Survival rates of coho and chinook salmon with respect to climate and habitat effects

Arni Magnusson

Salmon survival

- **Important part of regional economies**
- **Symbol of relatively untouched ecosystems**

Long-term decline in wild salmon runs . . .

Major hatchery releases started in the 1960s and 1970s
Today, over 50% of catches in the Pacific Northwest are of hatchery origin

Hatchery salmon are tagged before release, and the recovery data can be used in survival rate analysis

What affects survival rate

HATCHERY

Smolt weight
(Bilton et al. 1982,
Green & Macdonald 1987)

FRESHWATER

River flow rate
(Scarnecchia 1981,
Skalski 1996)

River temperature
(Holtby 1988,
Baker et al. 1995)

Dams
(Mathur et al. 1996,
Skalski 1998)

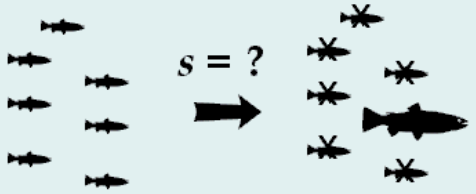
OCEAN

Early predation
(Fisher & Pearcy 1988,
Mathews & Ishida 1989)

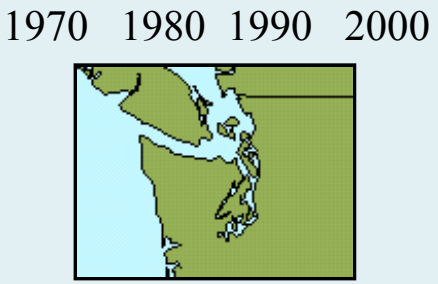
Aleutian Low
→ Upwelling
→ SST
(Scarnecchia 1981,
Nickelson 1986,
Beamish 1993,
Mantua et al. 1997)

Research outline

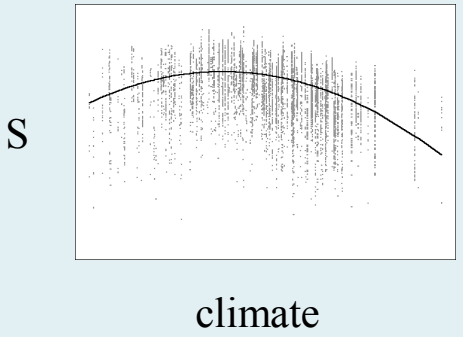
1 **Estimate marine survival rate of hatchery-reared coho and chinook salmon, using tag recovery data**



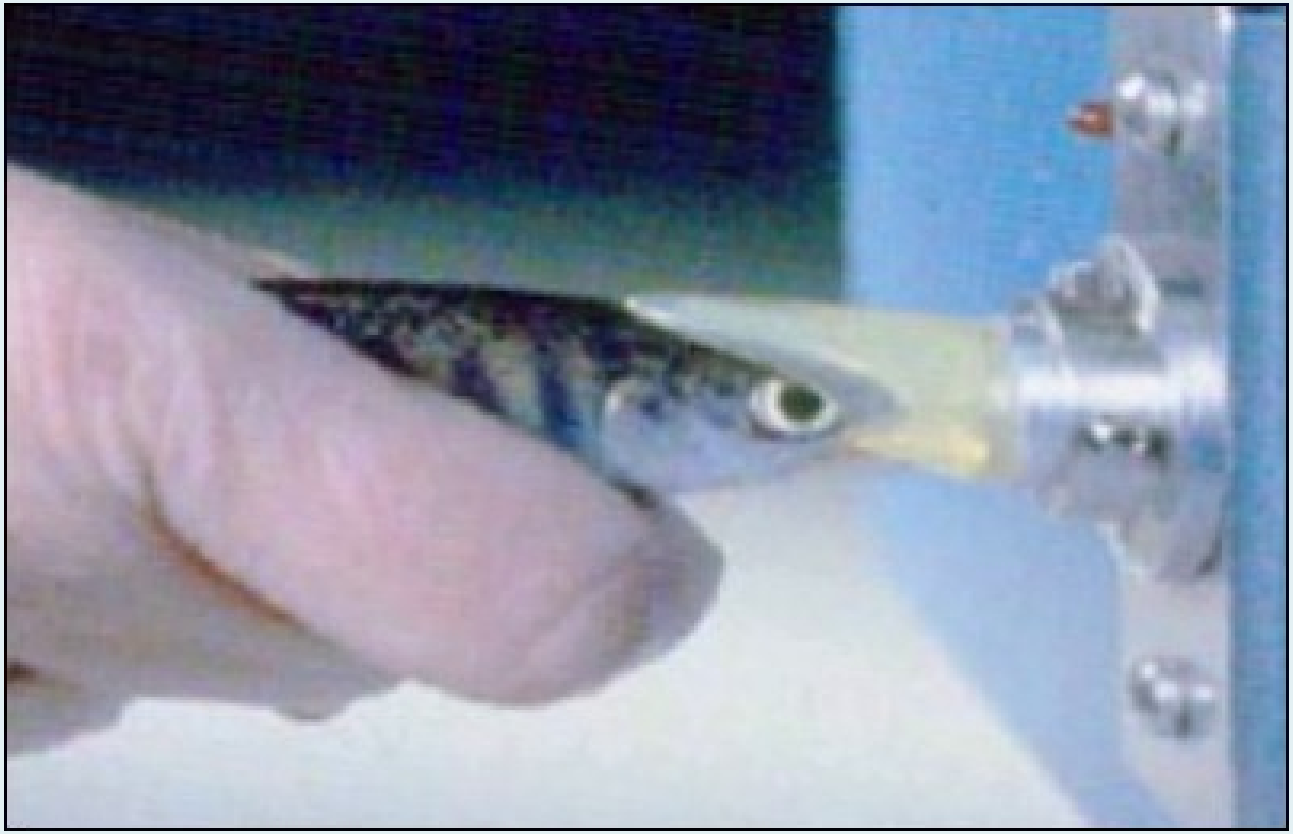
2 **Describe the spatial and temporal trends of survival rate**



3 **Fit regression models to explore how the observed survival rates relate to climate and habitat variables**

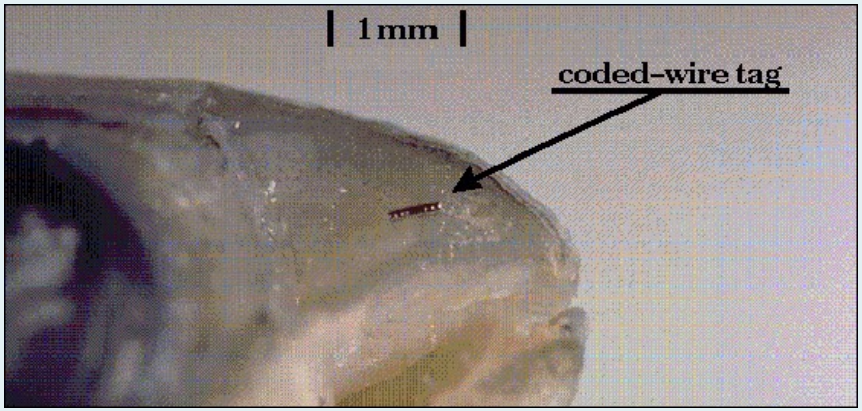


Coded-wire-tag data



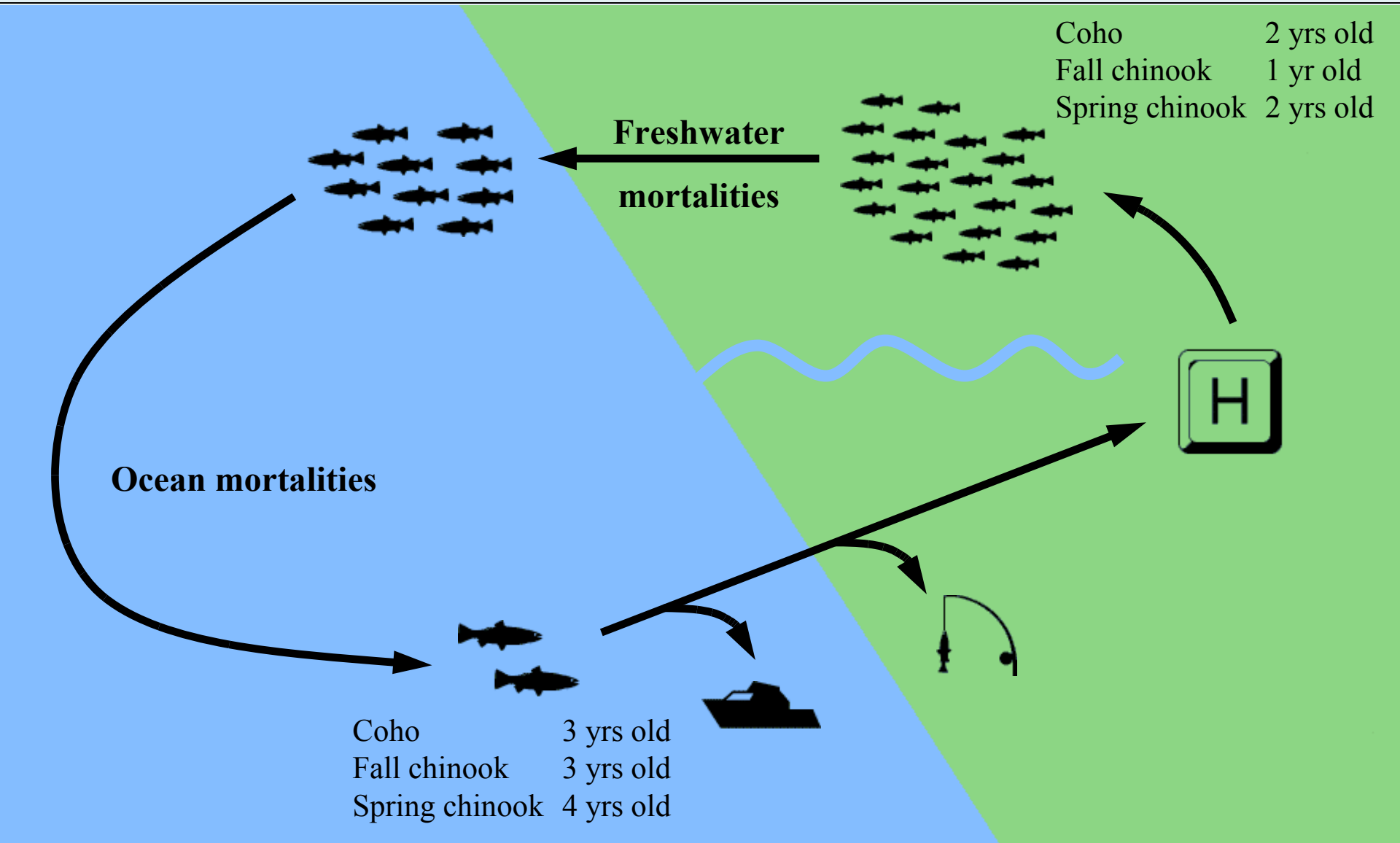
Coded-wire-tag data

Juveniles are tagged and their adipose fin is clipped off before release, distinguishing a fish as tagged.



Some years later, when the salmon return to spawn, adipose-clipped fish are caught by commercial and sports fishermen, and their heads are inspected.

Releases and recoveries



Survival rate

$$= \frac{\text{Recovered adults}}{\text{Released smolts}}$$

Recoveries are transformed to a standardized age to allow survival rate comparison between regions:

Coho	$\rightarrow$ 3 yrs old
Fall chinook	$\rightarrow$ 3 yrs old
Spring chinook	$\rightarrow$ 4 yrs old

CWT database

PSMFC Regional Mark Information System

www.rmis.org

CWT group 062933

State	Locality	Hatchery
CA	Sacramento River	Feather River

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Tag code	Species	Brood year	Release year	Released
062933	Chinook	1994	1995	139443

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062933	Chinook	1994	1995	139443

Rec age 2	Rec age 3	Rec age 4
14	1712	182

Adult mortality rate

	Age				
	2	3	4	5	6
Coho	0.5	0.5	0.5	0.5	0.5
Chinook	0.4	0.3	0.2	0.1	0.1

(Argue et al. 1983, Chinook Technical Committee 1989)

CWT group 062933

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14	1712	182
× 0.6		/ 0.7

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CA	Sacramento River	Feather River

Tag code	Species	Brood year	Release year	Released
062933	Chinook	1994	1995	139443

Rec age 2	Rec age 3	Rec age 4
14	1712	182
× 0.6		/ 0.7
8	1712	260

$$\text{Survival rate} = \frac{\sum \text{Implied 3 yr olds}}{\text{Released}} = \frac{1\,980}{139\,443} = 1.42\%$$

Interpreting survival rate

$$\text{Survival rate} = \frac{\text{Recovered adults}}{\text{Released smolts}}$$

A high survival rate in a certain area does not necessarily imply that the runs are of great magnitude.

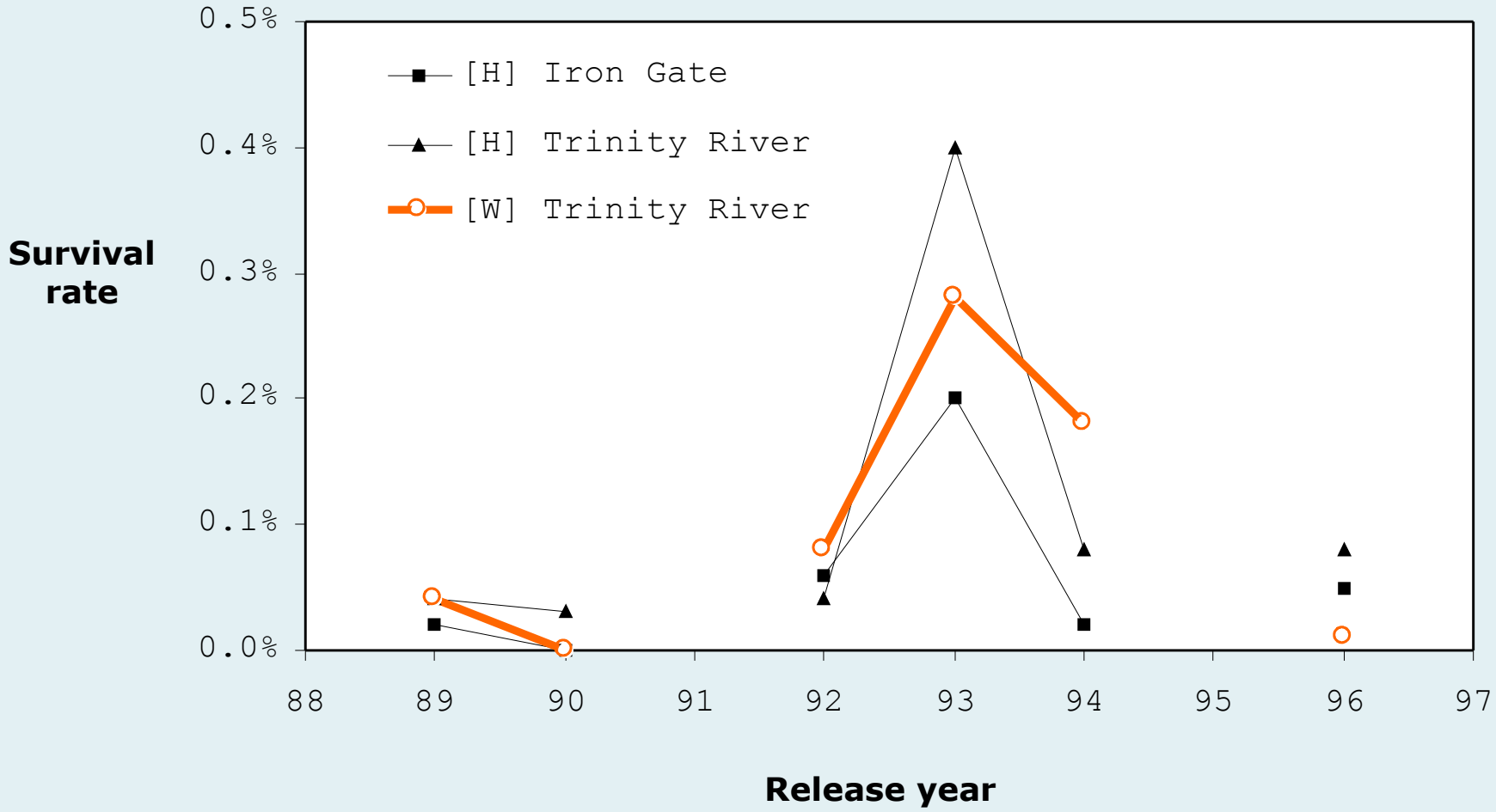
Rather, survival rate is the likelihood of a smolt surviving to adulthood, given the time and site of release.

Hatchery and wild salmon

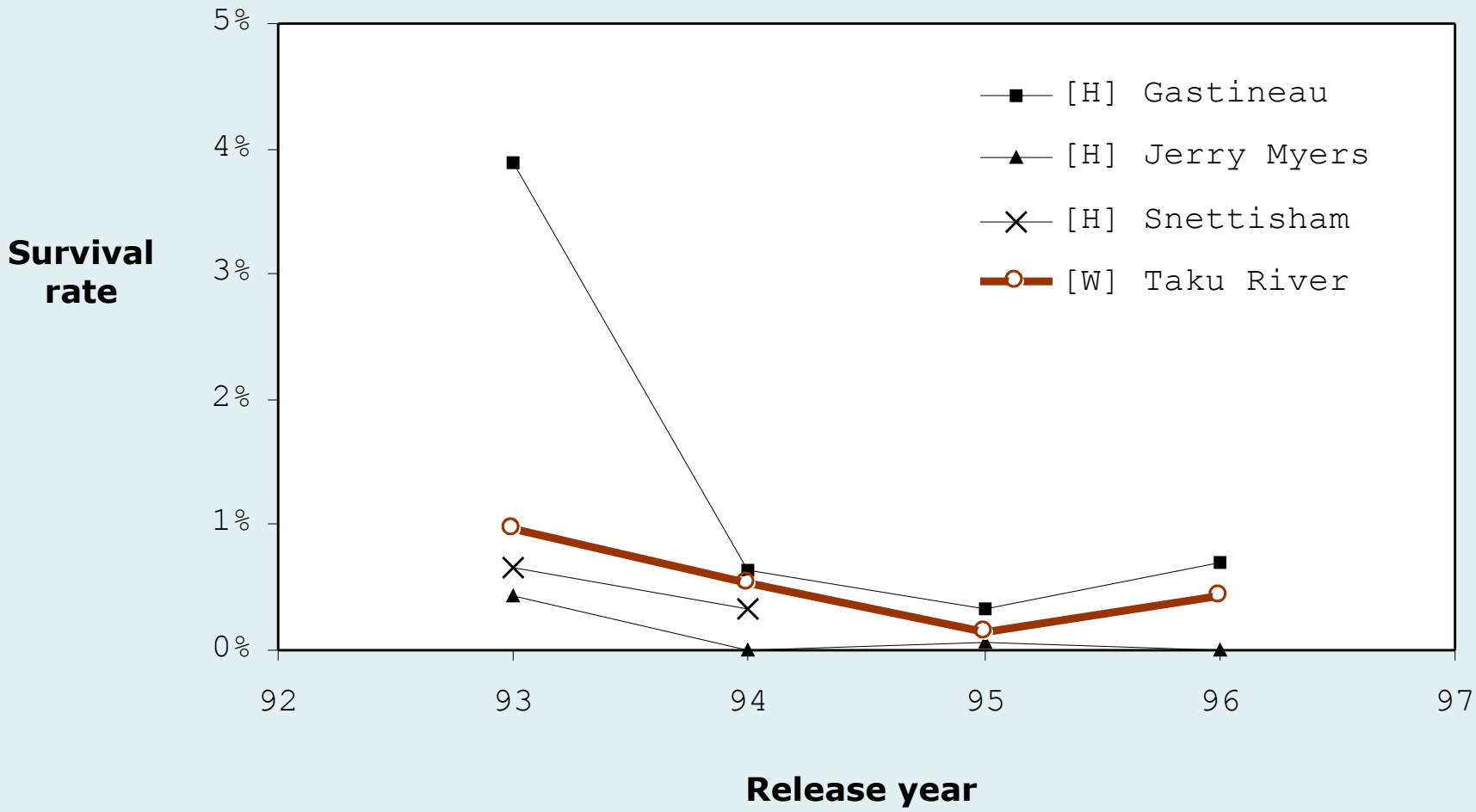
Coded wire tags are generally used for hatchery-reared smolts, but the CWT database also contains some release and recovery data from studies where wild salmon have been tagged.

These data allow local comparisons between hatchery and wild salmon survival rates.

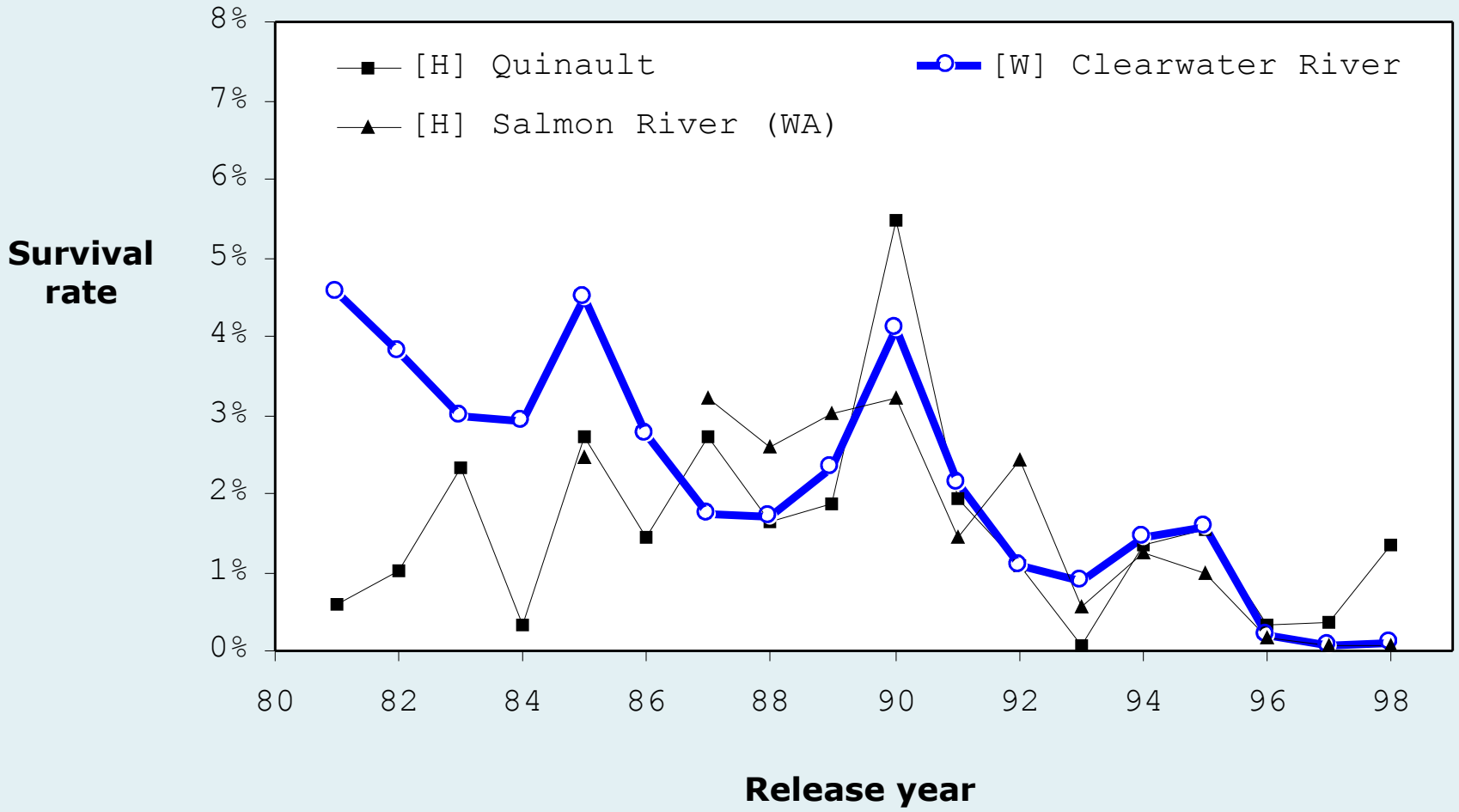
Fall chinook in Klamath Basin (CA)



Spring chinook in Lynn Canal (AK)



Coho in Clearwater River (WA)



Hatchery and wild salmon

From the CWT data available, the survival rate patterns look very similar.

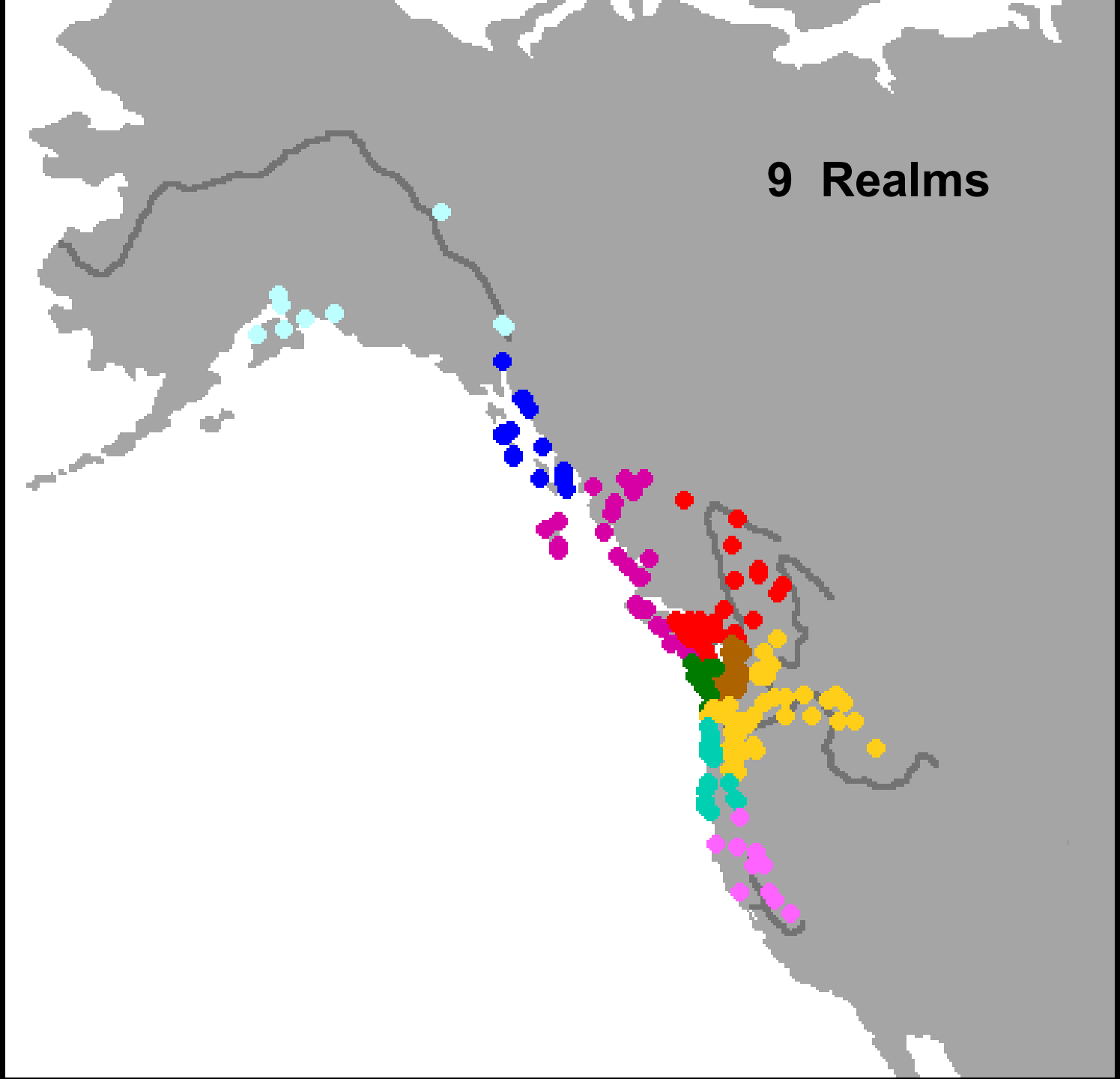
Earlier comparison studies have also indicated that hatchery and wild salmon survival rates follow similar patterns, but survival rates of wild salmon are generally somewhat higher.

(Nickelson 1986, Emlen et al. 1990)

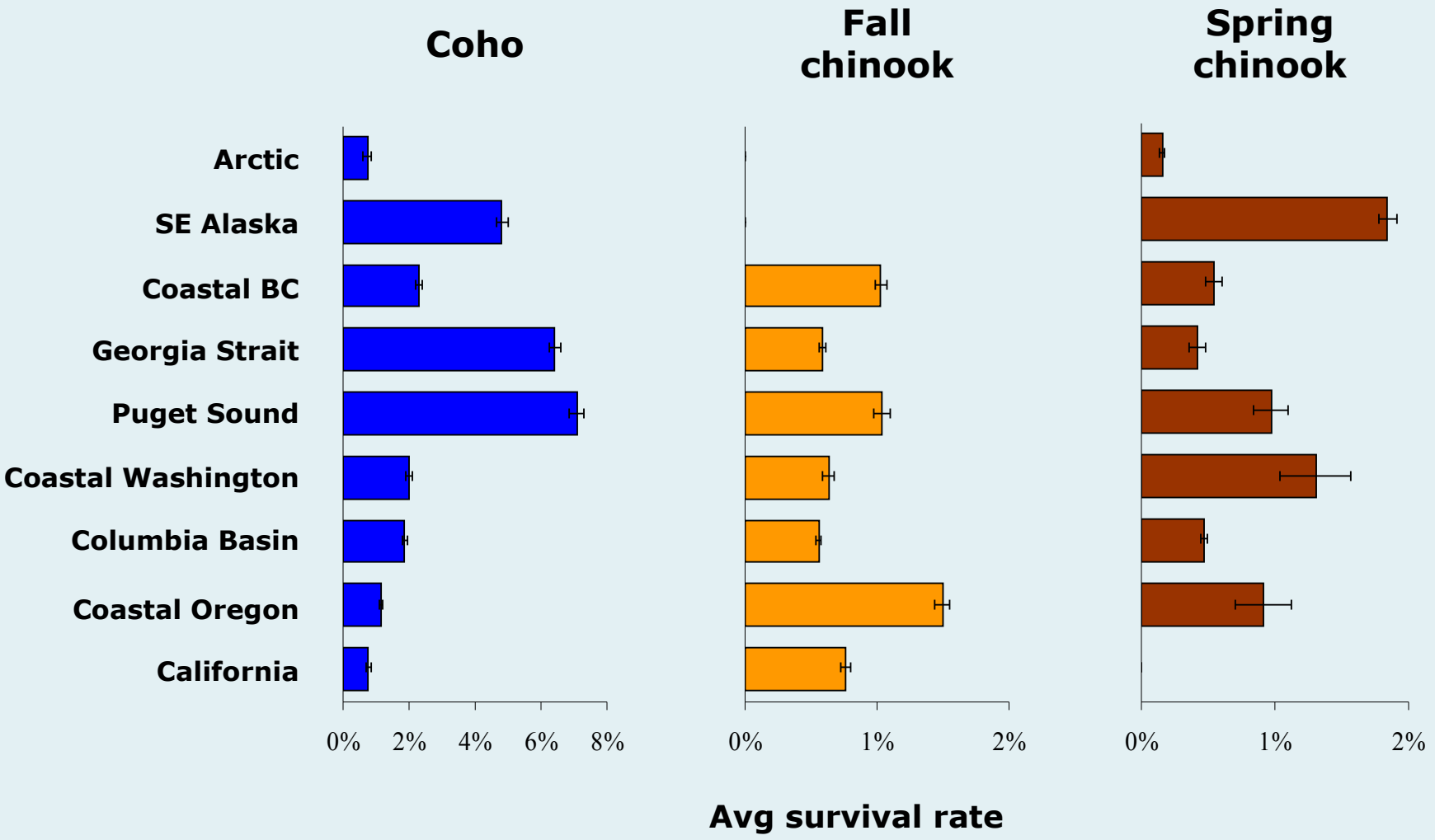
Overview of the survival rate data

18659 CWT groups from 206 hatcheries

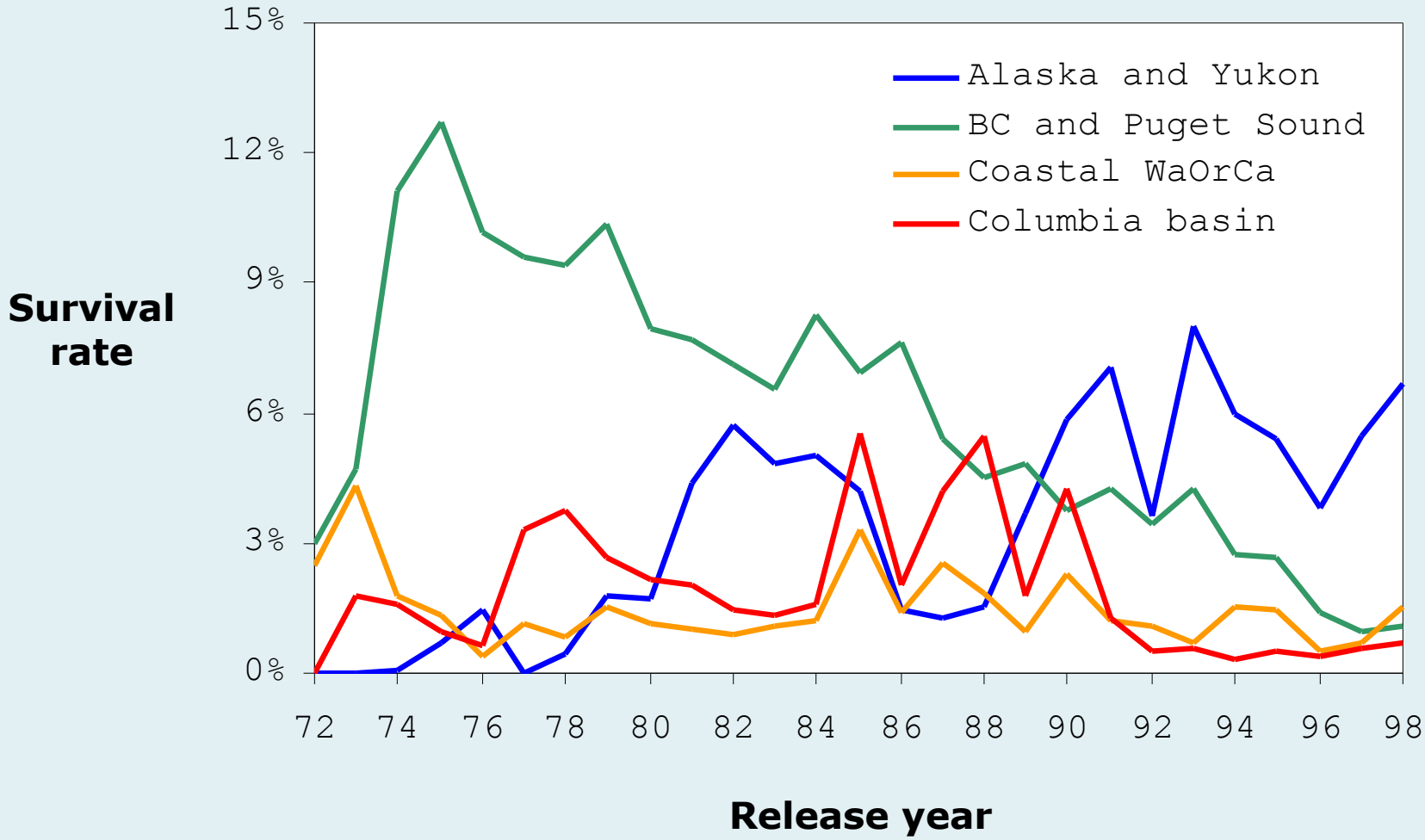
	Hatcheries	Release Years	CWT Groups	Avg Survival
Coho	128	1972-1998	7279	3.4%
Fall chinook	126	1972-1996	7857	0.8%
Spring chinook	69	1973-1996	3523	0.9%


9 Realms

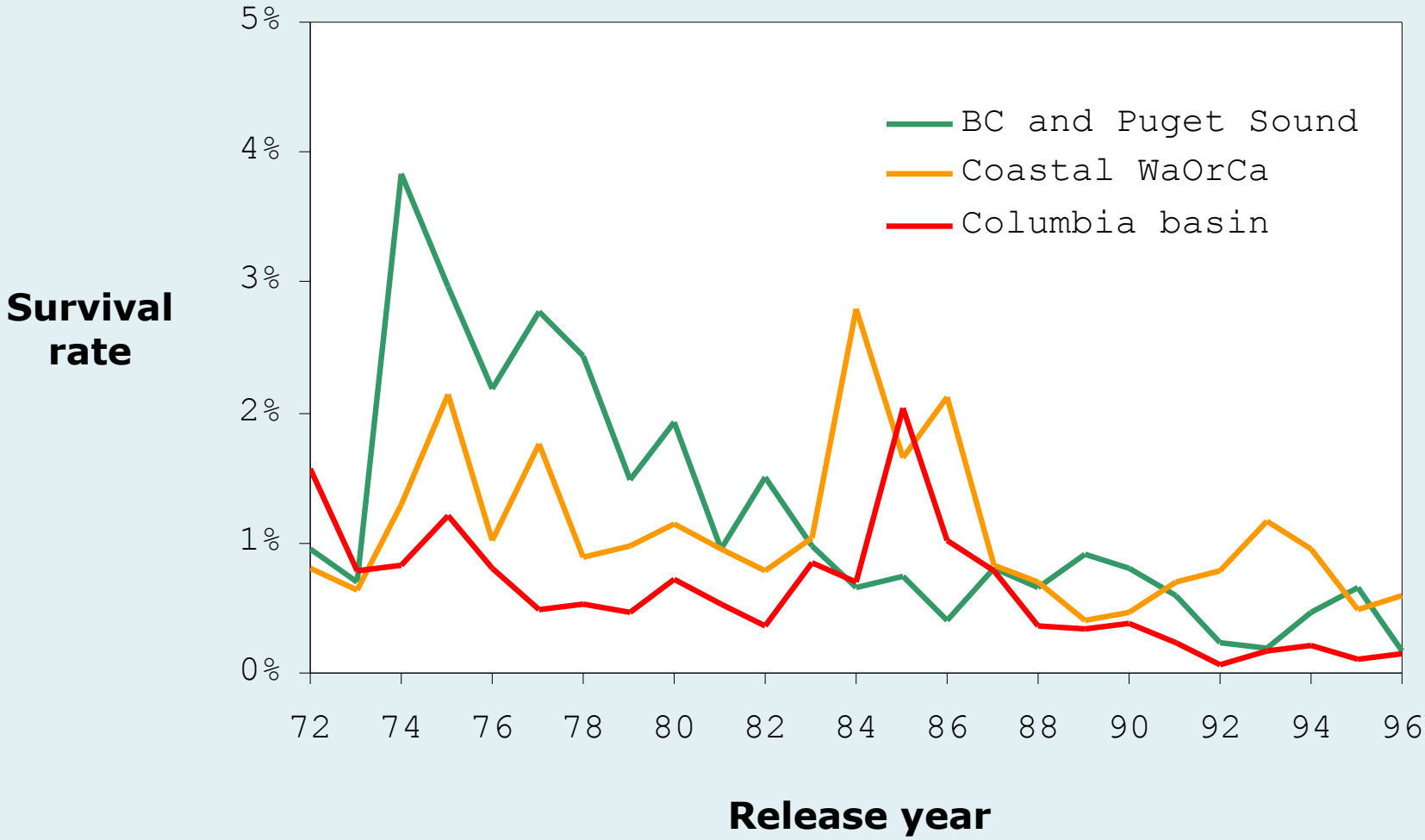
Survival rate by Realm



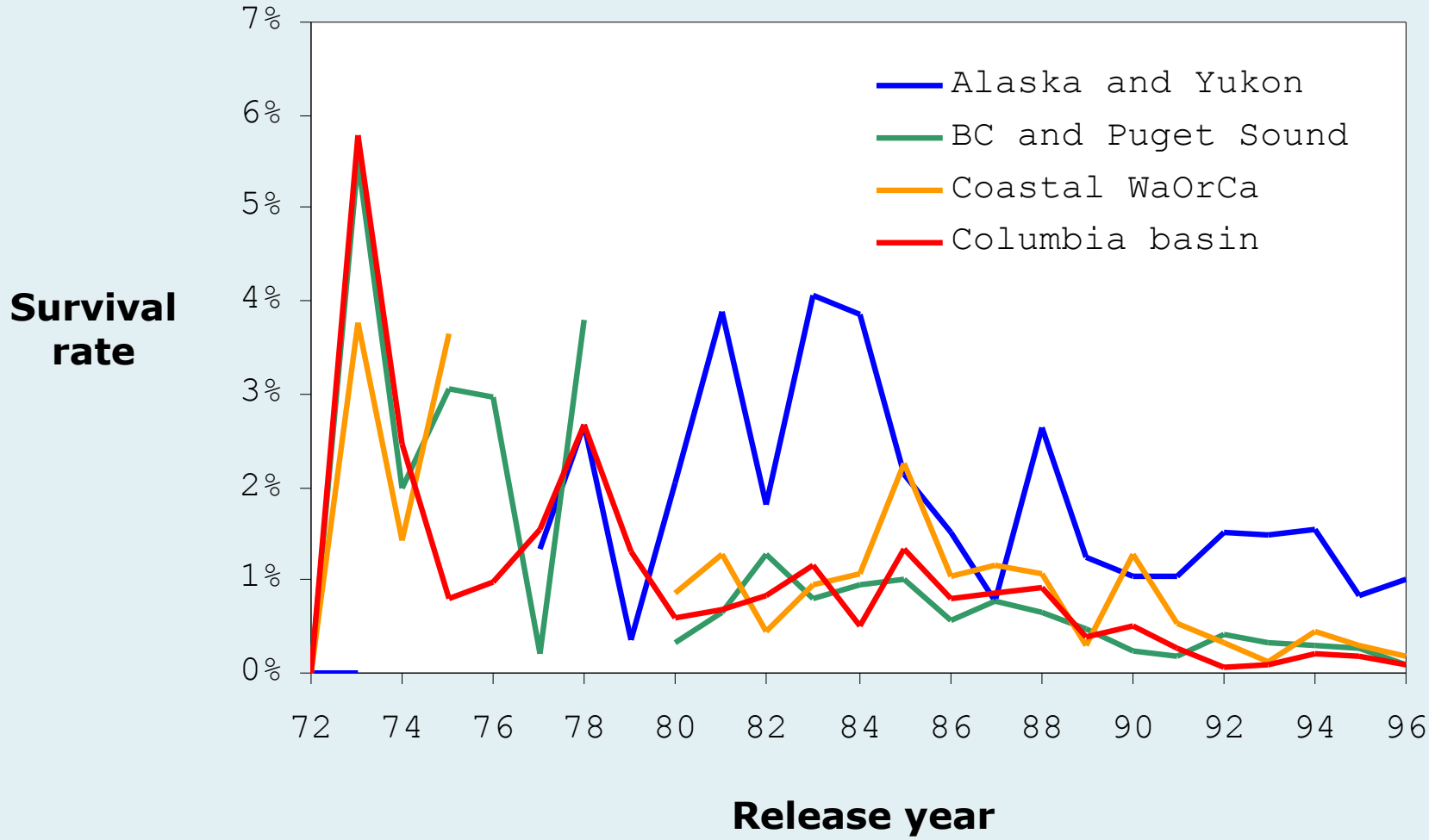
Coho survival rate by Domain



Fall chinook survival rate by Domain



Spring chinook survival rate by Domain



Some observations

- **For both coho and chinook, the long-term trends are:**

   **in AK**

   **in BC, WA, OR, and CA**

- **For both coho and chinook, the mid and late 1980s showed:**

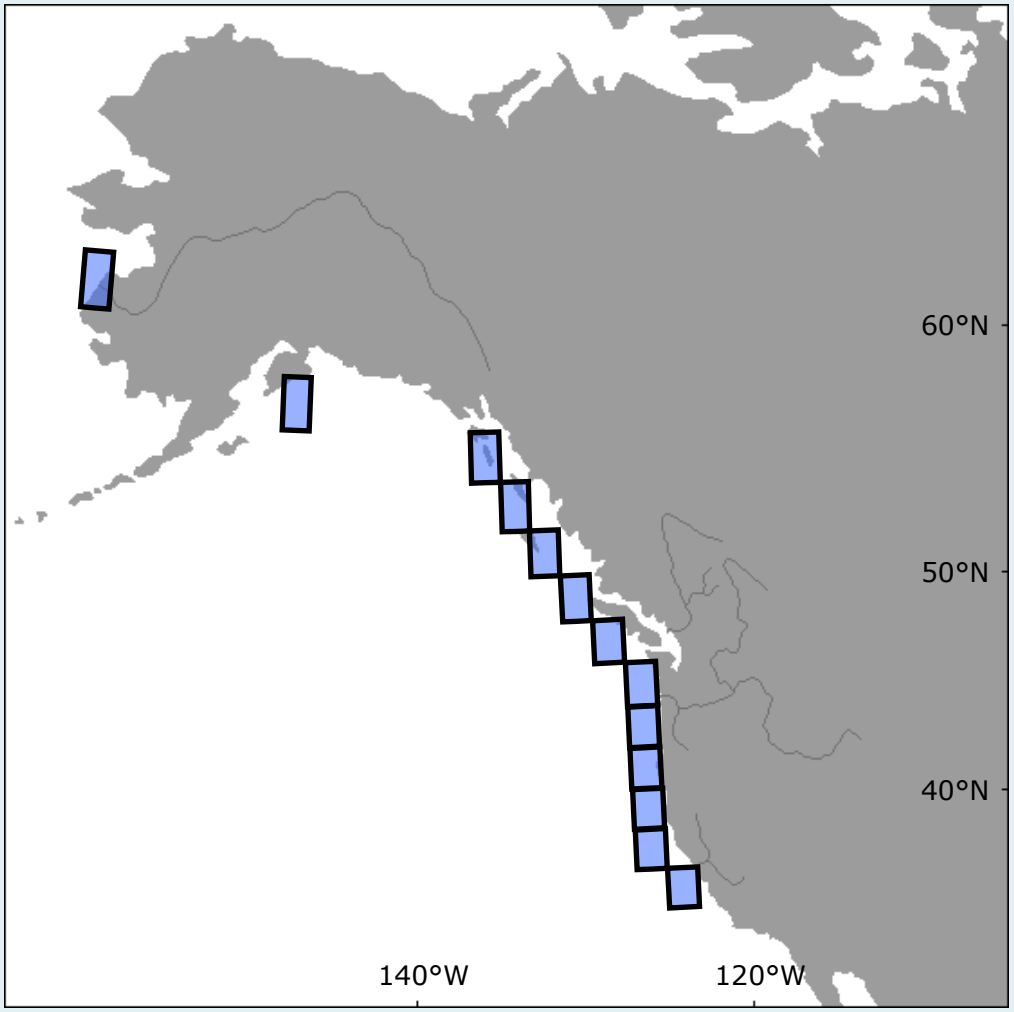
   **in AK**

   **in BC, WA, OR, and CA**

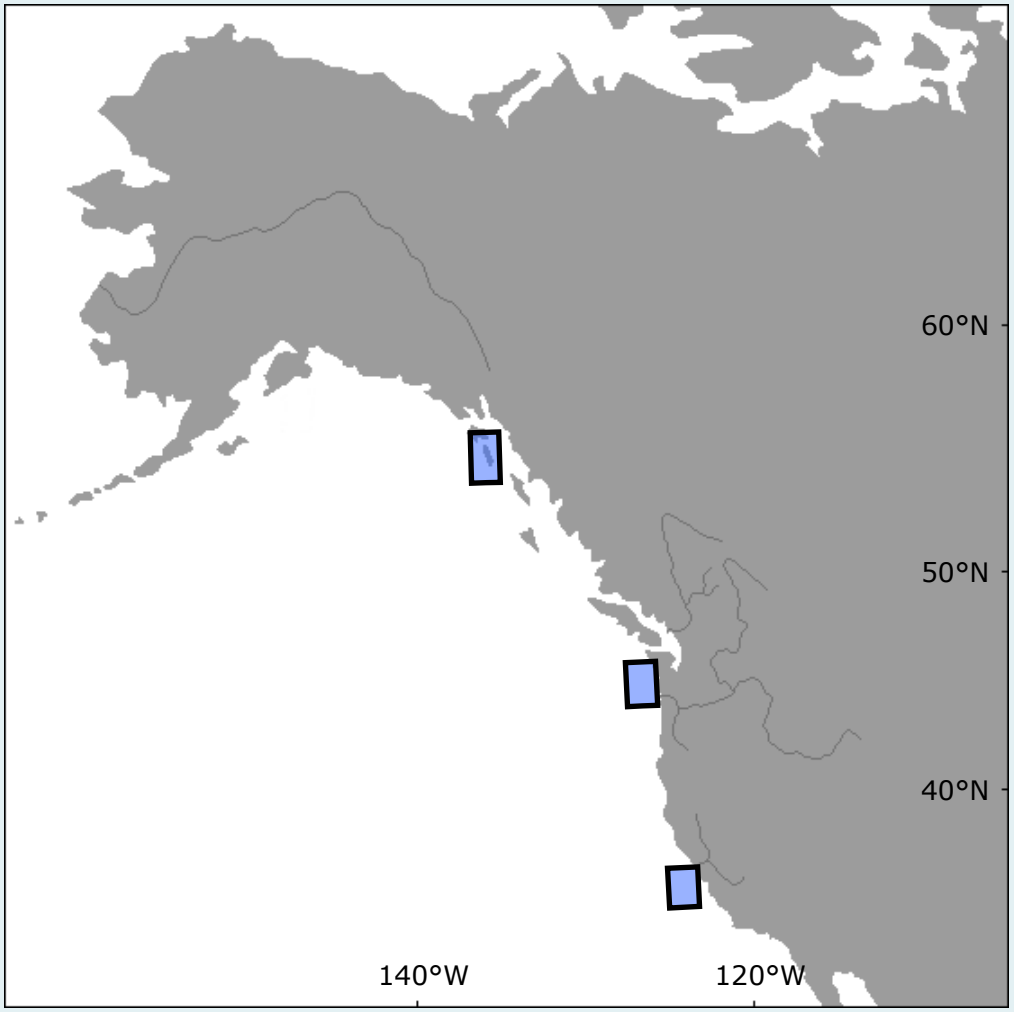
Climate data

- **Aleutian low**
- **Upwelling**
- **SST (Sea surface temperature)**
- **ENSO (El Niño southern oscillation)**
- **PDO (Pacific decadal oscillation)**

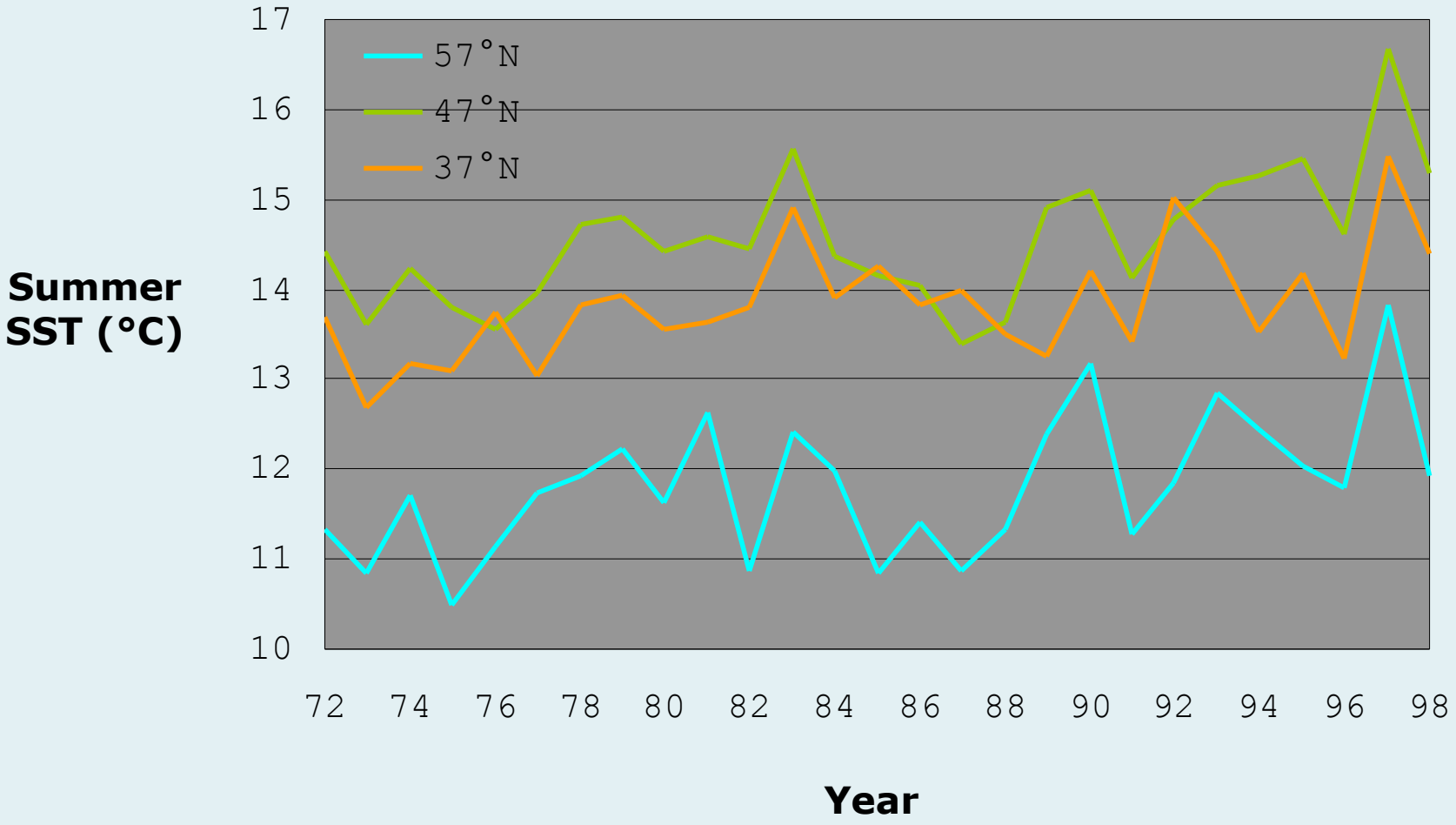
Sea surface temperature



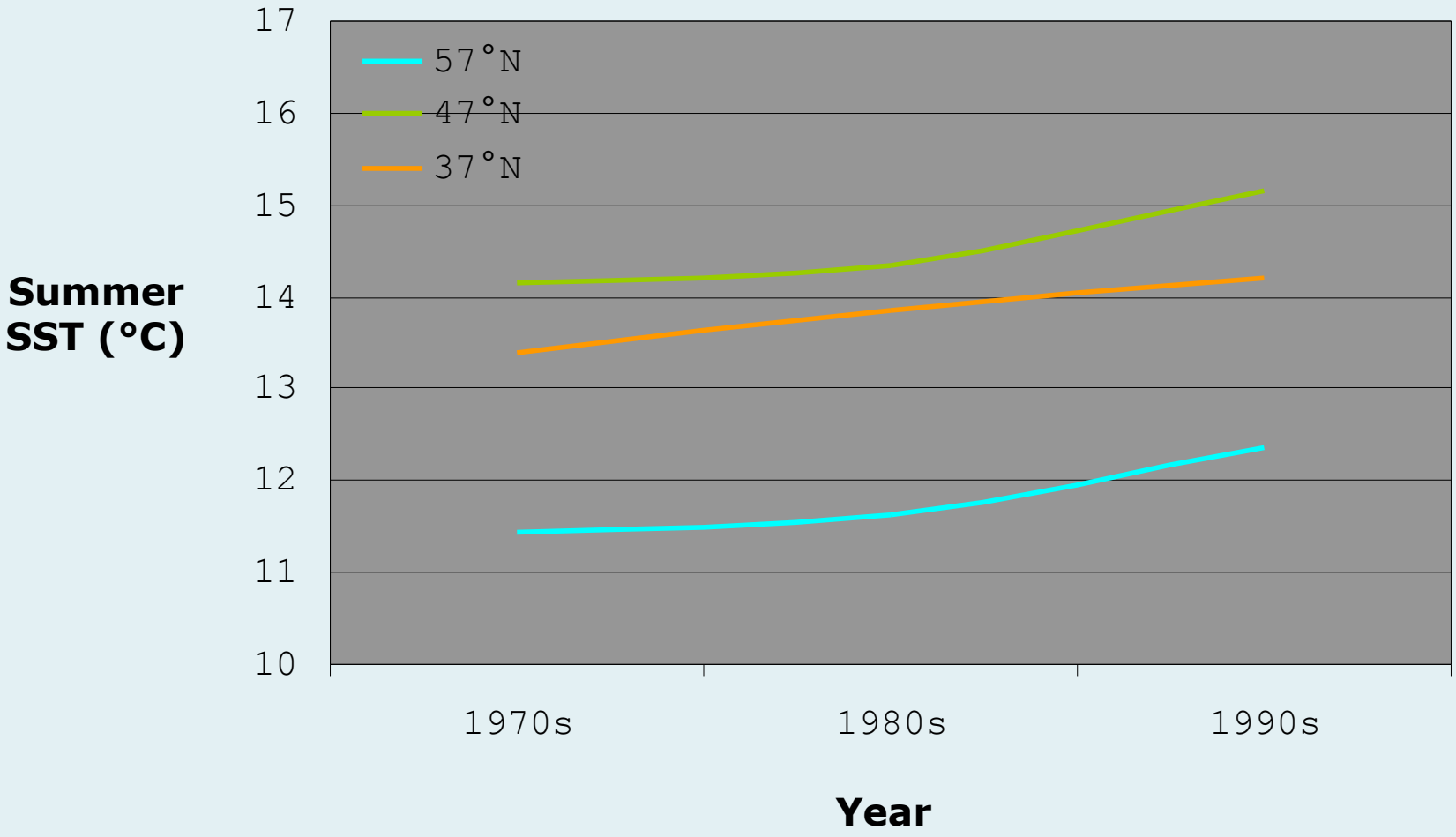
Sea surface temperature



Sea surface temperature



Sea surface temperature



Regression analysis

Use each CWT group as one datapoint, where

Survival rate is the response (dependent) variable
SST is the predictor (independent) variable

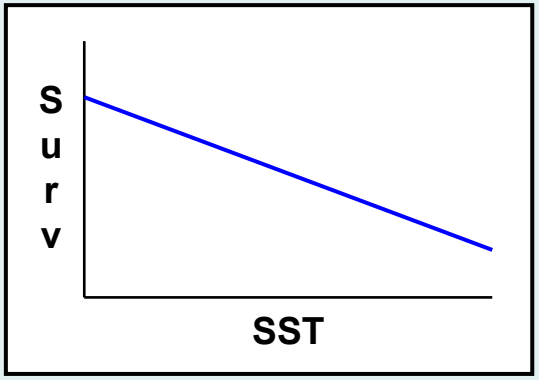
Objectives:

(1) Explore the form of the Survival~SST relationship

(2) Quantify the goodness of fit and test significance

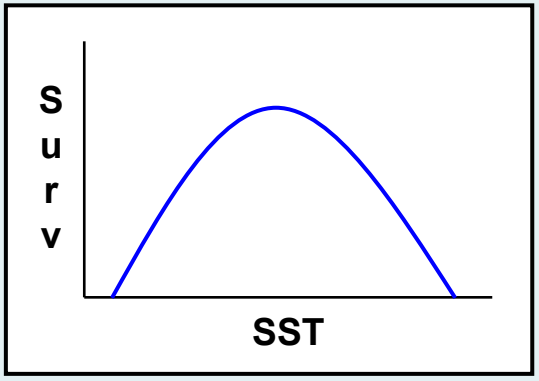
Form of Survival~SST relationship

Linear?



(Scarnecchia 1981,
McGie 1984,
Nickelson 1986,
Johnson 1988,
Emlen et al. 1990,
Holtby et al. 1990)

Dome-shaped?



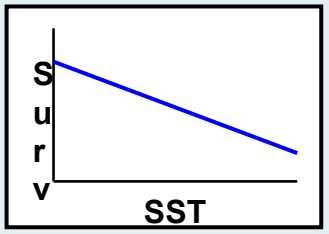
(Gargett 1997,
Ryding and Skalski 1999,
Hobday and Boehlert 2001)

GLM and survival rate

Generalized linear model (GLM)
with Poisson error distribution

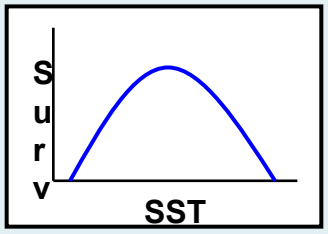
Linear term only:

$$\log \hat{S} = \hat{\beta}_0 + \hat{\beta}_1 SST$$

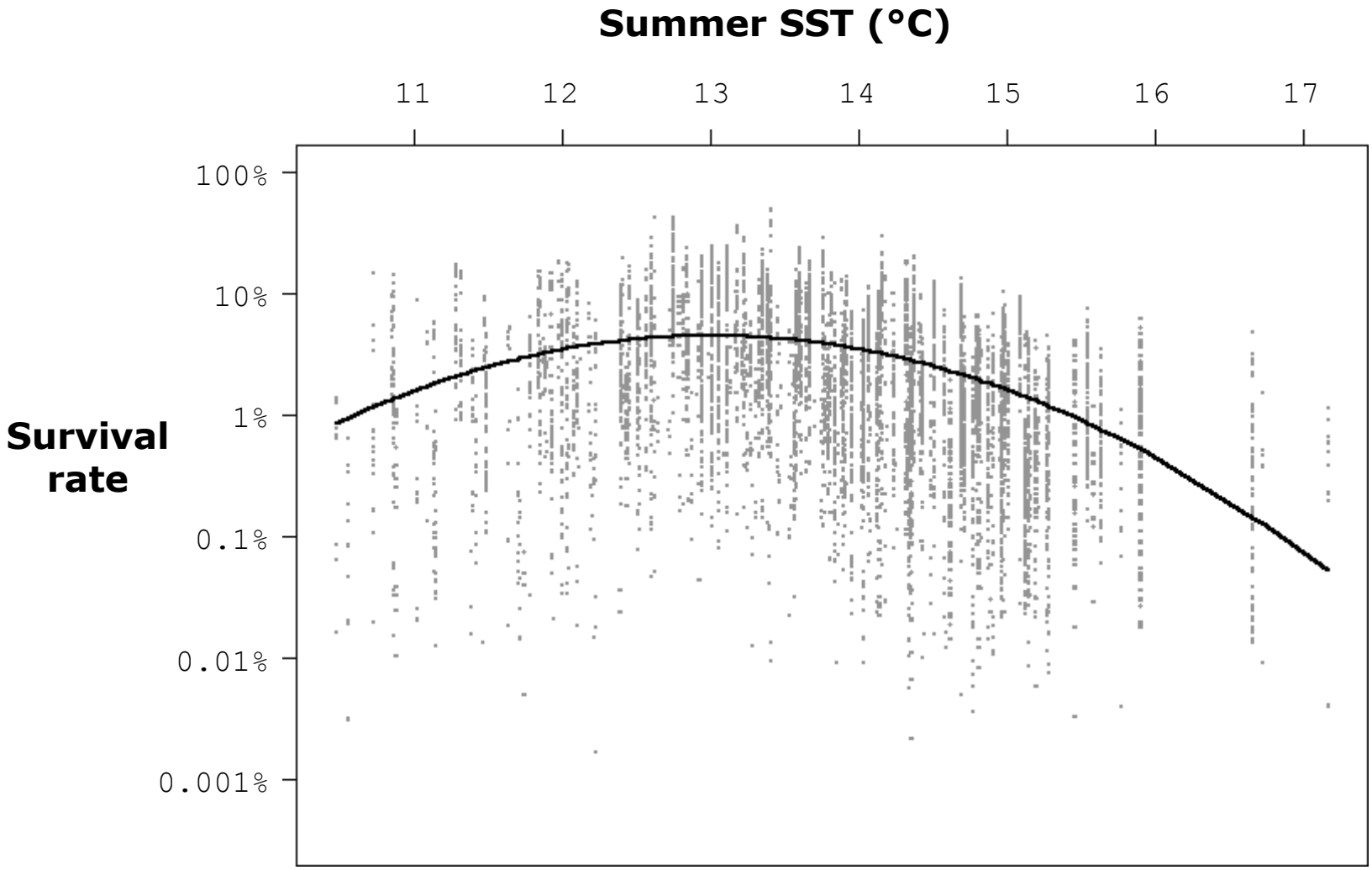


Linear and quadratic term:

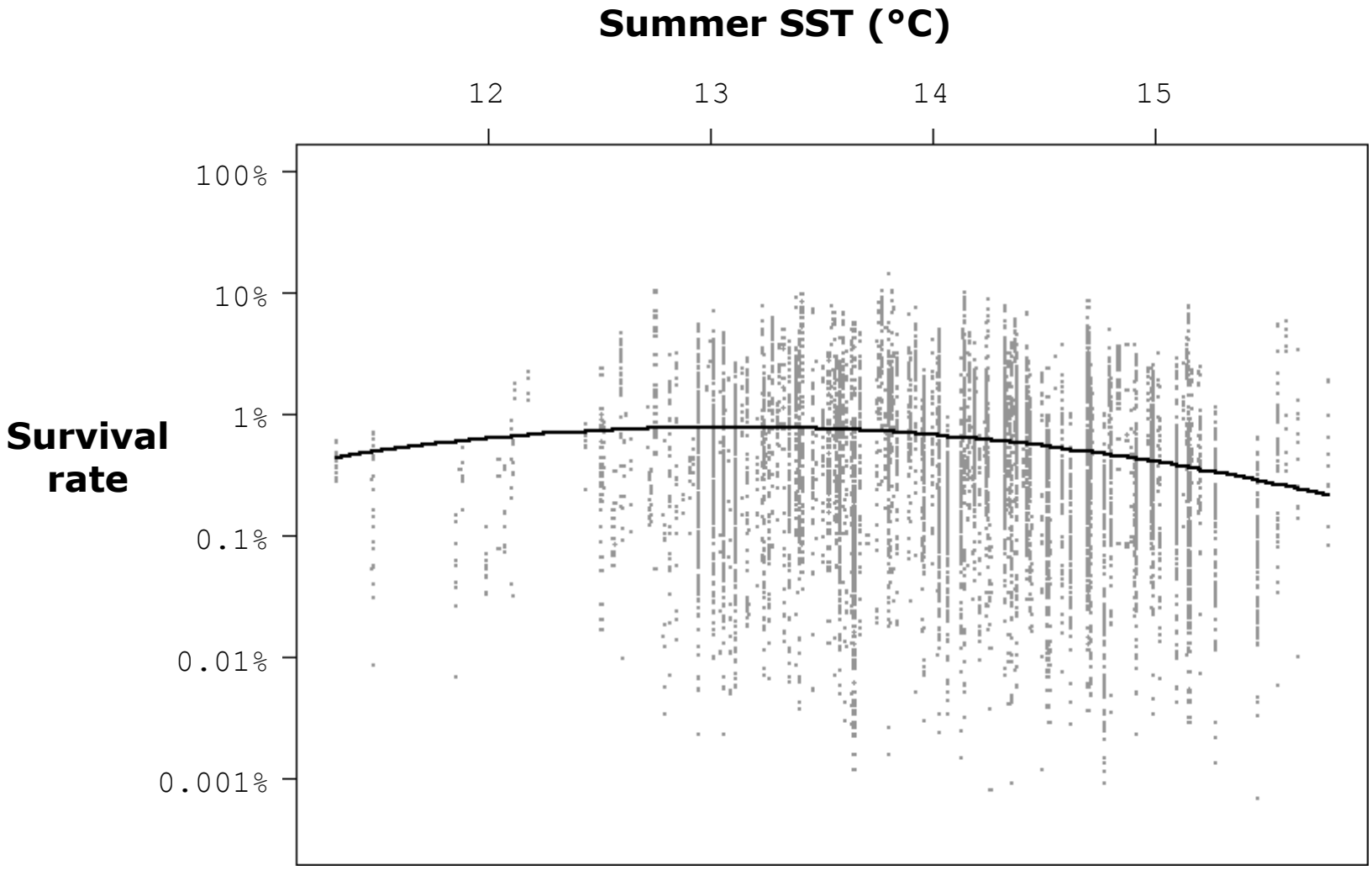
$$\log \hat{S} = \hat{\beta}_0 + \hat{\beta}_1 SST + \hat{\beta}_2 SST^2$$



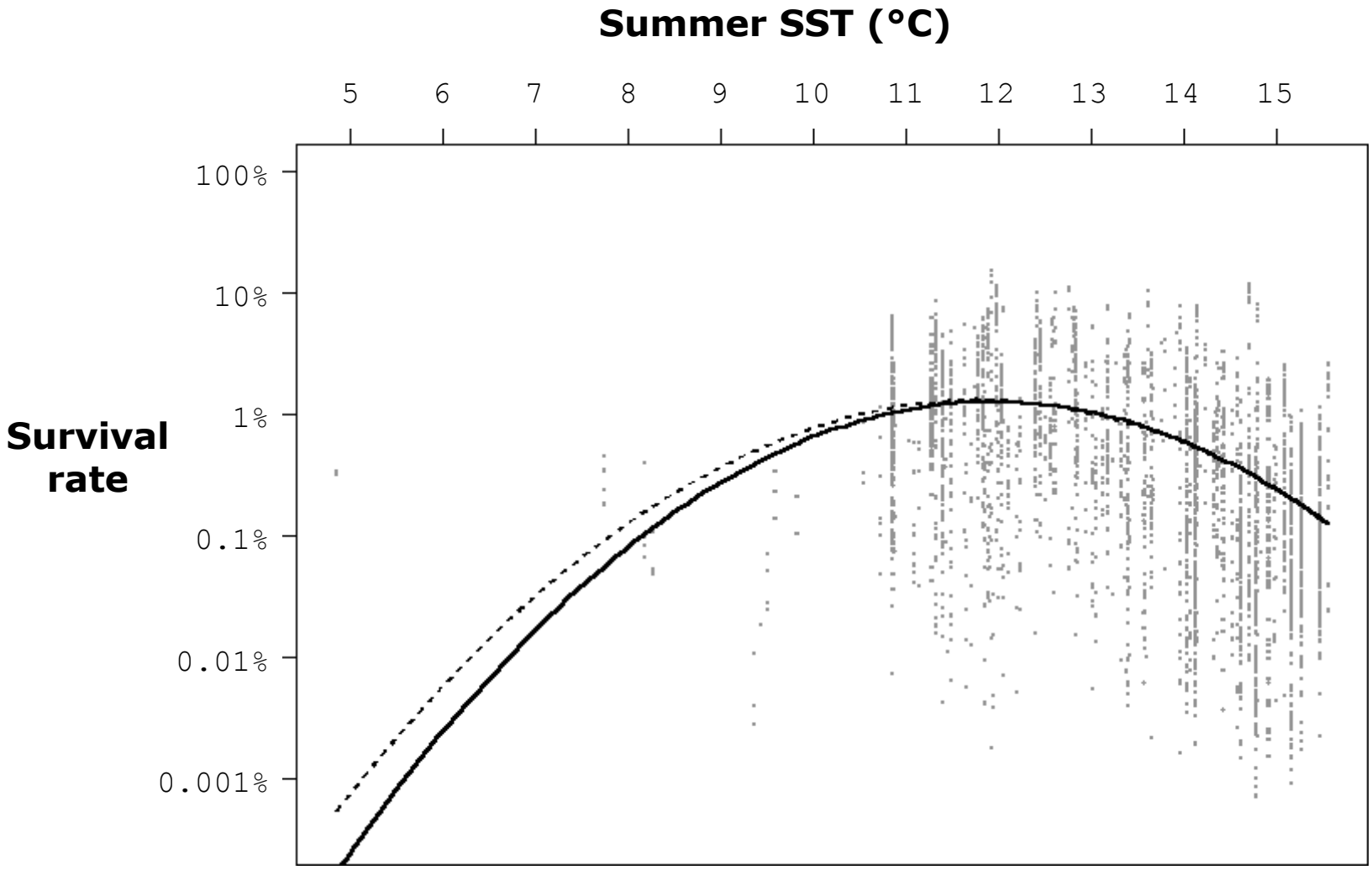
Coho Survival~SST



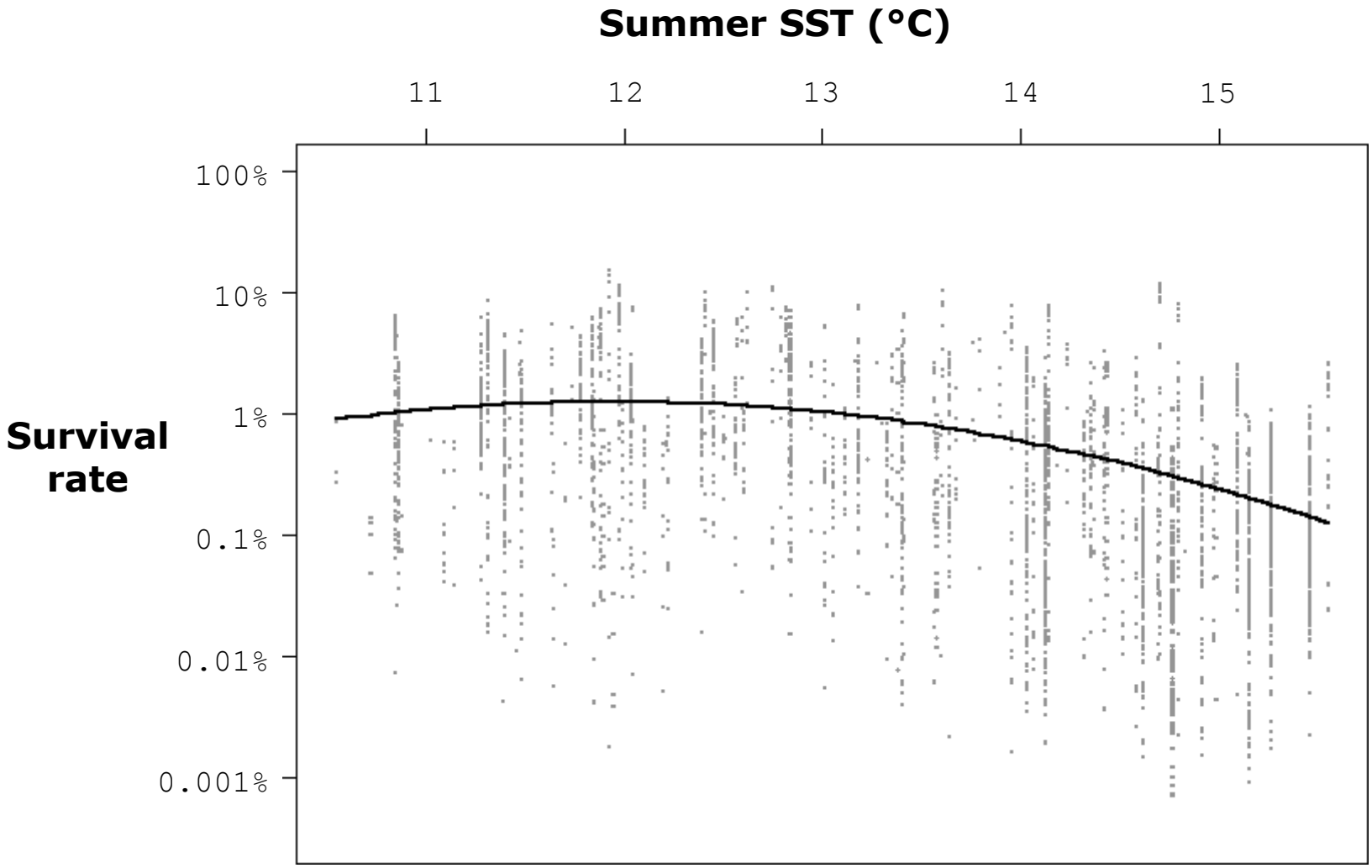
Fall chinook Survival~SST



Spring chinook Survival~SST



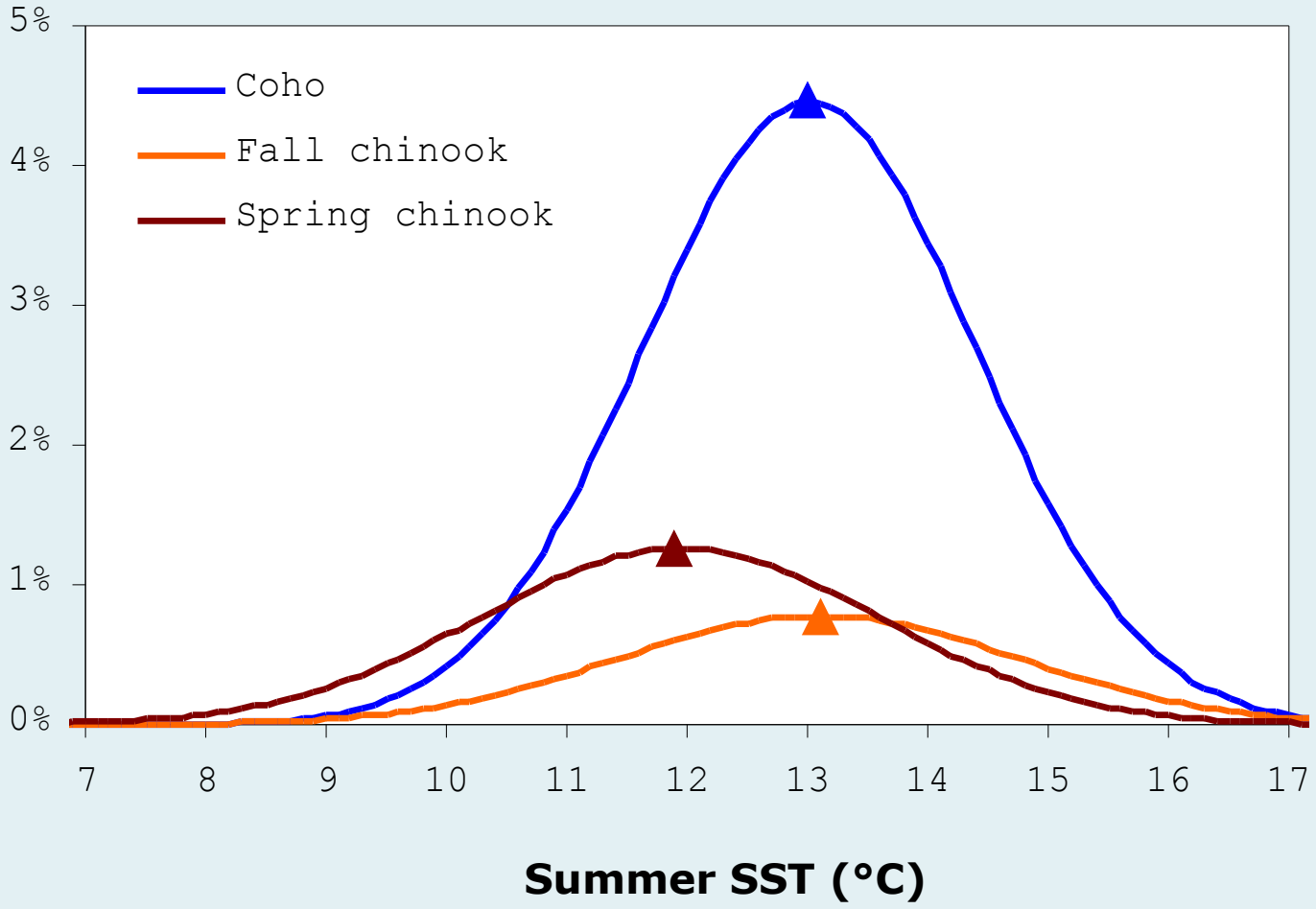
Spring chinook Survival~SST



Variation explained by SST

	Coho	Fall chinook	Spring chinook
Year:Domain	0.464	0.339	0.424
$SST+SST^2$	0.189	0.041	0.186
Comparison	41%	12%	44%

SSTsummer and survival

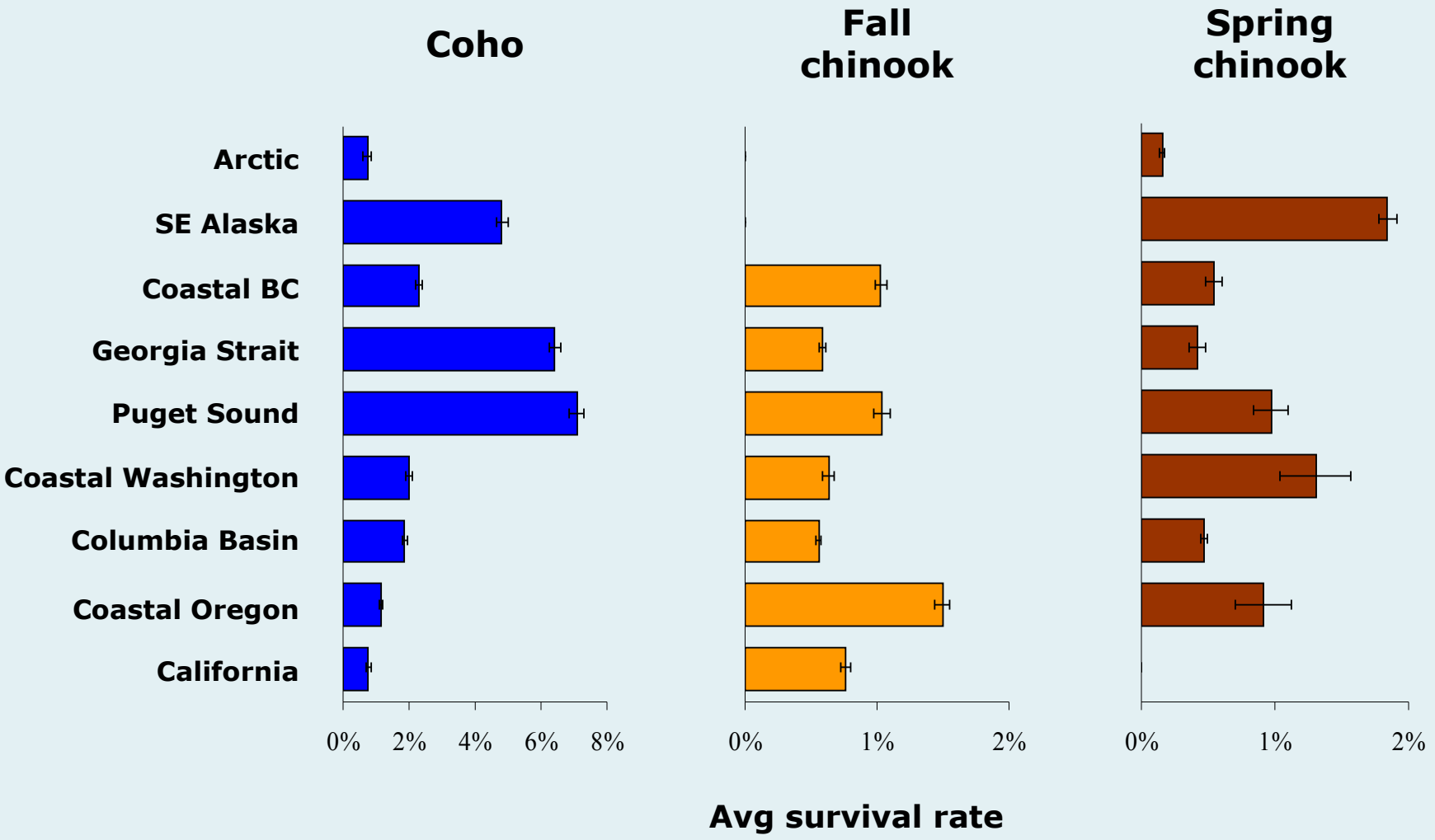


Optimal SST

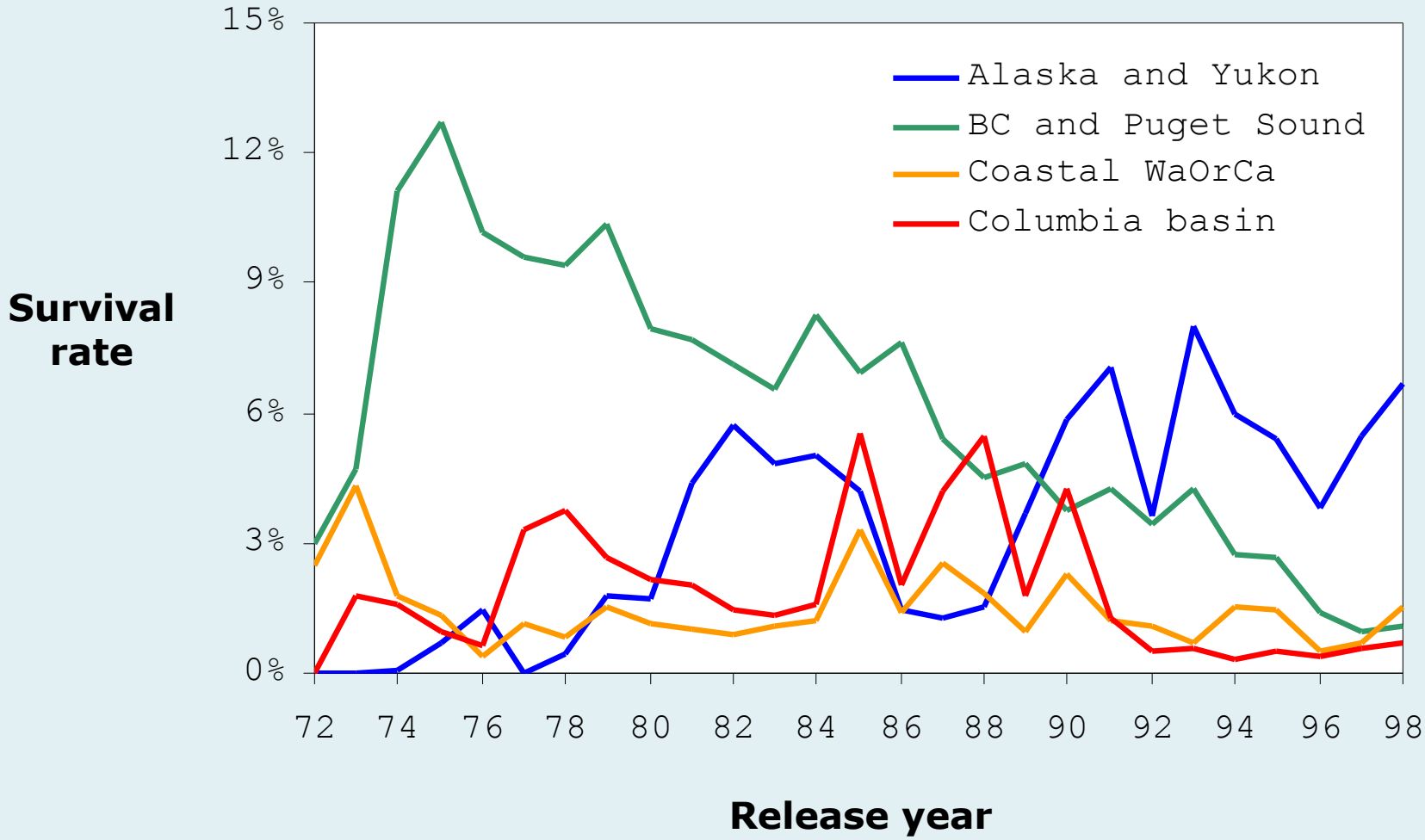
$$S\hat{S}T_{opt} = \frac{-\hat{\beta}_1}{2\hat{\beta}_2}$$

	Coho	Fall chinook	Spring chinook
SST+SST^2	13.01 (0.07)	13.10 (0.32)	11.79 (0.42)
SmoltWt+SST+SST^2	12.95 (0.08)	12.84 (0.40)	6.77 (4.21)

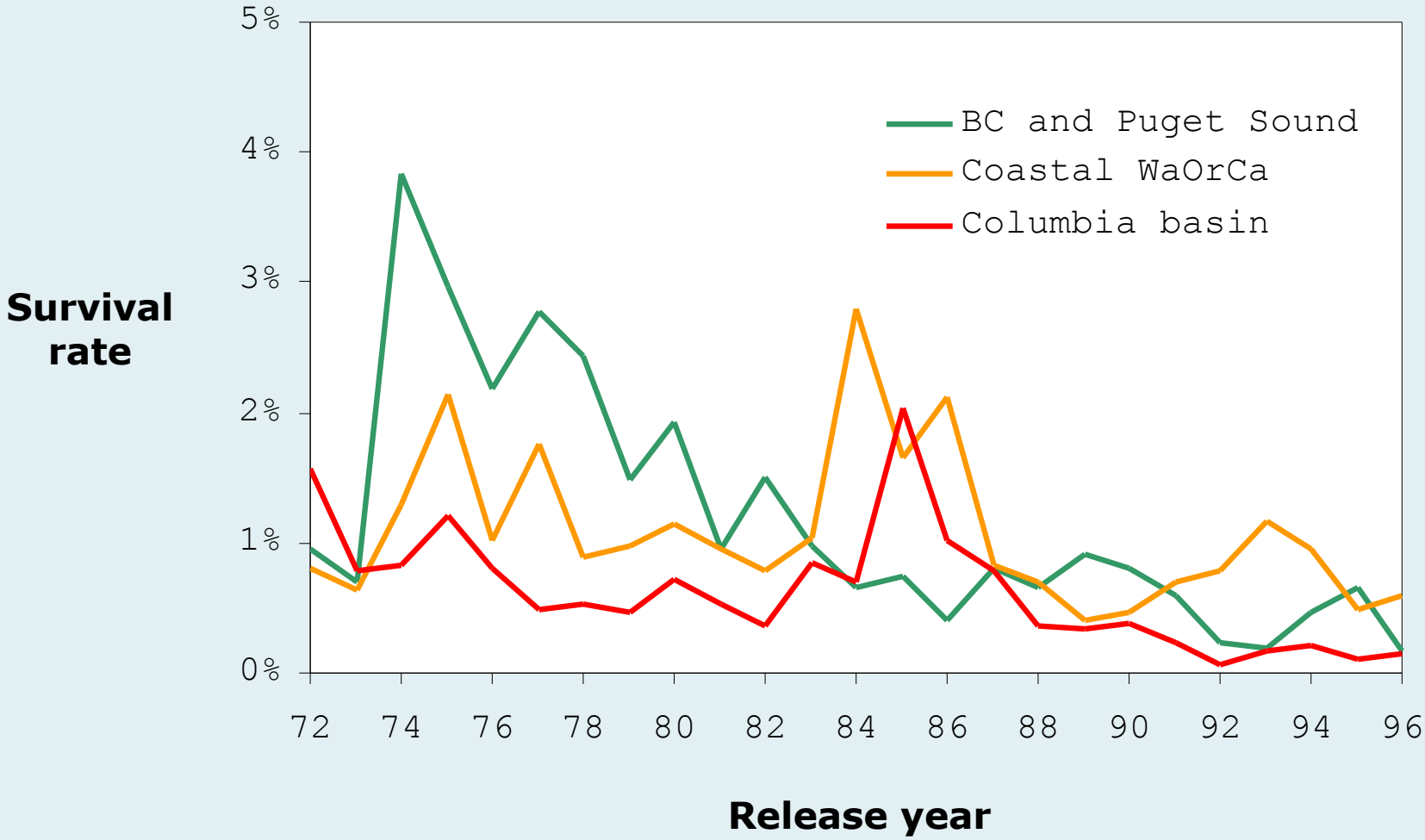
Survival rate by Realm



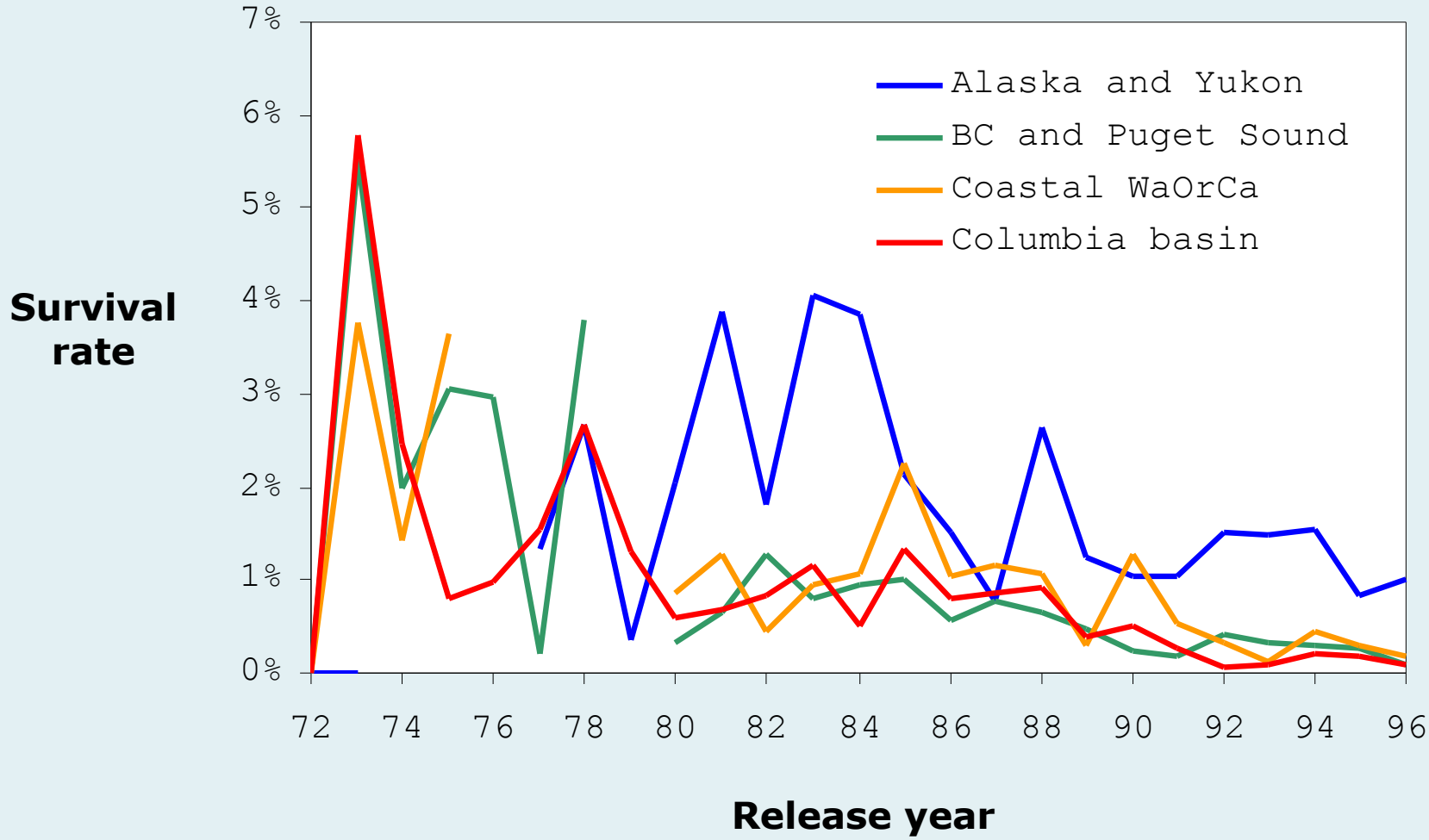
Coho survival rate by Domain



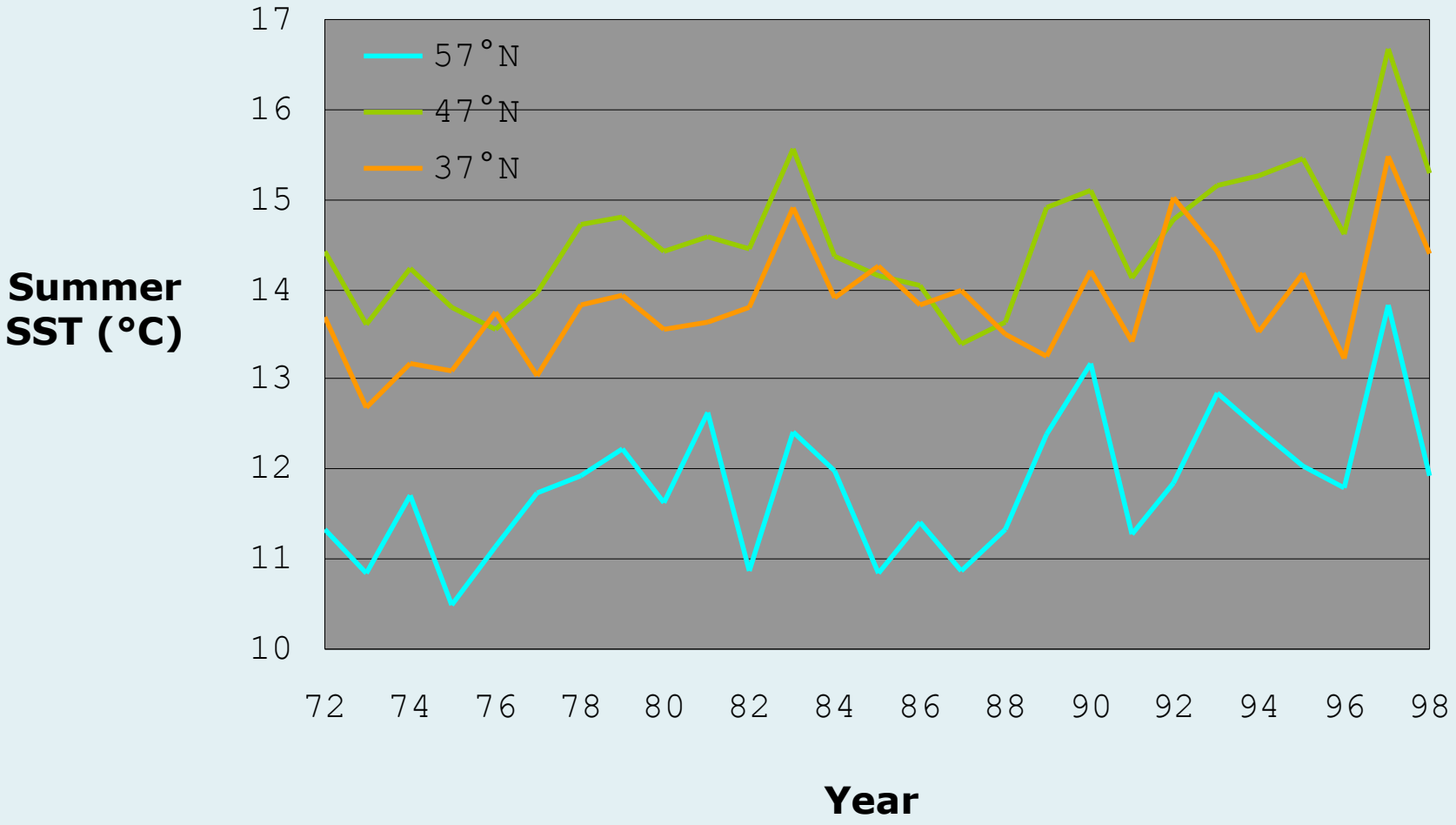
Fall chinook survival rate by Domain



Spring chinook survival rate by Domain



Sea surface temperature



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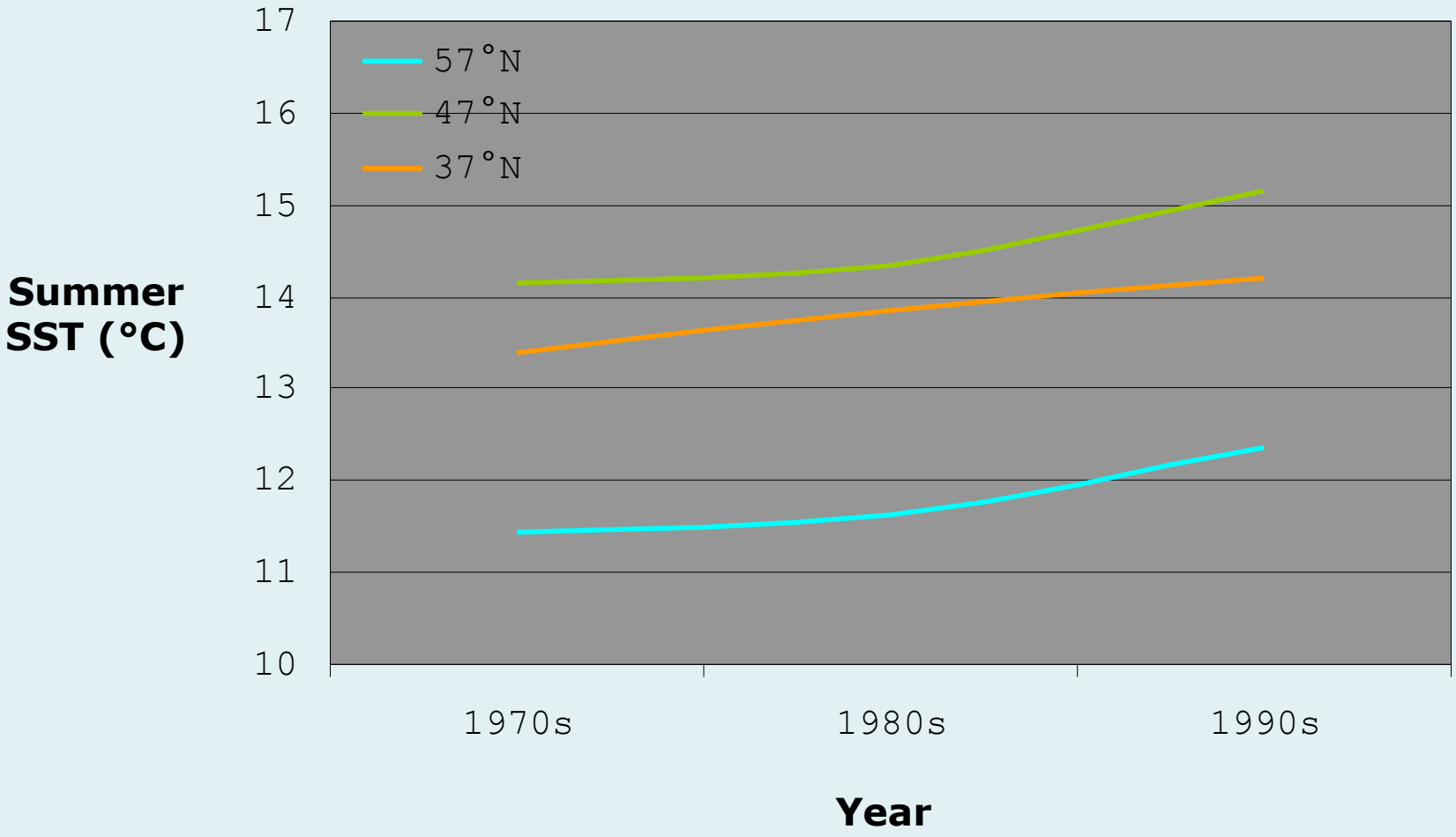

Main conclusions

1. **There is a highly significant relationship (quadratic in log-space) between survival rate and summer SST. The explaining power of the SST predictor is stronger for coho and spring chinook (40% of regional-annual variability) than for fall chinook (12%).**

2. **For fall chinook and coho, SST_{opt} is around 13°C (better determined for coho), but such an optimum could not be estimated from the spring chinook data.**

Thanks

Committee: Ray Hilborn (UW, SAFS)
John Skalski (UW, SAFS)
Gordon Swartzman (UW, CQS)

CWT data: Ken Johnson (RMIS)
Jim Longwill (RMIS)
Dan Webb (RMIS)

SST data: Steven Hare (IPHC)

Hatchery locations: Laurie Weitkamp (NMFS)
Brenda Atkins (DFO)