

# Are over-escapement and delayed density dependent mortality important contributors to the Fraser sockeye situation?

DFO Science Branch Fraser Sockeye Workshop

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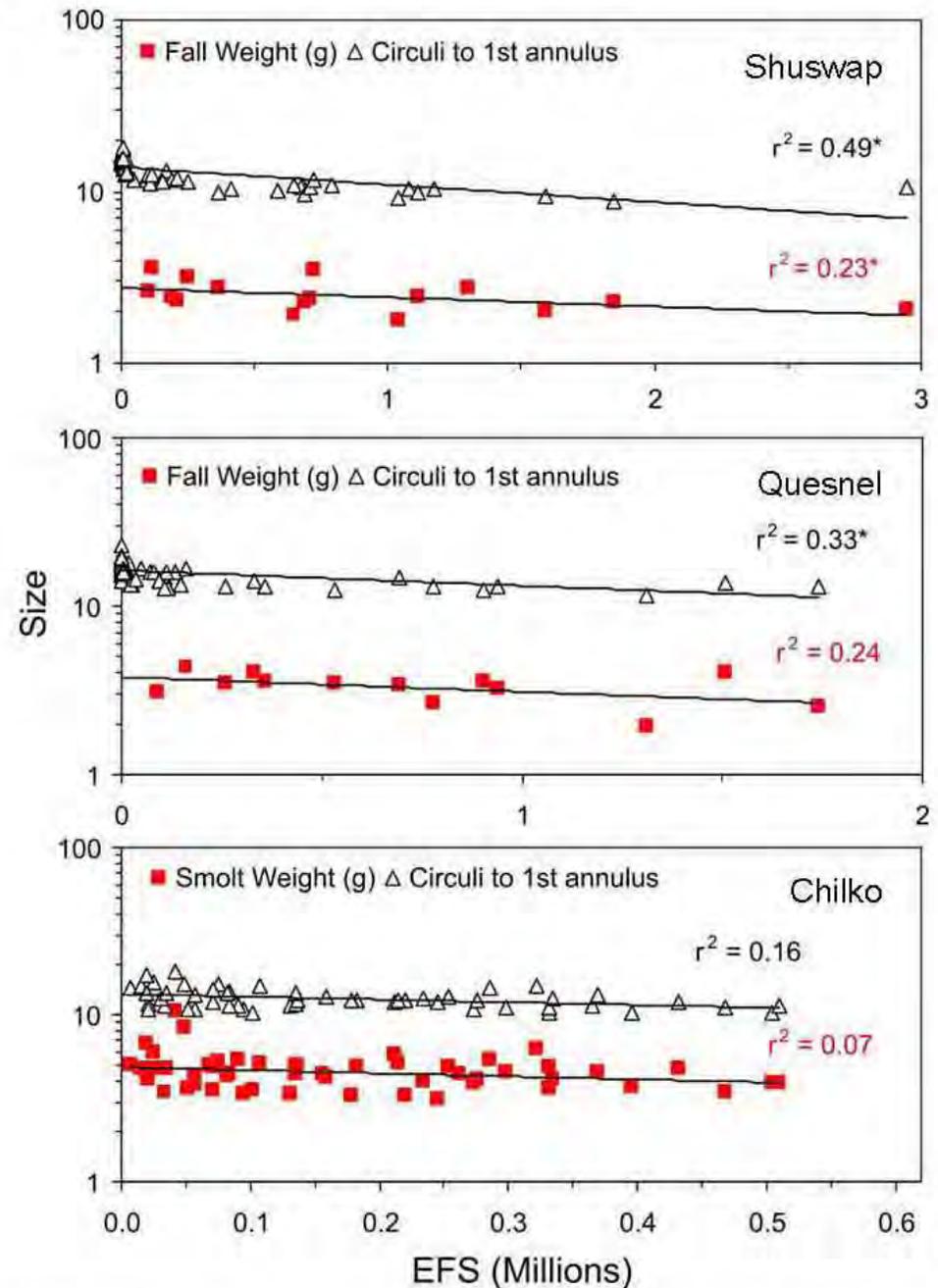
# Over-Escapement

- **Over-Escapements and Density-Dependence**
  - A large escapement in a given brood year causes the number of resulting adults to be extremely low due to competition for limited resources, disease etc. (Peterman & Dorner 2011)
  - Over-escapement is considered to have negative consequences for stock productivity at escapements greater than 200%  $S_{max}$  (Walters et al. 2004; Clark et al. 2007)
  - Explicit in Ricker S/R Model

# Trends in Juvenile Size

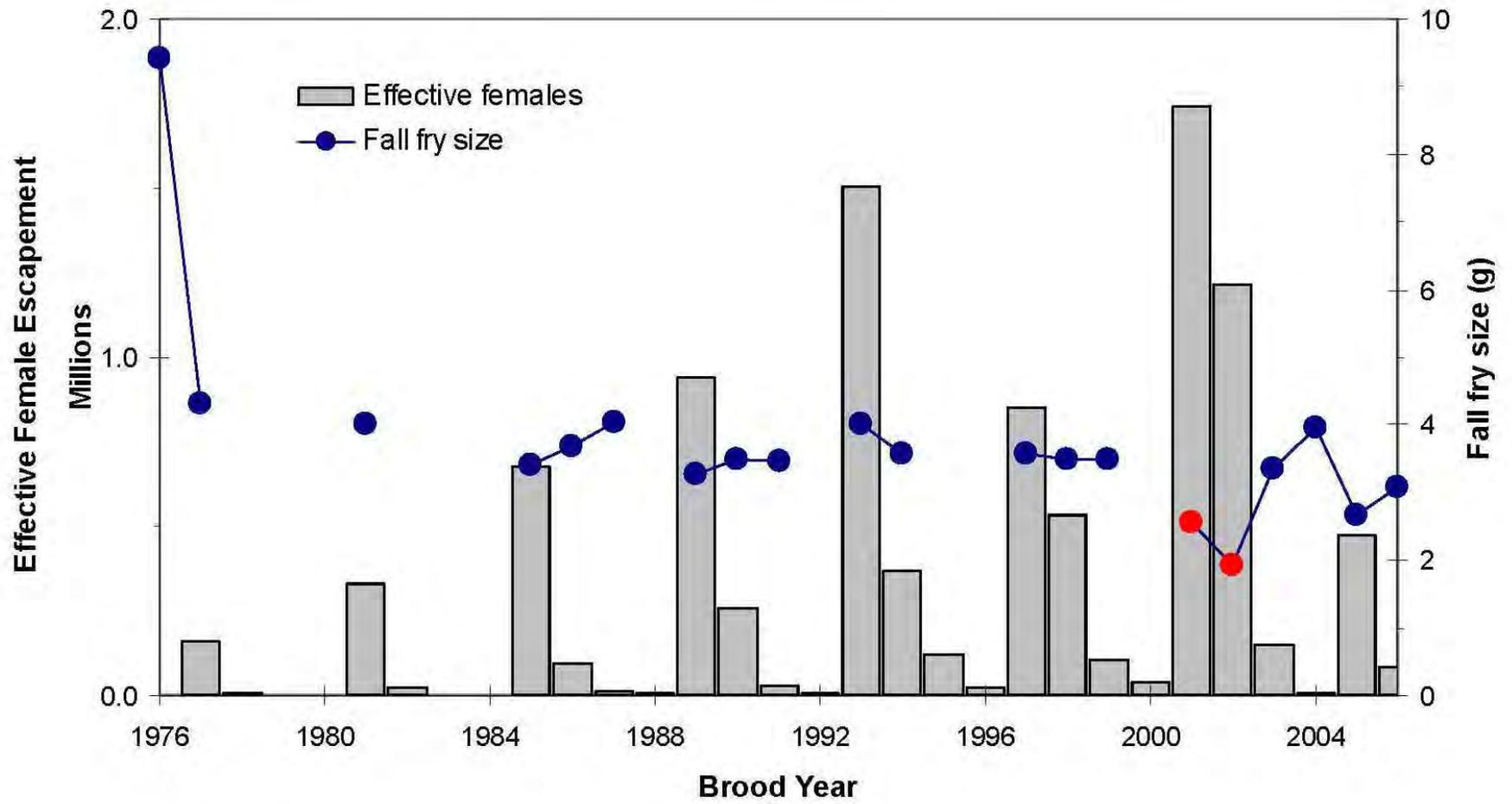
Shuswap, Quesnel & Chilko lakes

- Evidence of density-dependent growth in Shuswap (fry & circuli) and Quesnel (circuli)
- No evidence of density-dependent growth in Chilko to date



Modified from Selbie et al. 2010, PSC Workshop Report; Woodey, Lapointe & Hume. *in prep*

# Quesnel Lake



# Delayed Density Dependence (DDD)

- **Delayed Density-Dependence** (Brood Year Interactions)
  - Large escapements in a brood year negatively impact the brood year and at least the following three broods (Peterman & Dorner 2011)
  - Explicit in Larkin S/R Model
  - A proposed explanation for cyclic dominance in Fraser sockeye
- **Hypothetical Mechanisms for Cyclic Dominance**
  - Dominant Cycle Line (1)
    - Simple density-dependent mechanisms (dominant brood year)
  - Successive Cycle Lines (2-4)
    - Severe inter-annual depletion of nursery lake food webs
    - Disease on densely populated spawning grounds
    - Increased reproduction and survival of long-lived sockeye predators



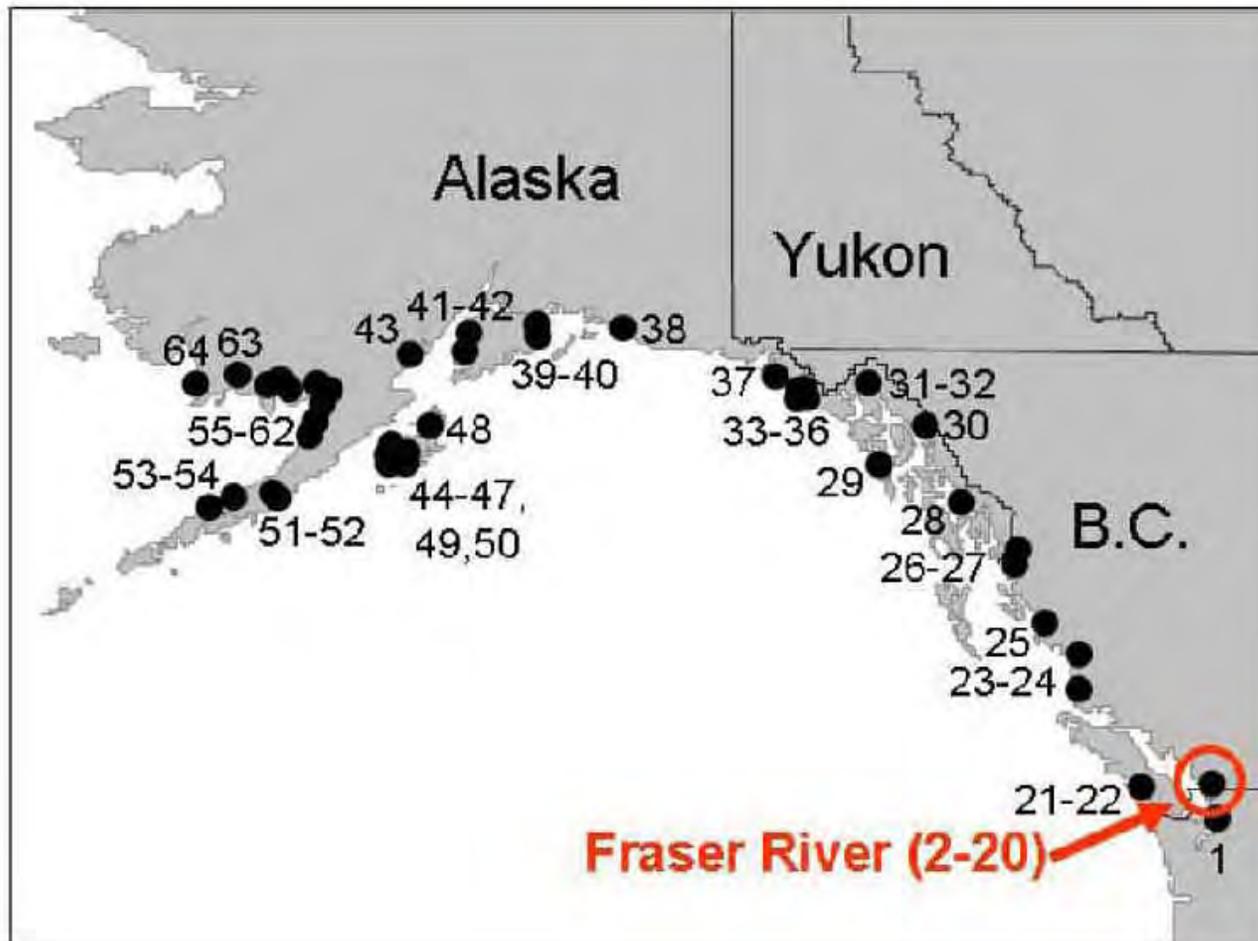
The Cohen Commission of Inquiry  
into the Decline of Sockeye Salmon  
in the Fraser River

February 2011

TECHNICAL REPORT 10

# Fraser River Sockeye Production Dynamics

Randall M. Peterman and Brigitte Dorner



# DDD: Fraser Stock-Recruit Evidence

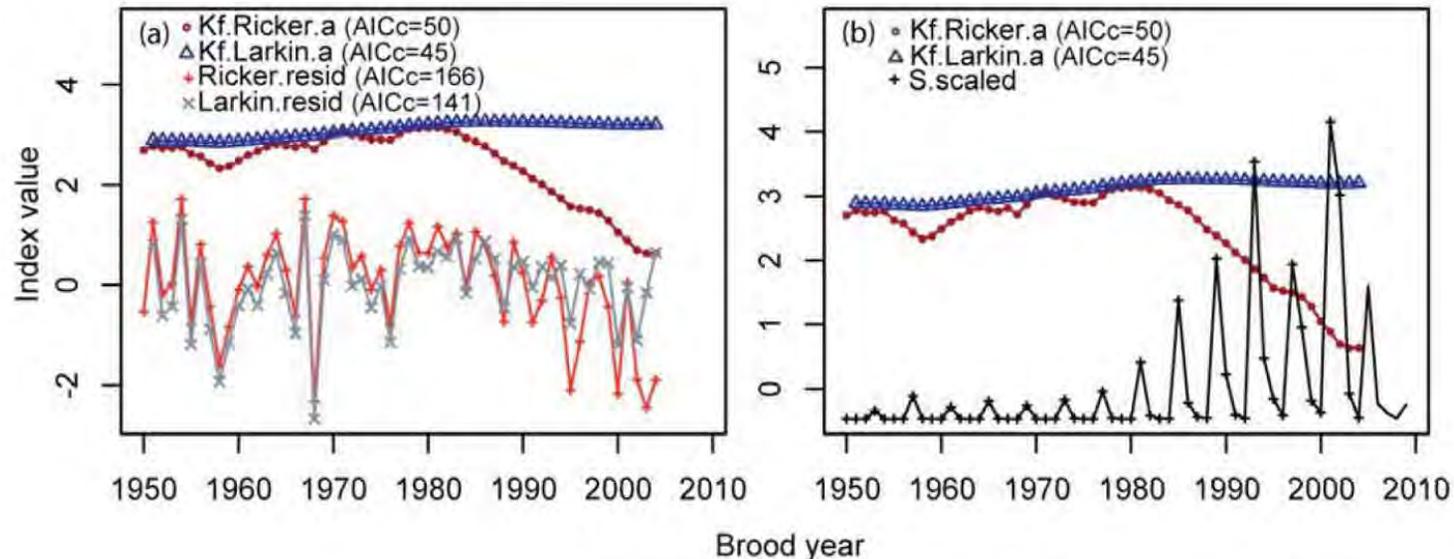
- **Annual R/S Abundance Data** (Peterman & Dorner 2011)
  - Across 19 Fraser stocks, few instances of productivity reductions below replacement, and none following large escapements
  - May be related to weaker density-dependence in S/R data for these Fraser populations (Peterman et al. 1998)
  - Conclusion - No evidence of catastrophic stock collapse from DDD (Walters et al. 2004; Peterman and Dorner 2011)
- **Periodic R/S Abundance Data** (Peterman & Dorner 2011)
  - Periods of depressed production in Quesnel, Chilko and Fennell stocks following periods of elevated escapement
  - Conclusion – R/S data indicates evidence of DDD in specific stocks

# DDD: Fraser Stock-Recruit Evidence

- **Stationary Model Comparisons** (Peterman & Dorner 2011)
  - Comparative fit of Ricker and Larkin models
  - Downward trend in Ricker residuals but not Larkin residuals = DDD
- **Stationary Model Residuals: Larkin vs. Ricker**
  - Larkin fit better than Ricker in 12 of 19 Fraser stocks
  - Both models generated a declining productivity index in all stocks except Scotch Creek, but Larkin declines less than Ricker
  - Conclusion – Stationary models indicate some evidence of DDD across stocks

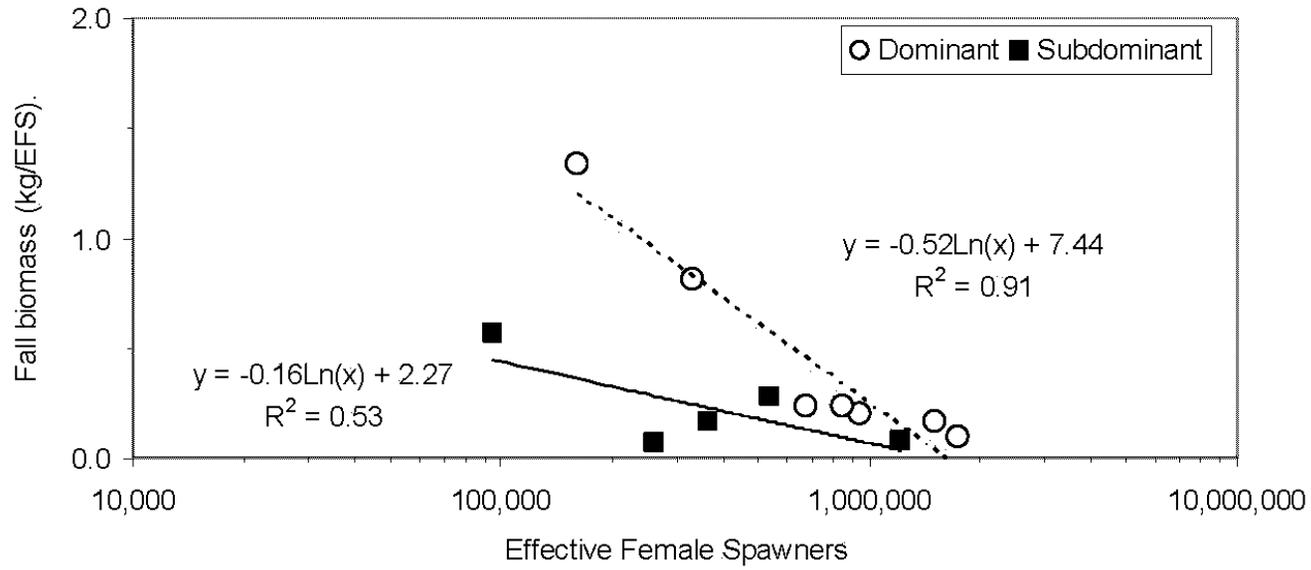
# DDD: Fraser Stock-Recruit Evidence

- **Kalman Filter: Non-Stationary Larkin vs. Ricker**  
(Peterman & Dorner 2011)
  - Overall productivity patterns similar to stationary models, but differences between Ricker and Larkin more pronounced
  - Larkin better fit in only 9 of 19 stocks
  - Scotch, Quesnel, Stellako – Larkin model best fit
  - Conclusion - DDD occurs in some stocks, but not all; Quesnel most pronounced evidence

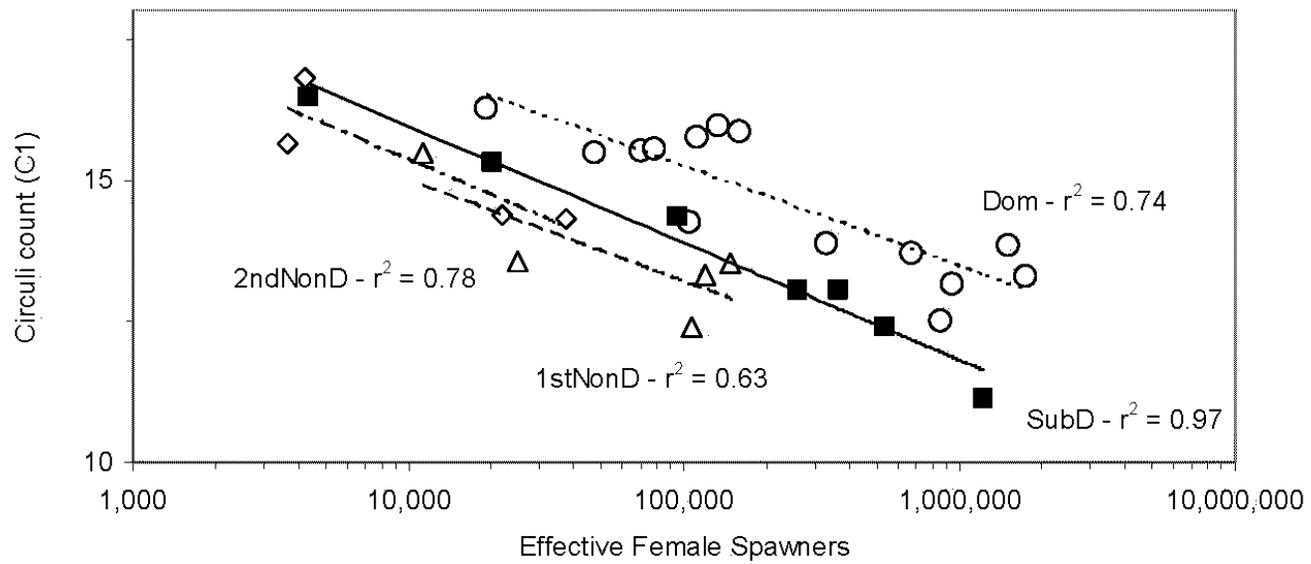


Modified from Peterman and Dorner 2011, Cohen Commission Report #10

Quesnel Lake



Horsefly River - Quesnel Lake



# DDD: Fraser Stock-Recruit Evidence

- Stationary and Non-Stationary Ricker & Larkin  $b$  parameters (Peterman & Dorner 2011)
  - Main  $b$  parameters indicate DD and/or DDD
  - Where DDD is evident (Larkin), no tapering off of DDD effects
  - Conclusion – Where DDD exists, it persists across the entire 4 year cycle (in agreement with Woodey, Lapointe and Hume); Causal mechanisms of DDD most likely stock-specific

# Overall Fraser S/R Conclusions

- **Over-Escapement, DD & DDD in Fraser Stocks**
  - Many Fraser stocks are sensitive to simple density-dependence
  - Evidence exists of DDD in several stocks, and it is likely an important regulatory mechanism in specific stocks (i.e. Quesnel), in relation to increased spawner abundances
- **DDD & Fraser Declines**
  - DD and DDD likely contribute to reduced productivity in a number of stocks, but are unlikely the cause of the widespread declines observed within and beyond the Fraser River

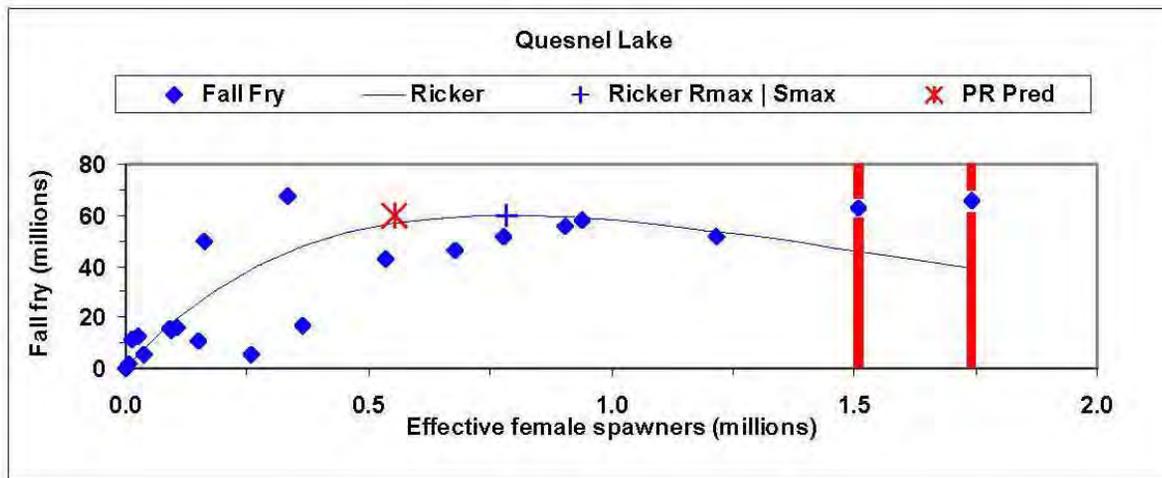


**The Future?**

# Record Escapements

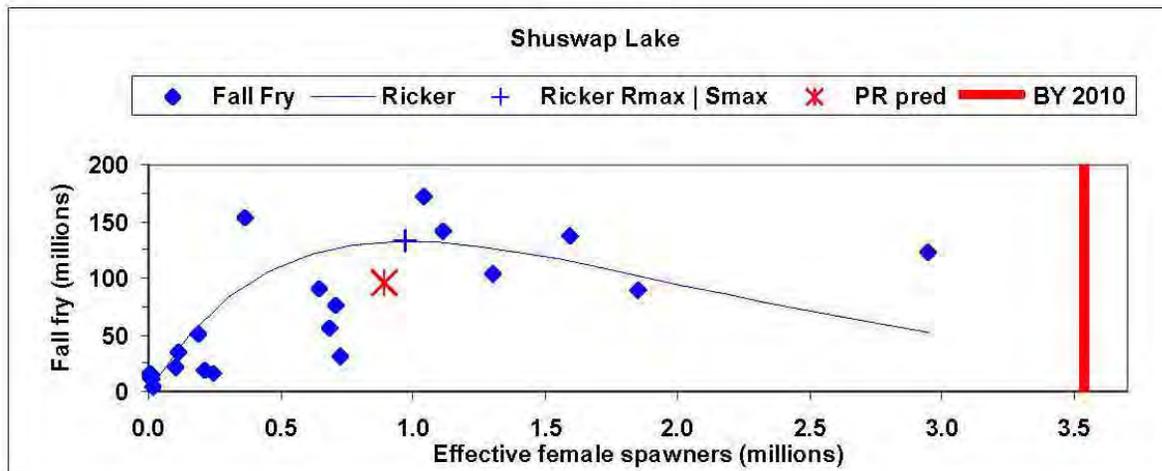
## Quesnel (2001-02)

$S/R_{\text{adult}}$ : 187-223%  $S_{\text{max}}$   
 $S/R_{\text{juvenile}}$ : 155-222%  $S_{\text{max}}$   
 PR model: 280-334%  $S_{\text{max}}$



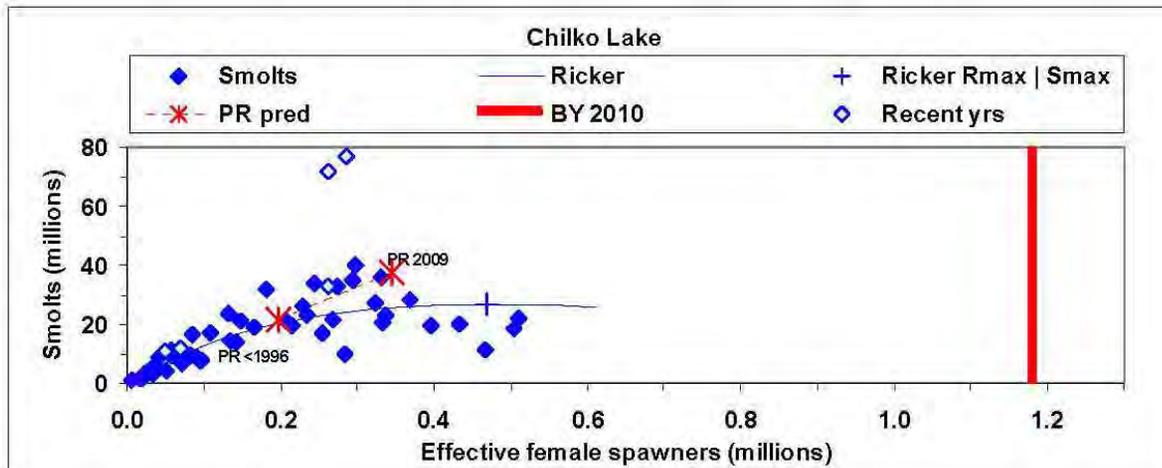
## Shuswap (2010)

$S/R_{\text{adult}}$ : 215%  $S_{\text{max}}$   
 $S/R_{\text{juvenile}}$ : 366%  $S_{\text{max}}$   
 PR model: 481%  $S_{\text{max}}$



## Chilko (2010)

$S/R_{\text{adult}}$ : 547%  $S_{\text{max}}$   
 $S/R_{\text{juvenile}}$ : 252%  $S_{\text{max}}$   
 PR model: 357%  $S_{\text{max}}$



# Lessons from Alaska

- **Over-Escapement & Productivity** (Clark et al. 2007)
  - Declines in long-term productivity and increased spawner abundance variability when escapement goals were exceeded
  - Believed to be linked to surpassing nursery ecosystem productive capacity
- **Delayed Density Dependence** (Clark et al. 2007)
  - Detected DDD in 5 stocks where over-escapement occurred
  - R/S fell below replacement for 2-5 yr following consecutive over-escapements

# Lessons from Alaska

- Fraser Analogues?
  - Quesnel is the only Fraser stock to receive consecutively high over-escapements (2001-2002); hypothesized explanation of persistent depressed Quesnel productivity
- 2010-2011 In The Fraser: Shuswap and Chilko
  - Potentially severe DD in 2010
  - Depending upon 2011 escapement, possible repeat of the Quesnel/Alaskan examples
  - Little known of lake and stock responses at high escapements
  - Quesnel Lake long-term research the only documented food web response to high escapements

# Active Freshwater Research

- **Cycle-Line Interactions & Cyclic Dominance**  
(Pacific Salmon Commission and DFO Lakes Research Program)
  - Woodey, Lapointe & Hume, *in prep* – Quesnel and Shuswap
  - Evidence for delayed density dependence, and resource availability/predator interactions
- **Effects of Large Escapements on Lake Ecosystems and Stock Productivity**
  - Shuswap (2010), Chilko (2010) and Quesnel (2001-02)
- **Food Webs, DD/DDD & Juvenile Condition**  
(DFO Lakes Research & Environmental Watch programs)
  - Study of littoral and pelagic food web utilization & fish abundance/condition throughout full cycle with over-escapement in Shuswap Lake
  - Understand possible resource-limitation mechanisms for DD/DDD



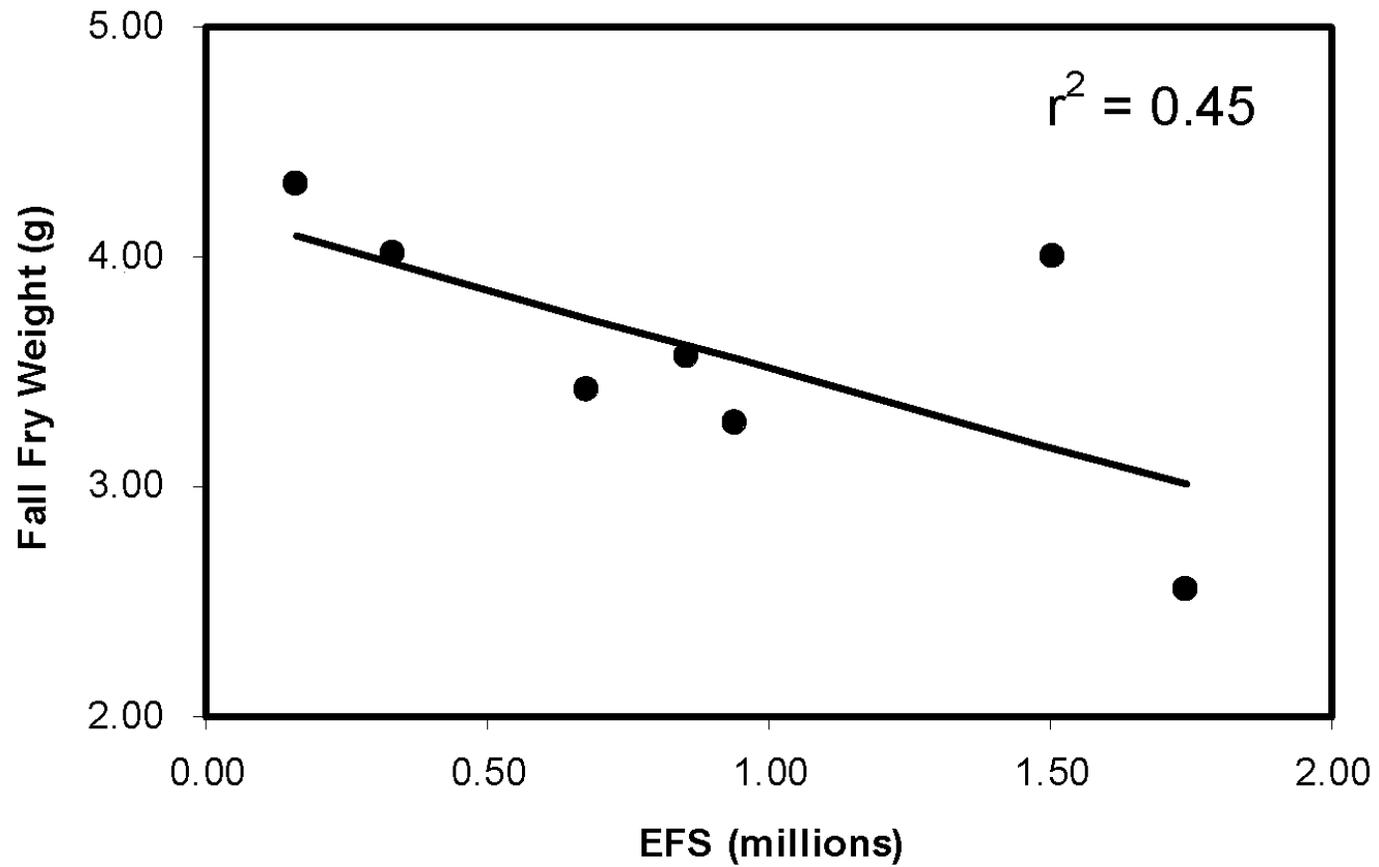
**Adams River at Shuswap Lake, 2010**  
**(early in run)** Photo courtesy of Richard Bailey, DFO

# Adams River (early in run), 2010

Photo courtesy of Richard Bailey, DFO



**Quesnel Dominant Cycle Line  
Fall Fry Size vs. Parental Esc. (1977-2001)**



**Quesnel Dominant Cycle Line  
Fall Fry Size vs. Parental Esc. (1977-2001)**

