Appendix C (Part 1 of 2): Background Speakers' Presentations

An appendix to the report:

Peterman R.M., D. Marmorek, B. Beckman, M. Bradford, N. Mantua, B. Riddell, M. Scheuerell, M. Staley, K. Wieckowski, J. Winton, C. Wood. 2010. Synthesis of evidence from a workshop on the decline of Fraser River Sockeye. June 15-17, 2010. Vancouver Island Conference Centre, Nanaimo B.C., 123 pp + 35 pp. appendices.

Names of the two presenters who provided introductory background talks are hypertext linked to their slide presentations.

Session: Overview of the Fraser Sockeye Situation

1. Mike Lapointe, PSC
2. Timber Whitehouse and Arlene Tompkins, DFO

Overview of Fraser sockeye situation

Mike Lapointe
Pacific Salmon Commission

1

Topics

1. 2009 – What happened?
2. Longer term trends in returns
3. Productivity indices and trends
4. Where and when to look for causes?

2

2009 Fraser River Forecasts

- 10.5 million sockeye
- 17.5 million pink salmon… BUT

Forecasts are very uncertain!

Sockeye in 2009

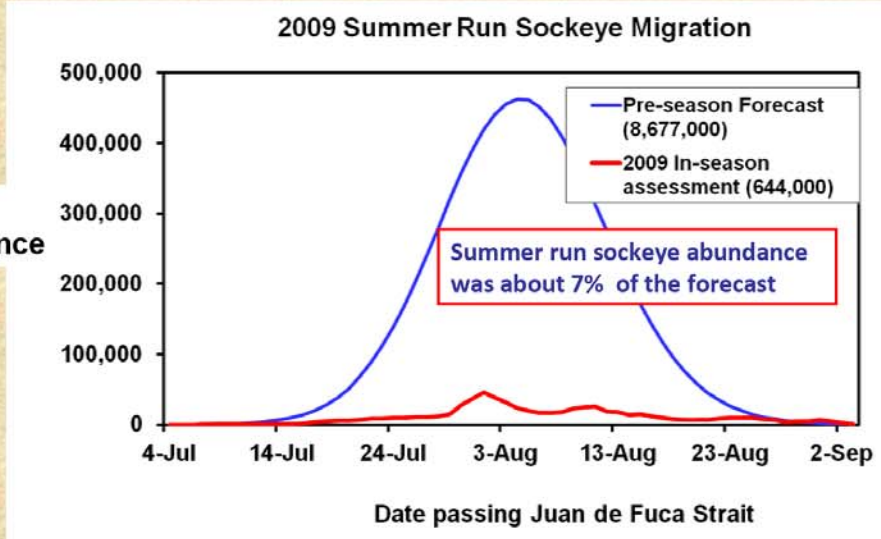
1 in 4 chance of return *less than* 6M

1 in 4 chance of return *greater than* 19M

Fishery Managers plan for range of returns

3

Fisheries are ***NOT*** opened based on Forecasts.



2009 Sockeye return

- Pre-season forecast 10.5M

  (Range 3.5M-37.6M)

- Preliminary post-season: 1.5M (lowest since 1947)

5

2009 Sockeye catch

- Total catch 124,000
- 8% of the run was harvested leaving 92% of the run available for spawning escapement

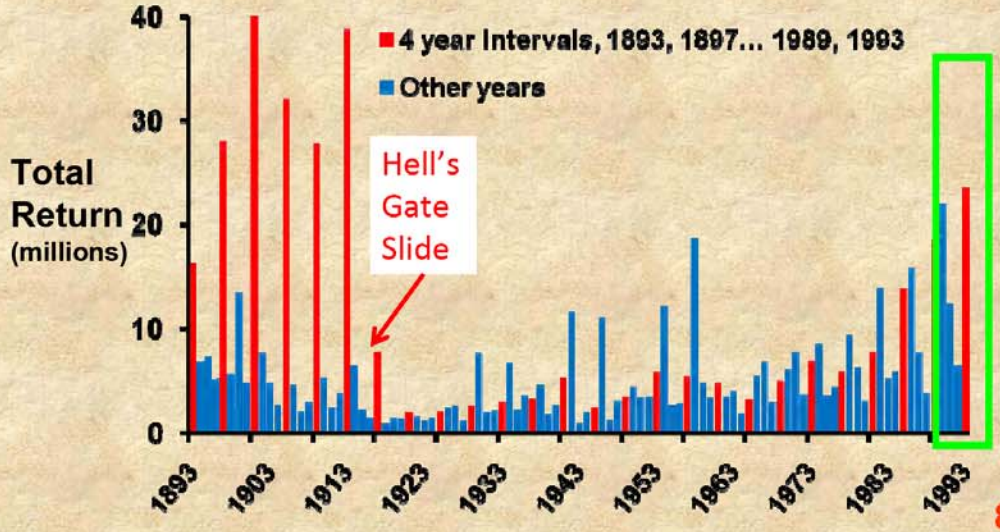
6

2009 Sockeye Spawning escapements

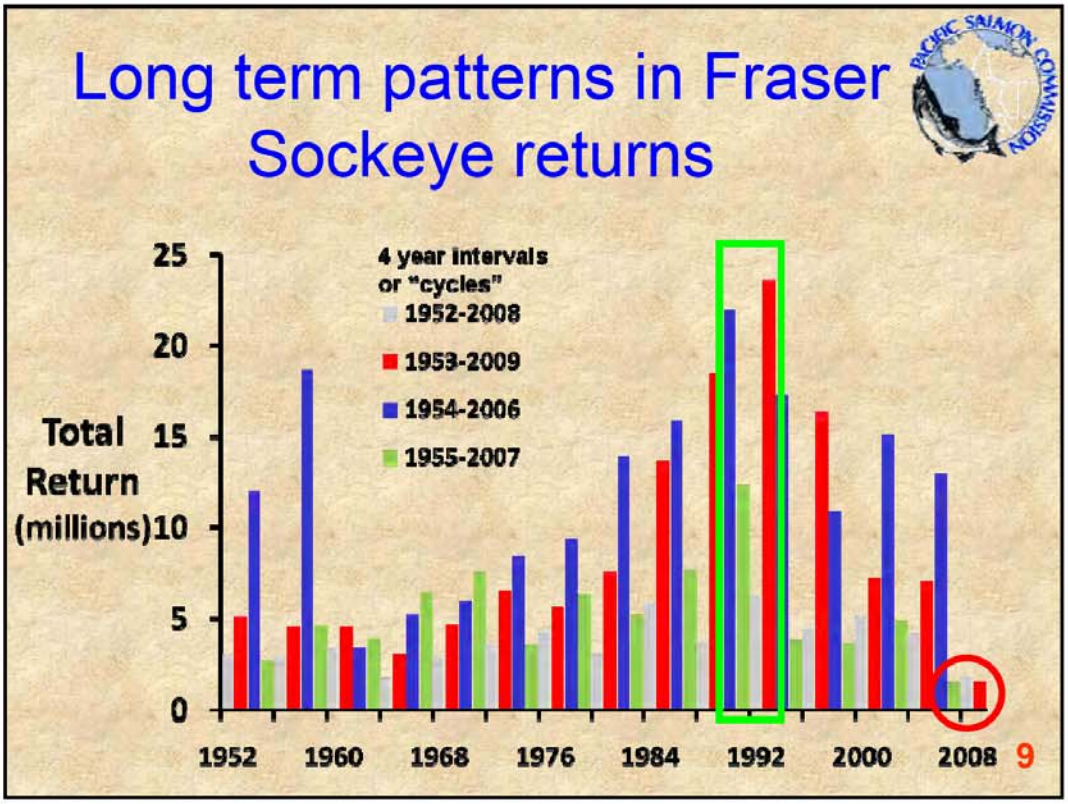
Management group	2009 escapement (adults)	Average escapement (2009 cycle; 1953,57,61,…2005)
Early Stuart	45,000	222,000
Early Summer	92,000	100,000
Summer	478,000	1,853,000
Late	441,000	139,000
Total	1,056,000	2,314,000

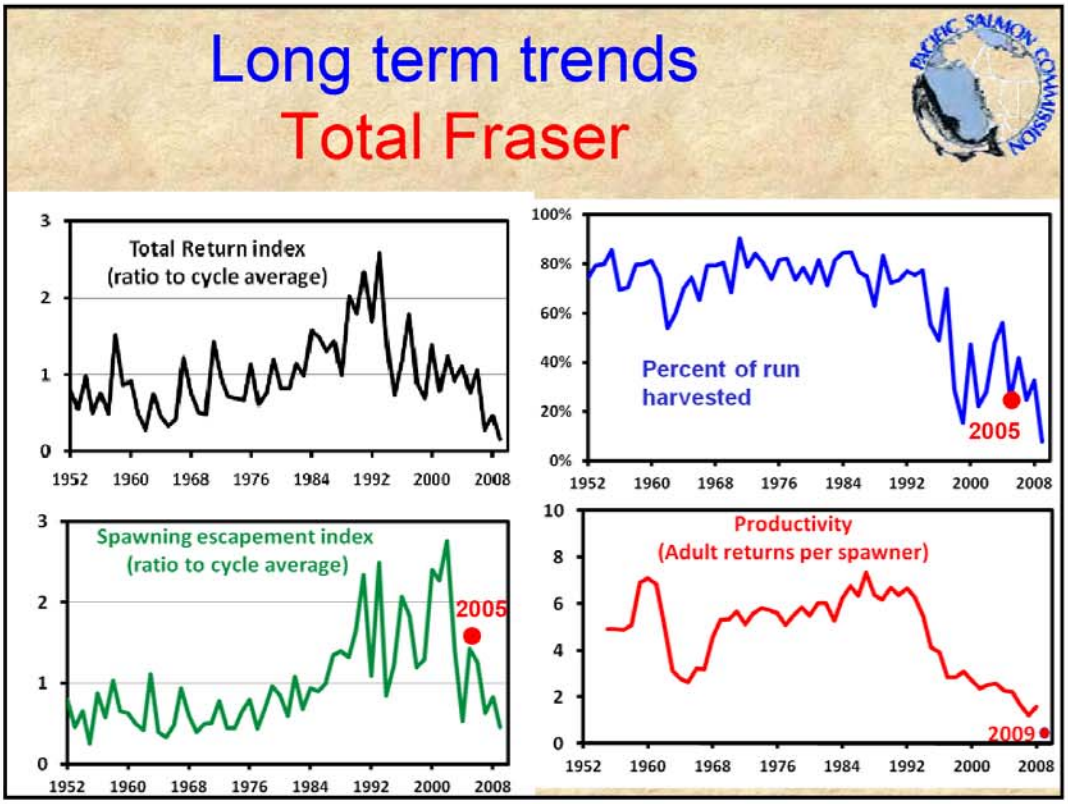
7

Long term patterns in Fraser Sockeye returns

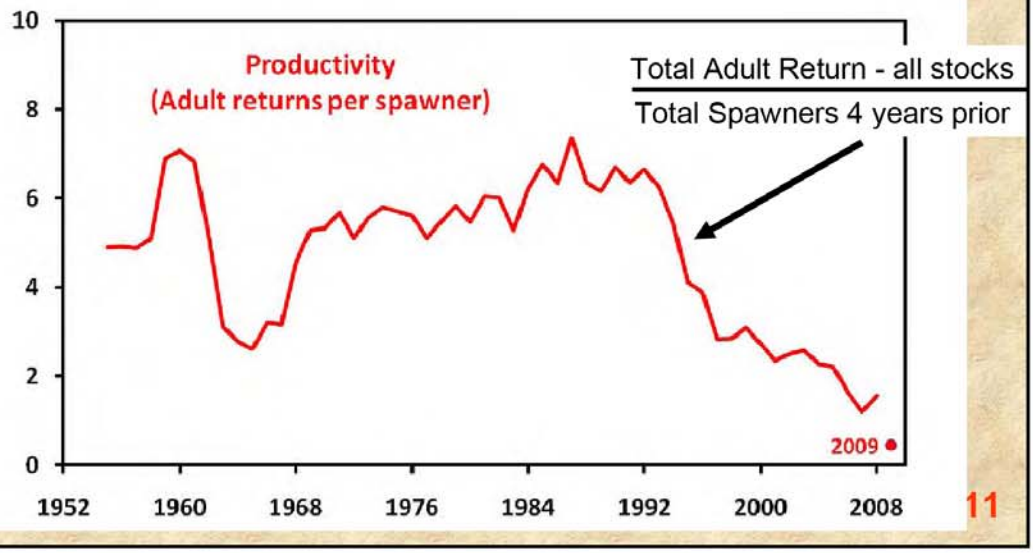


8


Long term patterns in Fraser Sockeye returns
4 year intervals or "cycles"
1952-2008
1953-2009
1954-2006
1955-2007
Total Return (millions)
25
20
15
10
5
0
1952
1960
1968
1976
1984
1992
2000
2008
9

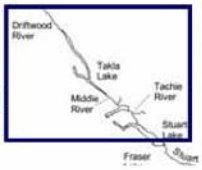

Long term trends
Total Fraser
Total Return index (ratio to cycle average)
Percent of run harvested
2005
Spawning escapement index (ratio to cycle average)
2005
Productivity (Adult returns per spawner)
2009
1952
1960
1968
1976
1984
1992
2000
2008

Productivity
Total Fraser

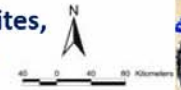


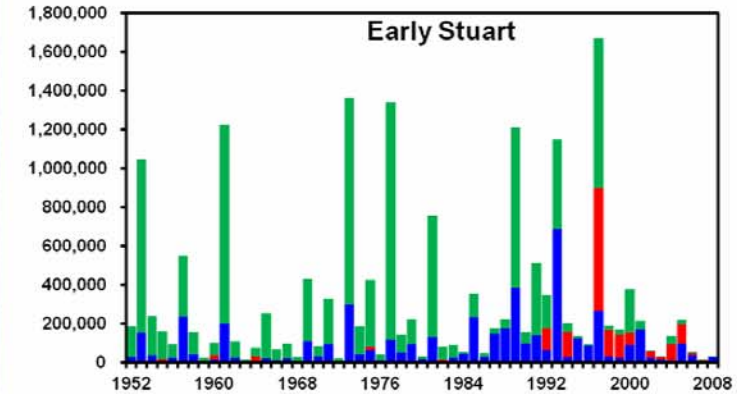
11

Early Stuart Run



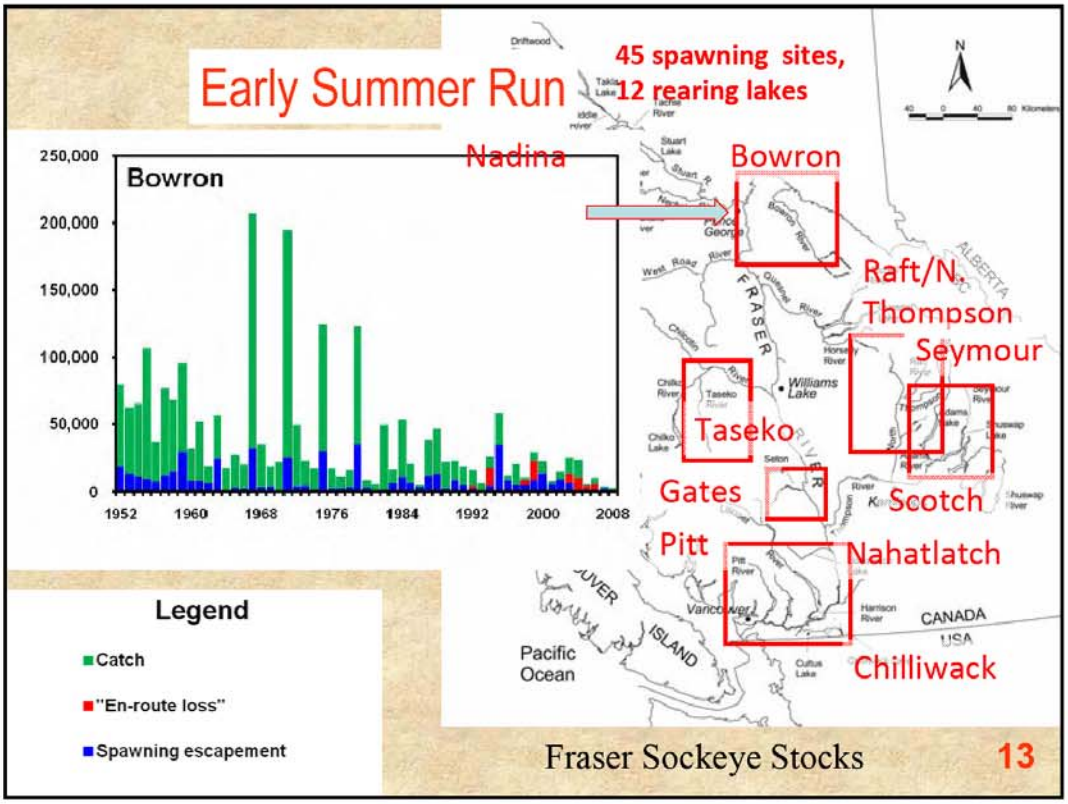
43 spawning sites,
3 rearing lakes

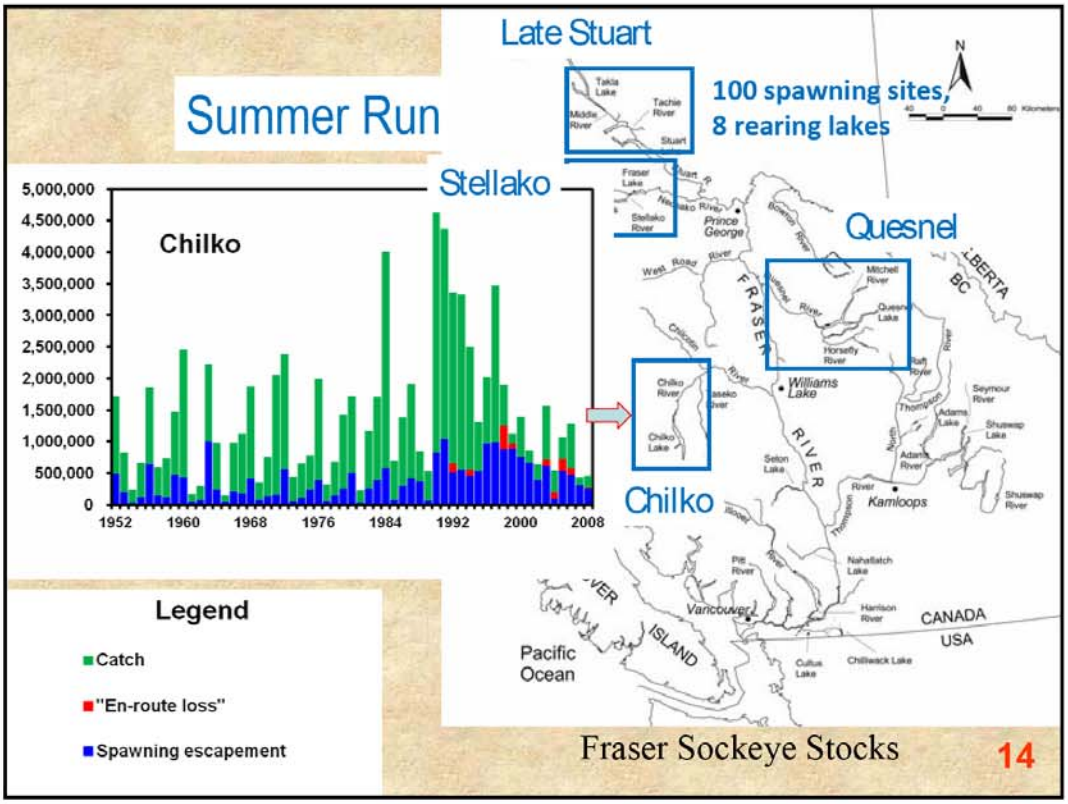


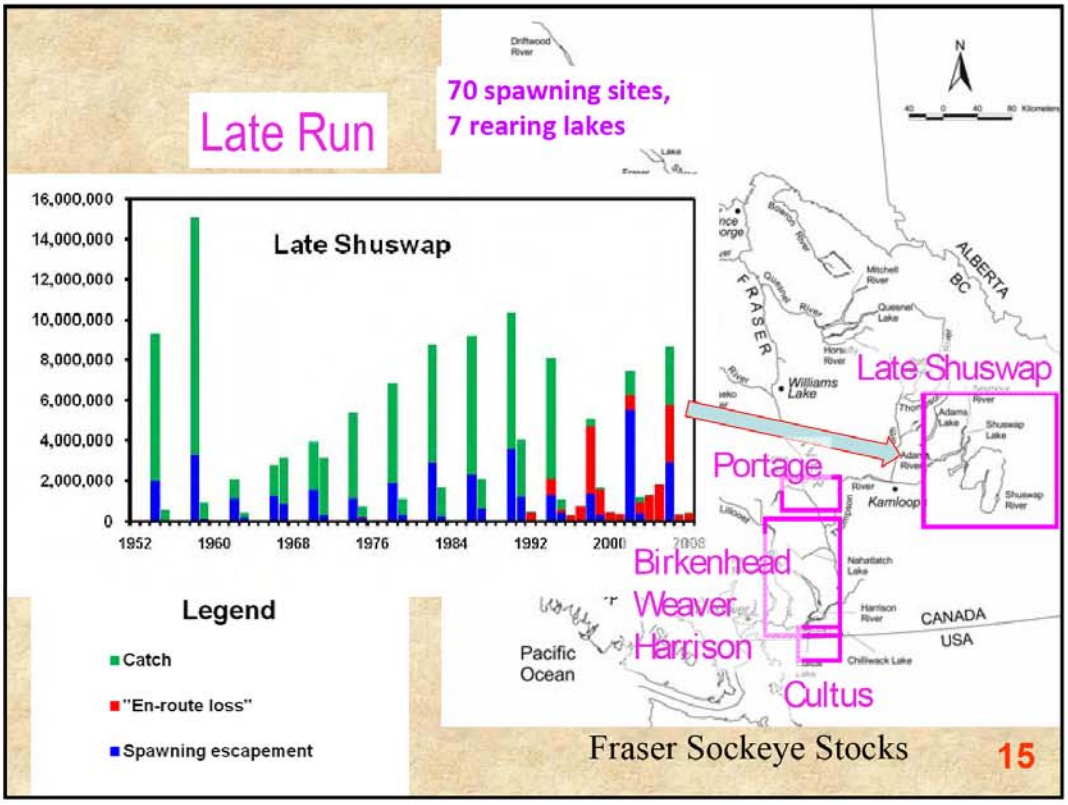


Fraser Sockeye Stocks

12


Early Summer Run
45 spawning sites,
12 rearing lakes
Nadina
Bowron
Raft/N. Thompson
Seymour
Taseko
Gates
Scotch
Pitt
Nahatlatch
Chilliwack
Bowron
250,000
200,000
150,000
100,000
50,000
0
1952
1960
1968
1976
1984
1992
2000
2008
Legend
Catch
"En-route loss"
Spawning escapement
Pacific Ocean
CANADA
USA
Fraser Sockeye Stocks
13


Late Stuart
Summer Run
100 spawning sites,
8 rearing lakes
Stellako
Quesnel
Chilko
Chilko
5,000,000
4,500,000
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1952
1960
1968
1976
1984
1992
2000
2008
Legend
Catch
"En-route loss"
Spawning escapement
Pacific Ocean
CANADA
USA
Fraser Sockeye Stocks
14



Productivity indices

- [Returns (or recruits)]/spawner
- Recruits/(effective female spawners)
- Residuals Ricker model

$$Ln(R/S)= a – bS + v$$

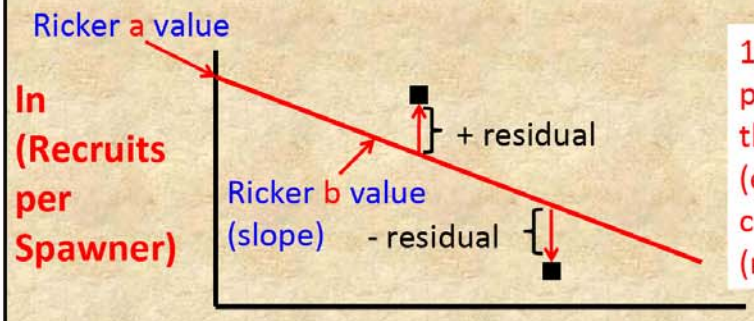
- Deviations of time varying a_t from average a $a_t – bS + w$ Ln(R/S)=
- Residuals from Larkin model

$$Ln(R/S_t)= a – b_0S_t + b_1S_{t-1} + b_2S_{t-2} + b_3S_{t-3} +v$$

Effects of prior brood years' spawner abundances on productivity

Productivity indices
Why residuals?

- Expect productivity to decline with increasing spawner abundance (Ricker model)

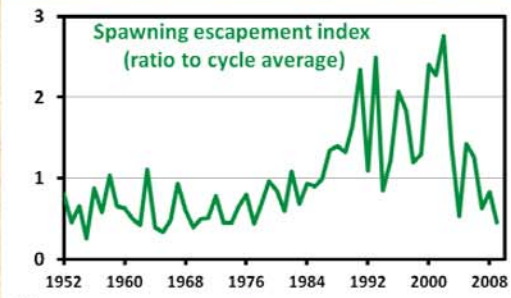


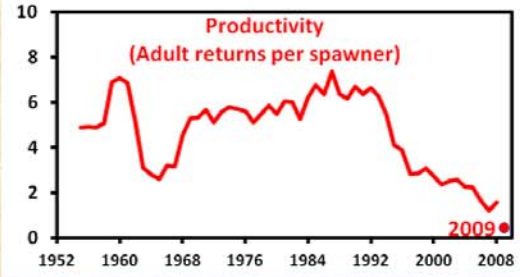
17/18 Fraser populations show this pattern (exception Scotch creek), but r^2 is low (mean 16%) [1]

17

Notes: 1 Based on regressions of Ln(age 4 Recruits/effective female) vs. eff females)

Productivity indices
Why residuals?

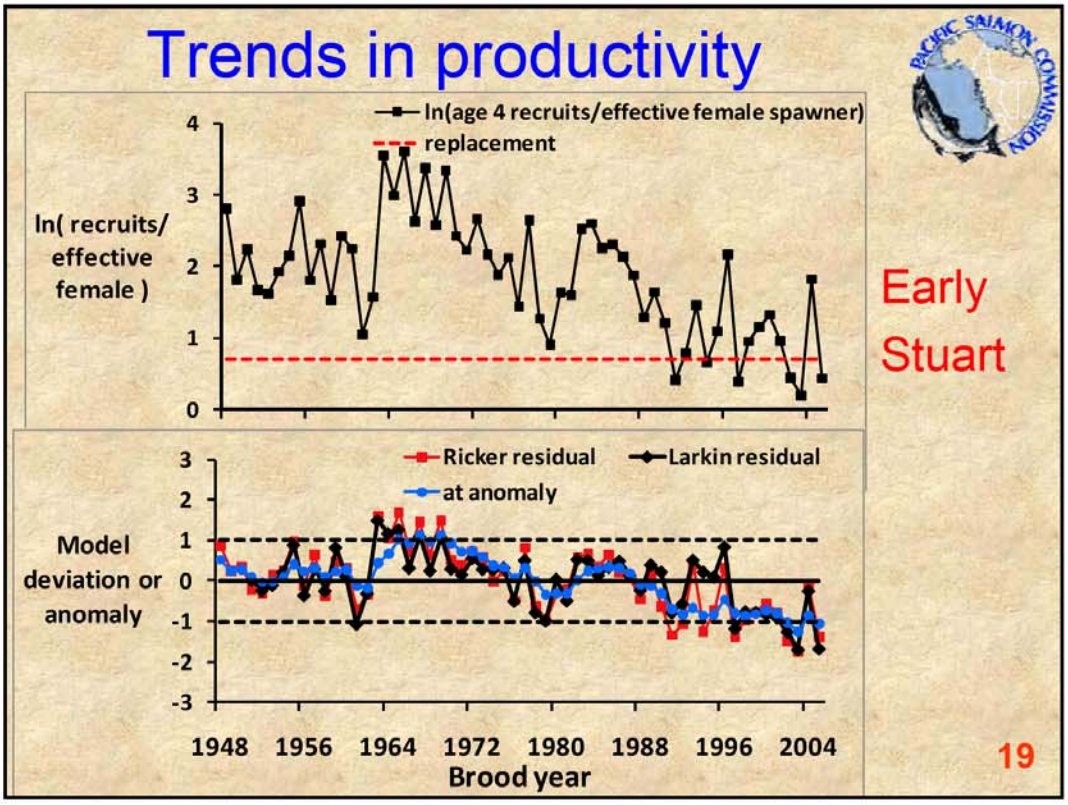


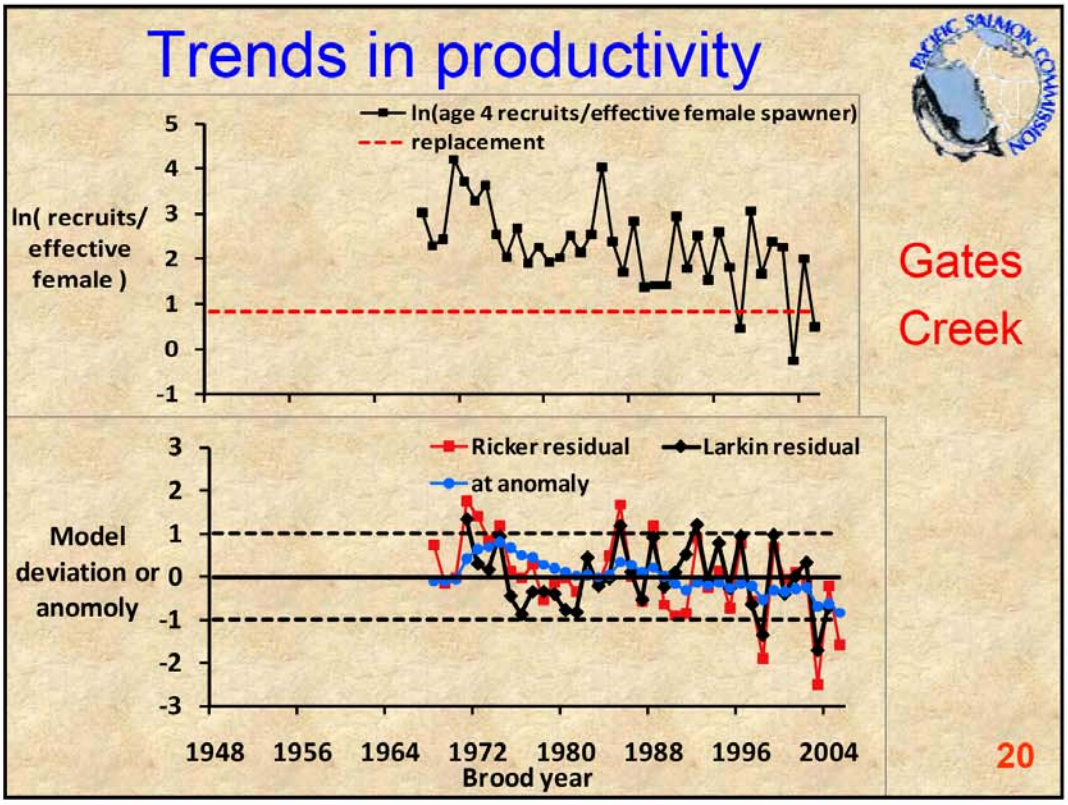


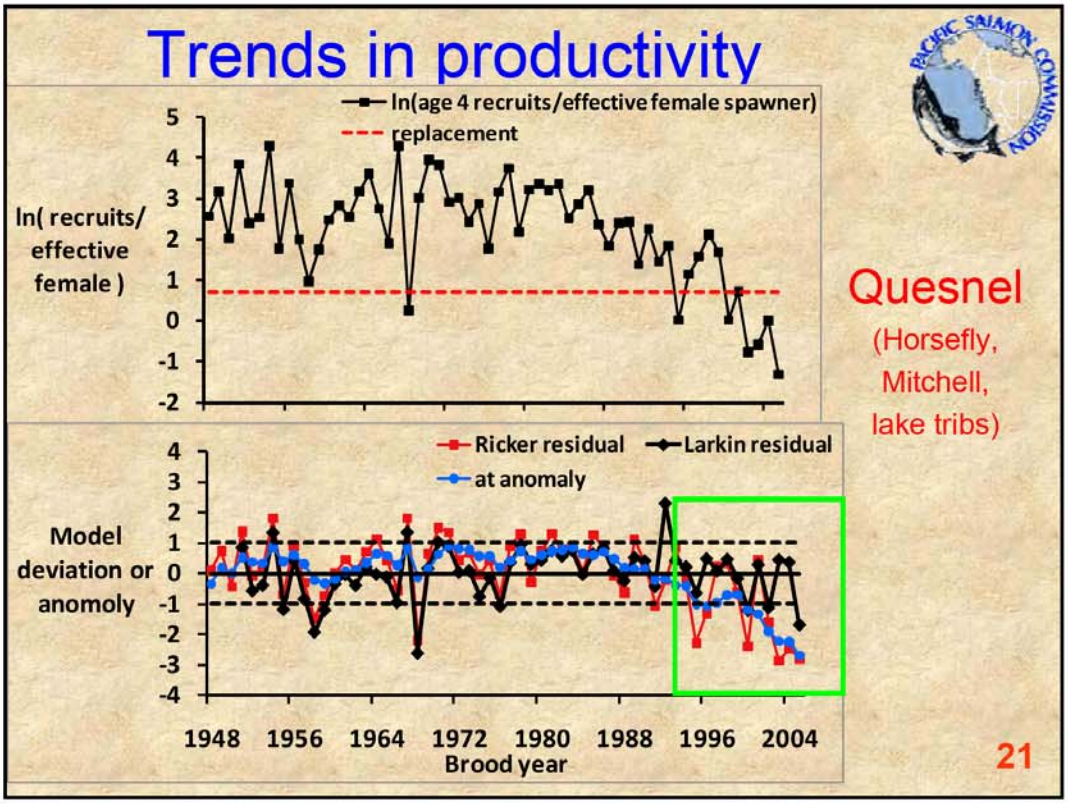
Trends in residuals used to examine productivity patterns remaining after removing effects related to changes in spawner abundance

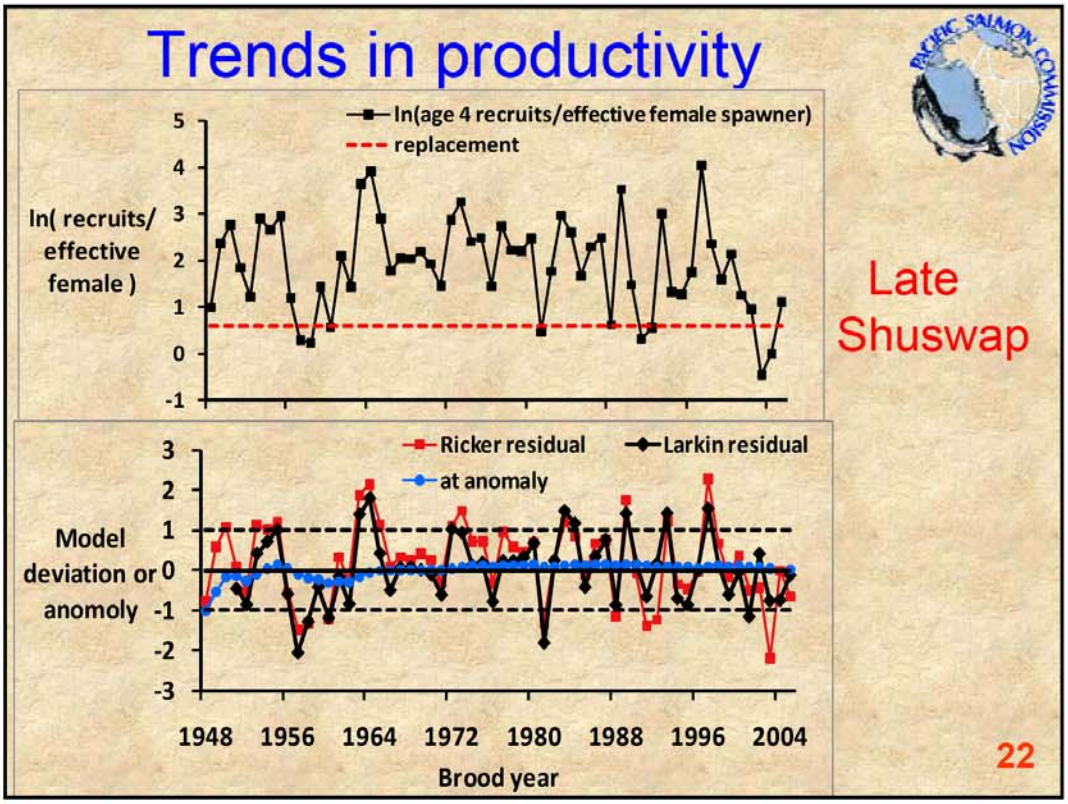
Productivity measure	Spawner abundance effects
Ricker residual	Brood year
a_t anomaly	Brood year
Larkin residual	Brood &prior yrs

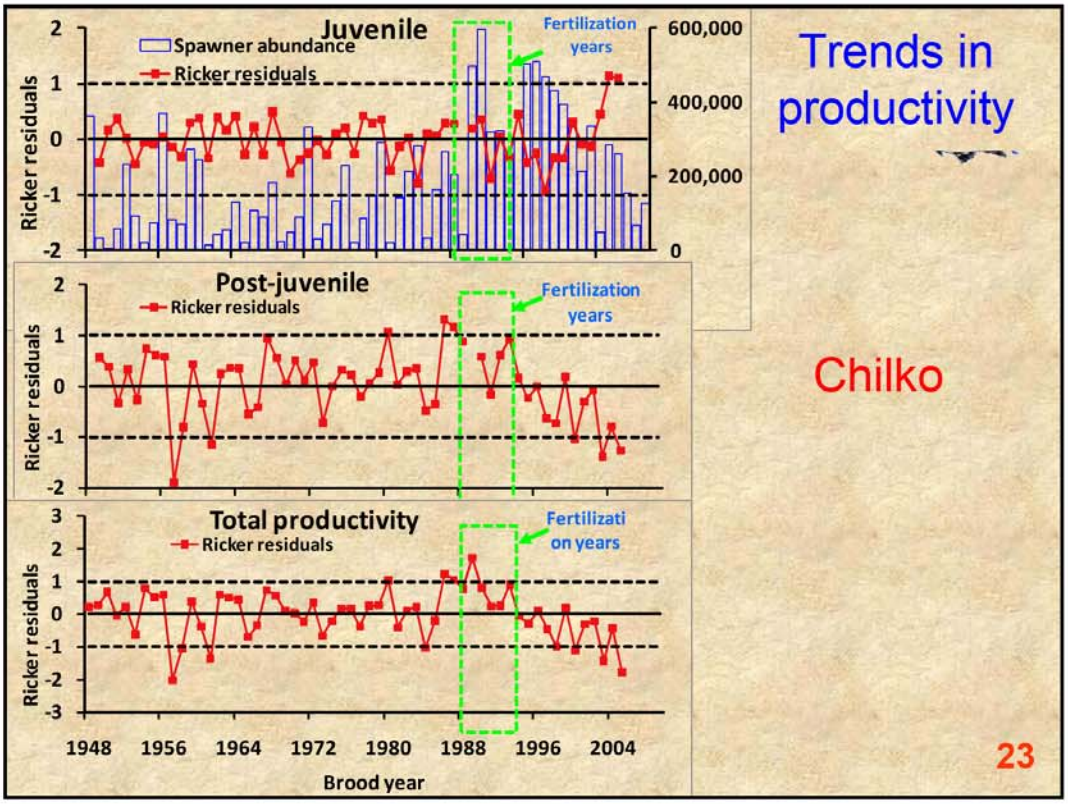
18

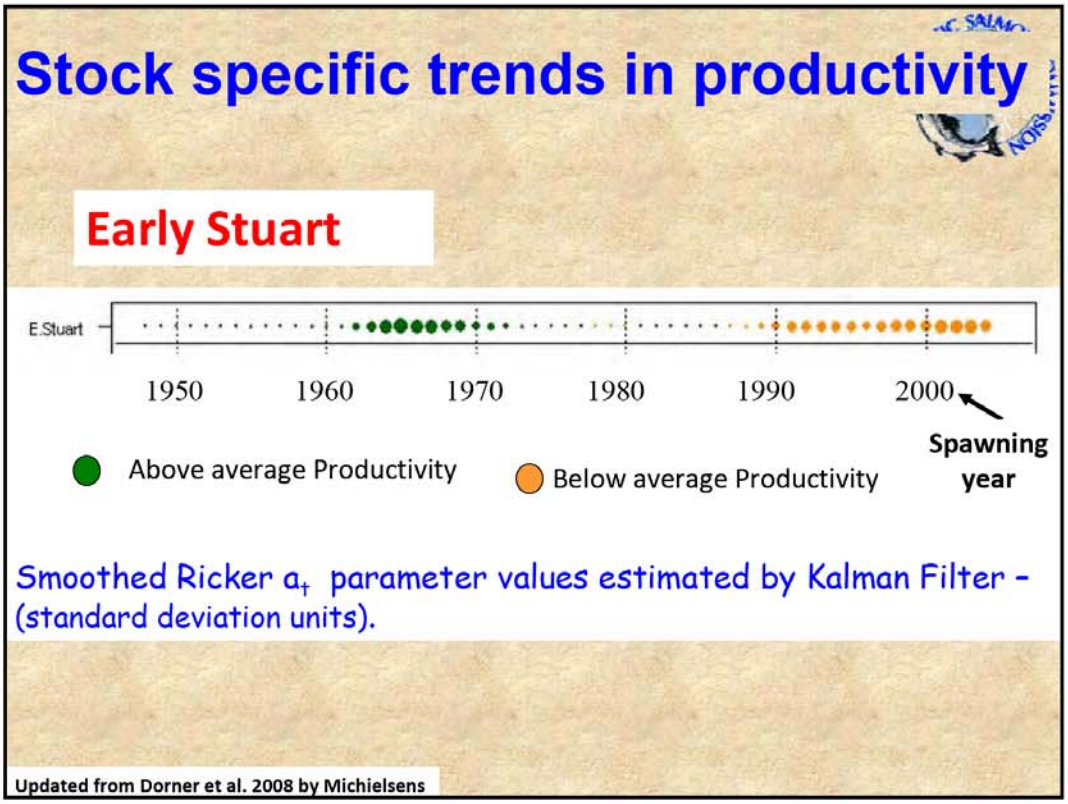

Trends in productivity
ln(age 4 recruits/effective female spawner)
replacement
ln(recruits/ effective female)
Ricker residual
Larkin residual
at anomaly
Model deviation or anomaly
1948 1956 1964 1972 1980 1988 1996 2004
Brood year
Early Stuart
19

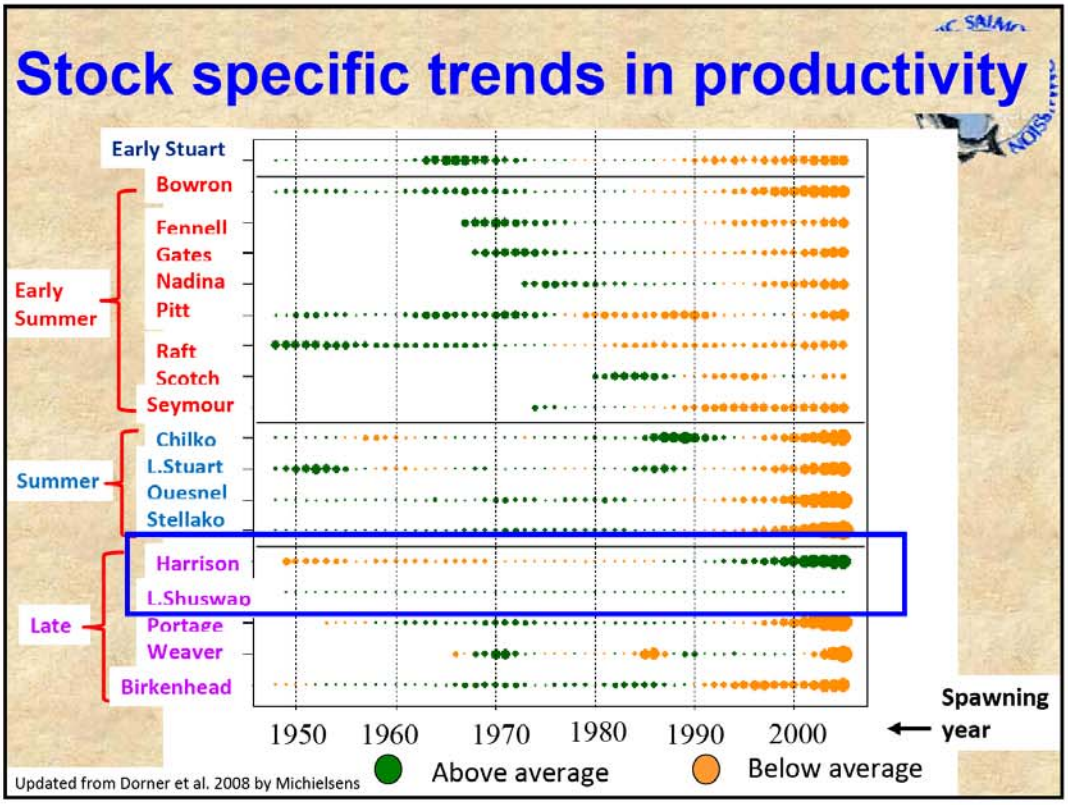

Trends in productivity
ln(age 4 recruits/effective female spawner)
replacement
ln(recruits/ effective female)
Ricker residual
Larkin residual
at anomaly
Model deviation or anomoly
1948 1956 1964 1972 1980 1988 1996 2004
Brood year
Gates Creek
20

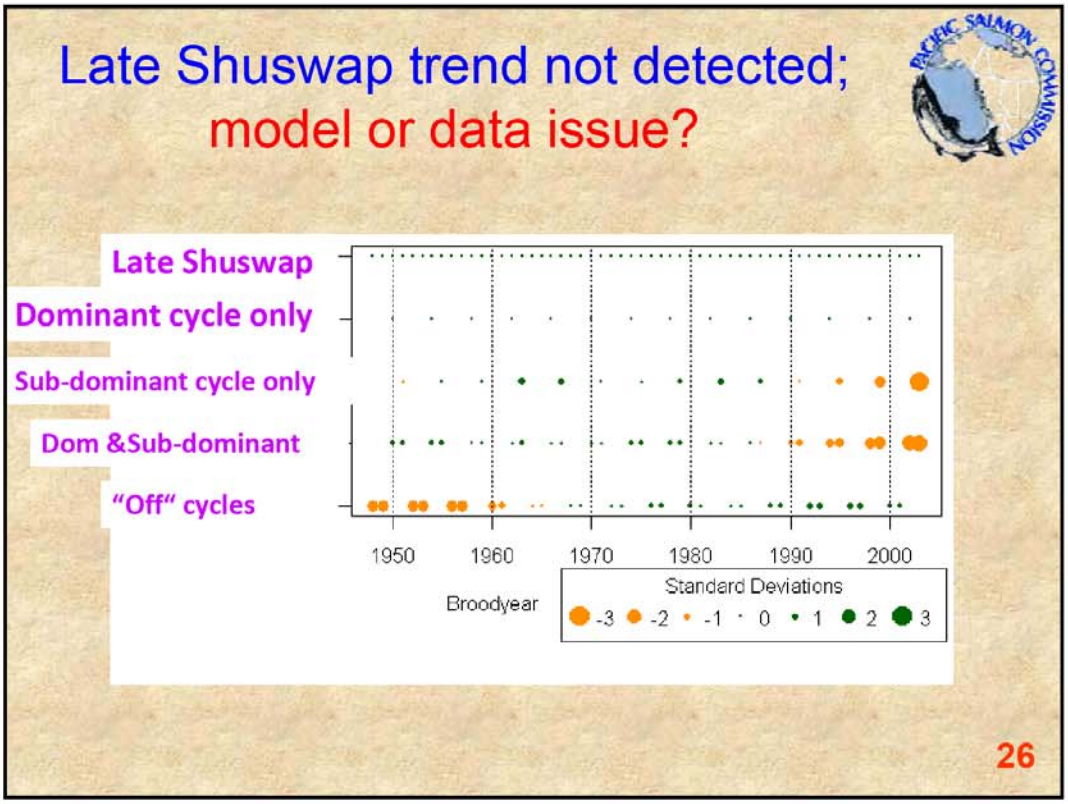

Trends in productivity
ln(age 4 recruits/effective female spawner)
replacement
ln(recruits/ effective female)
Ricker residual
Larkin residual
at anomaly
Model deviation or anomoly
1948 1956 1964 1972 1980 1988 1996 2004
Brood year
Quesnel
(Horsefly, Mitchell, lake tribs)
21


Trends in productivity
ln(age 4 recruits/effective female spawner)
replacement
ln(recruits/ effective female)
Ricker residual
Larkin residual
at anomaly
Model deviation or anomoly
1948 1956 1964 1972 1980 1988 1996 2004
Brood year
Late Shuswap
22


Juvenile
Spawner abundance
Ricker residuals
Fertilization years
Ricker residuals
600,000
400,000
200,000
0
Post-juvenile
Ricker residuals
Fertilization years
Total productivity
Ricker residuals
Fertilization years
1948
1956
1964
1972
1980
1988
1996
2004
Brood year
Trends in productivity
Chilko
23

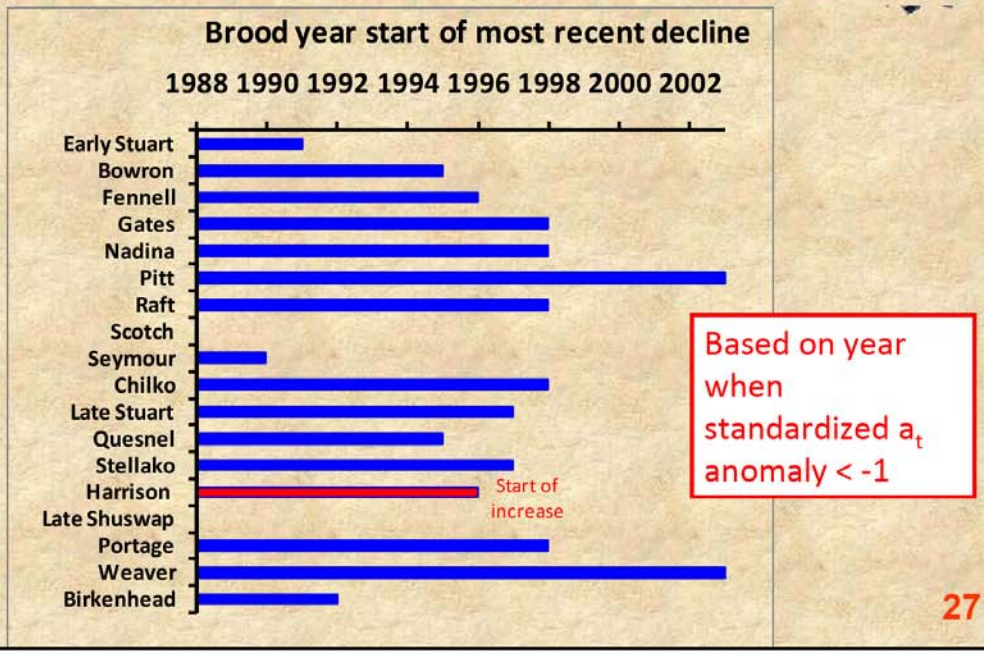

Stock specific trends in productivity
Early Stuart
E.Stuart
1950
1960
1970
1980
1990
2000
Spawning year
Above average Productivity
Below average Productivity
Smoothed Ricker a_t parameter values estimated by Kalman Filter - (standard deviation units).
Updated from Dorner et al. 2008 by Michielsens


Stock specific trends in productivity
Early Stuart
Bowron
Fennell
Gates
Nadina
Pitt
Raft
Scotch
Seymour
Chilko
L.Stuart
Quesnel
Stellako
Harrison
L.Shuswap
Portage
Weaver
Birkenhead
Early Summer
Summer
Late
1950
1960
1970
1980
1990
2000
Spawning year
Above average
Below average
Updated from Dorner et al. 2008 by Michielsens


Late Shuswap trend not detected;
model or data issue?
Late Shuswap
Dominant cycle only
Sub-dominant cycle only
Dom &Sub-dominant
"Off" cycles
1950
1960
1970
1980
1990
2000
Broodyear
Standard Deviations
-3
-2
-1
0
1
2
3
26

Stock specific trends in productivity

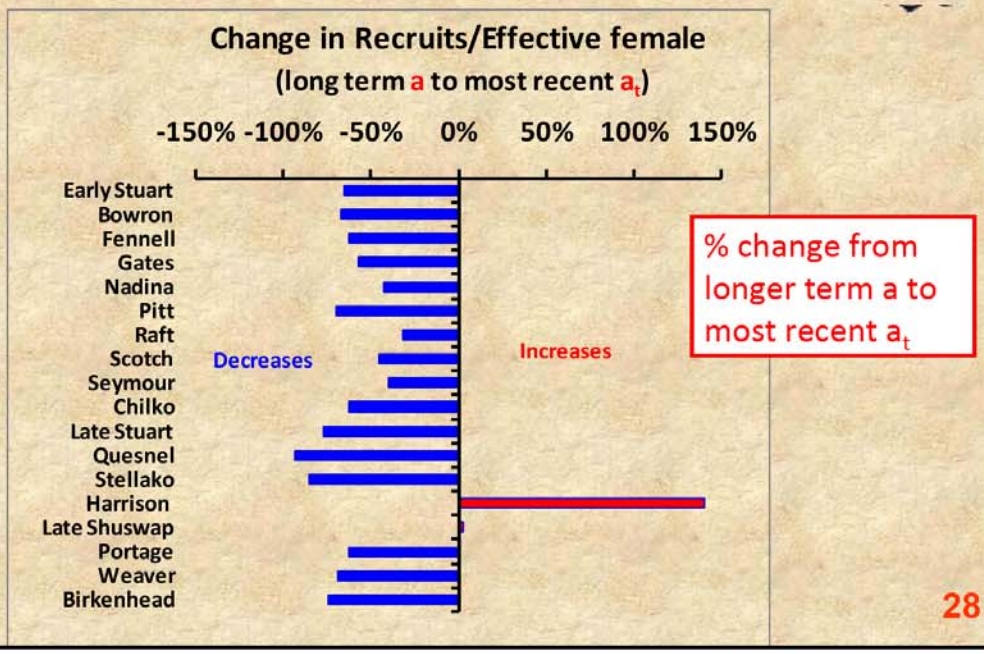
When did most recent declines begin?



27

Stock specific trends in productivity

How much has productivity declined?



28

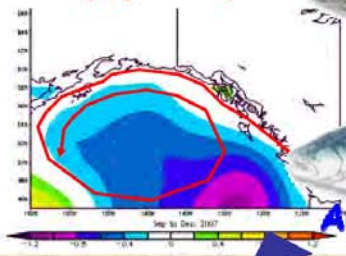
Where and when to look for causes of low productivity?

29

Fraser Sockeye life cycle

Typical pattern

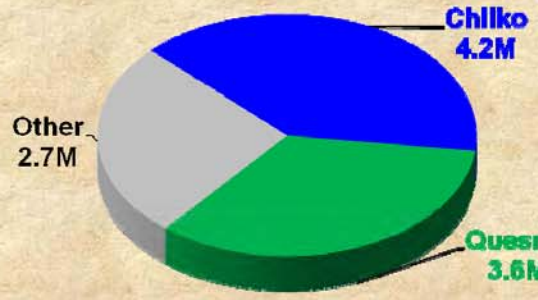
Smolts exit Fraser, migrate north along coast, after 2 yrs at sea (Gulf of Alaska) most adults return in fall 2009 (4 yrs old)



30

2009 Fraser River sockeye forecasts

Total Forecast 10.5M



75% of the return in two stocks

- 77 million smolts left Chilko Lake in 2007 (nearly 2 times 50 yr max)!
- 52 million fry were estimated in Quesnel lake in the fall of 2006 (slightly below average for the 2009 cycle)
- Good signals for freshwater survival from the 2005 spawning

31

2009 Returns

Stock-group	Pre-season Forecast	Post-season estimate (prel).
Chilko	4,175,000	270,000
Quesnel	3,575,000	220,000
Total Sockeye	10,488,000	1,505,000

32

Sherlock's Theory!

Colonel Mustard did it in the ocean with a _____?

33

Ocean mortality hypothesis
Some caveats

1. For Chilko smolts, can't rule out mortality during downstream migration (650 km).

2. For Quesnel fall fry can't rule out addition mortality in lake (9 months) or mortality during downstream migration.

34

Spatial scale of covariation among stock in productivity

- **Positive correlation in productivity among stocks within species -- pinks, chum, sockeye at regional-scale (~ 500 to 800 km)**

- **Environmental processes that drive this biological variation should have this same spatial scale**

Mueter et al. (2002) *Fish. Oceanog.*

Mechanisms for covariation

At which life stage does most covariation arise?

Late freshwater or early ocean life stages

What is driving spatial covariation in productivity?

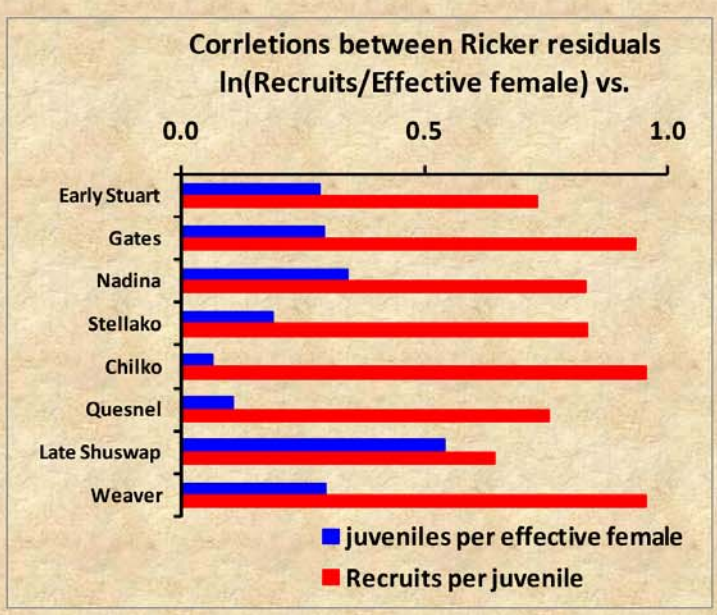
- Upwelling?
- Coastal sea-surface temperature (SST)?
- Coastal sea-surface salinity?

spatial scale of covariation~ 500 km, same as salmon productivity

Asked same question:
Is there positive correlation across locations?

Mueter et al. (2002a)

Post-juvenile stage has highest correlations with overall productivity



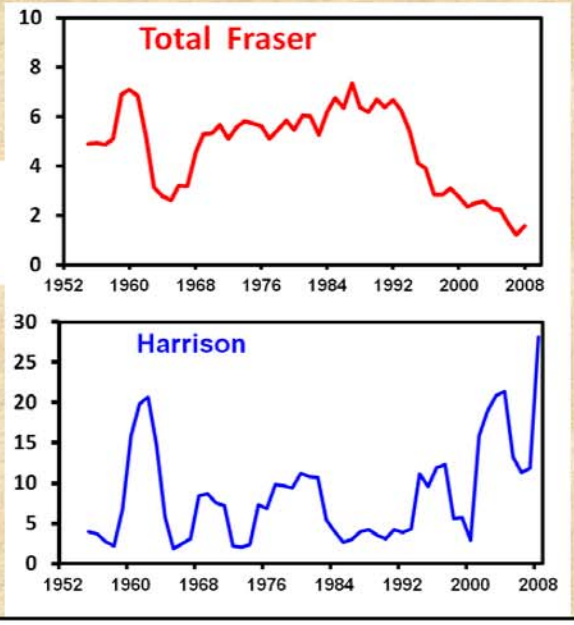
37

Life history clues?

38

Harrison sockeye Productivity

Productivity (Adult returns per spawner)



39

Harrison sockeye Life history

Life history	Most Sockeye	Harrison
Fry rearing	Lake (1 year)	Sloughs, estuary (few months)
Ocean entry	2 years after spawning	< 1 year after spawning
Ocean residence	2 years	2 *and* 3 years
Age at return	4 years	3 *and* 4 years
Ocean entry of 2009 return	2007	2007 for age 3 fish 2006 for age 4 fish

40

Harrison sockeye Productivity of 2009 return

Year	Total Fraser Sockeye	Harrison
2007 Ocean entry	0.5 returns/spawner	1.8 (age 3 fish from 2009 return)
Smolt migration route	**Most use Johnstone Strait**	**Some, perhaps most use Juan de Fuca Strait**
2006 Ocean entry	**3.0 returns/spawner**	**0.04 returns/spawner (age 4 from 2009 return & age 3 from 2008 return)**
		400,000 spawners (2005;33 times average!)

41

Multi-year clues?

low returns in 2009,2008 & 2007

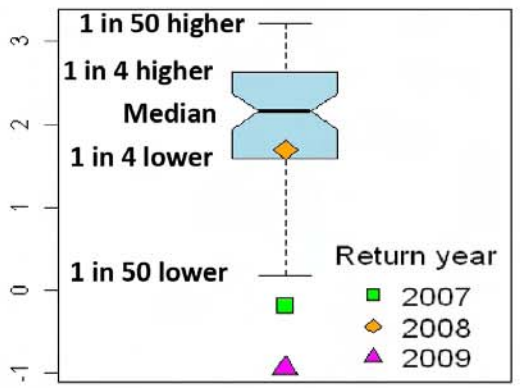
Shared causes?

42

Return rates not equally anomalous

Productivity index

(ln (age 4 return per female spawner)



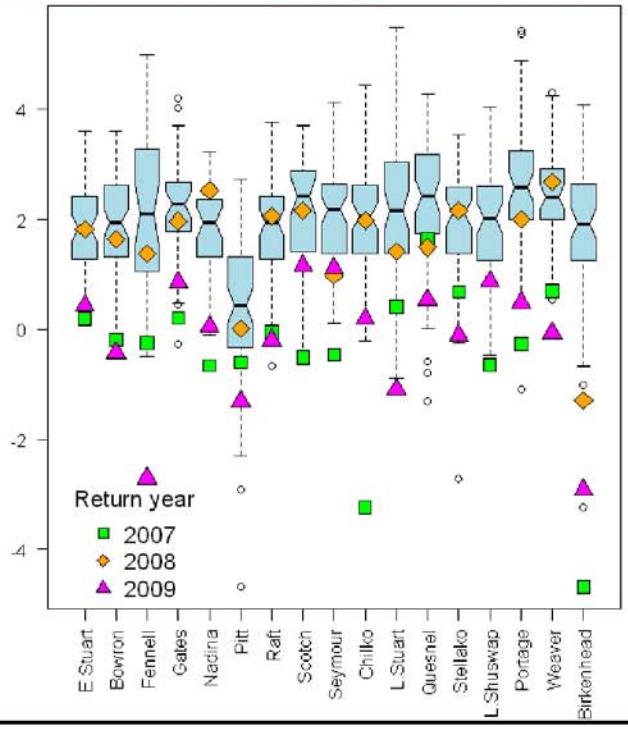
Summer Run

43

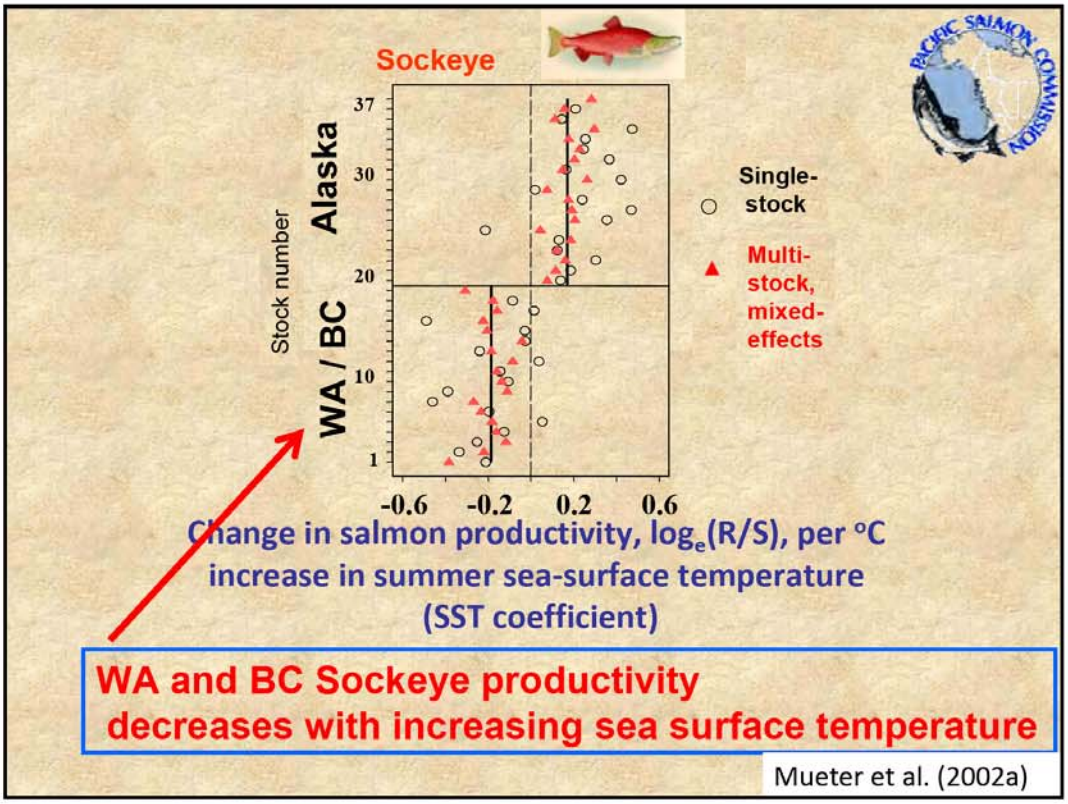
Return rates not equally anomalous

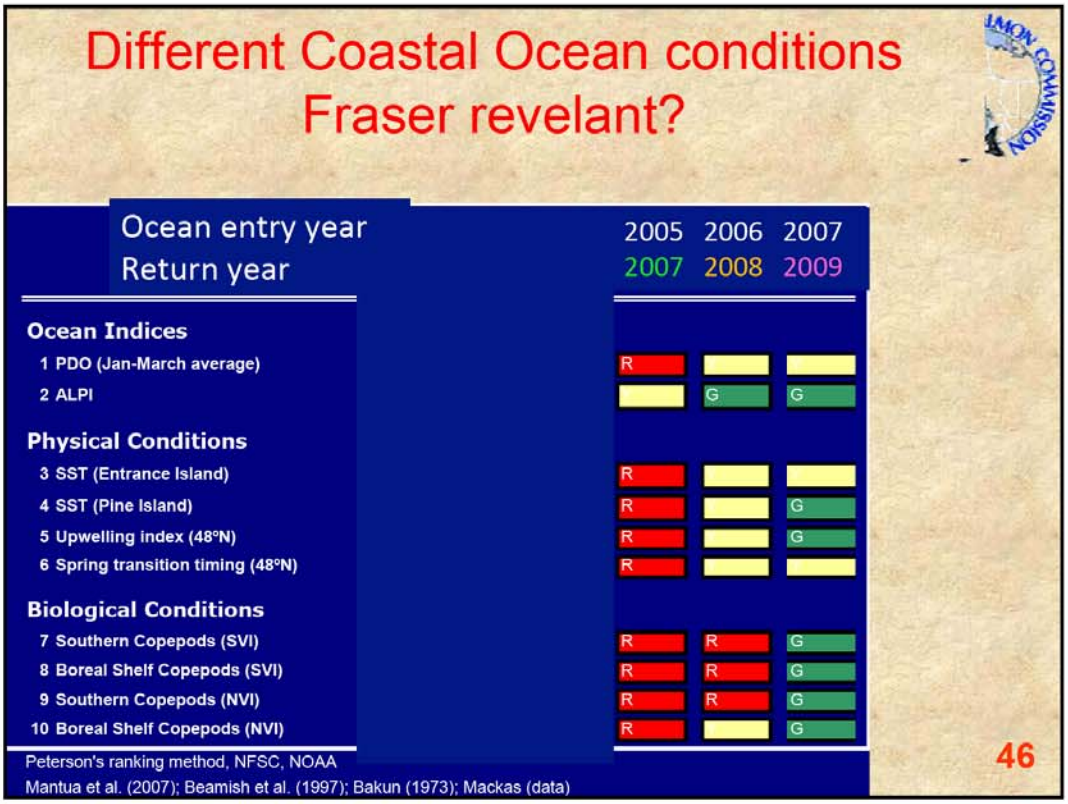
Productivity index

(ln (age 4 return per female spawner)

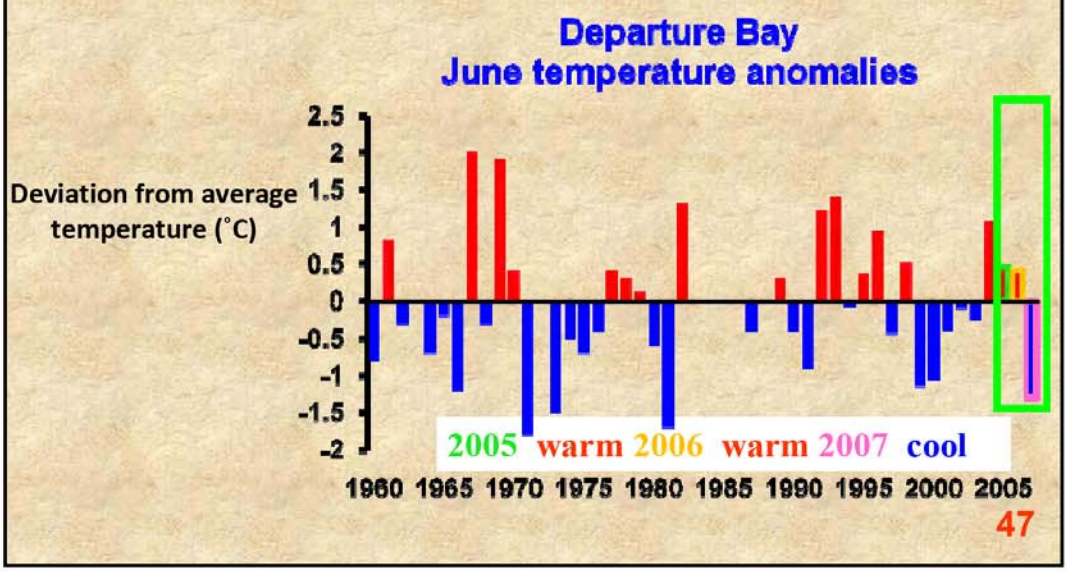


44


Sockeye
Stock number
Alaska
WA / BC
37
30
20
10
1
-0.6
-0.2
0.2
0.6
Single-stock
Multi-stock, mixed-effects
Change in salmon productivity, log$_e$(R/S), per °C increase in summer sea-surface temperature (SST coefficient)
WA and BC Sockeye productivity decreases with increasing sea surface temperature
Mueter et al. (2002a)


Different Coastal Ocean conditions Fraser revelant?
Ocean entry year
Return year
2005 2006 2007
2007 2008 2009
Ocean Indices
1 PDO (Jan-March average)
2 ALPI
Physical Conditions
3 SST (Entrance Island)
4 SST (Pine Island)
5 Upwelling index (48°N)
6 Spring transition timing (48°N)
Biological Conditions
7 Southern Copepods (SVI)
8 Boreal Shelf Copepods (SVI)
9 Southern Copepods (NVI)
10 Boreal Shelf Copepods (NVI)
R
G
Peterson's ranking method, NFSC, NOAA
Mantua et al. (2007); Beamish et al. (1997); Bakun (1973); Mackas (data)
46

Georgia Strait conditions different (More Fraser relevant?)



47

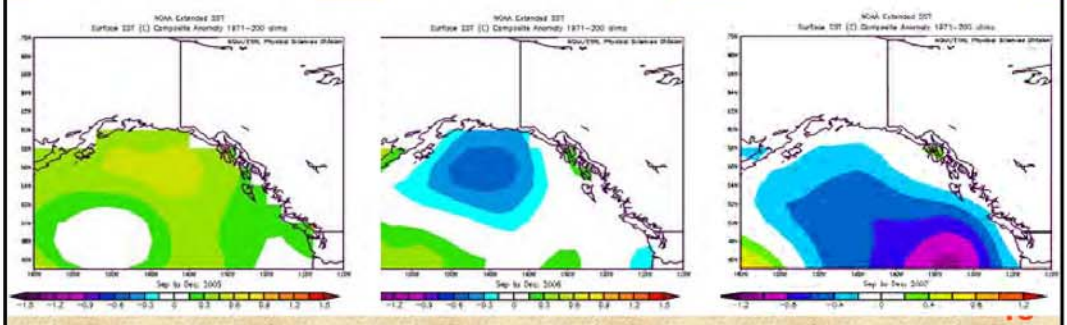
Different conditions in Gulf of Alaska

Sept-December SST anomalies year of arrival

Blue = cold, Green Yellow = warmer

Significant to fish?

2007 return | 2008 return | 2009 return



Summary of multi-year comparisons

1. 2008 productivity was below average for most stocks but much higher than 2007 and 2009.

2. Readily available data on environmental factors *do not show* a common pattern even among the most anomalous years (2007 & 2009).

49

Summary of multi-year comparisons

3. The extremely low productivity in 2007 (2005 ocean entry) was consistent with warm coastal and open ocean conditions that have been linked to poor marine survival of salmon.

4. However the productivity in 2009 similar (in some cases lower) to 2007 despite cooler than average ocean temperatures and *seemingly* more favorable conditions.

Underscores the futility of these broad comparisons and the need for Fraser specific indicators.

50

Data on ocean life stages lacking!

Smolts exit Fraser, migrate north along coast, after 2 years at sea (Gulf of AK), 4 yr old adults return in fall

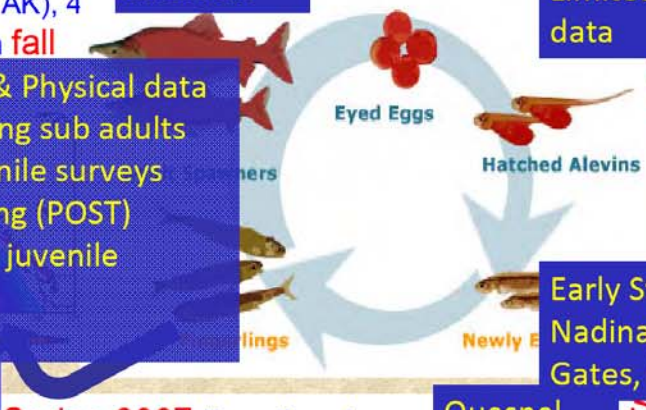
Excellent monitoring, all stocks

Winter 2005

Limited data

Winter 2006

Limited Biological & Physical data
Old high seas tagging sub adults
Georgia Strait juvenile surveys
Cultus smolt tagging (POST)
Discovery passage juvenile sampling



Early Stuart, Nadina, Gates, Weaver

Chilko last seen spring 2007

Spring 2007 fingerlings leave lake, migrate down the Fraser River, entering ocean as smolts

Quesnel last seen fall 2006

Spring 2006, fry migrate to lake

I had help!!

Catherine Michielsens
Steve Latham
Sue Grant
Randall Peterman

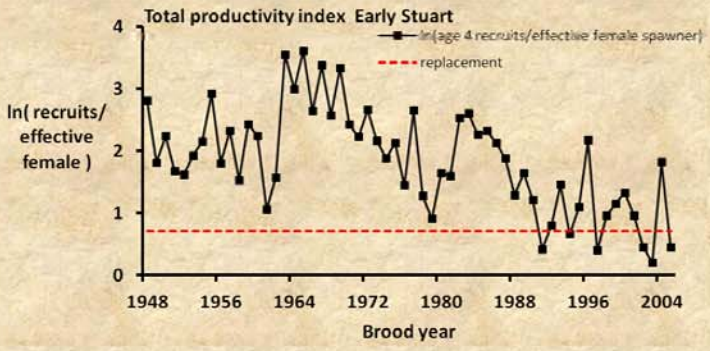
Thanks!

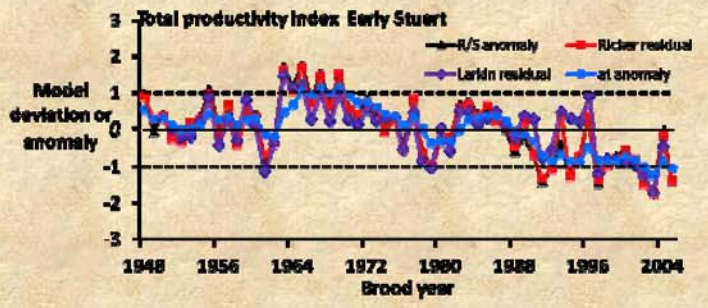
52

The End

53

Trends in productivity

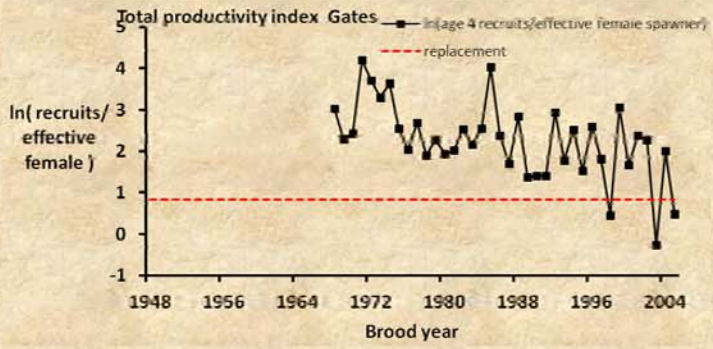


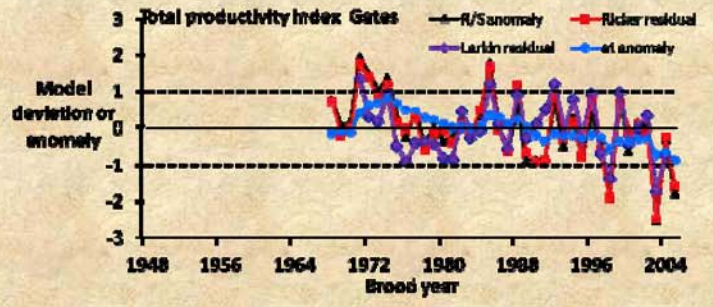


Early Stuart

54

Trends in productivity

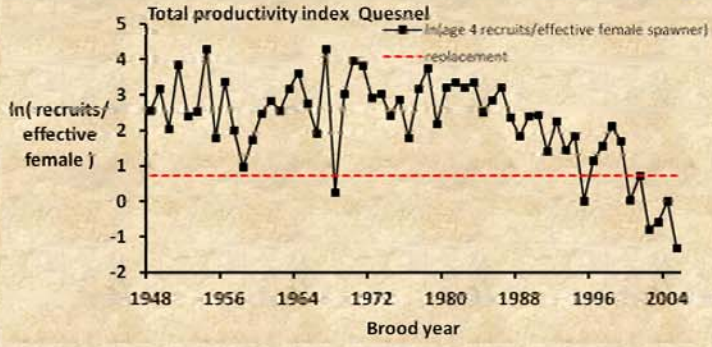


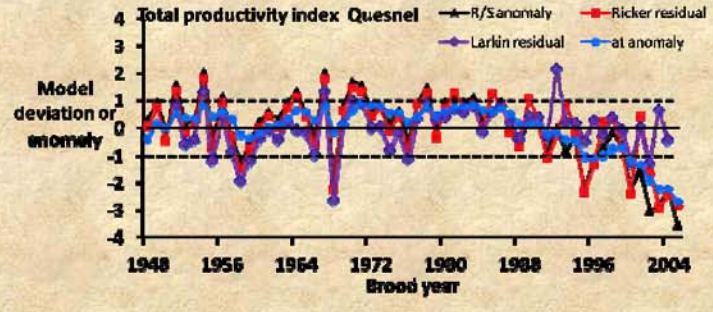


Gates Creek

55

Trends in productivity

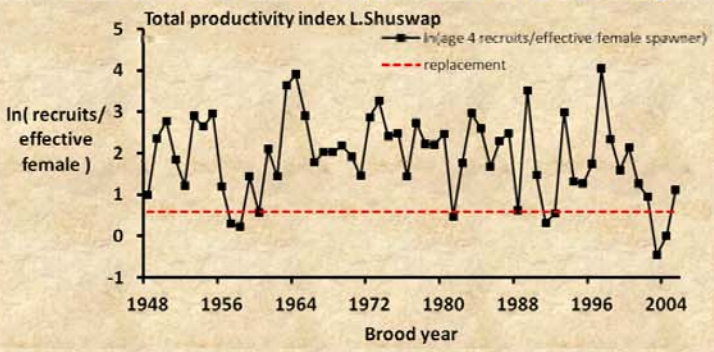


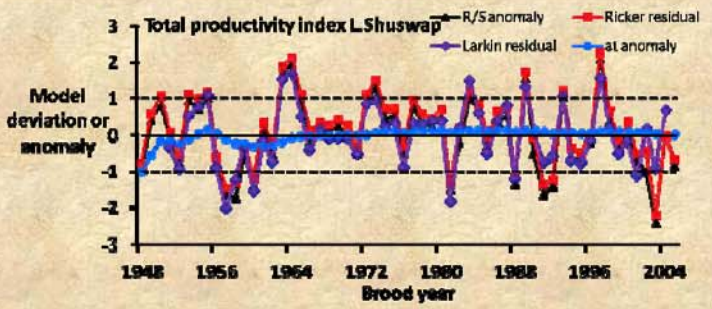


Quesnel
(Horsefly, Mitchell, lake tribs)

56

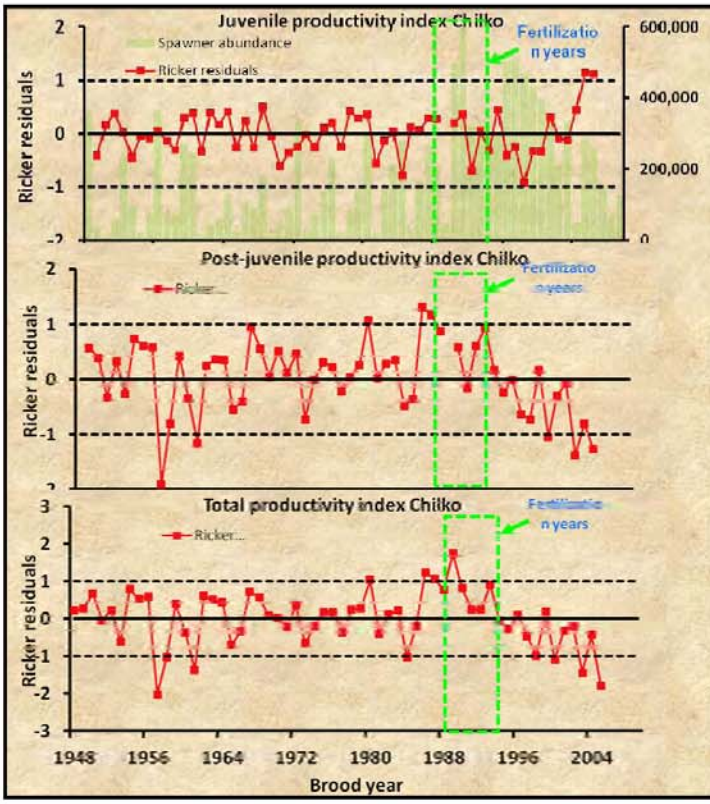
Trends in productivity





Late Shuswap

57



Trends in productivity

Chilko

58

Supplemental slides

59

Productivity

60

Indices of productivity

- Recruits/(effective female spawners)
  a. Carcasses are examined in spawning areas for sex ratio
  b. a sample of females is scored: 100% (none of few eggs left in carcass), 50% (some eggs left in carcass), 0% (most or many eggs left in carcass)
  c. Weighted average % spawned calculated from b.
  d. effective females = females X % spawned
  e. (1 - %spawned) often referred to as pre-spawn mortality

61

Indices of productivity

Ricker model residuals

- Ricker model
- $R_t=S_t e^{(a-bSt) + v}$; $\ln(R_tS_t) = a - bS_t + v_t$
- a (intercept), b(slope) estimated by regression,
- Residual = v_t observed productivity – model predicted productivity
- $v_t = \ln(R_tS_t) - a - bS_t$
- for Fraser sockeye if S_t is spawing stock in year t, R is recuitment of age 4 in year t+4 and age 5 in year t+5

62

Indices of productivity

Time varying a_t values

- Ricker model with time varying a value
- $R=Se^{(a_t-bS)+v}$; $\ln(R/S) = a_t - bS + vt$
- $a_t = a_{t-1} + w$ (Random walk model)
- analogous to trying to detect a trend the Ricker model residuals resulting from a mode with constant a parameter
- See Dorner et al. 2008 (Can. J. Fish. Aquatic Sci. 65:1842:1866)

63

Stock specific trends in productivity

	Brood year that most recent decline began[1]	Long term average a	Most recent a_t	long term average R/EFS from a	Most recent R/EFS from a_t	% change in R/EFS
Early Stuart	1991	1.90	0.84	6.7	2.3	-65%
Bowron	1995	2.38	1.28	10.8	3.6	-67%
Fennell	1996	2.75	1.77	15.7	5.9	-62%
Gates	1998	2.40	1.56	11.0	4.8	-57%
Nadina	1998	1.97	1.42	7.2	4.1	-42%
Pitt	2003	1.10	-0.11	3.0	0.9	-70%
Raft	1998	2.06	1.68	7.8	5.4	-31%
Scotch	na since 97 [2]	1.76	1.15	5.8	3.2	-46%
Seymour	1990	2.05	1.54	7.7	4.7	-40%
Chilko	1998	2.70	1.73	14.8	5.6	-62%
Late Stuart	1997	2.38	0.90	10.9	2.5	-77%
Quesnel	1995	2.32	-0.38	10.2	0.7	-93%
Stellako	1997	2.26	0.37	9.6	1.4	-85%
Harrison [3]	1996	2.12	2.99	8.3	19.9	140%
Late Shuswap	na sa =0.1[4]	1.99	2.02	7.4	7.5	3%
Portage	1998	3.13	2.15	23.0	8.6	-63%
Weaver	2003	2.71	1.54	15.1	4.7	-69%
Birkenhead	1992	2.30	0.95	10.0	2.6	-74%

Notes: 1 last year when smoothed anomoly > -1
2 smooth anomoly has not been < -1 since 1997
3 Harrison start of increase - smoothed anomoly > +1
4 method did not detect trend in a for Late Shuswap

64

Post-juvenile stage has highest correlations with overall productivity

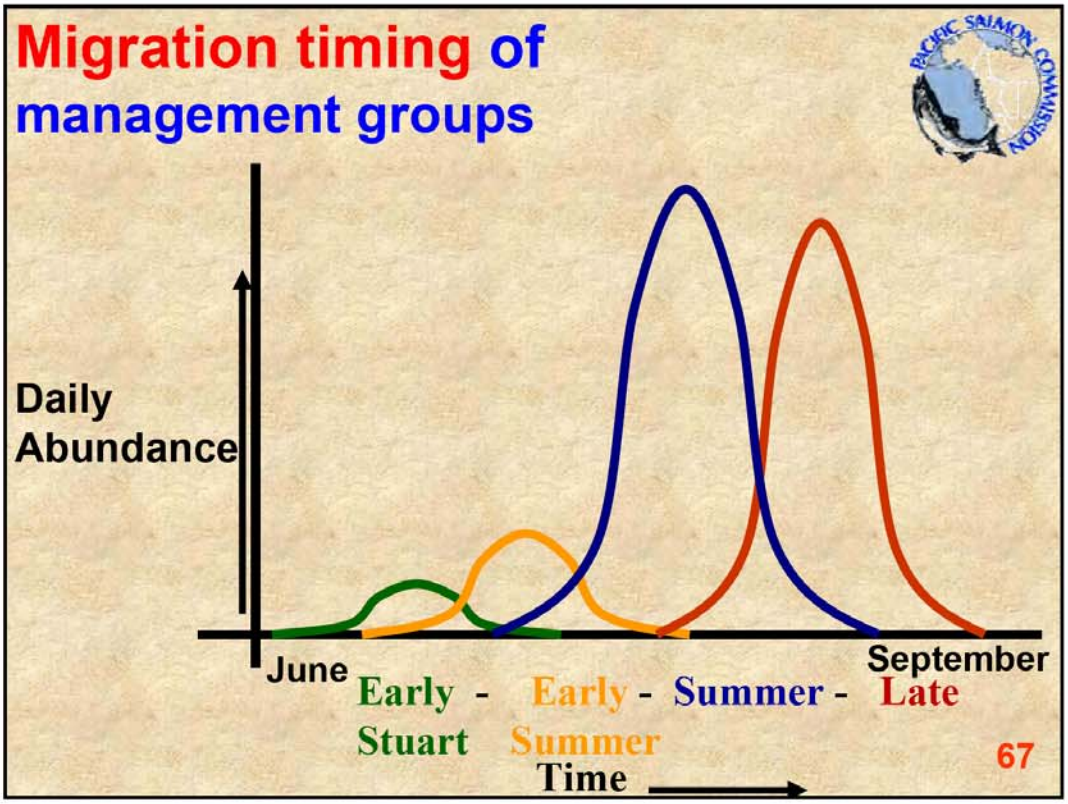
Correlations between Ricker model residuals

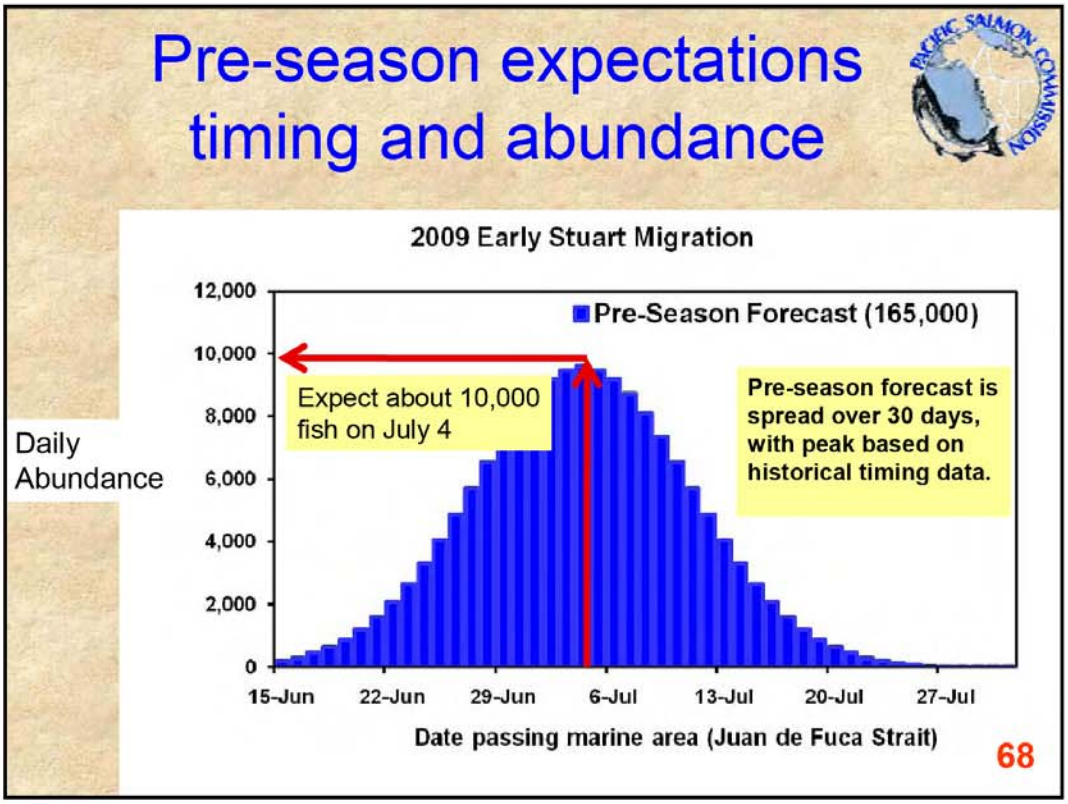
Recruits per effective female vs.

	n years	Juveniles per effective female	Recruits per juvenile
Early Stuart	16	0.29	0.73
Gates	38	0.30	0.93
Nadina	33	0.34	0.83
Stellako	13	0.19	0.83
Chilko	56	0.07	0.95
Quesnel	19	0.11	0.76
Late Shuswap	15	0.54	0.64
Weaver	38	0.30	0.96

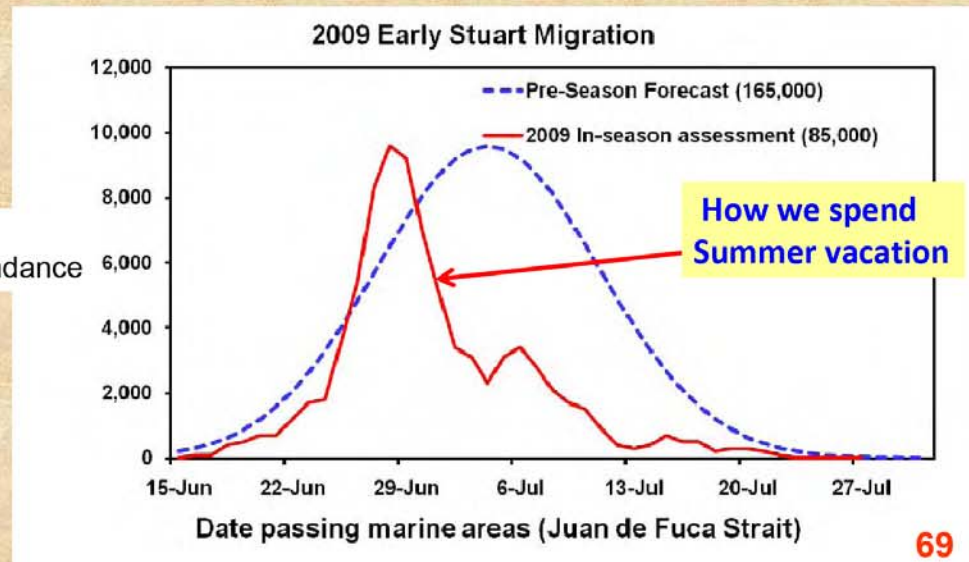
65

66


Migration timing of management groups
Daily Abundance
June
September
Early Stuart
Early Summer
Summer
Late
Time
67

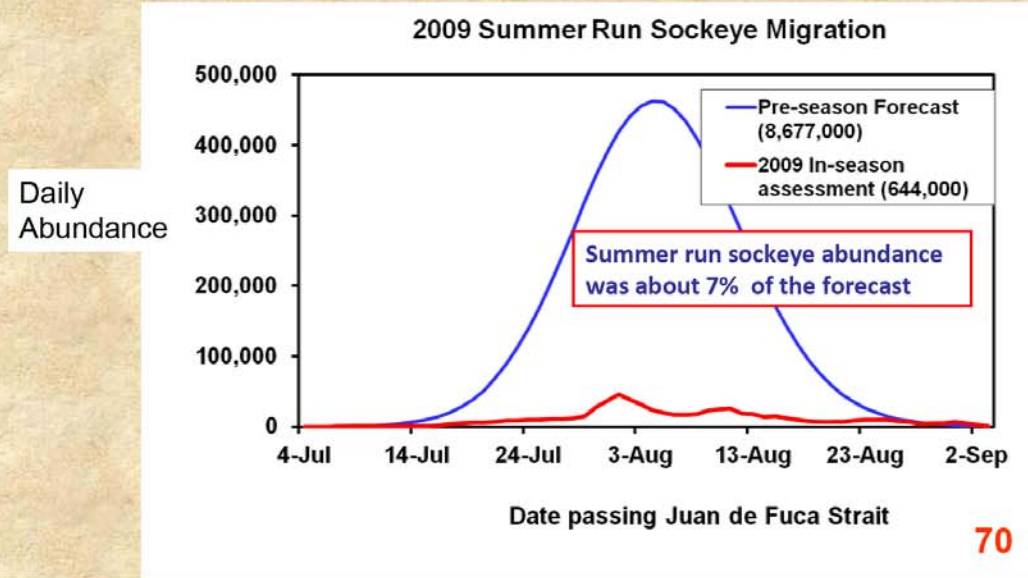

Pre-season expectations timing and abundance
2009 Early Stuart Migration
Pre-Season Forecast (165,000)
Expect about 10,000 fish on July 4
Pre-season forecast is spread over 30 days, with peak based on historical timing data.
Daily Abundance
12,000
10,000
8,000
6,000
4,000
2,000
0
15-Jun
22-Jun
29-Jun
6-Jul
13-Jul
20-Jul
27-Jul
Date passing marine area (Juan de Fuca Strait)
68

In-season assessments



69

In-season assessments



70

- Result:

Summer sea-surface temperature: spatial scale ~ 500 km, same as salmon productivity

- Models including stock-specific summer SST
  - Fit data much better than models without SST

- How much change in salmon productivity has occurred in past for each °C increase in SST?

72

Causal factors concepts
Critical period hypothesis

- variation in productivity/survival rates is caused by events/factors during a particular time (and location) in the salmon life cycle

e.g. food in first few months at sea in Georgia Strait

Principle Data/model needs:

- knowledge of space/time locations of salmon and causal agents
- quantitative data on relative abundance of salmon and magnitude of factors
- model relating salmon and factor with some explanatory mechanism

73

Causal factors concepts
Critical period hypothesis

Challenges/Assumptions:

- Identification of period/location; Fraser sockeye at sea for more than 24 months, pass through area of more than 1 million km^2
- correlation between critical period survival and overall survival depends on both relative magnitude ***and*** variation in subsequent survival periods.
- (e.g. see Bradford 1992;Fish. Bull (US) 90:439-453.)

74

Causal factors concepts
Whole life cycle hypothesis

- variation in productivity/survival rates is caused by the cumulative effects of a whole series of events/factors across the whole fishes life cycle.

e.g.

Principle Data/model needs:

- knowledge of space/time locations of salmon and causal agents
- measurements of multiple factors and relative abundance along the migration path
- complex model relating salmon survival and the multiple factors with some explanatory mechanism

75

Causal factors concepts
Whole life cycle hypothesis

Challenges/Assumptions:

- Self evident, but testable? (i.e. hard to reject without proof of critical period)
- Collection of data over entire life cycle is expensive
- Precision of survey data vs. model complexity and number of parameters.
- models break down due to complexity and non-stationarity

76

Fraser sockeye example

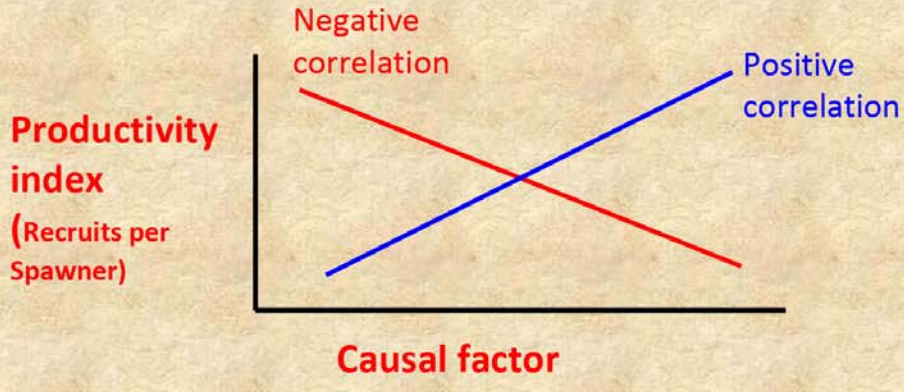
- correlations of productivity indices at different life stages

Positive correlation

77

Causal factors concepts
Types of relationships

1. Correlation analyses



78

Causal factors concepts
Types of relationships

2. Model Co-variate analyses

Model

Ln (R/S) = a +bS +cfactor

- parameter c quantifies relationship between factor and residual
- model could be linear or non-linear
- multiple factors could be added/tested
- does inclusion of factor improve the fit of model?

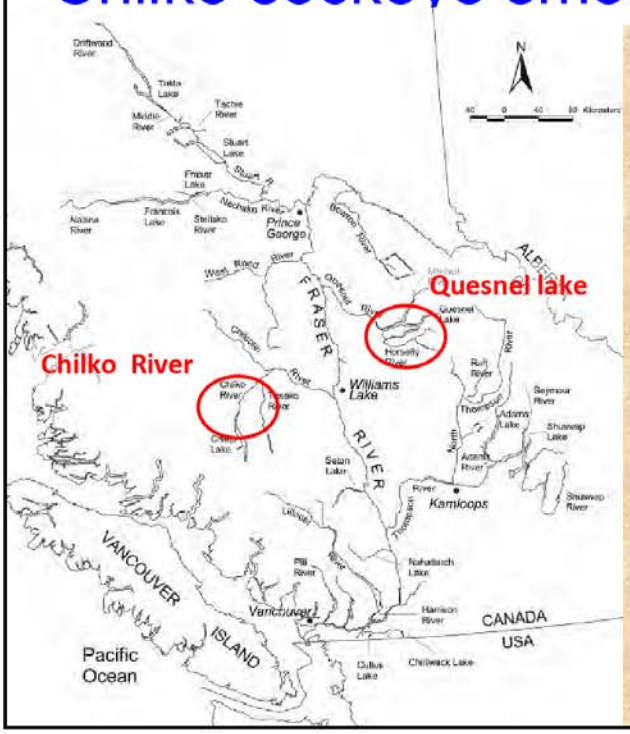
79

Methods for estimating juvenile abundance

1. Fry traps (Nadina, Gates, Weaver, Early Stuart)
2. Acoustic lake surveys (fry; Shuswap, Quesnel)
3. Smolt Weir (Chilko)

80

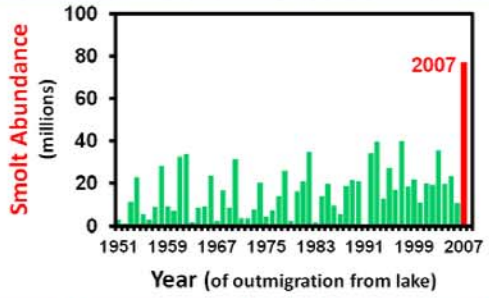
Chilko sockeye smolt program

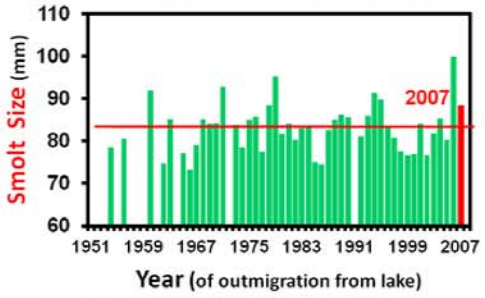


81

Chilko sockeye smolt data

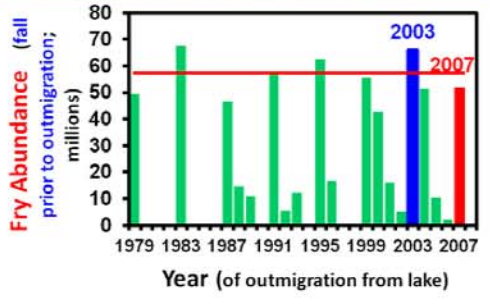
Source: DFO stock assessment

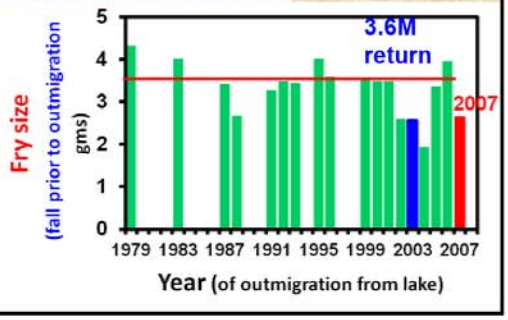




Quesnel lake sockeye fry data

Source: DFO Lake program





2009 Productivity relative to average

Freshwater (fry or smolt / female)

Below average:

Early Stuart, Gates

Near average:

Quesnel, Weaver

Above average:

Nadina, Chilko

No Juvenile data for other stocks

"Post Fry" (returns/fry or smolt)

Below average:

Early Stuart, Chilko, Quesnel, Weaver, Nadina, and Gates

Note: DFO concerns about fry data quality for E. Stuart, Gates?

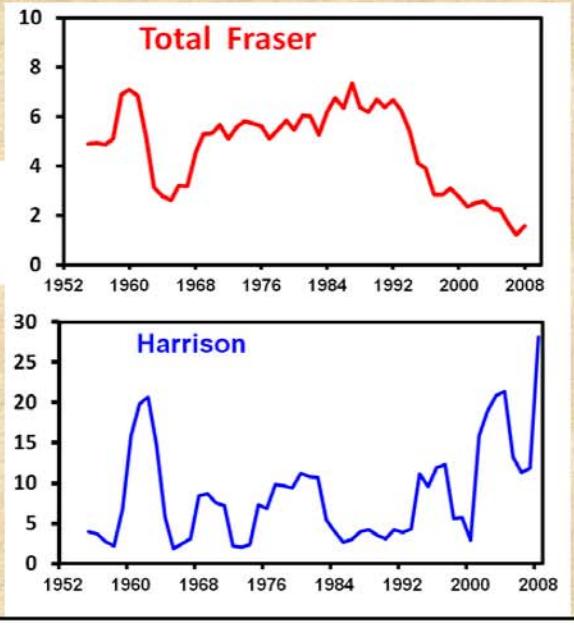
83

Life history clues?

84

Harrison sockeye Productivity

Productivity (Adult returns per spawner)



85

Harrison sockeye Life history

Life history	Most Sockeye	Harrison
Fry rearing	Lake (1 year)	Sloughs, estuary (few months)
Ocean entry	2 years after spawning	1 year after spawning
Ocean residence	2 years	2 *and* 3 years
Age at return	4 years	3 *and* 4 years
Ocean entry of 2009 return	2007	2007 for age 3 fish 2006 for age 4 fish

86

Harrison sockeye Productivity of 2009 return

Year	Total Fraser Sockeye	Harrison
2007 Ocean entry	0.5 returns/spawner	1.8 (age 3 fish from 2009 return)
Smolt migration route	**Most use Johnstone Strait**	**Some, perhaps most use Juan de Fuca Strait**
2006 Ocean entry	**3.0 returns/spawner**	**0.04 returns/spawner (age 4 from 2009 return & age 3 from 2008 return)**
		400,000 spawners (2005;33 times average!)

87

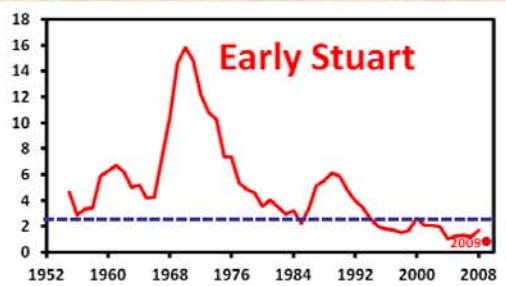
Potential candidate weapons

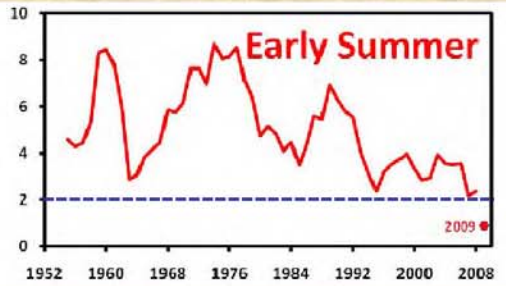
a. Poor food – the fish starved?
b. Predators – something ate them?
c. Disease - they got lethally ill
d. Parasites – those pesky sea lice?
e. Contaminants – poisoned on outmigration in Fraser estuary?
f. Other
g. All of the above, some of above, none of the above?

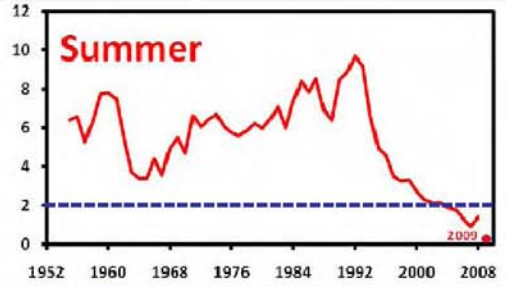
88

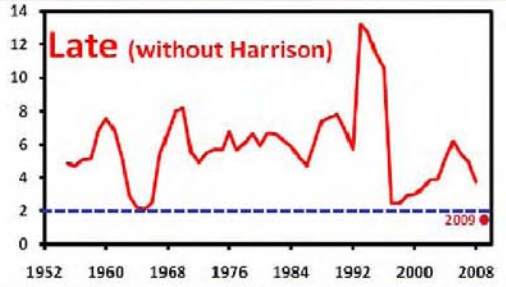
89

Productivity
by Management group









Start of productive declines not coincident – different mechanisms? time or stock effect?

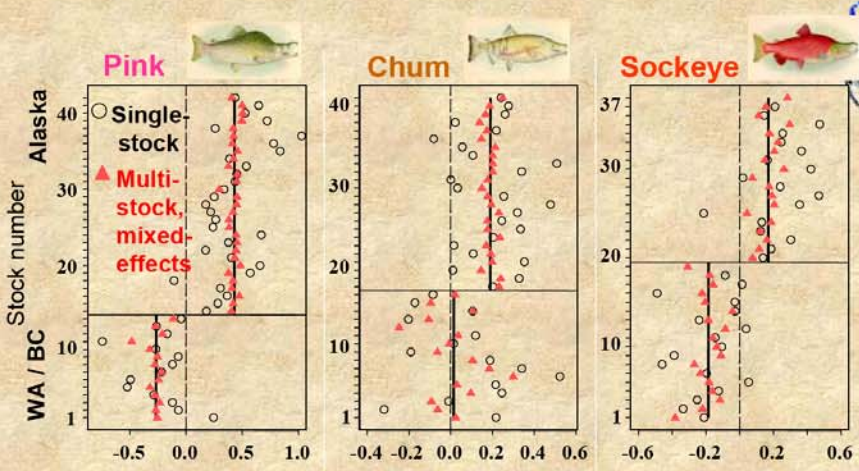
- Some plots here from Forecast document comparing R/EFS, Ricker residuals and Kalman a values converted to R/EFS
- Stocks that show declines starting in different time periods

91

Productivity metrics and interpretations here

- Influence of time period on Kalman a trends
- Influence of spawning escapements on Kalman a trend

92



Change in salmon productivity, $\log_e(R/S)$, per °C increase in summer sea-surface temperature (SST coefficient)

WA and BC Sockeye productivity (R/S) decreases with increasing sea surface temperature

Mueter et al. (2002a)

Mechanisms, part 2

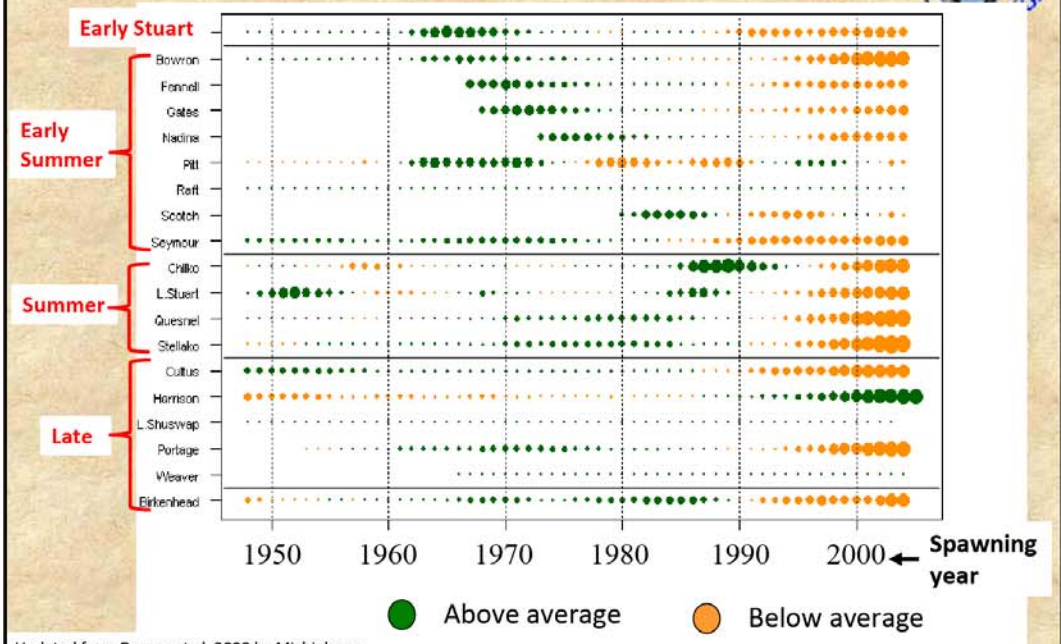
What is driving spatial covariation in productivity?

- Upwelling?
- Coastal sea-surface temperature (SST)?
- Coastal sea-surface salinity?

Asked same question:

Is there positive correlation across locations?

Stock specific trends in productivity



Updated from Dorner et al. 2008 by Michielsens

Return rates not equally anomalous

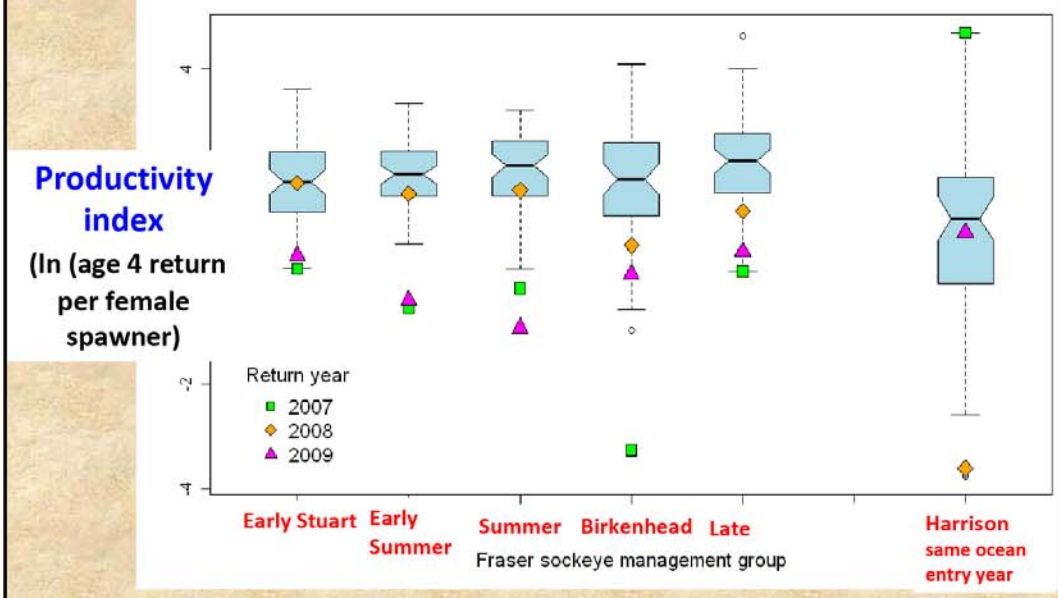
Summer Run 58 years of historical data

Brood year	Effective Females	Age 4 Recruits (thousands)	Age 4 recruits/ Effective female	Productivity ln(Age 4 recruits/ Effective female)	
1948	374	1829	4.9	1.6	
1949	132	2724	20.7	3.0	
1950	86	1126	13.1	2.6	
1951	110	1055	9.6	2.3	
1952	254	1862	7.3	2.0	
1953	241	2823	11.7	2.5	
1954	96	1918	19.9	3.0	
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	
2000	854	1979	2.3	0.8	
2001	2313	5197	2.2	0.8	
2002	1723	2069	1.2	0.2	
2003	547	455	0.8	-0.2	2007 return
2004	161	872	5.4	1.7	2008 return
2005	1033	408	0.4	-0.9	2009 return

Productivity Quantiles	
1 in 50 higher	3.2
1 in 4 higher	2.6
Median	2.2
1 in 4 lower	1.6
1 in 50 lower	0.2

96

Return rates not equally anomalous



Was the 2009 return a rare event?

- Probability of a 1.5M return given the pre-season forecast <<1%!
- Chilko marine survival implied by 2009 return is 3/1000, about ¼ of the previous 50 year minimum!!

98

Fisheries and Oceans Canada | Pêches et Océans Canada

Pacific Salmon Commission
Bilateral Scientific Workshop to Examine the Decline in Fraser River Sockeye

Overview of the Issue:
Review Historical Data on Other Salmon Populations

Timber Whitehouse and Arlene Tompkins

June 15, 2010

1

Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

Objectives

- Compare coast-wide performance of other stocks/ species relative to year of spawning, sea entry, and return relative to Fraser sockeye
- Examine apparent similarities or divergences in life history, survival, productivity, distribution in both marine and freshwater environments.

2

Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

Use Signals From Other Salmon Stocks

Salmon characterized by complex life history strategies

- Variable Freshwater Residence (1 -18 months)
  - Lake or stream type (sockeye)
  - Ocean or stream type (Chinook)
- Variable Ocean Residence
  - Pink & Coho, adults return after 1 year
  - Chinook, Chum, & Sockeye, adults return at multiple ages, 2-4 years later

3

Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

Stock & Species Comparisons

- Patterns of similarities / divergence as indicators
  - Species / stocks within Fraser watershed
  - Species / stocks coast wide
- Forecast Performance
- Comparisons (survival, return, productivity) relative to:
  - 2009 Return Year
  - 2007 Ocean Entry Year
  - 2005 Brood Year

4

Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

Cross Species Comparison

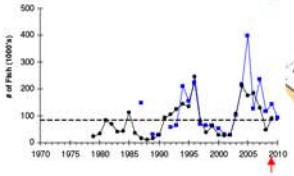
Species	Year		
	Brood (Spawn)	**Ocean Entry**	Return
FR Sockeye	**2005**	**2007**	**2009**
Sockeye	2005, 2006	**2007**	2009-10
Chinook	2005, 2006	**2007**	2008-11
Coho	2005	**2007**	2008
Chum	2006	**2007**	2010
Pink	2006	**2007**	2008

5

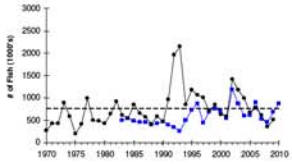
Canada

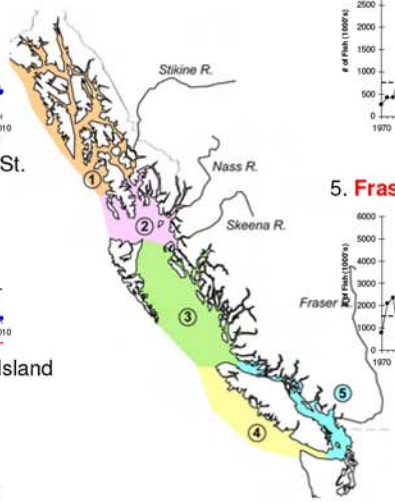
Coast Wide Sockeye Forecast Performance: Returns versus Predicted

1. **Alaska - Transboundary**

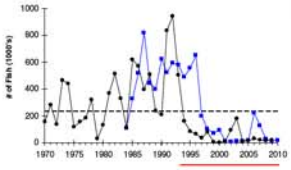


2. North Coast – Dixon Entrance

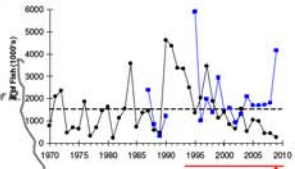




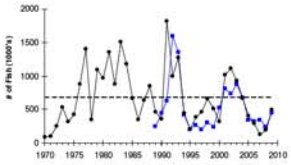
3. Central Coast – Hecate St.



5. **Fraser R. – Georgia Basin**



4. West Coast Vancouver Island

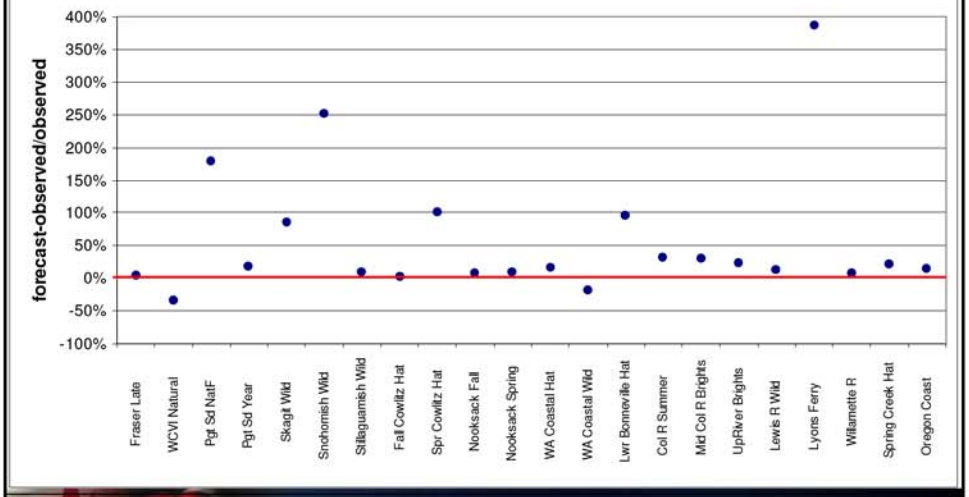


Observed Returns
Forecast Returns
All Year Average

6

Fisheries and Oceans Canada | Pêches et Océans Canada

2009 Chinook Forecast Compared to Observed Return

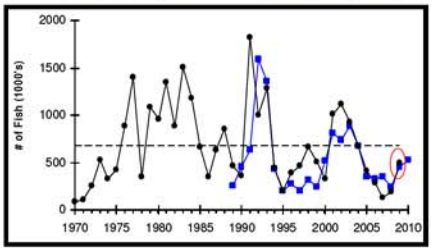


7

Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

Forecast Performance: Exceptions to Fraser SX



2009 **Barkley Sound** sockeye returned below average but as predicted.

2009 Return within **10%** of the prediction.

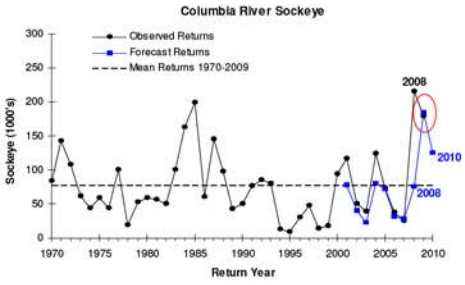
Survival Stanza Method (Hyatt et al., 1989).

2009 **Columbia River** sockeye returns above average (as predicted).

2009 Return within **3%** of the prediction.

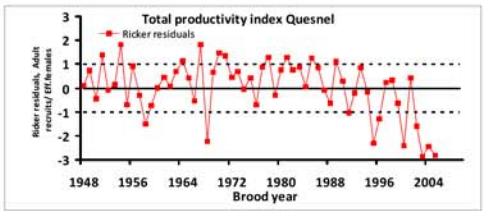
Other returns > forecast:

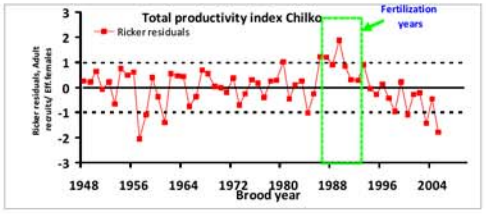
- Bristol Bay, Ak
- Smiths Inlet, BC
- Okanagan, BC

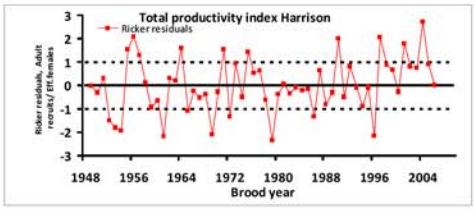


8

Canada







Comparison Productivity Within Fraser Sockeye Stocks

Summer run stocks
Comprised 82% total preseason forecast
Actual return 10% forecast

Late run stock
Comprised 9% total preseason forecast
Actual return 300% forecast

9

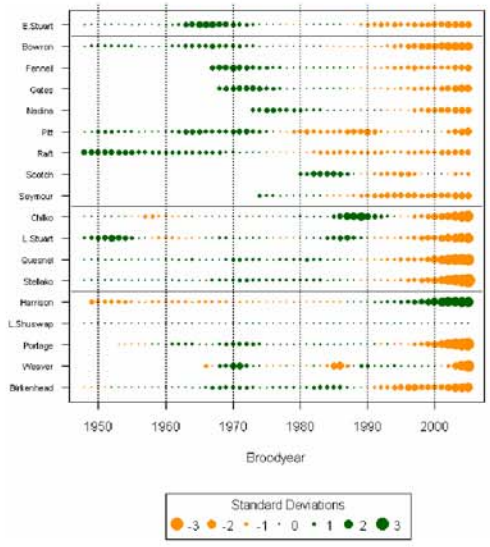
Comparison of Fraser Sockeye Productivity

Early Stuart

Early Summer

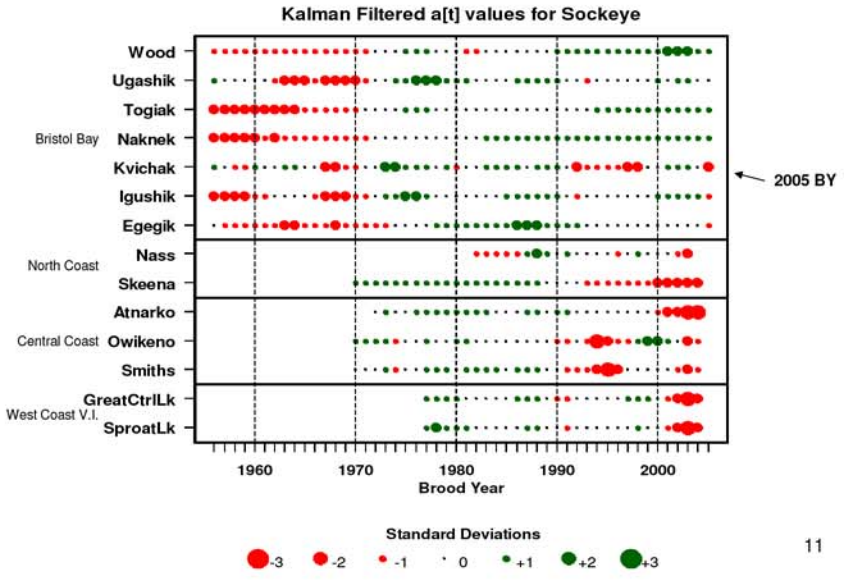
Summer

Late



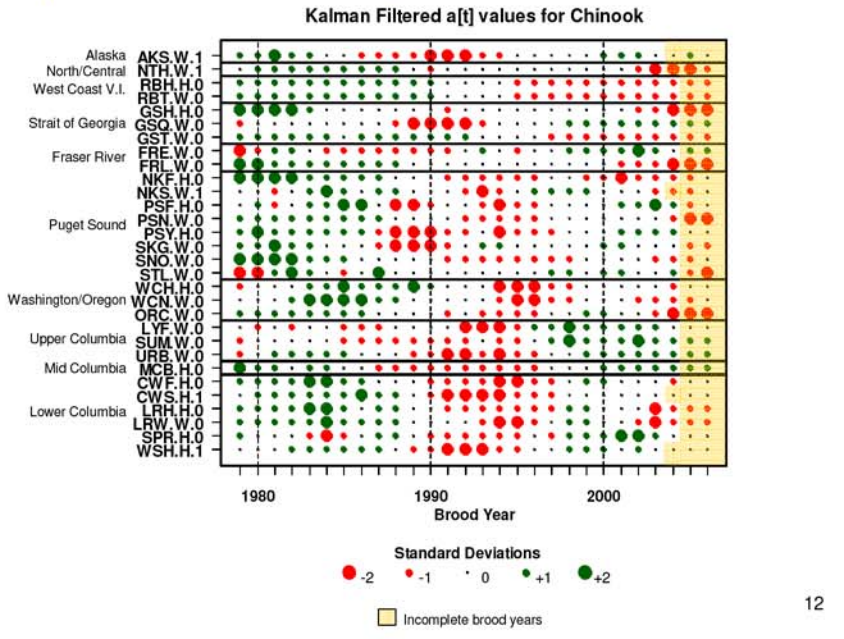
10

Comparison of Sockeye Productivity Outside Fraser



11

Comparison Productivity Across Chinook Stocks

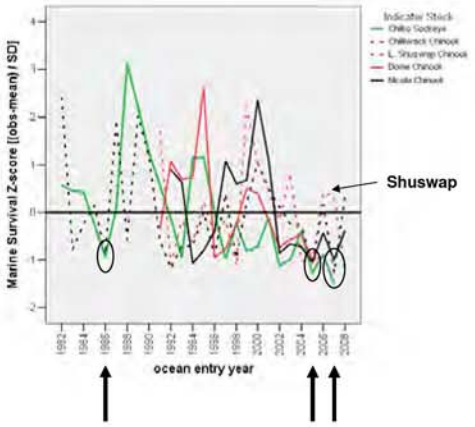


12

Fisheries and Oceans Canada | Pêches et Océans Canada

Comparison Marine Survival: Fraser Chinook

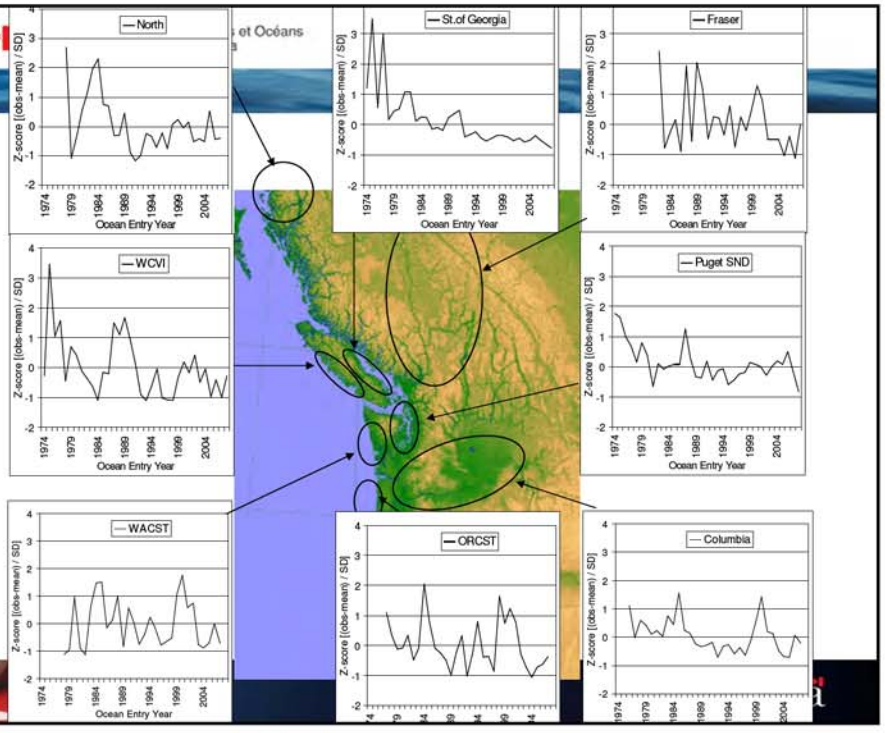
- Poor marine survival events coincided for Chilko Sockeye and Fraser Chinook in OEY 1986, 2005, & 2007
- As with Chilko Sockeye, Chilliwack Chinook survival was extremely low for OEY 2007
  - 92% below average & about 40% less than lowest measured over 27 years



13

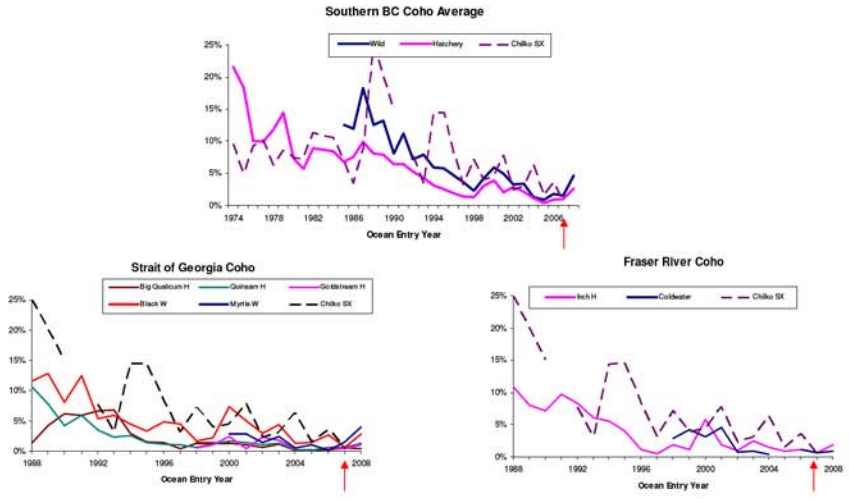
Canada

Chinook Marine Survival



Fisheries and Oceans Canada | Pêches et Océans Canada

Comparison Marine Survival :Southern BC Coho



15

Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

Observations Consistent with Fraser Sockeye:

Other salmon populations experienced poor performance related to 2009 return year or 2007 Ocean Entry Year:

- 2009 Sockeye returns to SEAK were lower than forecast
- 2009 Skeena Sockeye returns half of forecast
- 2009 Lake Washington Sockeye returns were lowest on record but predicted, declining trend since 2006
- 2009 return Fraser late ocean type Chinook were 92% below average
- 2007 OEY (2005 BY, 2009 RY) Fraser stream type Chinook performed poorly
- 2007 OEY (2005 BY, 2008 RY) GSTR Coho performed poorly (marine survival < 1%)
- 2007 OEY (2006 BY, 2008 RY) Pink performed poorly coast wide

16

Canada

Fisheries and Oceans Canada | Pêches et Océans Canada

Observations Inconsistent with Fraser Sockeye:

Response observed in Fraser Sockeye in 2009 was not a coast wide phenomenon similar to 2005 Ocean Entry Year:

- 2009 returns to other sockeye populations were as forecast or greater (Bristol Bay, Smith Inlet-Long Lake, Harrison, Barkley Sd, & Okanagan Lake)
- 2007 OEY survival & 2009 returns of Fraser summer run ocean type Chinook (Shuswap indicator) were good
- 2009 Fraser pink salmon & other pink stocks had large returns

17

Canada

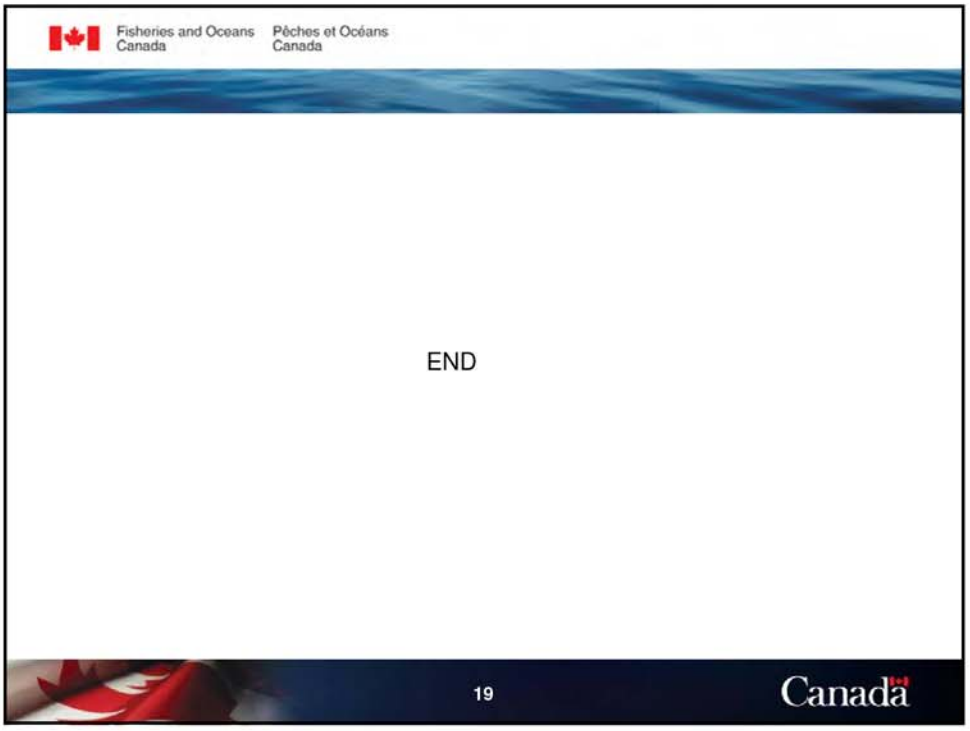
Fisheries and Oceans Canada | Pêches et Océans Canada

Summary

- Comparison among stock & species aggregates did not identify a uniform response based on geographic location of natal stream or utilization of Strait of Georgia
- However coincidental poor ocean survival among several, but not all, Fraser Sockeye, Fraser Chinook & southern BC Coho stocks for OEY 2007
- Time & location-specific factors need to be considered (e.g. time of estuary residence, time of ocean entry, & migration path)
- Likely multiple factors operating at various scales that account for varied responses in salmon populations
- Stock specific data (commonalities, signals) can be used to inform hypotheses & identify areas for further monitoring & investigation

18

Canada


Fisheries and Oceans Canada
Pêches et Océans Canada
END
19
Canada