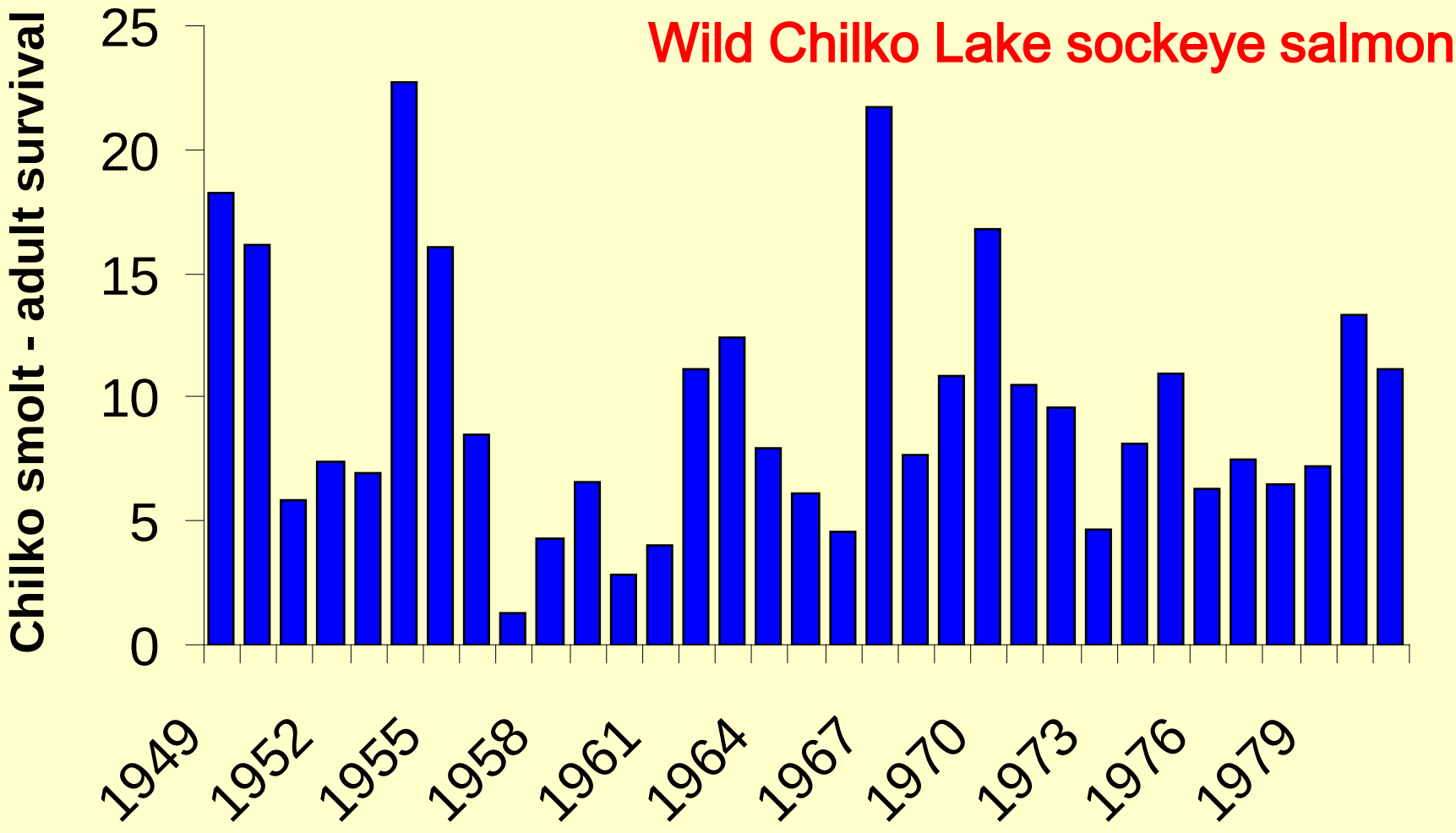
Survival at Sea

A. Average Marine Mortality
B. Life Cycles of specific populations
C. Size-Survival
D. Variation among years
E. Ocean – Upwelling
F. Long-term Trends
G. Predators

Average percent marine survival for wild populations

Species	Average survival rate
chum	1.4%
pink	2.8%
Chinook	3.1%
coho	10.4
sockeye	13.1%

In any population, there is considerable variation in marine survival



Stage-specific mortality and the dynamics of Fraser River chum salmon

Adults	387,210
Females	200,444
Eggs per female	3,250
Fry	91,990,000
Egg to fry survival	14.17%
Adults	812,893
Fry to adult survival	1.19%
Return per spawner	2.16

Beacham and Starr. 1982. Fishery Bulletin 80: 813-825

Stage-specific mortality of wild Lewis River chinook

Eggs per female	5,122
Egg to fry survival	65.3%
Fry per female	3,345
Fry to smolt survival	10.05%
Smolts per female	336
Smolt to adult survival	2.38
Adults per female	8
Escapement	48.8%
Returning spawners per female	3.9

McIsaac, D.O. PhD thesis. University of Washington

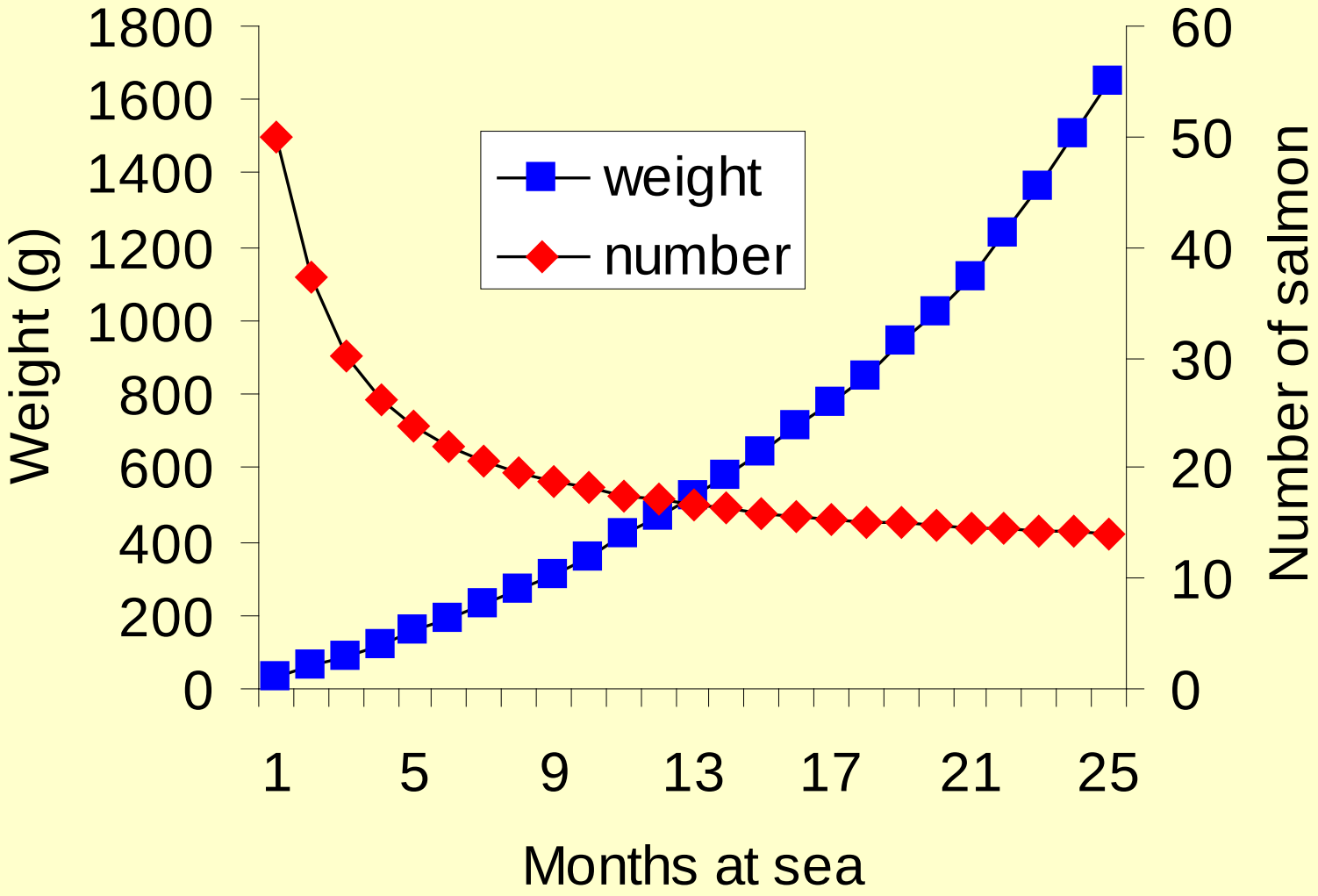
Stage-specific mortality of Bella Coola pink salmon

Life history stage	Mortality	Survivors
Fry *		60,000,000
1st 40 days	65%	21,000,000
final 410 days	85%	3,150,000
Fishing *	85%	472,500
50% females *		236,250
2,000 eggs/female *		472,500,000
Egg to fry *	87.3%	60,000,000

* Hypothetical values assumed to balance the cycle

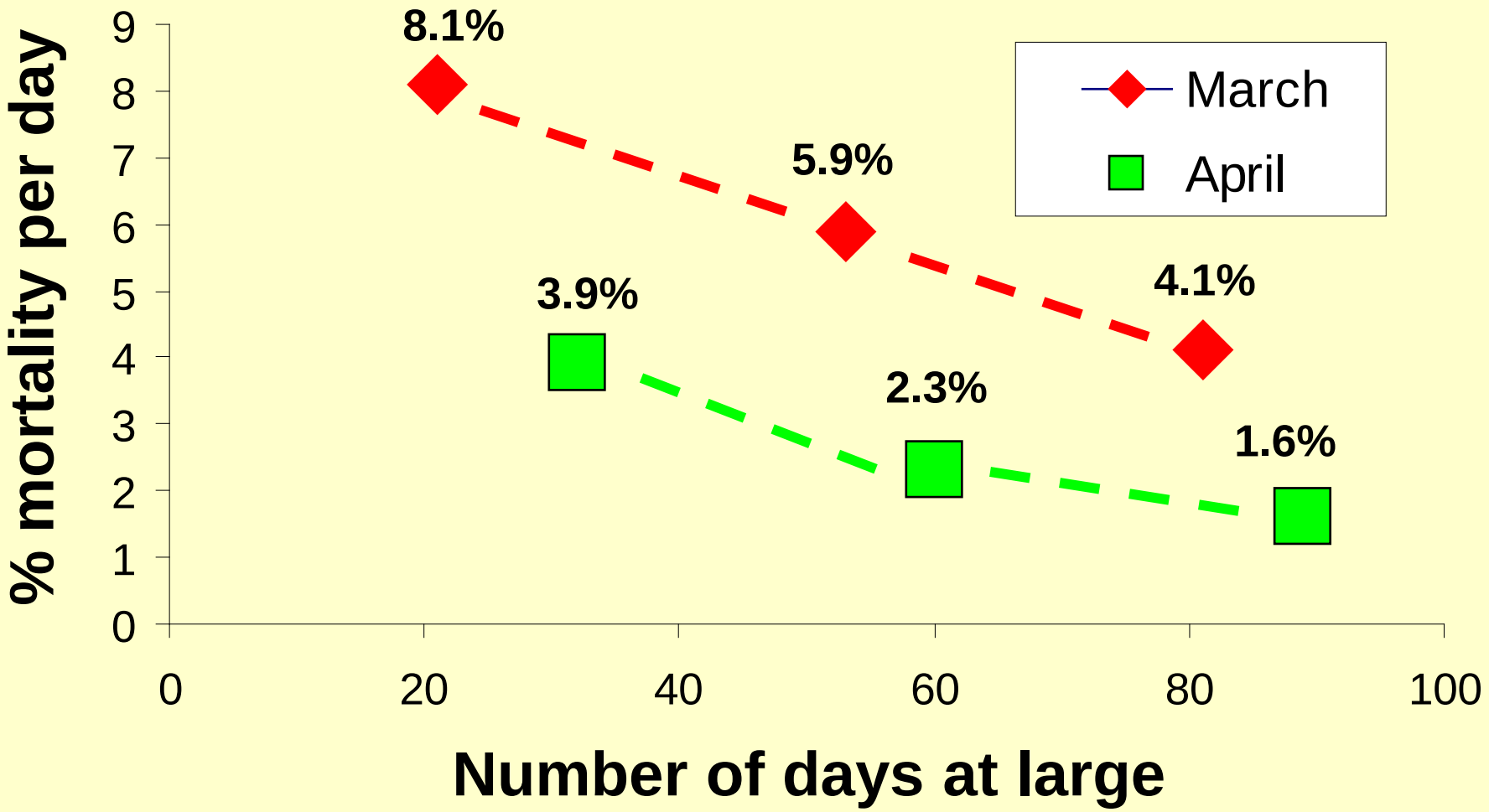
R.R. Parker. 1968. J.F.R.B.C. 25: 757-794

Mortality should be is highest on small salmon, soon after they enter the ocean. As they grow, mortality rates are assumed to decrease (e.g., Karluk Lake sockeye salmon: Ricker 1976).



Estimates of average daily mortality of unfed chum salmon fry from Southeast Alaska

(Wertheimer and Thrower 2007 AFS Symposium 57)



Estimated mortality rate of Columbia River and coastal Oregon coho salmon (1982-1985)

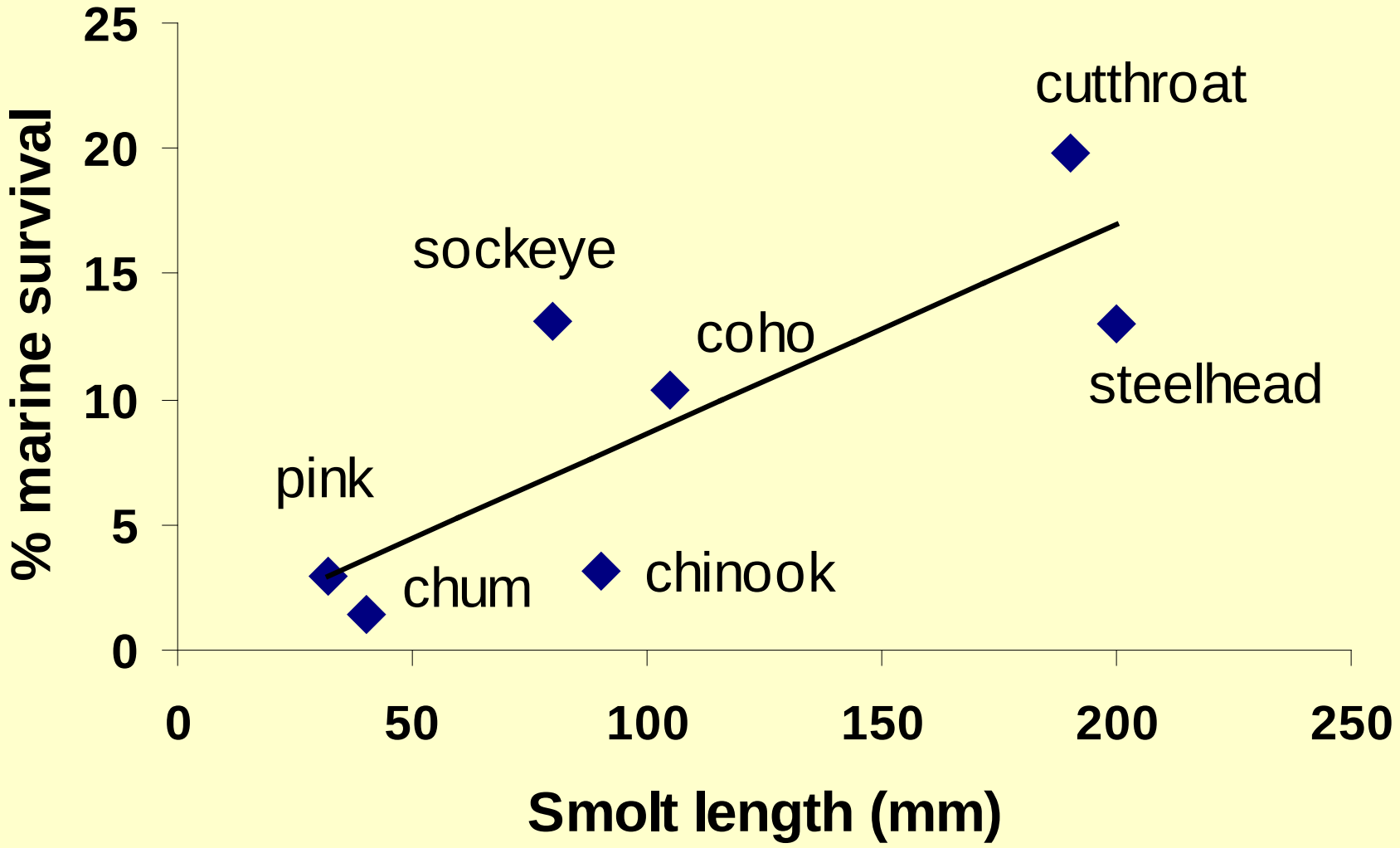
Date	Days at sea	Millions of salmon	% mortality per day	% mortality per period
May 1	0	35.24		
June 17	47	8.50	2.92	75.9
Sep 11	133	3.87	0.91	54.5
Sep 1	488	1.11	0.35	71.3

William Pearcy and Joseph Fisher, Oregon State University

What controls the survival of salmon at sea?

- **Attributes of the fish**
  - **species**
  - **size**
  - **entry point**
  - **wild vs. hatchery reared**
  - **migration date**
- **Attributes of the environment**
- **Predators**

Smolt size and variation in marine survival among species



Geographic variation in marine survival of wild coho salmon

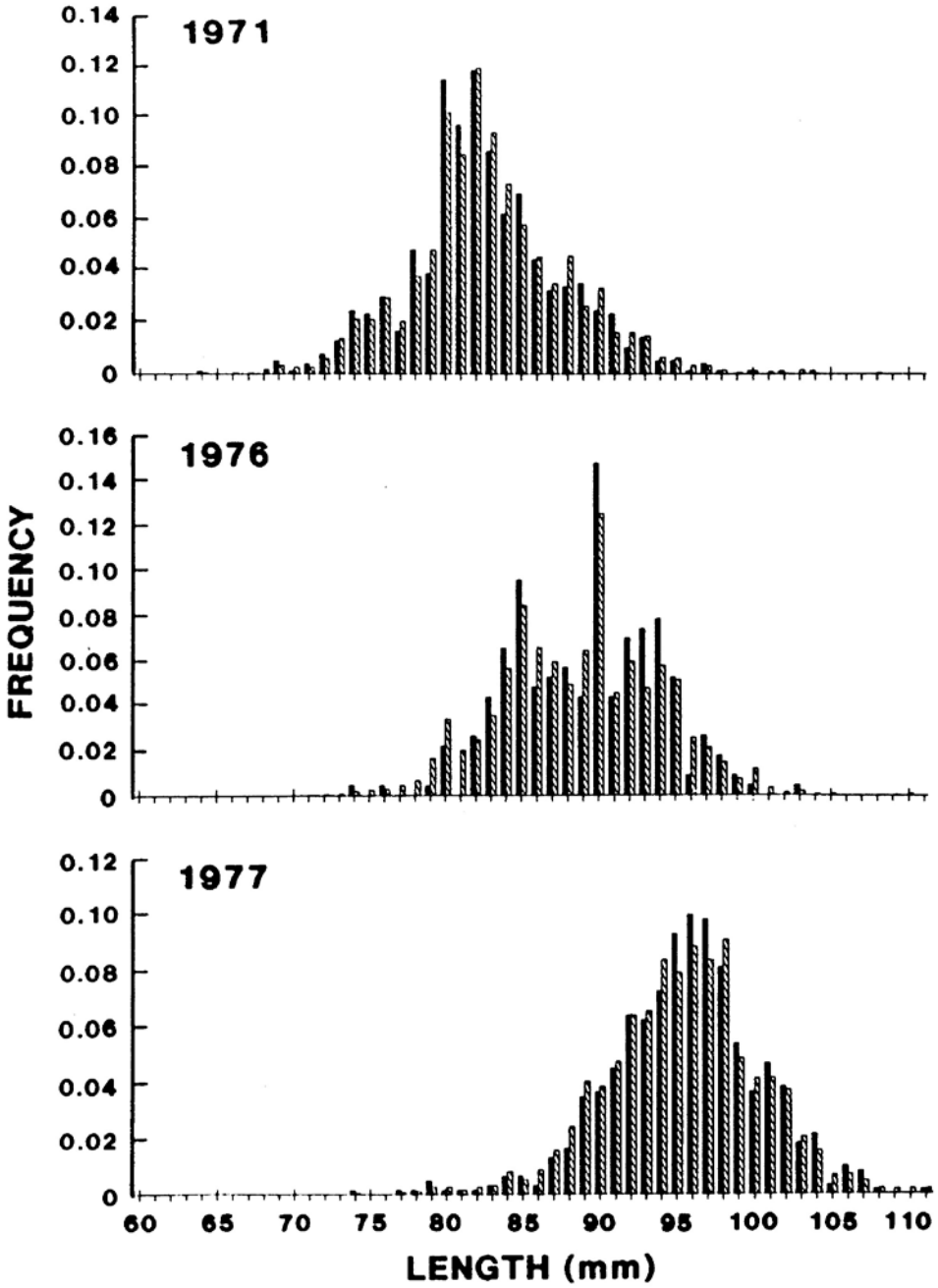
Region	Site	Years	Survival
SE Alaska	Auke Cr.	1980 - 2004	20.3
	Berners R.	1990 - 2004	17.8
	Hugh Smith L.	1984 - 2004	12.9
	Taku R.	1992 - 2004	12.0
N British Columbia	Lachmach R.	1988 - 2003	10.0
	Zolzap Cr.	1993 - 2004	5.9
S British Columbia	Black Cr.	1986 - 2004	7.1
	Salmon R.	1987 - 2004	8.5
Puget Sound	Big Beef Cr.	1979 - 2003	17.2
	Deschutes R.	1980 - 2004	13.1
WA coast	Queets R.	1982 - 2003	5.5
	Bingham Cr.	1983 - 2004	4.4

Shaul et al. 2007 NPAFC Bull. 4: 93-104

Interaction between smolt size and latitude on survival of sockeye salmon: Bigger is better, and northerly populations do better

Smolt size	South (< 55° N)	Middle (56–60° N)	North (> 60° N)
Small (71-76 mm)	5.9	16.7	17.7
Medium (97 mm)	12.6	25.1	32.0
Large (134-139 mm)	17.1	37.0	39.1

(Koenings et al. 1993)



Salmon smolts vary in size *among* years.

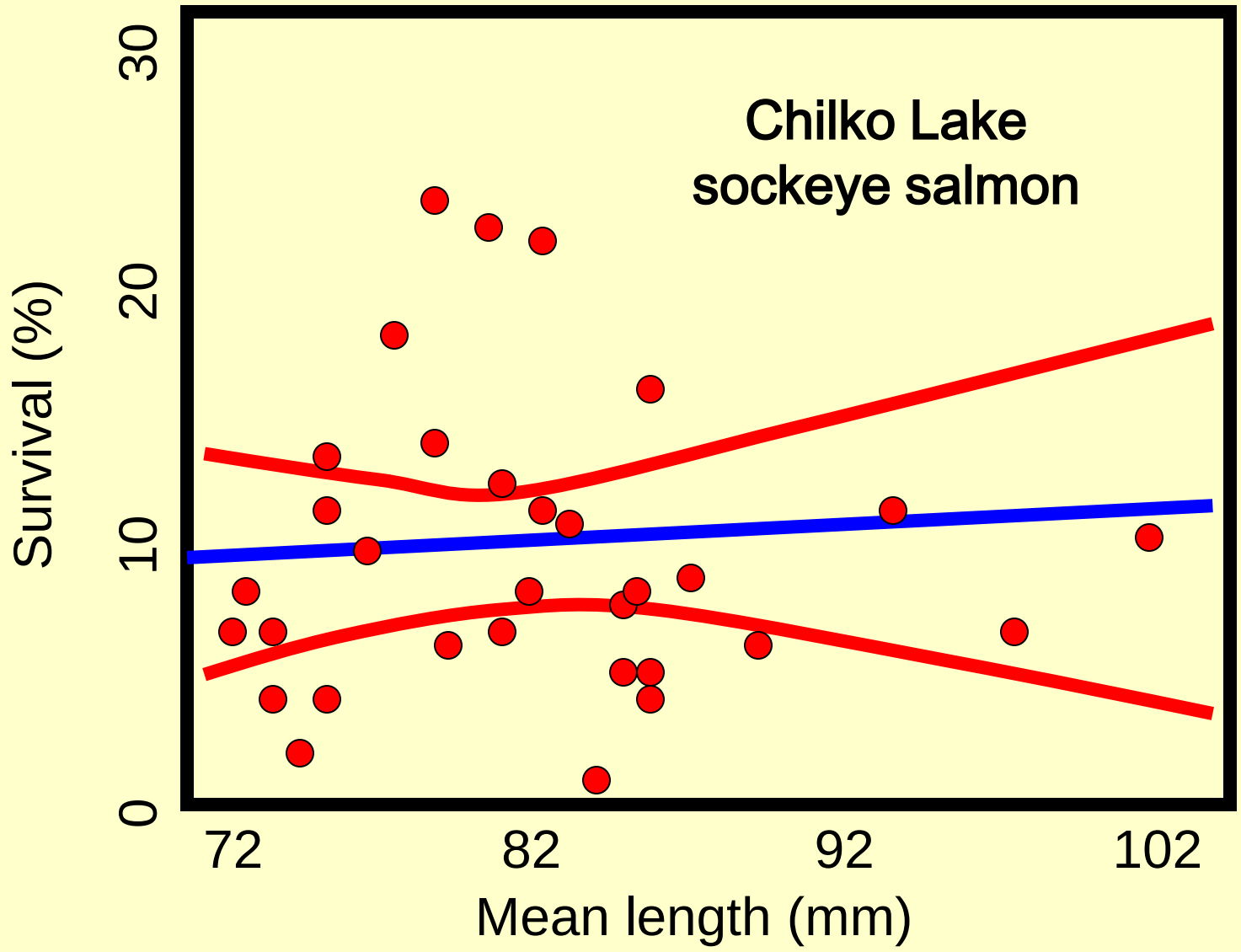
Does size affect their likelihood of survival?

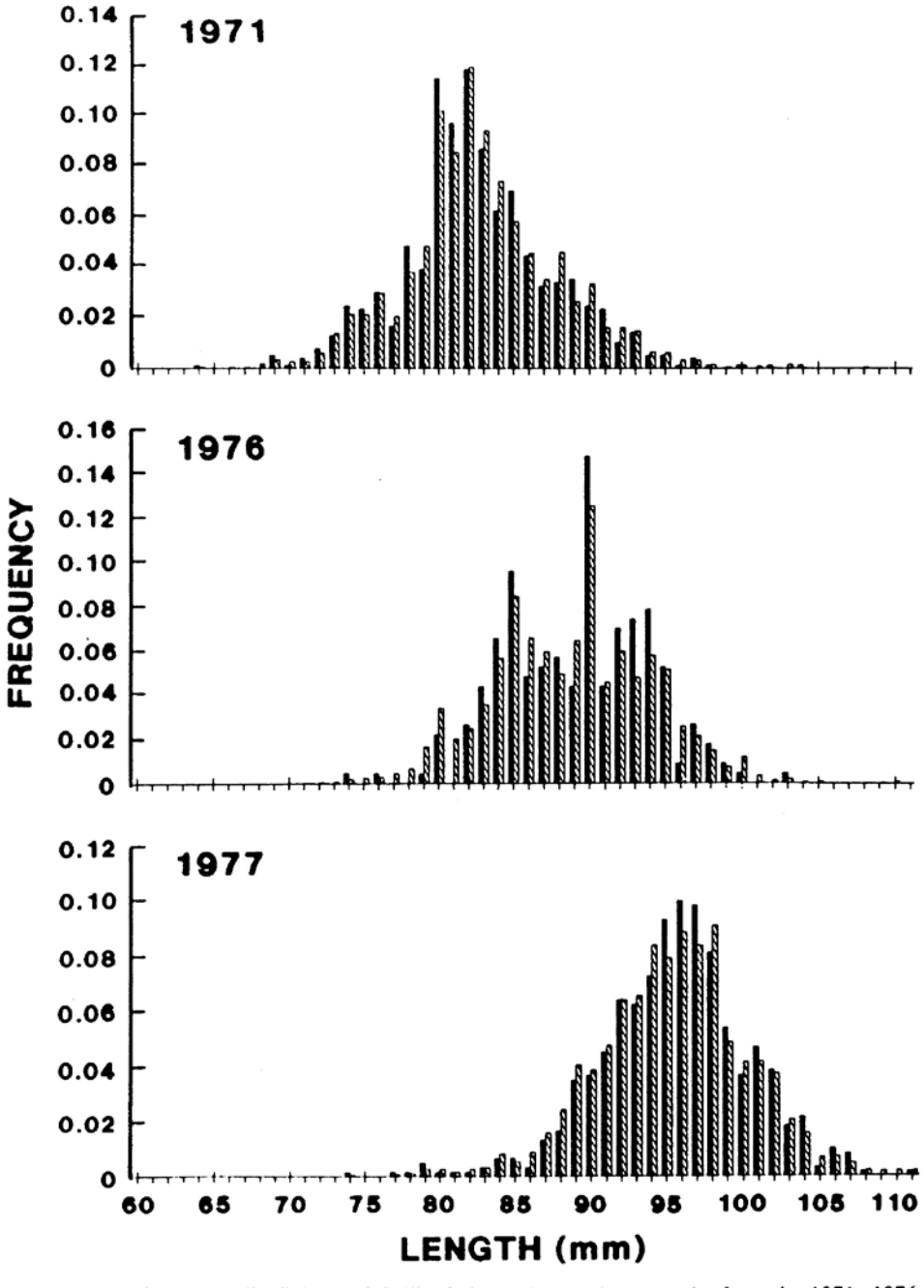
Example:

Chilko Lake sockeye salmon: length distributions among years

Henderson and Cass. 1991. CJFAS.

Mean smolt fork length was not related to marine survival variation among years





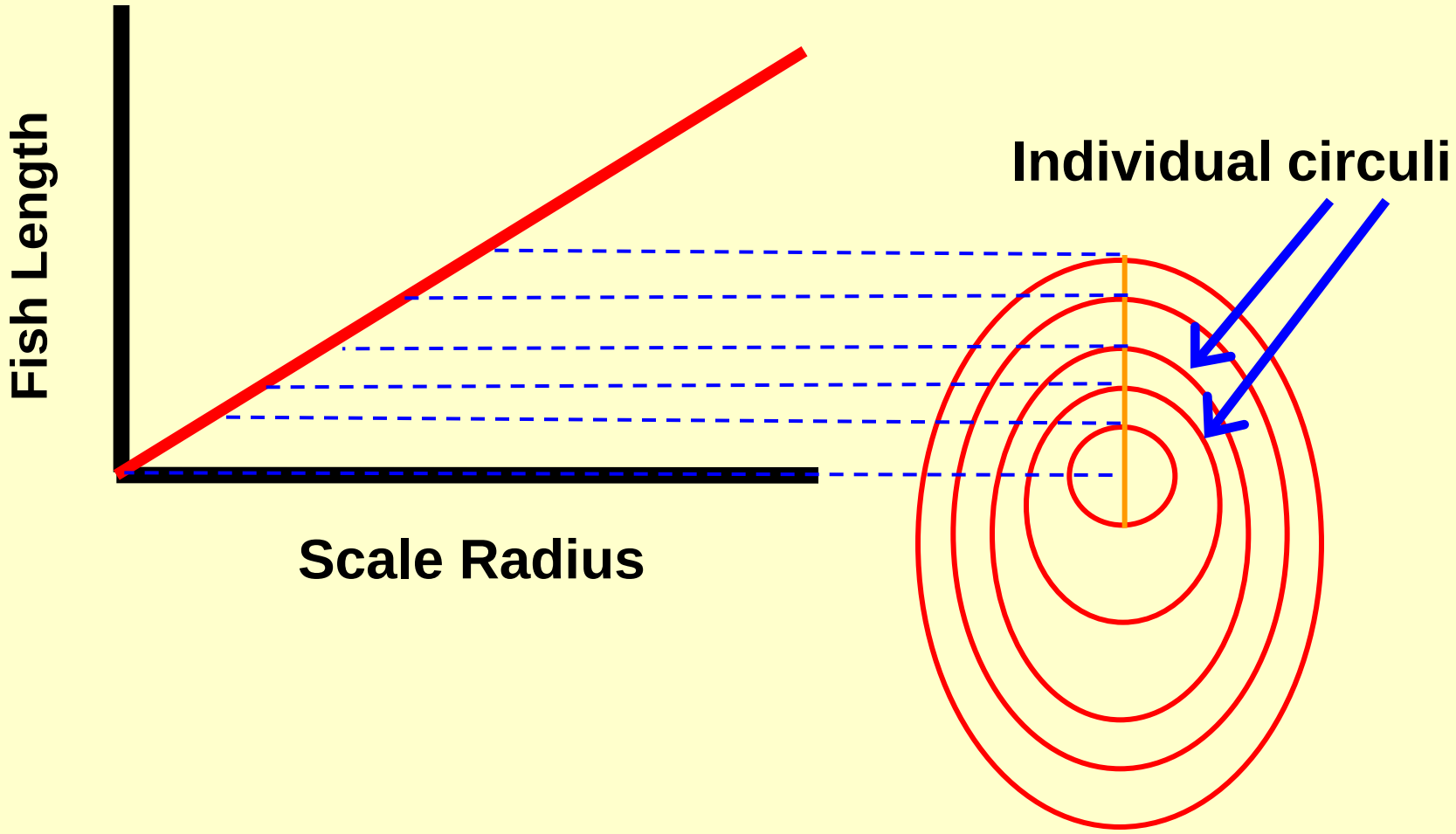
Salmon smolts vary in size *within* years.

Does size affect their likelihood of survival?

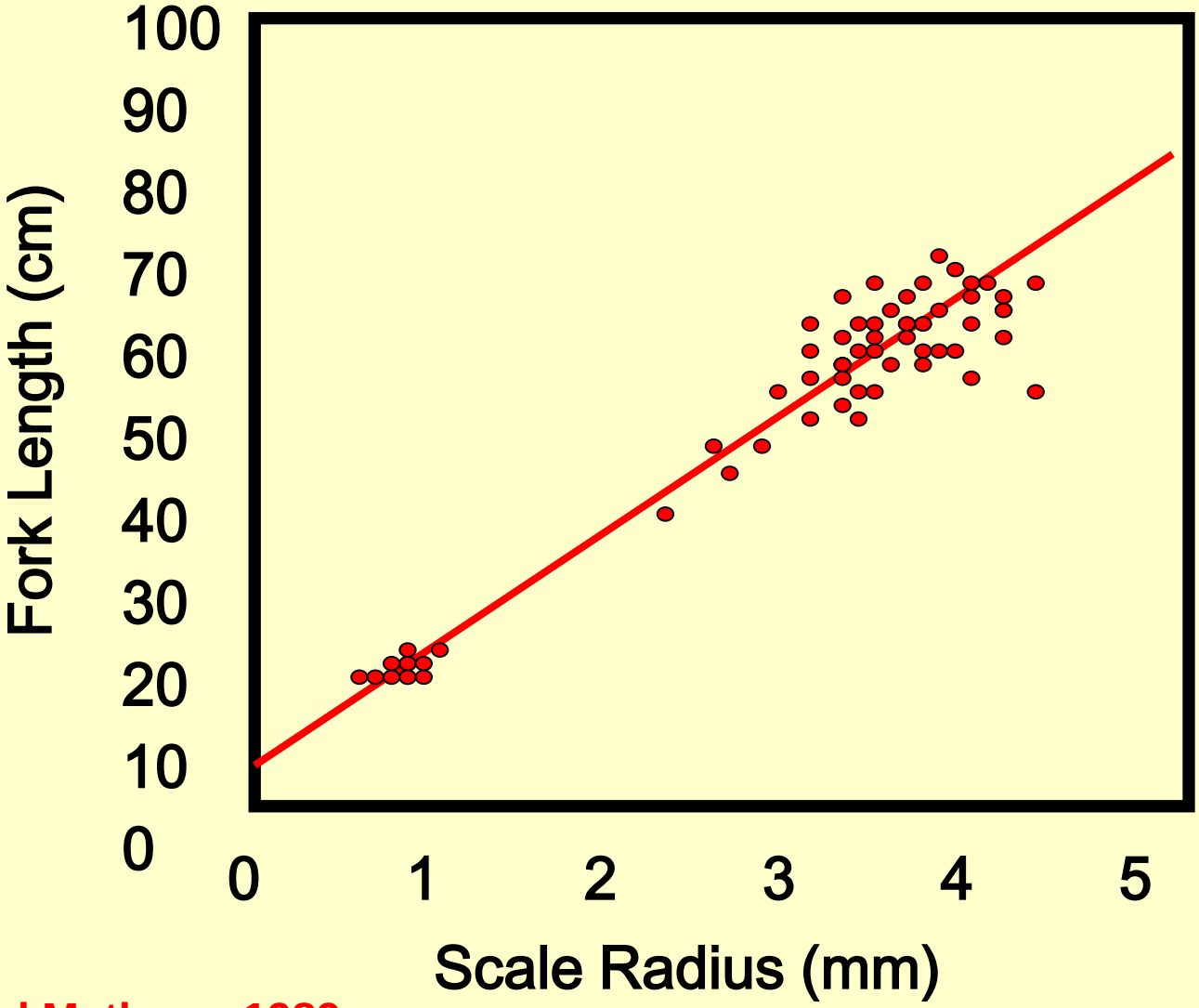
Chilko Lake sockeye salmon

Henderson and Cass. 1991. CJFAS.

Growth History

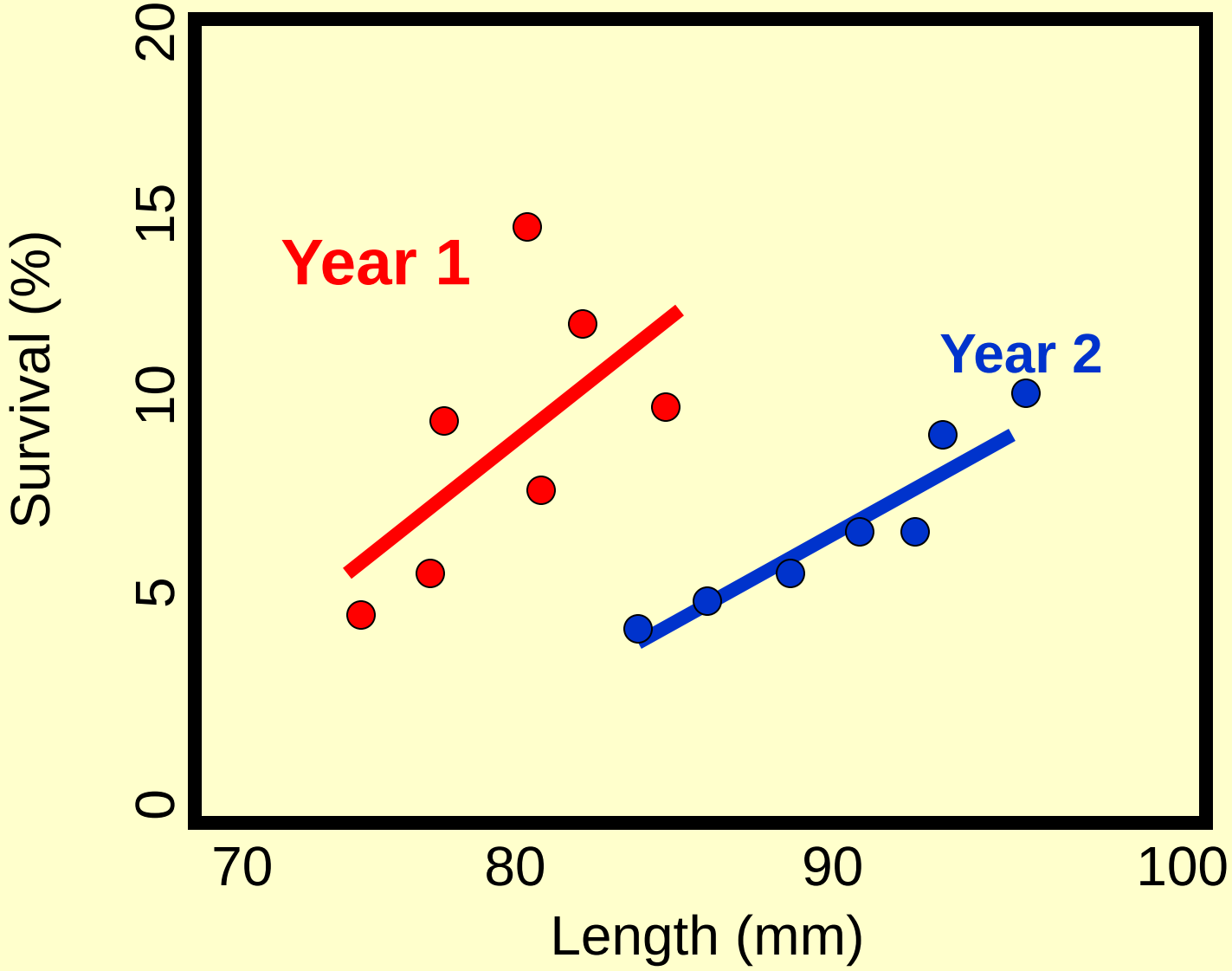


Relationship between fish length and scale radius



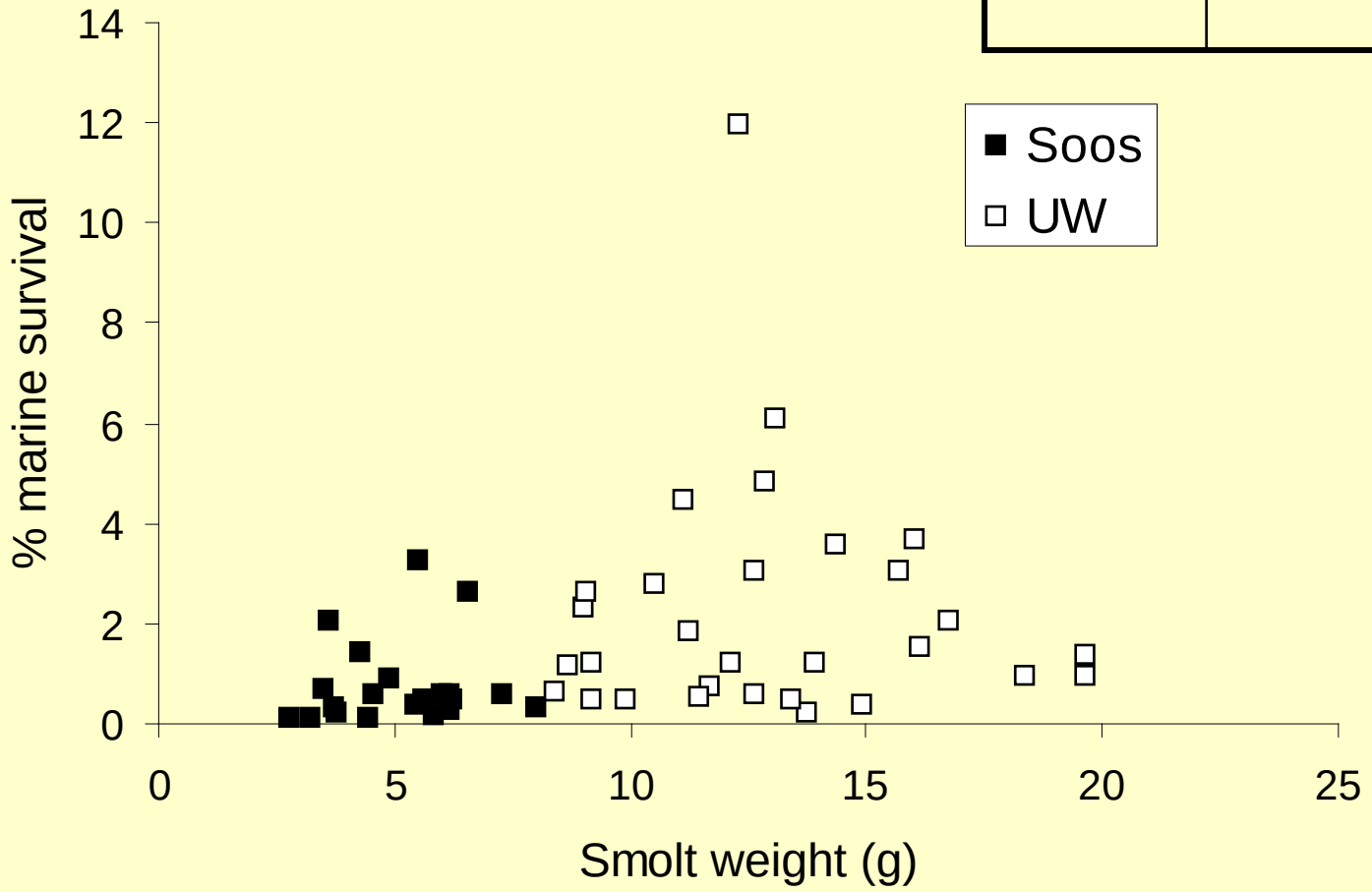
Ishida and Mathews 1989.

Within a year, larger Chilko Lake sockeye salmon smolts were more likely to survive than smaller ones



Size was related to survival of hatchery ocean-type Chinook salmon between hatcheries, but not among years

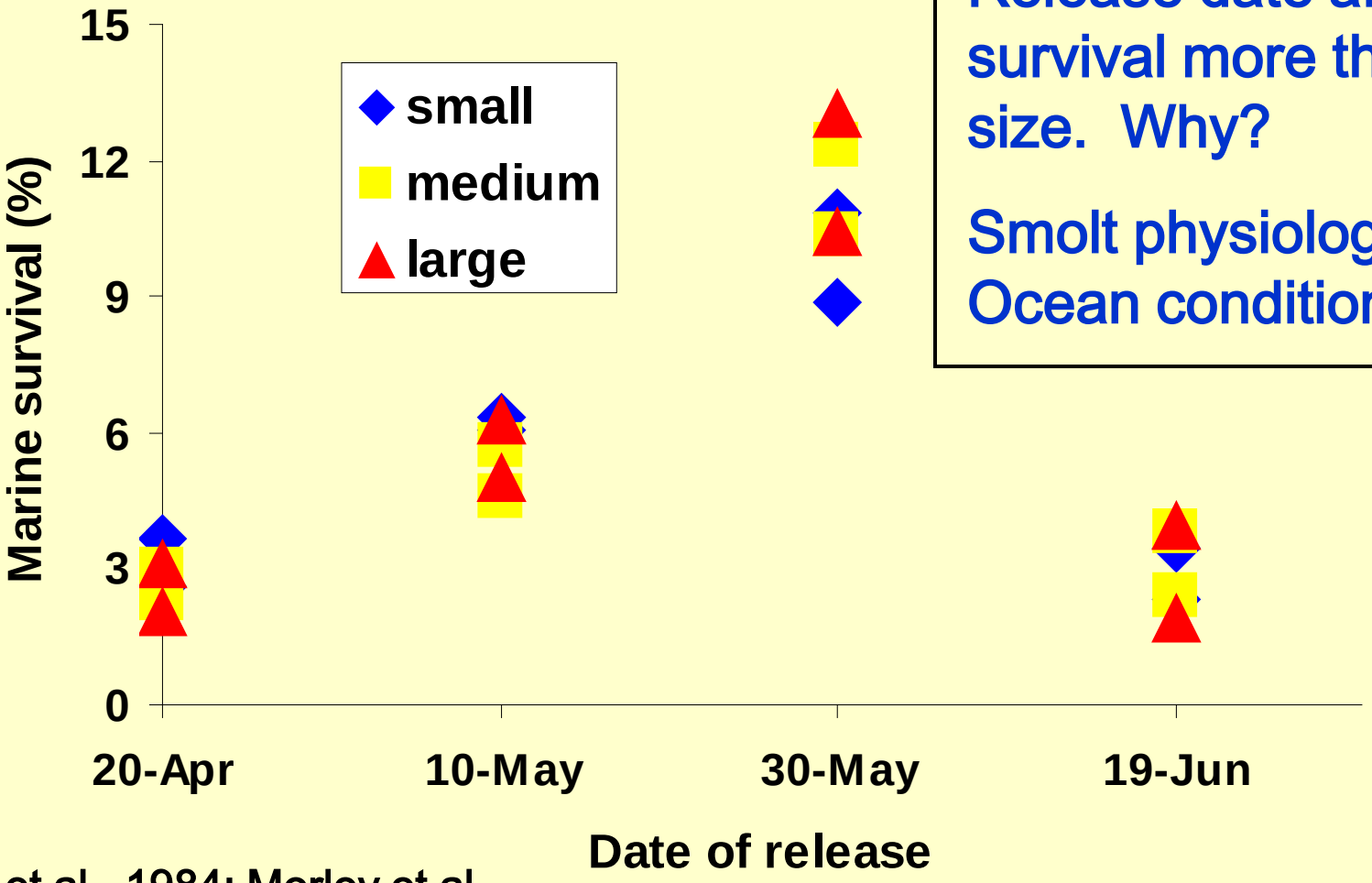
Site	Weight	% survival
UW	12.9	2.2
Soos	5.3	0.8



So, body size does not strongly affect survival *among* years, but it does seem to play a role in variation in survival *within* years.

But, for a hatchery to release *larger* fish, they may hold them *longer*. What is the interaction between *size and release date* in controlling survival of salmon going to sea in a given year?

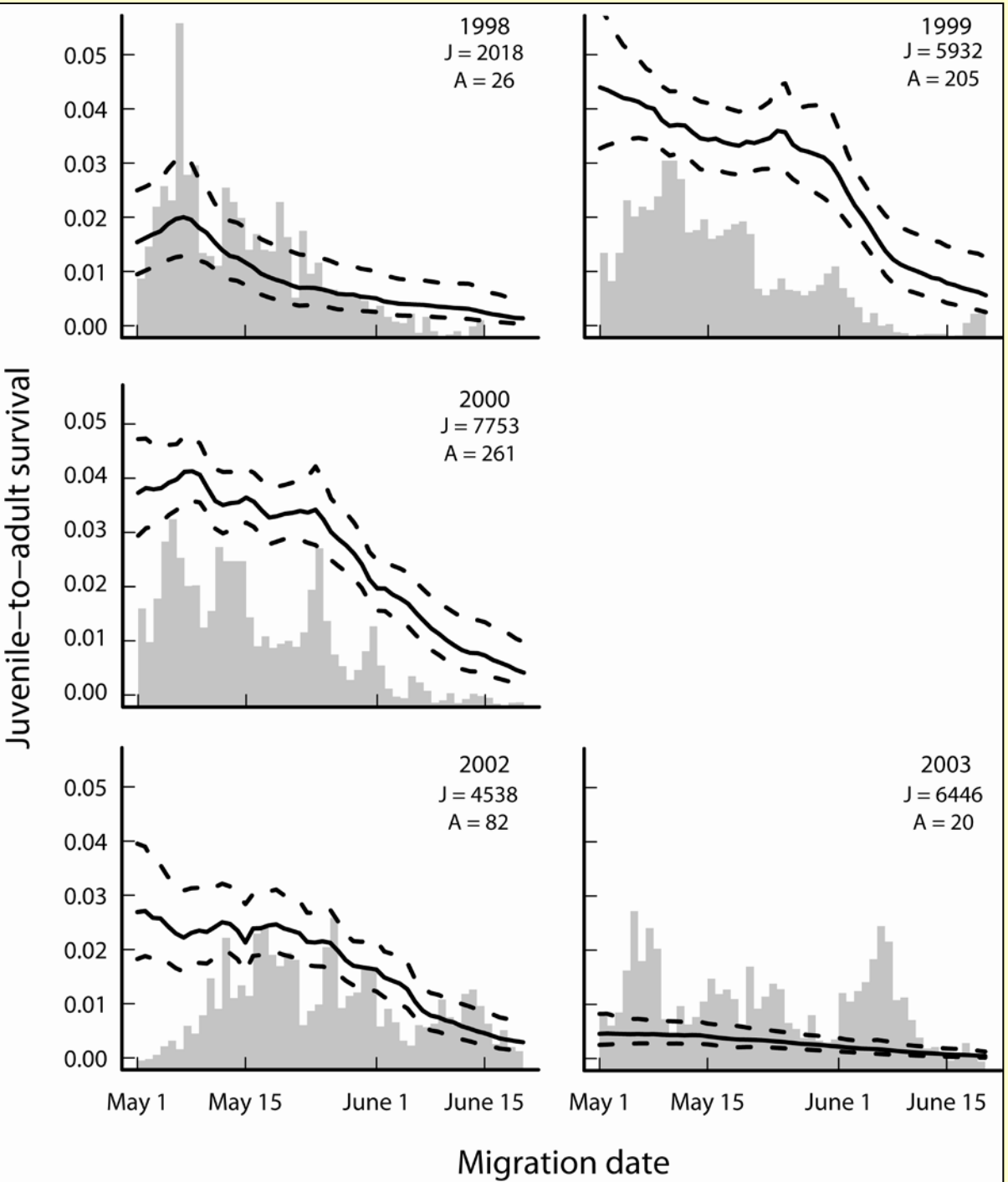
Survival of coho salmon from three size groups, differing from each other by 5 g



Release date affected survival more than size. Why?

Smolt physiology?
Ocean conditions?

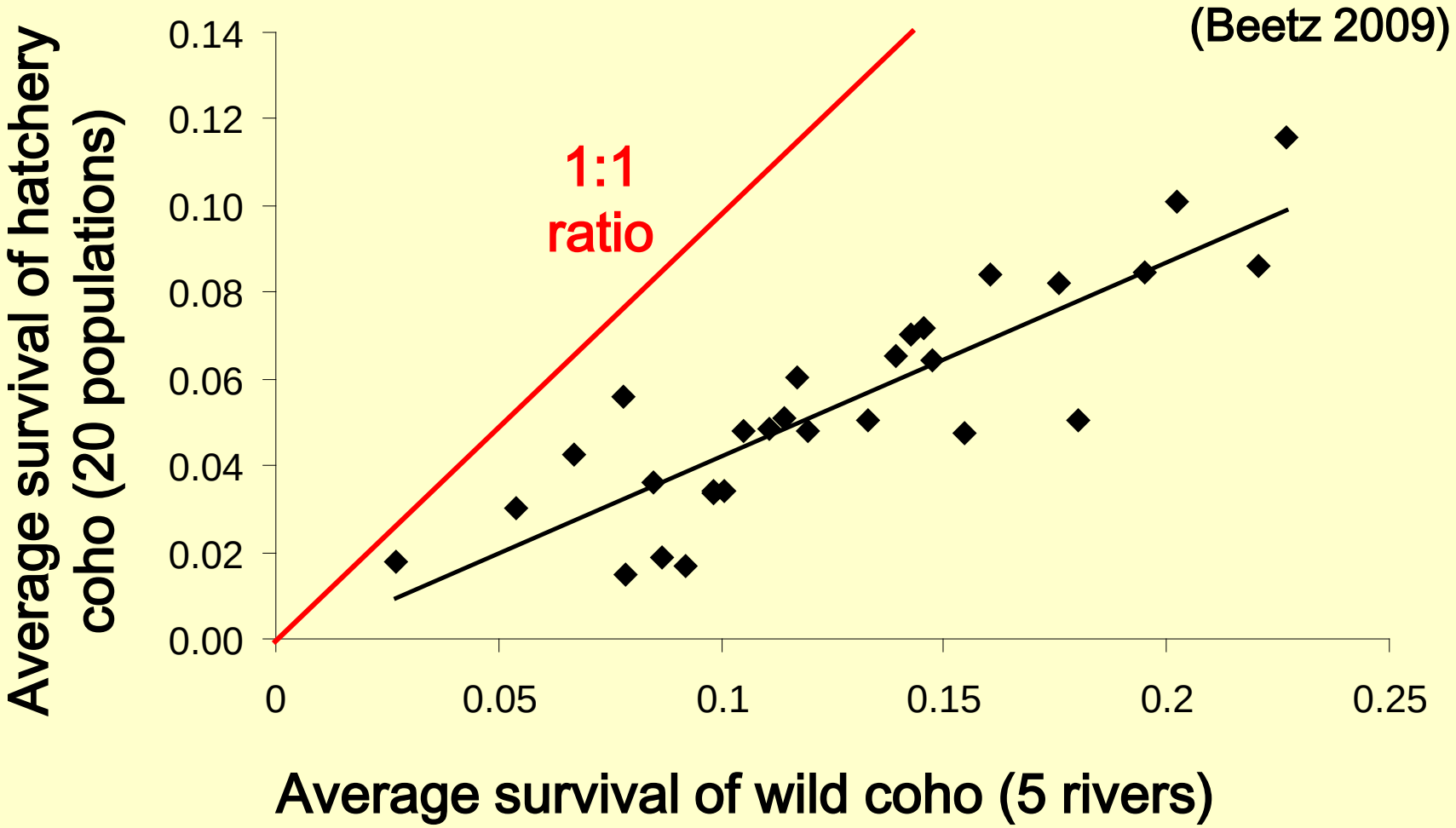
Bilton et al. 1984; Morley et al. 1988. Quinsam River Hatchery.



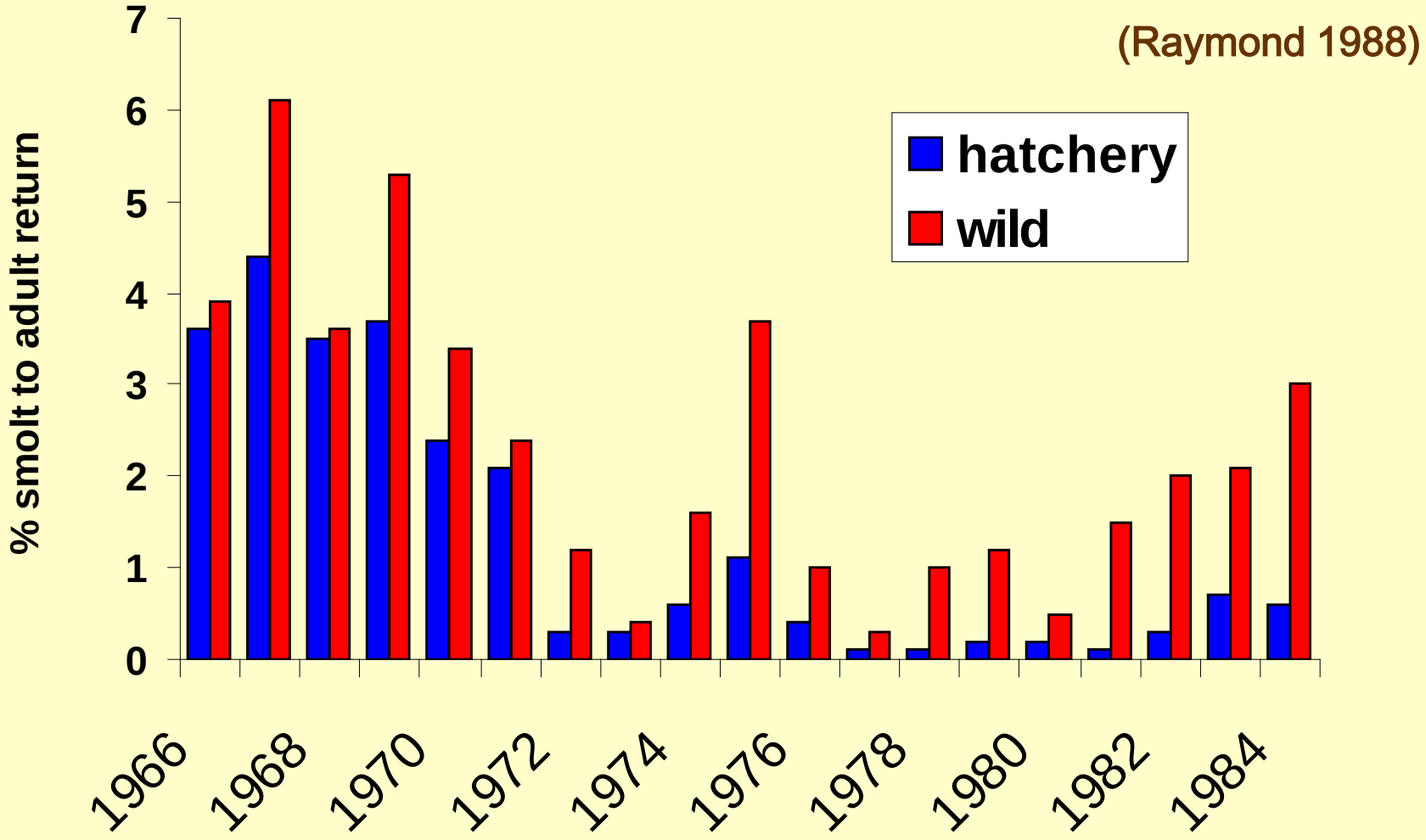
Other evidence that date may play a large role in survival at sea.

Survival of Chinook salmon from the Columbia River declined later in the season, though the patterns varied among years (Scheuerell et al. 2009).

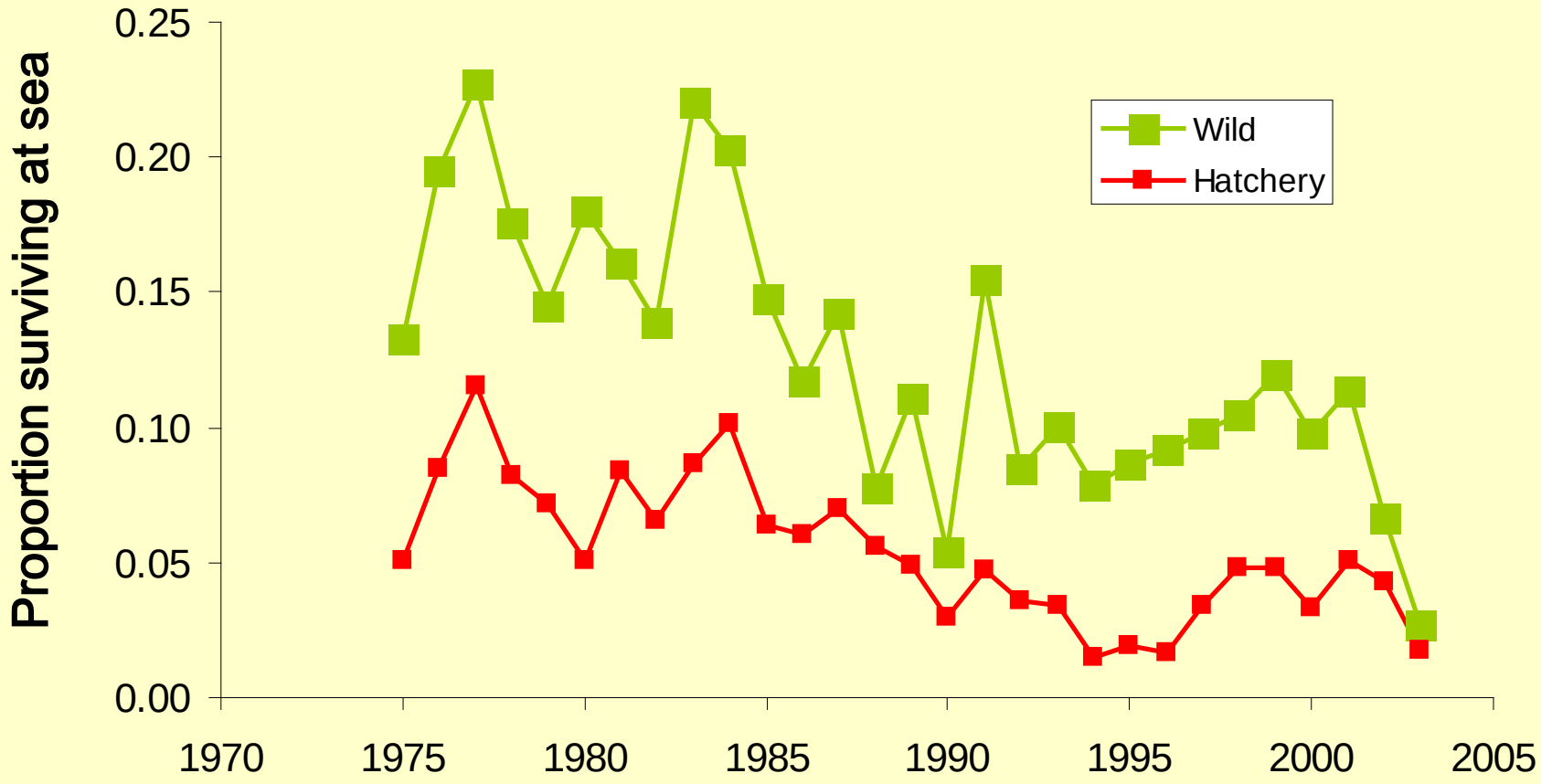
In a given year, wild and hatchery survival rates were correlated, but wild coho salmon had consistently higher survival rates in Washington



Sometimes there are trends in survival (e.g., stream-type Chinook salmon smolts from the Snake River.



Washington coho salmon also show trends over time, and the superior performance of wild fish



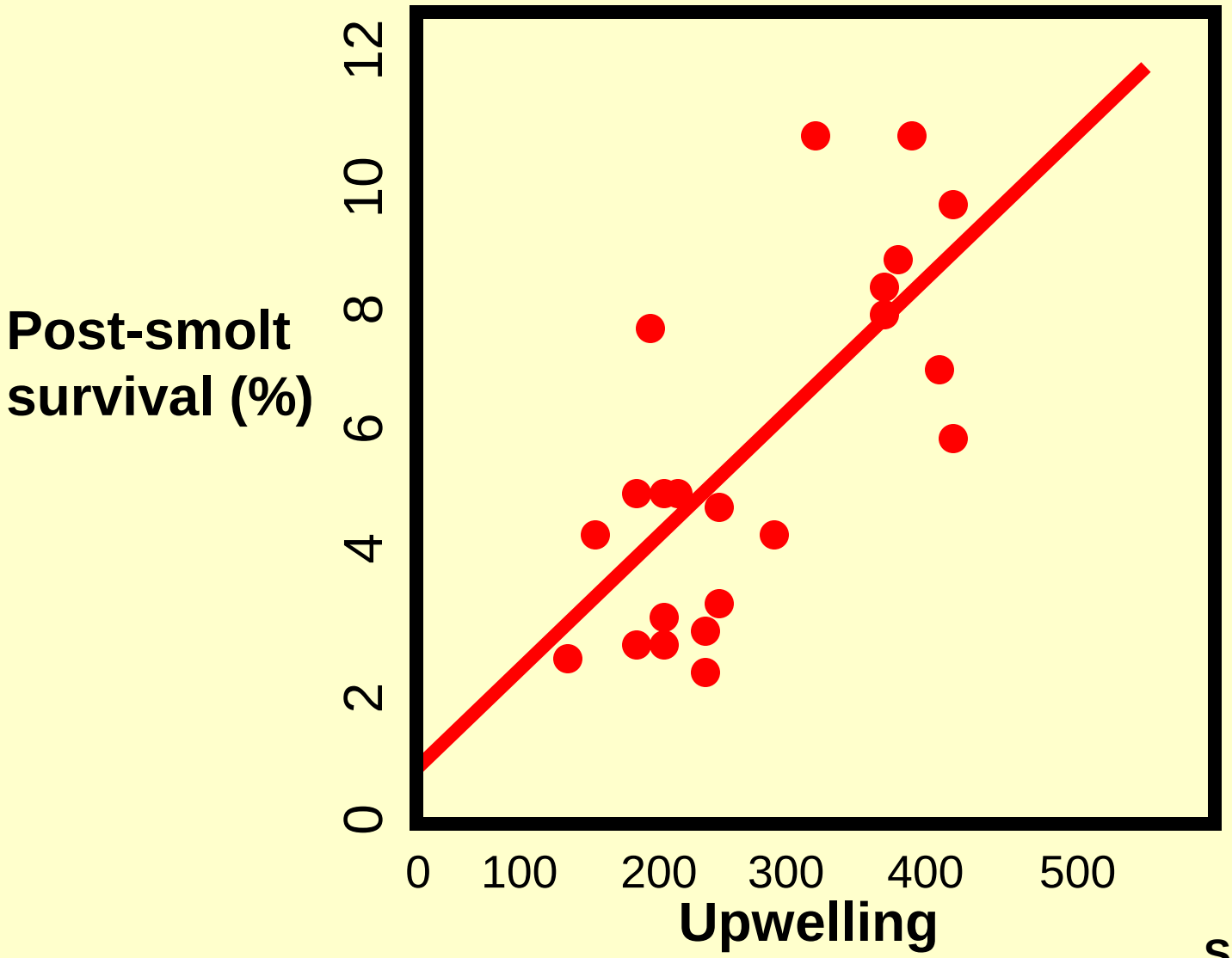
Beetz 2009

For a long time, many salmon biologists viewed the ocean as:

1) Not limiting salmon production
2) Not changing in any important ways
3) Not knowable anyway

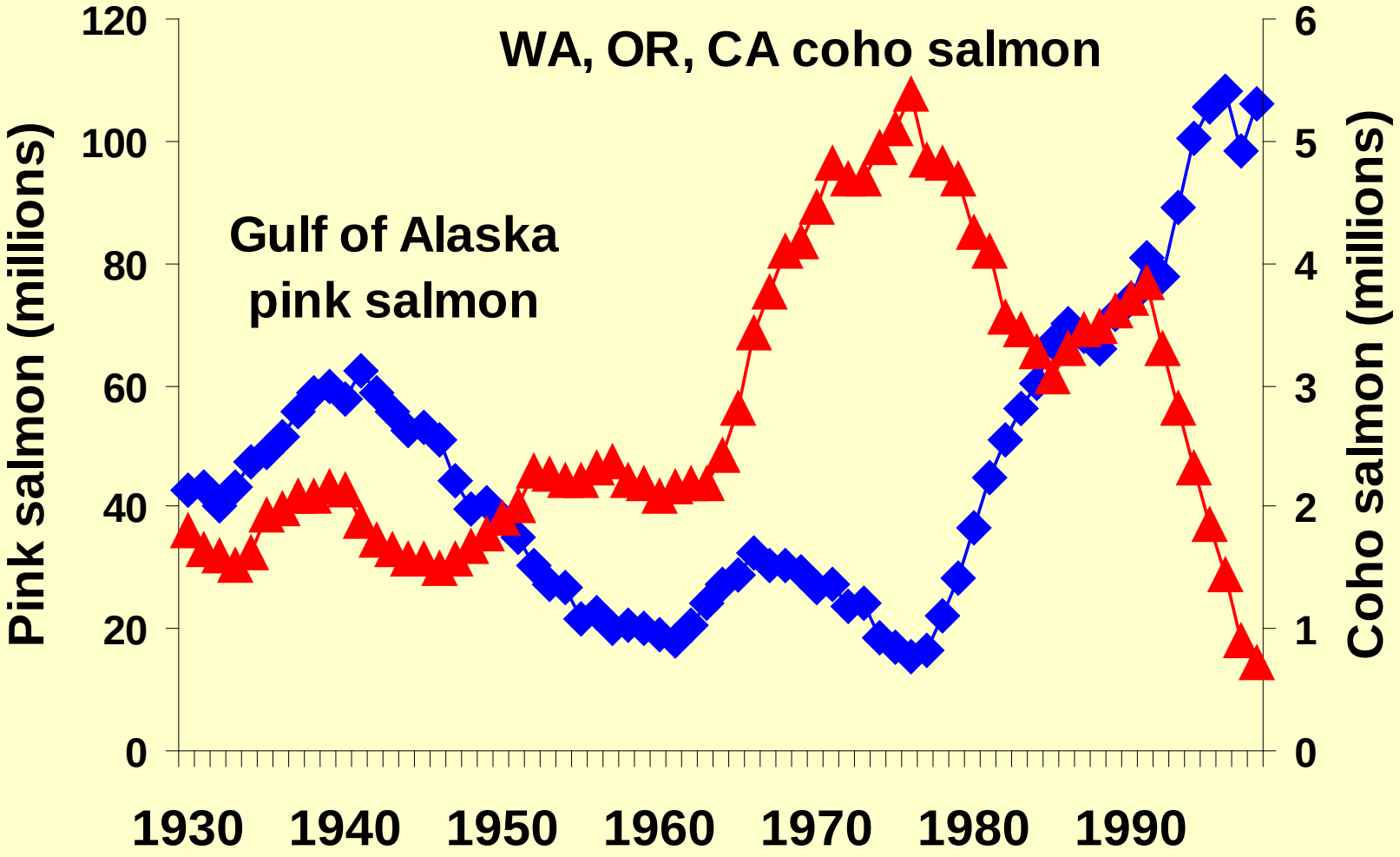
But, in the early 1980s, variation in marine survival made people re-think all this…

Marine survival of Oregon hatchery coho salmon was positively related to an index of upwelling off the coast

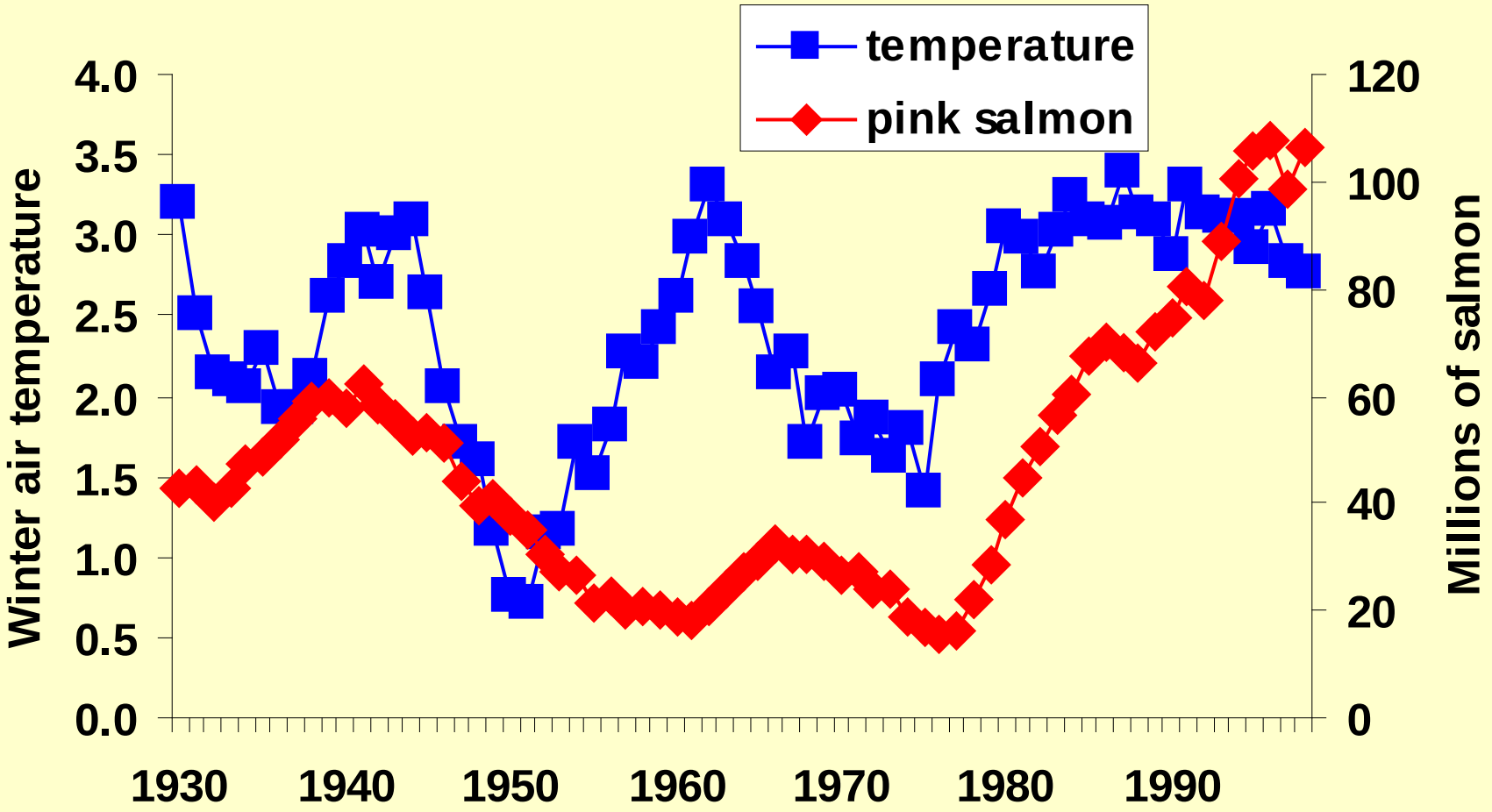


S. Mathews (1984)

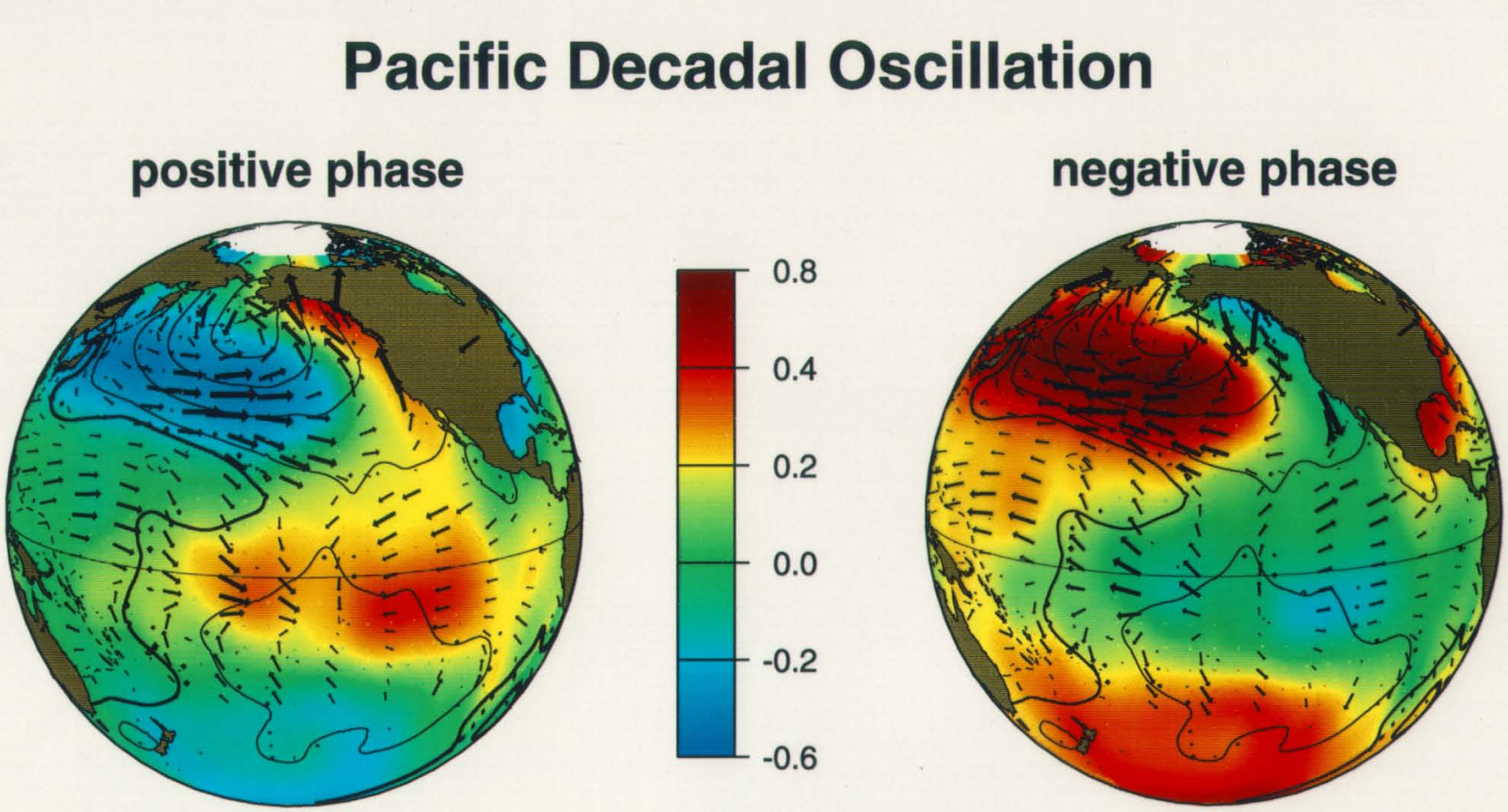
Comparison of pink salmon caught in the Gulf of Alaska with coho catches in Washington, Oregon and California (Francis and Sibley, updated)



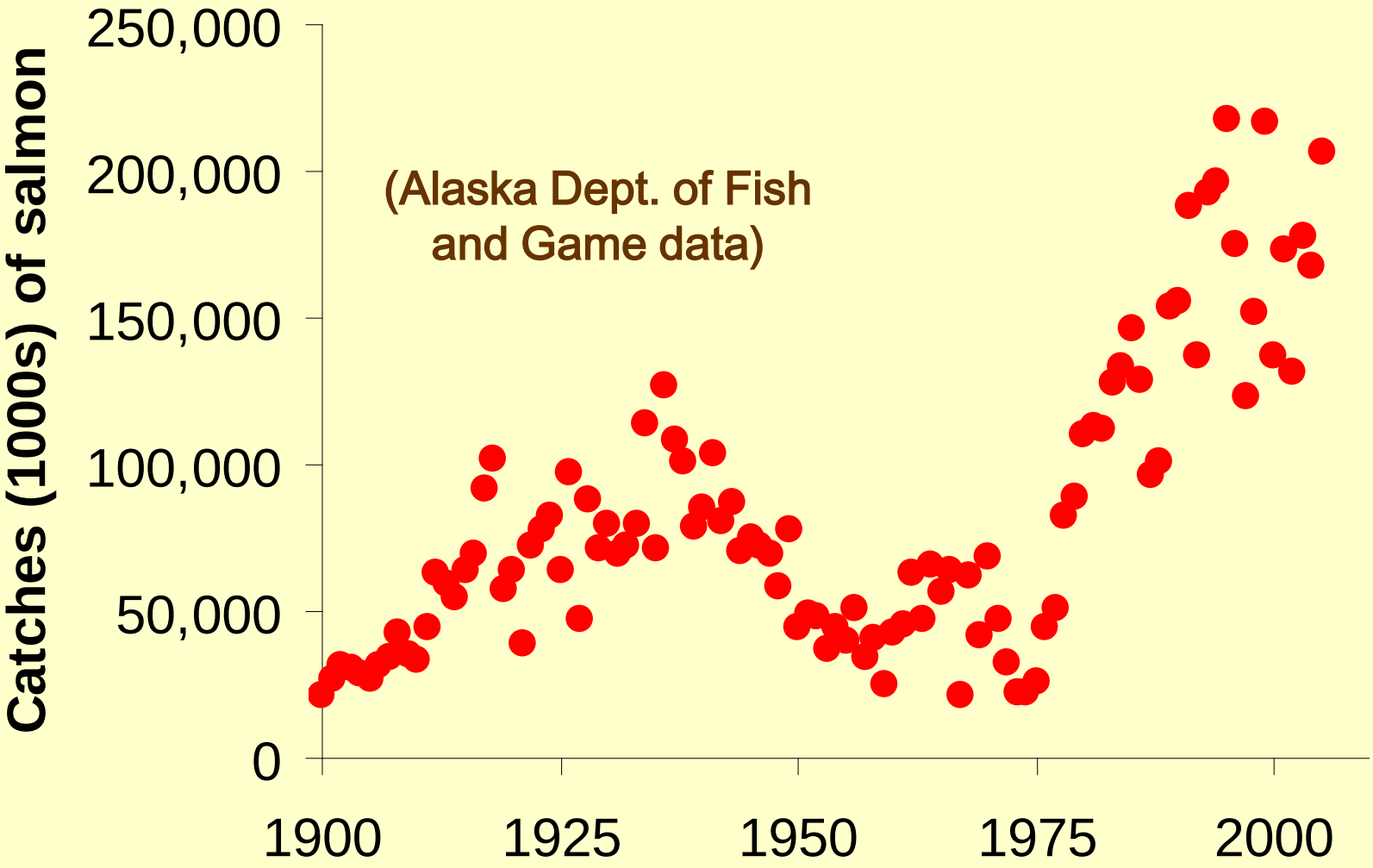
Pink salmon catches in central and southeast Alaska seem to follow winter temperatures (November - March air temperatures in Sitka, southeast Alaska).

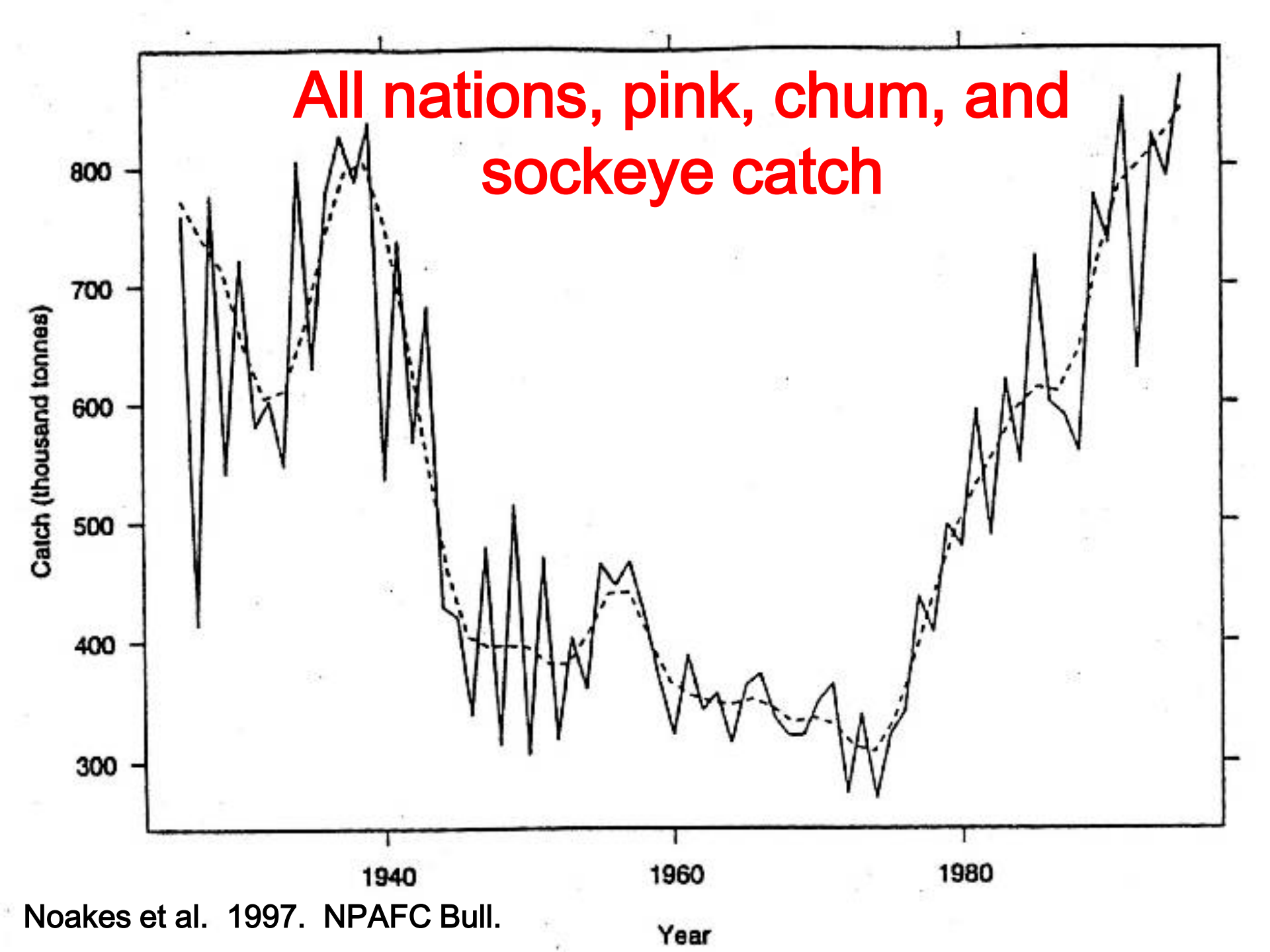


We now understand that climate and ocean conditions are linked. There are "regimes" that favor salmon in one part of the range but not others



Commercial catches of all salmon species in Alaska





Noakes et al. 1997. NPAFC Bull.

Yes, but what do the fish actually die of?

Presumably, the proximate cause of death is normally predation, though the fish may be weakened by disease, lack of stored energy, or poor seawater adaptation, and the vulnerability to predation may be extended if growth is slow.

But, who eats them?

There is no coastwide “enemy of salmon” but rather losses to many different species, depending on the size of the salmon and the region. Overall, little progress has been made on this issue.

Predators: Are harbor seals (for example) a significant predator on salmon?

- ✓ How many seals are there? 12,990 prior to pupping and 15,810 afterwards.
- ✓ How much fish do they eat? 1.9 kg or 4.3% body weight per day per seal
- ✓ What is the composition of their prey?

(Olesiuk 1993)

Mostly Pacific hake from April to November and mostly Pacific herring from December to March in the Strait of Georgia

Estimated mean smolt fork length of Chilko Lake sockeye salmon as outmigrants and surviving adults

Year	Outmigrants	Adults	Probability
1971	81.7 (294)	82.3 (291)	< 0.05
1976	88.8 (194)	89.2 (280)	> 0.05
1977	95.7 (192)	97.3 (292)	< 0.01

In general, fish that survived to adulthood had been larger as smolts than those that died, in a given year (Henderson and Cass 1991).

Life History Stage	pink	chum	sockeye	coho	chinook	steelhead	cutthroat
female length (mm)	522	683	553	643	871	721	413
fecundity	1648	2876	3654	2878	5401	4923	1197
egg size (mg)	190	290	130	220	300	150	110
egg to fry survival	0.12	0.13	0.13	0.25	0.38	0.29	
fry size (mm)	32	34	28	33	35	28	25
fry to smolt survival			0.26	0.17	0.10	0.14	
smolt size (mm)	32	40	80	105	60-120	200	190
smolt to adult survival	0.03	0.01	0.1	0.1	0.03	0.1	0.2
adults per female	5.2	5.1	15.7	12.5	6.4	25.5	
egg to smolt survival			0.02	0.02	0.10	0.01	
adults per female			10.2	5.4	17.5	9.2	

Sockeye salmon marine survival

Koenings et al. 1993 CJFAS