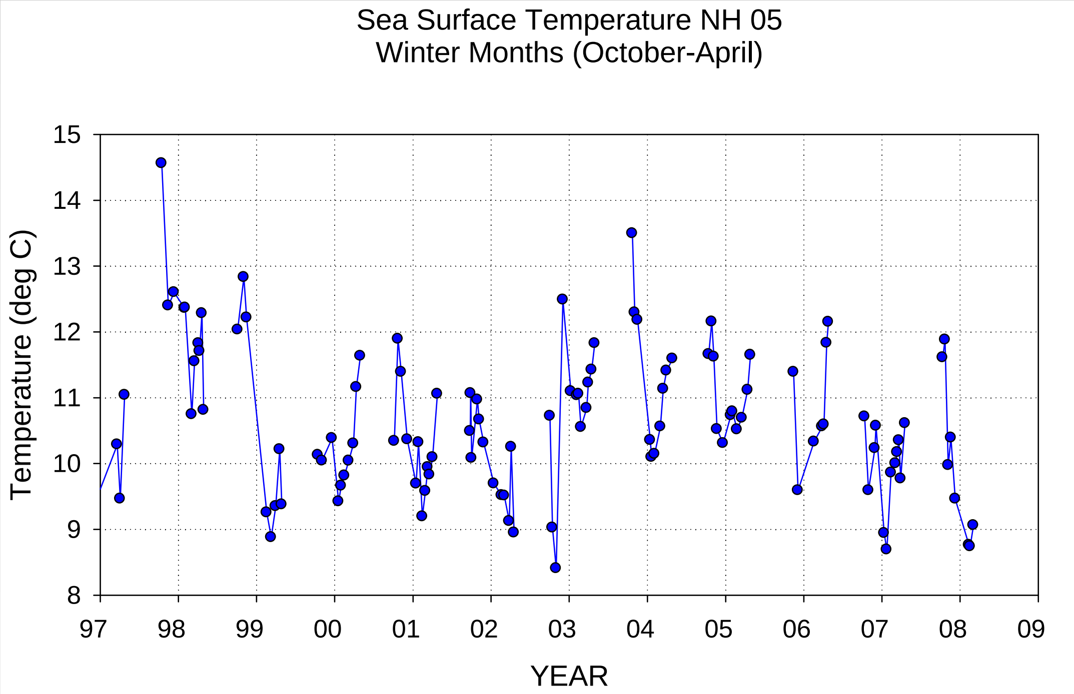
- Length of upwelling season equals fall date – spring date
- Longer upwelling seasons (as indexed by summer copepod communities) result in higher coho salmon survival

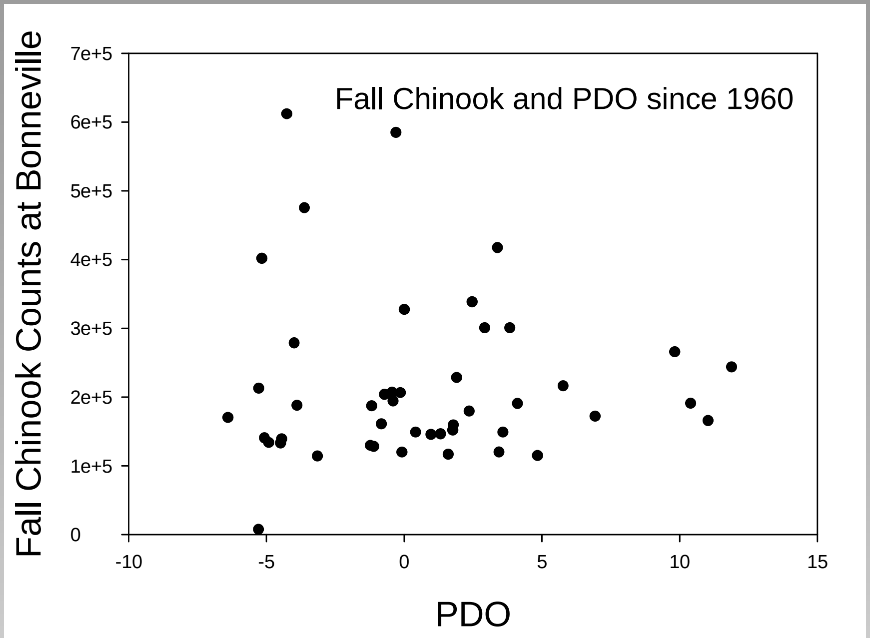
Northern Copepods as ecological indicators of coho survival and fall Chinook returns

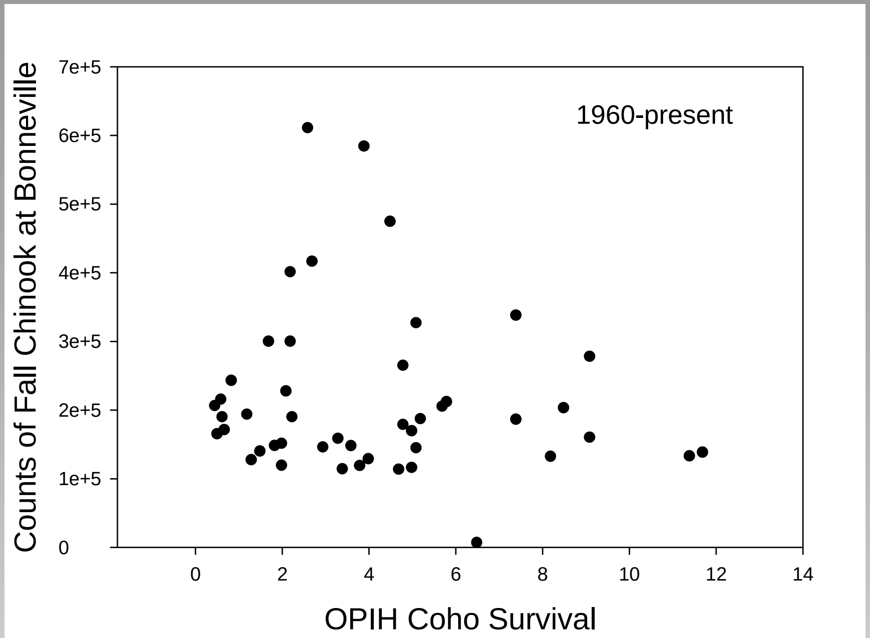


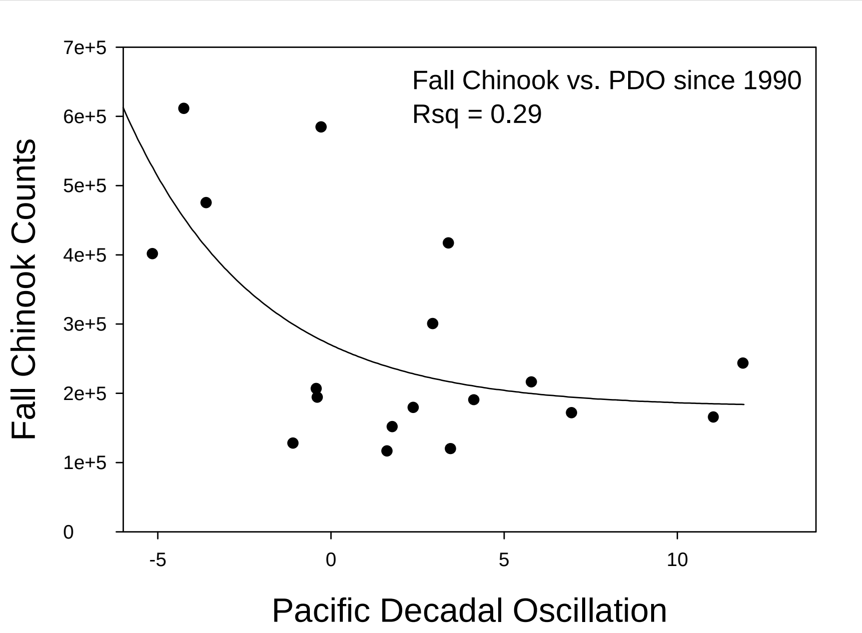


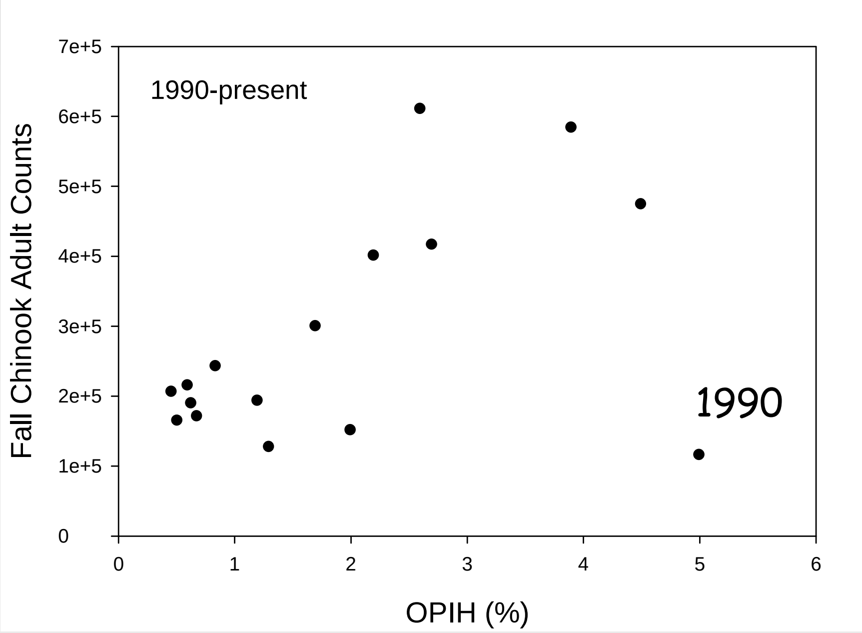

PDO v Sept Coho Catch
Catch of Coho in September
PDO-May-September Average
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-8
-6
-4
-2
0
2
4
6

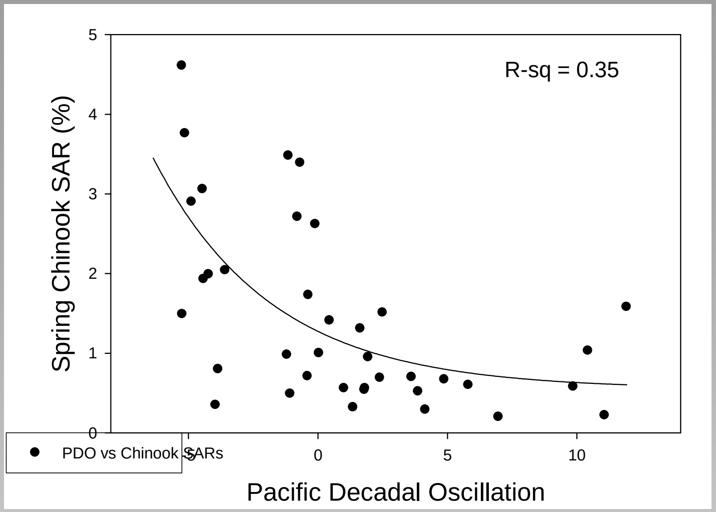

Sea Surface Temperature NH 05
Winter Months (October-April)
Temperature (deg C)
YEAR
15
14
13
12
11
10
9
8
97
98
99
00
01
02
03
04
05
06
07
08
09

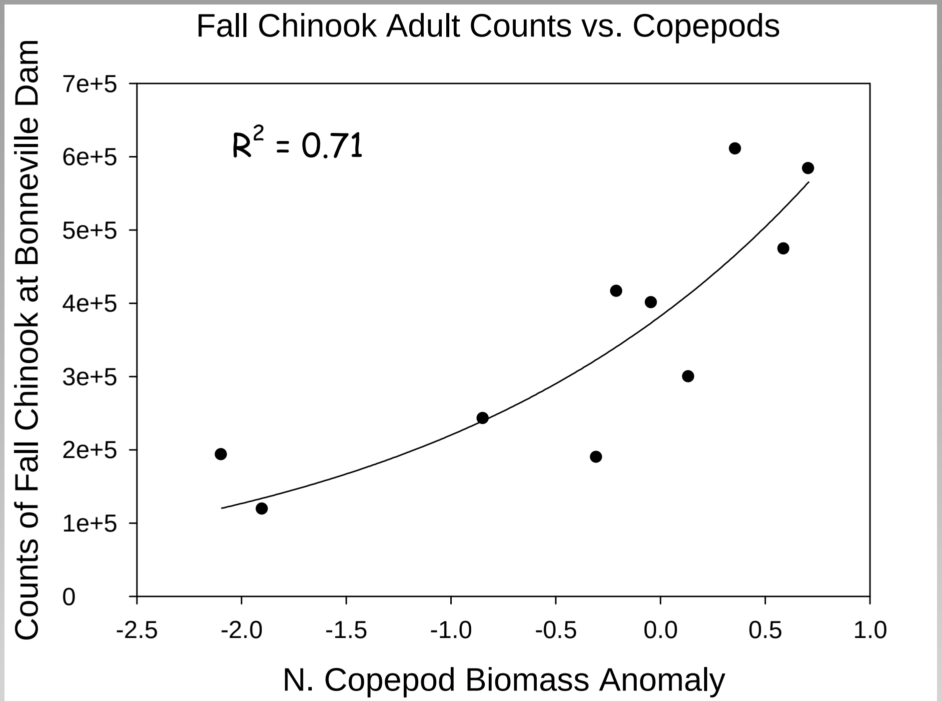

Fall Chinook and PDO since 1960
Fall Chinook Counts at Bonneville
PDO
7e+5
6e+5
5e+5
4e+5
3e+5
2e+5
1e+5
0
-10
-5
0
5
10
15

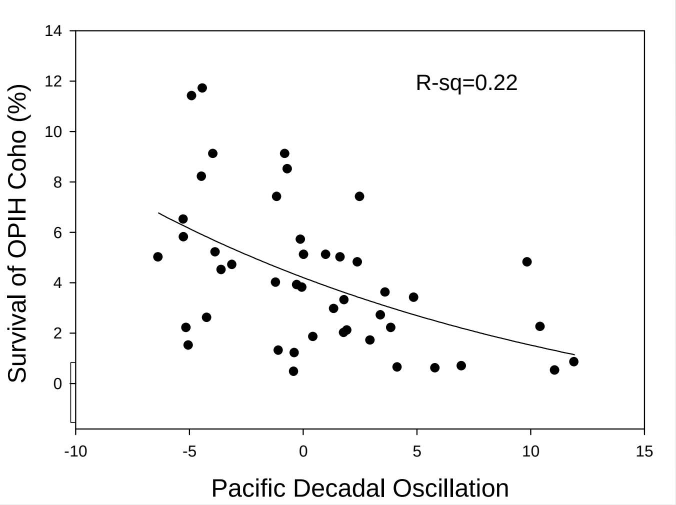

1960-present
Counts of Fall Chinook at Bonneville
OPIH Coho Survival
7e+5
6e+5
5e+5
4e+5
3e+5
2e+5
1e+5
0
0
2
4
6
8
10
12
14


Fall Chinook vs. PDO since 1990
Rsq = 0.29
Fall Chinook Counts
Pacific Decadal Oscillation
7e+5
6e+5
5e+5
4e+5
3e+5
2e+5
1e+5
0
-5
0
5
10

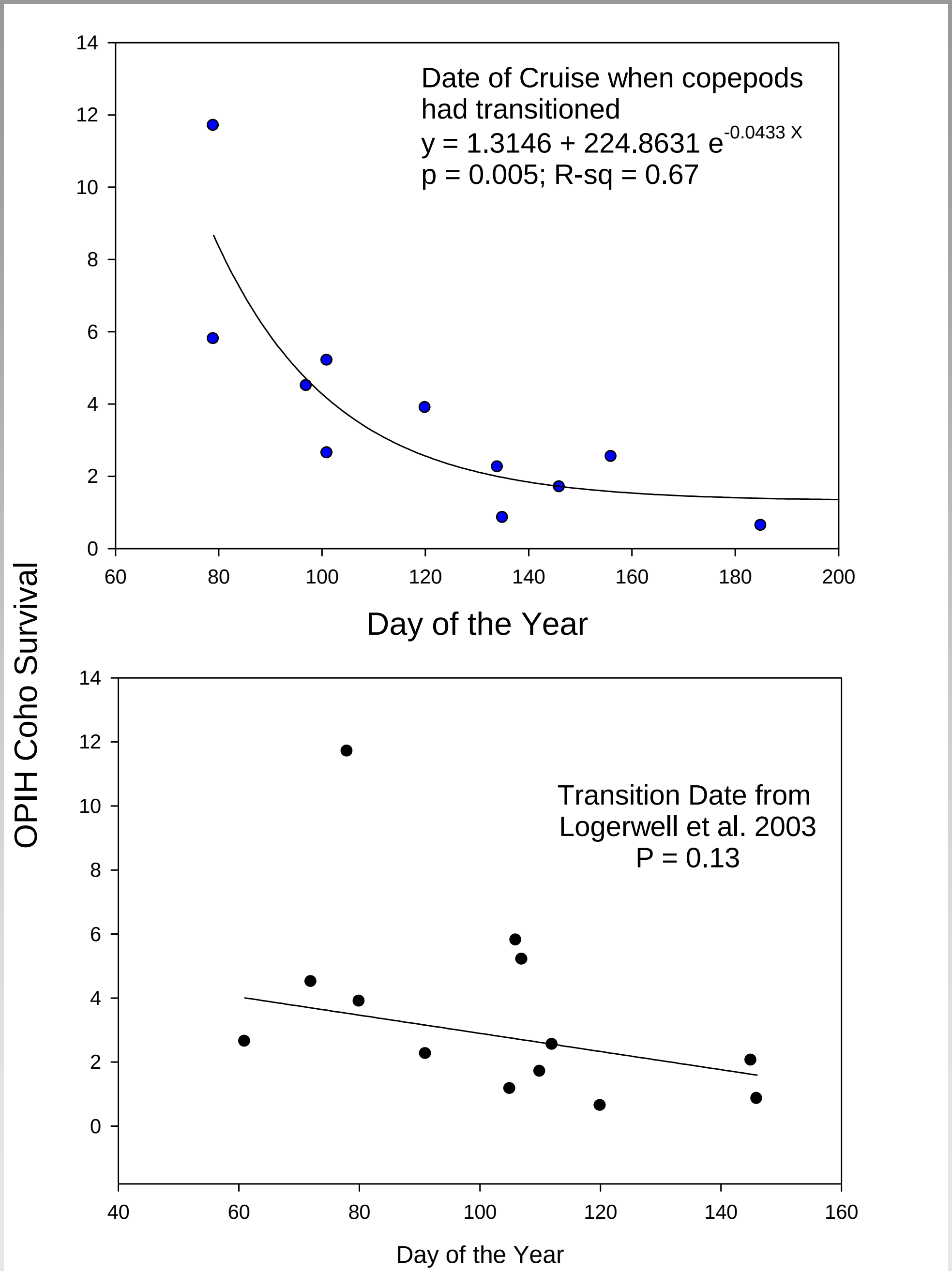

1990-present
1990
Fall Chinook Adult Counts
OPIH (%)
7e+5
6e+5
5e+5
4e+5
3e+5
2e+5
1e+5
0
0
1
2
3
4
5
6


R-sq = 0.35
Spring Chinook SAR (%)
PDO vs Chinook SARs
Pacific Decadal Oscillation


Fall Chinook Adult Counts vs. Copepods
R^2 = 0.71
Counts of Fall Chinook at Bonneville Dam
N. Copepod Biomass Anomaly

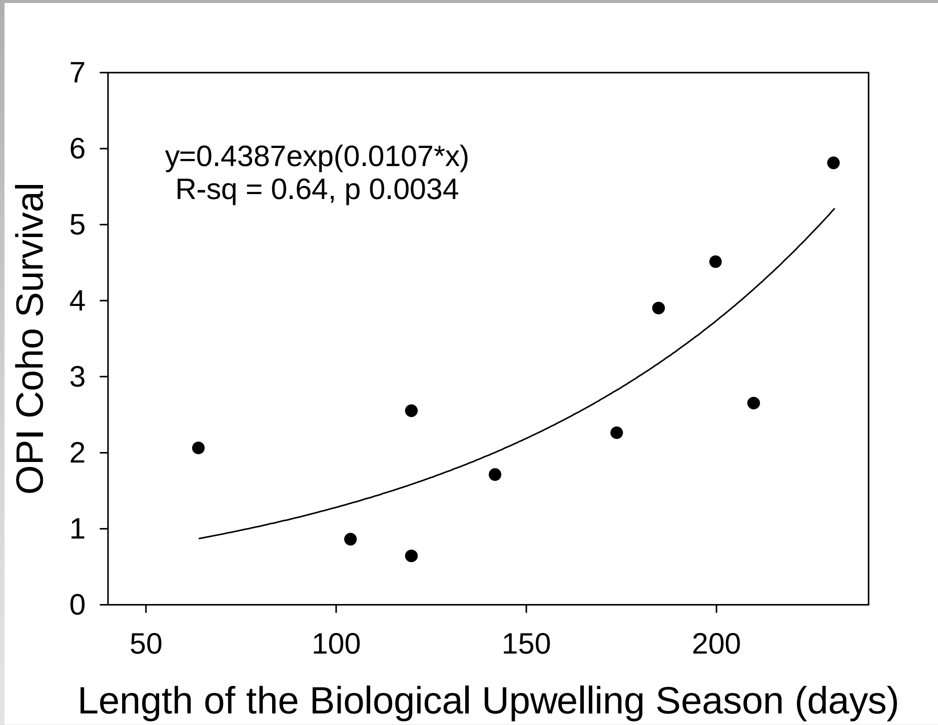

R-sq=0.22
Survival of OPIH Coho (%)
Pacific Decadal Oscillation

Coho salmon survival vs. spring transition Dates



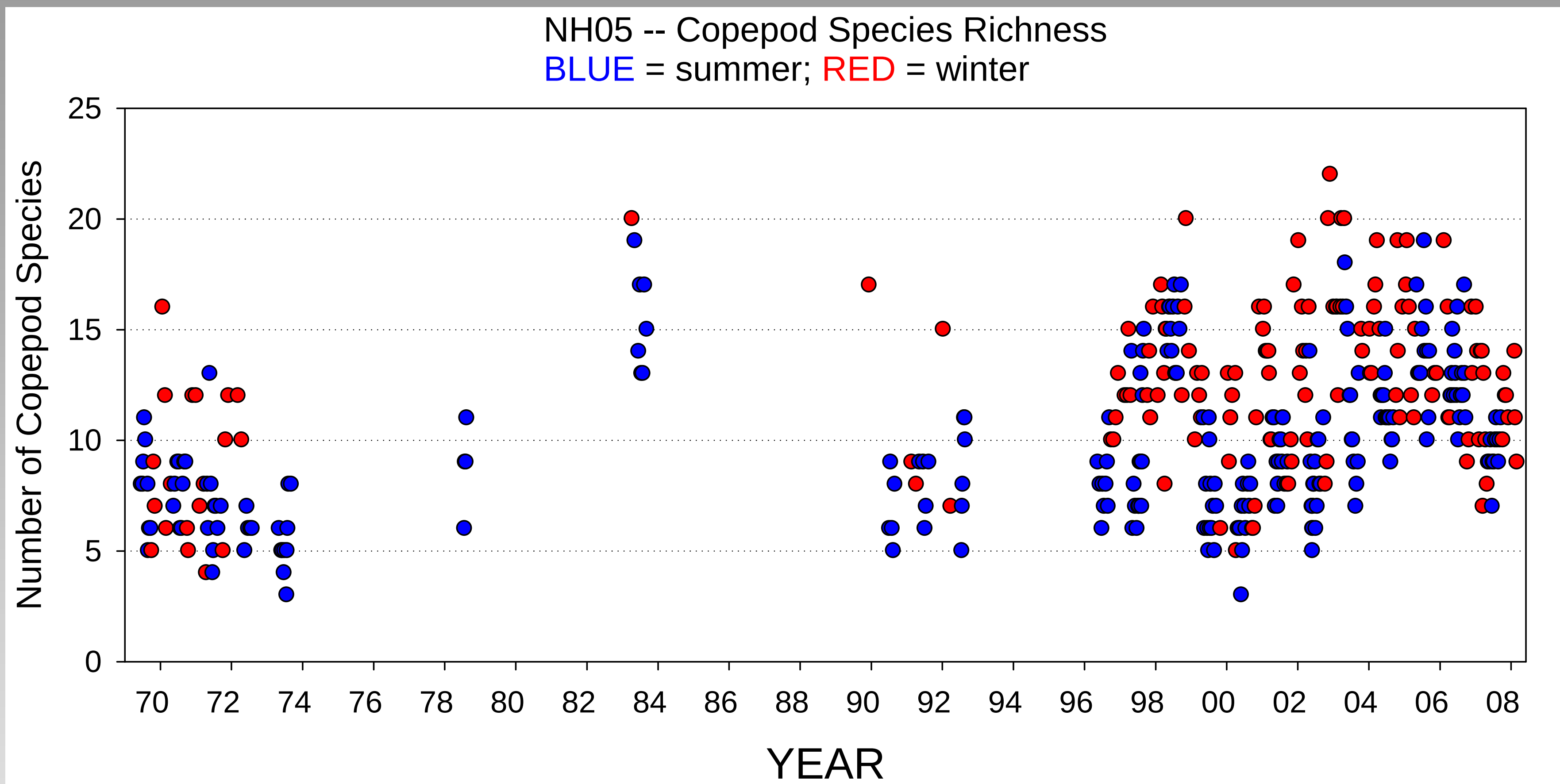
- Early transition yields better coho survival
- “Biological” transition dates better correlated with coho than “physical” transition dates

Length of upwelling season vs. coho survival



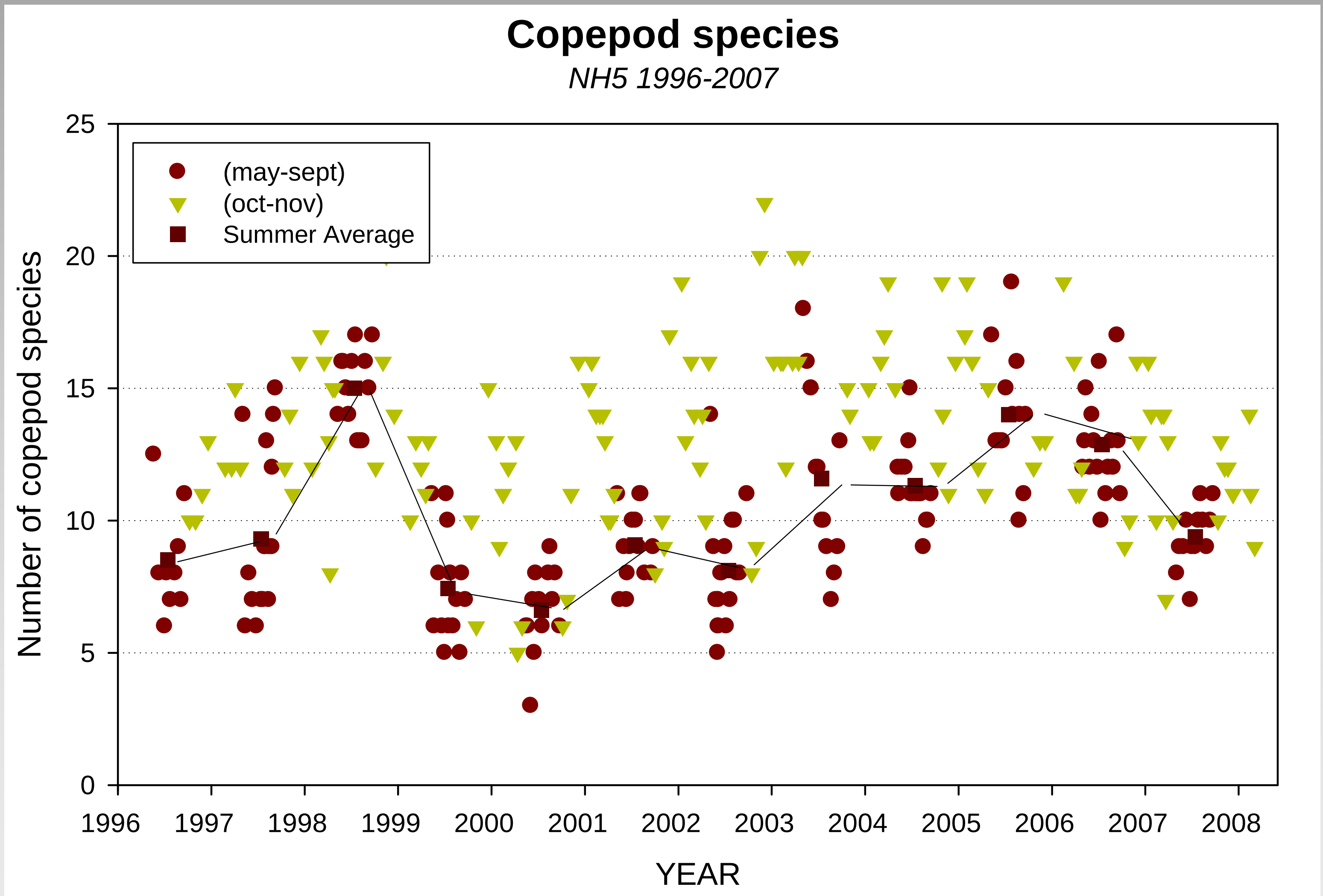
- Length of upwelling season equals fall date – spring date
- Longer upwelling seasons (as indexed by summer copepod communities) result in higher coho salmon survival

Copepod biodiversity has increased over the past few years

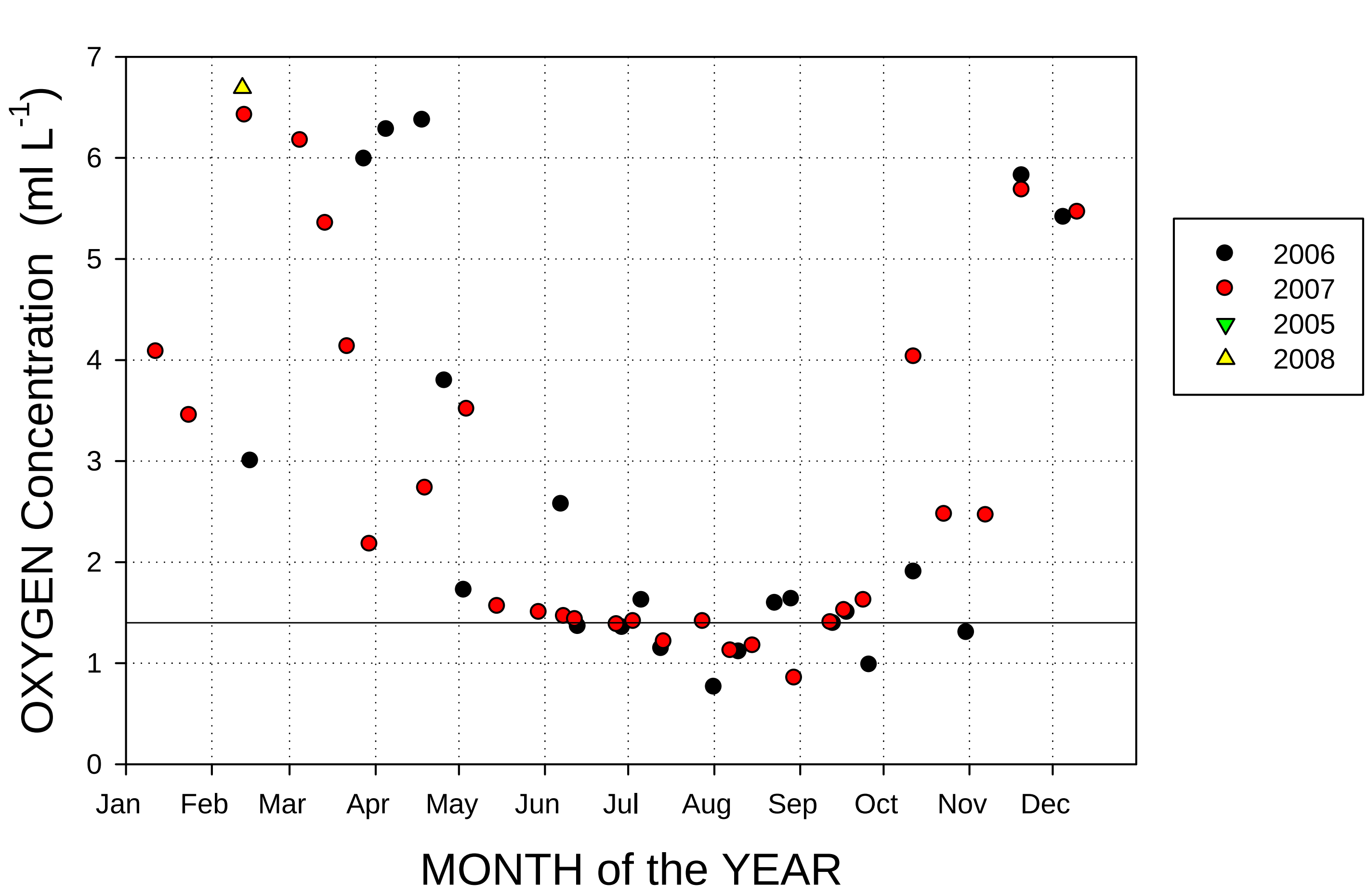


A more diverse copepod community is seen now as compared to 1970s. This may be first indication that we will find a different copepod community (and different food chain structure) in the future.

Species Richness 1996-2008

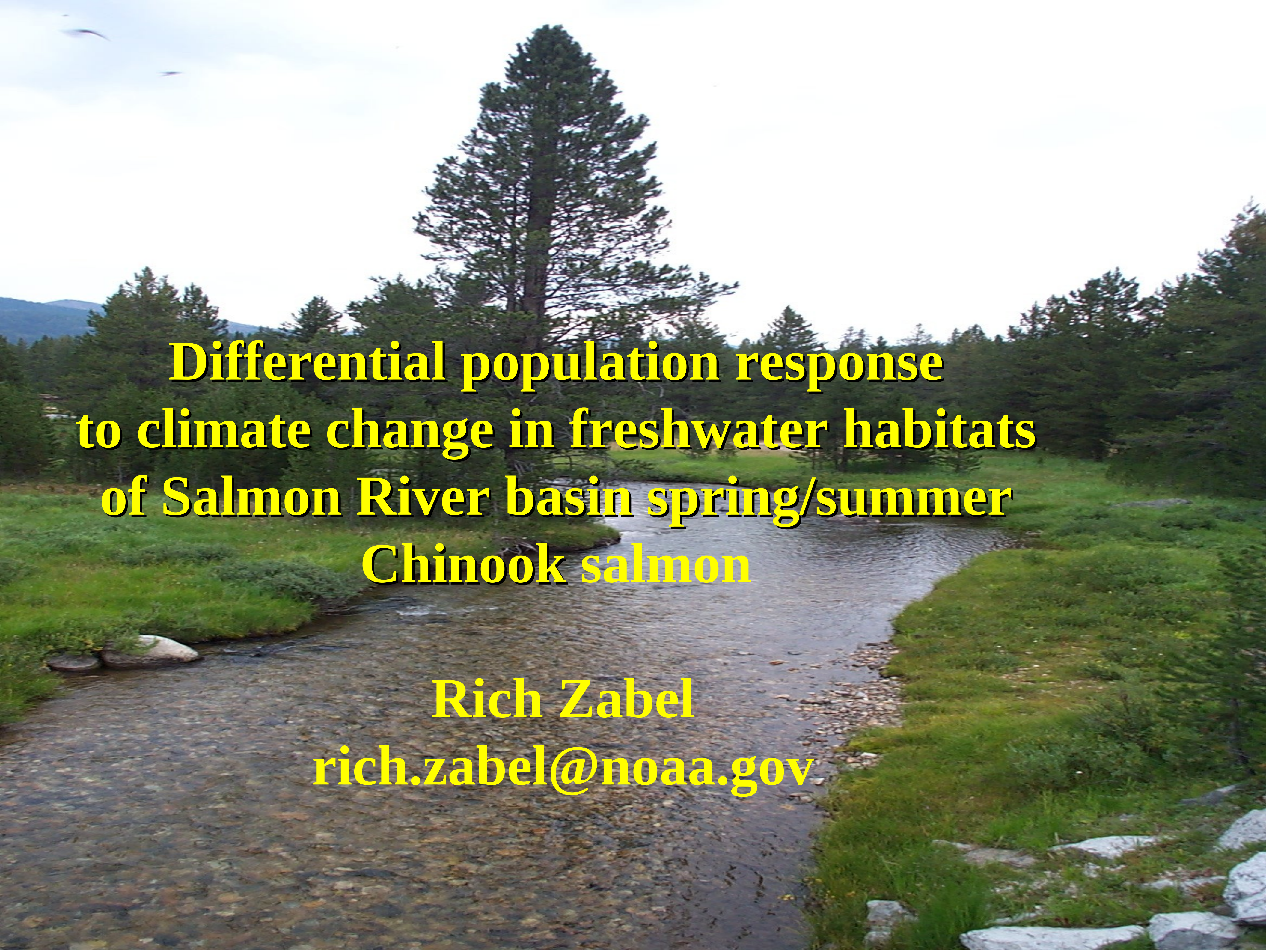


Hypoxia



OXYGEN Concentration (ml L^{-1})
7
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
MONTH of the YEAR
2006
2007
2005
2008

- Rich Zabel:
  - Differential population response to climate change in freshwater habitats of Salmon River basin spring/summer Chinook salmon



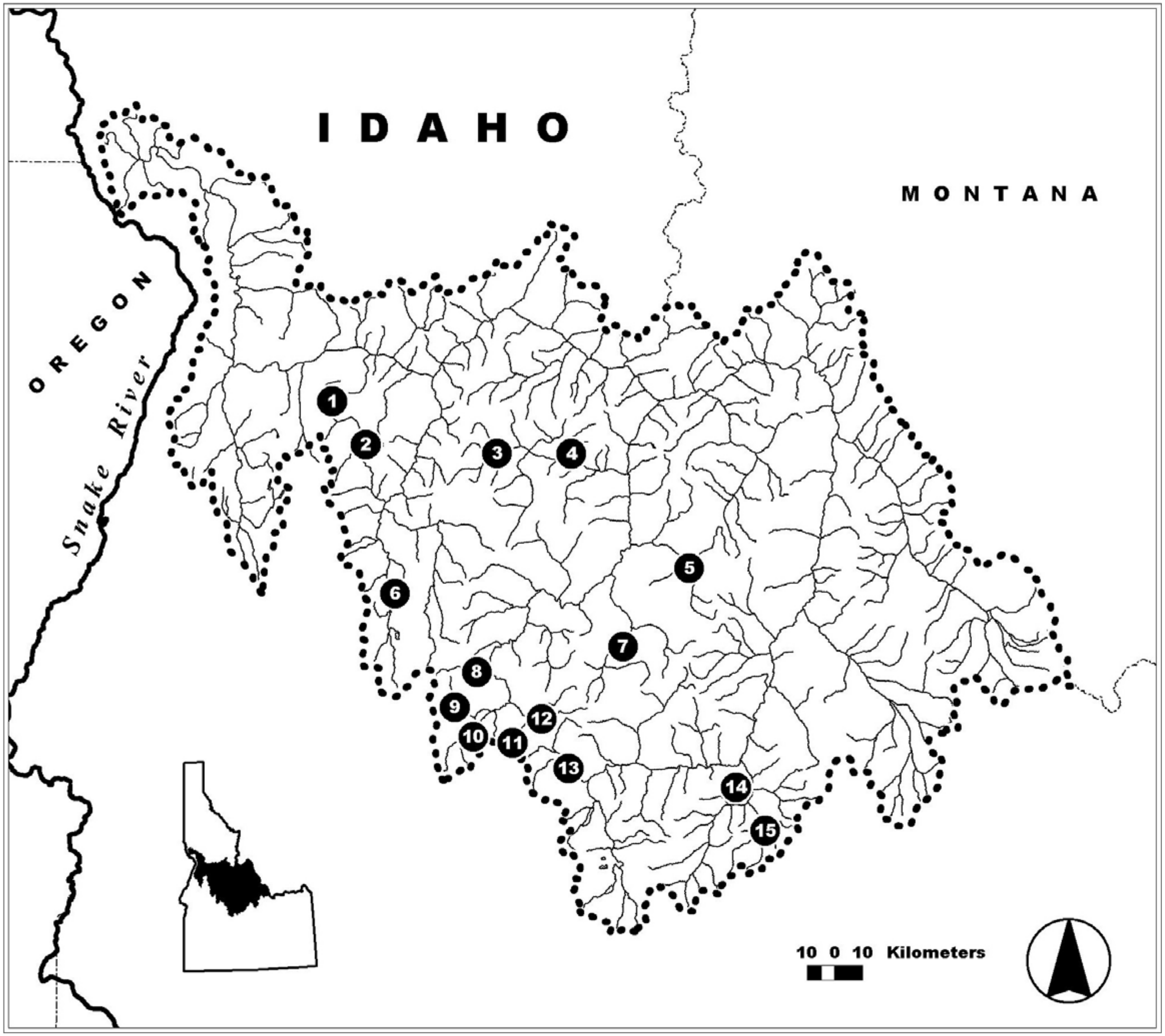
Differential population response to climate change in freshwater habitats of Salmon River basin spring/summer Chinook salmon

Rich Zabel
rich.zabel@noaa.gov

1) Response of juvenile survival to variability in freshwater climate

2) Population viability under climate change scenarios

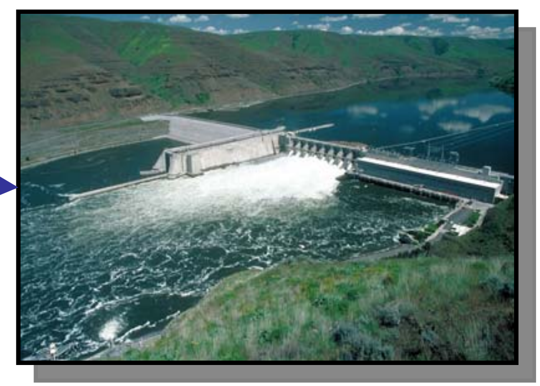
Salmon River basin Chinook salmon: 15 streams, 12 years

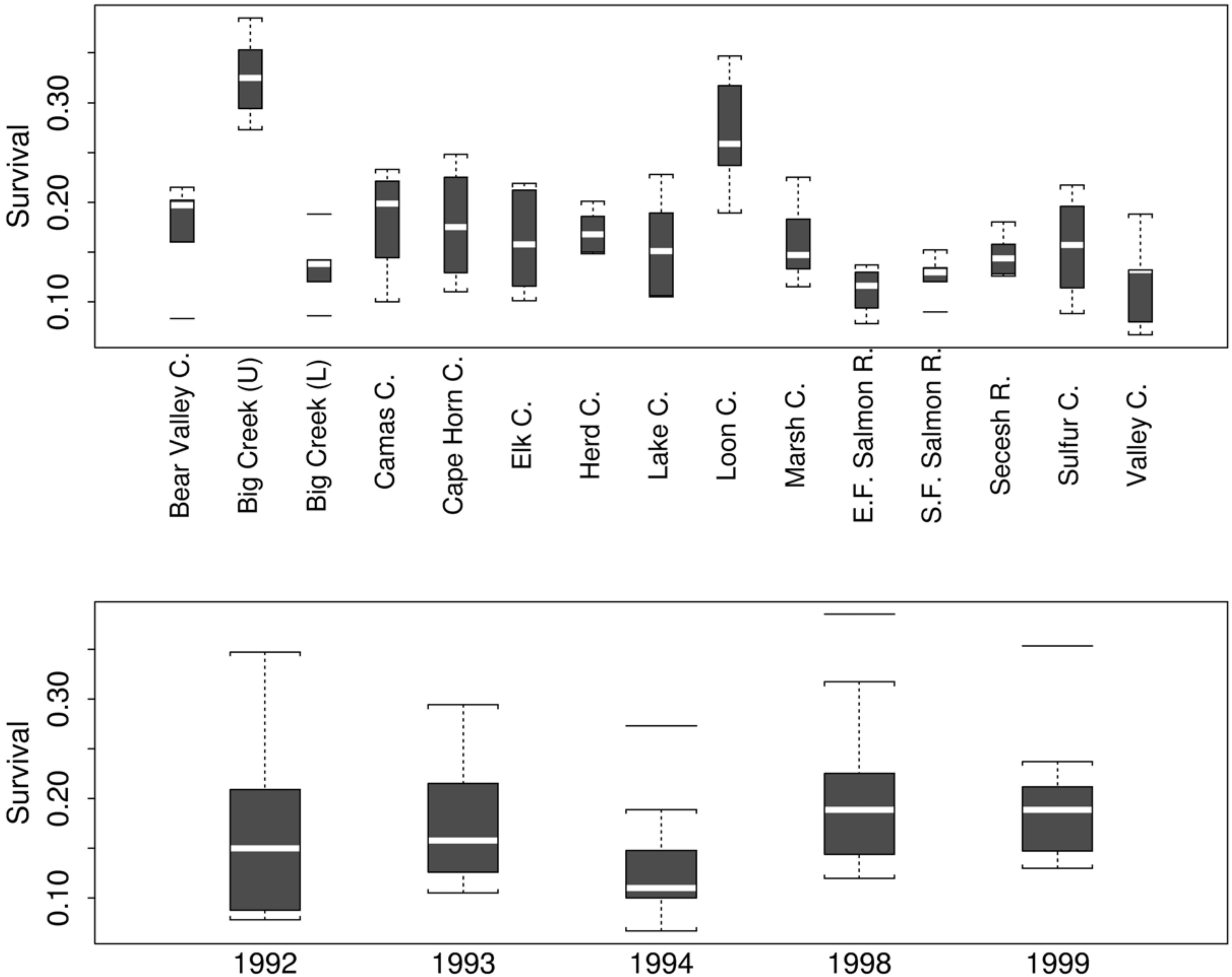


Estimating parr-to-smolt survival

Fish tagged
as parr …

… and then
detected as
migratory smolts





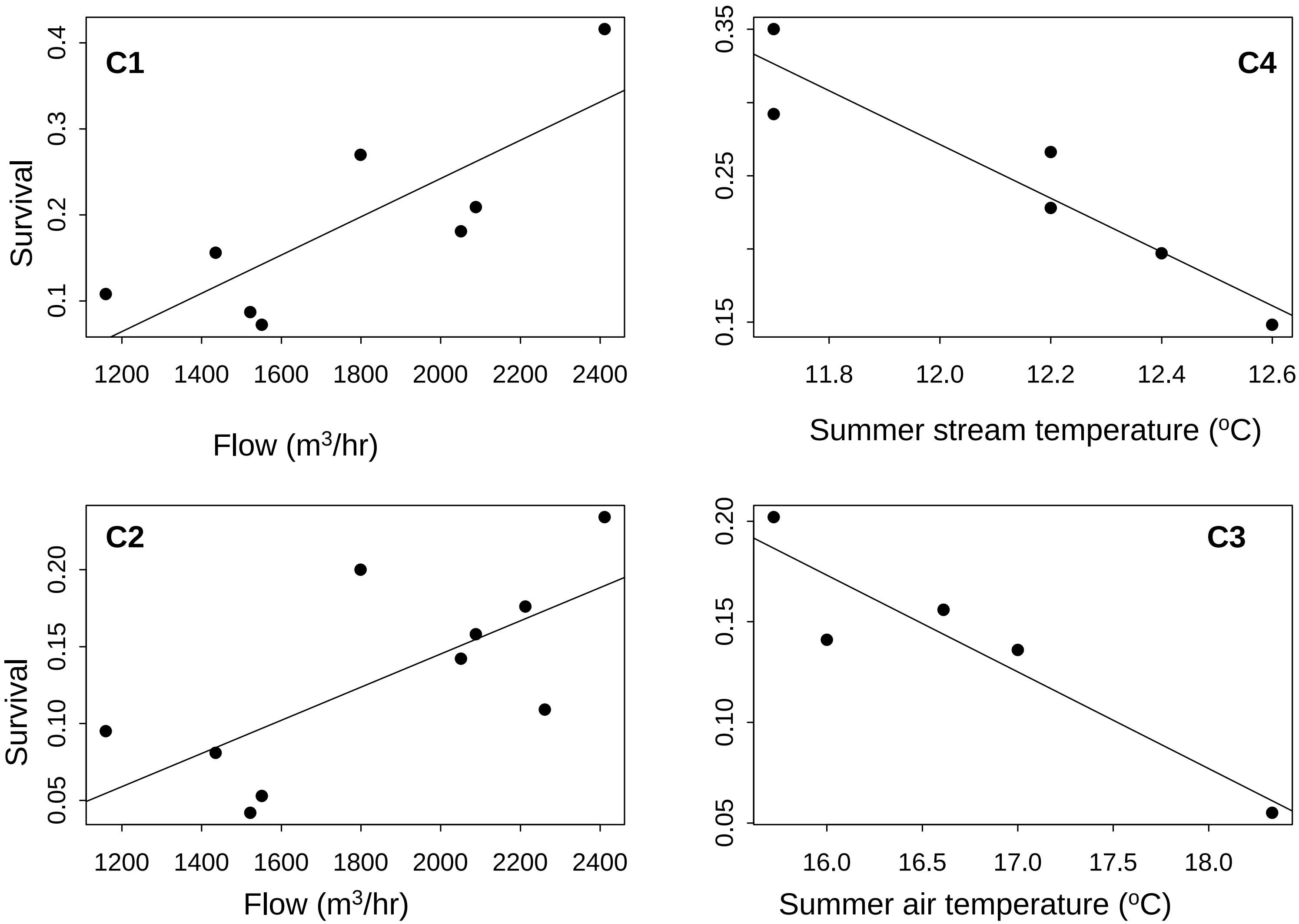
Survival
0.10
0.20
0.30
Bear Valley C.
Big Creek (U)
Big Creek (L)
Camas C.
Cape Horn C.
Elk C.
Herd C.
Lake C.
Loon C.
Marsh C.
E.F. Salmon R.
S.F. Salmon R.
Secesh R.
Sulfur C.
Valley C.
Survival
0.10
0.20
0.30
1992
1993
1994
1998
1999

High Elevation Narrow

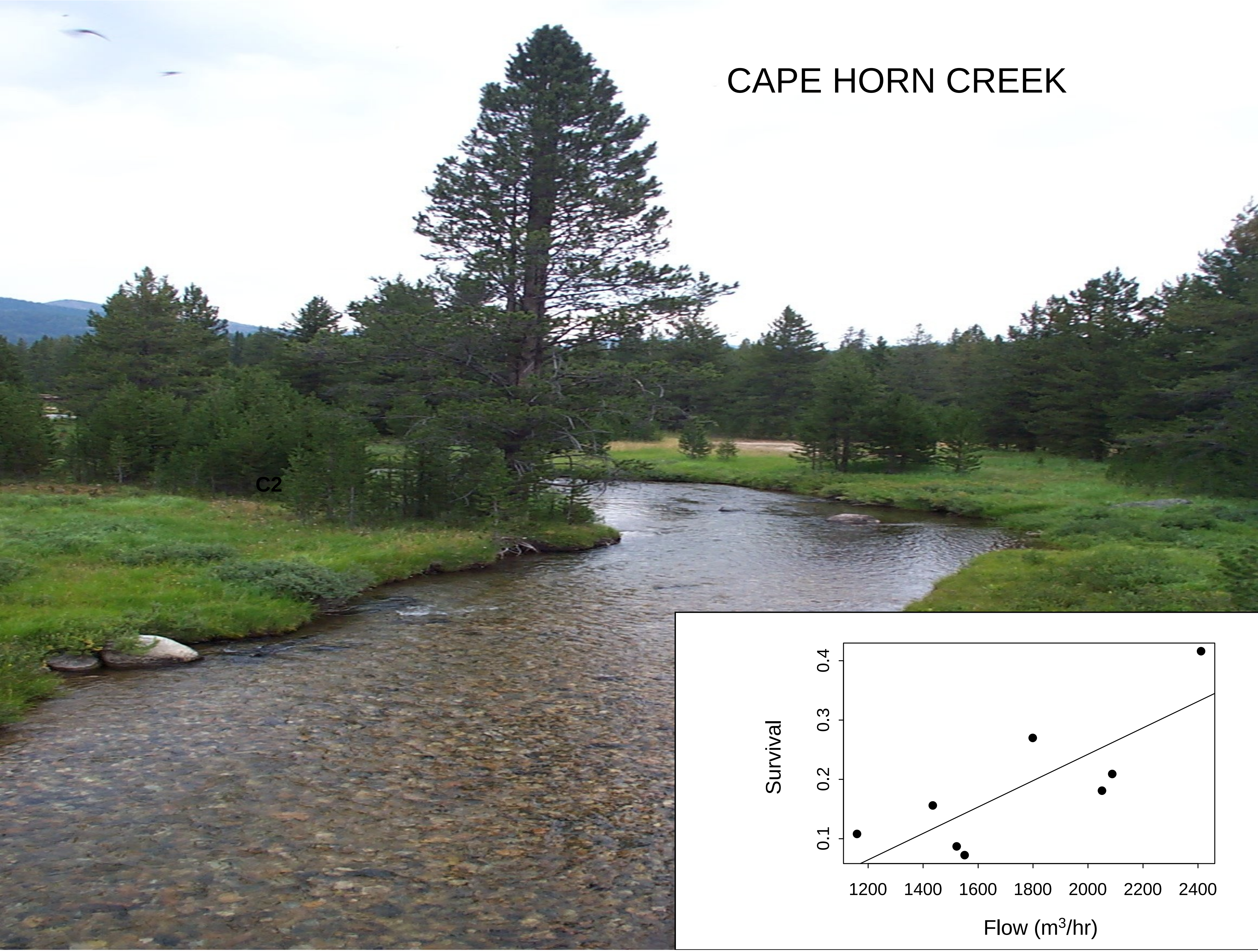
Low Elevation Wide

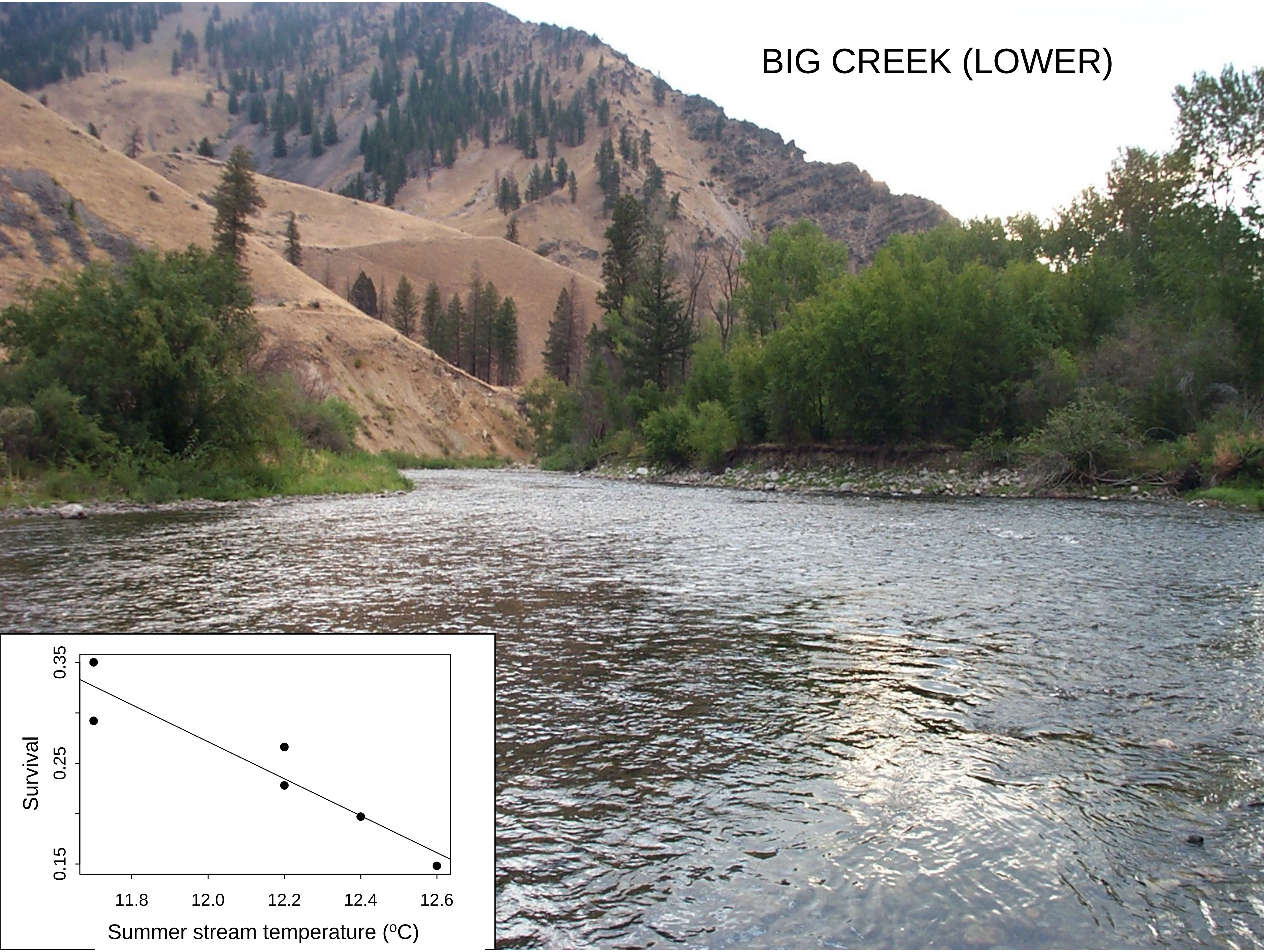
Summer Chinook

Spring Chinook



CAPE HORN CREEK

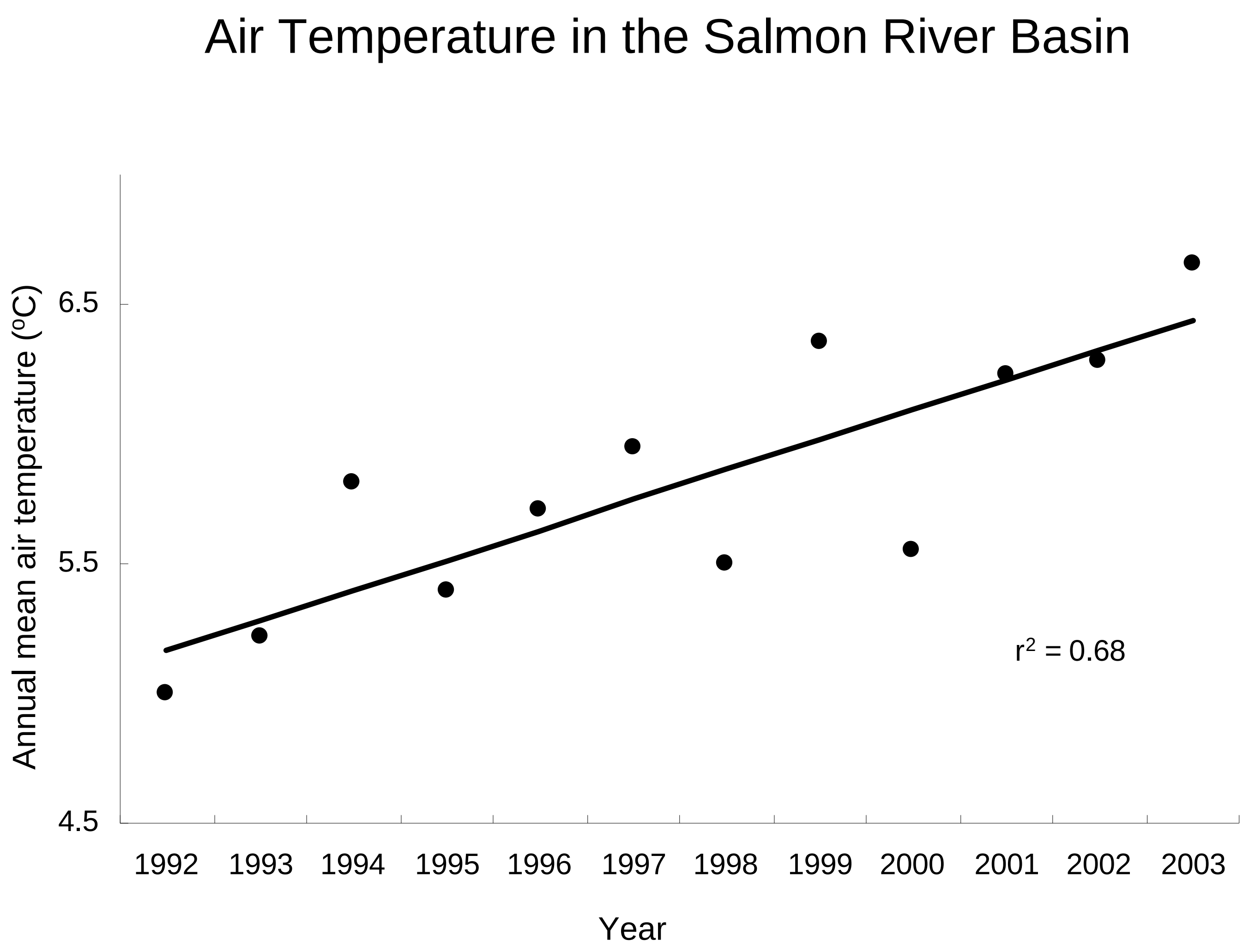


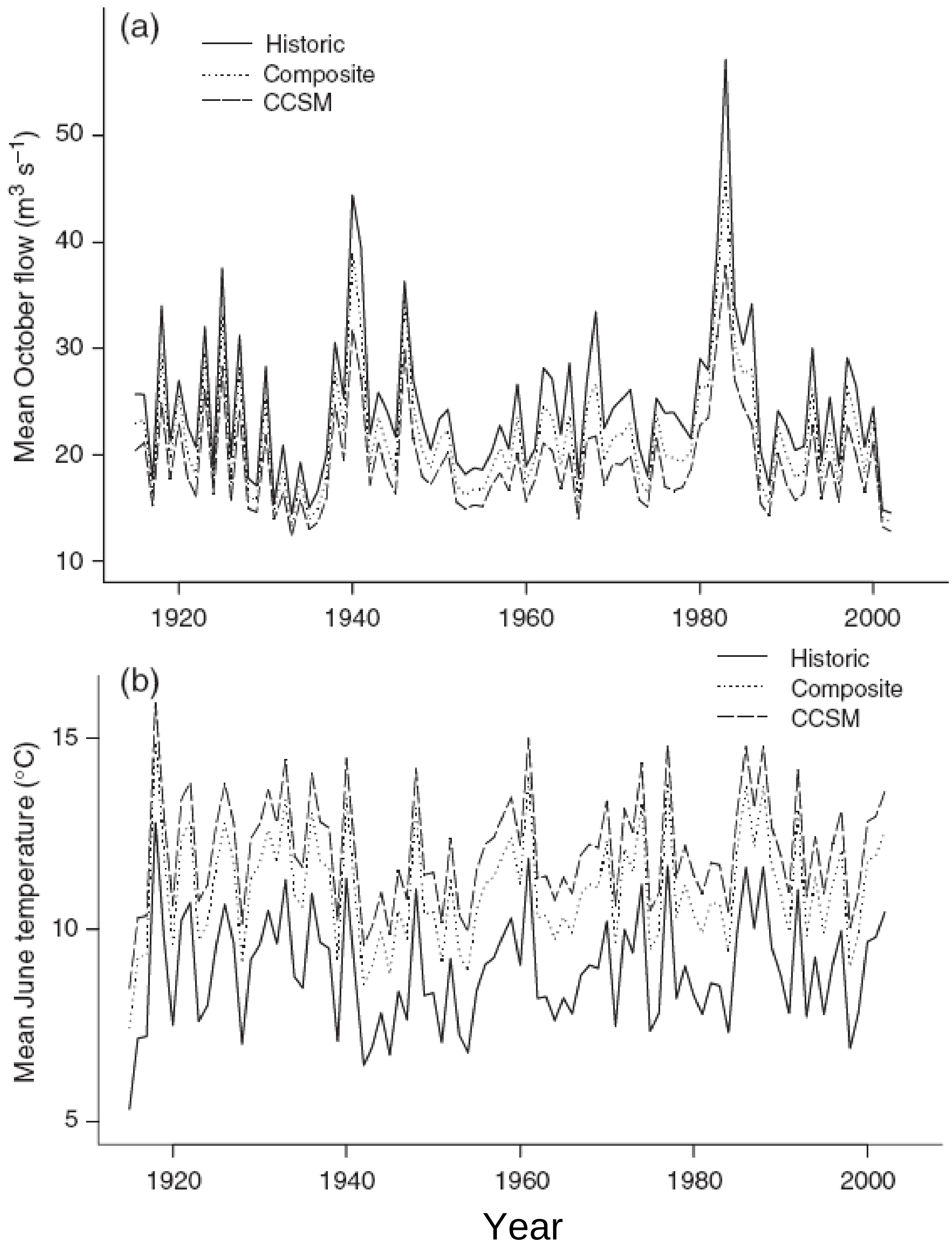

BIG CREEK (LOWER)
Survival
0.35
0.25
0.15
11.8
12.0
12.2
12.4
12.6
Summer stream temperature (ºC)

Conclusions

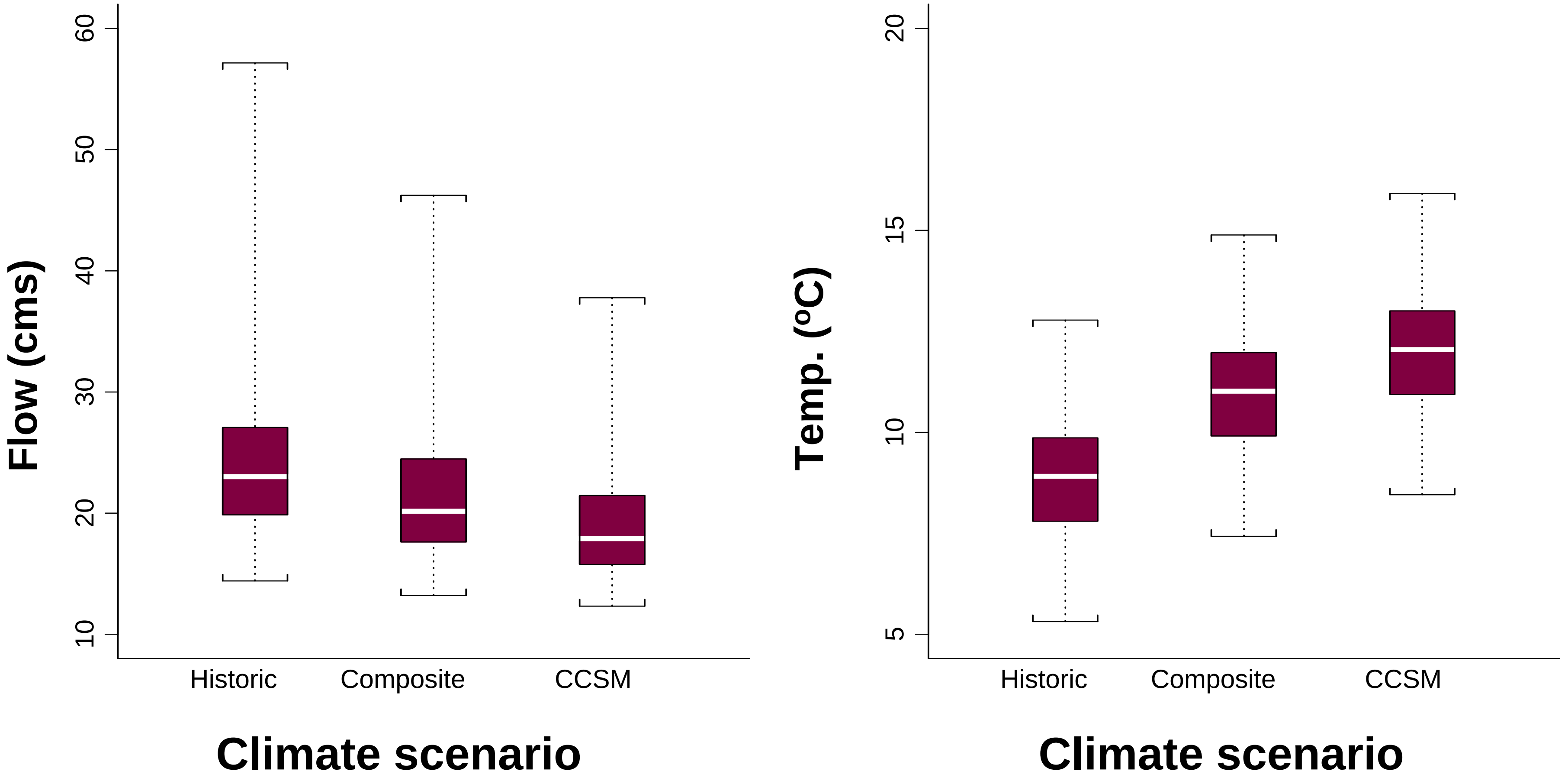
- Differential response of populations to freshwater climate
- Response mediated by habitat conditions

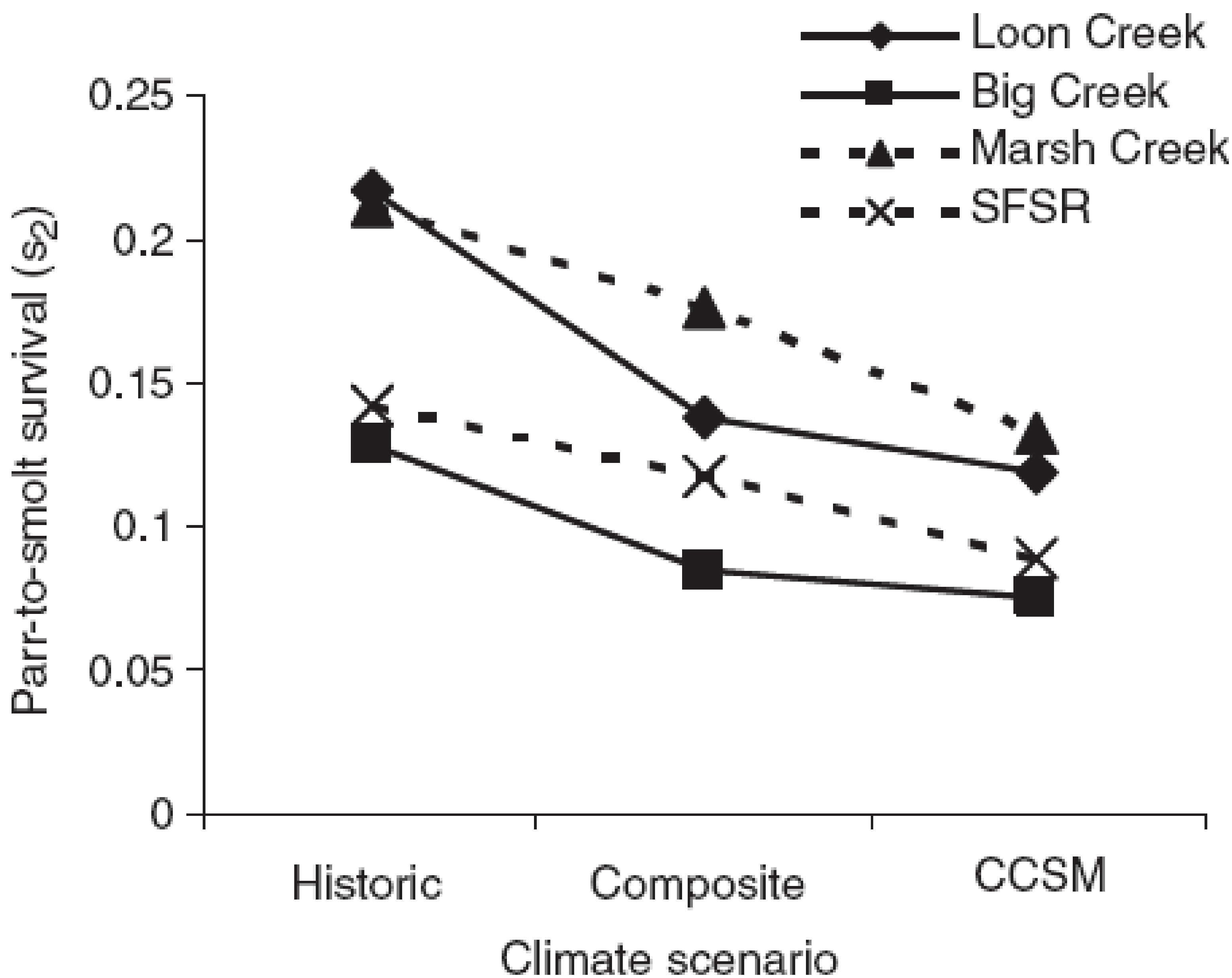
Changes in Salmon River basin climate



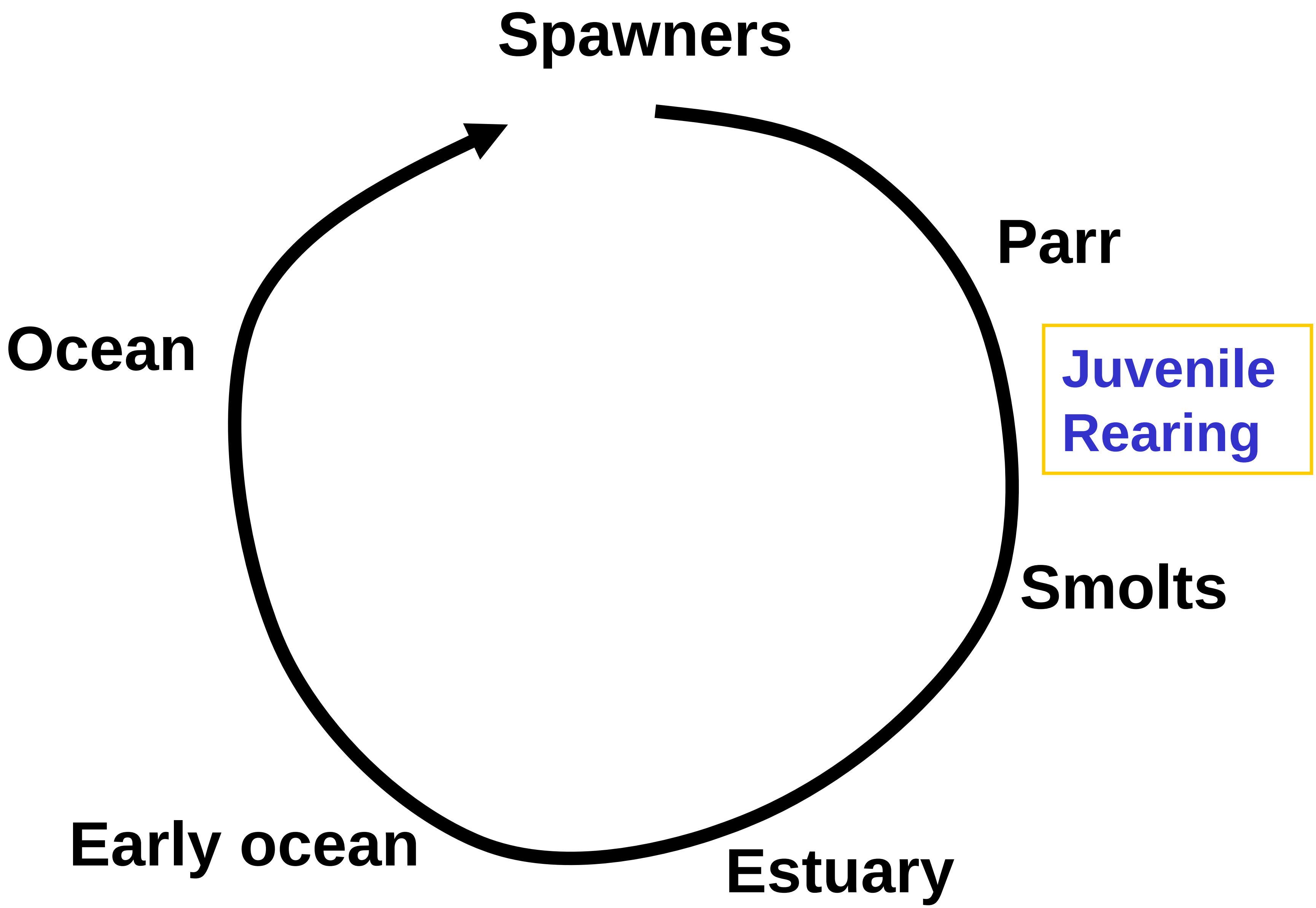


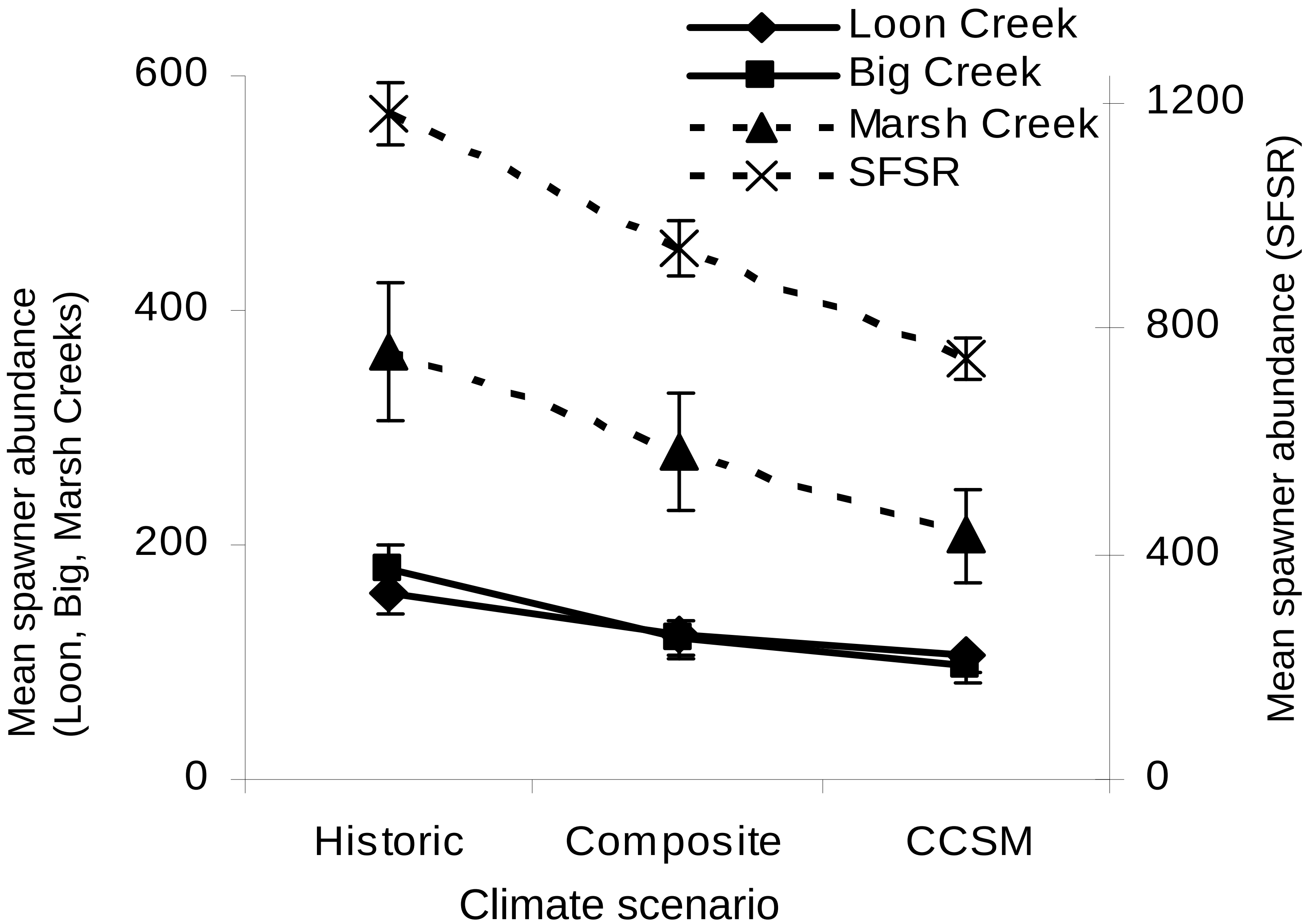
(a)
Historic
Composite
CCSM
Mean October flow (m3 s−1)
50
40
30
20
10
1920
1940
1960
1980
2000
(b)
Historic
Composite
CCSM
Mean June temperature (°C)
15
10
5
1920
1940
1960
1980
2000
Year


Flow (cms)
10
20
30
40
50
60
Historic
Composite
CCSM
Climate scenario
Temp. (ºC)
5
10
15
20
Historic
Composite
CCSM
Climate scenario

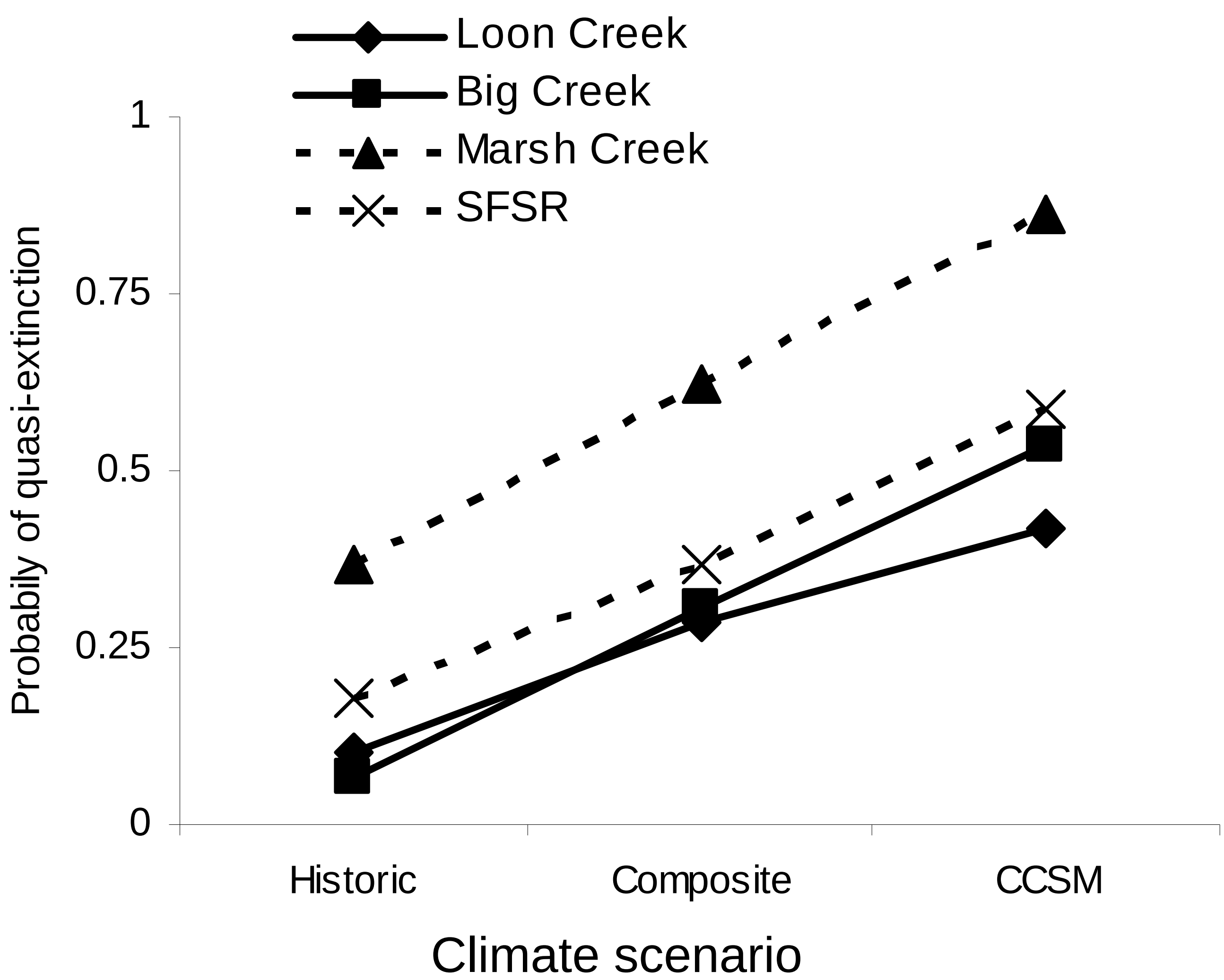

Loon Creek
Big Creek
Marsh Creek
SFSR
0.25
0.2
0.15
0.1
0.05
0
Parr-to-smolt survival (s_2)
Historic
Composite
CCSM
Climate scenario

Life-cycle of Snake River Sp/Su Chinook salmon





Loon Creek
Big Creek
Marsh Creek
SFSR
600
400
200
0
1200
800
400
0
Mean spawner abundance (Loon, Big, Marsh Creeks)
Mean spawner abundance (SFSR)
Historic
Composite
CCSM
Climate scenario



Loon Creek
Big Creek
Marsh Creek
SFSR
1
0.75
0.5
0.25
0
Probabily of quasi-extinction
Historic
Composite
CCSM
Climate scenario

Conclusion

Potentially very strong response of juvenile survival to climate change

But, among population diversity in response to climate may act as a buffer against the impacts of climate change

Future Directions

- How do life-history traits (e.g., migration timing) respond to climate change?
- Changes in growth rates and climate
- Changes in survival through the hydrosystem with climate change using COMPASS

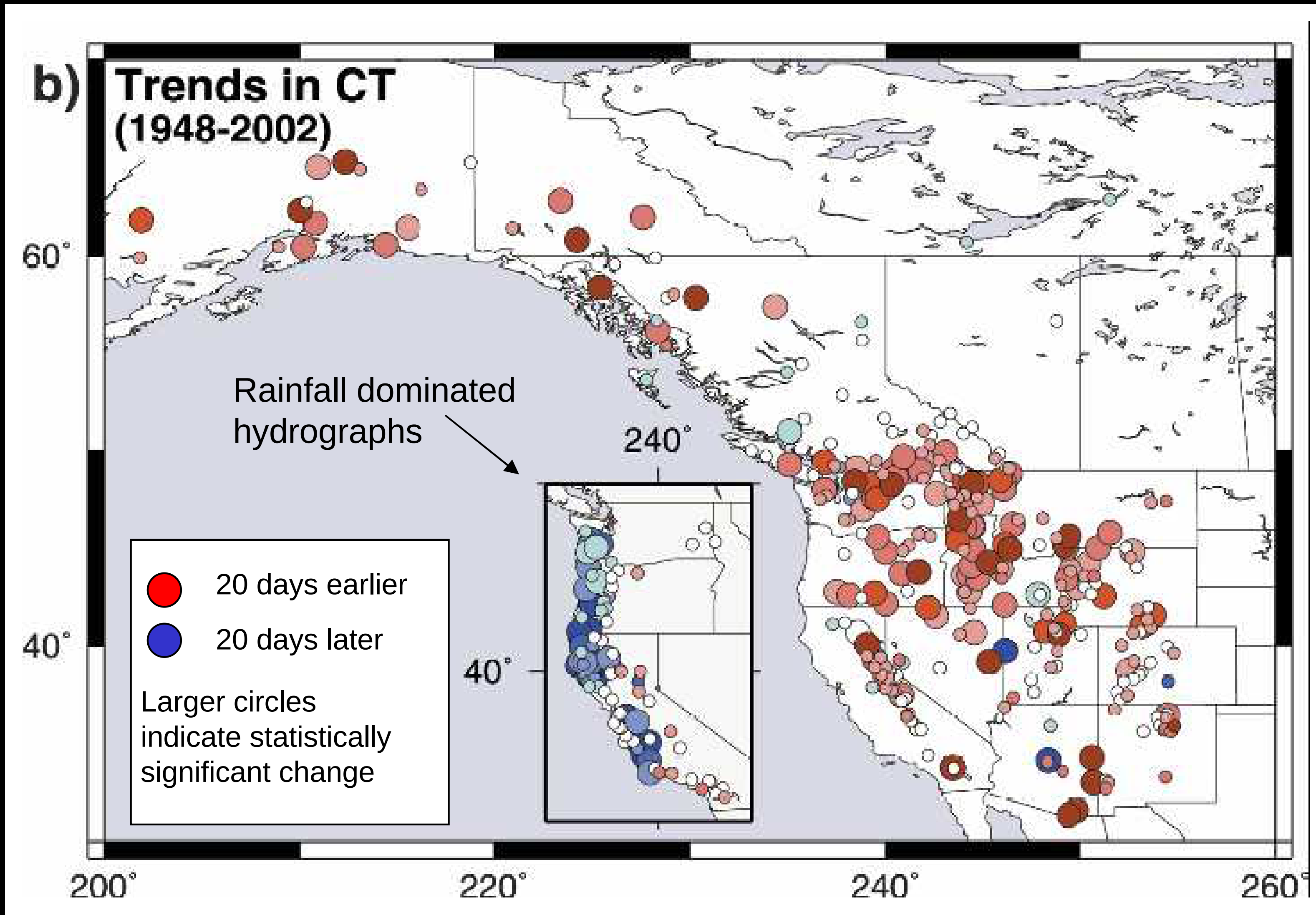
- **Tim Beechie:**
  - **Using beaver to restore incised streams in the interior Columbia River basin**

Using beaver dams to restore incised streams in the Columbia basin

Tim Beechie, Michael Pollock, Chris Jordan

Northwest Fisheries Science Center
NOAA Fisheries, Seattle, Washington

Climate change: less summer flow



CT = timing of runoff center of mass

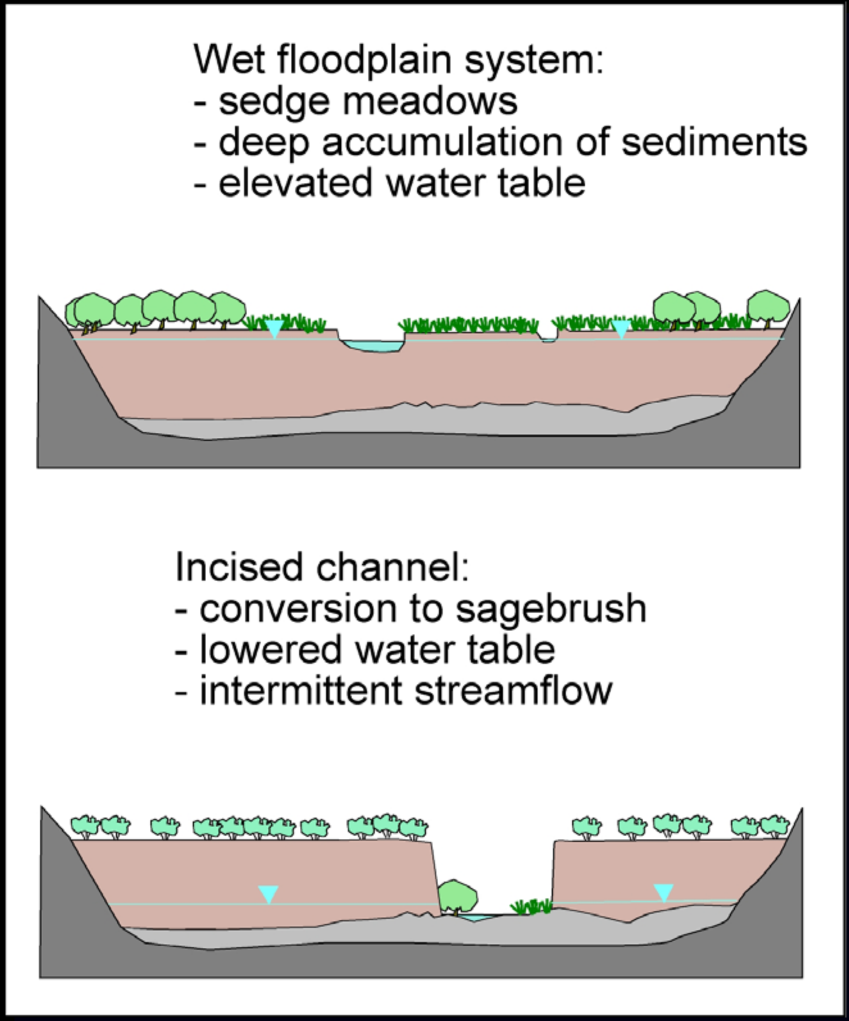
Stewart et al. 2004

Channel incision: less summer flow

Historical Conditions

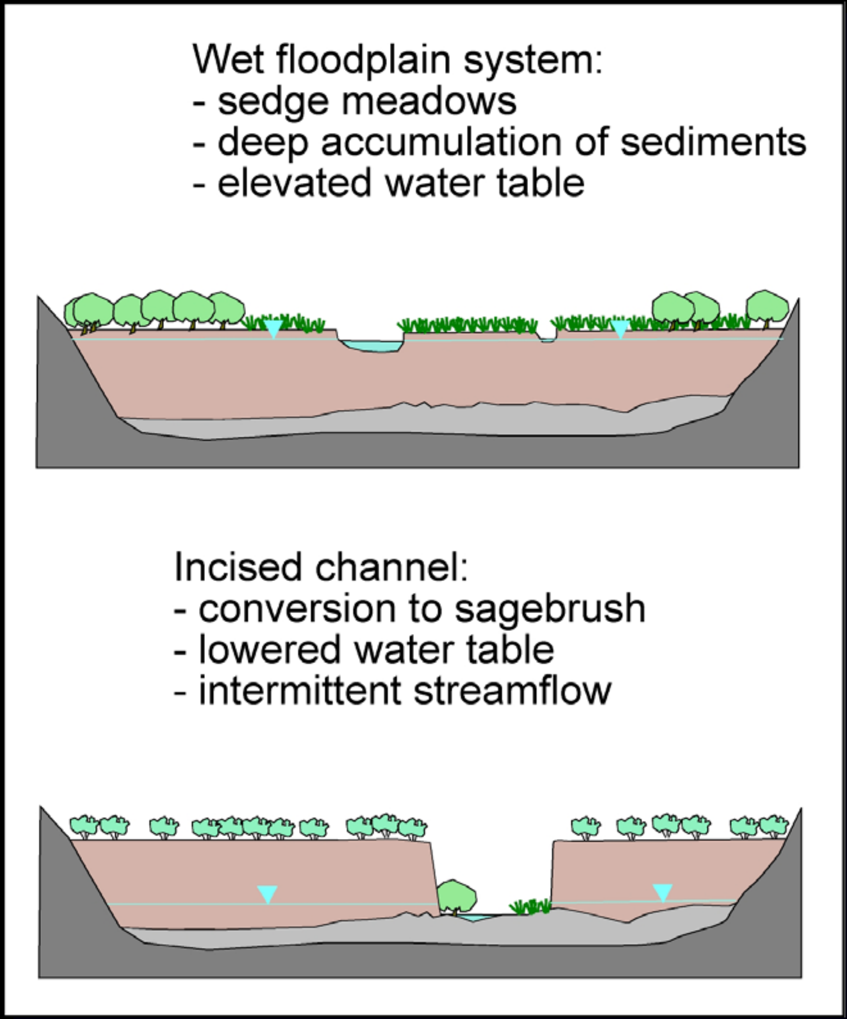
"…they were well stocked in beaver… the river is well lined with willows…" (Peter Skein Ogden, Fall, 1825)

"…beaver in considerable numbers …. valley widens, covered by luxuriant grass… " (Andrew McClure, August, 1858)



Channel incision: less summer flow

- Altered floodplain vegetation
- Loss of flood refugia
- Streams dry in late summer
- Increased stream temperature



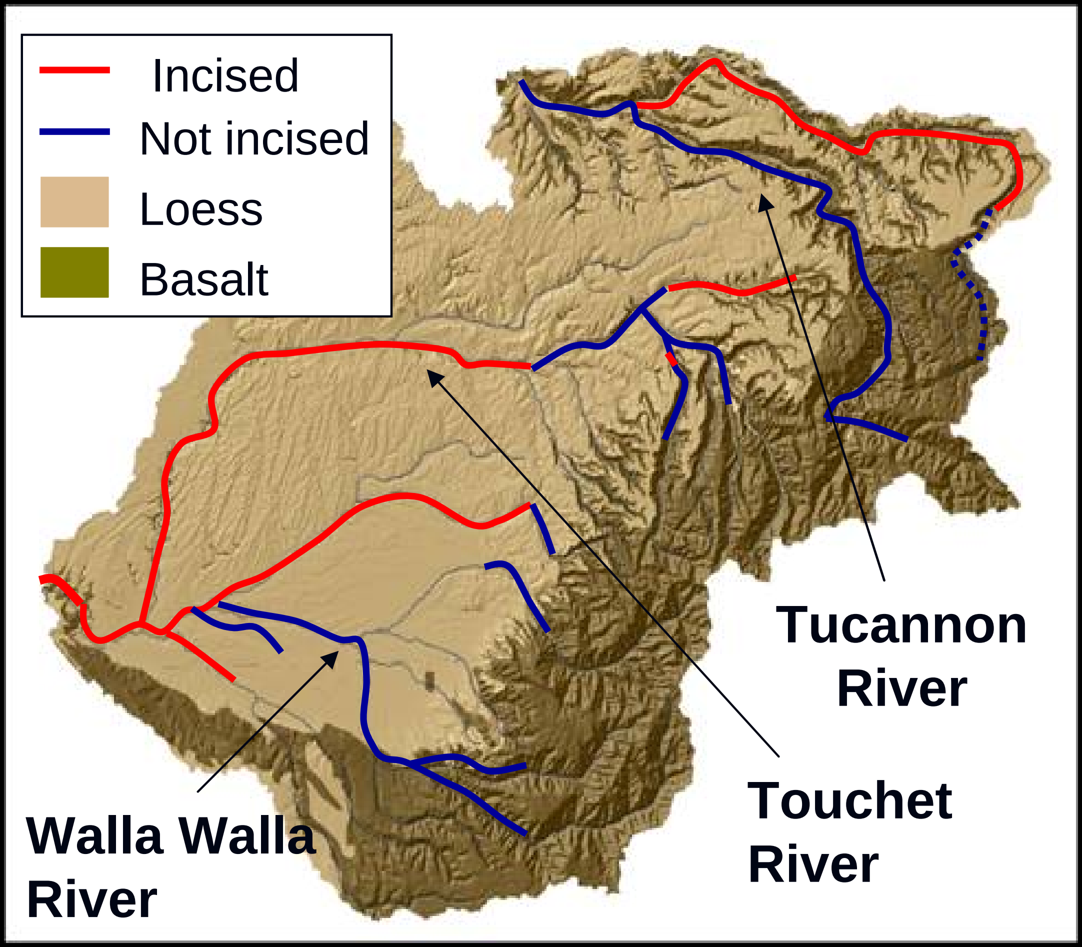
Restoration to counter climate change?

- Increased aquifer storage
- Increased stream flow
- Reduced irrigation demand

Pollock et al. (2003)

A wide-spread opportunity

- Over 500 km of stream mapped
- Over 50% incised
- Typically in fine-grained floodplains



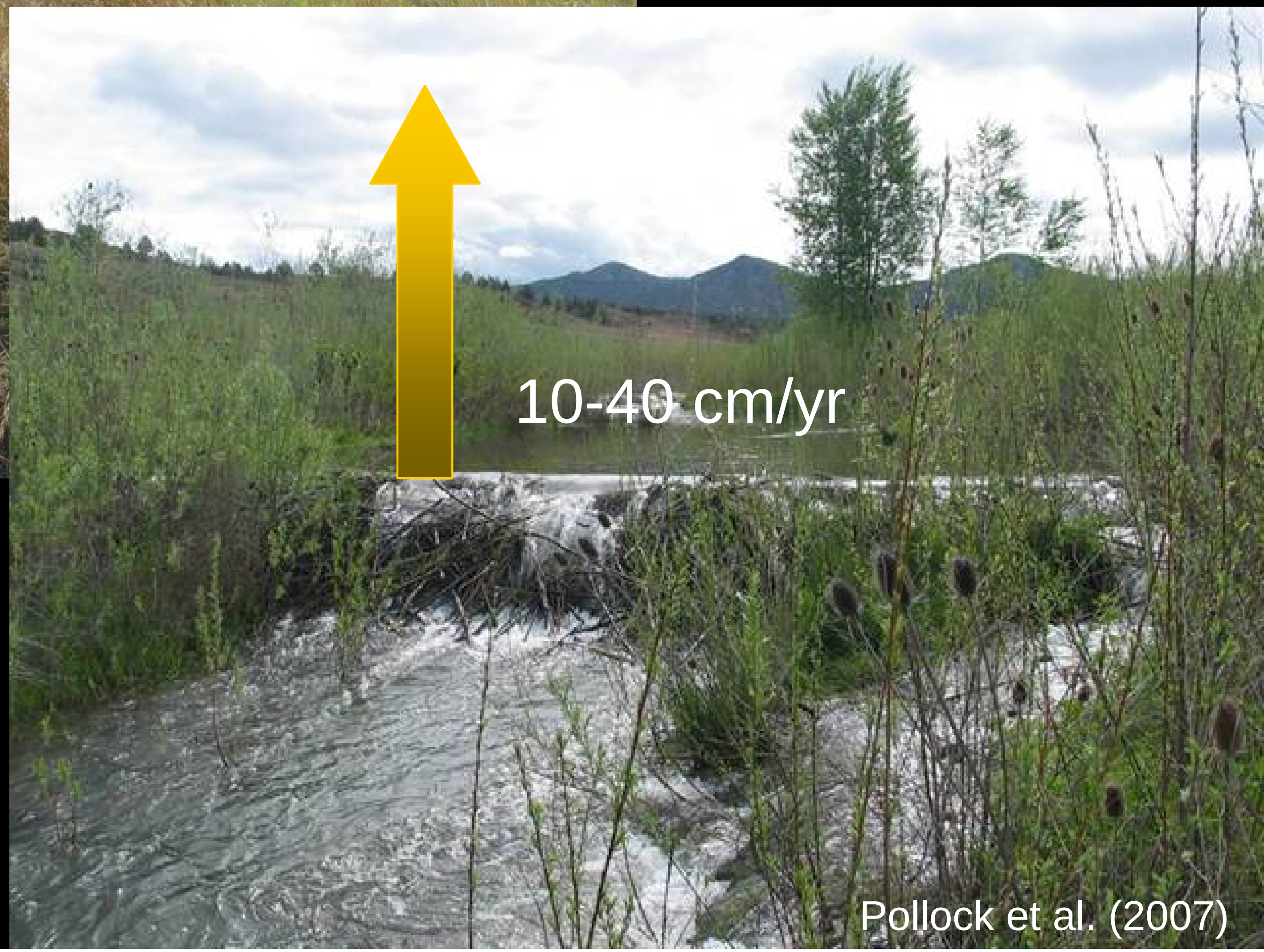
Beechie et al. (in press)

Using beaver dams for restoration

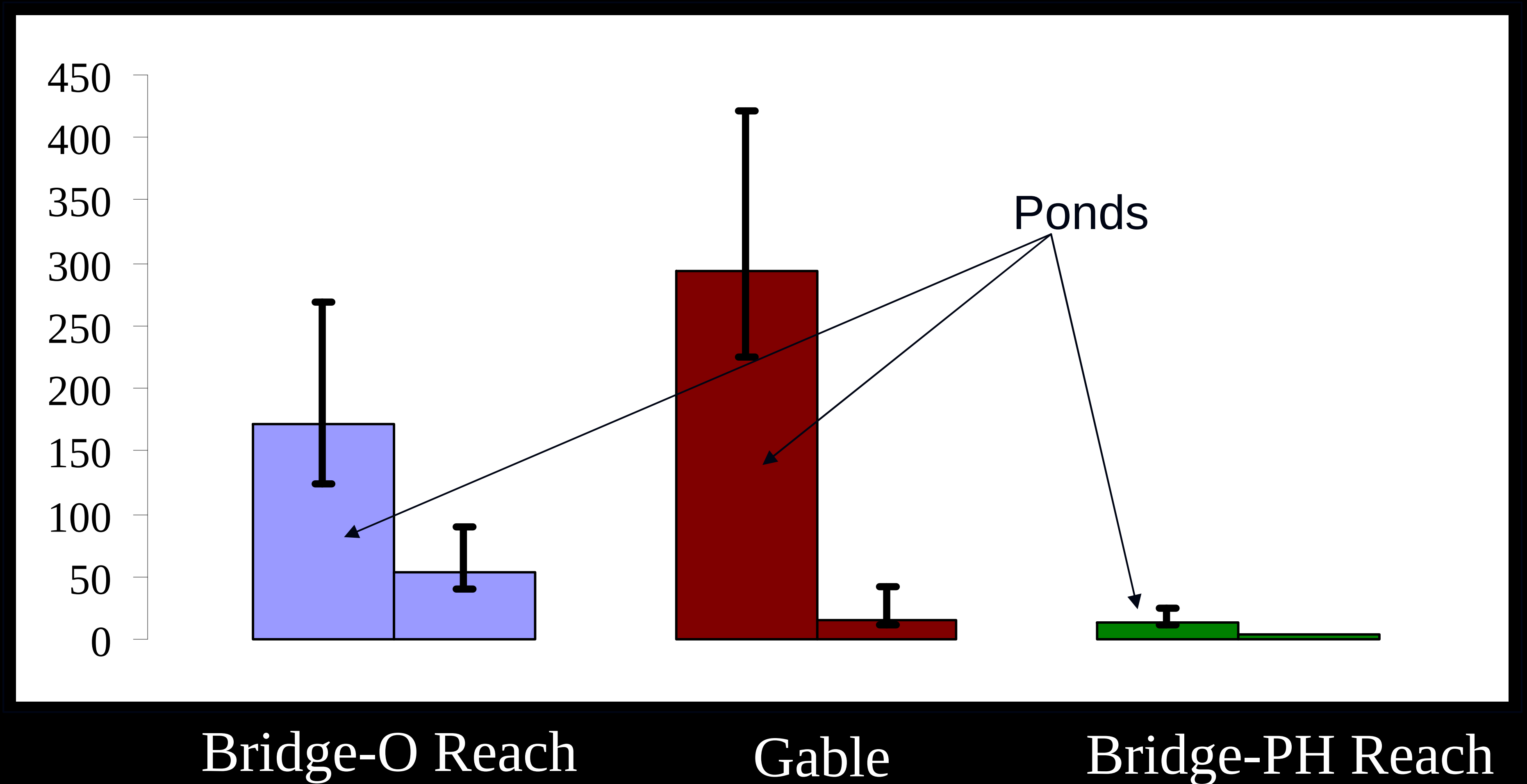
- Increased sediment retention
- Increased floodplain connectivity

Pollock et al. (2003)


~3 cm/yr
Beechie et al. (in press)


10-40 cm/yr
Pollock et al. (2007)

Steelhead use of beaver ponds

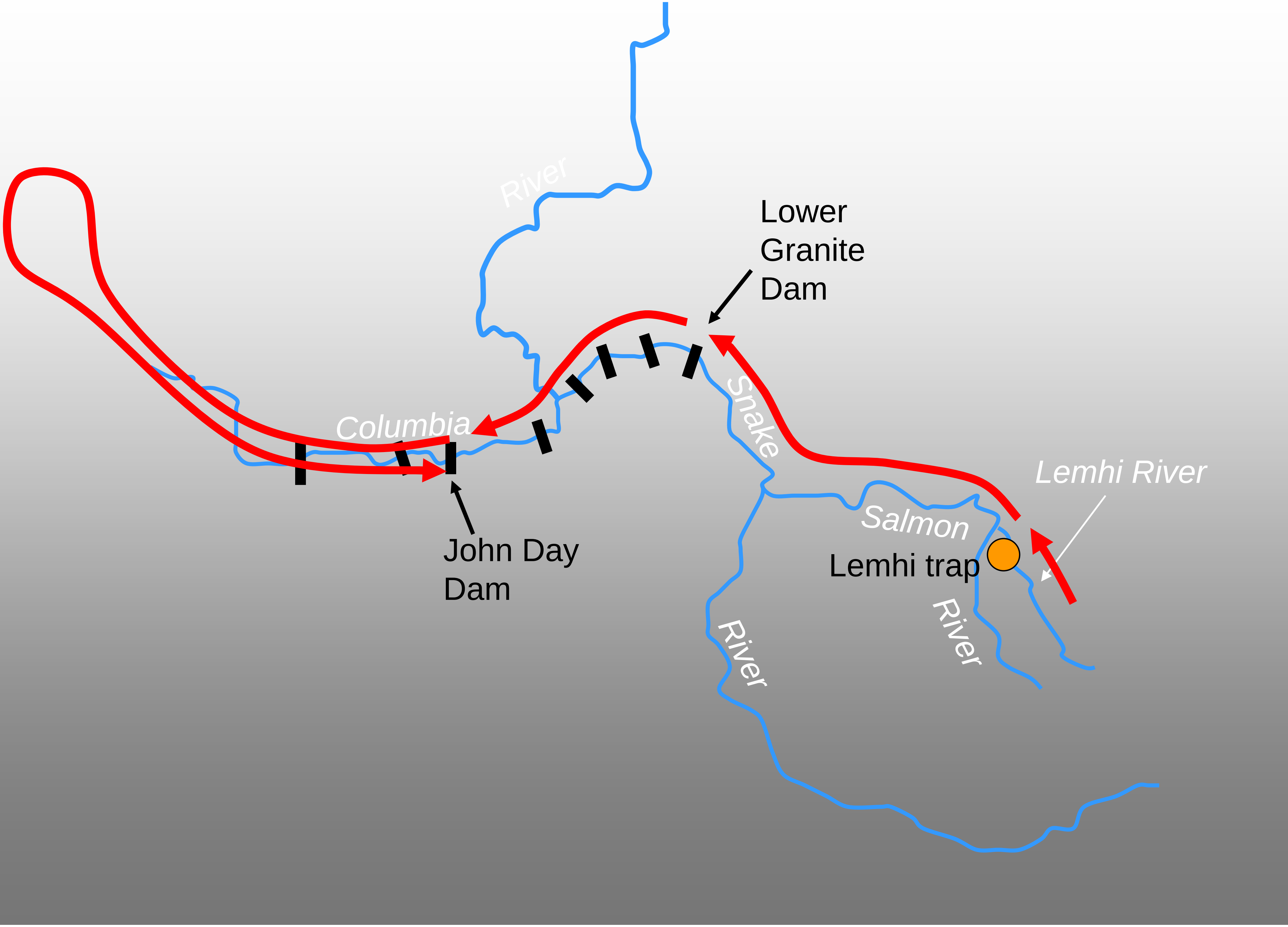


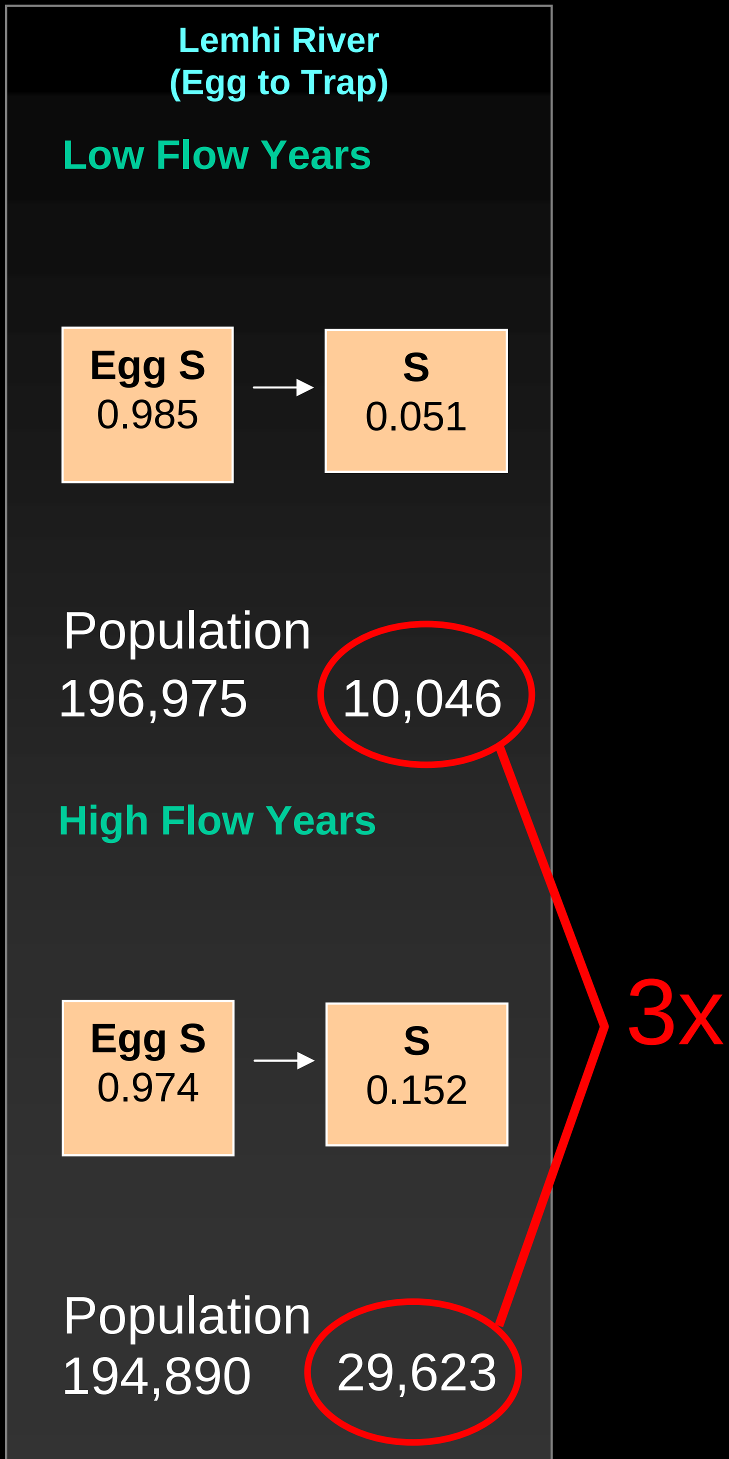
Pollock et al. (in press)

Conclusions

- Incised channel restoration increases summer flows
  - Counters flow loss from climate change
  - Decreased irrigation demand

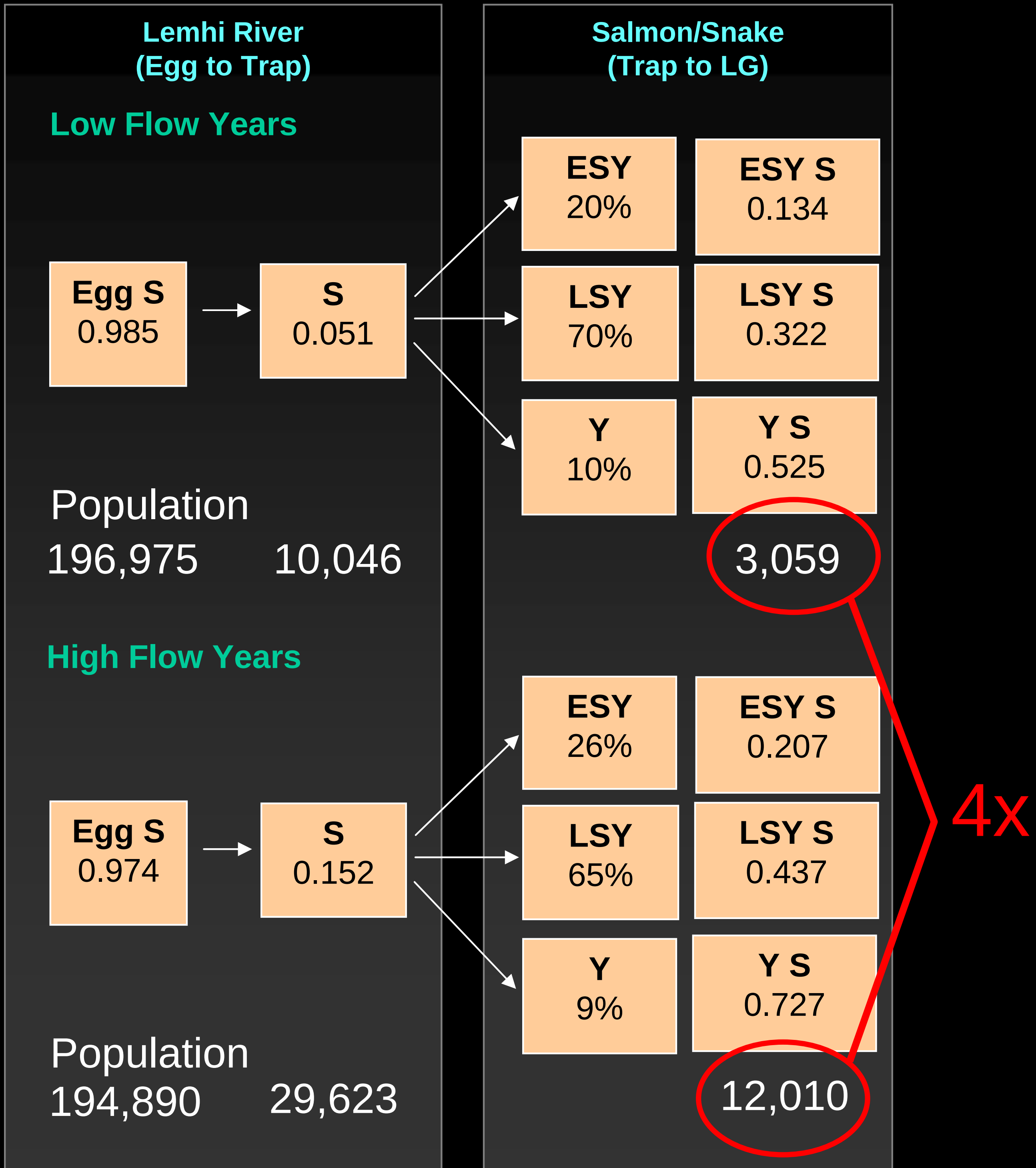
- Predictions of summer flow are feasible
  - Runoff models need to modified
  - Storage cells need to be parameterized


River
Lower
Granite
Dam
Columbia
Snake
Lemhi River
Salmon
Lemhi trap
John Day
Dam
River
River



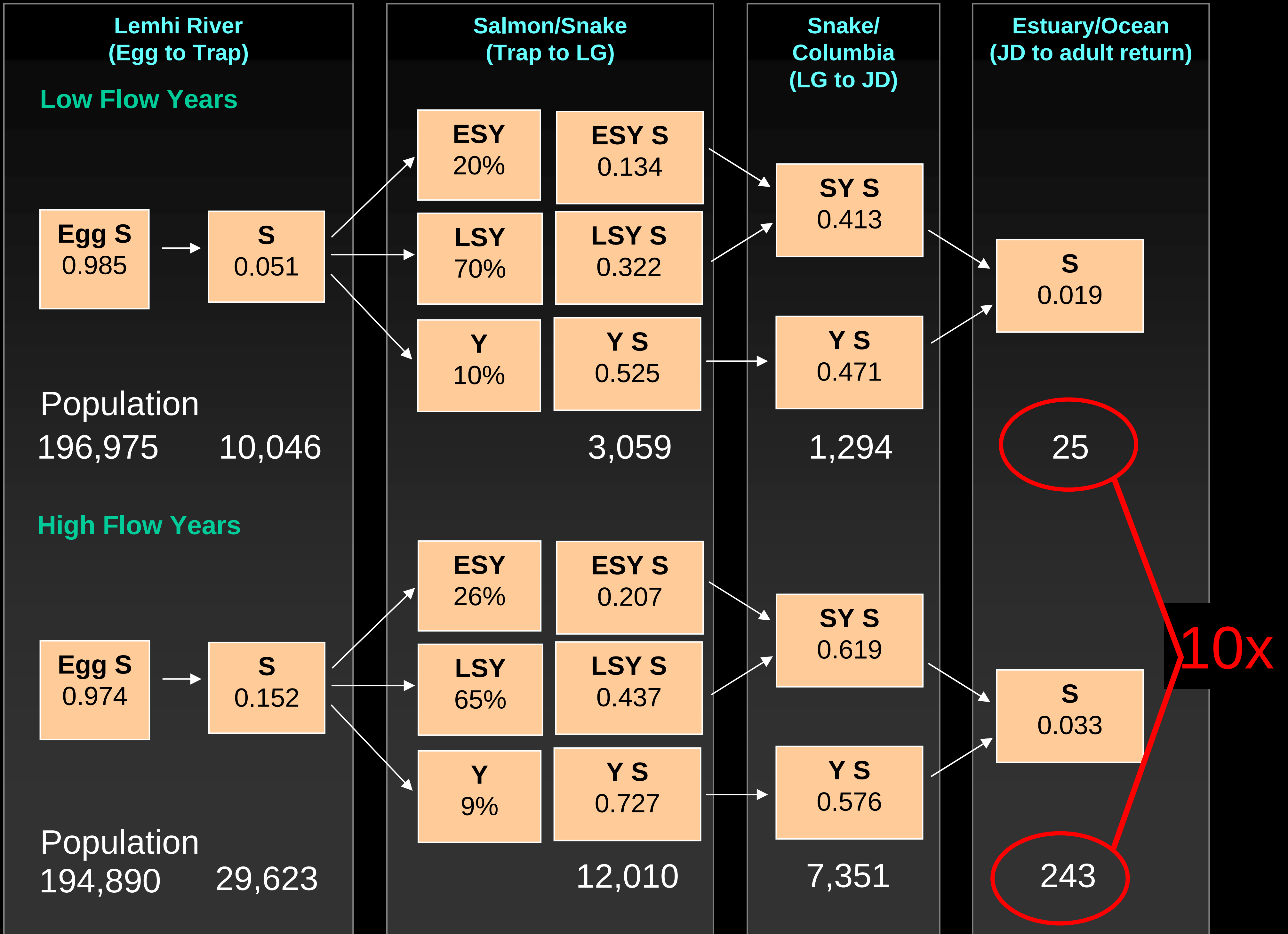
ESY (early subyearlings), LSY (late subyearlings), SY (subyearlings), and Y (yearlings)

Arthaud et al. (in review)



ESY (early subyearlings), LSY (late subyearlings), SY (subyearlings), and Y (yearlings)

ESY (early subyearlings), LSY (late subyearlings), SY (subyearlings), and Y (yearlings)



ESY (early subyearlings), LSY (late subyearlings), SY (subyearlings), and Y (yearlings)

Climate change and restoration effectiveness

- Climate change effects are not the same everywhere
- Some restoration actions more robust than others

	Restoration effectiveness	
Climate effect	Sensitive	Robust
Small	Good	Good
Modest	Fair	Good
Large	Poor	Good