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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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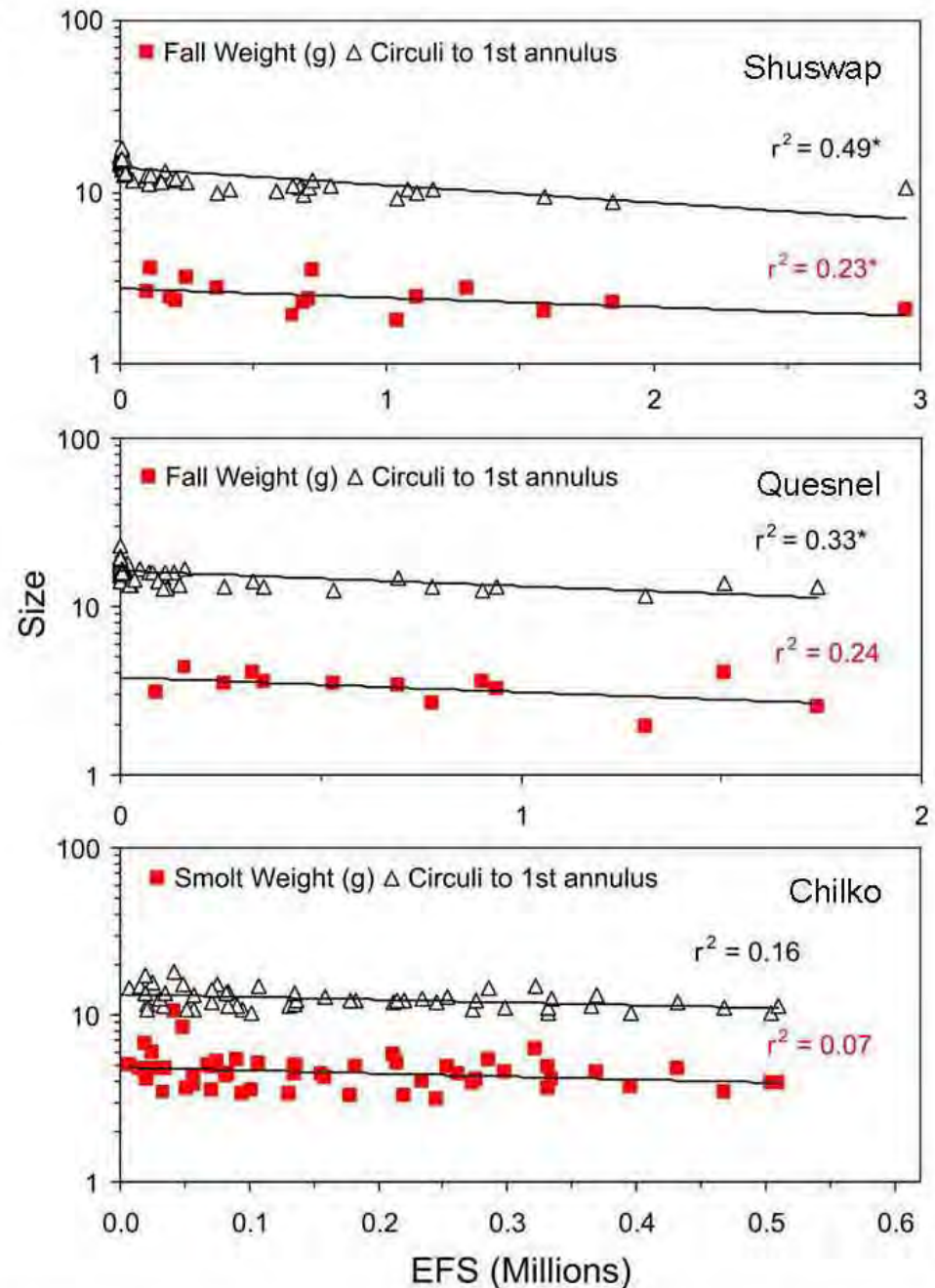
Over-Escapement

- 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

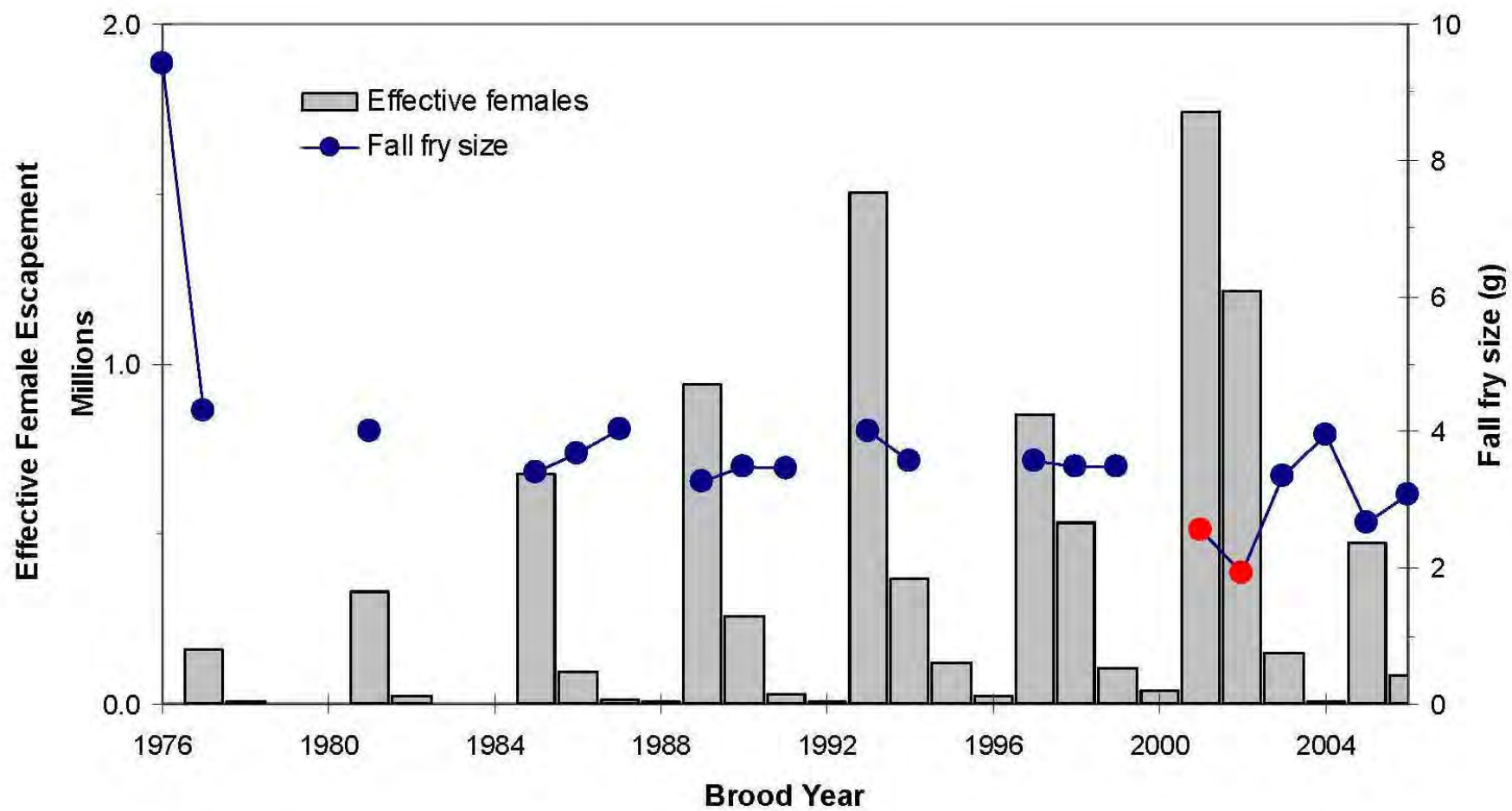
Shuswap, Quesnel & Chilko lakes

- 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



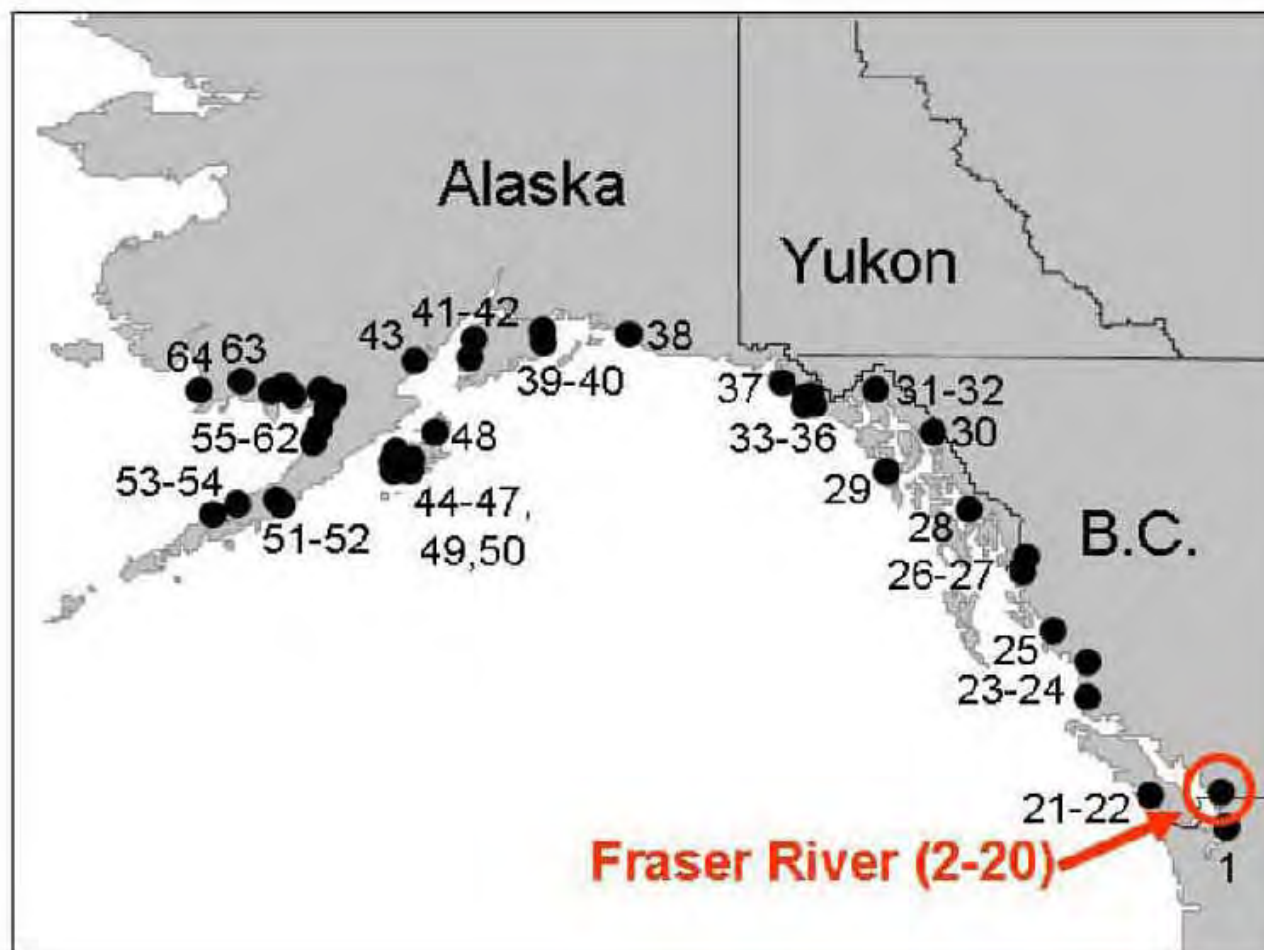
The Cohen Commission of Inquiry
into the Decline of Sockeye Salmon
in the Fraser River

February 2011

TECHNICAL REPORT 10

Fraser River Sockeye Production Dynamics

Randall M. Peterman and Brigitte Dorner



DDD: Fraser Stock-Recruit Evidence

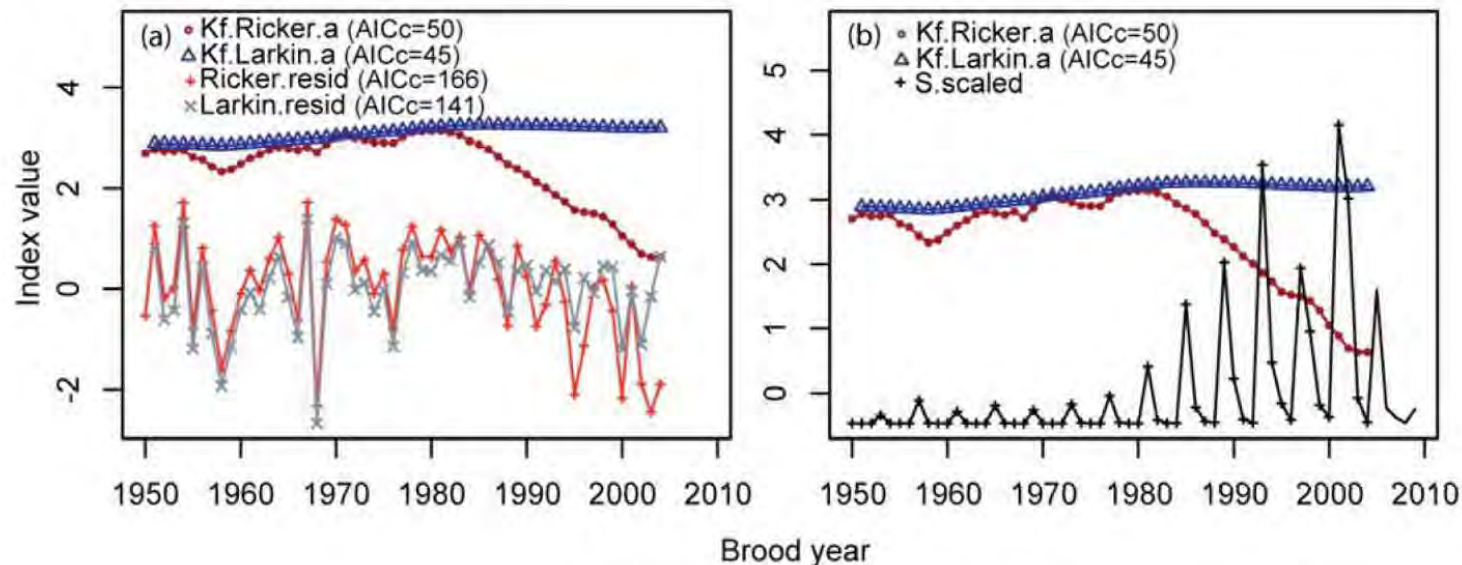
- **Annual R/S Abundance Data** (Peterman & Dorner 2011)
 - Across 19 Fraser stocks, few instances of productivity reductions below replacement, and none following large escapements
 - May be related to weaker density-dependence in S/R data for these Fraser populations (Peterman et al. 1998)
 - Conclusion - 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

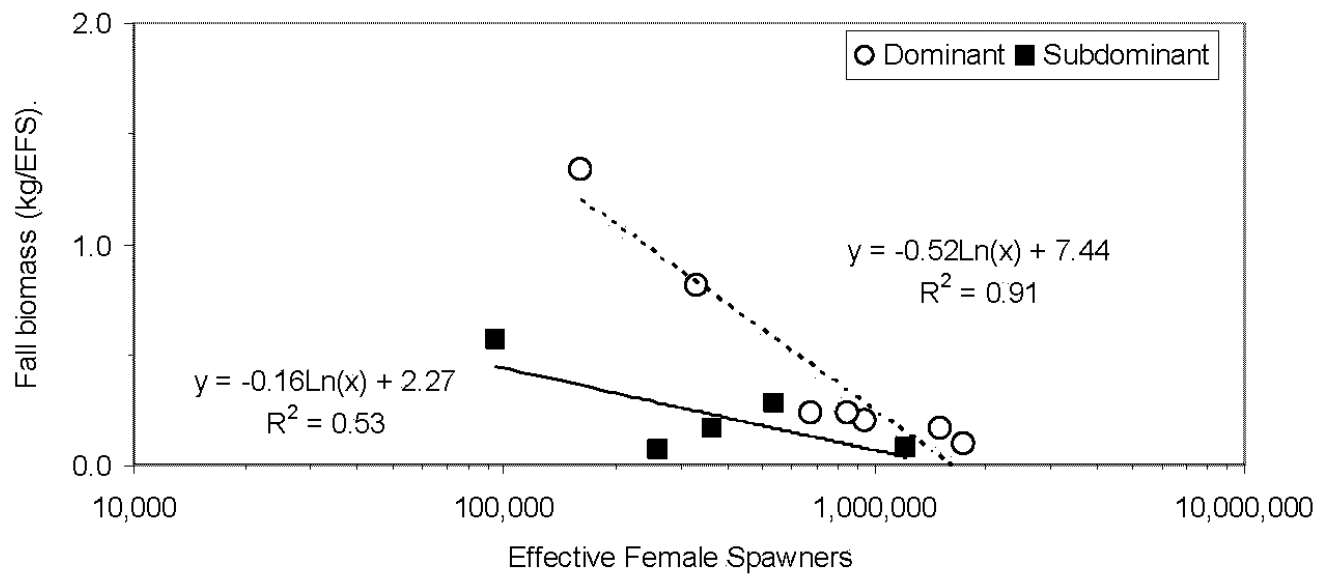
DDD: Fraser Stock-Recruit Evidence

- 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

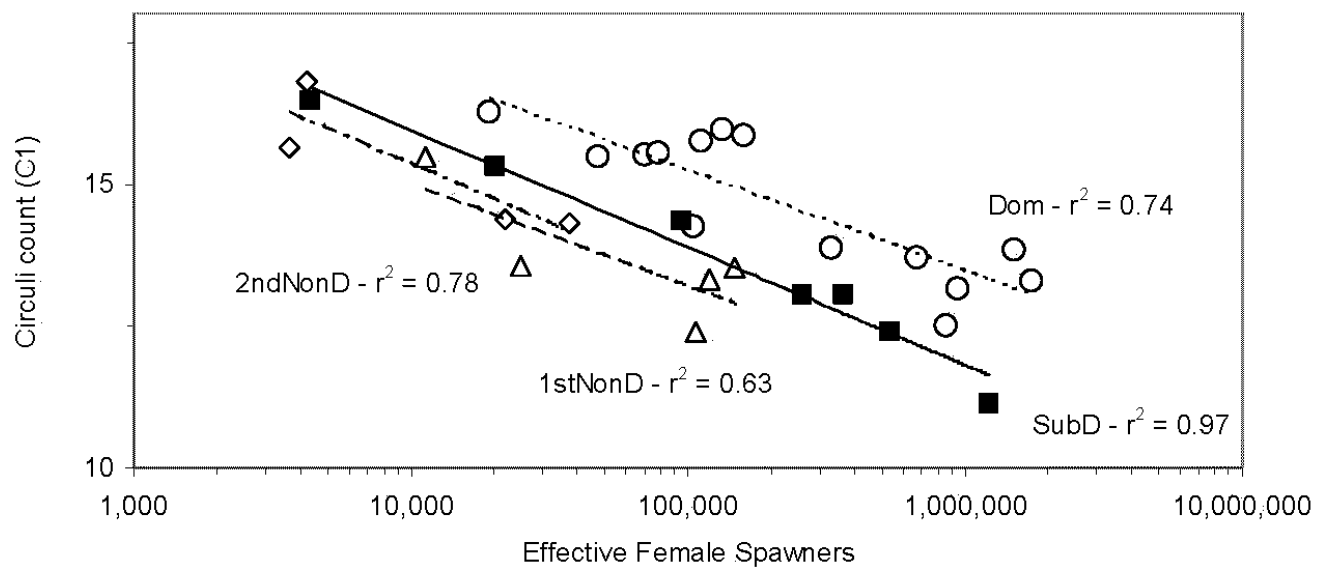


Modified from Peterman and Dorner 2011, Cohen Commission Report #10

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

A pair of hands, rendered in a realistic style, are shown holding a glowing, translucent blue sphere. The sphere has a bright white center and a blue outer layer with a subtle, swirling pattern. The text "The Future?" is written in a bold, black, sans-serif font across the middle of the sphere. The background is dark and filled with intricate, swirling, ethereal patterns in shades of blue and white, suggesting a cosmic or futuristic theme.

The Future?

Record Escapements

Quesnel (2001-02)

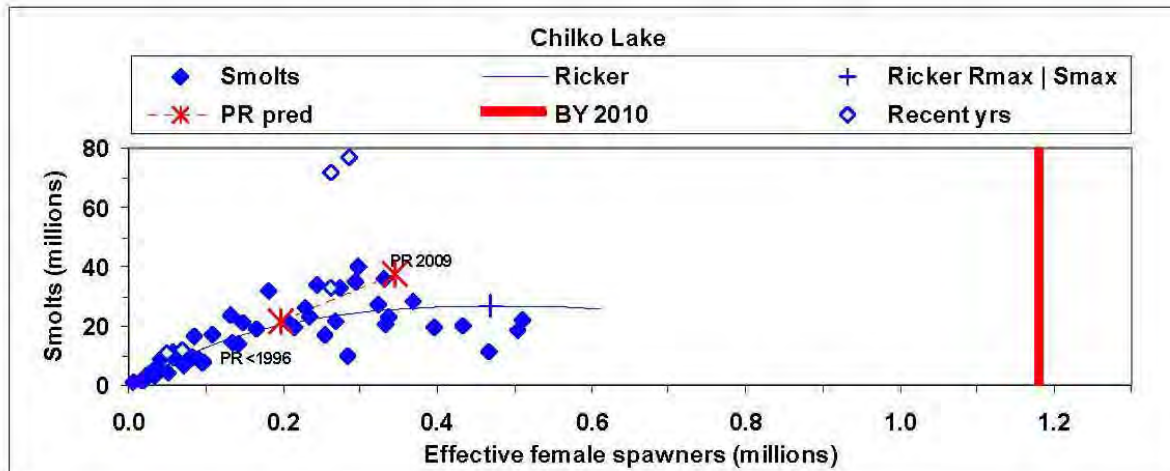
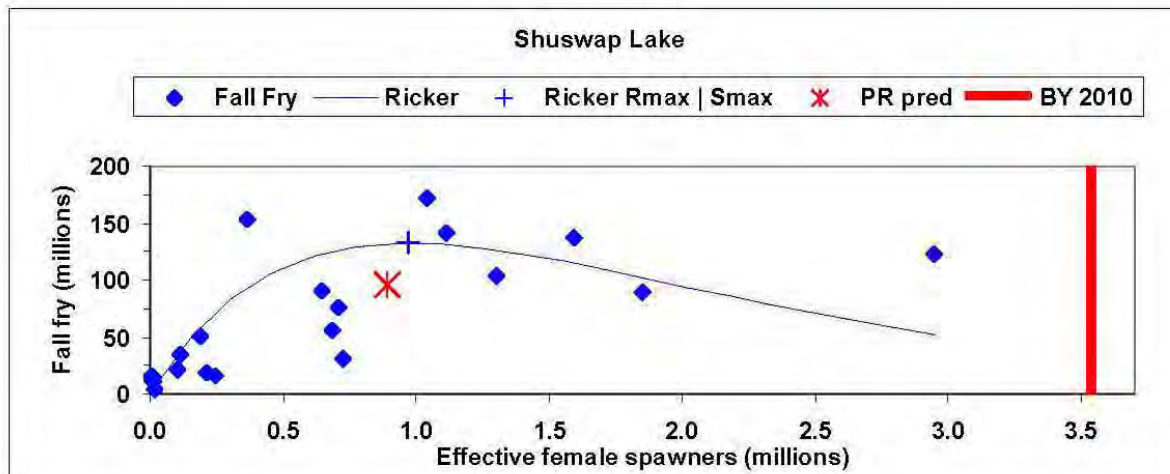
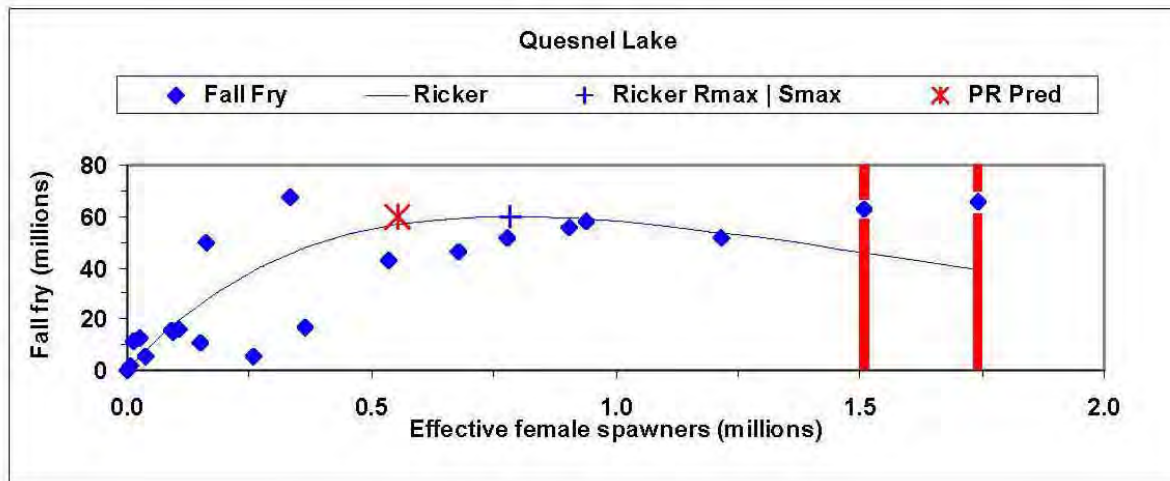
S/R_{adult} : 187-223% S_{max}
 S/R_{juvenile} : 155-222% S_{max}
 PR model: 280-334% S_{max}

Shuswap (2010)

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

Chilko (2010)

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



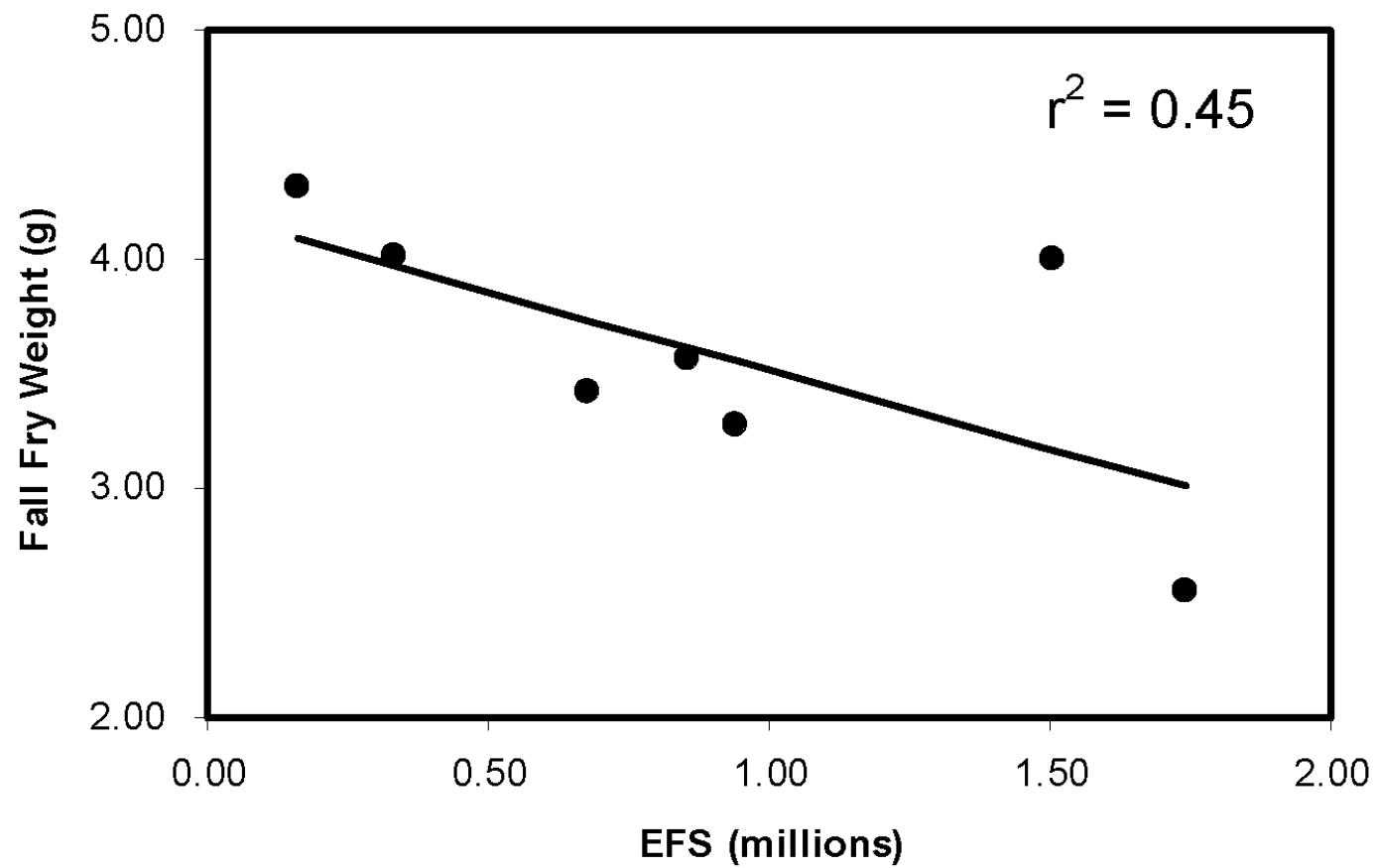
Adams River at Shuswap Lake, 2010
(early in run) Photo courtesy of Richard Bailey, DFO

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)

