Water management and fish in the Columbia River

James Anderson
School of Aquatic and Fishery Sciences
University of Washington

Presented to the Columbia River Task force
June 28, 2005

Reviews are conflicting

- Independent Scientific Advisory Board **"the prevailing flow-augmentation paradigm, which asserts that in-river survivals will be proportionately enhanced by any amount of added water, in no longer supportable. It does not agree with information now available."**

- National Academy of Science Panel "**when river flows become critically low or water temperatures excessively high.. Pronounced changes in salmon migfratory behavior and lower survival rates are expected"**

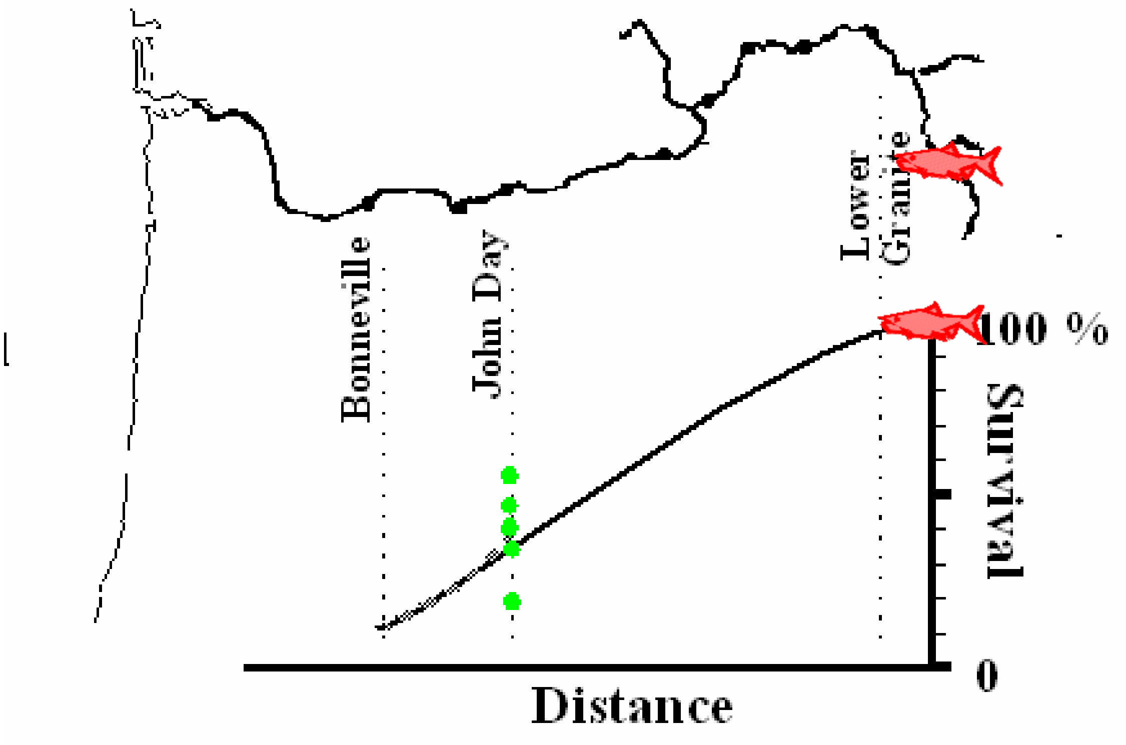
Relevant questions

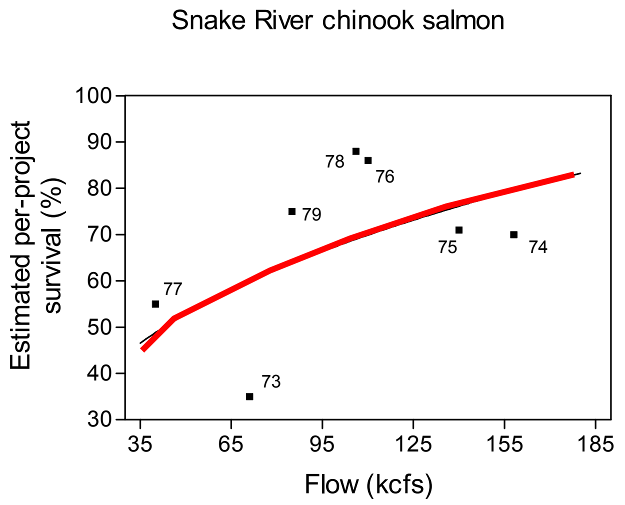
- What is a critical flow?
- What is an excessive temperature?
- How does irrigation affect temperature and flow?
- What is the quantitative effect on smolt survival?

The spring chinook story

Before Columbia River water policy the scientists at the National Marine Fisheries Service studied fish survival and found

In the past spring chinook passage survival was poor





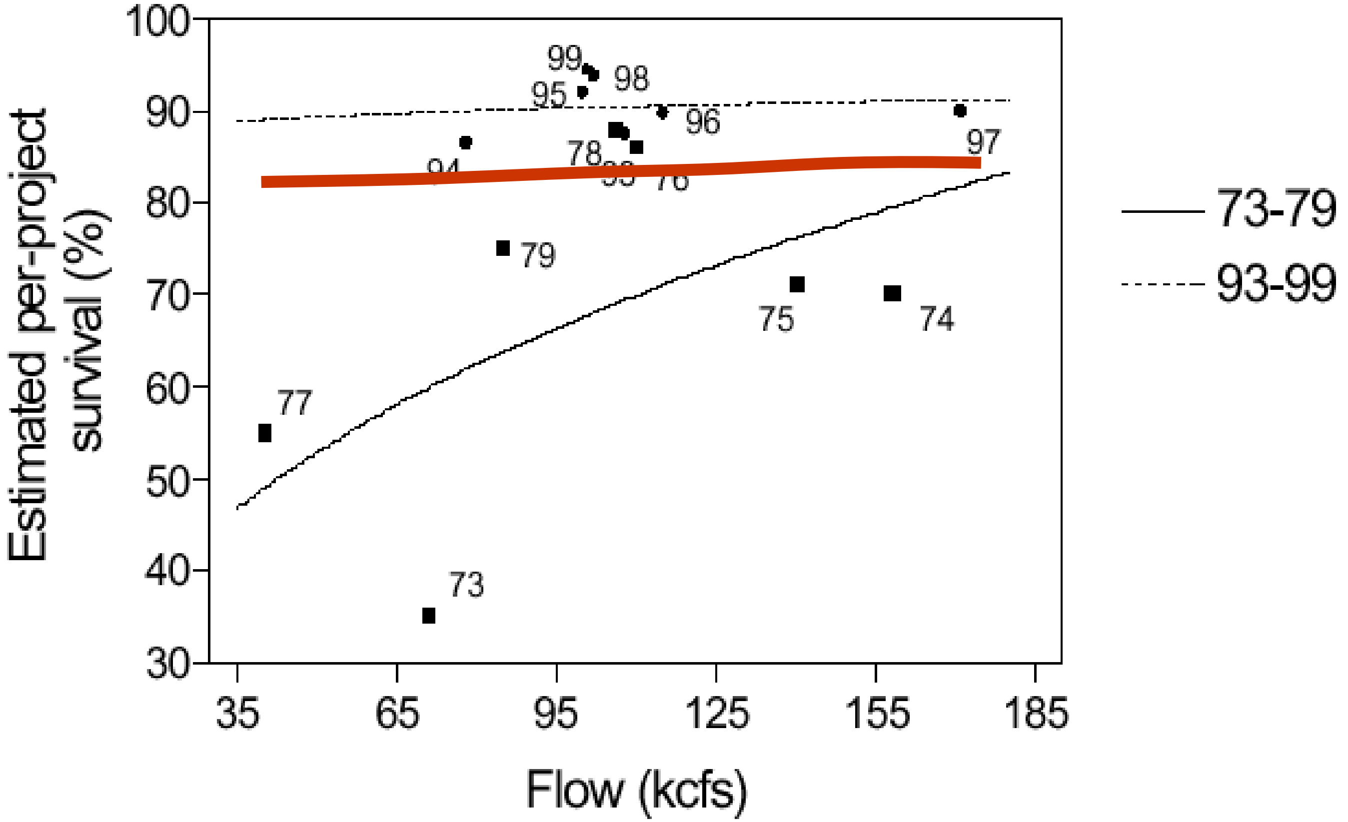
Flow believe to have strong effect on survival

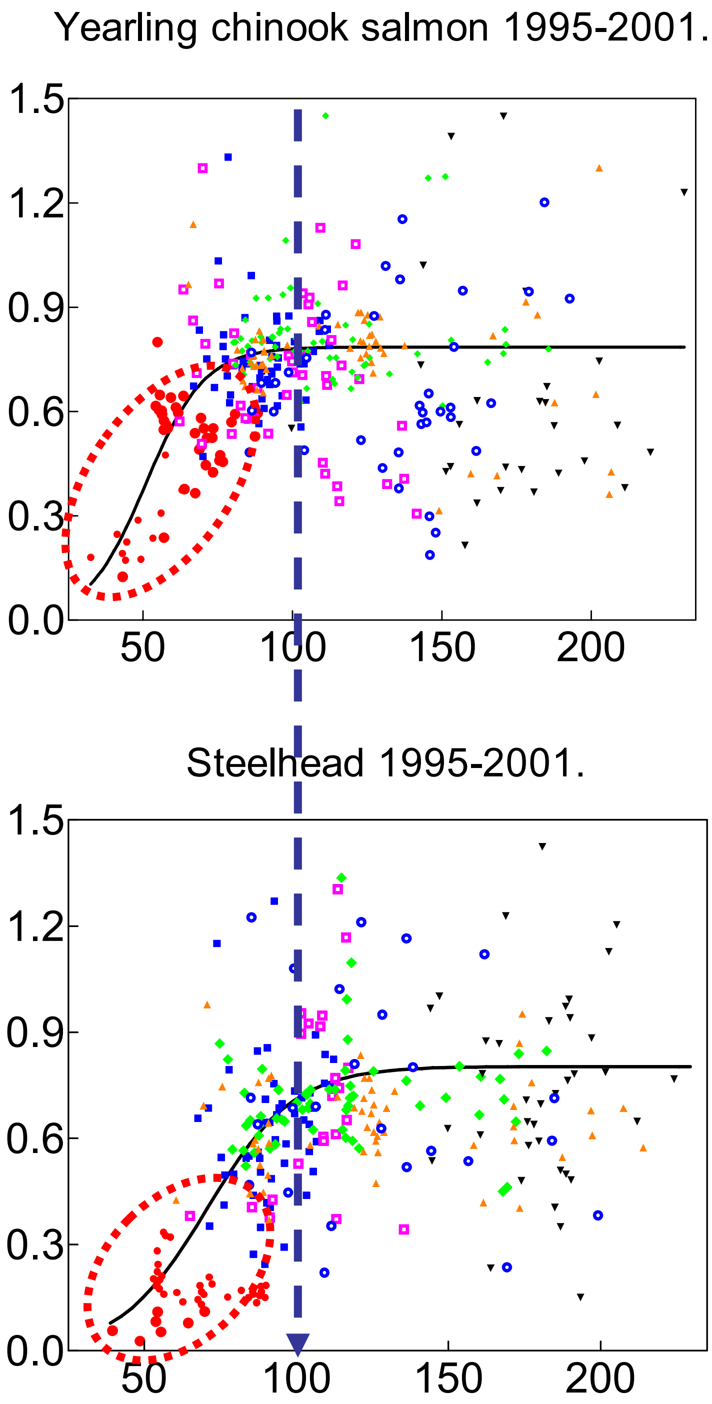
Based on these studies a flow augmentation policy was established for spring chinook and steelhead

With the 1995 Biological Opinion flow targets were established

With the 2000 Biological Opinion water withdrawals were also limited

Studies in 1990s did not show a flow-survival relationship

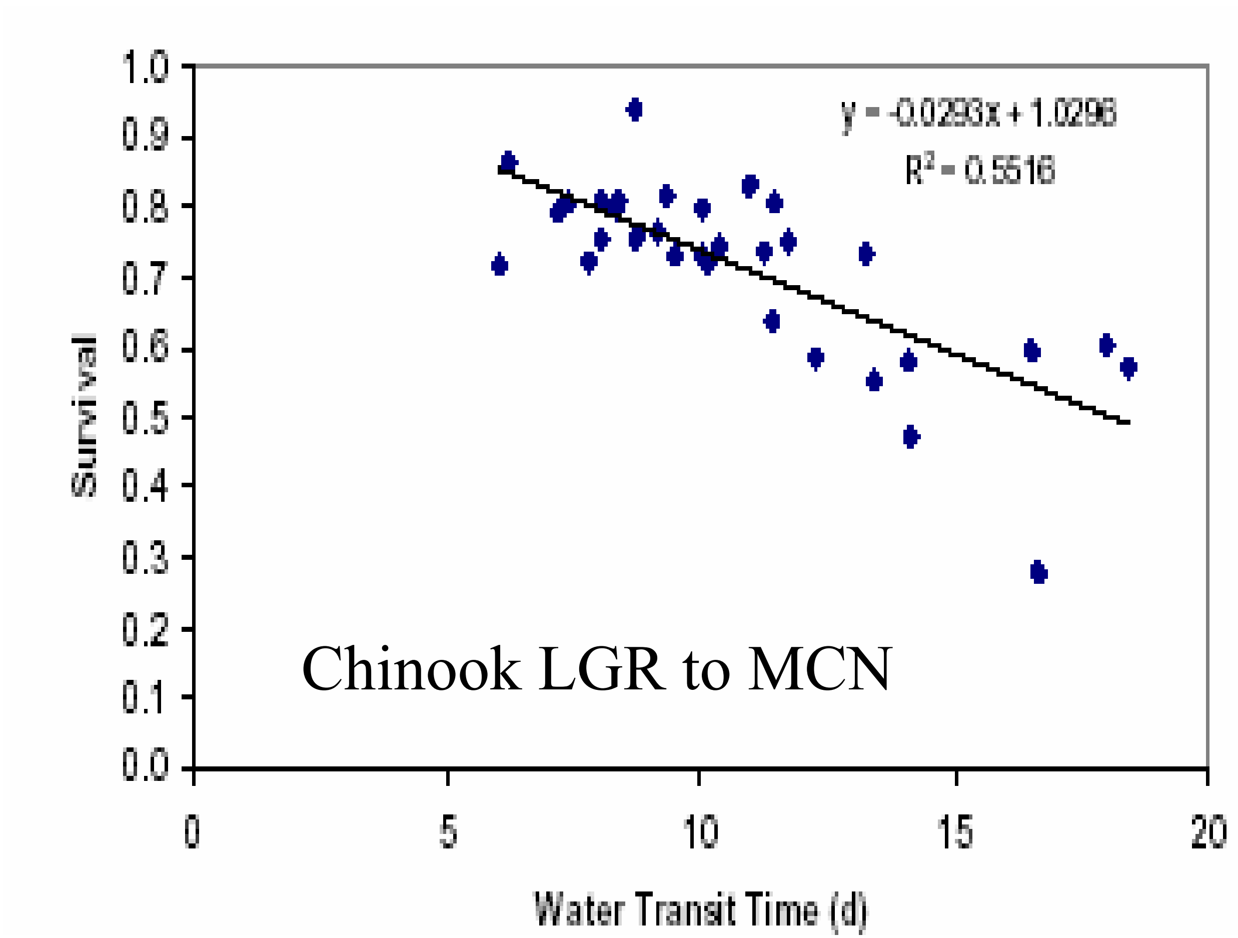




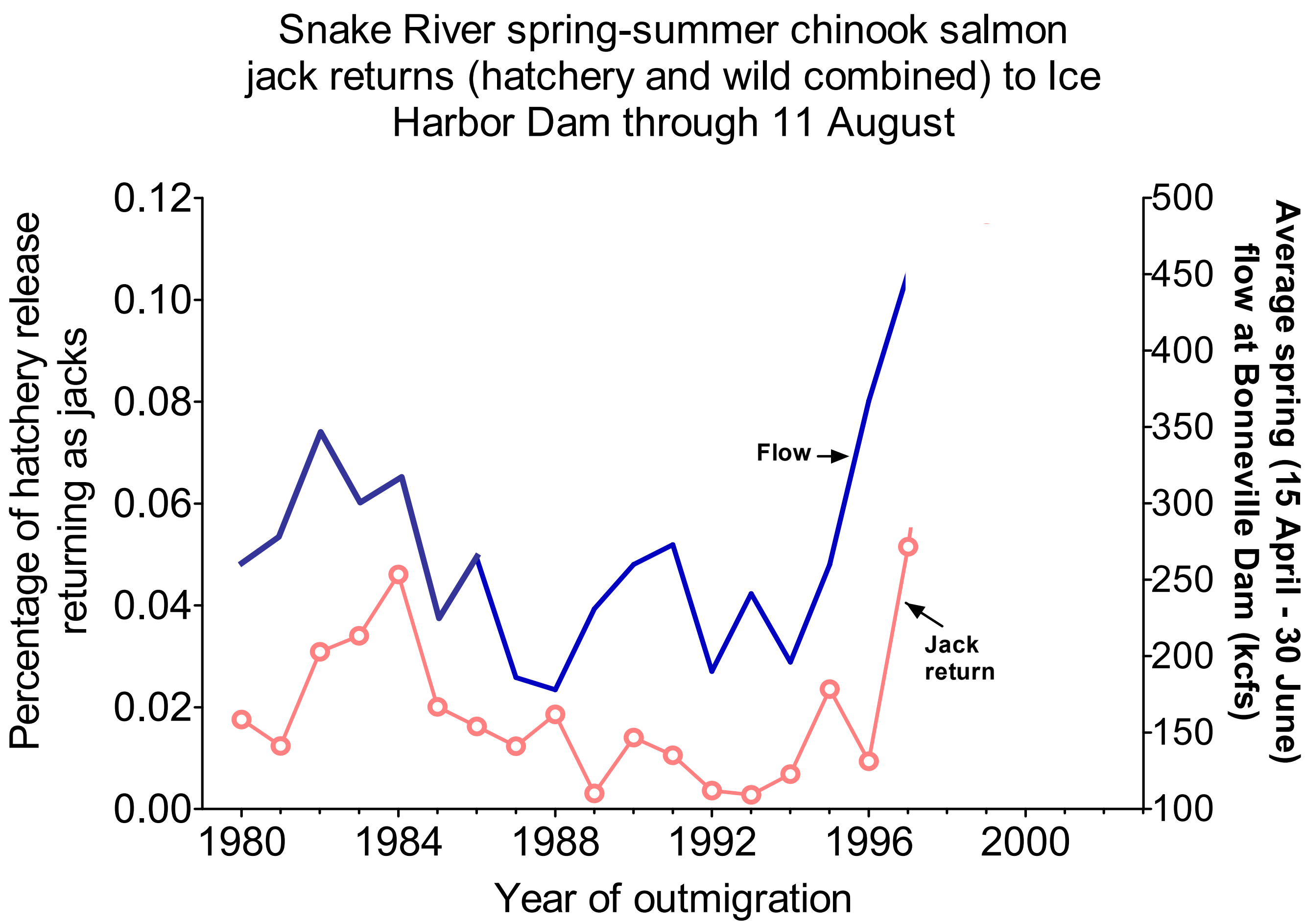
But with data in the low flow year 2001 a flow survival relationship reappeared

NMFS suggested flow relates to survival below a threshold of ~ 100 kcfs

Fish Agencies also demonstrated a fish survival-travel time relationship



NMFS noted a pattern between flow and jack returns suggesting flow may affect adults



Evidence supporting flow augmentation and restricted withdrawals

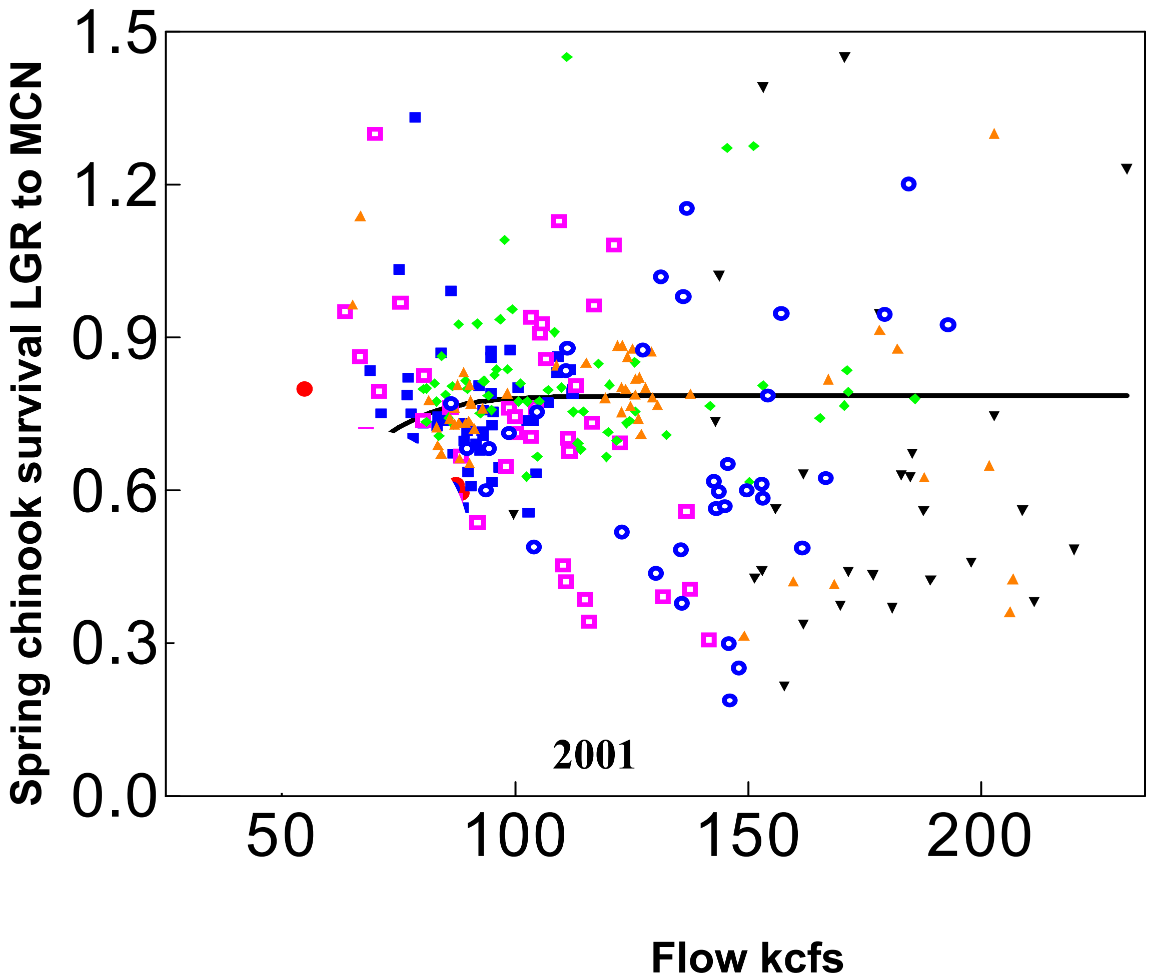
- Between year flow-survival pattern at low flows
- Between year water travel time–survival pattern
- Adult returns varied with flow during smolt migration

However, a closer look at the data challenges these conclusions

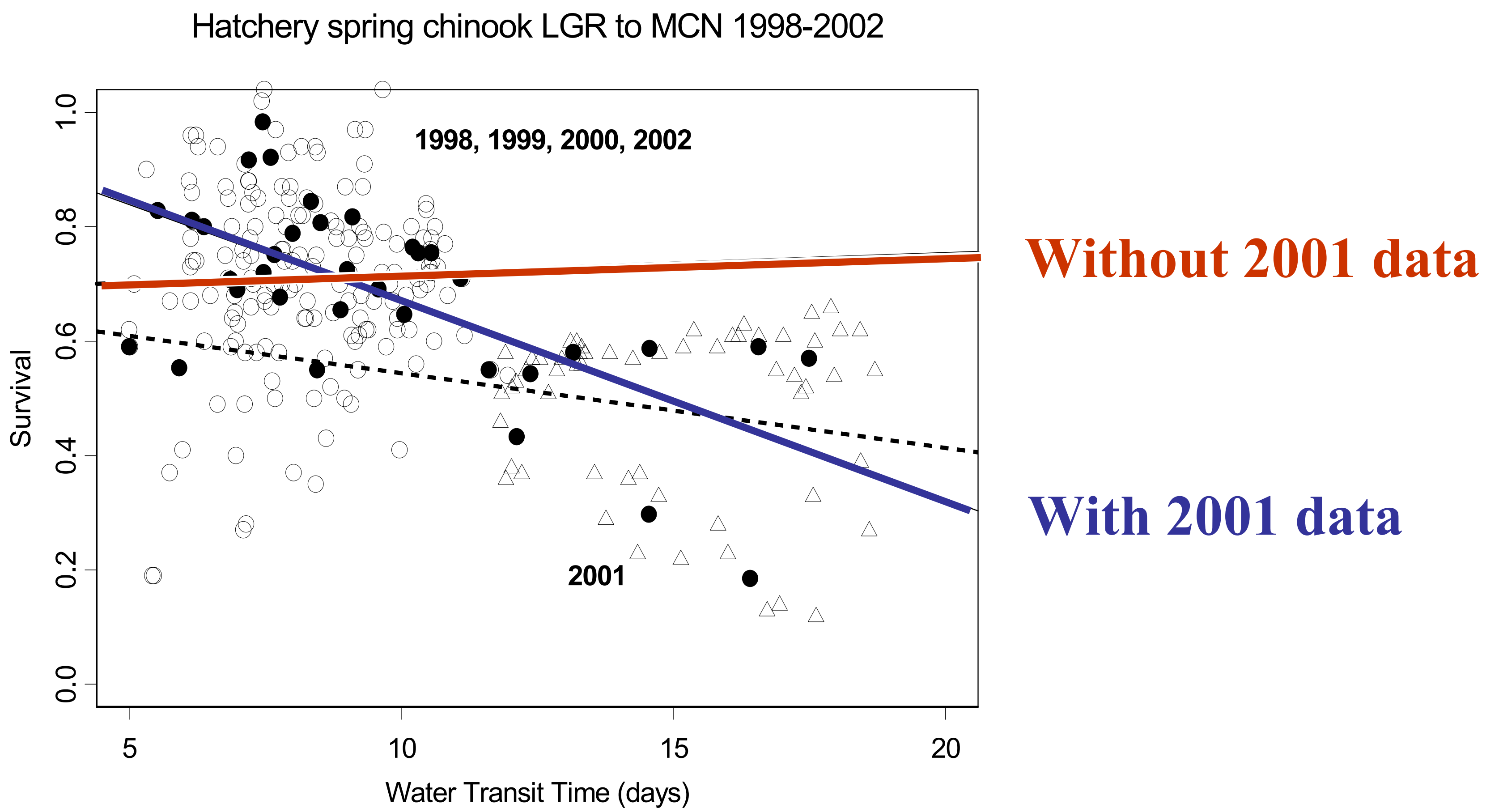
Flow threshold is driven by 2001

- Remove 2001 and the flow survival relationship disappears

Yearling chinook salmon 1995-2001.



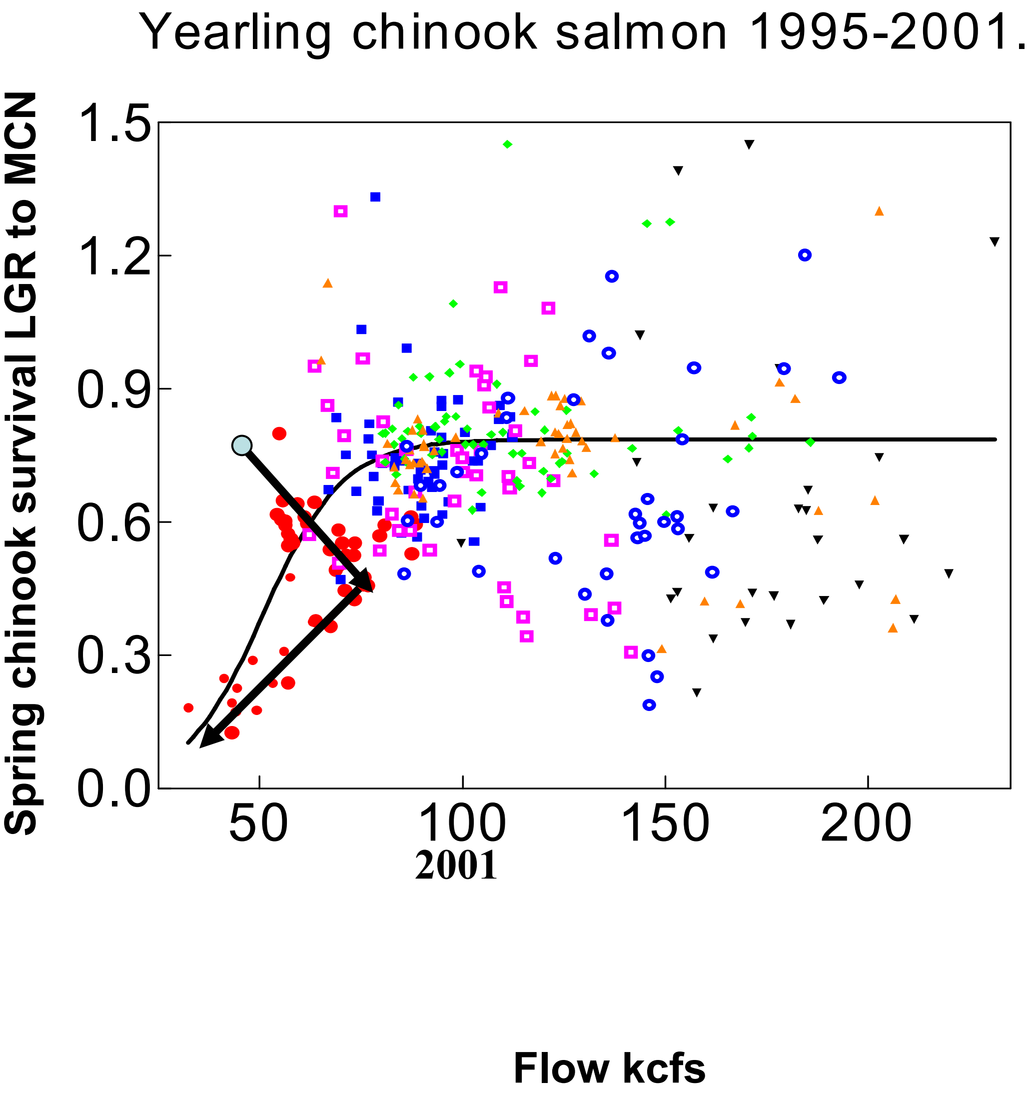
Survival-travel time relationship is driven by 2001



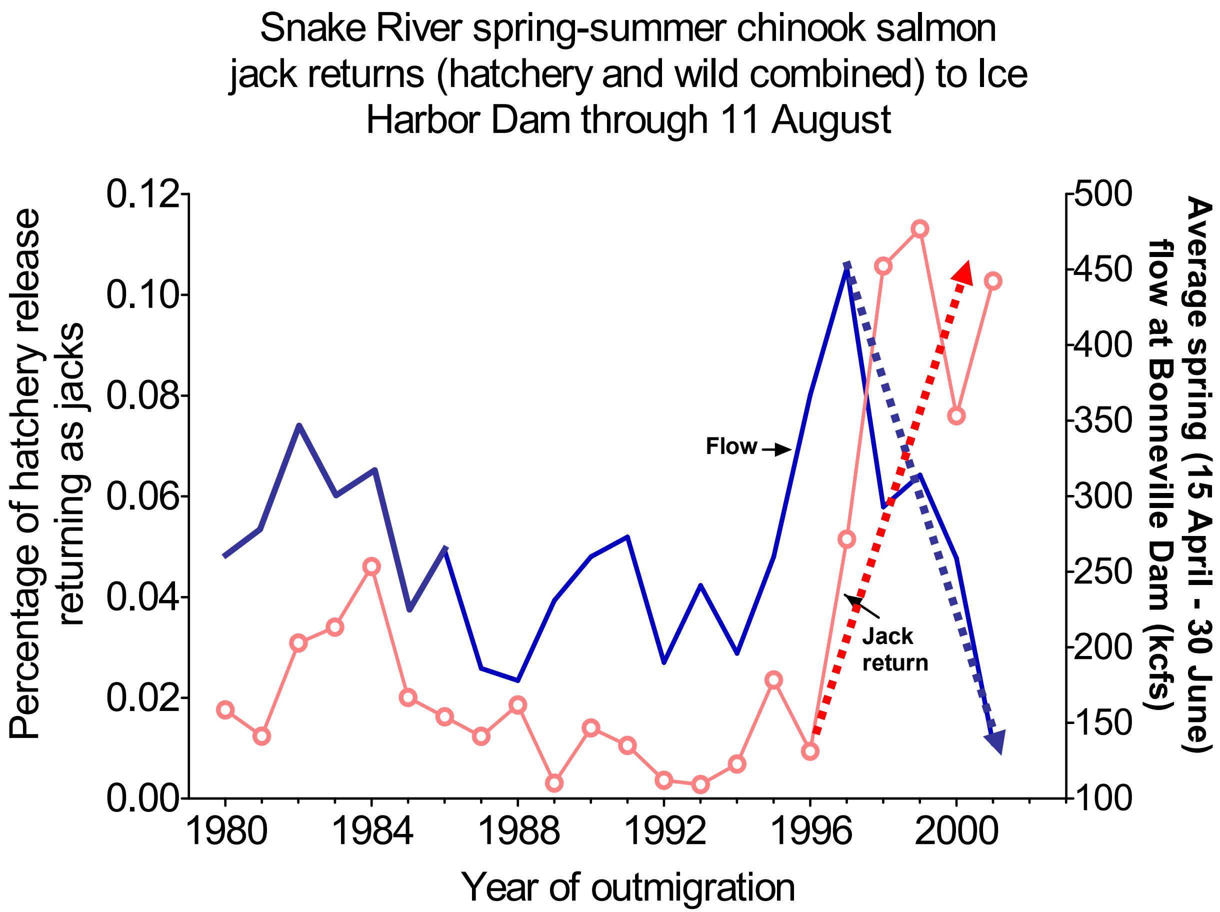
The 2001 within year pattern cannot be generated by the assumed flow relationship

- In early spring survival *decreases* with *increasing* flow

- In late spring survival decreases with *decreasing* flow



Jack returns-flow relationship broke with change in ocean conditions



Evidence supporting flow augmentation and restricted withdrawals

- Between year flow-survival pattern at low flows
- Between year water travel time–survival pattern
- Adult returns varied with flow during smolt migration

So what explains the between and within year patterns?

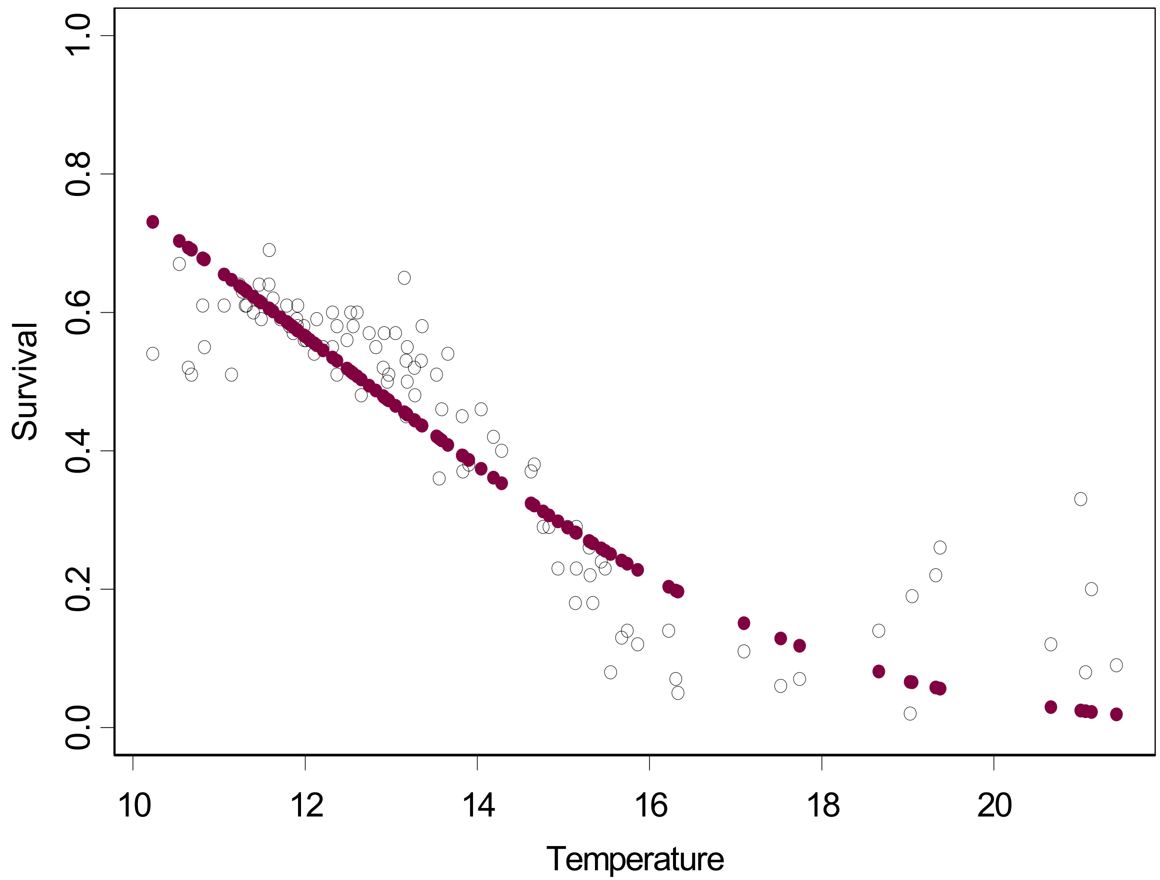
Water Temperature

The 2001 survival can be explained by an increase in temperature only

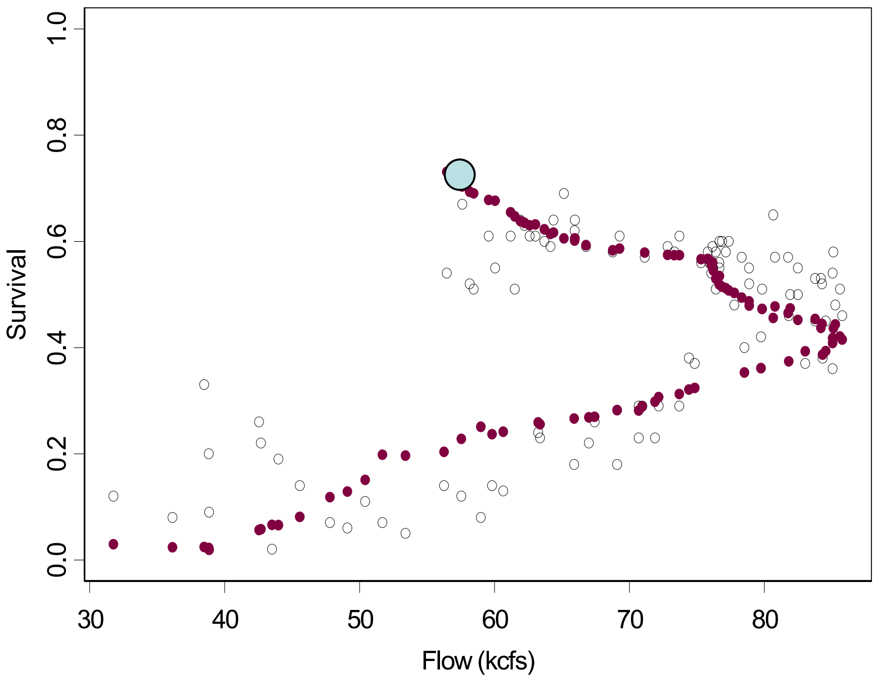
2001 Survival
LGR - MCN

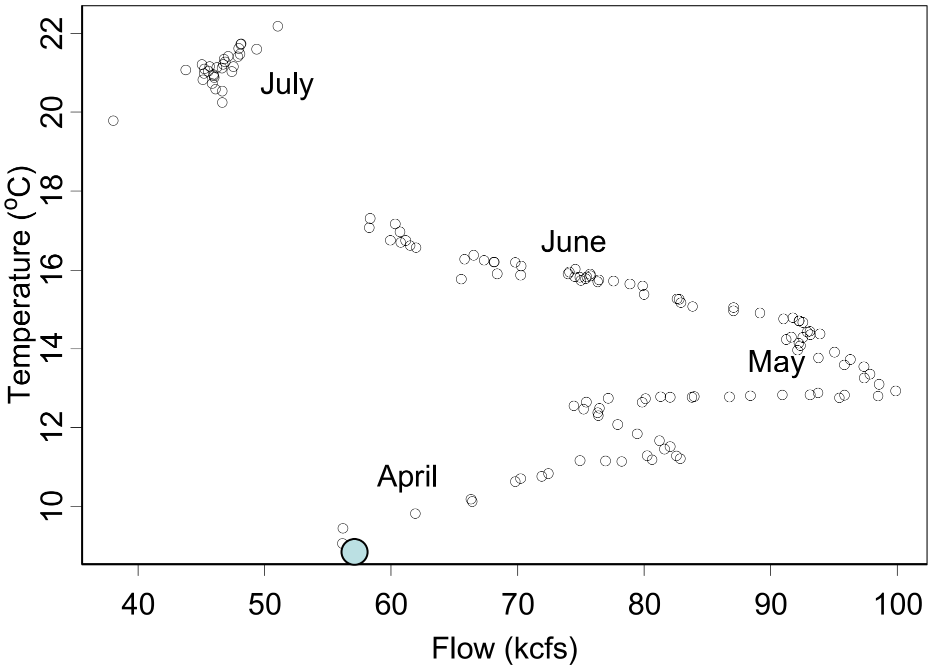
Data = o

Model = ♦



Temperature also generates the in-season flow-survival pattern



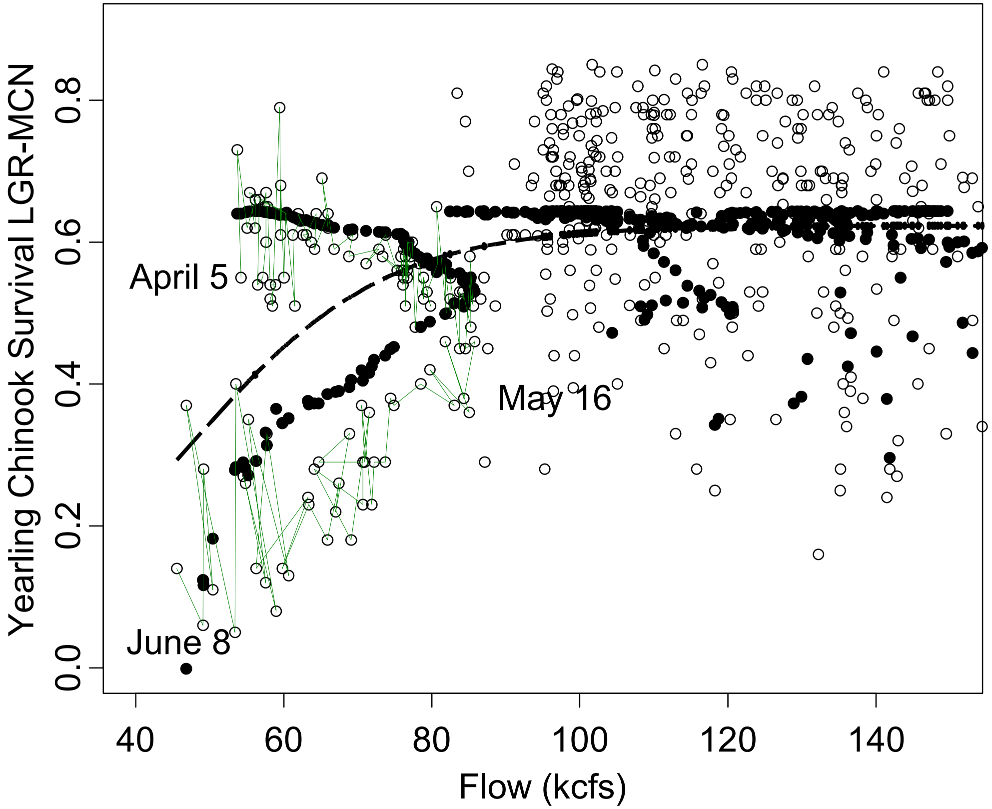


2001 Survival
LGR - MCN

Data = o

Model = ♦

Temperature is sufficient to produce broken stick and within season patterns



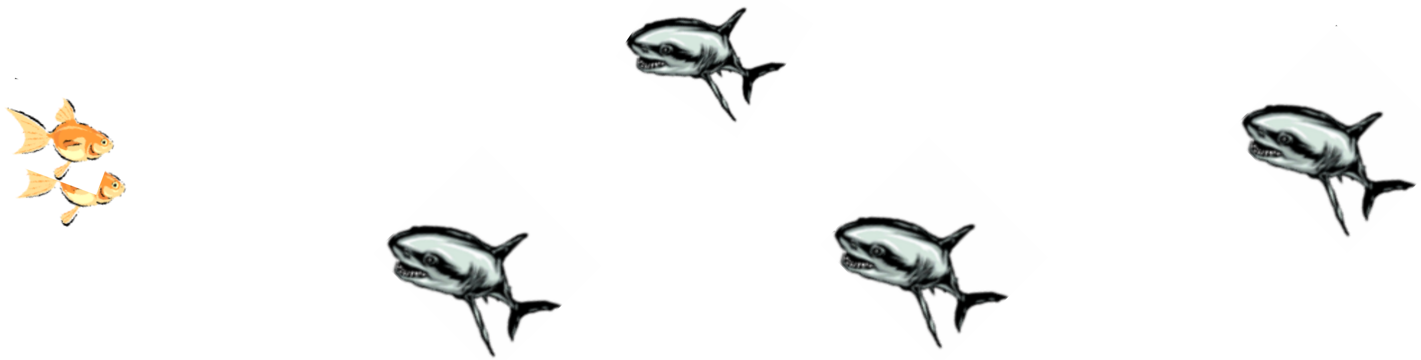
Data = o

Model = ●

An explanation for why temperature

- Migrating smolts pass a gauntlet of stationary predators
- survival depends on the number of predators encountered (depends on migration distance)

- With higher temperature predator activity increases
- encounters more likely so survival is lower over migration



The XTθ survival model is based on

ELSEVIER
Available online at www.sciencedirect.com
SCIENCE DIRECT
Ecological Modelling xxx (2005) xxx–xxx
ECOLOGICAL MODELLING
www.elsevier.com/locate/ecolmodel

Mean free-path length theory of predator–prey interactions: Application to juvenile salmon migration

James J. Anderson[a,*], Eliezer Gurarie[a], Richard W. Zabel[b]

[a] School of Aquatic and Fishery Sciences, University of Washington, Box 358218, Seattle, WA 98195, USA
[b] Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd. East Seattle, WA 98112, USA

Received 3 February 2004; received in revised form 30 November 2004; accepted 10 January 2005

$$S = \exp\left(-a\theta^m \sqrt{X^2 + \omega^2 T^2}\right)$$

X = Distance

T = Travel time

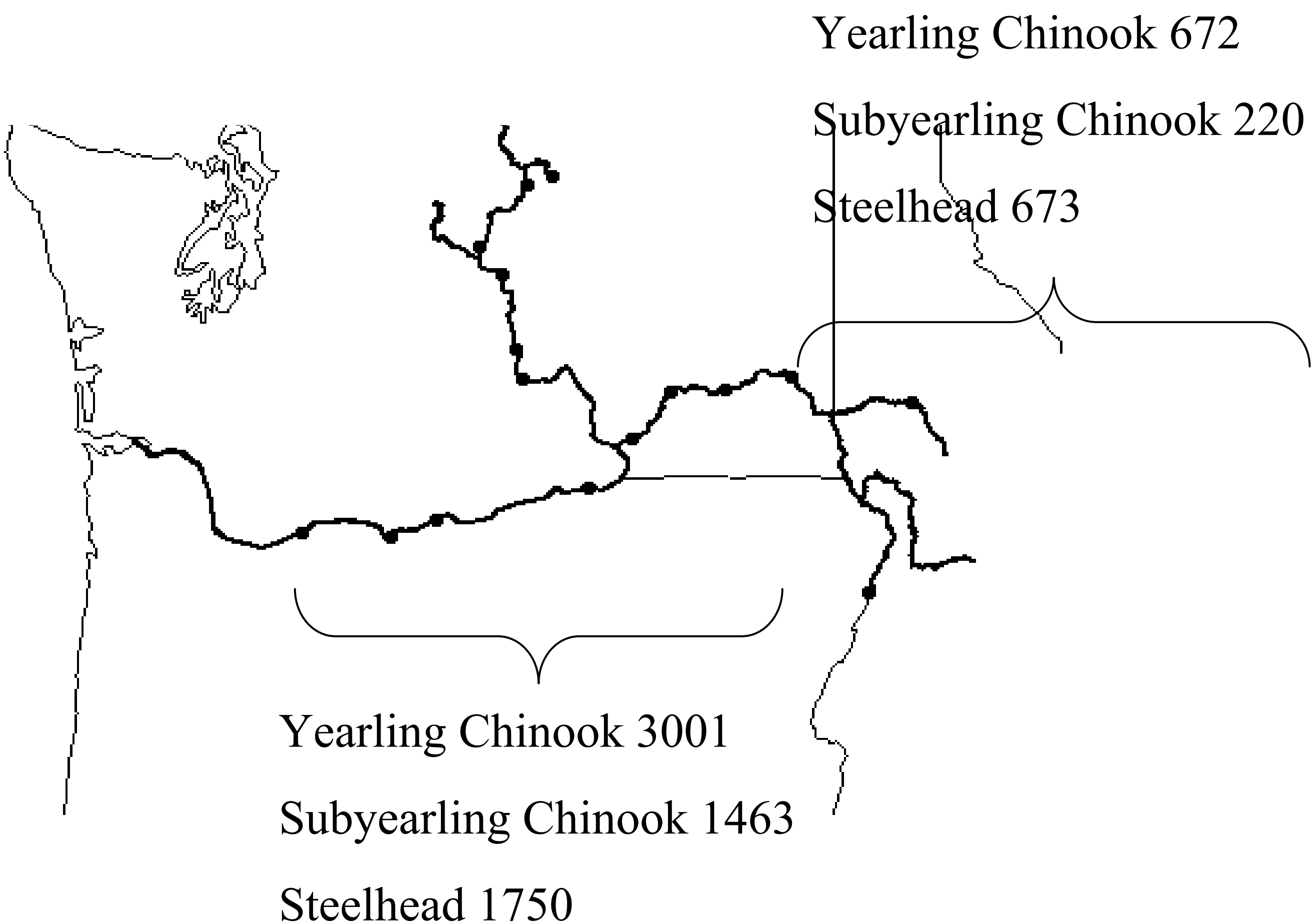
θ = Temperature

ω = Random predator-prey encounter velocity:

a = Coefficient depend predator density and predator reaction distance

m = Coefficient is predator activity with temperature

Fitting XTθ model to data
1995-2003

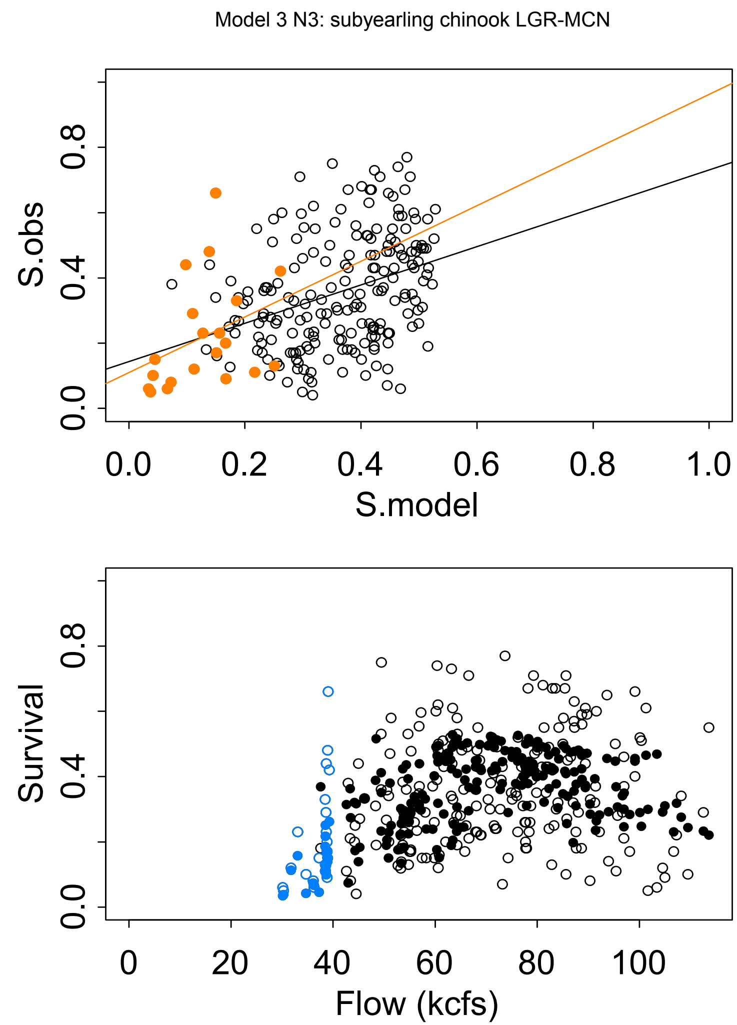


Anderson and Van Holmes manuscript

	Rank	Eq. No.	Covariates	No. para.	Flow - surv break point	2001 pattern?	Biol. Mech ?	r-sqr
Full model →	**1**	**17**	***Q, Z, V, X, B***	**7**	**Y**	**Y**	**Y**	**0.30**
	2	16	*Q, Z, V, X,* S_{dam}	6	Y	Y	Y	0.29
CRiSP 1.7 →	**3**	**10**	***Q, X,*** S_{dam}	**2**	**Y**	**Y**	**Y**	**0.23**
CRiSP 1.6 →	4	3	*T, Q,* S_{dam}	2	Y	Y	Y	0.18
	5	7	T_w, *B, Q*	4	Y	Y	N	0.17
	6	6	*D, F, Q*	4	Y	Y	N	0.15
	7	12	*F Q*	3	Y	Y	N	0.12
	8	14	*Q*	3	Y	Y	N	0.08
	9	15	*Z*	3	Y	Y	N	0.06
	10	11	*F*	3	Y	N	N	0.15
Sigmodial →	**11**	**2**	***F***	**3**	**Y**	**N**	**N**	**0.08**
	12	8	T_w	2	Y	N	N	0.08
	13	9	*F*	2	Y	N	Y	0.07
SIMPAS →	14	5	*X,* S_{dam}	1	N	N	Y	0.22
	15	1	*F, N*	3	N	N	N	0.21
	16	4	*T,* S_{dam}	2	N	N	N	0.14
	17	13	*F*	3	N	N	N	0.12

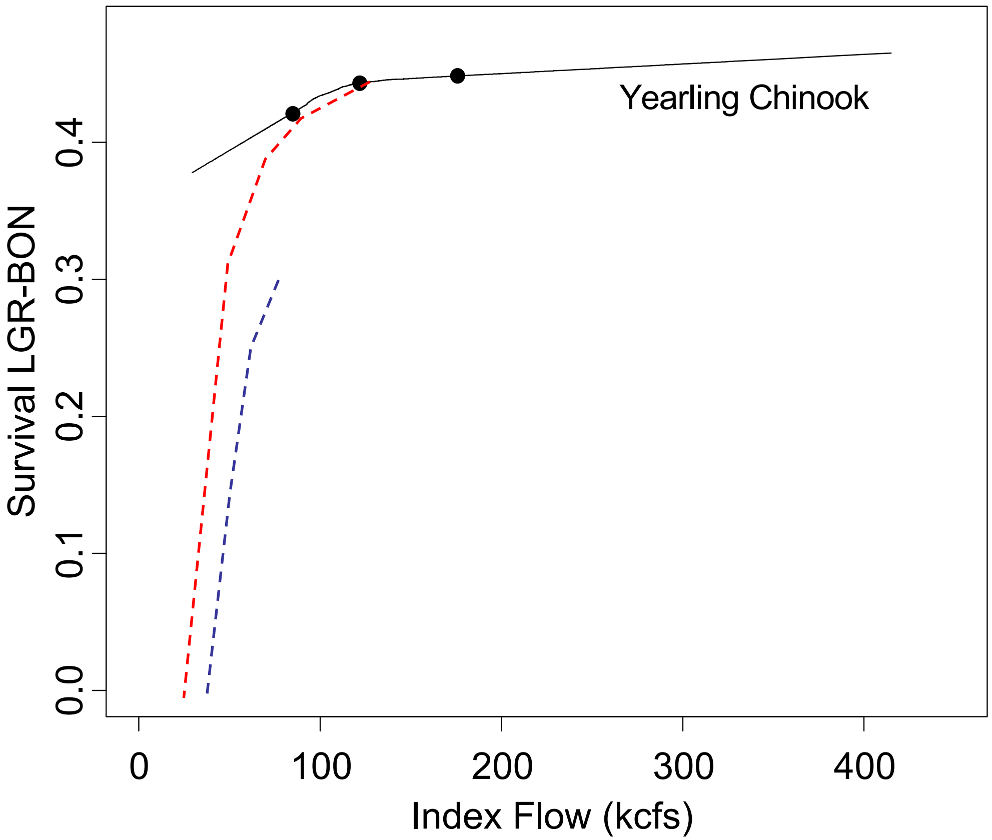
Effect of flow on fall chinook LGR-MCN

- Reasonable agreement between Data (○) and **XTθ** Model (●)
- Survival independent of flow above 40 kcfs
- 2001 (●) effect can be explained by temperature



Model sensitivity

Flow-Survival pattern LGR to BON with XTθ model compared to NOAA flow model



Example of NOAA yearling chinook relationship

Example of NOAA steelhead relationship

What about the effect of water withdrawals on fish survival?

we use models because the effect is unmeasurable

Effect of withdrawal on river properties

- The effect on water and fish travel time is *nil*

  (1 kcfs change increases water and fish transit times by a few hours over a two week to one month migration)

- The effect on temperature is *nil*

  (estimated 0.01^{o}C increase per 1 kcfs)

1 kcfs ~ 250,000 acre-ft./month

The effect on survival

- Accounting for temperature and velocity changes the XTθ model indicates 250,000 acre-ft/mo withdrawal has *virtually no impact* on fish survival (-0.008% on a base of 11.9%)

- Even according to the NOAA threshold-flow survival model withdrawal has an *unmeasurable and insignificant* impact on survival

Revisiting the NAS Panel

- "when river flows become critically low or water temperatures excessively high.. Pronounced changes in salmon migfratory behavior and lower survival rates are expected"

- However the review did not address what is critical or excessive

Conclusions

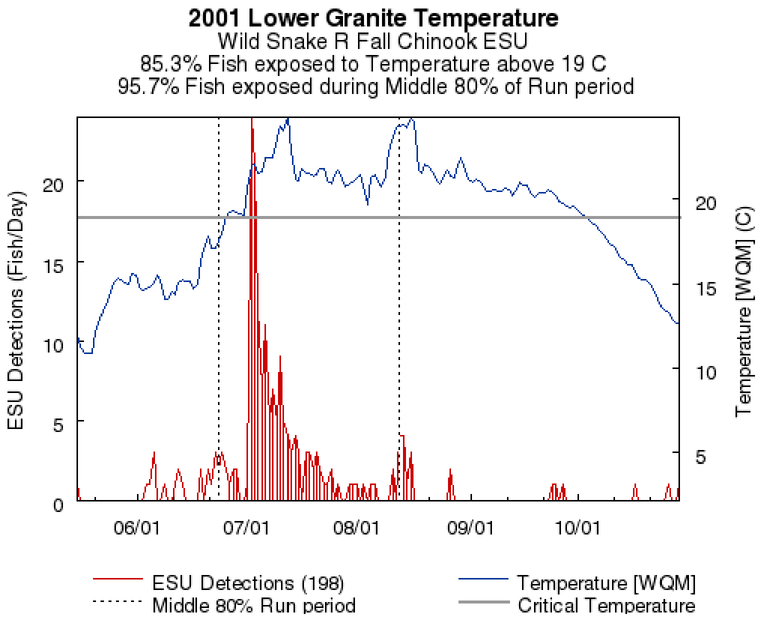
Our Research

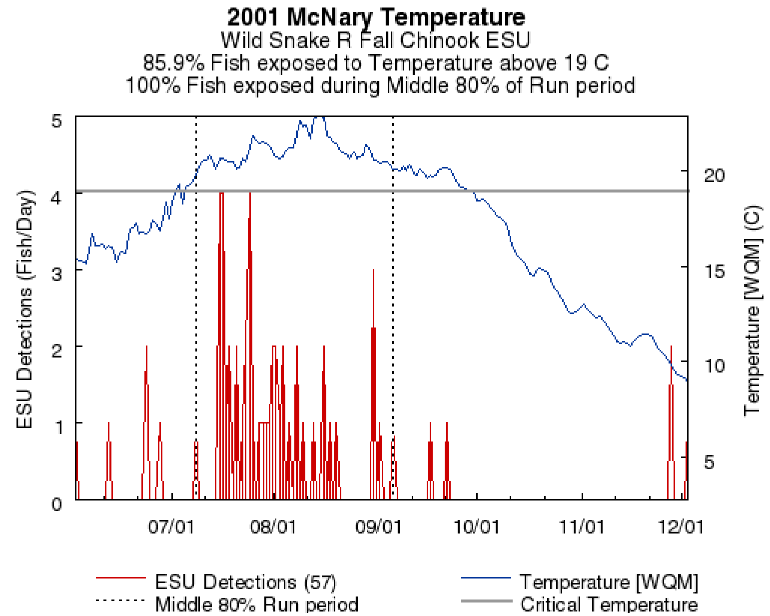
- Based on a decade of data
- Based on a biologically founded quantitative theory of smolt migration and survival

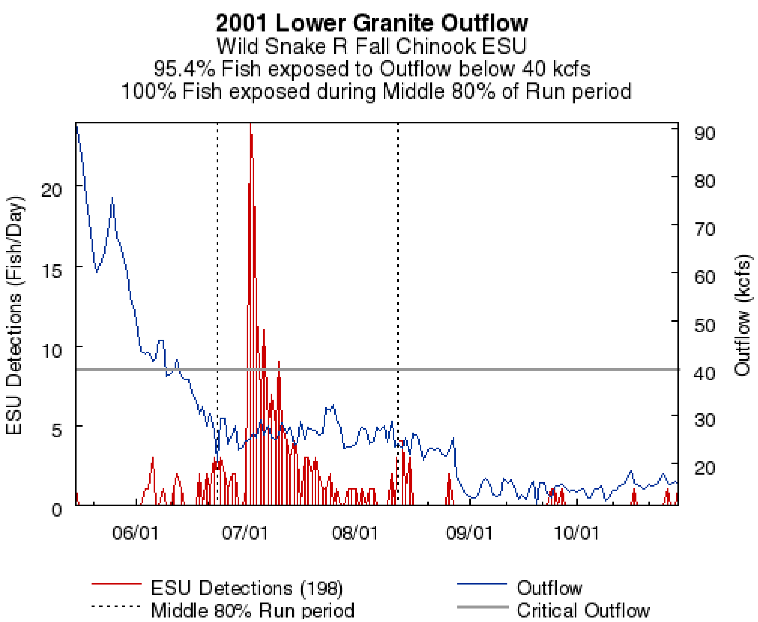
Indicates

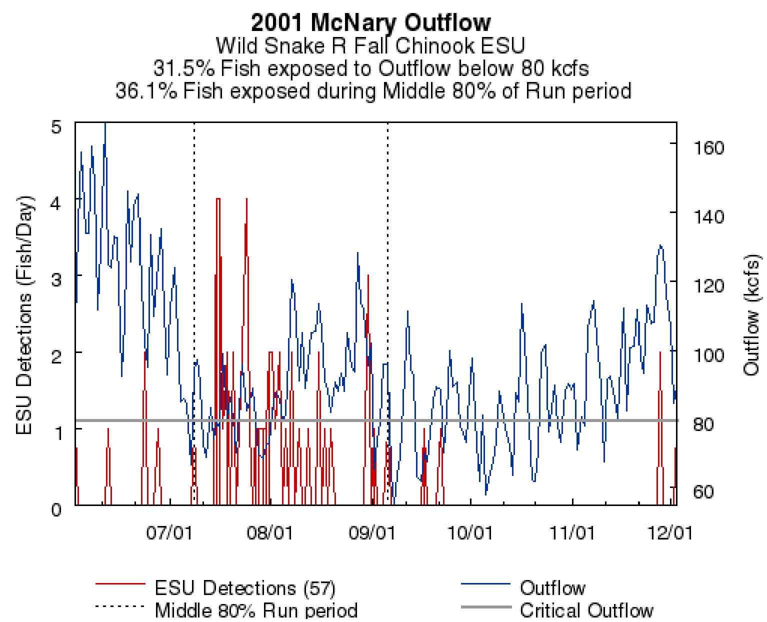
- Summer irrigation withdrawals, or mitigation enhancements, on the order or 250,000, acre-ft/mo will have no effect on smolts migrating through the Columbia River

Conditions in 2001

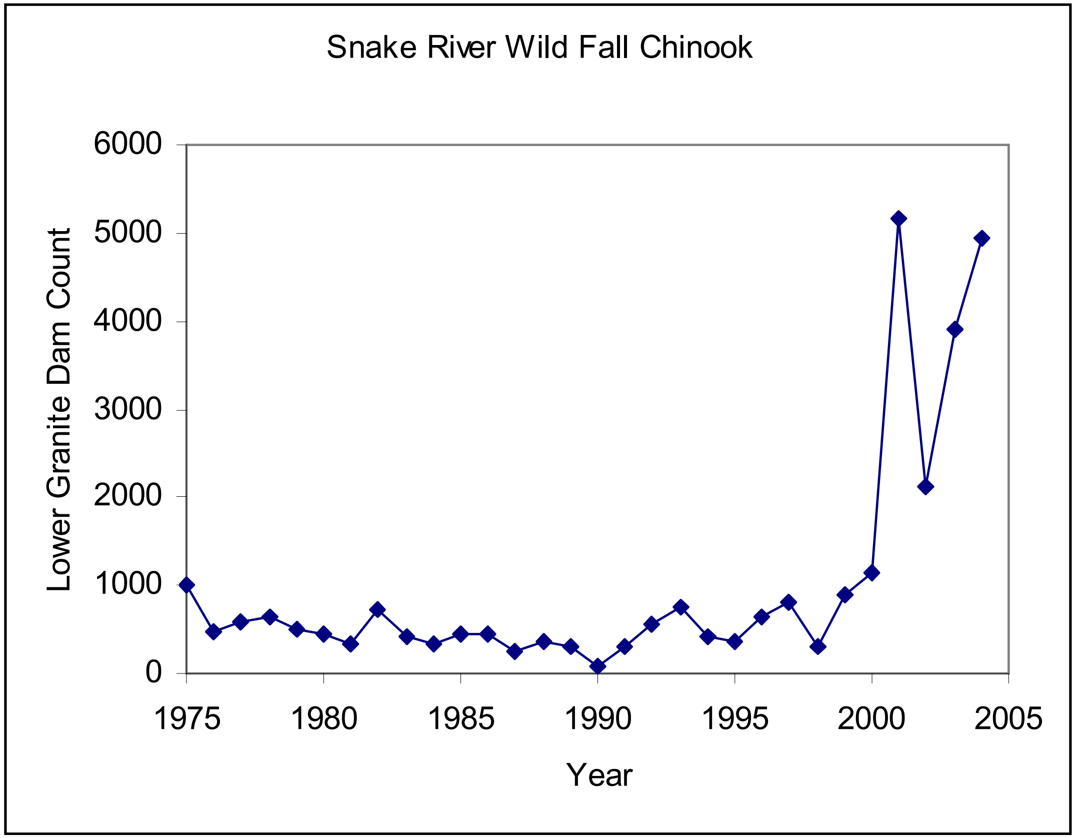




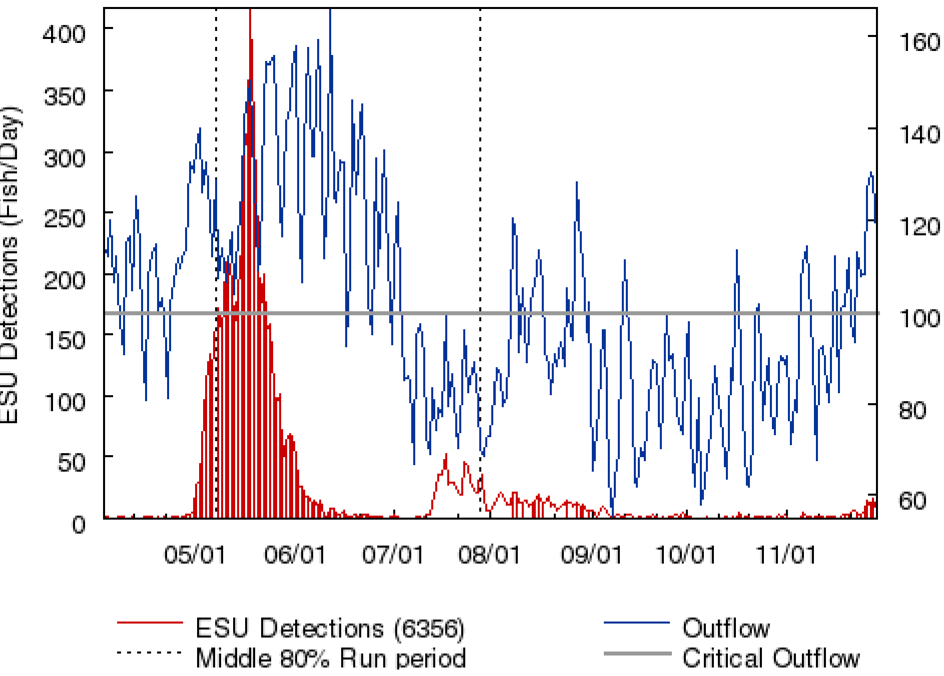




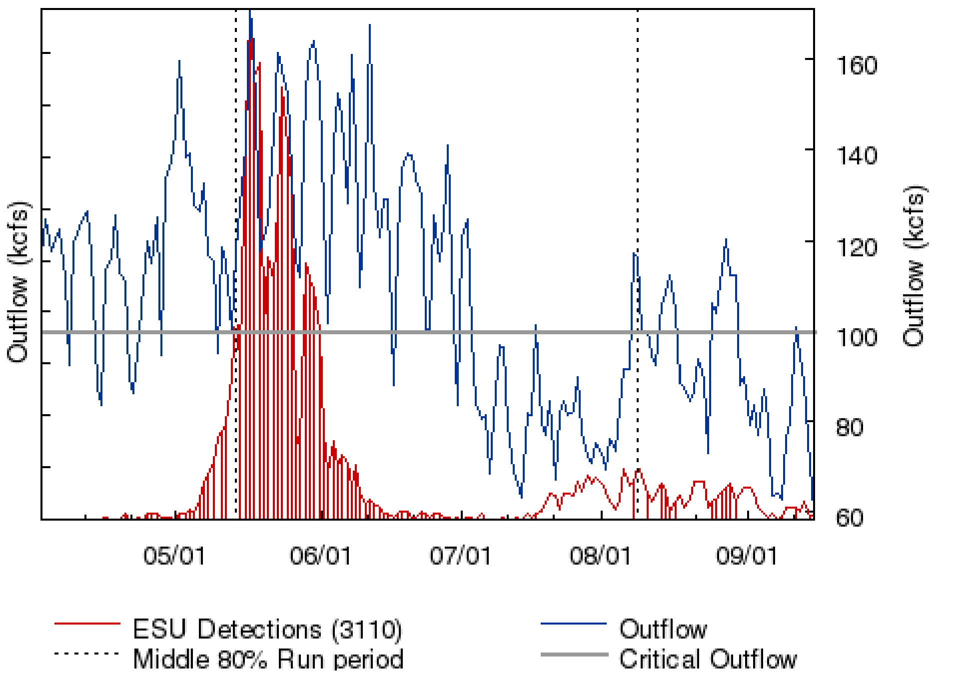
Snake River wild fall chinook have increased dramatically



2001 McNary Outflow
Hatchery Snake R Fall Chinook ESU
85.9% Fish exposed to Outflow above 100 kcfs
90.2% Fish exposed during Middle 80% of Run period



2001 John Day Outflow
Hatchery Snake R Fall Chinook ESU
84.2% Fish exposed to Outflow above 100 kcfs
91.4% Fish exposed during Middle 80% of Run period



Dependence of survival on velocity depends on ratio of migration velocity to random encounter velocity