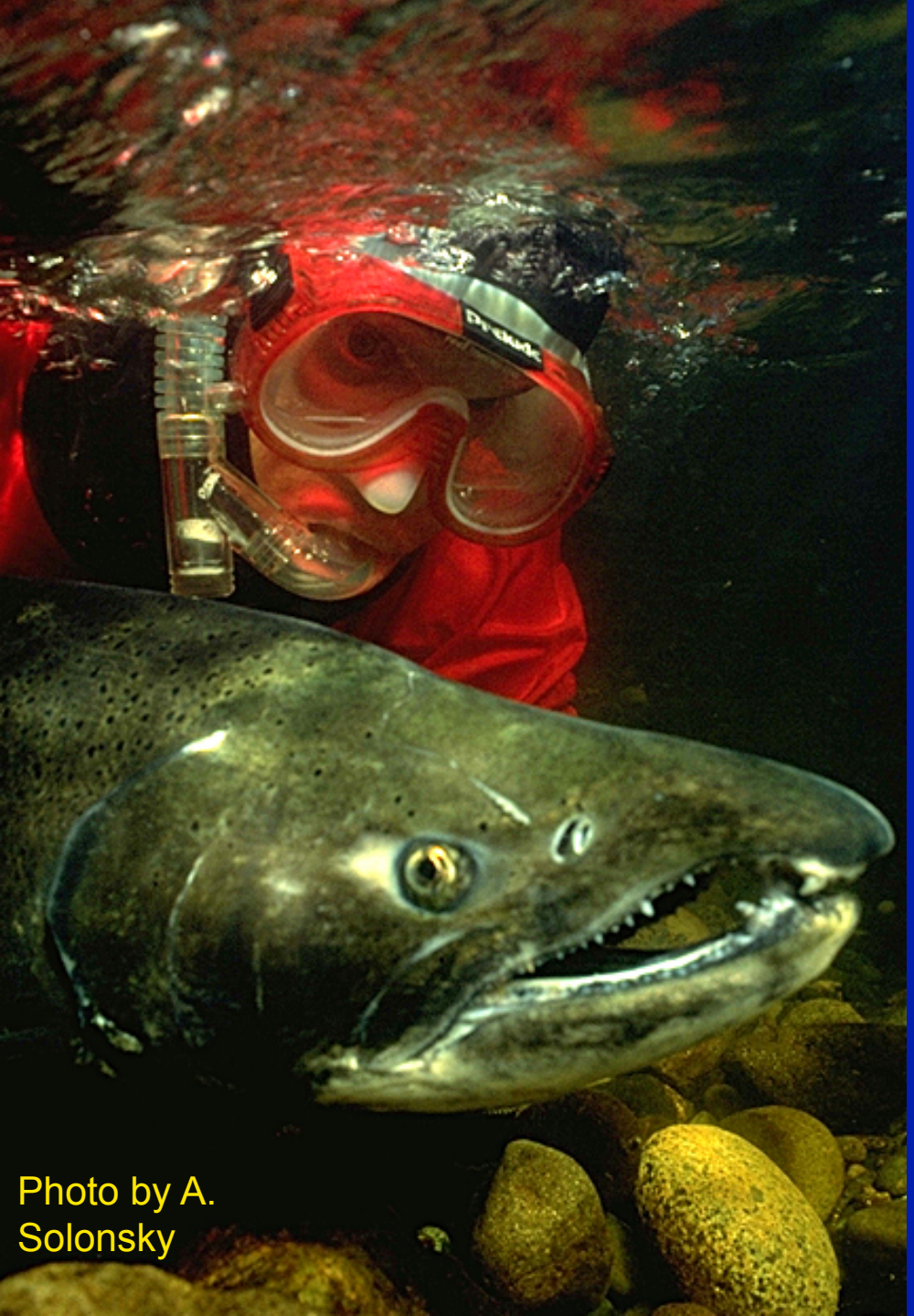


Photo by A. Solonsky

Density-Dependent Growth, Maturation & Survival of Chinook Salmon at Sea

Greg Ruggerone
(NRC, ISAB, ISRP)
Seattle, WA

Columbia River Food Webs:

Developing a Broader Scientific Foundation for Fish and Wildlife Restoration

Independent Scientific Advisory Board

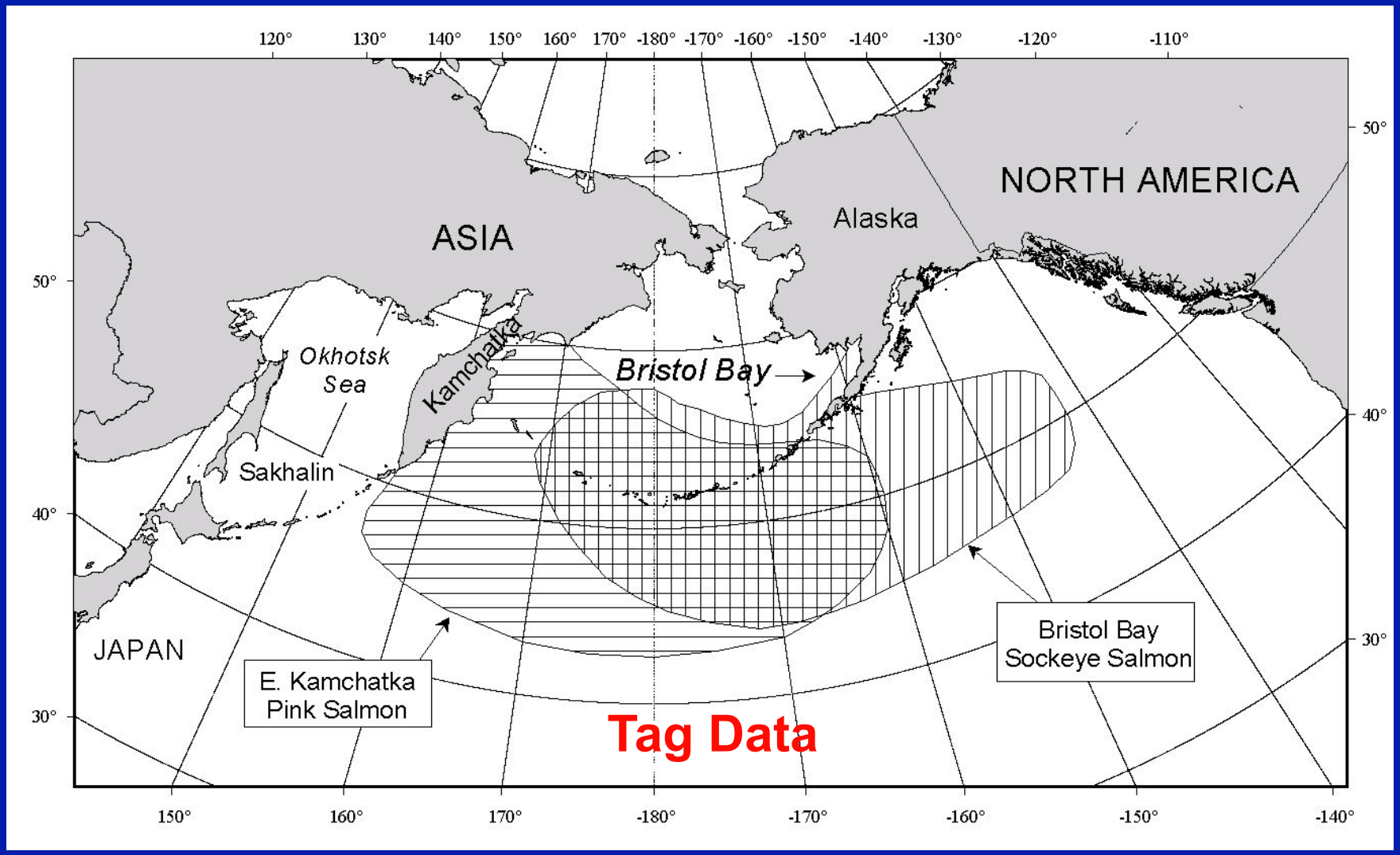
www.nwcouncil.org/library/isab/2011-1/

Outline

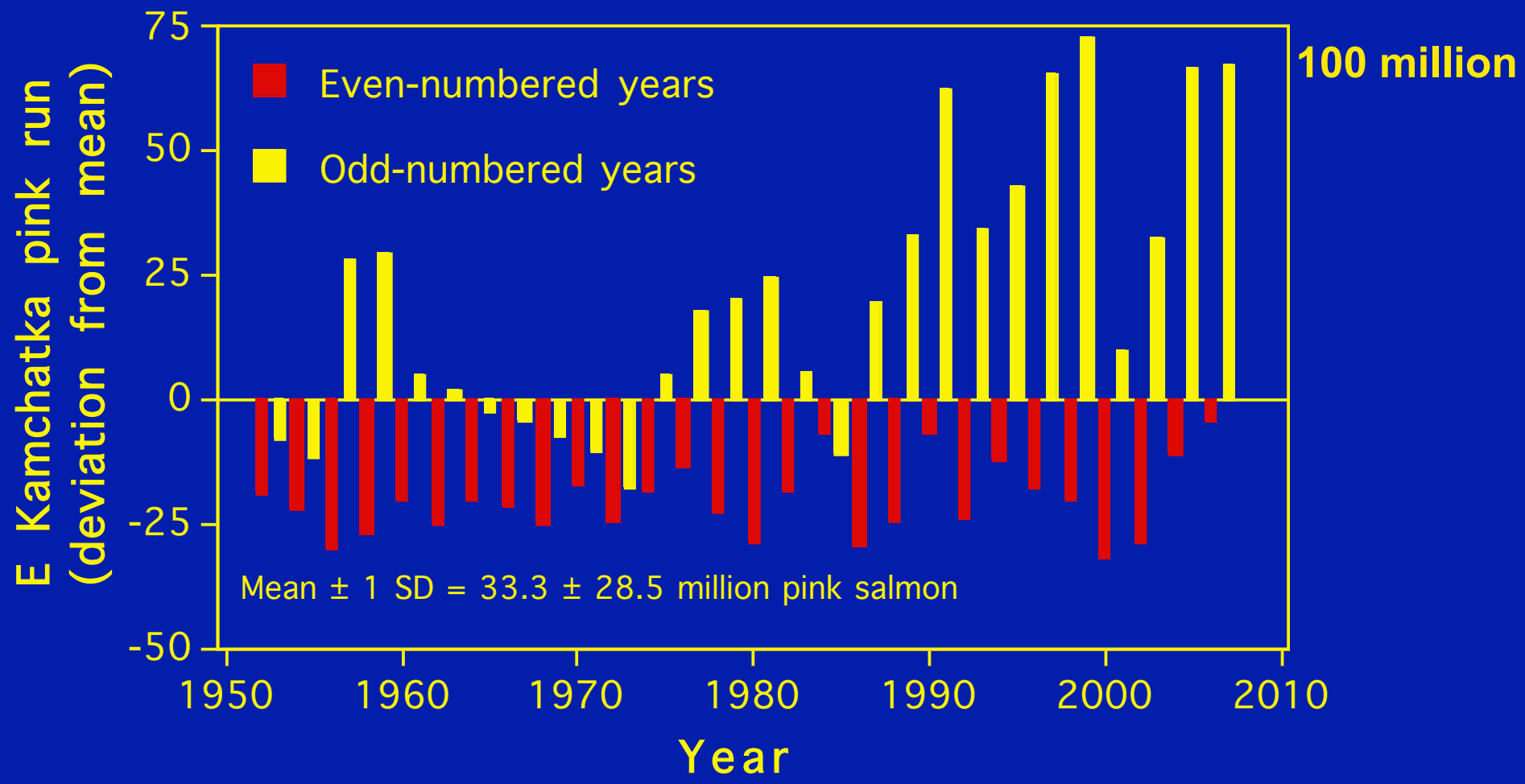
- Evidence for density-dependence at sea
  - Alaska & Fraser sockeye
  - Puget Sound Chinook
  - Columbia R Chinook
    - Ocean effects on growth
    - Density dependence

- Western Alaska Chinook
  - Growth dependent on earlier growth
  - Growth, age at maturation, survival
  - Gender

Overlap of E Kamchatka Pink & Bristol Bay Sockeye salmon

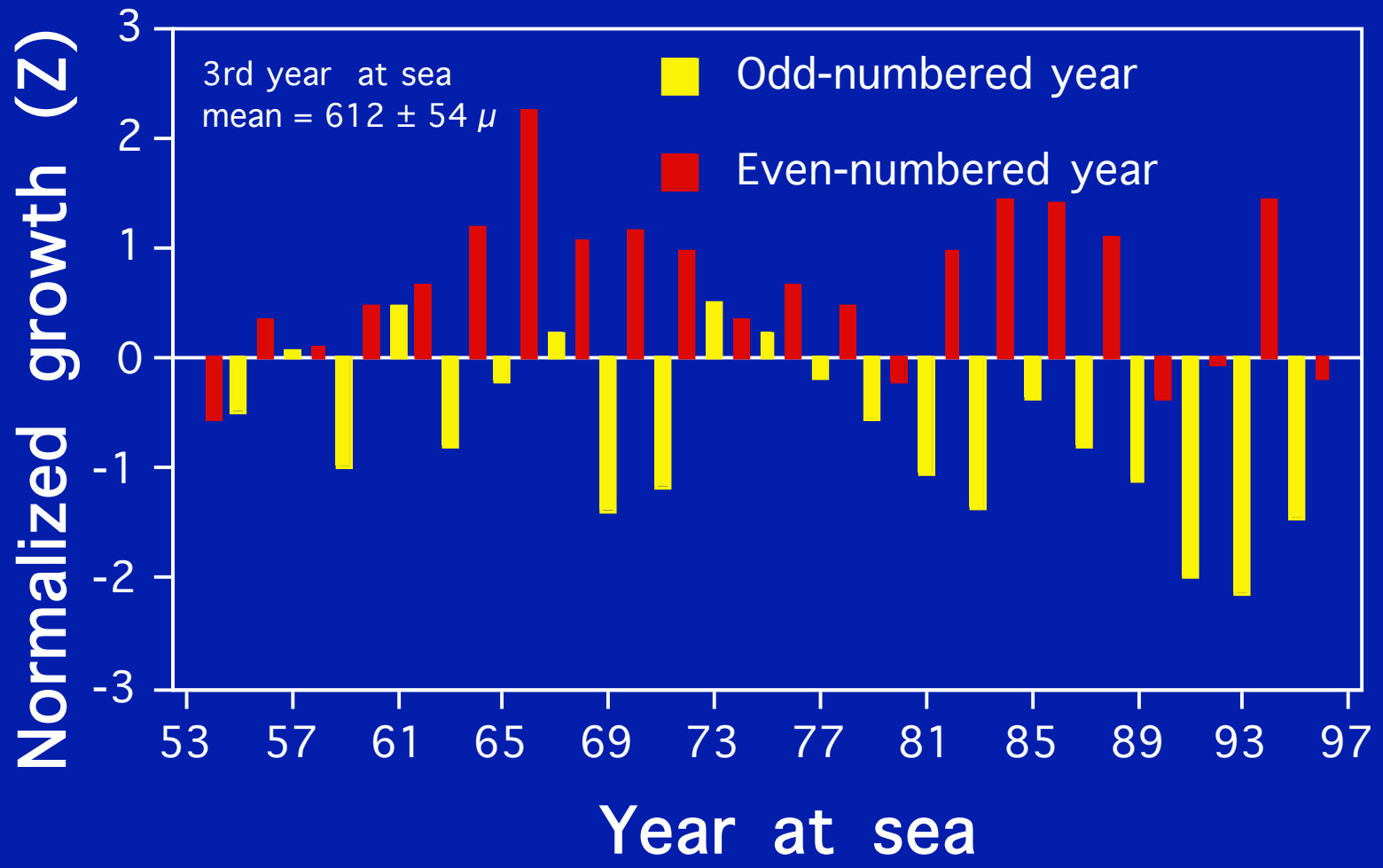


Eastern Kamchatka Pink Salmon Runs, 1952-2007
Natural Experimental Control



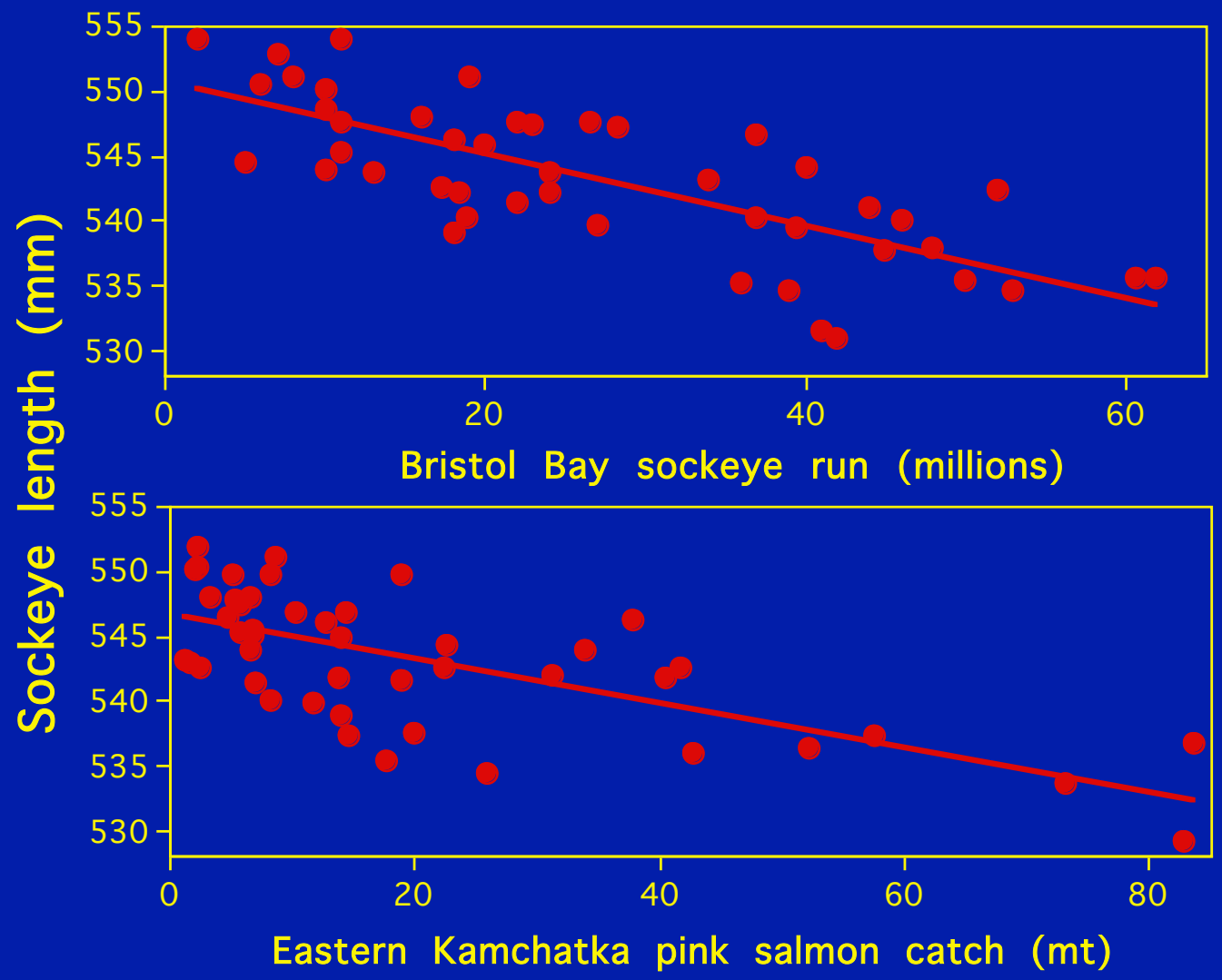
Odd-year pink salmon 39x more abundant in Bering Sea (Davis et al. 2005)

Sockeye growth reduced during odd years at sea (2nd & 3rd yrs)



Odd-year pink salmon 39x more abundant in Bering Sea (Davis et al. 2005)

Sockeye Length vs Sockeye & Pink Abundance, 1958-2003

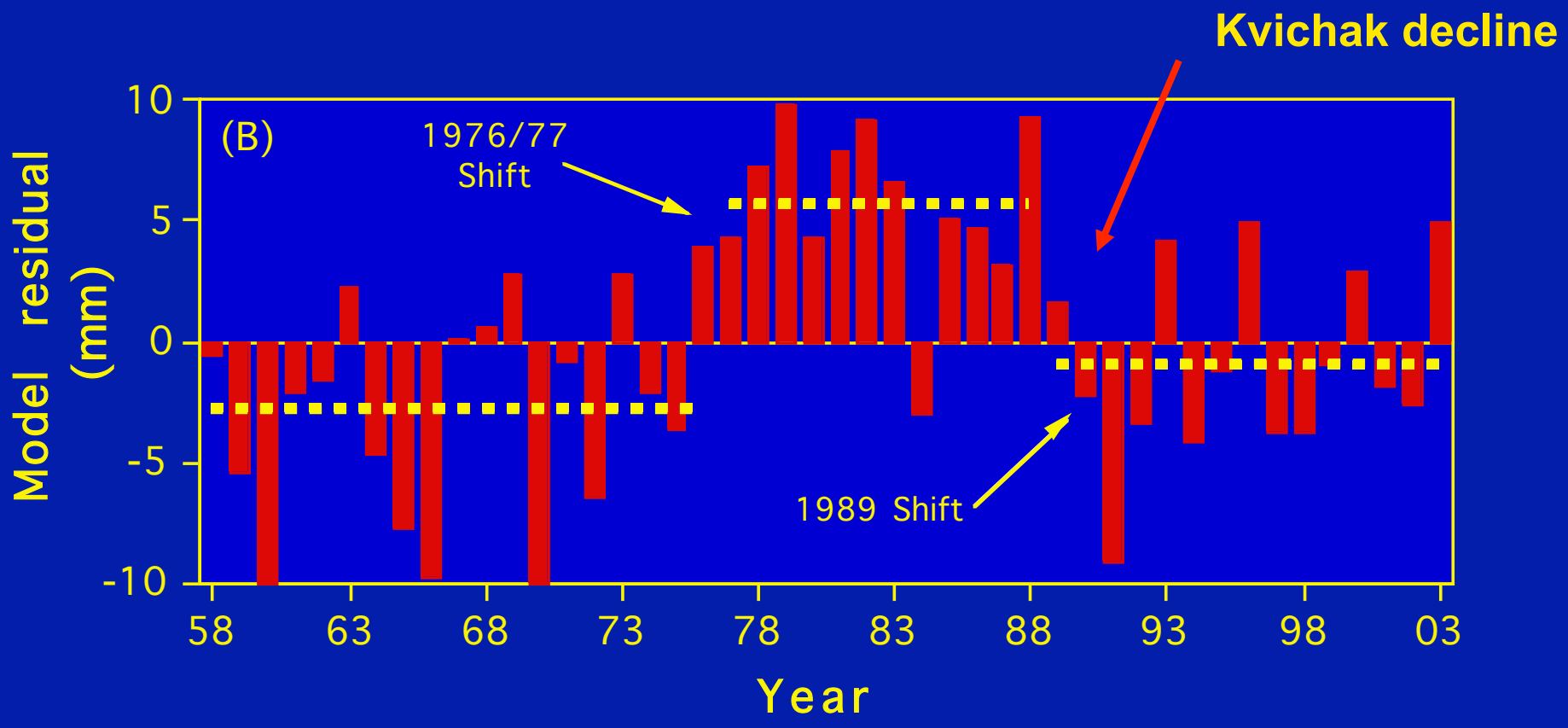


L (mm) = 550.0 - .275(sockeye) - .170(pink) + 10.3(period: 77-88) + 4.4(period: 89-03)

Ruggerone et al. 2007

Climate, Competition & Sockeye Length-at-Age

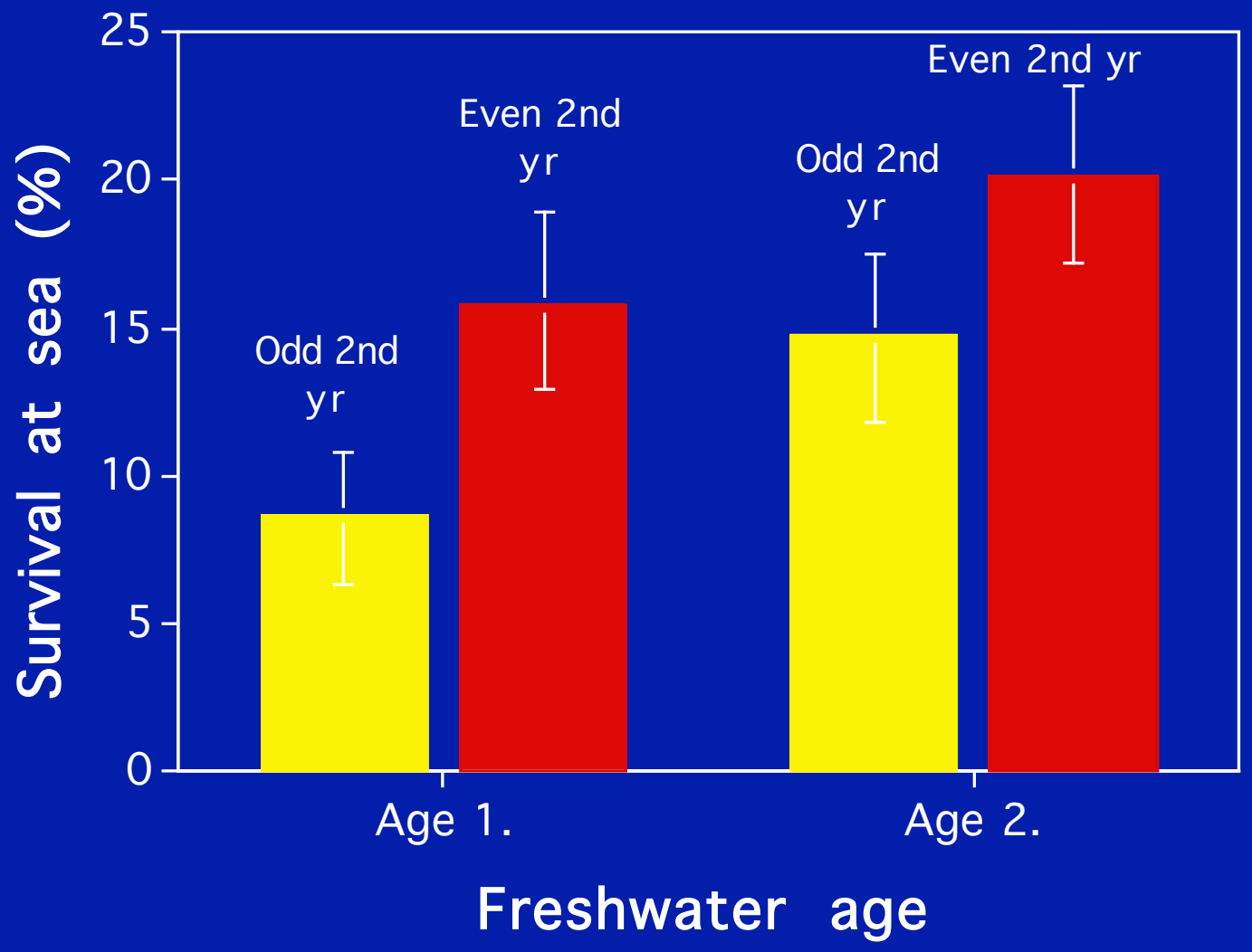
$L = 550.9 - .178(\text{sockeye}) - .144(\text{pinks}),\ r^2 = .40$



Ruggerone et al. 2007

Smolt to Adult Survival, 1977-1997

Age-1:
-45%
when
pinks

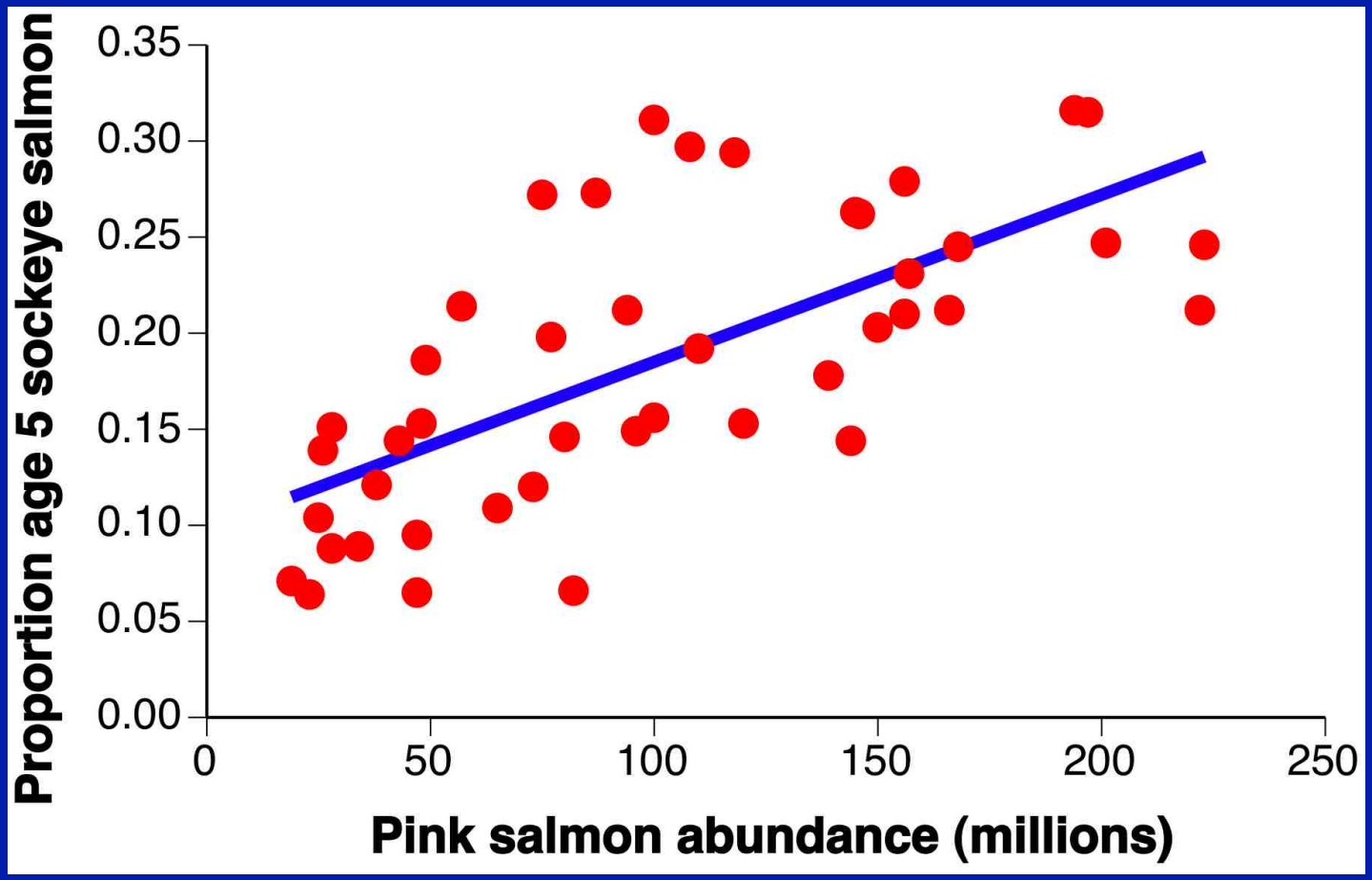


Age-2:
-26%
when
pinks

Ruggerone et al. 2003

Do Pink Salmon Adversely Affect Fraser River Sockeye Salmon?

Age at Maturation Increases with Pink Salmon

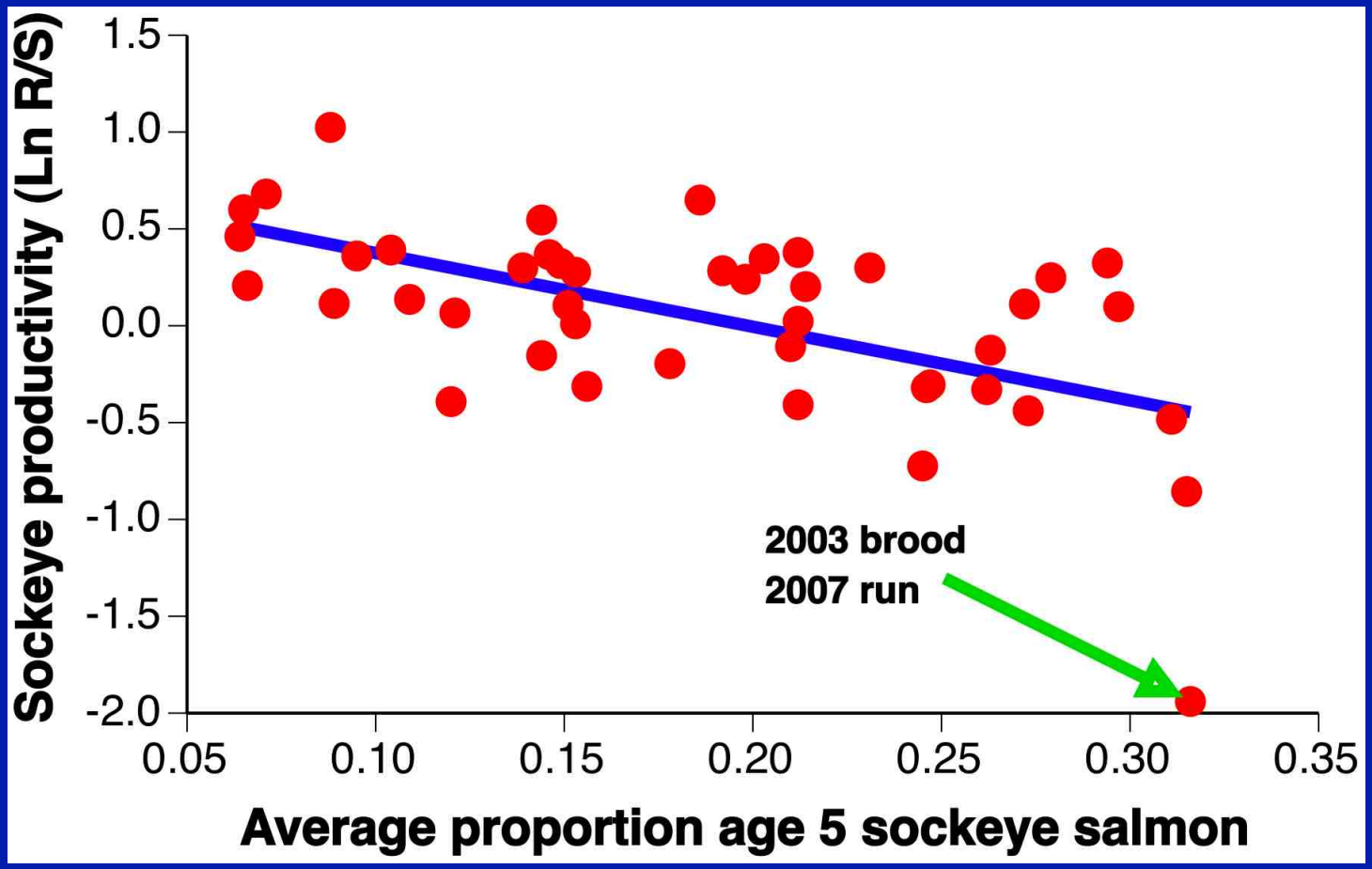


Sockeye length inversely related to pink & sockeye abundance

Mean of 16 sockeye stocks
BY 1961-2004

Same pattern in Bristol Bay

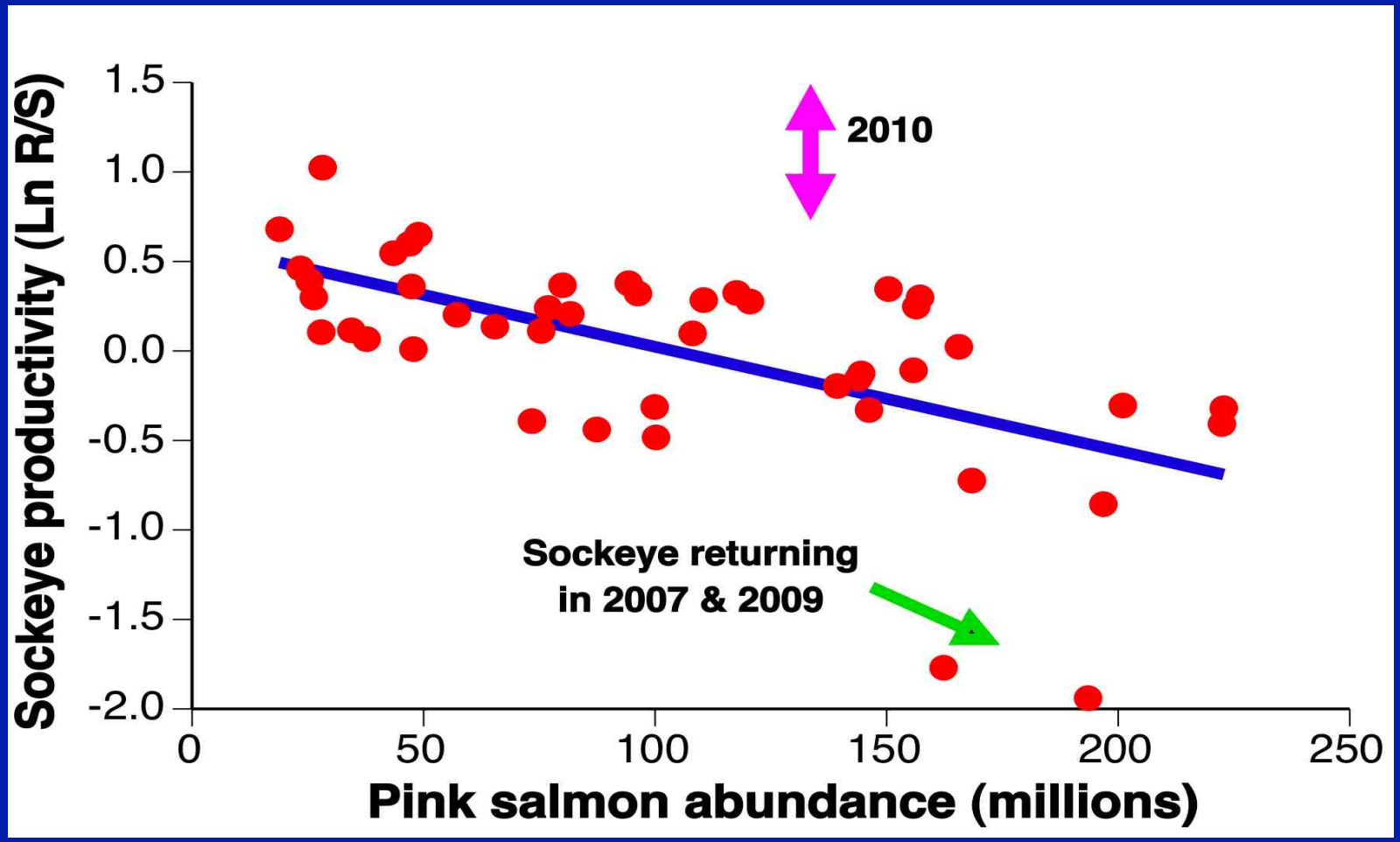
Sockeye Productivity Declines with Older Age



Same pattern in Bristol Bay

Sockeye Productivity v. North American Pink Abundance

16 stocks



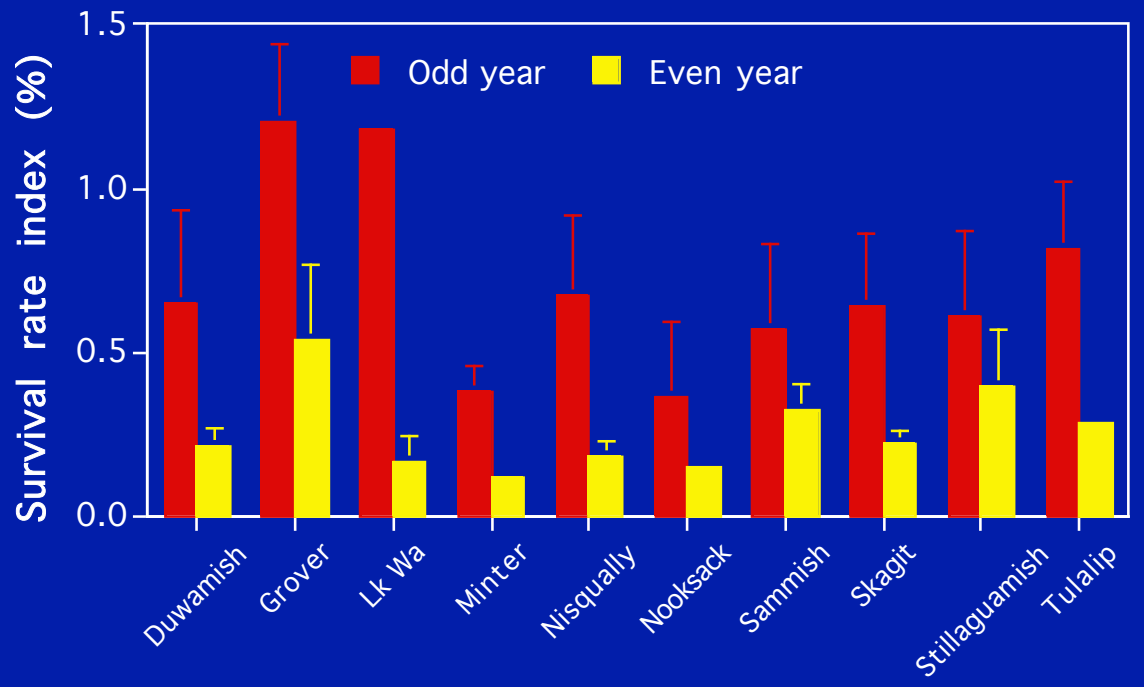
16 sockeye stocks (excl. Harrison & Shuswap) BY 1961-2005

Climate-induced competition between Puget Sound Chinook & pink salmon

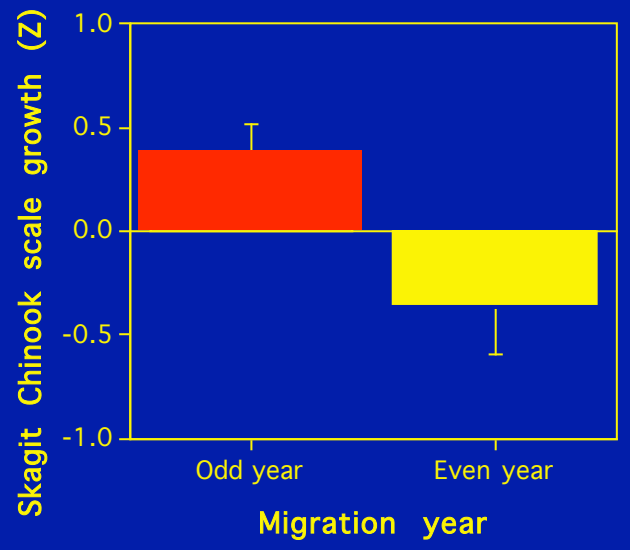
- 53.5 million coded-wire tags, 1972-1997.
- Release to recovery survival rates.
- Early marin growth.
- Age at maturation.

Chinook Survival 62% Lower when Migrating in Even Years w/ Pinks, 1984-97

Survival



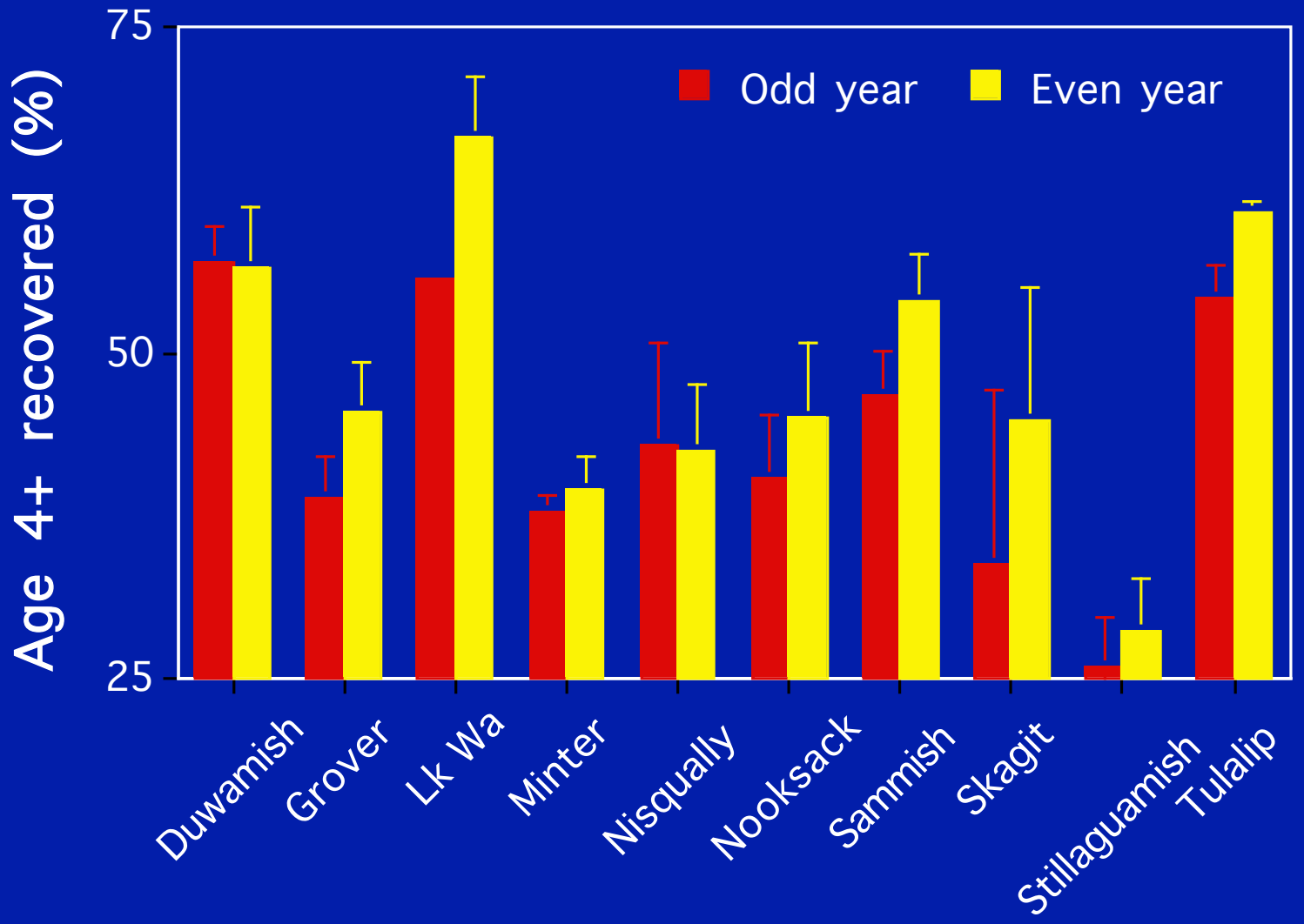
Growth



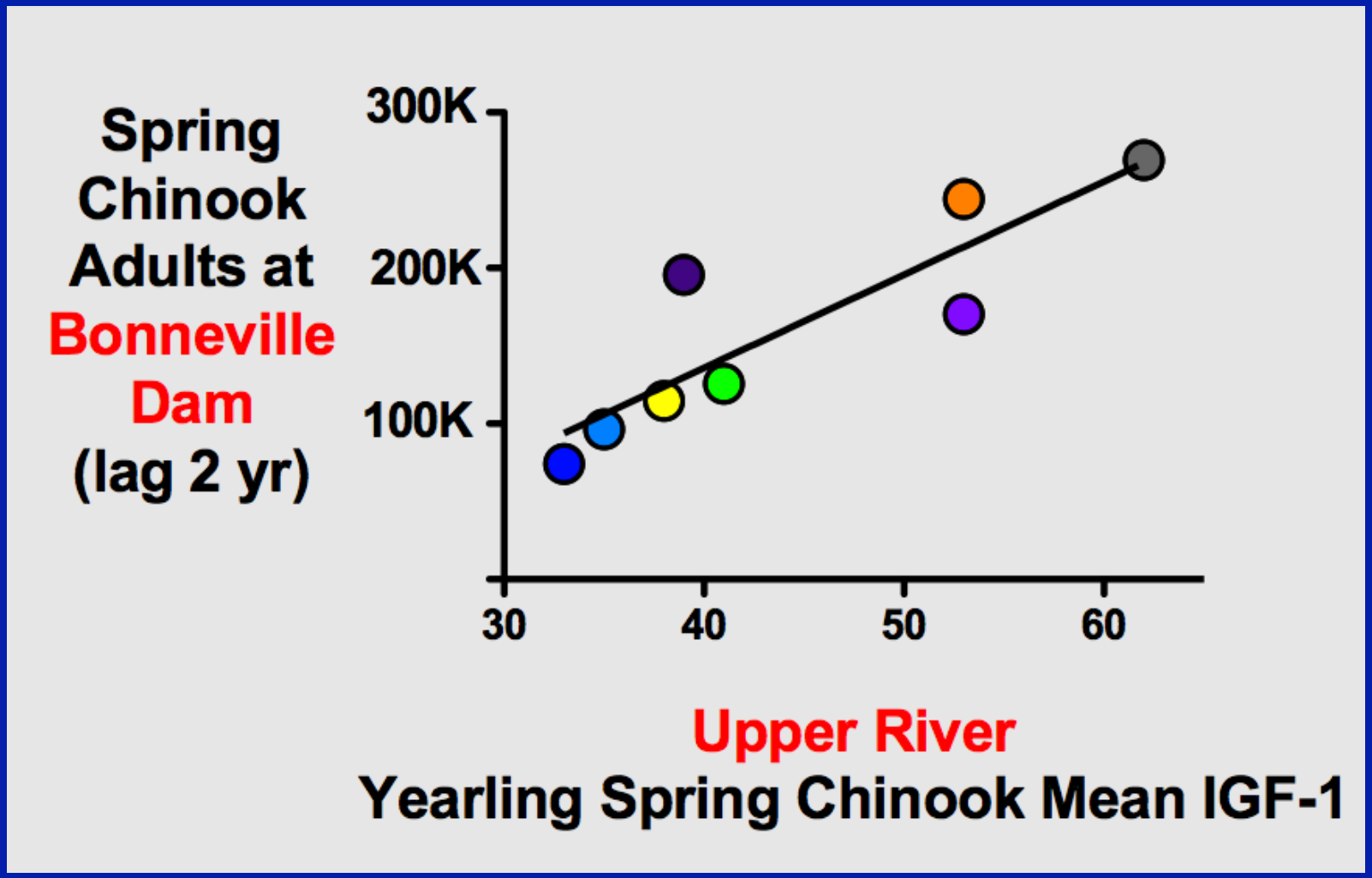
Ruggerone & Goetz 2004

Unpublished scale analysis

Age at Maturation Delayed:
Even-Year Smolts, 1984-97



Adult spring Chinook salmon abundance is related to growth of juveniles



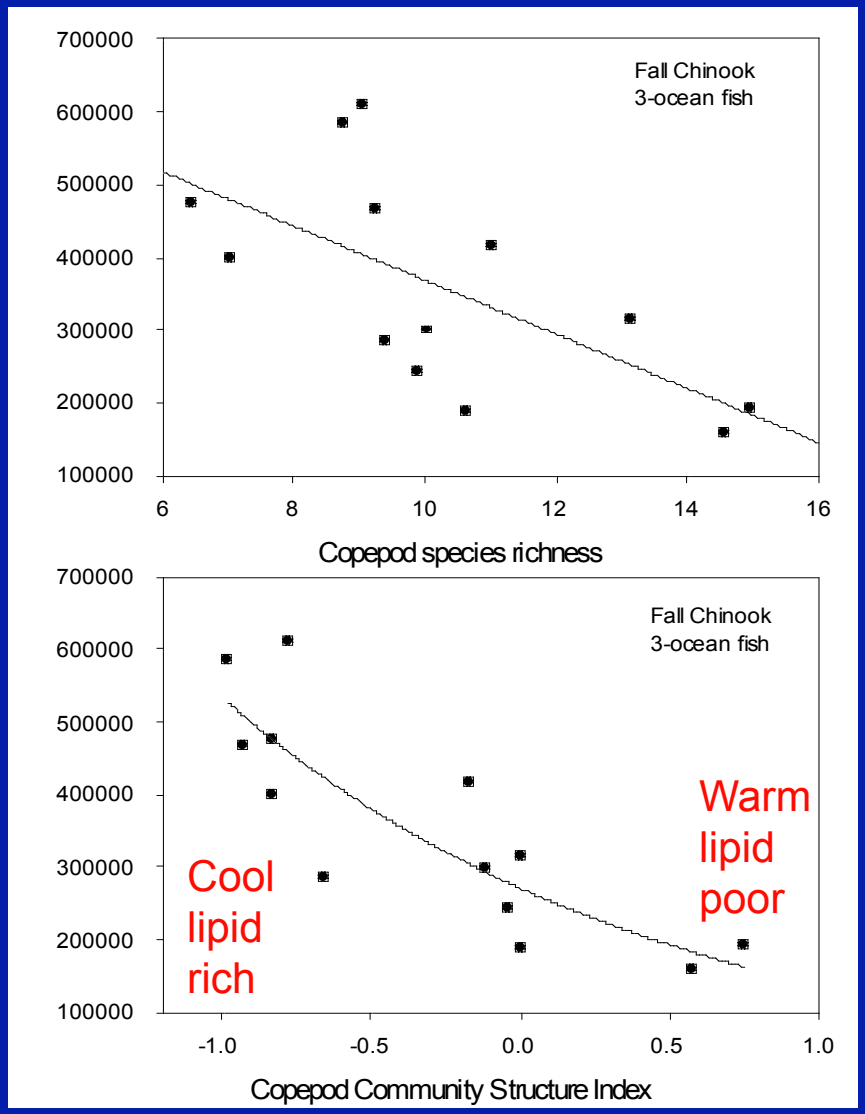
$r^2 = 0.77$
$p = .004$

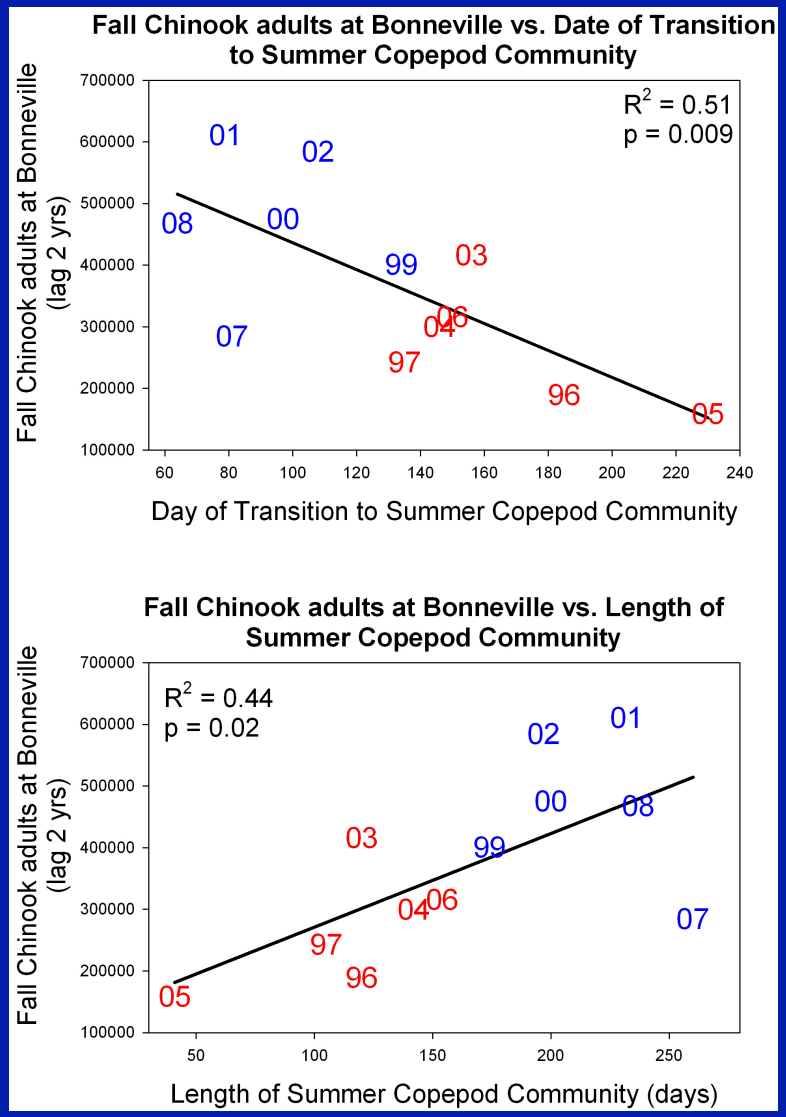
IGF-1 not related to CPUE

Years: 2000 to 2009

Beckman et al. unpublished
NOAA Fisheries, Seattle

Columbia Fall Chinook versus copepod indices

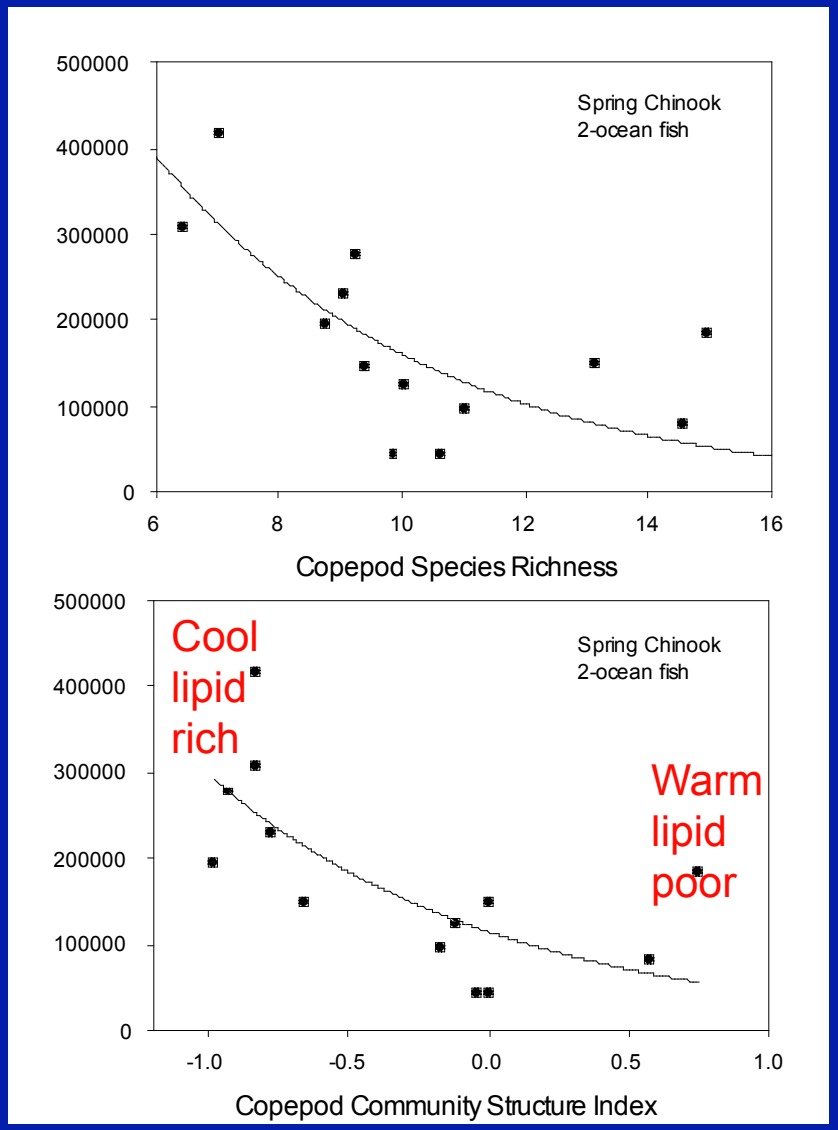


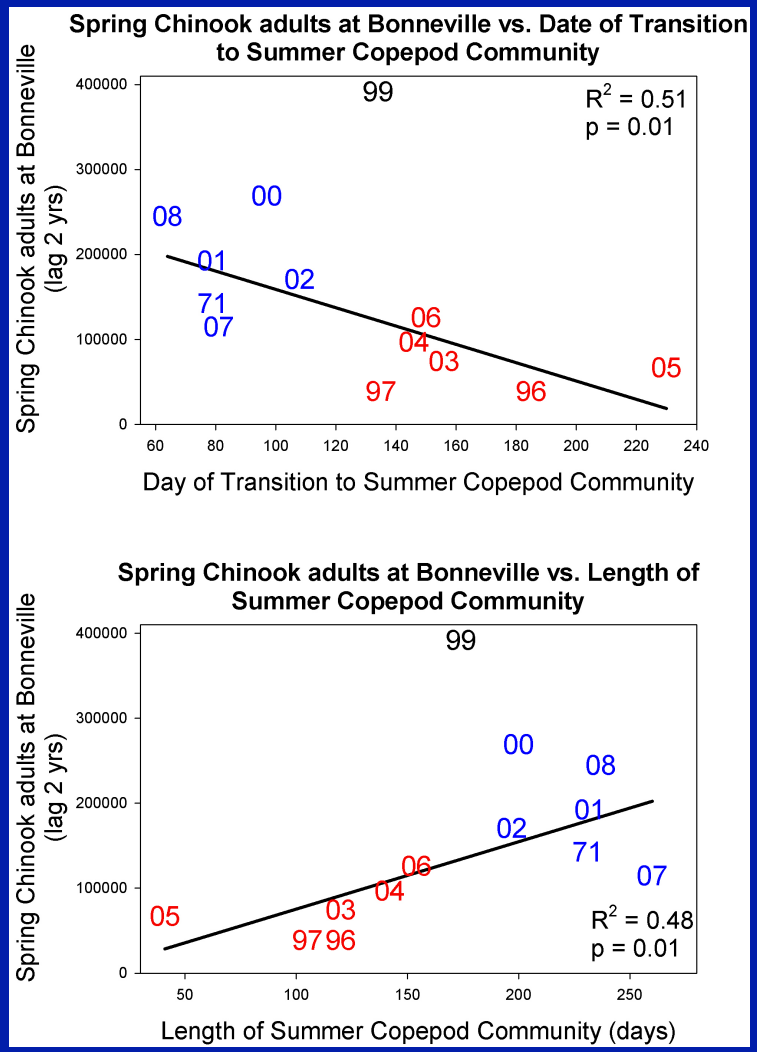


Bill Peterson, NMFS

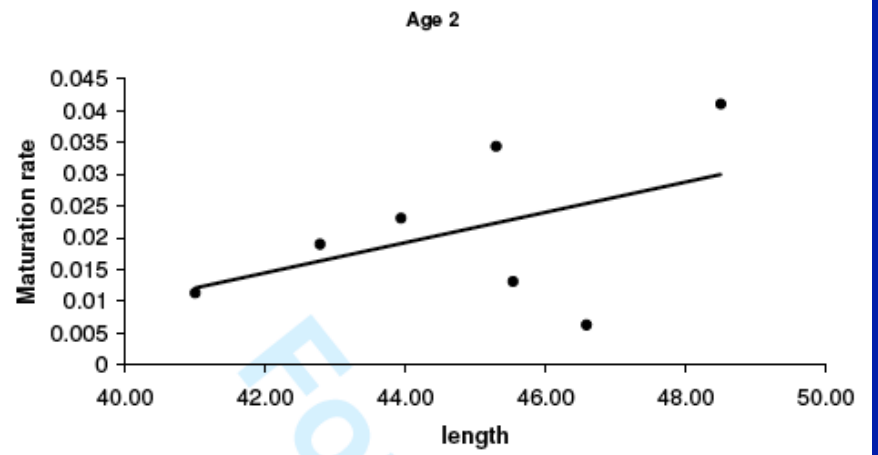
See NMFS web site

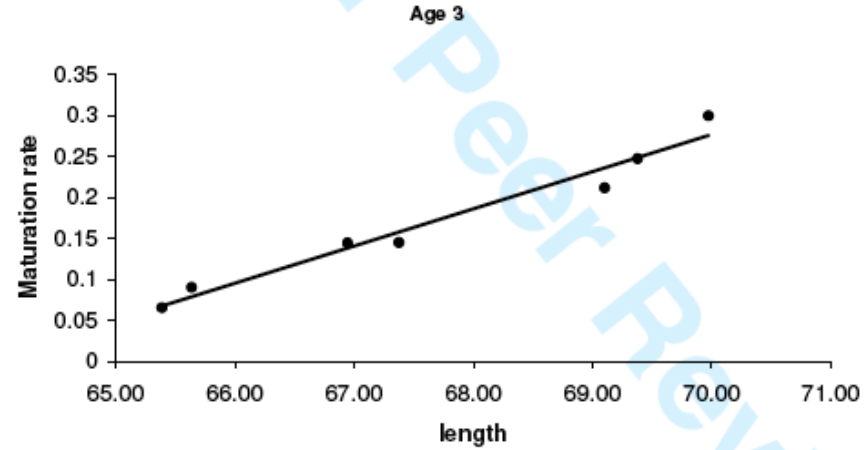
Spring Chinook versus copepod indices

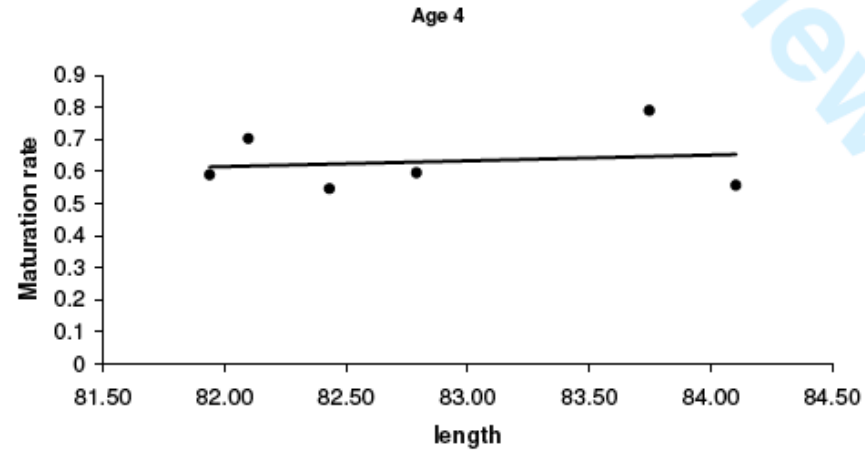




Bill Peterson, NMFS







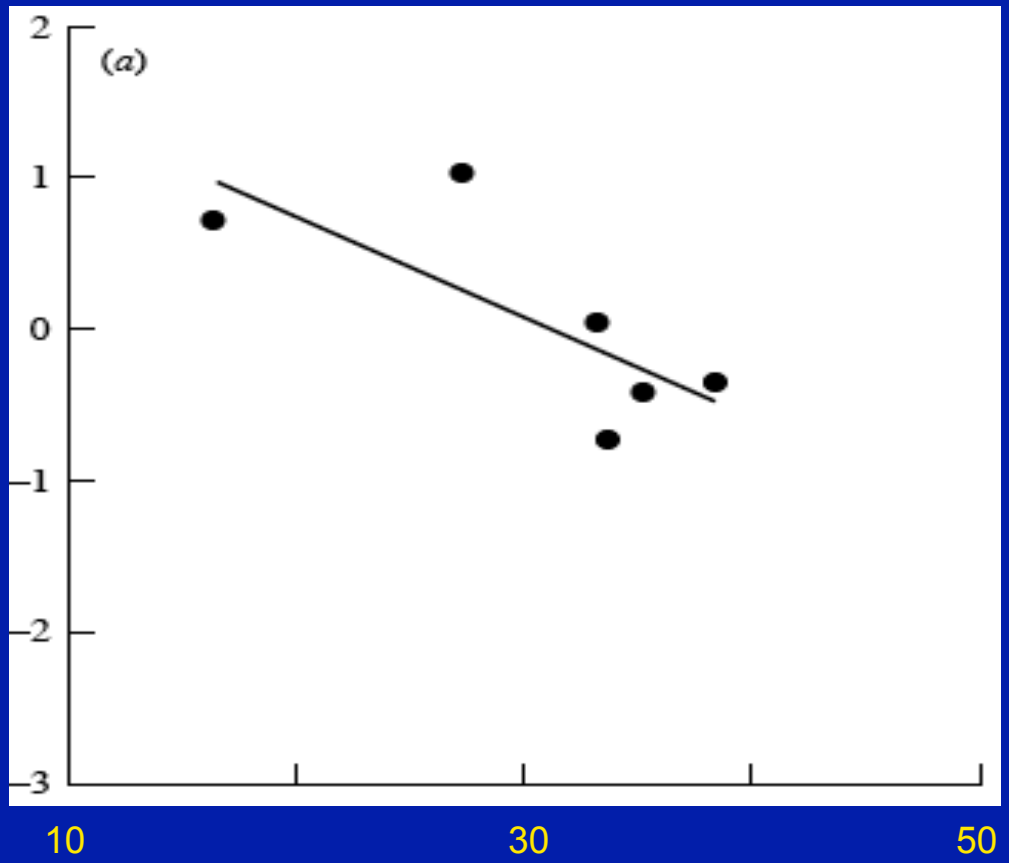
For Peer Review

Early maturation of Chinook is linked to greater length at Bonneville

Rishi Sharma
CRITFC

Columbia R Chinook: Density-dependent survival

Log survival wild spring Chinook



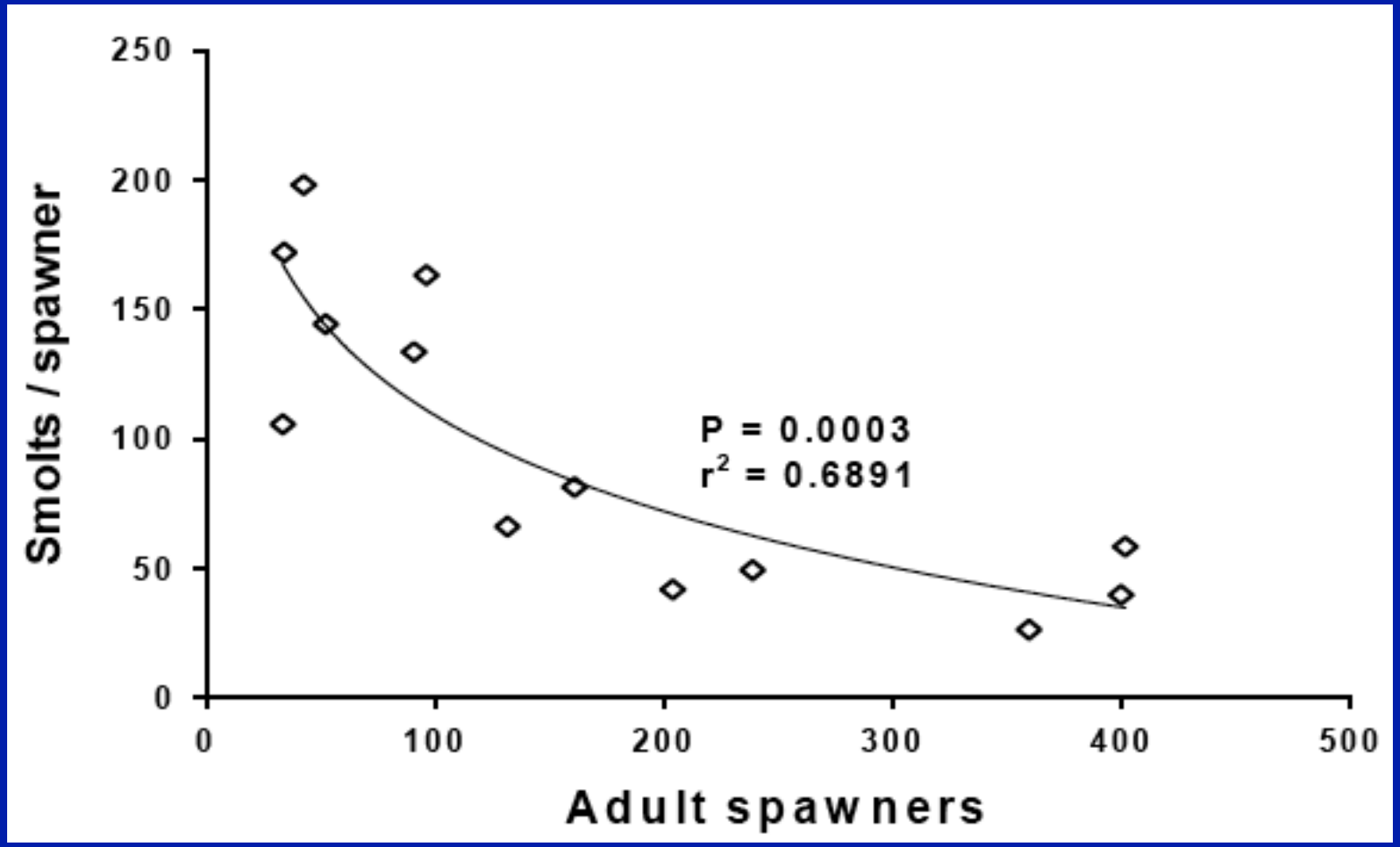
Excludes years of high ocean productivity (oyster condition index)

Release hatchery spring Chinook (millions)

1975-1995

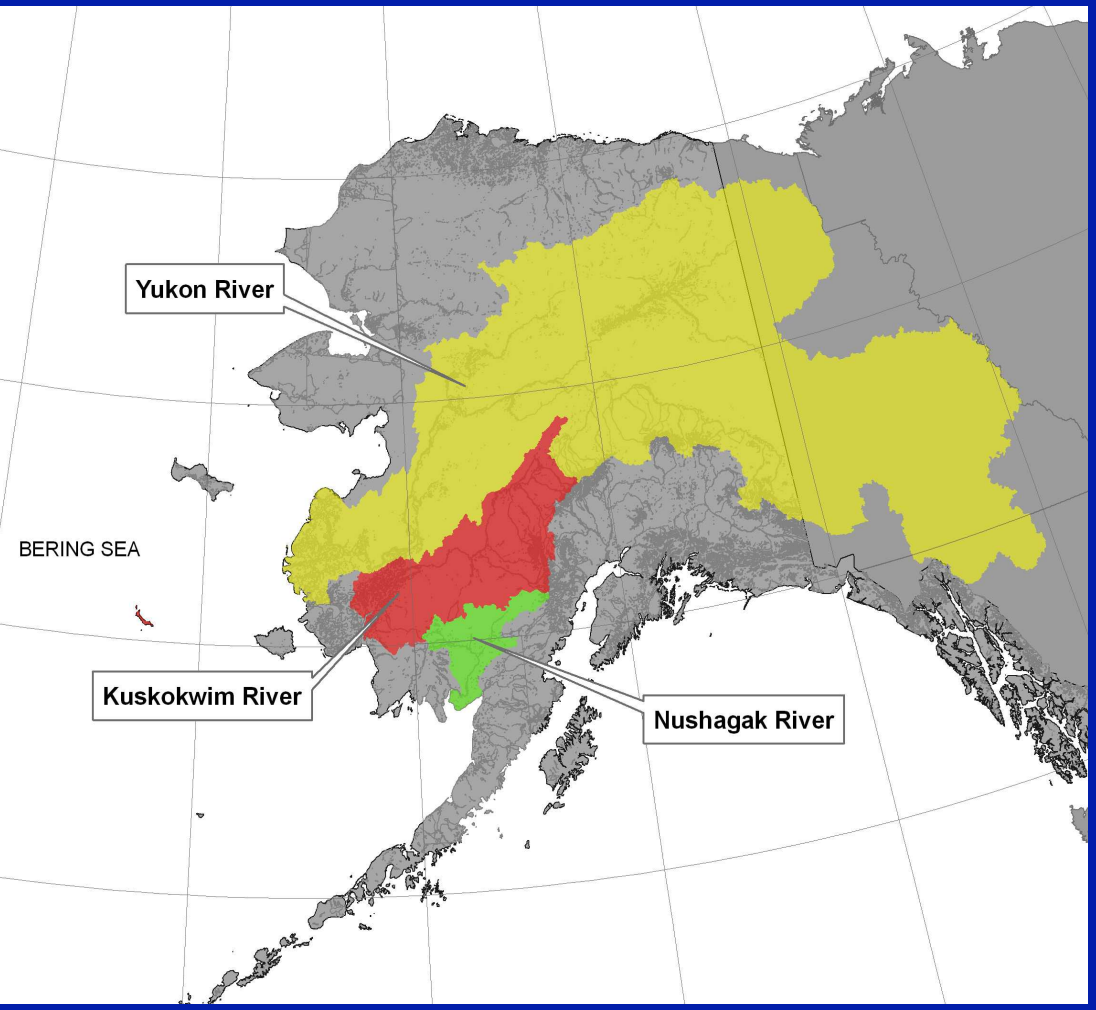
Levin et al. 2001

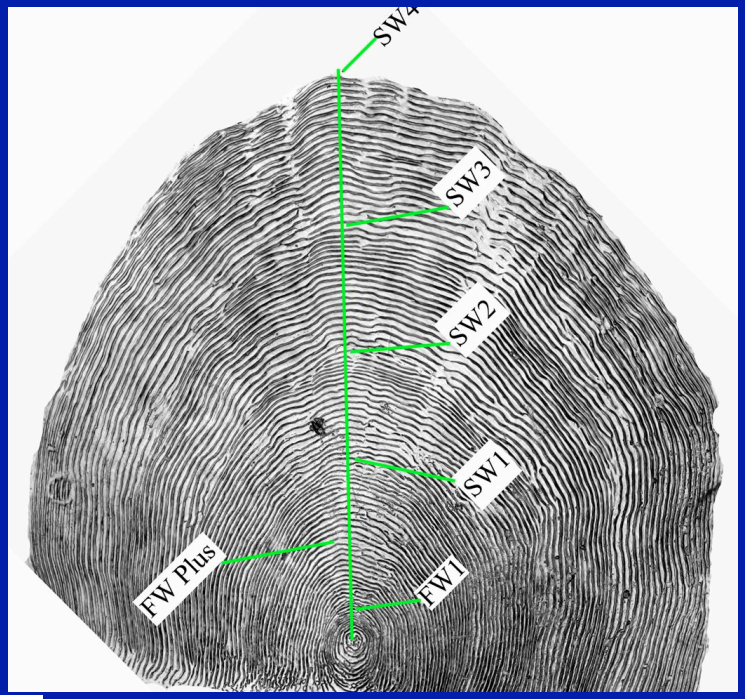
Density-dependence: Catherine Cr spring Chinook

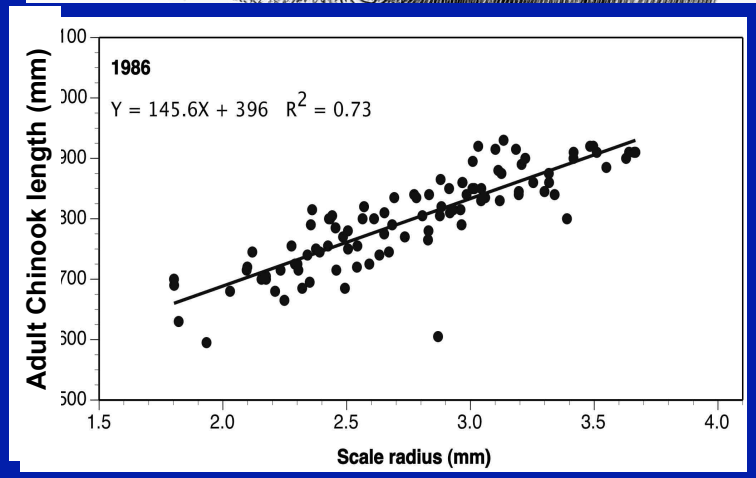


Carmichael et al., unpublished, LSRCP

Growth Characteristics of Yukon & Kuskokwim Chinook Salmon

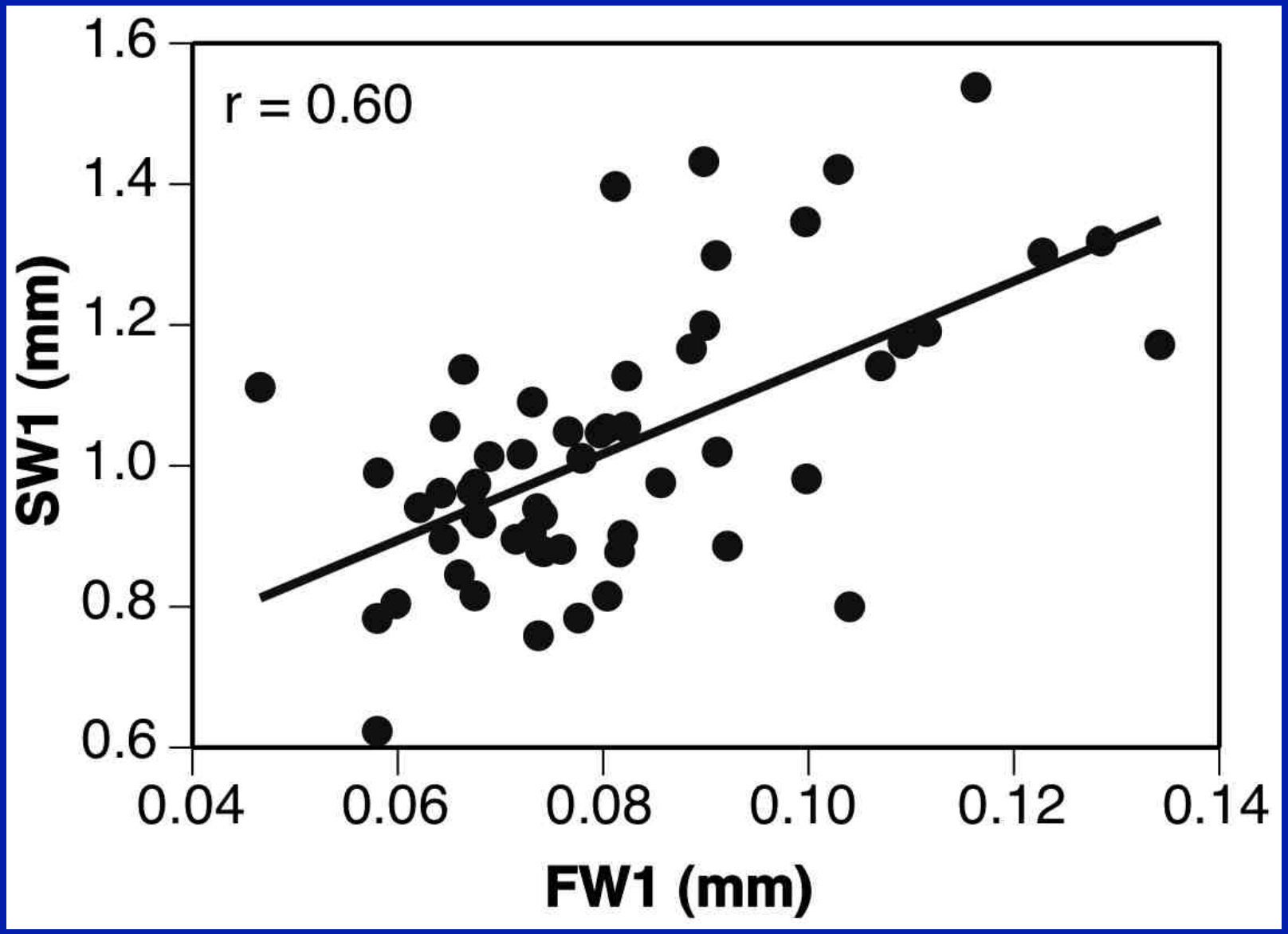






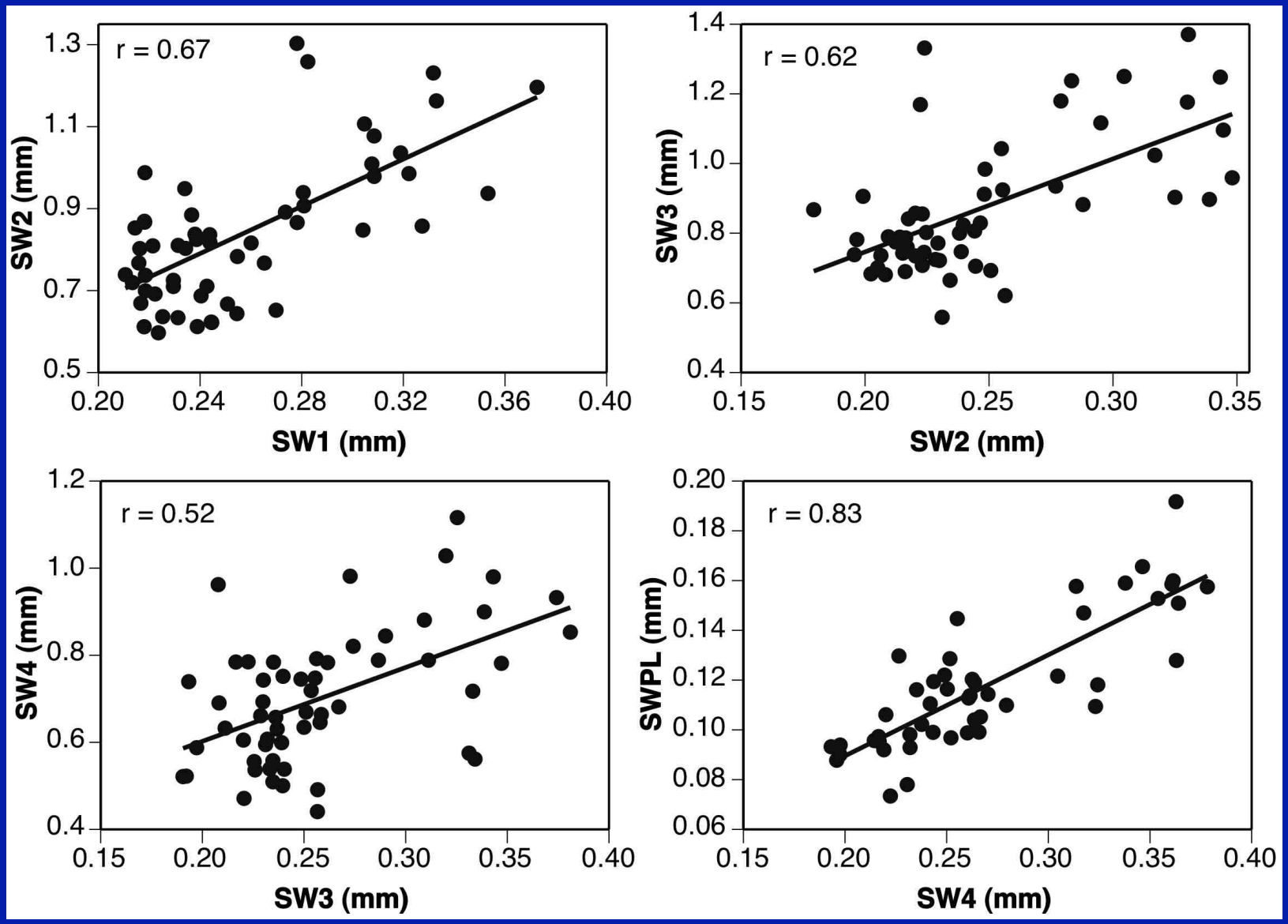
Chinook Ocean Growth is Dependent on Freshwater Growth

Year: 1991



Ruggerone et al. 2009

Chinook Growth at Sea Dependent on Previous Growth Consistent for Yukon & Kuskokwim Chinook



Ruggerone et al. 2009

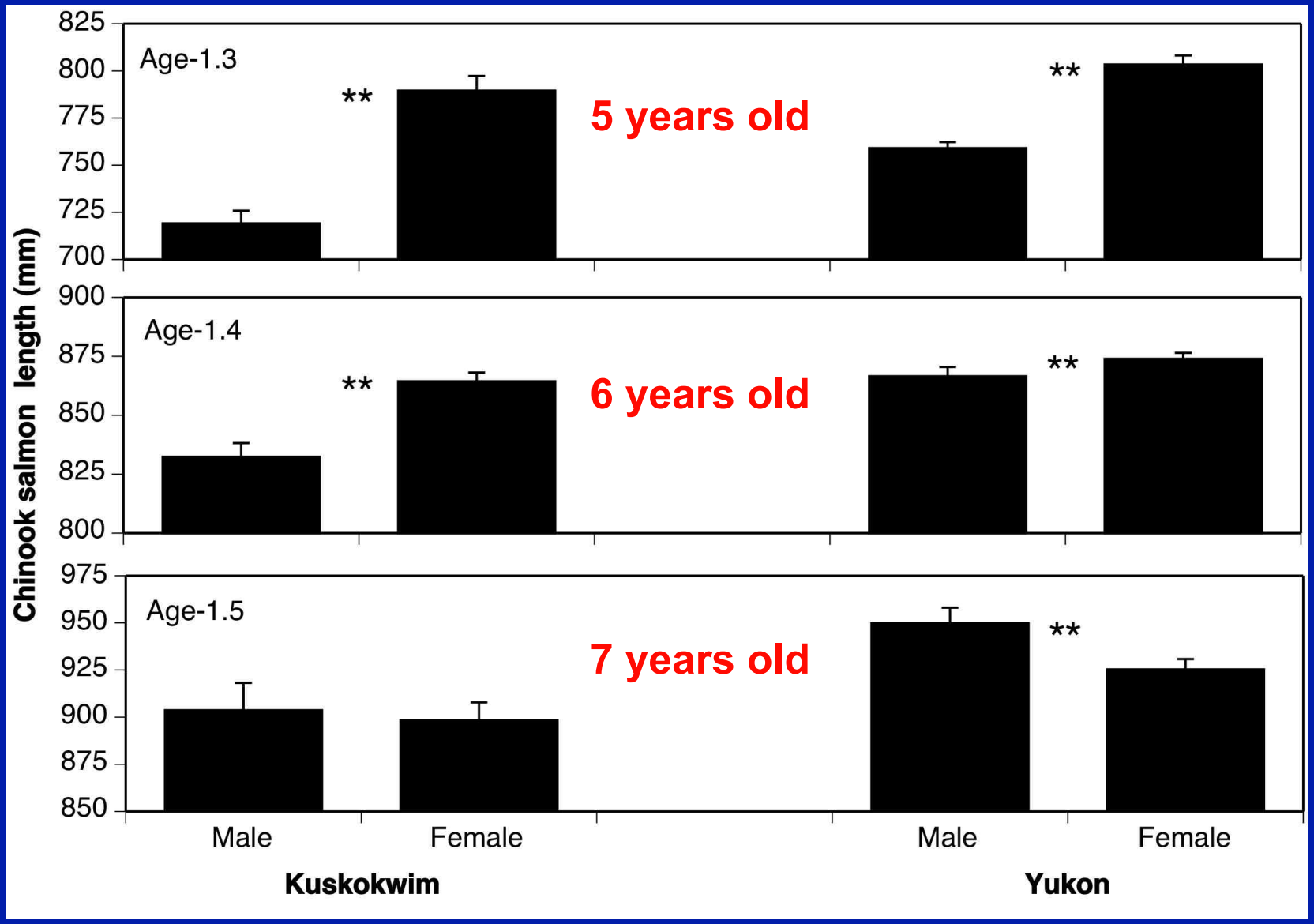
Chinook Growth & Life History

Are Male Chinook Bigger than Female Chinook at Age?

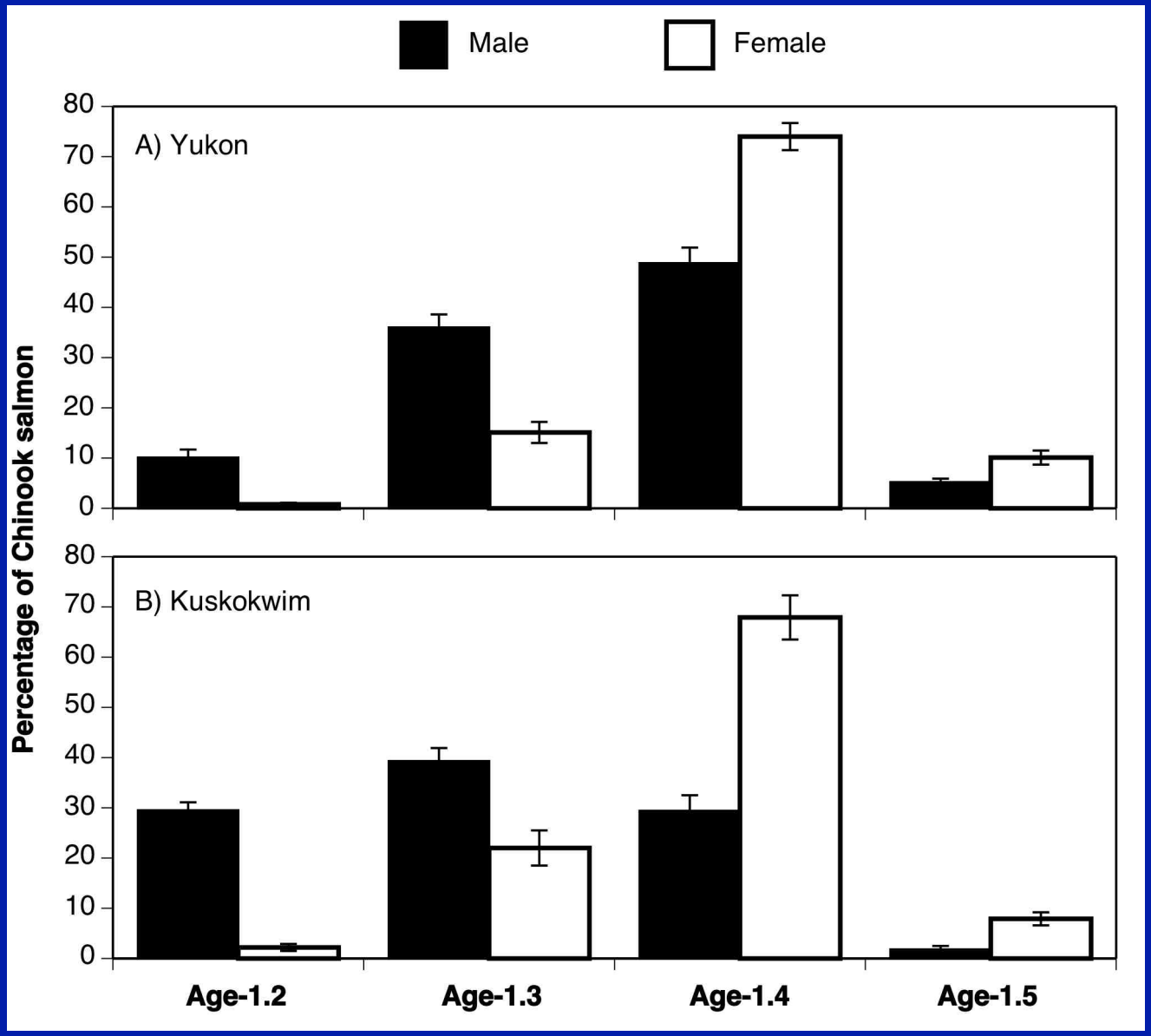
- Sockeye male > female at age.
- Chum male > female at age.
- Coho male < = female (Holtby & Healey 1986).

- Chinook Length at Age?

Female Length > Male Length



Female Chinook are older



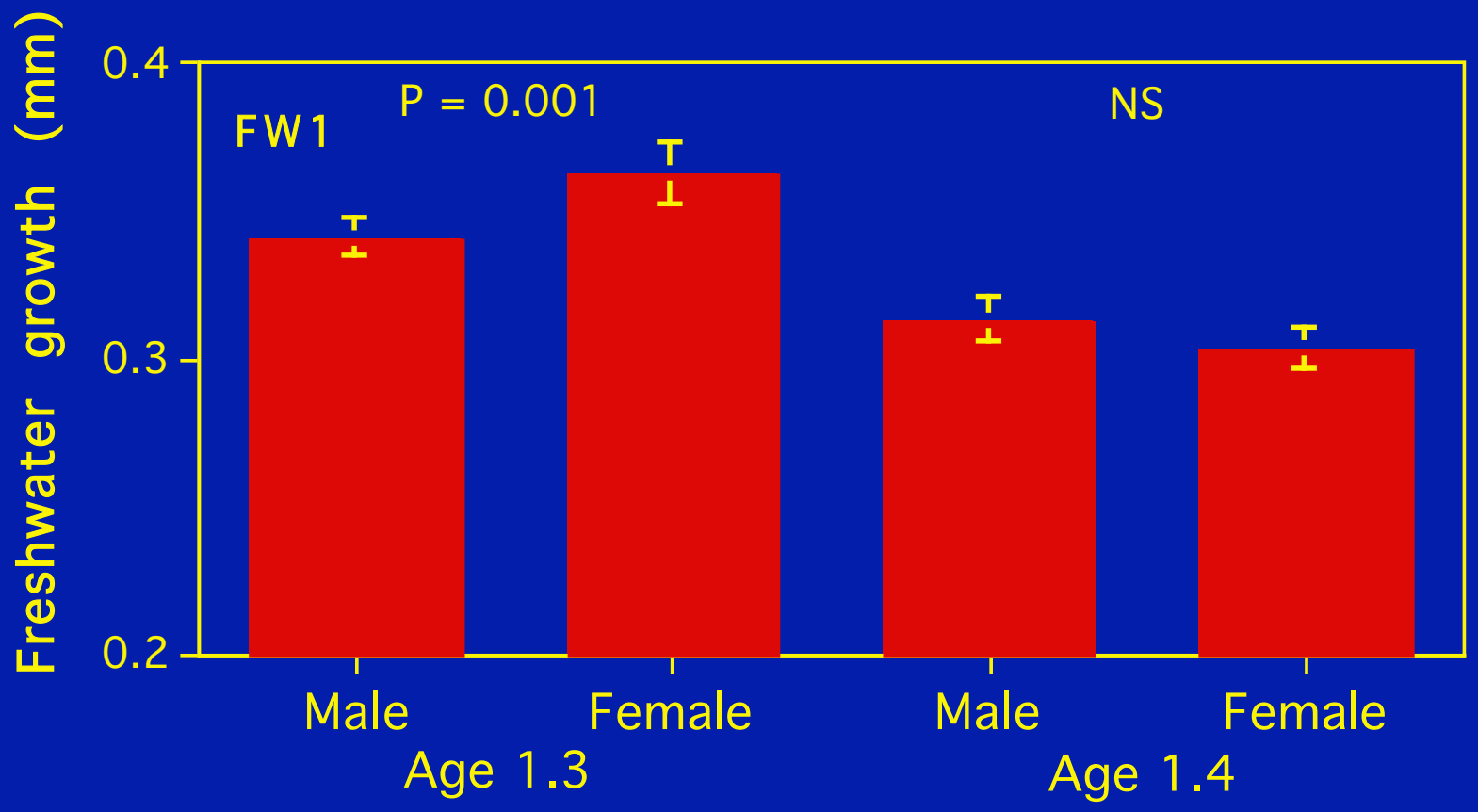
Growth/maturation differs among male and female Chinook

Lower river ASL, 1965-2004, large mesh only

Differential Growth Begins in Freshwater

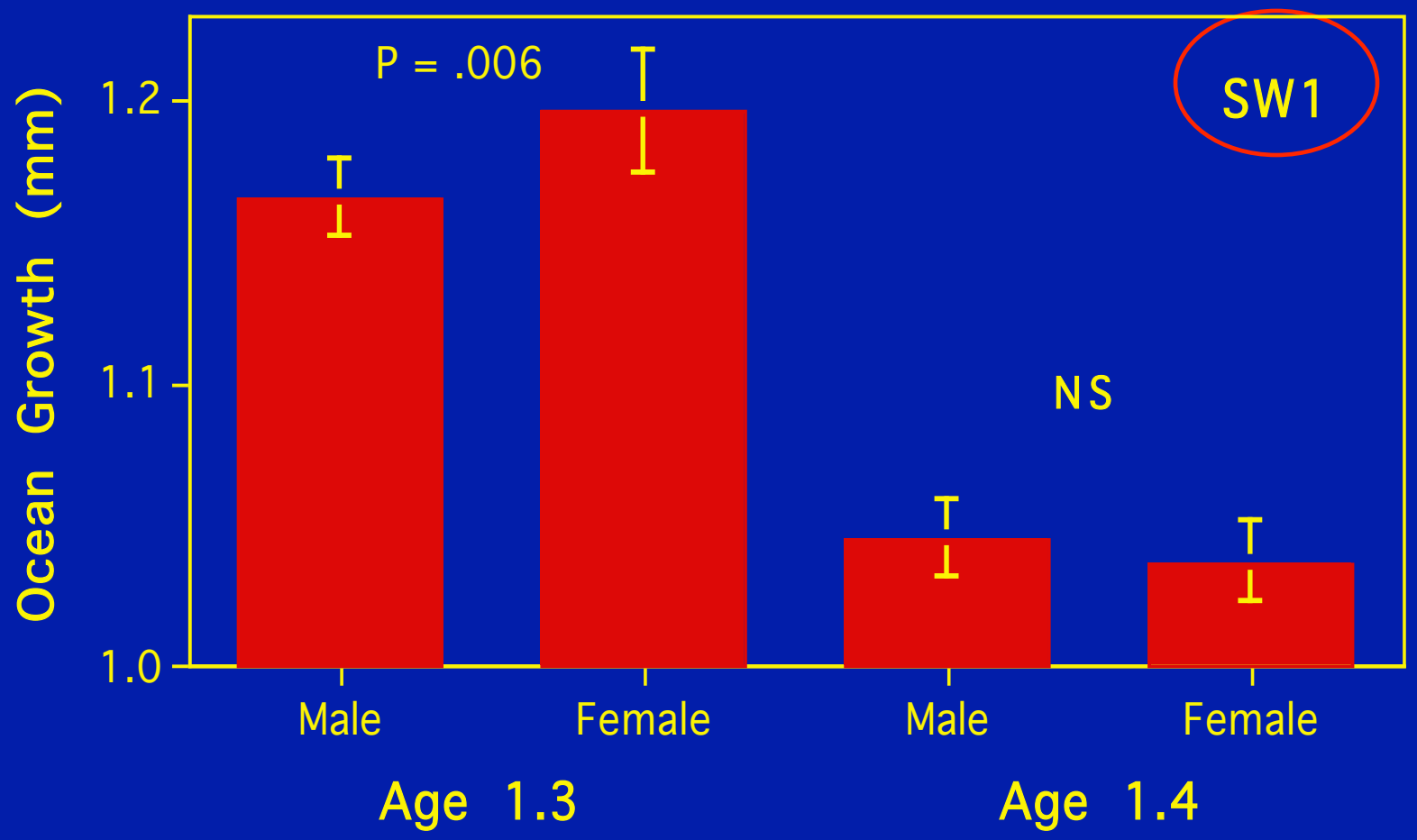
Age 1.3 > Age 1.4 freshwater growth

Age 1.3 Female > Male; Age 1.4 Female = Male



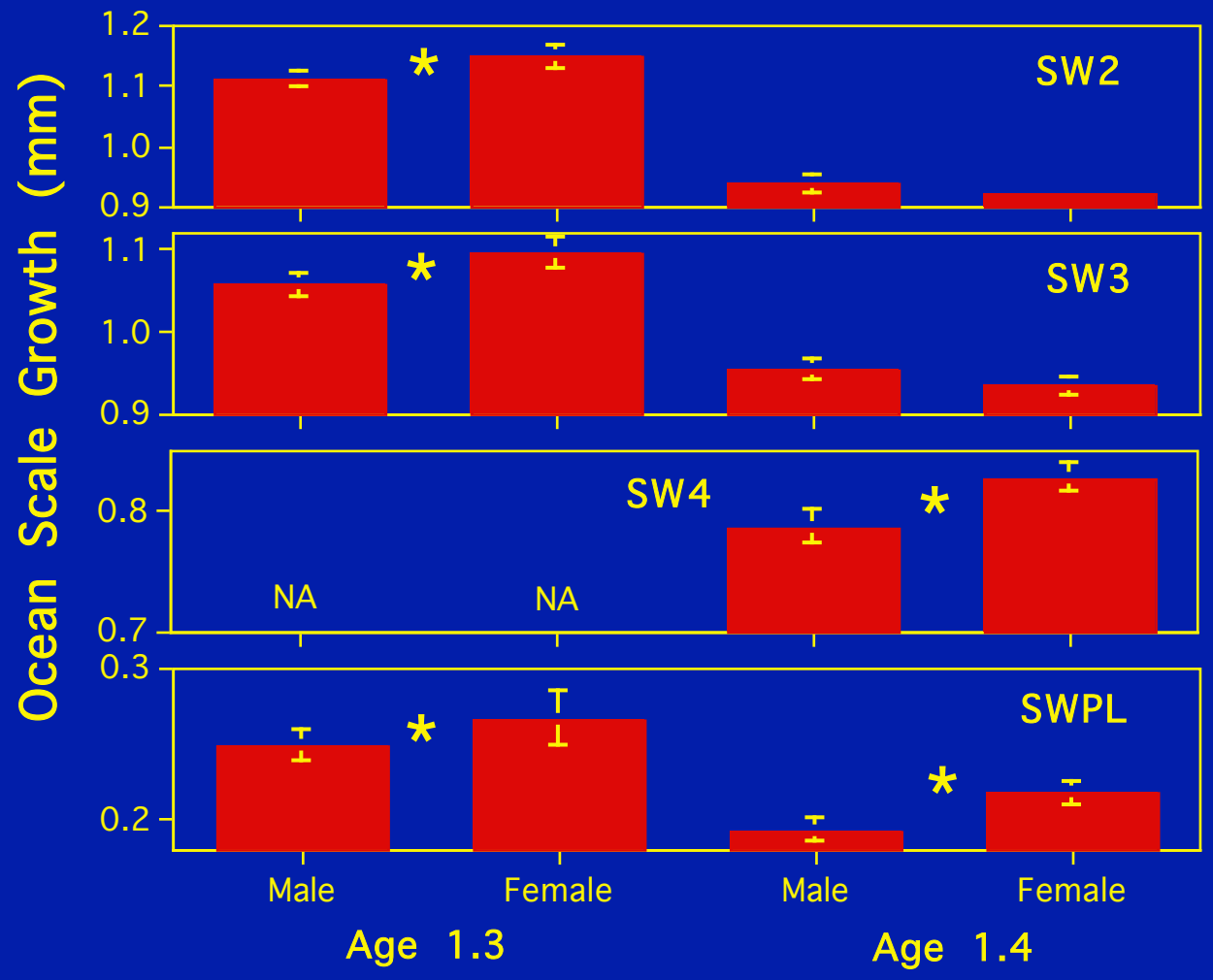
When Does Differential Growth Begin?

Age 1.3 > Age 1.4 SW1 Growth
Age 1.3 Female > Male



Patterns consistent for Yukon & Kuskokwim Chinook

Age 1.3 > Age 1.4 Growth
Age 1.4 Female > Male: Late Life



Fewer Adult Female Chinook vs Male Chinook

Tradeoff: Survival versus old age & fecundity

Stock	% female	SE	df	P-value
Yukon watershed				
Yukon mainstem	47.5%	1.0%	33	0.021
Gisasa R	31.8%	3.5%	9	< 0.001
Andreafsky R	36.4%	3.4%	10	0.003
Anvik R	40.8%	2.2%	24	< 0.001
Salcha R	42.8%	1.8%	27	< 0.001
Chena R	45.6%	2.8%	21	0.13
Kuskokwim watershed				
Kuskokwim mainstem	32.8%	3.1%	20	< 0.001
Kogrukluk R	33.7%	1.8%	29	< 0.001

ADFG raw data

Implication for Chinook

- Female Chinook tradeoff survival for greater size at maturation (length, age, fecundity).
  - Suggests growth is especially important for female Chinook
- Forecasting Chinook Abundance:
  - Use stock & gender specific length-at-age

The Columbia Squeeze:

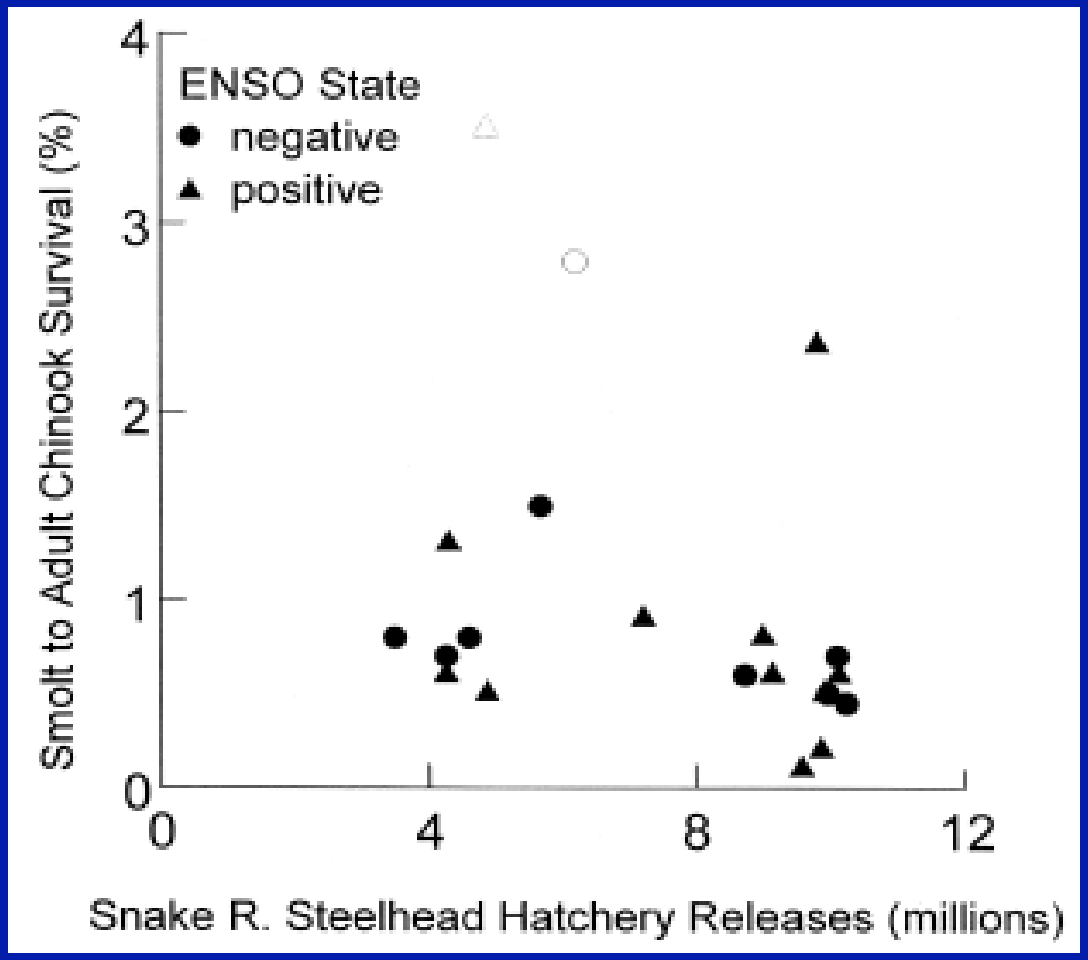
Early maturation & low fecundity does not offset high mortality in freshwater and the ocean.

Question:

If faster growth leads to earlier maturation, why are Alaskan and Columbia R Chinook now smaller at age and younger on average?

END

Columbia R Chinook: Density-dependent survival

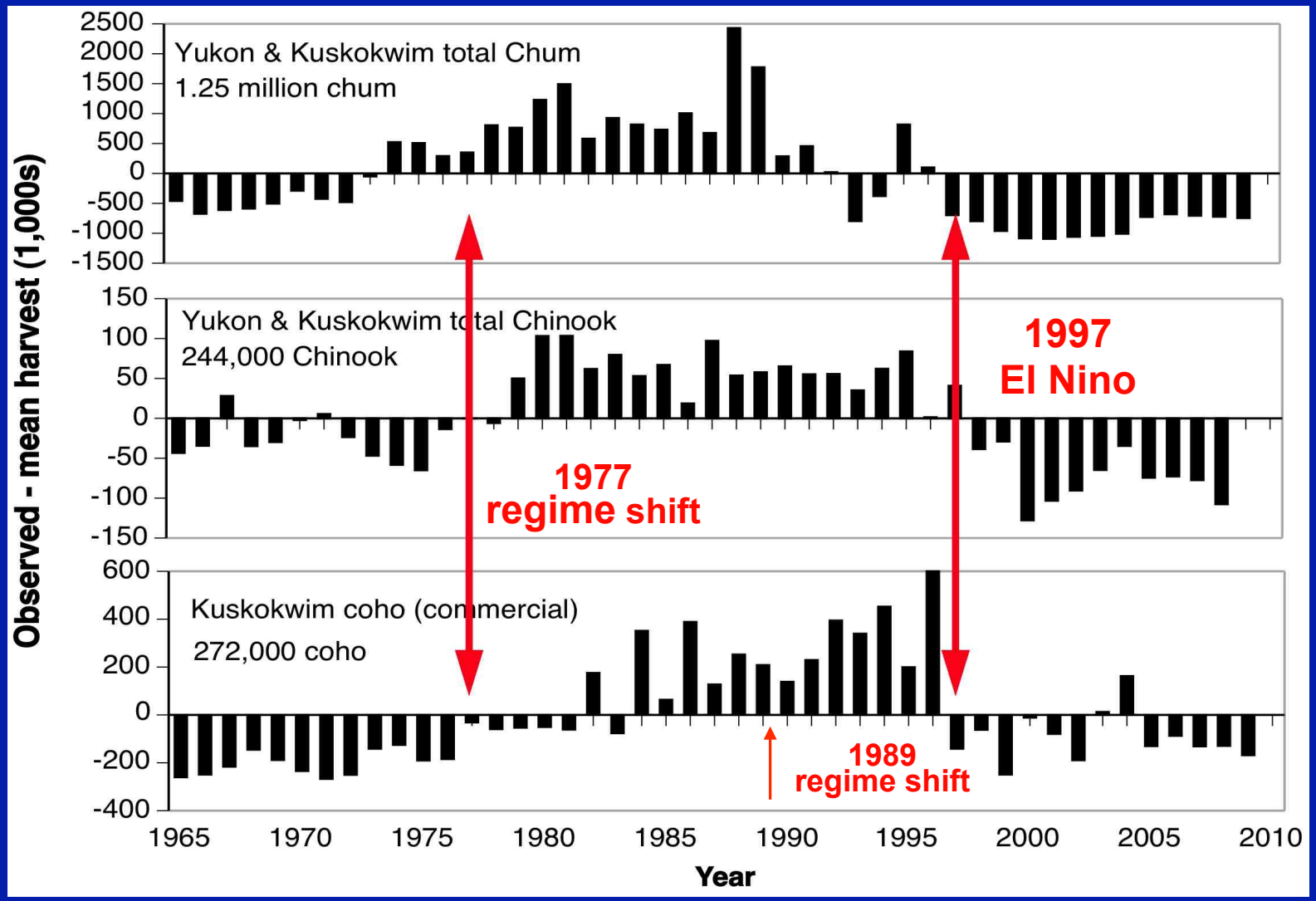


Partial P

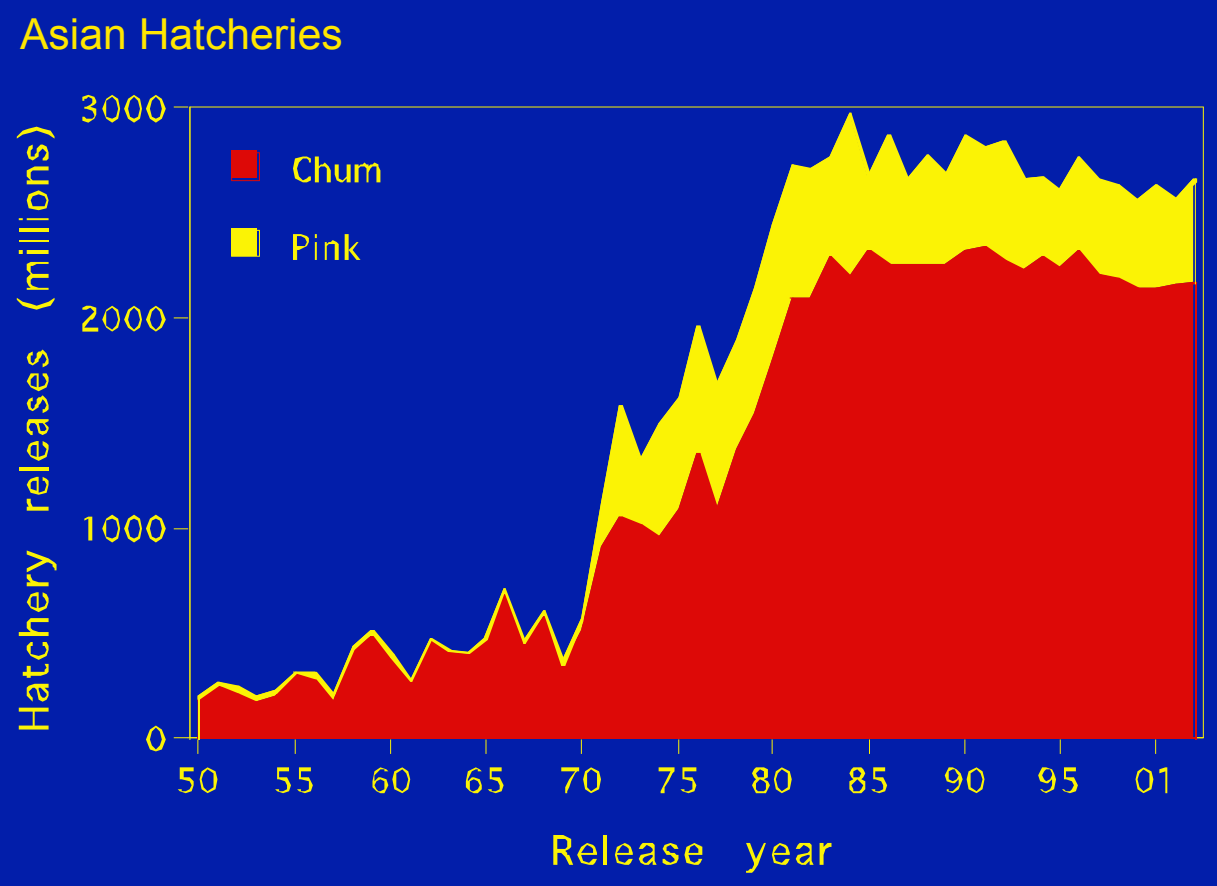
= 0.028

Levin and Williams 2002

Climate Shifts & Harvest Trends of AYK Salmon

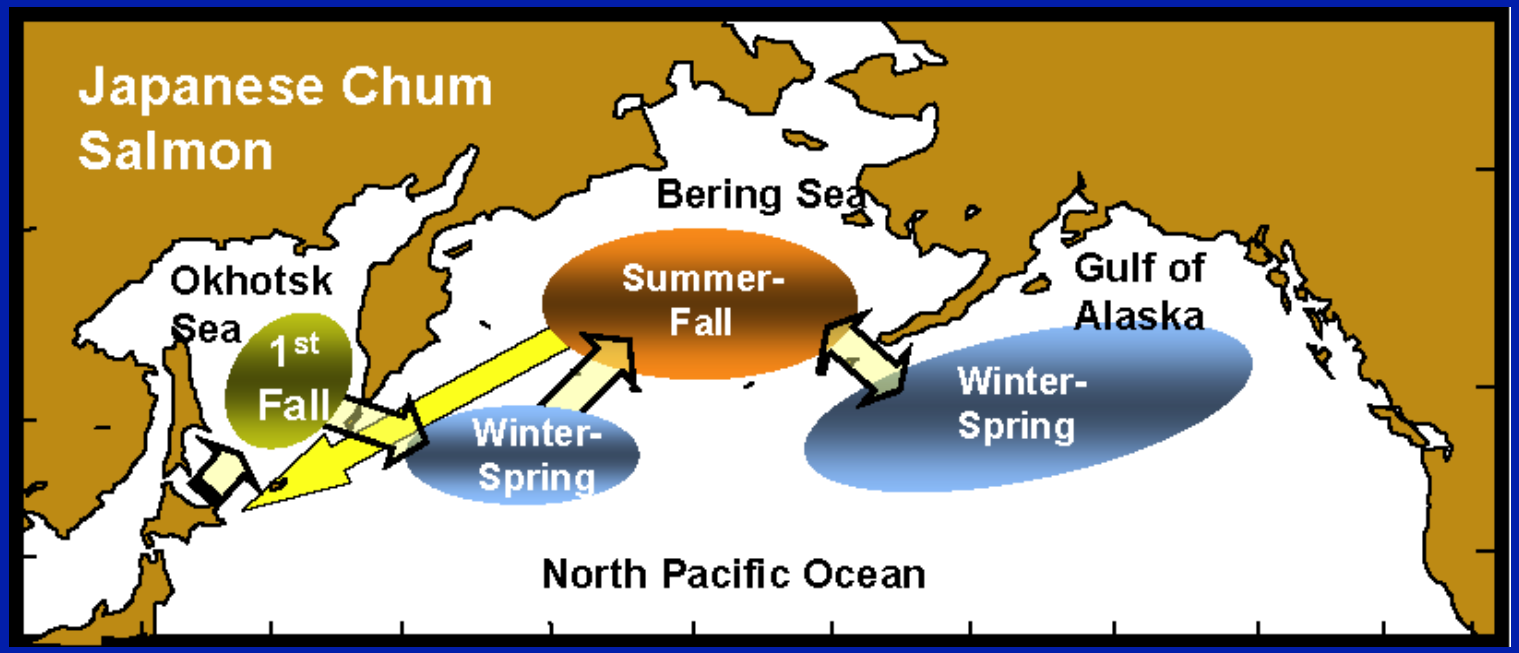


What is Effect of Asian Hatchery Chum on Chum Salmon in Western Alaska?



- High diet overlap among chum age groups; potential competition (Myers et al. 2005).
- High diet overlap between chum & sockeye near Aleutians (Davis et al. 2003)

Japanese Chum overlap with Norton Sound (AYK) Chum Salmon



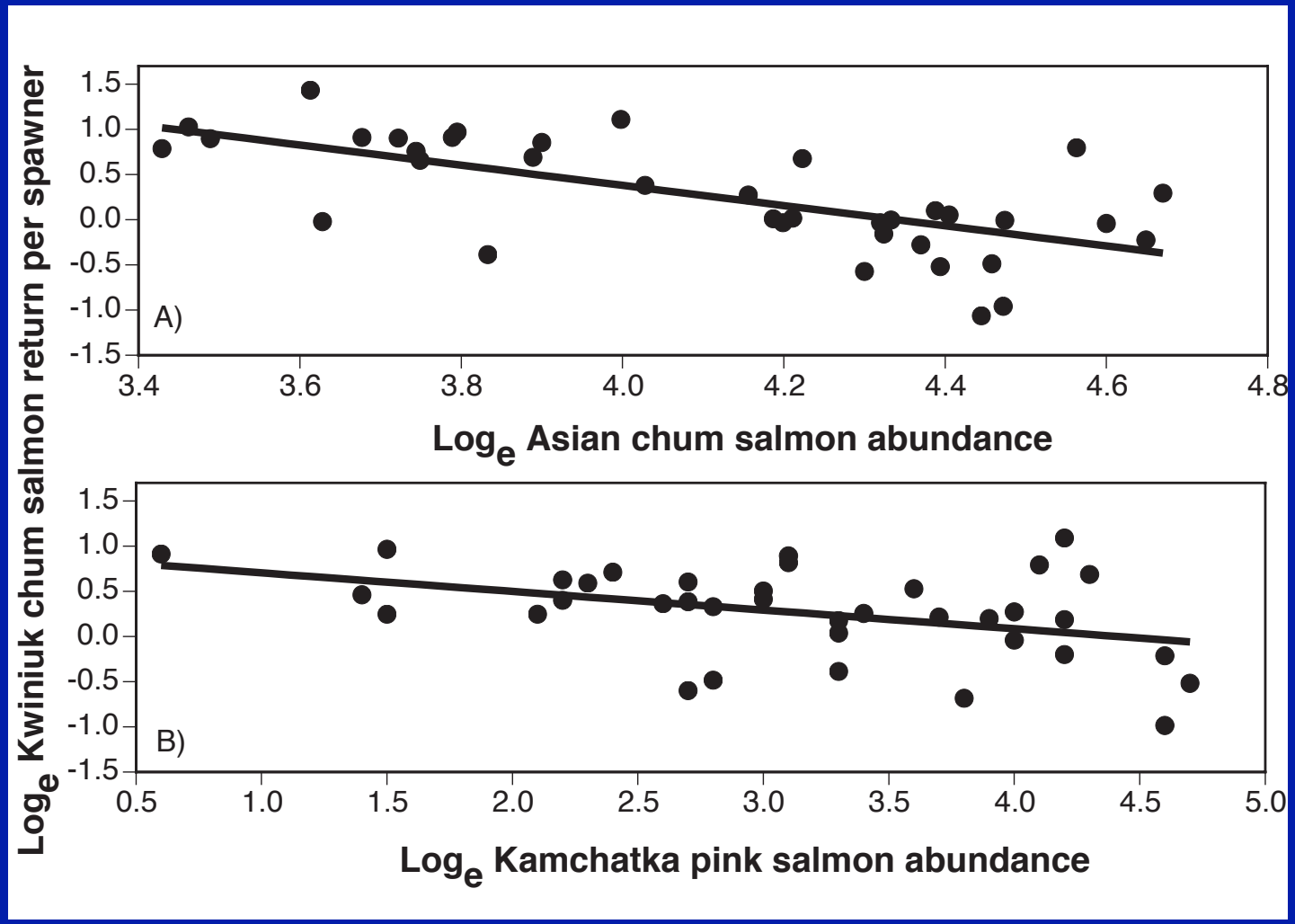
AYK chum overlap Japanese hatchery chum salmon

K. Myers, UW

Urawa et al. 2008

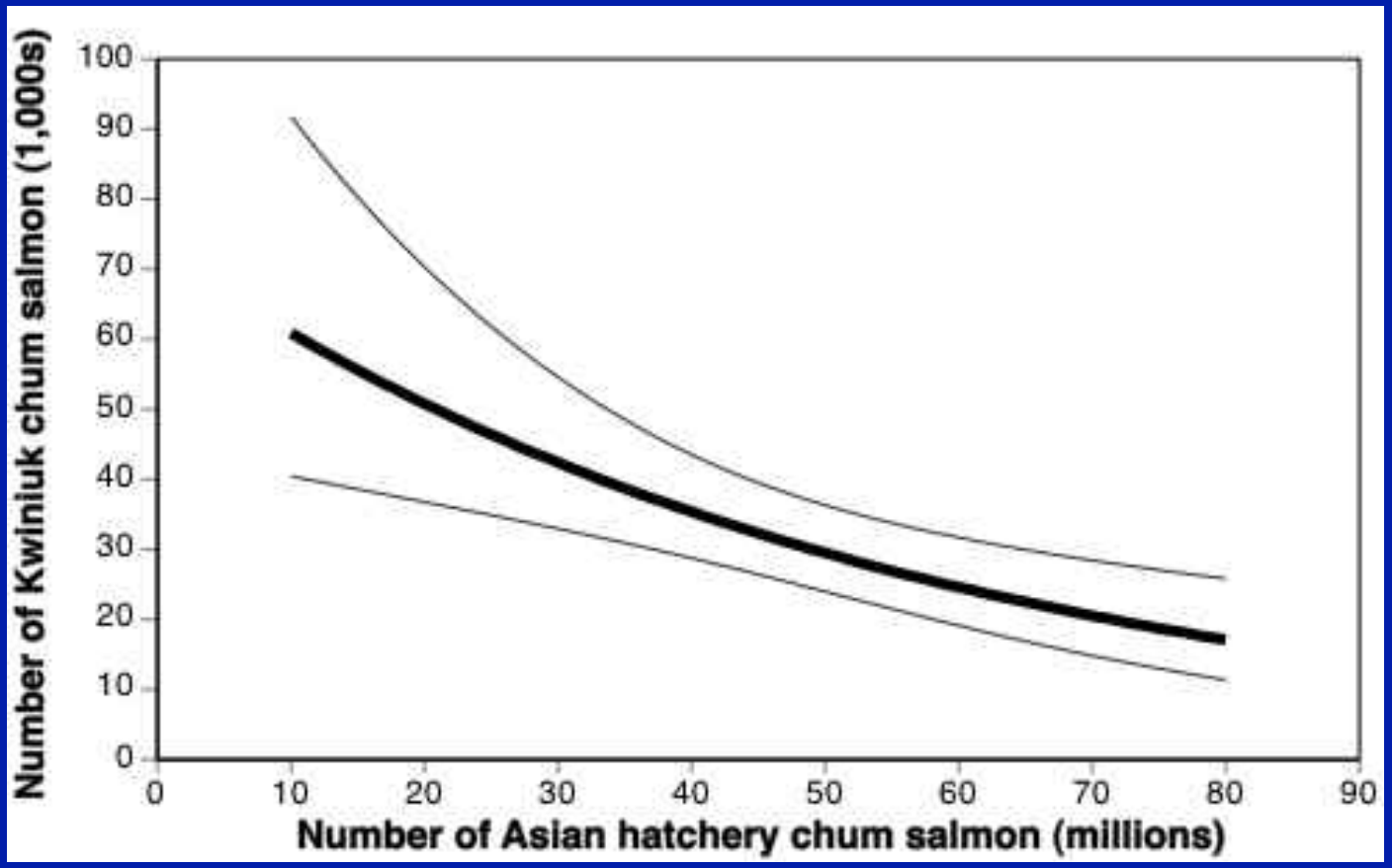
Kwiniuk Chum R/S v. Asian Chum & Asian Pink Salmon Abundance,

brood years 1965-2001



Log R/S = 12.97 - 1.118 (A. Chum) + 0.35 (Prod) - 0.74 (Escape) - 0.207 (K. pinks) R^2=0.68

Kwiniuk Abundance Declined 70% when more Hatchery Chum



Ruggerone et al. 2011