Identifying life history variation to inform recovery planning for Upper Willamette River Chinook Salmon

Christopher C. Caudill[1*], Samuel L. Bourret[1], Matthew L. Keefer[1], Benjamin J. Clemens[2], Brian P. Kennedy[1], Greg A. Taylor[3], and Cameron S. Sharpe[2]

[1]Department of Fish and Wildlife Sciences
University of Idaho, Moscow, ID, 83844-1136
*caudill@uidaho.edu (208-885-7614)
[2]Oregon Department of Fish & Wildlife, Corvallis Research Lab
[3]U.S. Army Corps of Engineers, Portland Distrct

Acknowledgments

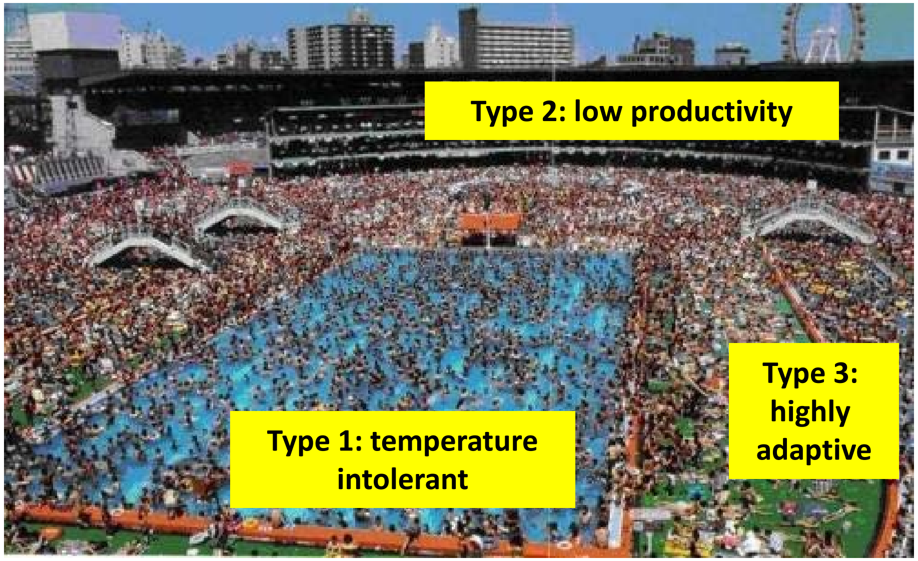
- NOAA – Kim Hatfield, Stephanie Burchfield
- ODFW – Lisa Borgerson, Kanani Bowden, Tom Friesen, Wayne Vandernaald, Todd Alsbury, Jeff Ziller, Kelly Reis, Joy Vaughan, Shivonne Nesbit, Kirk Schroeder, Craig Tinus, Michele Weaver
- UI – Travis Dick, Theresa Tillson, Dan Joosten, Charlie Erdman
- WSU – Jeff Vervoort, Charles Knaack
- PGE – Tim Shibahara
- USACE – David Griffith, Rich Piaskowski, and Robert Wertheimer

Presentation Objectives

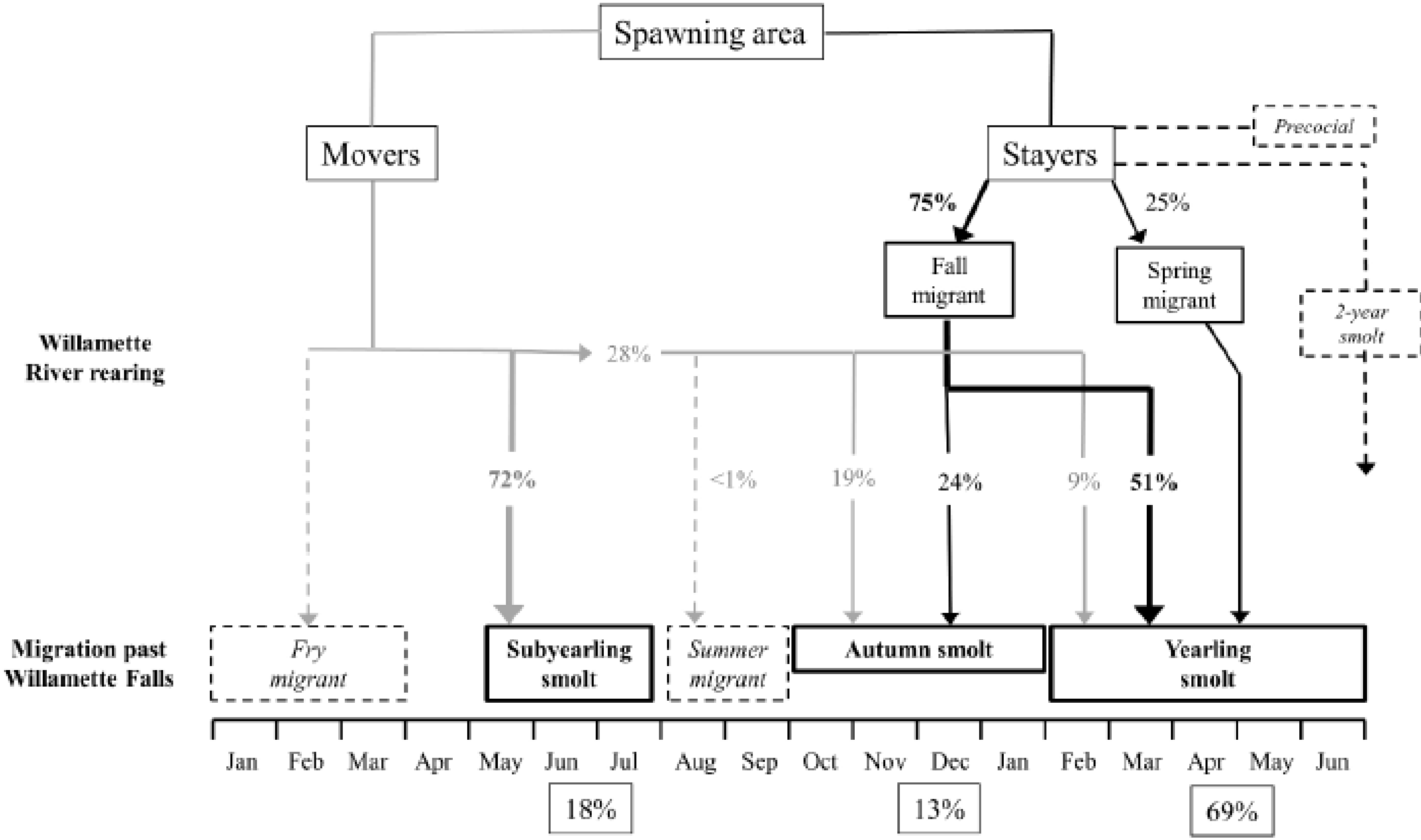
- Review broad patterns of life history variation in Chinook Salmon
  - Framework for aligning emerging concepts, historic classifications of salmon life histories, and terminology
  - Potential underlying mechanisms
  - LH variation across range of species
  - Review article in revision: Bourret et al. Diversity of juvenile Chinook salmon life history pathways *Reviews in Fish Biology and Fisheries*
- UWR Chinook Salmon, primarily outplant populations
  - On-going methods development and validation
- Relationships between juvenile life history and adult returns
  - Estimating relative performance of juvenile life history pathways

Broader goals

- Estimate relative contribution of juvenile Chinook life histories to adult returns
  - Some will inevitably be more/less 'successful'
  - Fitness & Population growth implications
- Preserve 'natural' LH variation/manage for expression
  - Buffer populations (Portfolio effect)
  - Adaptation potential
- Understanding = effective management of Willamette Chinook

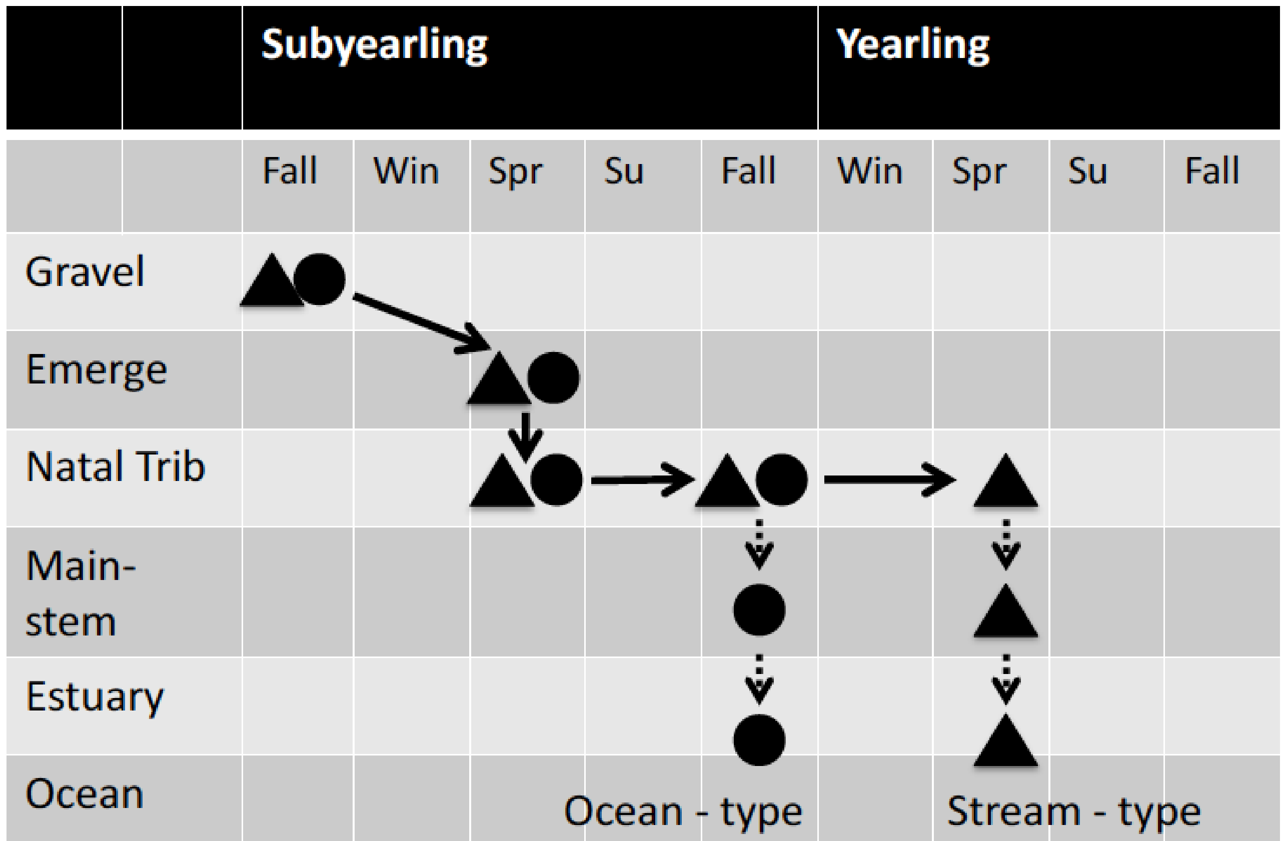


Singing to the choir…



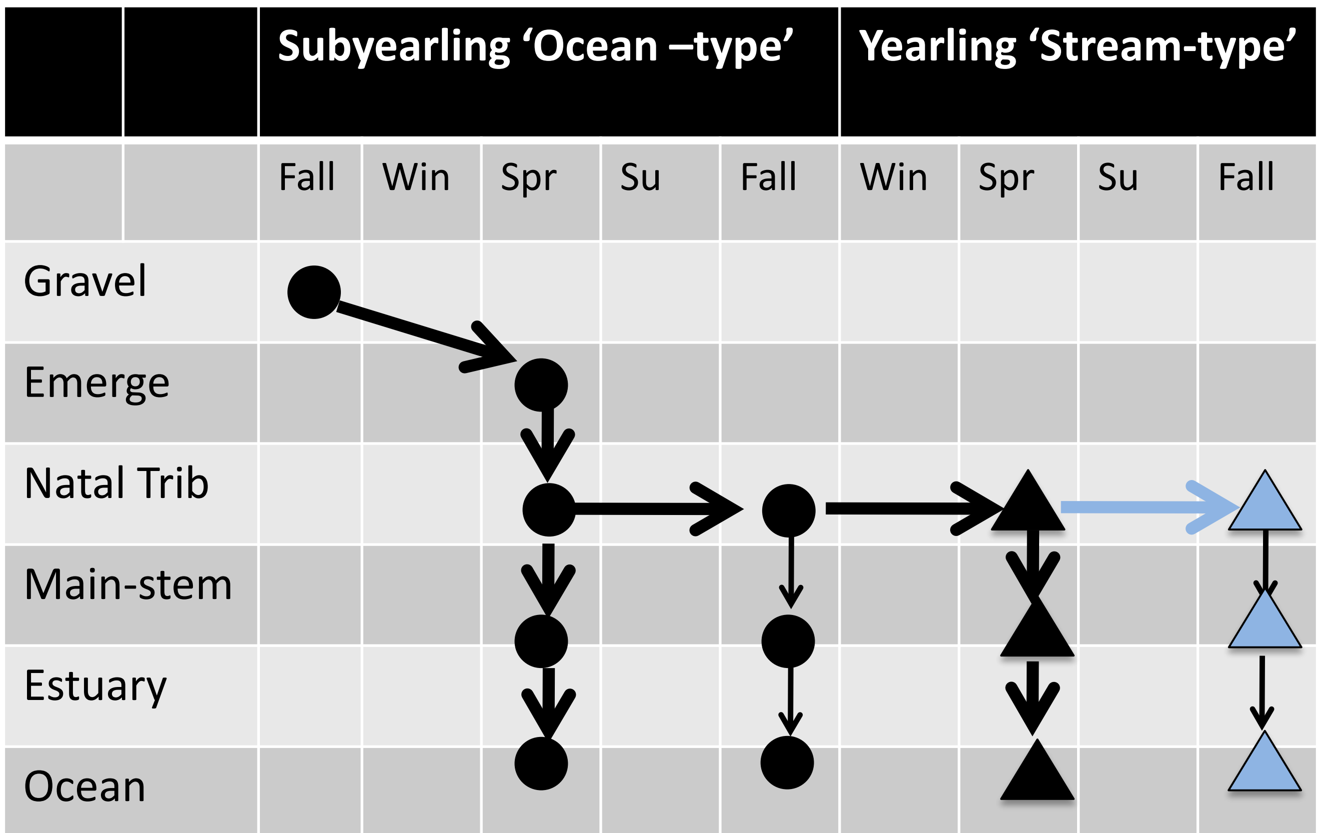
Schroeder et al (2015)

A historical (false) dichotomy…

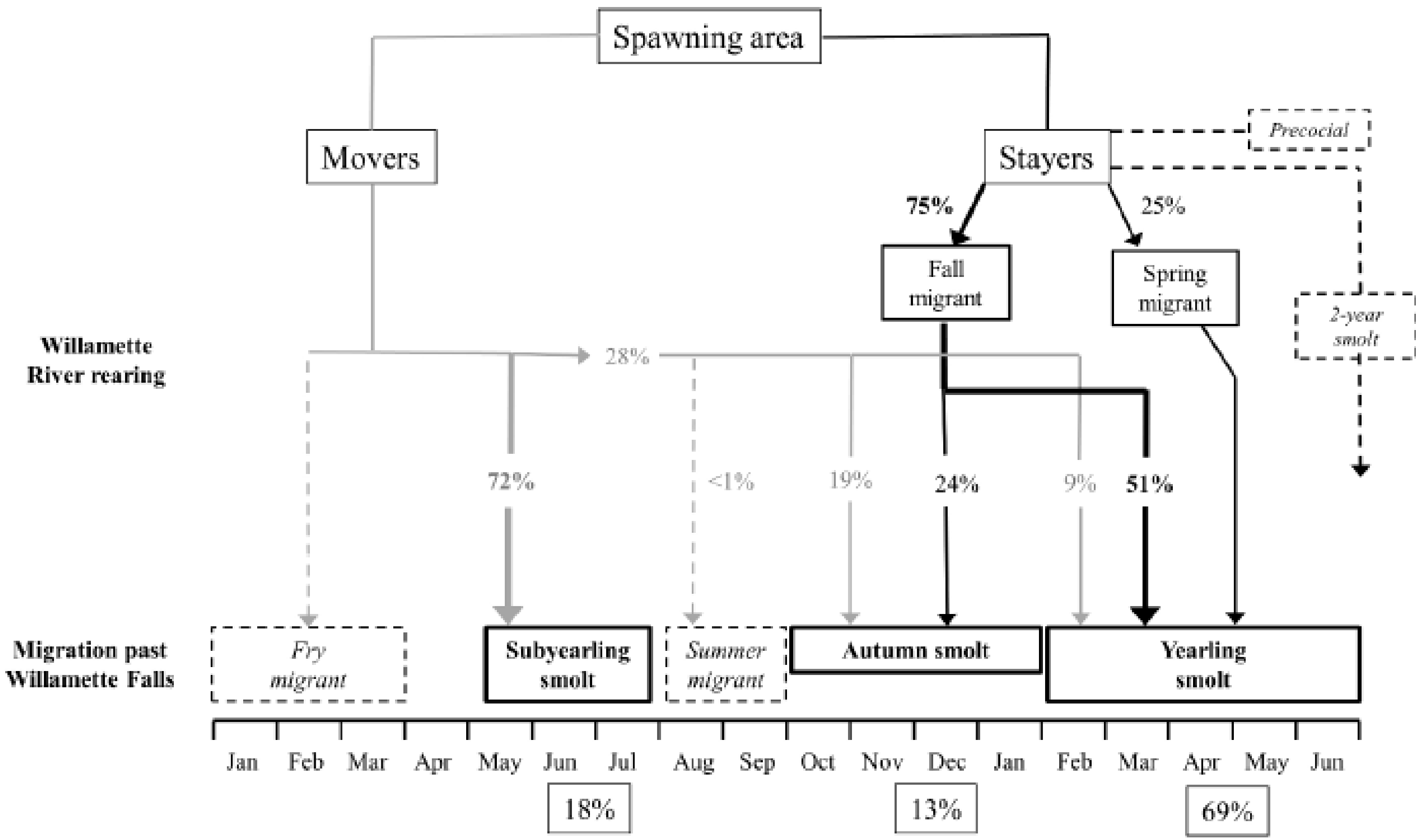


Chinook life history review

- The ‘historical’ concept (Mattson 1962)
  - “Early life history of WIL R spring Chinook salmon”



Schroeder et al. (2015): McKenzie and Santiam



Classifications

- Explicitly or implicitly recognize variation in timing of movement and the duration and diversity of rearing habitats used by individuals
- Need for explicit consideration of individual effects vs. population-scale phenomena and a framework that accommodates both

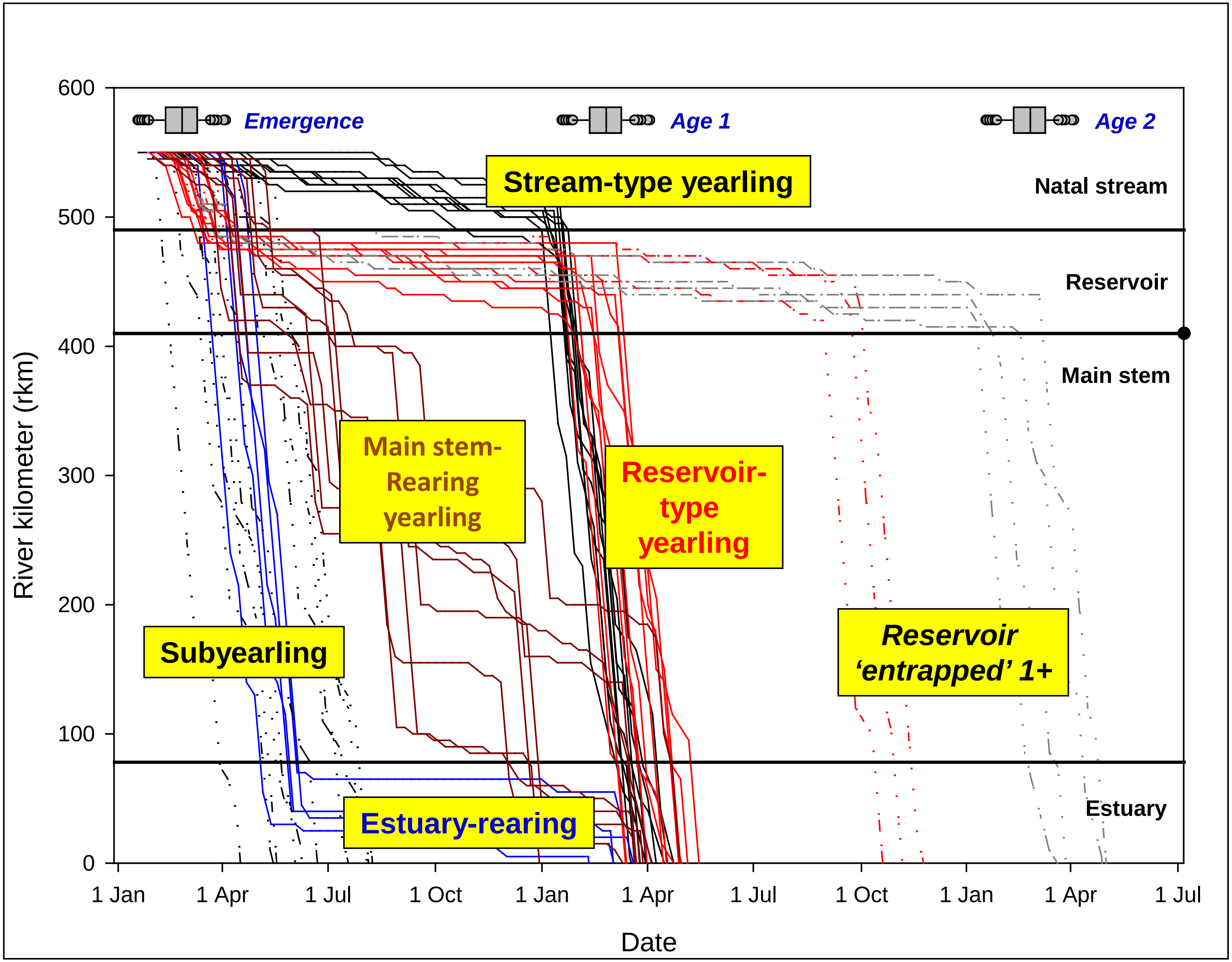
- **Life history pathway**: *individual* phenotypes with alternative life histories within populations

- Juvenile Chinook Salmon life history diversity defined by sequence and duration of stages
- Key transitions include developmental and ecological shifts

- Variation in transitions create a potential **continuum** of life history phenotypes within populations

- **Life history types** emerge at the *population scale* when there are discontinuities imposed by current environmental constraints, past selection, etc.
- Recommend a **multi-trait and hierarchical** approach

Chinook life history 'pathways'



Bourret et al.
(*in prep*)

Key traits and relationships

- **Developmental stage** (inflexible template): egg, alevin, fry, parr, smolt
- **Example Rearing Habitats (RH)** (potential sequence(s) relative inflexible)**:**

  Natal site (NS)

  Downstream River (DSR)

  Downstream Off Channel (DSOC)

  Downstream Lake (DSL)

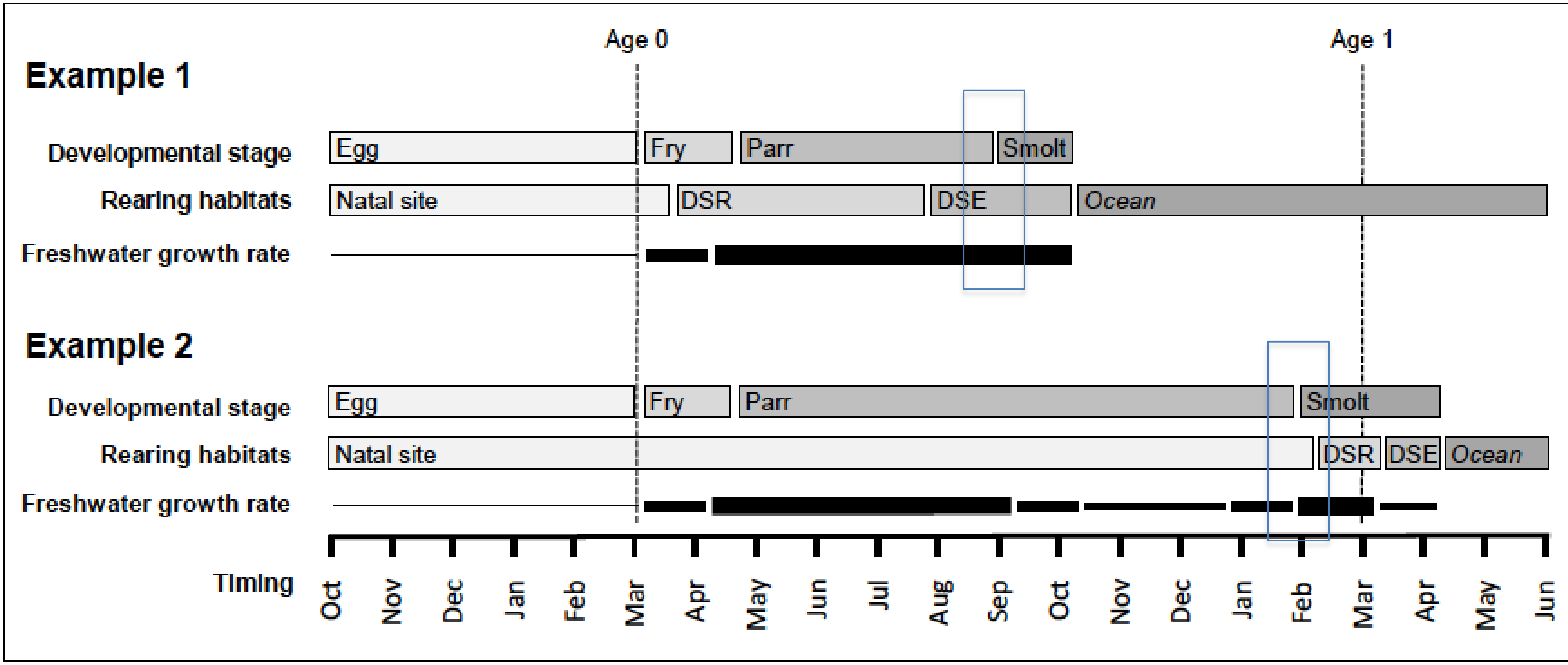
  Downstream Reservoir (DSRES)

  Downstream Estuary (DSE)
- **Timing of and Age at Transitions** (highly variable)**:**

  Age at movement among rearing habitats

  Location and age at **Parr-Smolt transformation**

  Age at Ocean entry: months post-emergence, season, or age



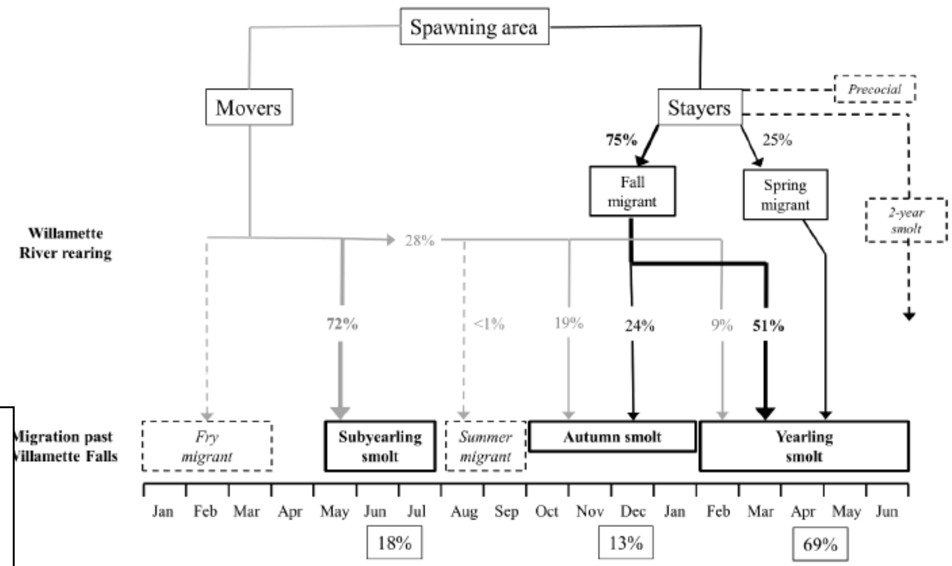
Approach applicable to individual pathways or populations

Intended as a framework to assist in standardization of terminology within and across systems

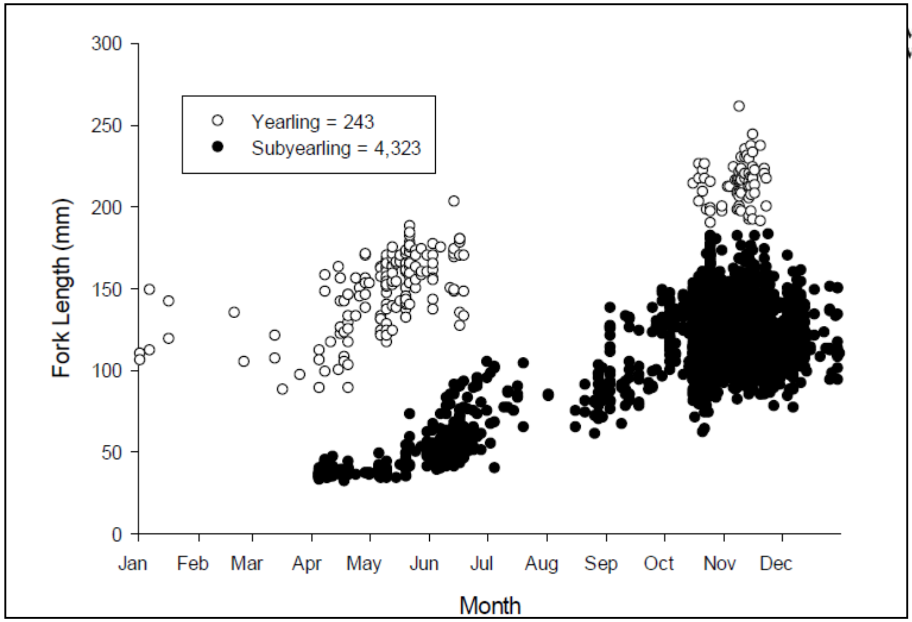
<u>Operational classifications</u> will differ by region depending on management questions, monitoring capacity and need for explicit quantitative information on habitat use and timing

Phenotypic variation is the norm!

- Willamette Valley



Schroeder et al (2015)



Romer et al. (2014, report to USACE)

Phenotypic variation is the norm!

Range-wide

River basin	State / Province	Life history traits and habitat used by juveniles: Adult run timing	Ocean entry timing	Ocean entry Age	Juvenile rearing habitat	Reference(s)
Sacramento	CA	SP, FA, late-FA, WI	mix	mix	NS DSR DSOC DSE	Kjelson et al. (1982) Yoshiama et al. (1998) Sommer et al. (2001) Beckman et al. (2007) Miller et al. (2010)
Sixes	OR	FA			NS DSR DSE	Reimers (1971)
Salmon	OR	FA	SP, SU, FA	subyearling	NS DSE	Bottom et al. (2005) Volk et al. (2010)
Willamette	OR	SP	mix	mix	NS DSRES DSR DSE	Mattson (1962) Friesen et al. (2007) Keefer et al. (2011) Bourret et al. (2014) Teel et al. (2014) Schroeder et al. (*in press*)
Snake, Clearwater,	ID	FA	mix	mix	NS DSRES DSR	Connor et al. (2002, 2005) Hegg et al. (2013)
Salmon	ID	SP, SU	SP, SU	mix	NS DSR	Bjornn (1971) Archord et al. (2011) Copeland & Venditti (2009) Copeland et al. (2014)

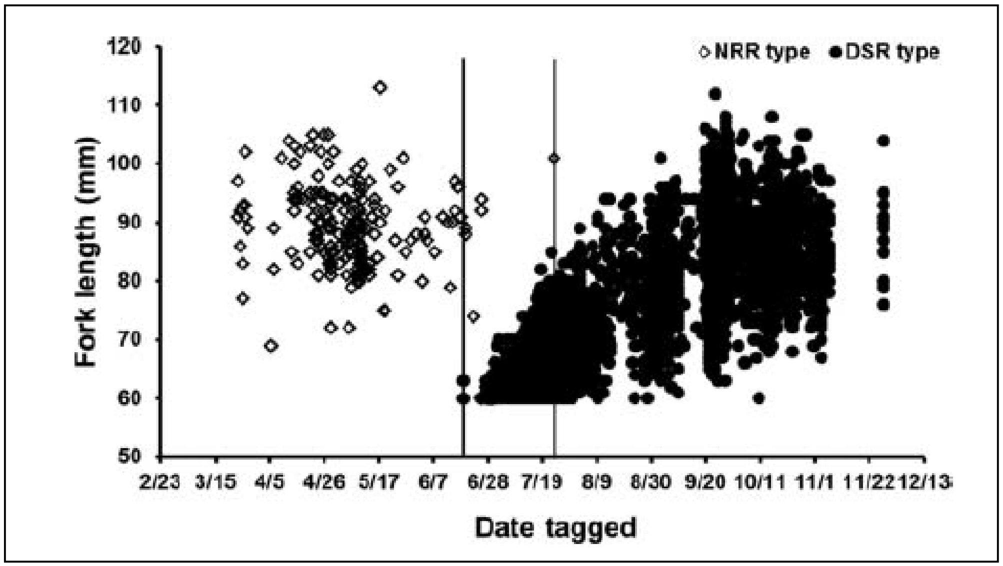
Bourret et al *in revision*

Chinook Life History (mark-recapture)

- “Gold standard”

Snake River diversity

Stream-type **Natal-Reach-Rearing** vs Down-Stream-Rearing:
Marsh Creek, Middle Fork Salmon River



Copeland et al. 2014 (TAFS)

Ocean-type sub-yearling vs **Reservoir-rearing yearling**:
Lower Snake River

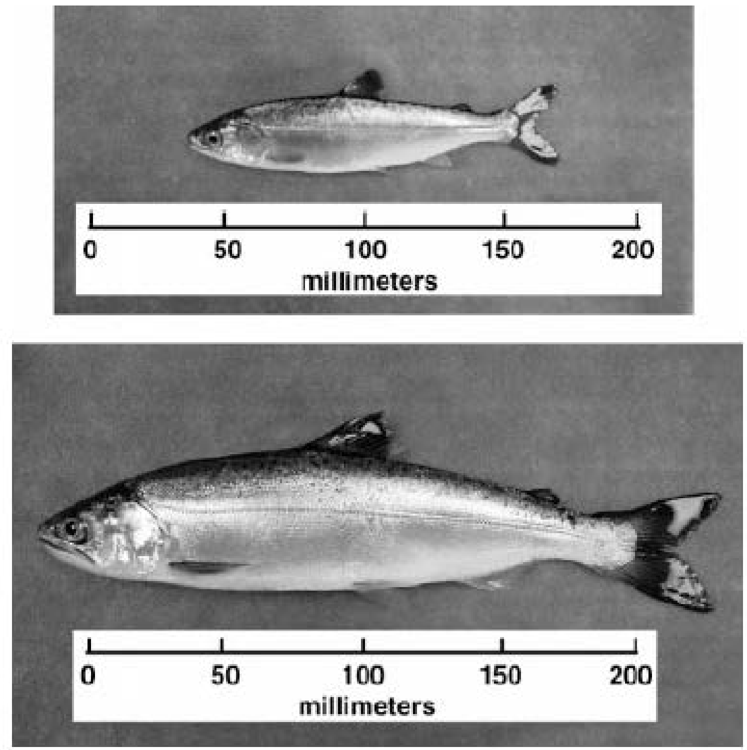
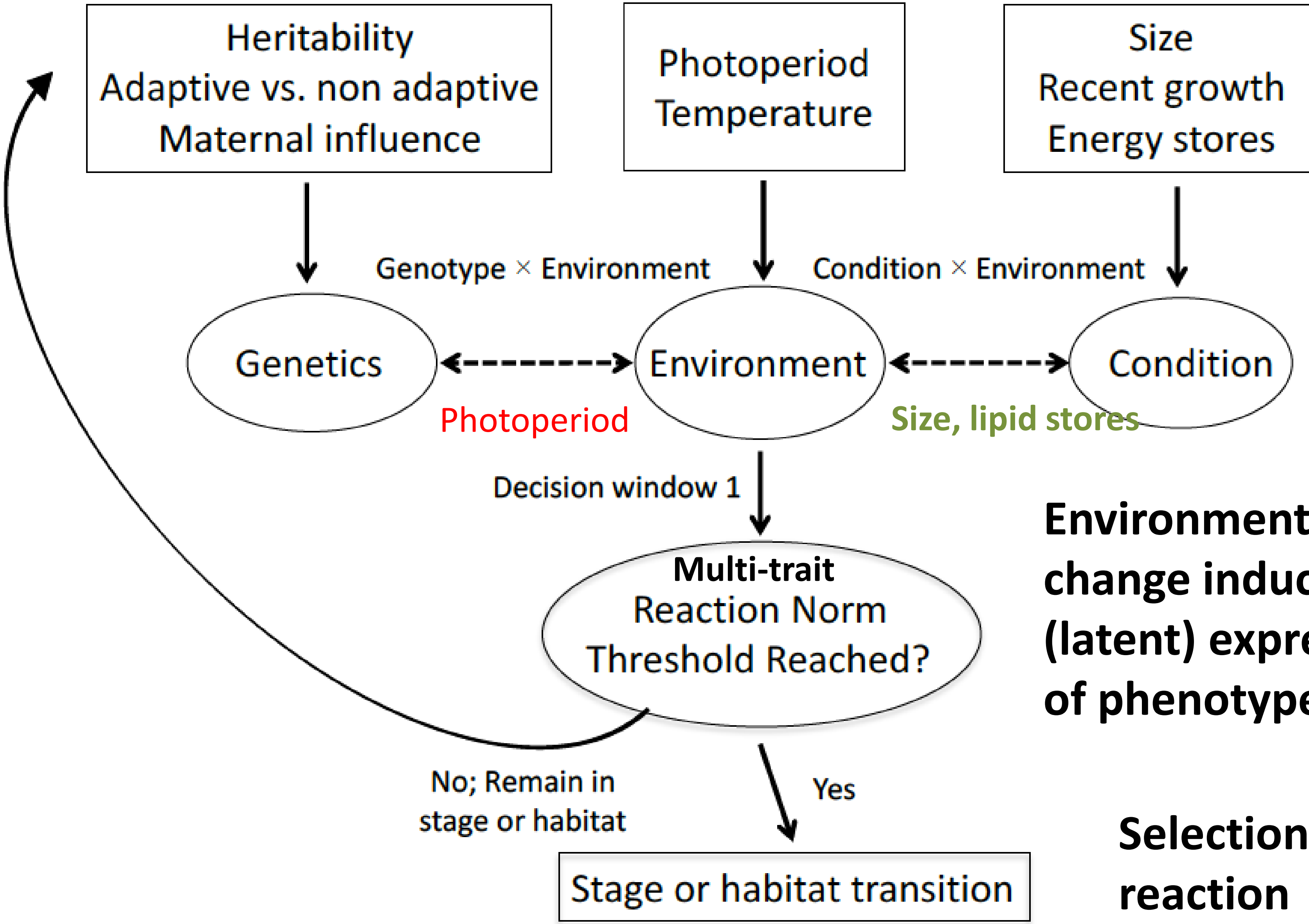


FIGURE 3.—Examples of an ocean-type fall Chinook salmon juvenile photographed in July 2004 (top panel) and a reservoir-type juvenile photographed in April 2004 (bottom panel) at Lower Granite Dam.

Connor et al. 2005 (TAFS)

Underlying mechanisms?

- Past paradigm: Phenotypic diversity ~ genetic diversity
- Emerging paradigm: **Phenotypic plasticity** and conditional strategies are widespread
- **Conditional strategies:** physiological condition/trait surpasses a genetically–based threshold and triggers one of several alternative life history pathways
- **Norm of reaction:** range of phenotypes expressed by a given genotype across environments (e.g., variation in threshold values)
- **Decision window:** seasonal or ontological period when an animal's physiological condition allows a transition in response to internal and environmental conditions



Environmental change induces (latent) expression of phenotypes

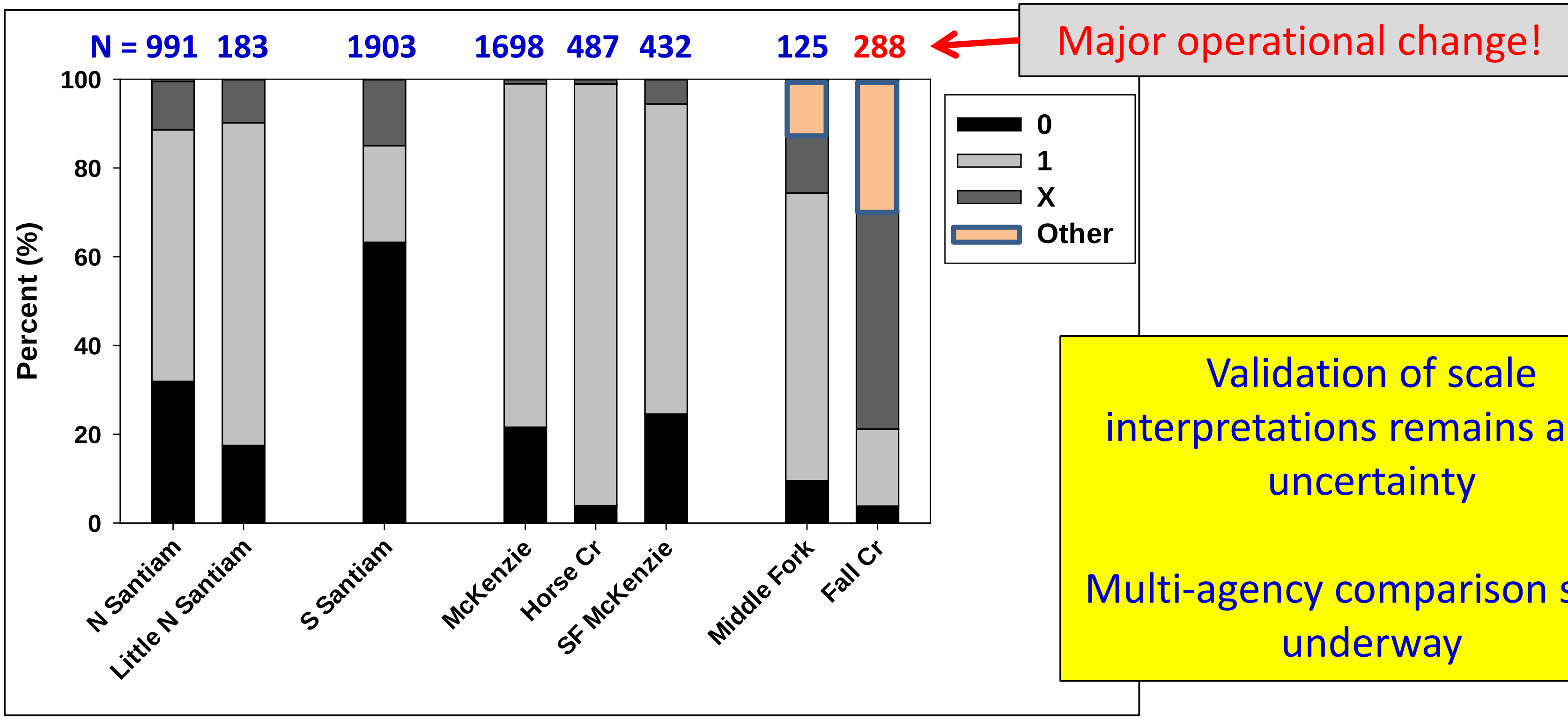
Selection on reaction norms?

Take-homes

- Typological thinking can be useful if nature cooperates—proceed with caution!
- Phenotypic plasticity widespread with populations
- Most populations, even classic interior 'stream-type' likely use(d) a variety of downstream habitats
- Juvenile life history pathway diversity? Effects on fitness and population production?
- Multiple life histories contribute to UWR Chinook returns at several scales
- On-going work to
  - identify major pathways (and discontinuities)
  - refine monitoring tools
  - evaluate impact on adult production

Composition varies through time and space

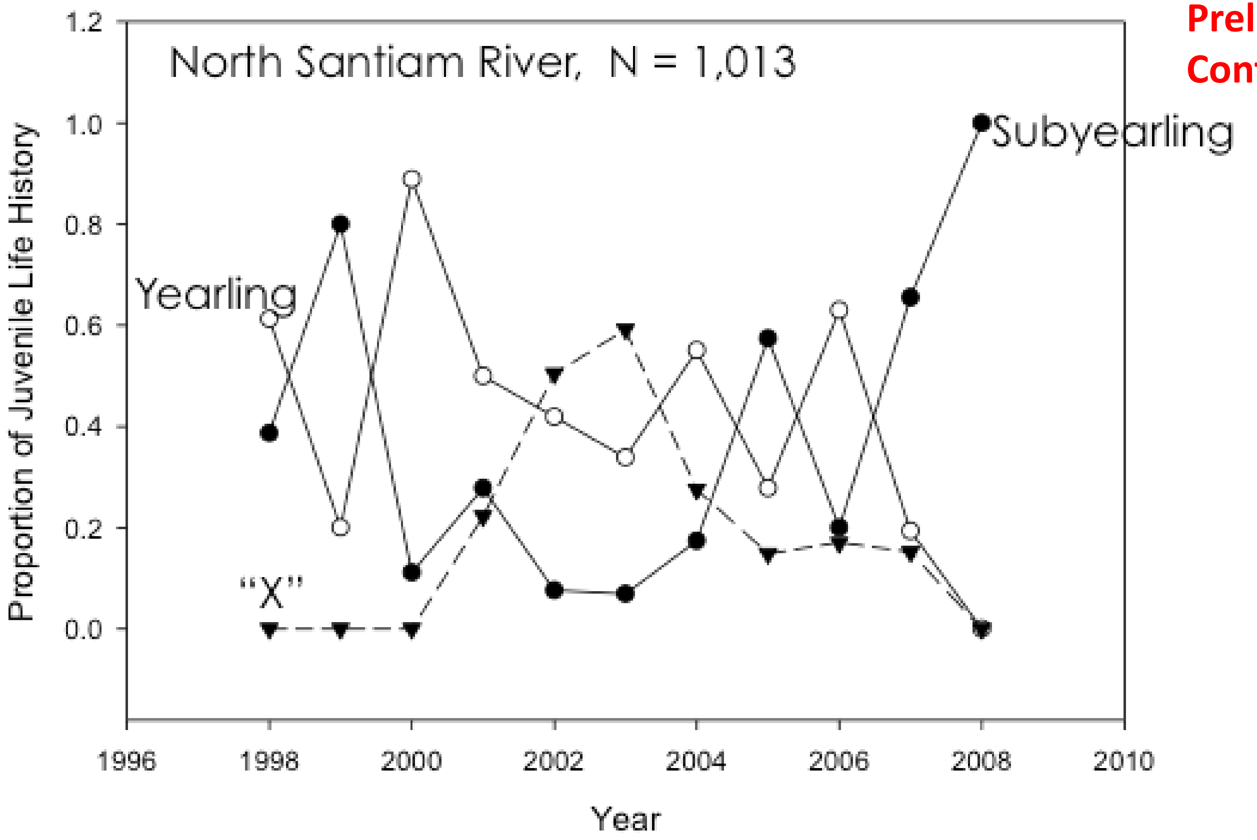
- ODFW Scale database example: “Snapshot”
  - Multiple years combined (~2000-2013)
  - Total N = 6,195 (some ambiguous fish censored)



Validation of scale interpretations remains a key uncertainty

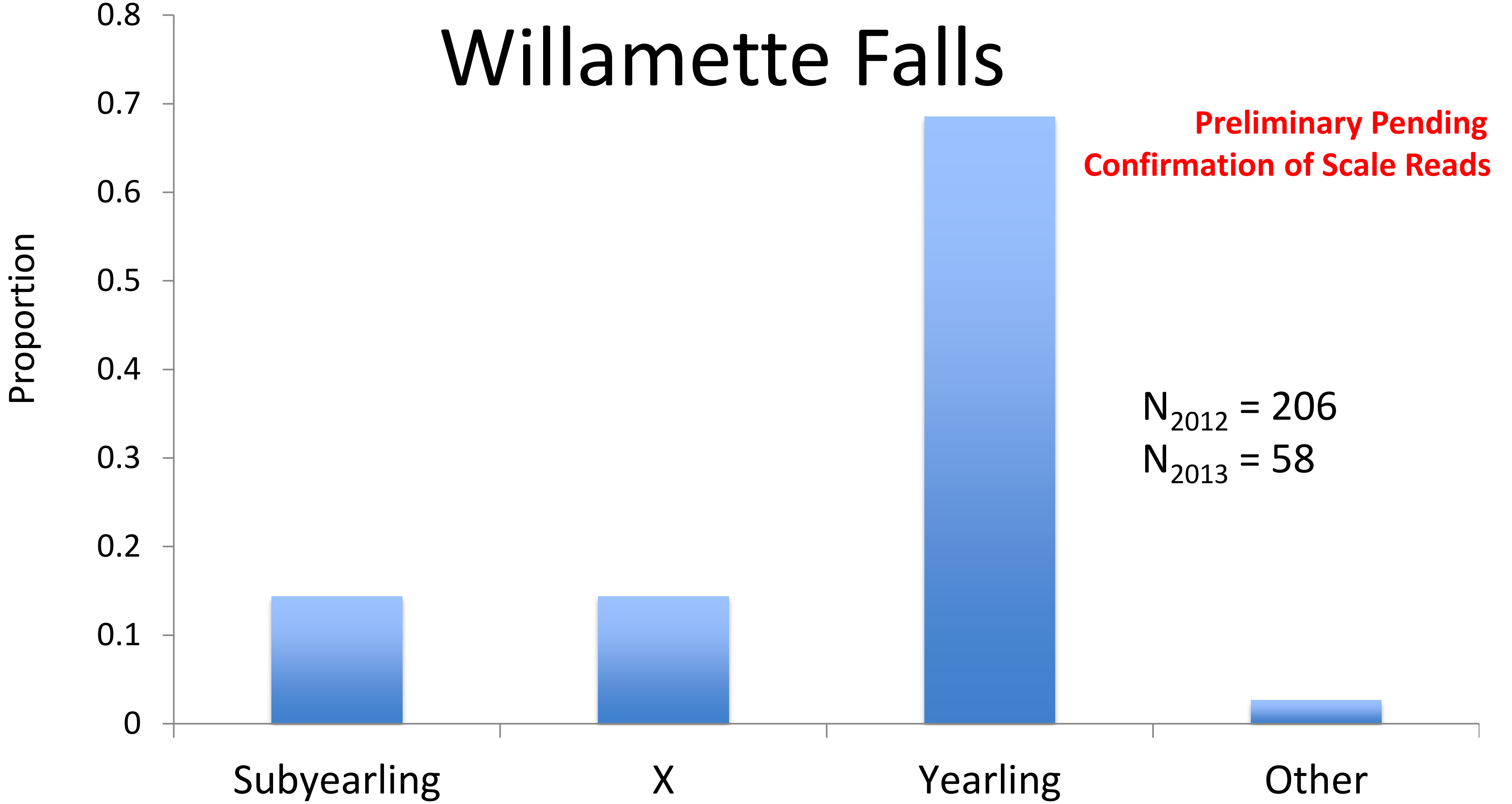
Multi-agency comparison study underway

Composition varies through time and space



Preliminary Pending Confirmation of Scale Reads

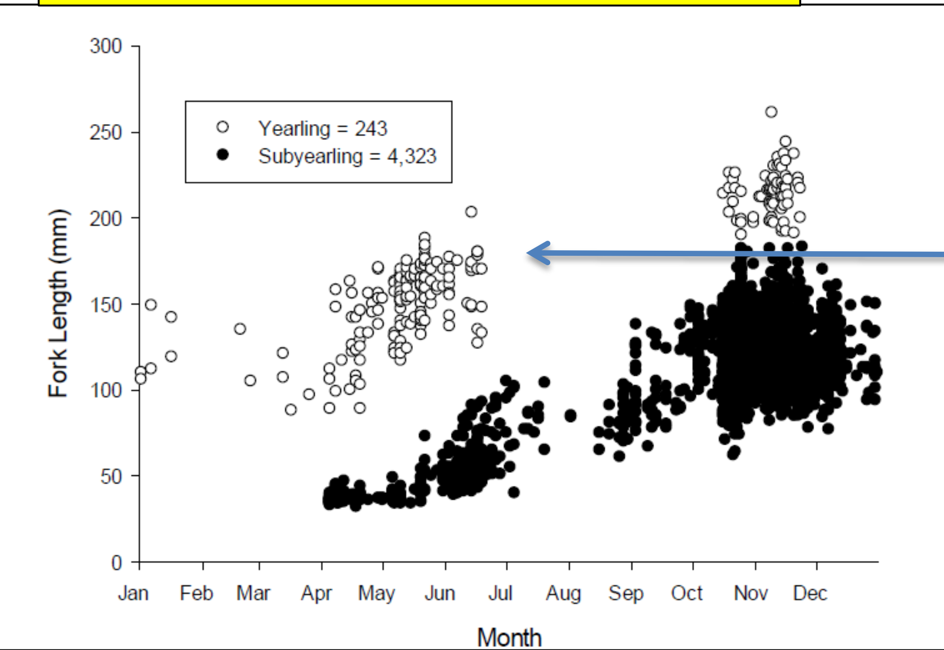
Composition in returning adults at Willamette Falls



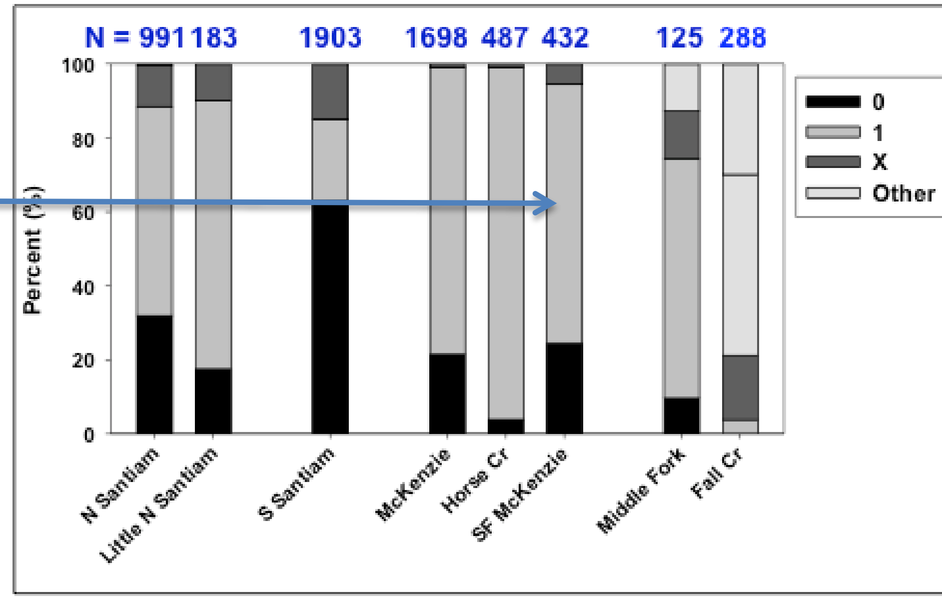
Proportion of all wild (unclipped) adult Chinook salmon radio-tagged at Willamette Falls by life history type, 2012-2013 combined

Shifts in life history composition between stages

Wild Chinook below Cougar (SF McKenzie)



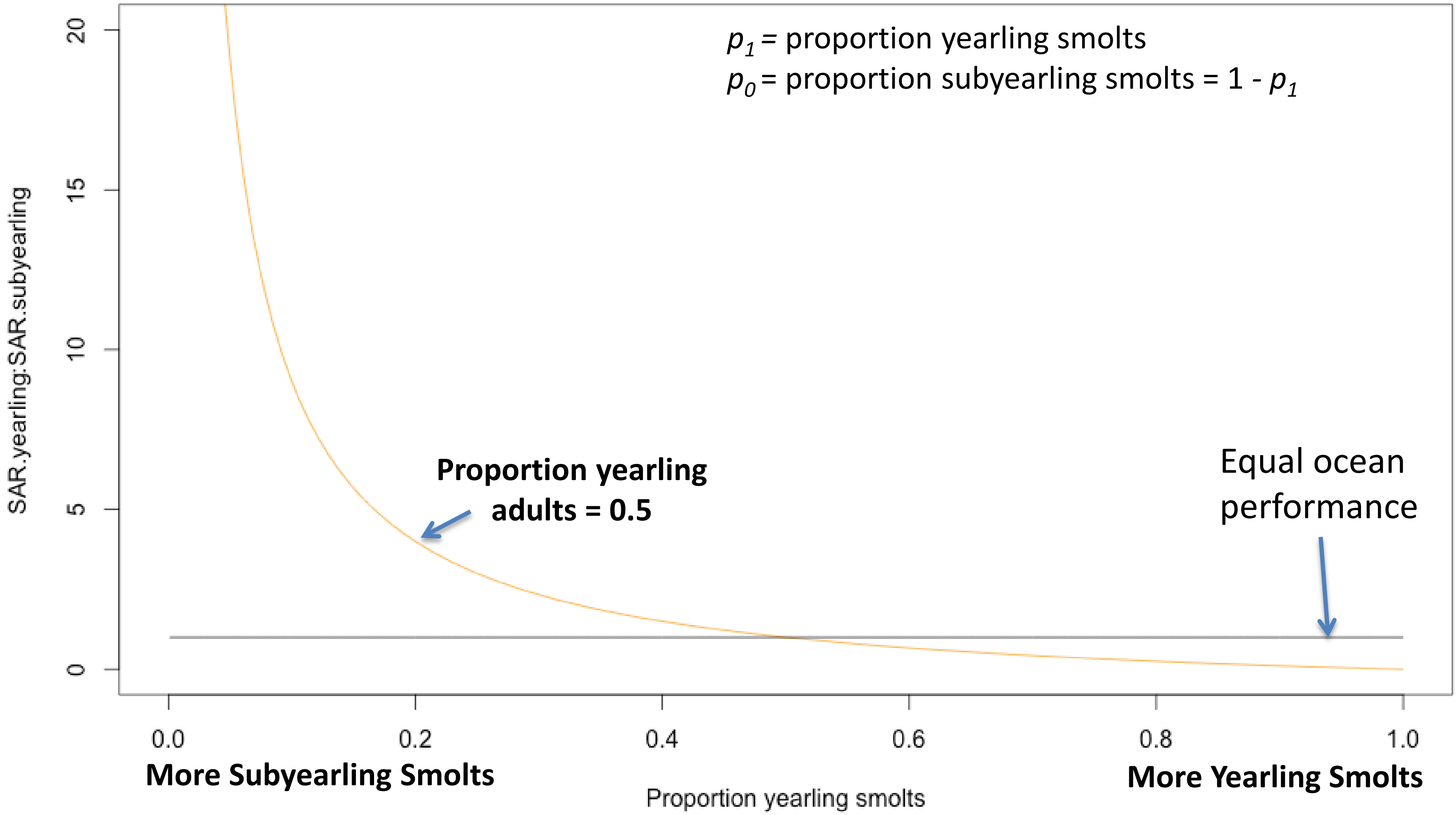
Life history composition of returning adult Chinook salmon by subbasin (2000-2013) from scales



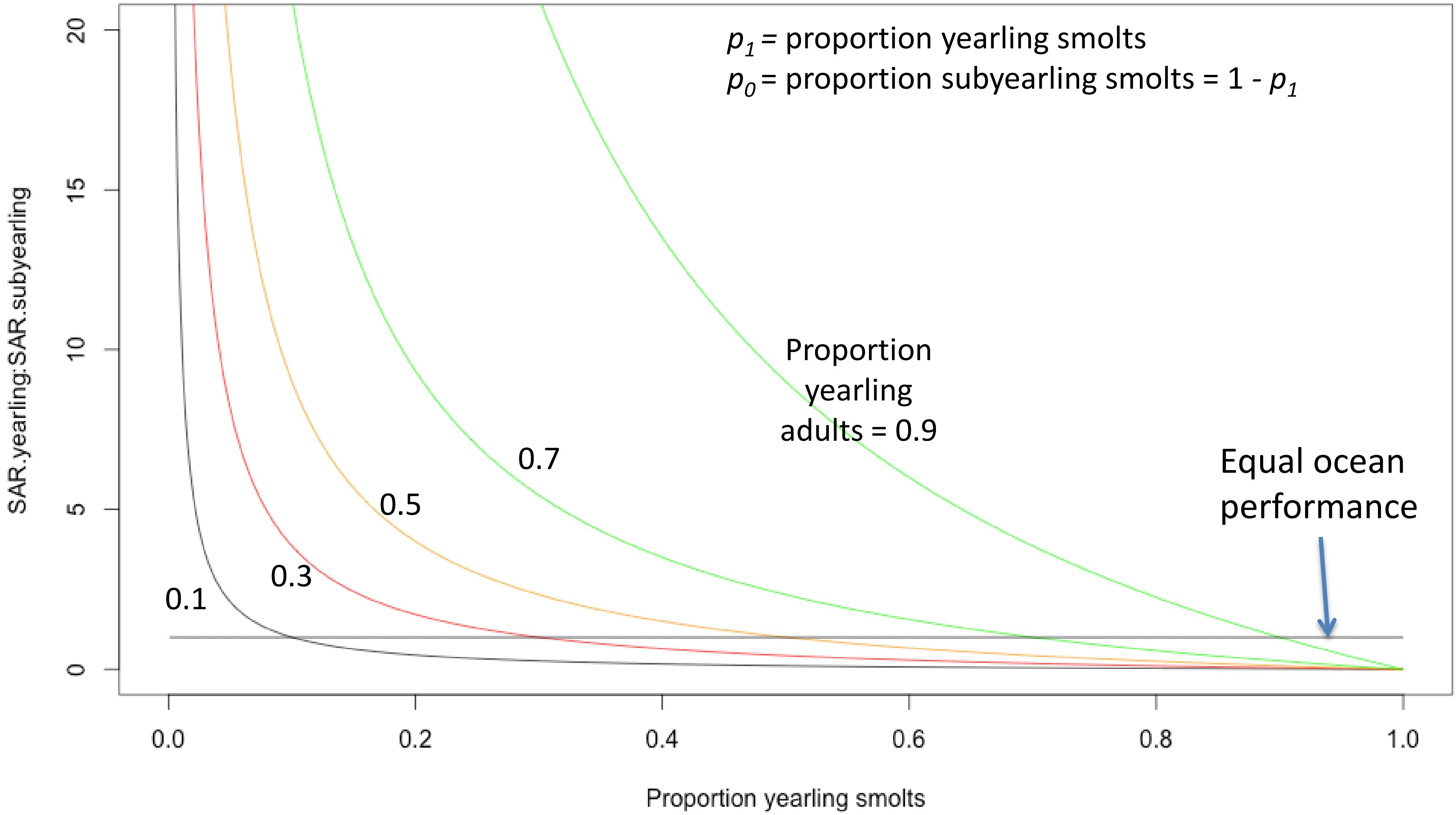
Romer et al 2014

Use shifts in composition between juveniles and adults to estimate relative SAR for different types in the absence of data on smolt production

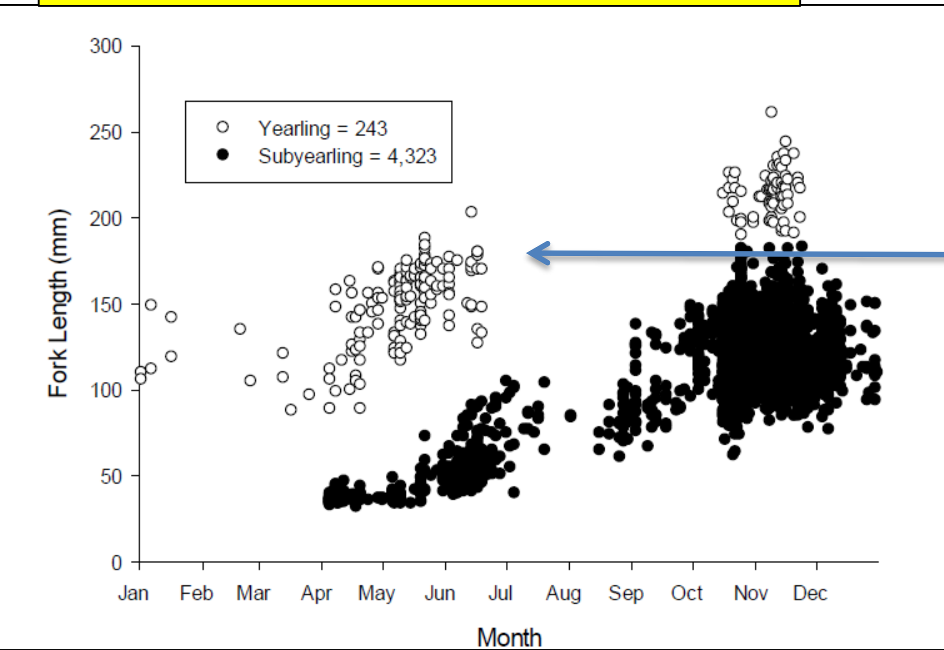
$$\frac{SAR_1}{SAR_0} = \frac{Adults_1}{Adults_0} * \frac{p_0}{p_1}$$



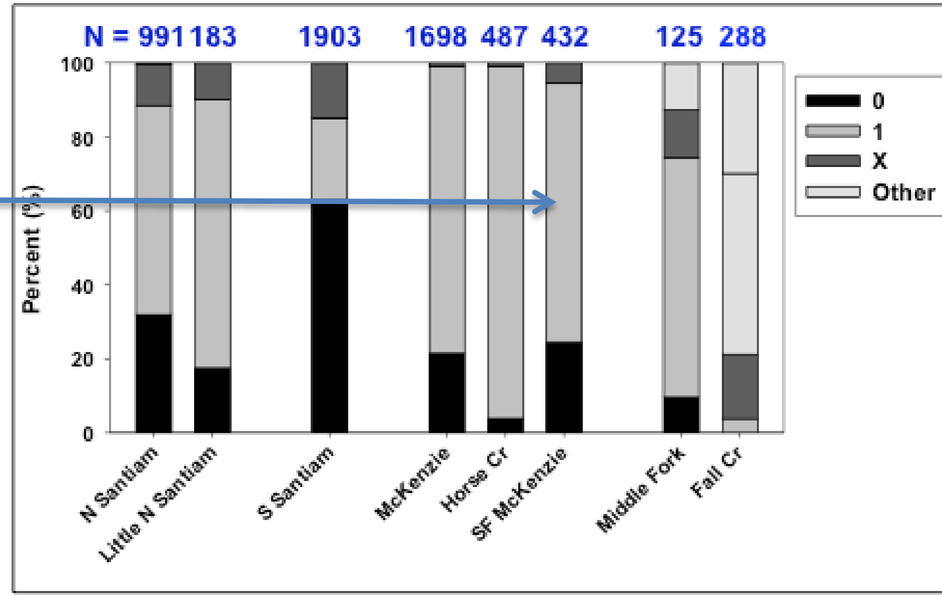
$$\frac{SAR_1}{SAR_0} = \frac{Adults_1}{Adults_0} * \frac{p_0}{p_1}$$



Wild Chinook below Cougar (SF McKenzie)



Life history composition of returning adult Chinook salmon by subbasin (2000-2013) from scales



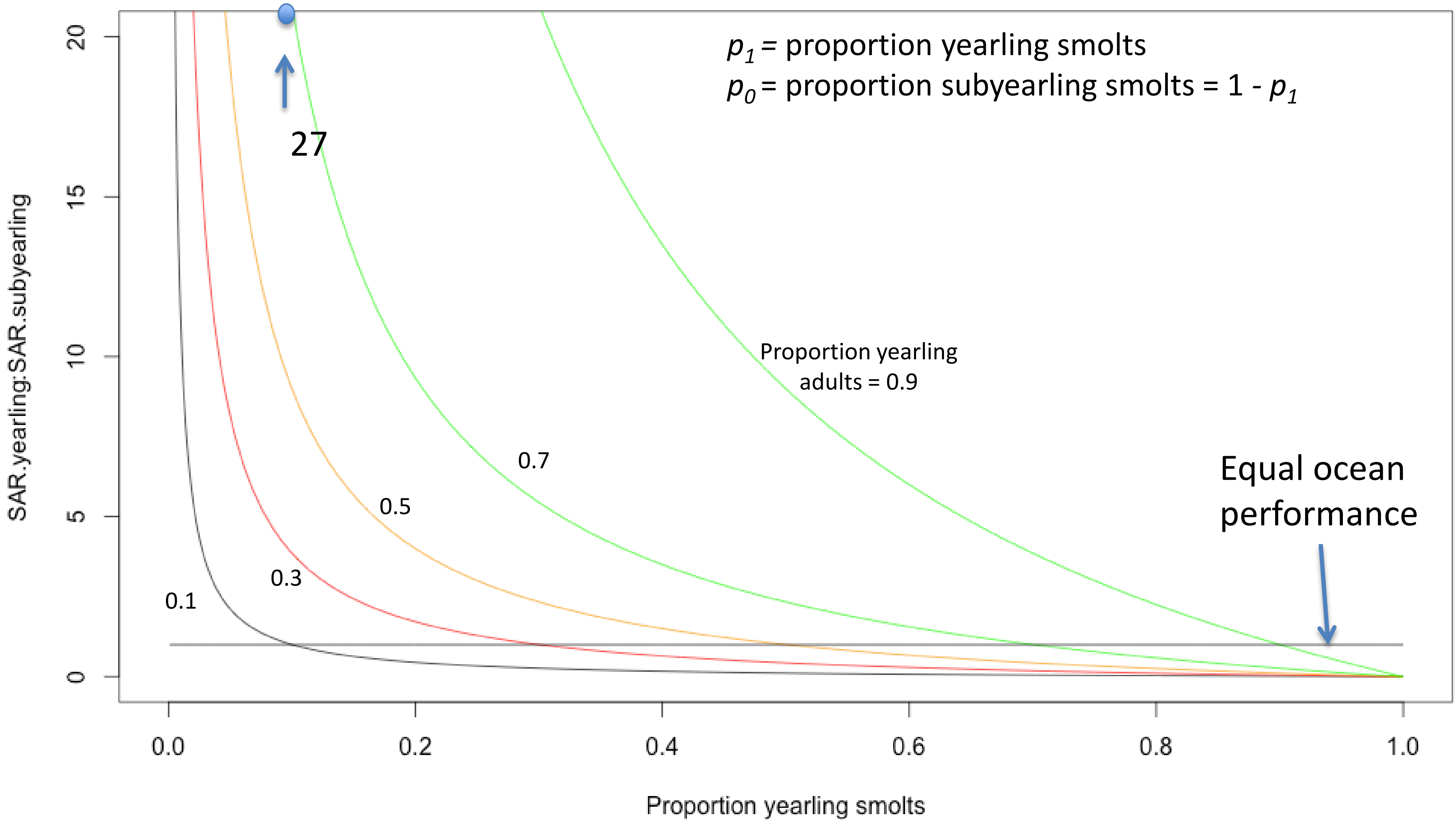
Romer et al 2014

~90% juveniles subyearlings Romer et al. 2014
~75% adult outplants smolted as yearlings ODFW Scale Database

= 0.9/0.1 * 75/25 = 9 * 3 = **27**

Analysis assumes subyearlings smolt as subyearlings and do not rear in mainstem

$$\frac{SAR_1}{SAR_0} = \frac{Adults_1}{Adults_0} * \frac{p_0}{p_1}$$



Summary

- Shifts in life history composition can provide proxy for marine performance in absence of smolt production data
  - reconstruction of baseline conditions
  - monitoring effects of system modifications and climate
  - evaluating potential benefit of actions affecting juvenile life history composition
- Assumes rapid ocean entry (!see first half of talk…!)

Summary

- Need for better understanding of downstream freshwater and estuary habitats
- Fitness and juvenile pathway changes through time and space
- Life history pathways affected by genes, **environment and condition**
- Plasticity and variation are the rule not the exception
- Plasticity and life history variation likely affect fitness and enhance the portfolio effect
- Understanding underlying mechanisms always important!

Acknowledgments

- NOAA – Kim Hatfield, Stephanie Burchfield
- ODFW – Lisa Borgerson, Kanani Bowden, Tom Friesen, Wayne Vandernaald, Todd Alsbury, Jeff Ziller, Kelly Reis, Joy Vaughan, Shivonne Nesbit, Kirk Schroeder, Craig Tinus, Michele Weaver
- UI – Travis Dick, Theresa Tillson, Dan Joosten, Charlie Erdman
- WSU – Jeff Vervoort, Charles Knaack
- PGE – Tim Shibahara
- USACE – David Griffith, Rich Piaskowski, and Robert Wertheimer

And Many More!