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Using Ocean Conditions to Forecast Salmon Runs: Lessons learned from a decade of sampling juvenile salmon at sea

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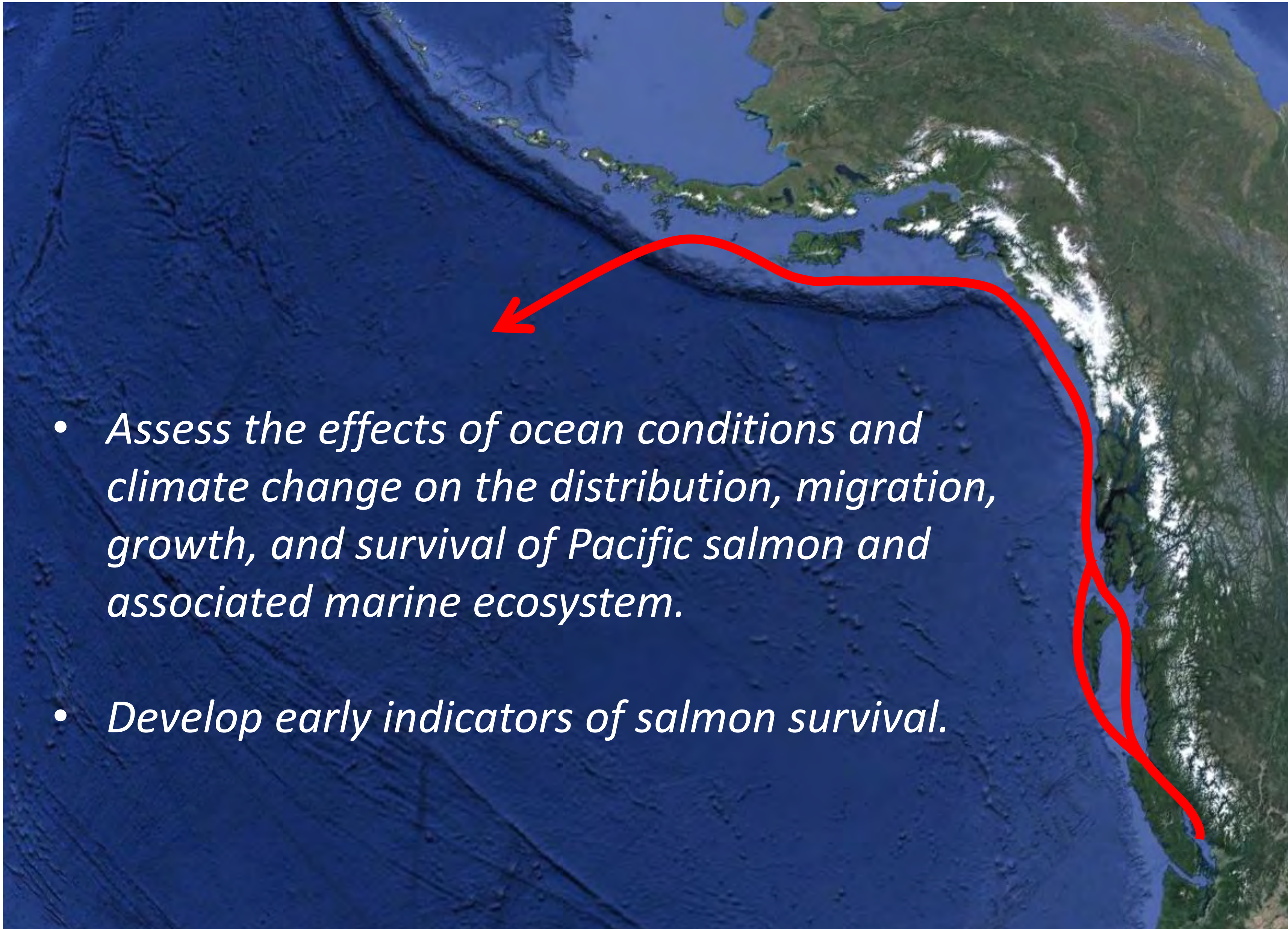
High Seas Salmon Program



- *Assess the effects of ocean conditions and climate change on the distribution, migration, growth, and survival of Pacific salmon and associated marine ecosystem.*

- *Develop early indicators of salmon survival.*

Early Attempts: The Hand Waving Approach

Salmon growth surveys were initiated in 1998. Growth patterns in 1998 indicated juvenile coho salmon off the west coast of Vancouver Island experience poorer ocean conditions than those in northern British Columbia and southeast Alaska. After a change in ocean conditions in 1999 coho size was similar in northern and southern regions. The results in 2001 show similar growth to that observed in 1999 and 2000. Adult salmon returns in 2001 were very good, indicating good survival for juveniles which entered the ocean in 1999. Thus, the continued good juvenile salmon growth seen in 2001 may translate to continued improved salmon returns in subsequent years. Measurement of stored energy reserves of the coho collected in 2001 indicates that these animals are in good condition with high energy reserves, suggesting ocean conditions have improved since 1998. Size differences seen in 2001 suggest that growth conditions favourable to good salmon returns have continued.

Source: DFO, 2002. 2001 Pacific Region State of the Ocean. DFO Science Ocean Status Report 2002 (2002).

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Qualitative Predictions: More Hand Waving

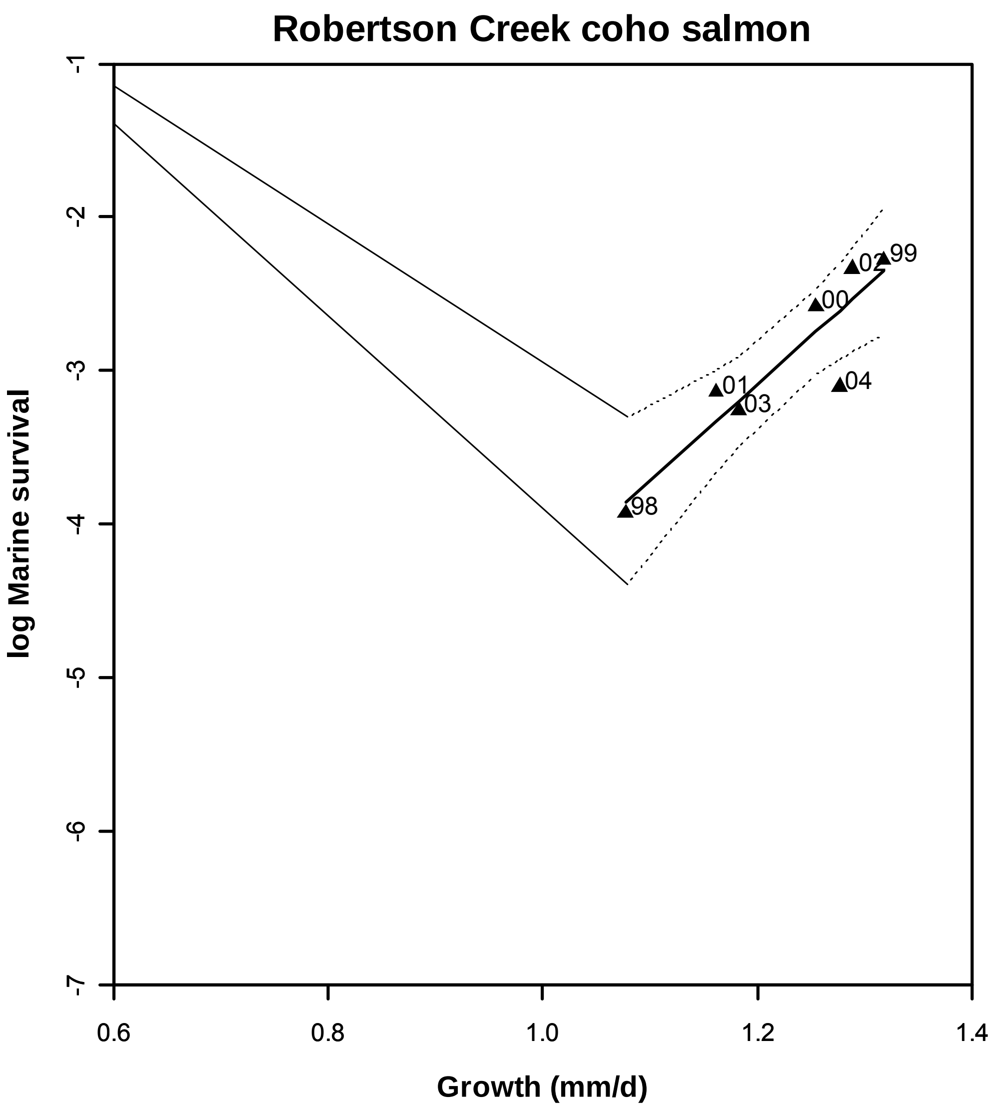
2005 Smolt Entry Year

Metrics for WCVI	Forecast
- *Low plankton biomass*	*Below average*
- *Early plankton peak*	*Below average*
- *More southern copepods*	*Below average*
- *Reduced growth*	*Below average*
- *High temperature*	*Below average*
- *Late/weak upwelling*	*Below average*
- *Low juvenile CPUE*	*Below average*

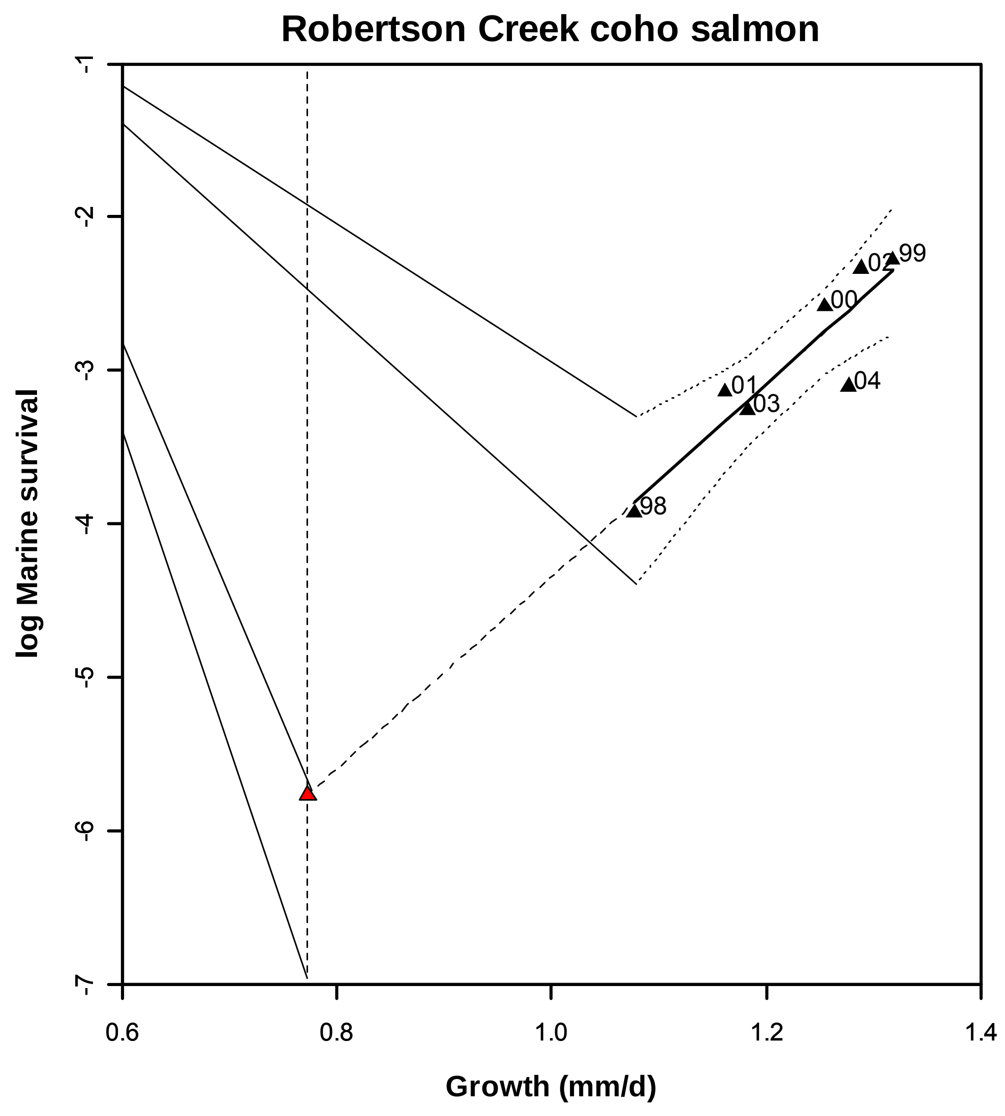
"Our truth is at the intersection of independent lies"

Levins (1966). Am. Sci. 54: 421-531

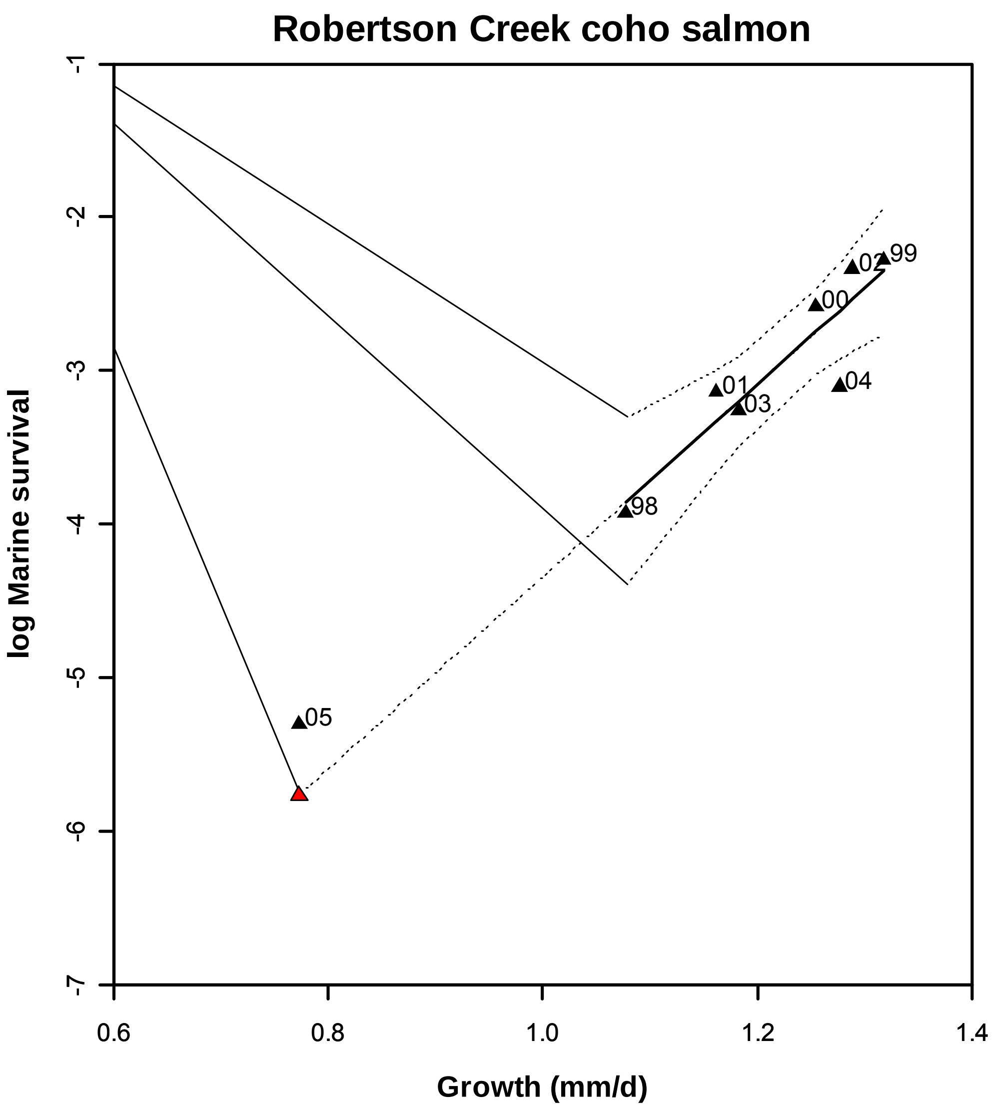
Toward a Quantitative Model



Going Beyond the Known Universe

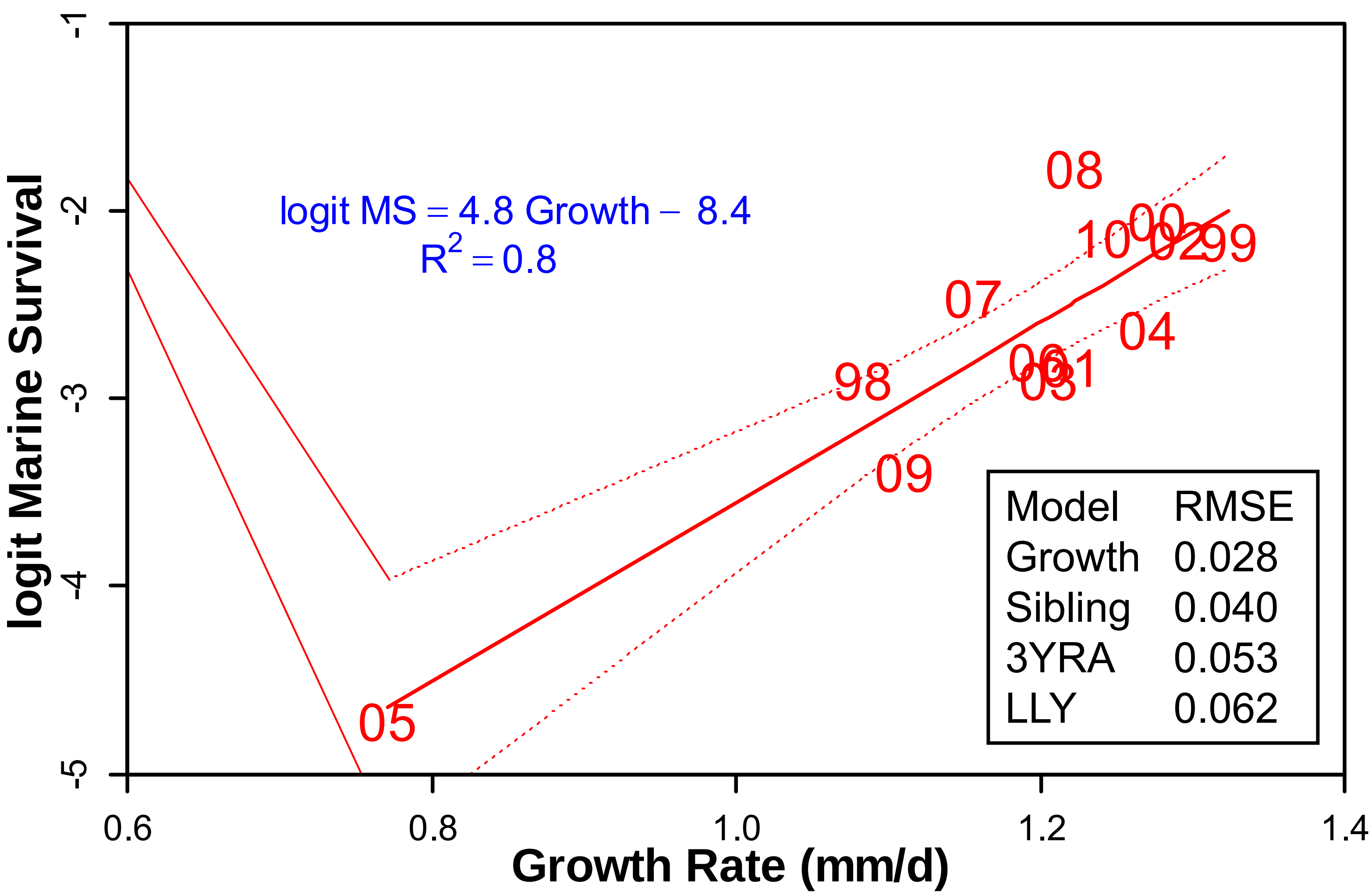


Lucky Guess?



Robertson Creek coho salmon
log Marine survival
Growth (mm/d)
-1
-2
-3
-4
-5
-6
-7
0.6
0.8
1.0
1.2
1.4
99
02
00
01
03
04
98
05

Formalizing Quantitative Predictions



Communicating Uncertainty to Managers

	2009	2010			2010	Change	Change
	Observed	Forecast	50% CI	Model	Observed	from forecast	from 2009
Johnstone Strait/Mainland Inlets							
Area 12	1,904	1,193	790 - 1904	3YRA	1,427	20%	-25%
Area 13	581	374	247 - 567	3YRA	294	-21%	-49%
Georgia Basin - West							
Big Qualicum Hatchery	0.004	0.004	0.002 - 0.006	LLY	0.005	39%	39%
Quinsam Hatchery	0.013	0.008	0.006 - 0.012	3YRA	0.008	0%	-40%
Goldstream Hatchery	0.010	0.005	0.002 - 0.015	3YRA	0.007	22%	-32%
Black Creek (wild)	0.0280	0.017	0.011 - 0.025	3YRA	0.016	-4%	-41%
Georgia Basin - East							
Myrtle Creek (wild)	0.038	0.048	0.010 - 0.203	RAT3	0.016	-67%	-58%
Lower Fraser							
Inch Hatchery	0.018	0.018	0.011 - 0.031	LLY	0.025	35%	35%
Str. Of Geo. Hatcheries	0.012	0.010	0.007 - 0.013	CPUE	0.013	27%	7%
Interior Fraser							
Interior Fraser watershed	24,443				41,470		70%
Thompson River aggregate	19,310	24,442	15,235 - 39,215	3YRA	34,771	42%	80%
South-west Vancouver Island							
Robertson (Stamp Falls) Hatchery	0.146	0.009	0.005 - 0.018	Sibling	0.033	267%	-77%
Carnation Creek (wild)	0.071	0.100	0.088 - 0.110	Euphausiid	0.010	-90%	-86%
Distribution Index (P_{inside})		0.264	0.0193 - 0.0350	Salinity			
Marine Growth model							
Robertson (Stamp Falls) Hatchery	0.146	0.049	0.040 - 0.060	Growth	0.033	-33%	-77%
Carnation Creek (wild)	0.071	0.015	0.010 - 0.020	Growth	0.010	-37%	-87%

Source: DFO, 2012. 2011 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/037.

Communicating Uncertainty to Managers

Sources of Uncertainty

Commercial by-catch of coho

There are no direct Canadian coho fisheries so any exploitation is the result of bycatch of coho in other fisheries. The coho caught in these fisheries are not monitored for adipose clips. The exploitation rates are estimated by using the by-catch of Indicator origin coho in non-targeted commercial fisheries from a base period of return years 1987 – 1997, and comparing the effort from this base period to the effort in 2010.

Sport catch

CWT-based estimates of sport fishing mortality have become less certain due to decreased participation by sport fishers in submitting adipose clipped head samples. An additional source of uncertainty is the unknown number of mortalities from the increased number of released catch in a mark-selective fishery. Prior work has shown that 10% of the released coho do not survive however in recent years the pinniped population has learned to follow recreational vessels and prey upon released coho so a 10% release mortality should be considered as a minimum rate.

Freshwater creel surveys were limited to Quinsam River, Nicomen Slough (Inch Creek Hatchery) and the Fraser River. Other freshwater fisheries were not monitored.

Predictive power of the time series models

The time series models used in this forecast assume that the observations from the past will continue into the future. The models have no predictive capability for changes to that trend.

Spawning Escapement and Abundance Estimates (Interior Fraser)

Annually spawning escapements for Interior Fraser River (Thompson) system are calculated summing individual escapement estimates for approximately 100 streams. The precision of the spawning estimate varies considerably between those intensively sampled (in the spawning surveys range considerably through the summation of extensive (low/unknown precision) and intensive (known precision) enumeration methods on approximately 100 streams within the interior watershed. Surveys are designed to reduce the amount of variability in the escapement estimates within and between systems, but the total precision of the aggregate estimate for Interior Fraser Coho is unknown.

Source: DFO, 2012. 2011 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/037.

The Art of Forecasting: Issues to Consider

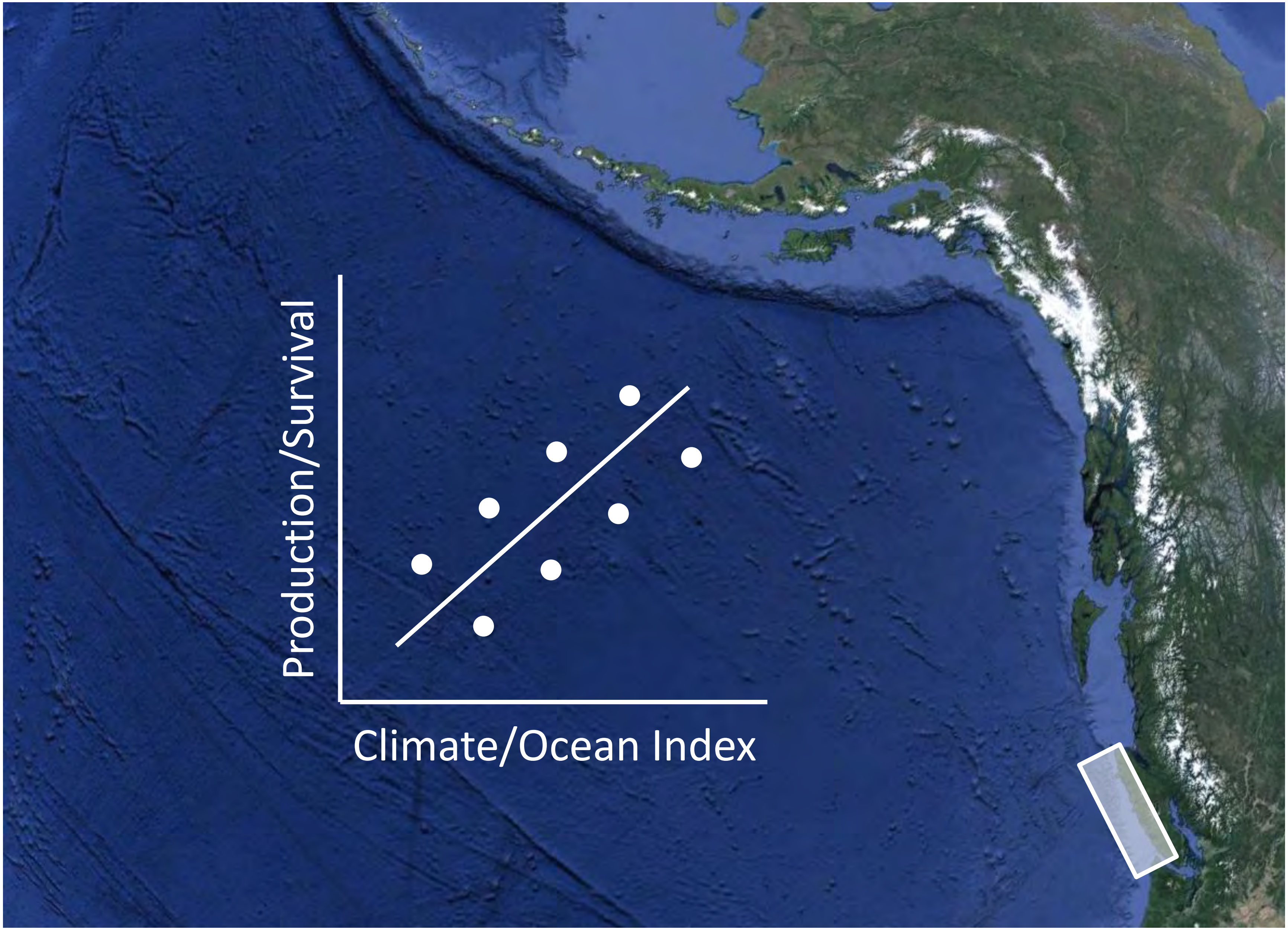
A) Biologically/ecologically relevant factors

B) Forecasting precision

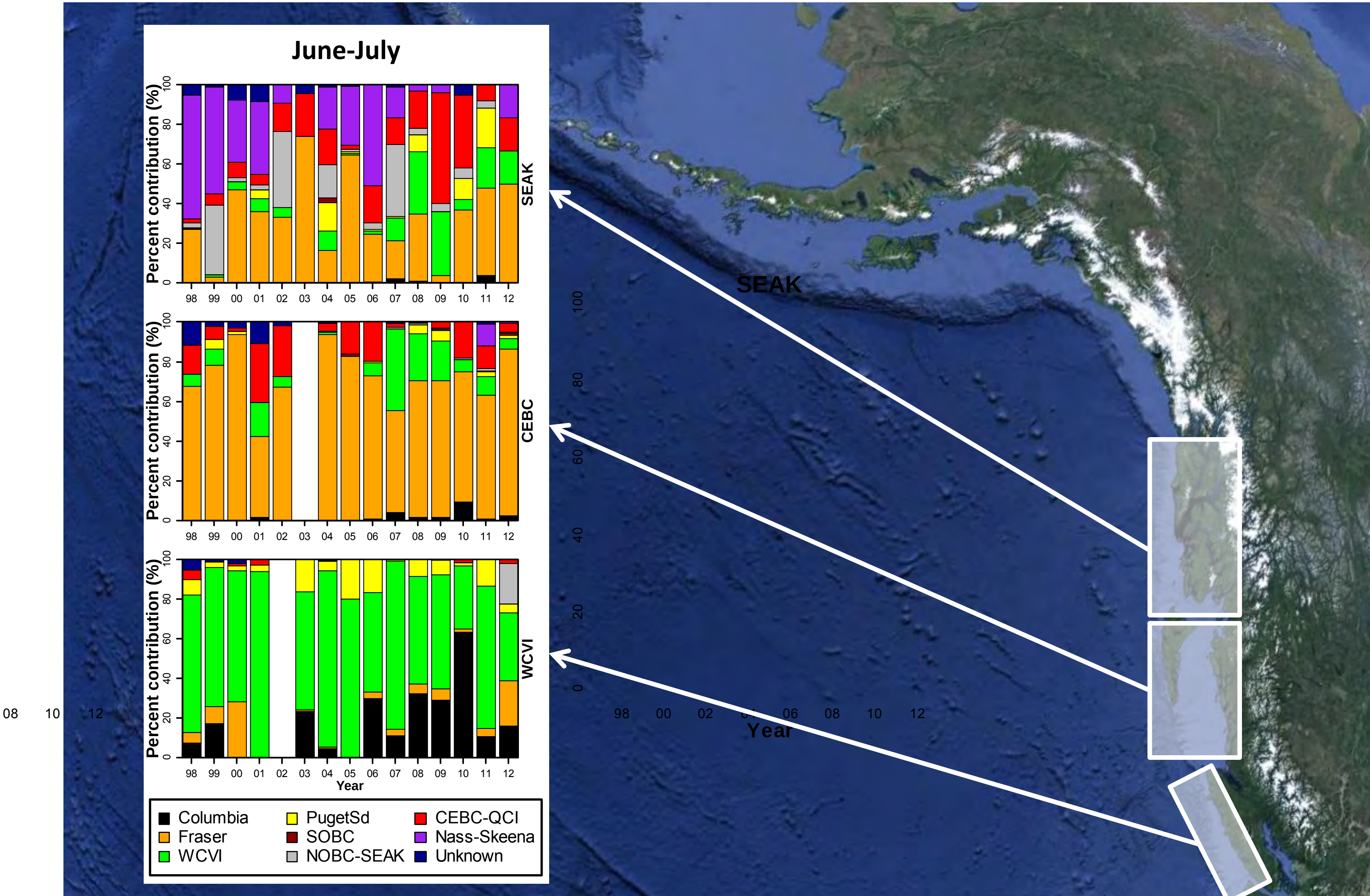
C) Shifting baselines

D) Regime shifts / Non-stationarity

A) Biologically/Ecologically Relevant Factors



Know Where the Fish Go



Updated from Tucker et al. 2009. Trans. Am. Fish. Soc. 138: 1458-1480

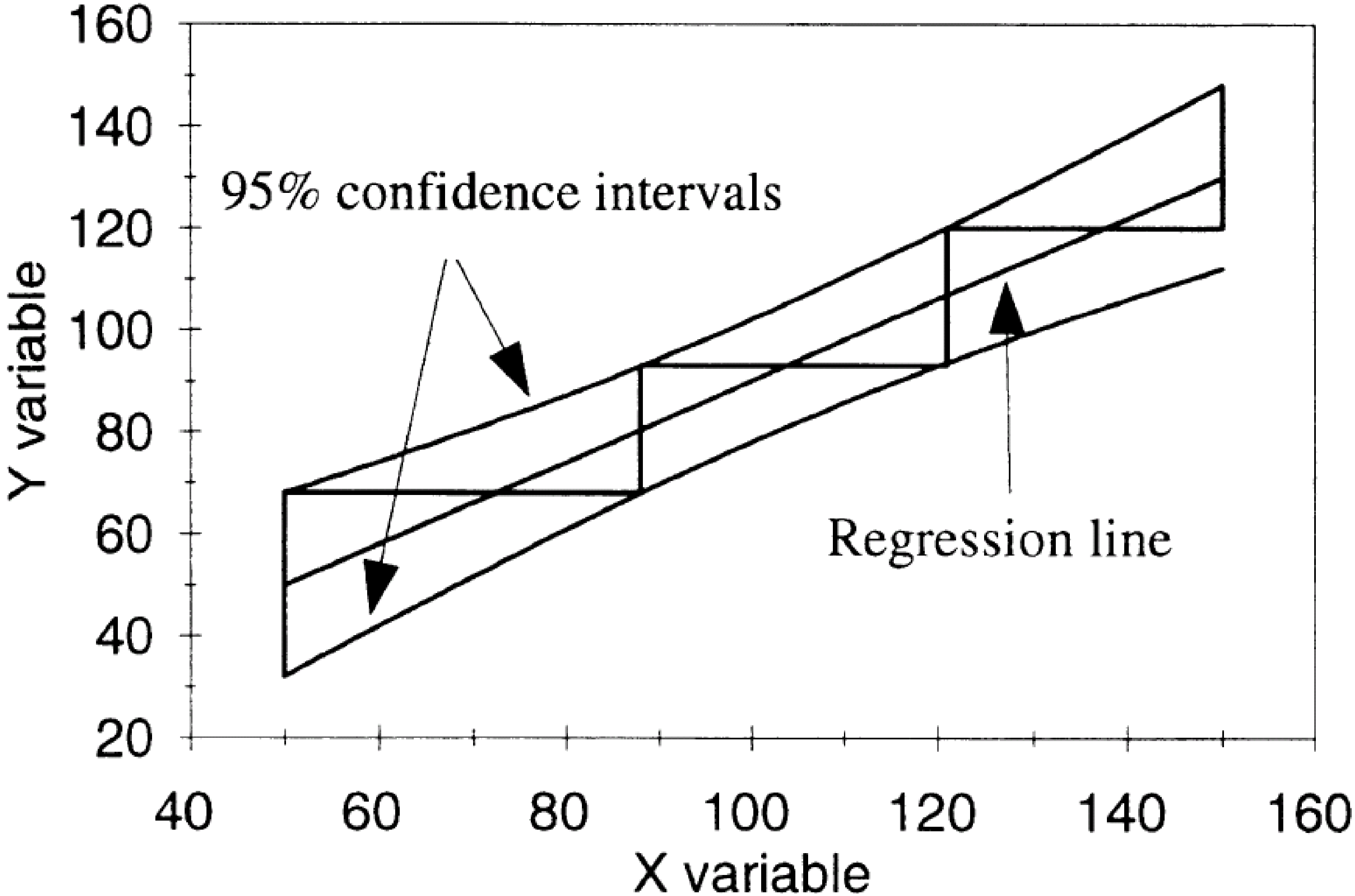
Fraser River Sockeye Survival Mechanisms

(BROOD YEAR) OCEAN ENTRY YEAR (RETURN YEAR)	(1996) 1998 (2000)	(1997) 1999 (2001)	(1998) 2000 (2002)	(1999) 2001 (2003)	(2000) 2002 (2004)	(2001) 2003 (2005)	(2002) 2004 (2006)	(2003) 2005 (2007)	(2004) 2006 (2008)	(2005) 2007 (2009)
Chilko Marine Survival	G	Y	G	G	R	Y	G	R		
Ocean Indices										
1 PDO (Jan-March average)	R	G	G	R	G	R	R	R	Y	Y
2 ALPI	R	G	Y	R	R	R	R	Y	G	G
Physical Conditions										
3 SST (Entrance Island)	R	G	G	G	G	R	R	R	Y	Y
4 SST (Pine Island)	R	G	G	G	Y	R	R	R	Y	G
5 Upwelling index (48°N)	G	G	R	Y	G	R	Y	R	Y	G
6 Spring transition timing (48°N)	G	G	Y	Y	G	Y	Y	R	Y	Y
Biological Conditions										
7 Southern Copepods (SVI)	R	G	Y	G	G	R	Y	R	R	G
8 Boreal Shelf Copepods (SVI)	R	G	G	Y	G	Y	R	R	R	G
9 Southern Copepods (NVI)	R	G	G	G	Y	R	Y	R	R	G
10 Boreal Shelf Copepods (NVI)	Y	G	G	R	G	R	R	R	Y	G

Lowest survival on record

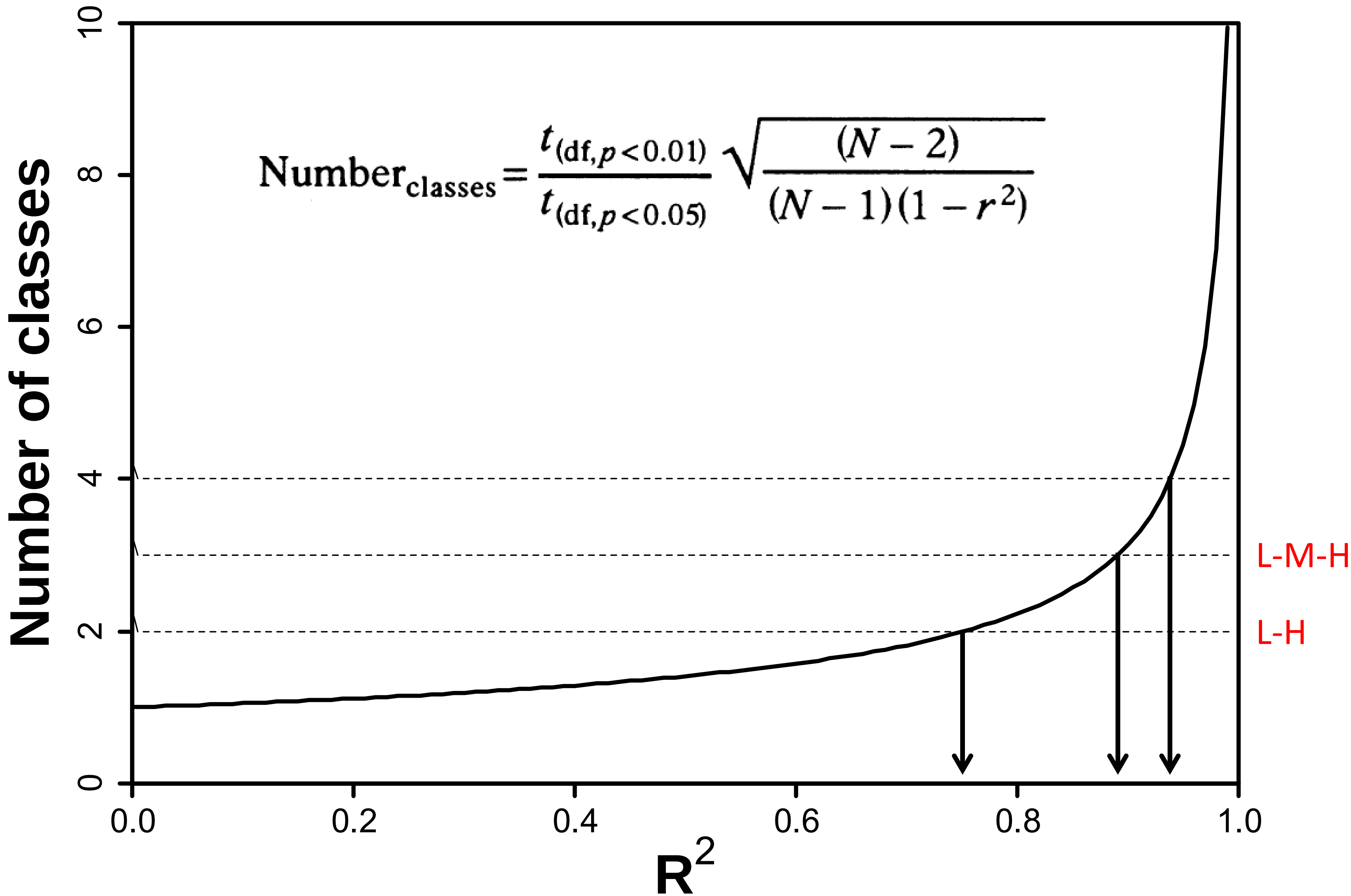
- 2007 Ocean Indicators selected were green (good for salmon survival)
- 2009 Fraser Sockeye returns (2007 Ocean Entry) lowest productivity on record
- Need more/better Strait of Georgia indices to predict Fraser sockeye!

B) Resolution power of regression models

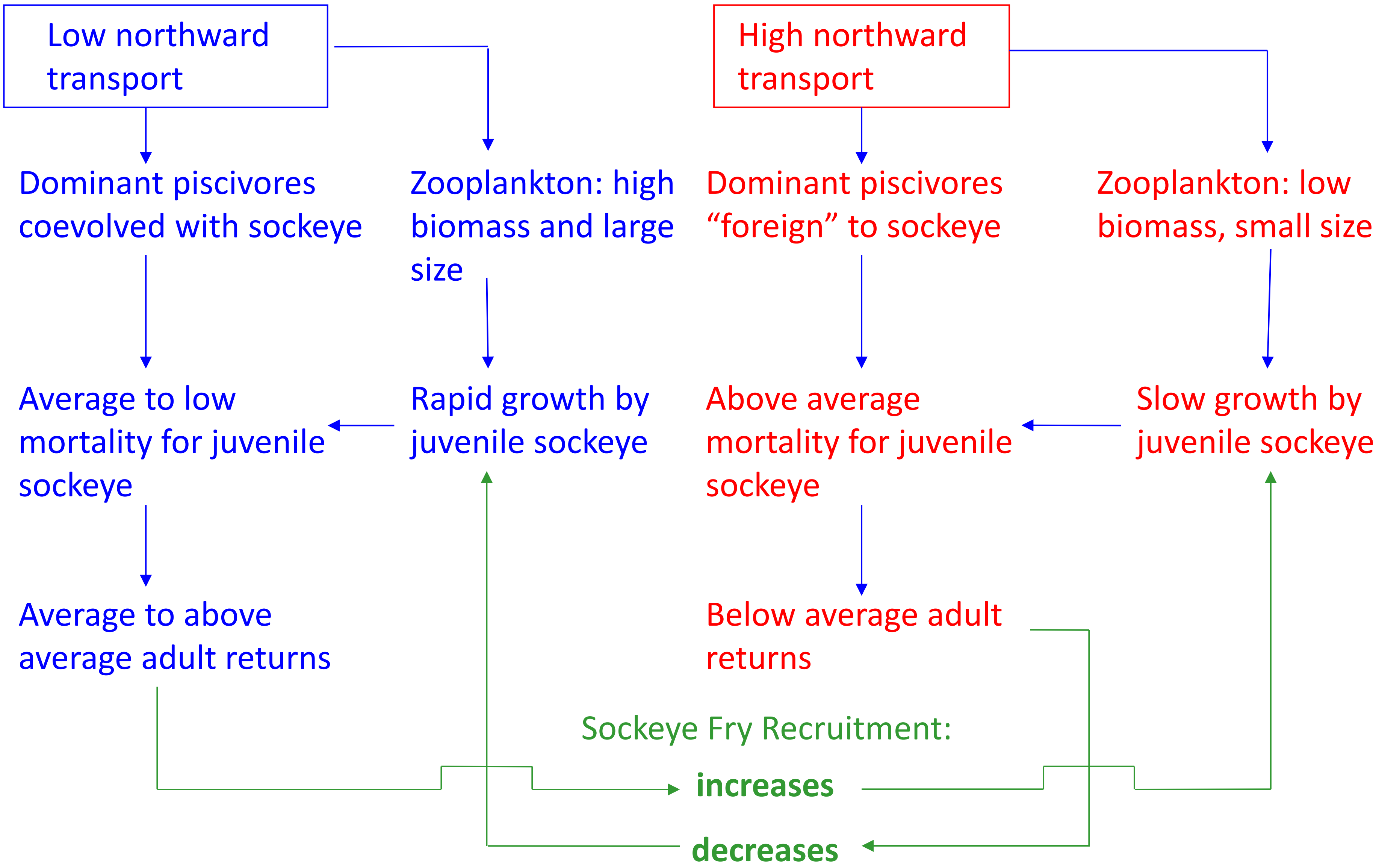


Source: Prairie. 1996. Can. J. Fish. Aquat. Sci. 53: 490-492.

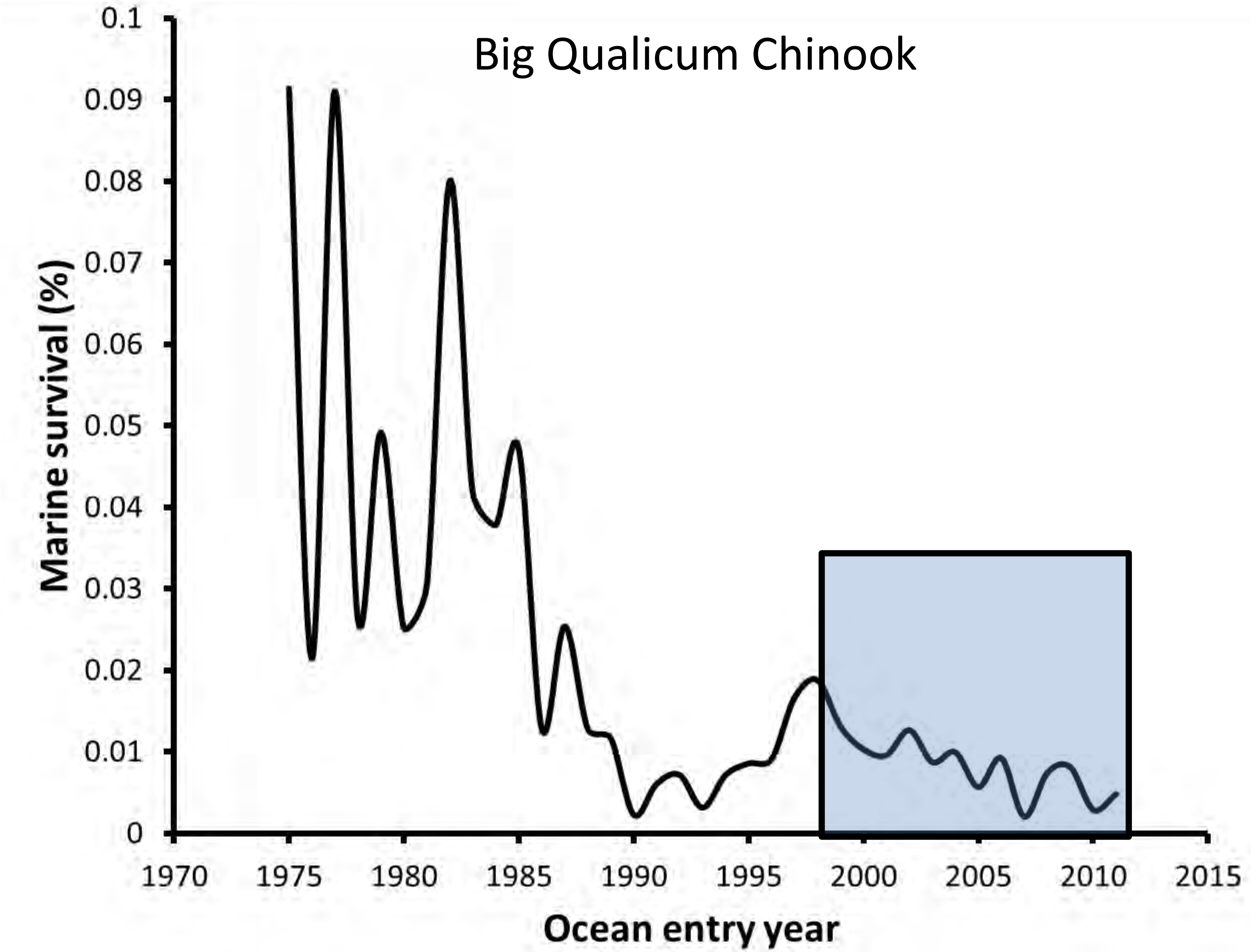
Number of Distinguishable Classes



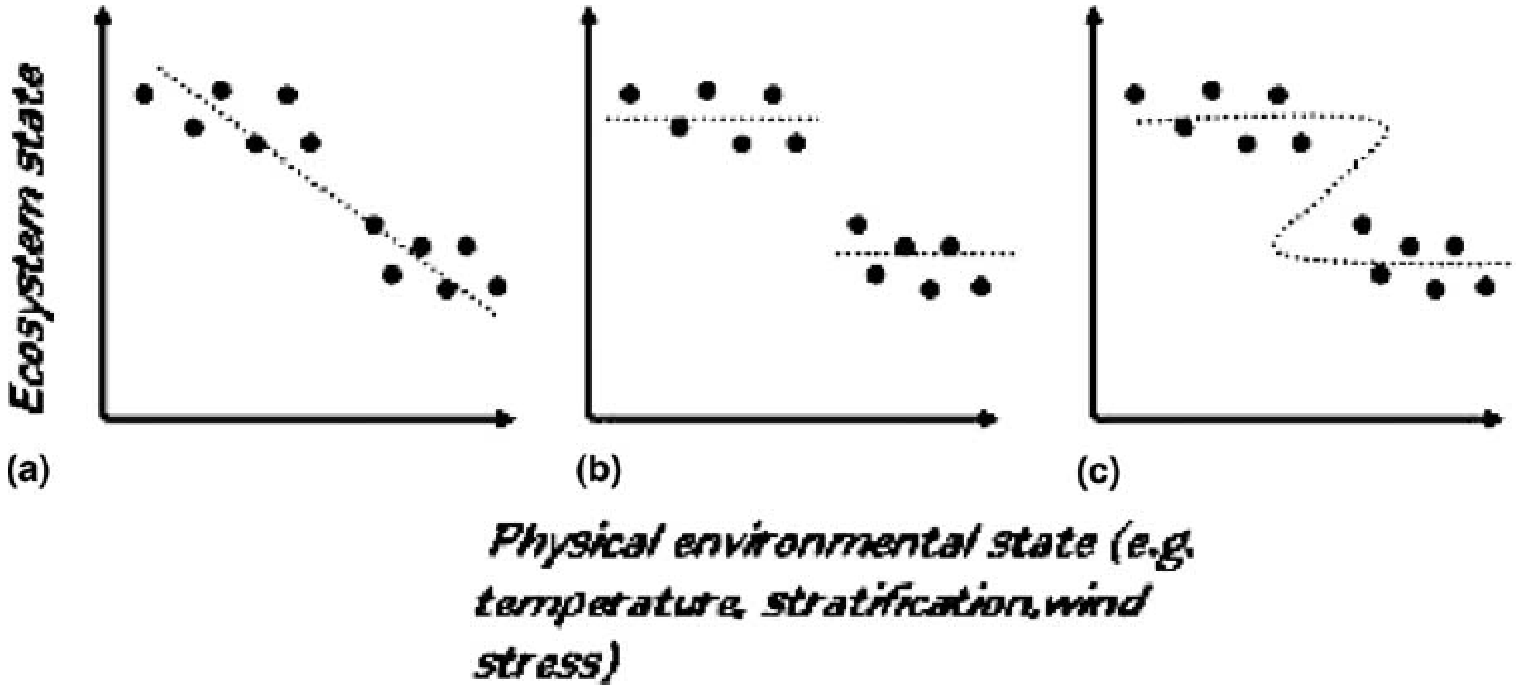
Two-State Model of El Nino – La Nina Mediated Production Responses of Barkley Sd. Sockeye (Hyatt et al. 1989)



C) The shifting baseline problem



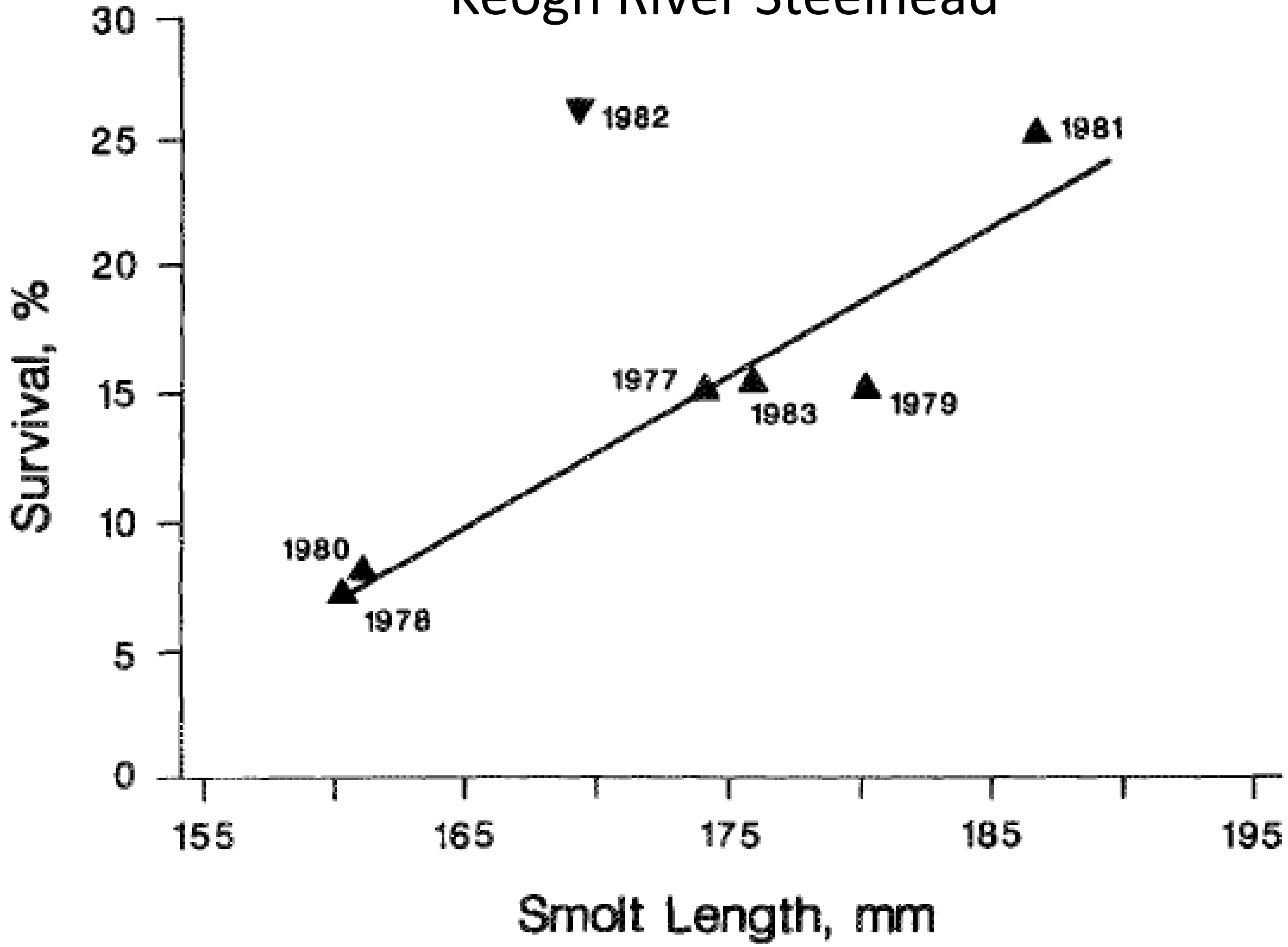
D) Non-linearities and regime shifts



Source: deYoung et al. 2004. Prog. Oceanogr. 60: 143-164

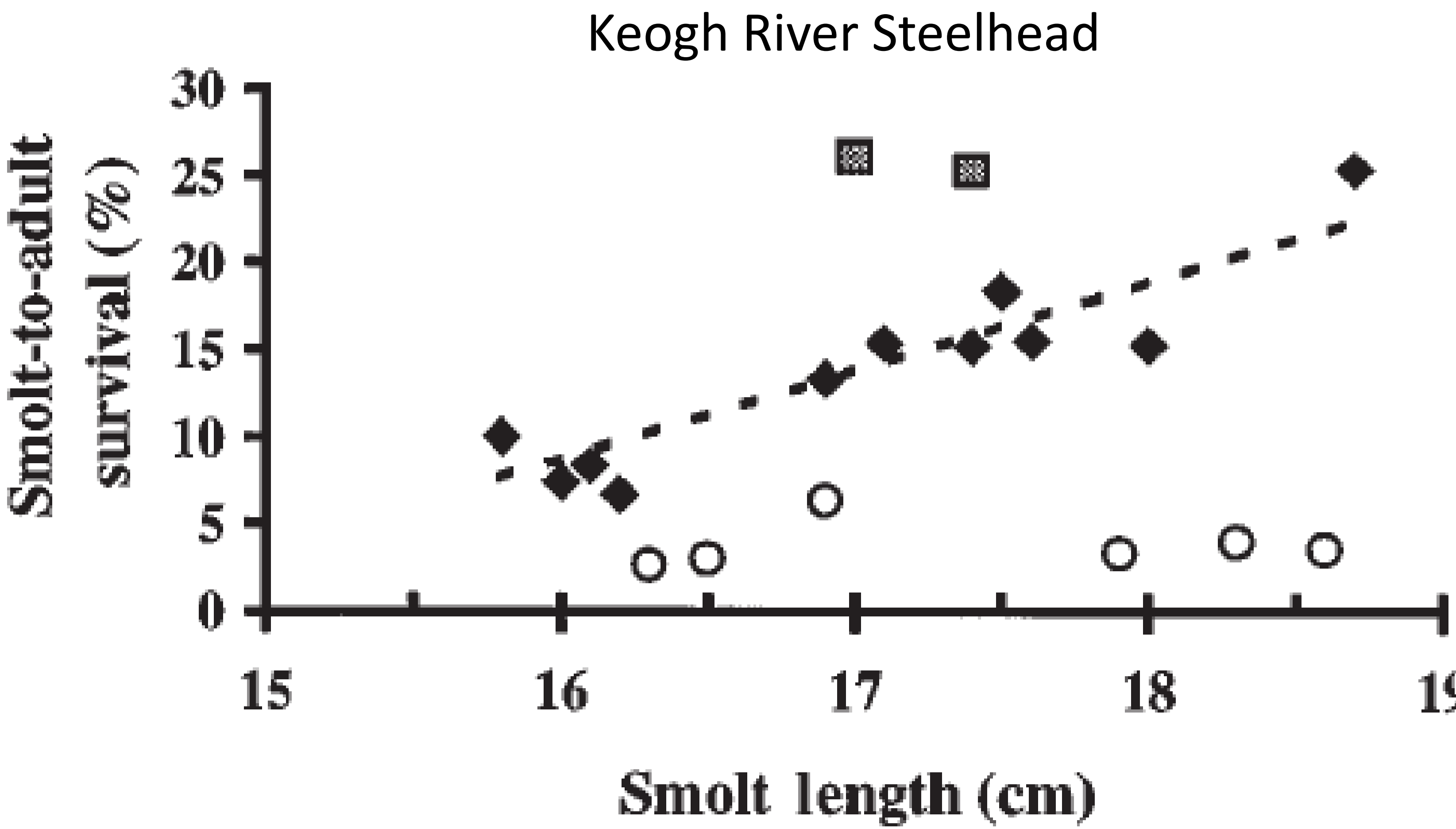
Publish before correlation breaks!

Keogh River Steelhead



Source: Ward & Slaney. 1988. Can. J. Fish. Aquat. Sci. 46: 1853-1858

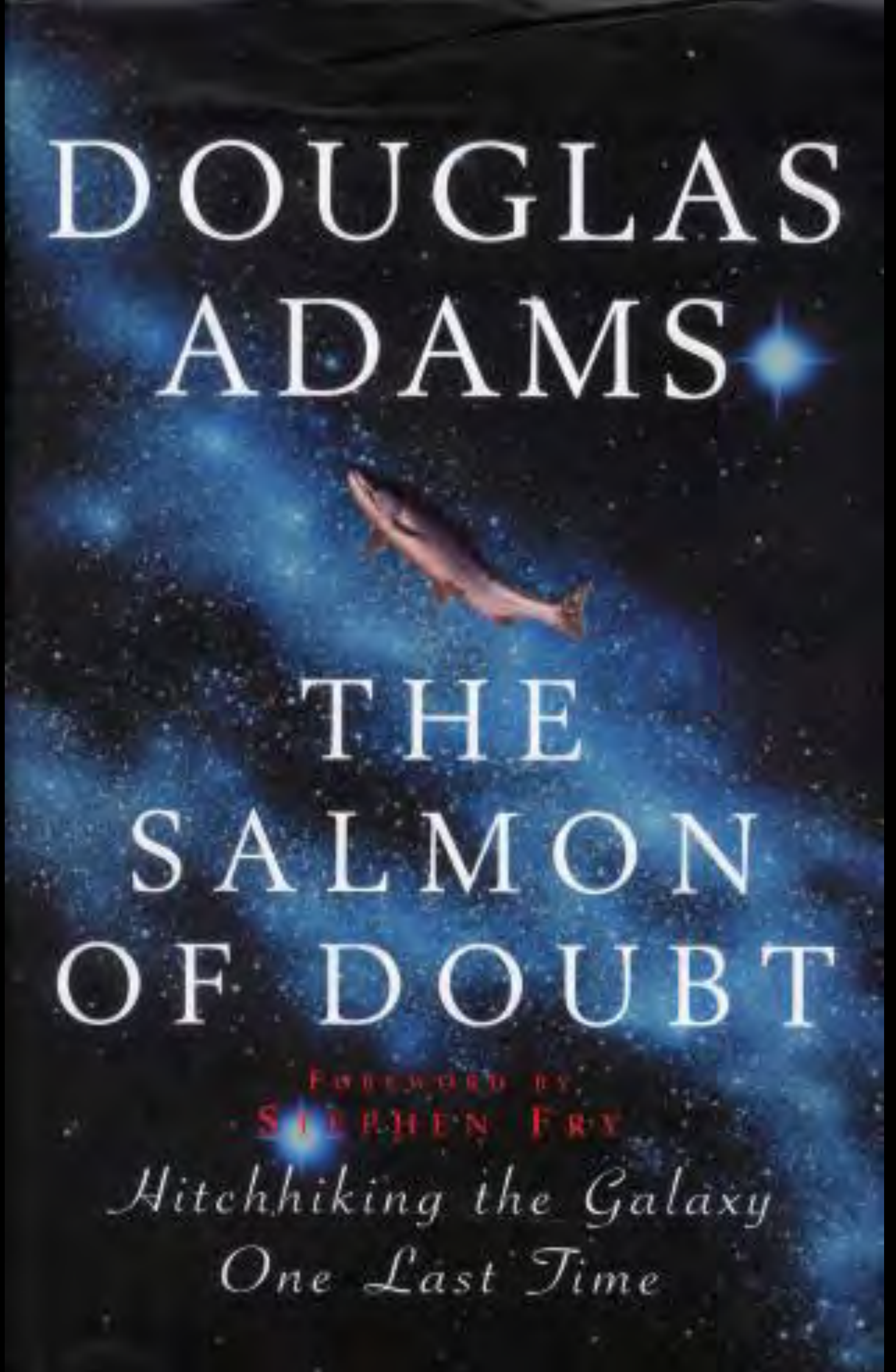
Also publish long after correlation breaks!



Source: Ward. 2000. Can. J. Fish. Aquat. Sci. 57: 298-306

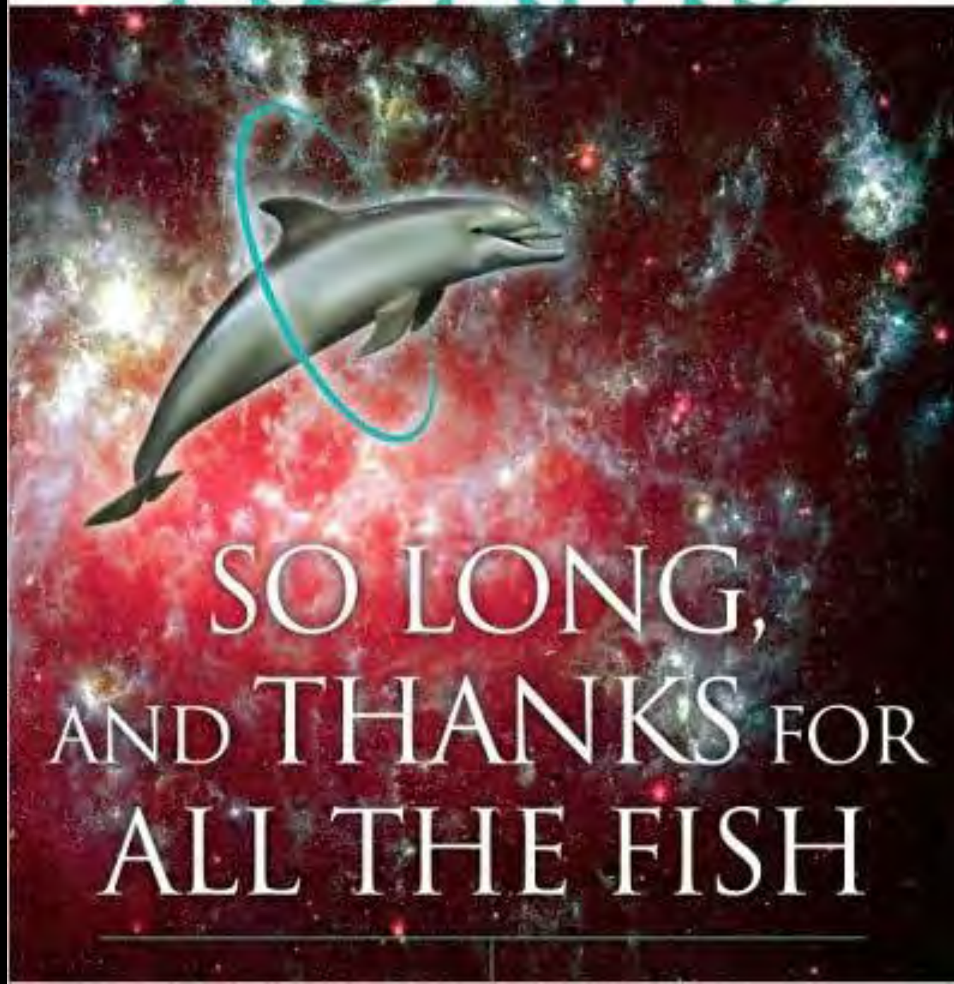
Communicating Uncertainty to Managers

- Models are only as good as the data that get into the models
- Know where the fish go: spurious correlations can be generated using conditions not encountered by salmon.
- Be realistic with the precision that can be achieved from any forecasting models: qualitative predictions may be the best we can achieve.
- Beware of shifting baselines and unstated assumptions.
- Be ready for surprises: correlations (and mechanistic models) break over time


DOUGLAS ADAMS
THE SALMON OF DOUBT
FOREWORD BY
STEPHEN FRY
Hitchhiking the Galaxy One Last Time

New York Times bestselling author of *The Hitchhiker's Guide to the Galaxy*

DOUGLAS ADAMS



SO LONG, AND THANKS FOR ALL THE FISH