Growth modulation and precocious male maturation in Yakima Hatchery Spring Chinook salmon: What have we learned so far?

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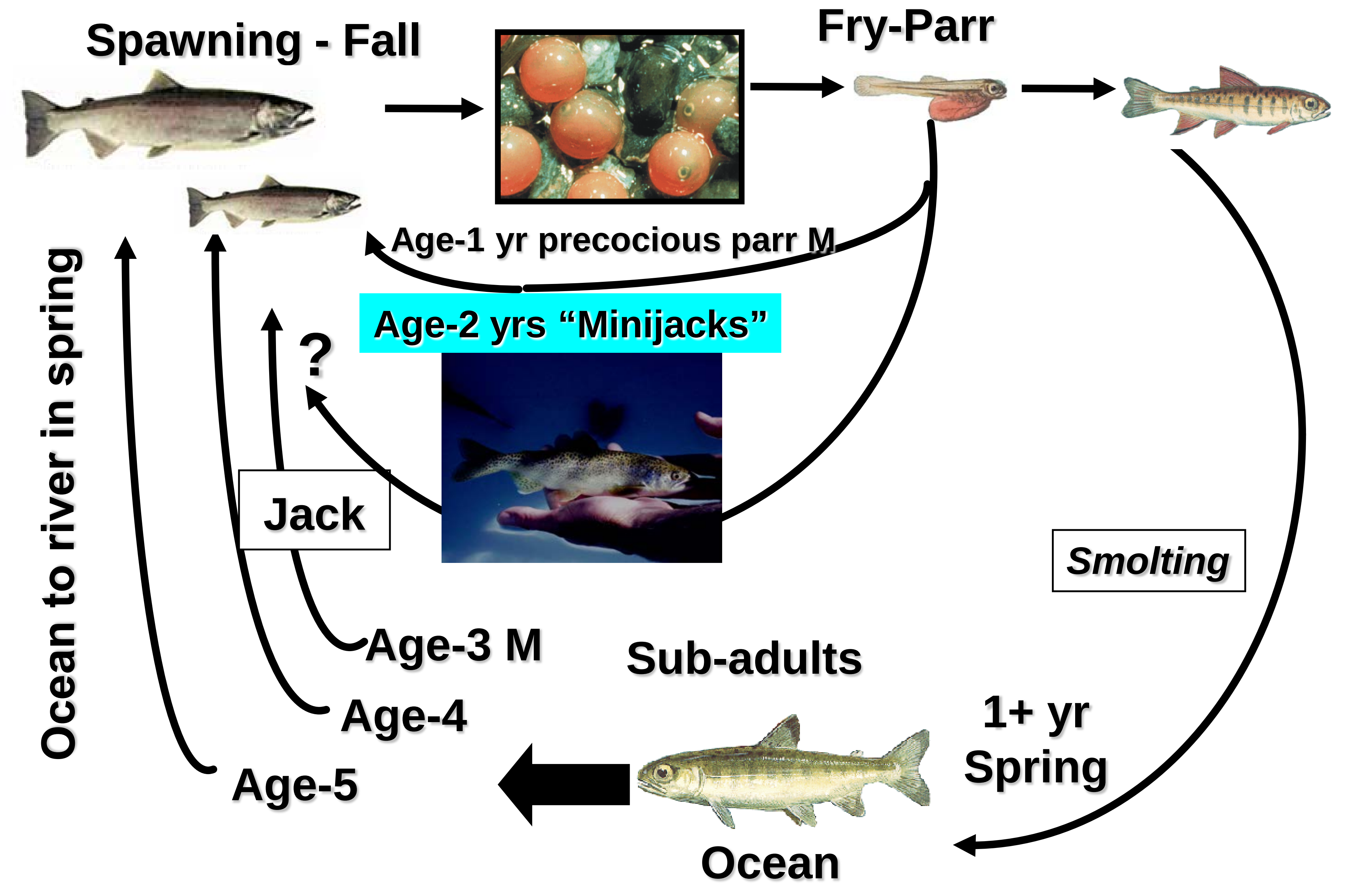
BPA contract # 200203100

Outline

- Introduction-precocious male maturation.
- The Yakima Hatchery Production Growth Modulation Experiment
- Results and what have we learned to date.
- Future approaches.

Spring Chinook Salmon

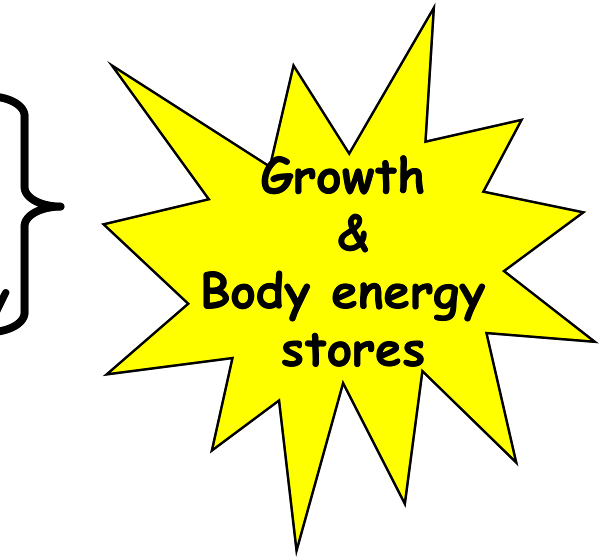


Variation in Age of Male Maturity

Mature male salmon

Factors Affecting Age of Maturation

- ✓ Genetics
- ✓ Environment
    - temperature
    - food availability
    - food quality



The Hatchery environment can significantly influence age of maturation

Goals of our ongoing research with the Yakima program

- Obtain baseline data on the physiological development and life-history diversity of wild and hatchery spring Chinook salmon.

- To develop rearing protocols to produce hatchery fish with morphological, physiological, and life-history attributes similar to their wild cohorts *"naturally selected populations should provide the model for successful artificially reared populations, in regard to population structure, mating protocol, behavior, growth, morphology, nutrient cycling, and other biological characteristics."*

-Recommendations of the Columbia River Basin Fish & Wildlife Program (Nov. 14, 2000) for artificial production state
-NMFS 2000 FCRPS Biological Opinion (9.6.5.3.4, RPA 184)
-Final Updated UPA for the FCRPS BiOp Remand Hatchery Substrategy 2.2
-Artificial Production Review and Evaluation (NWPCC, 2004, App.A, Table A-1)

We've been monitoring the physiology of Cle Elum Hatchery spring Chinook since implementation in 1997

On average 50% of male Yakima hatchery spring Chinook precociously mature at age-2

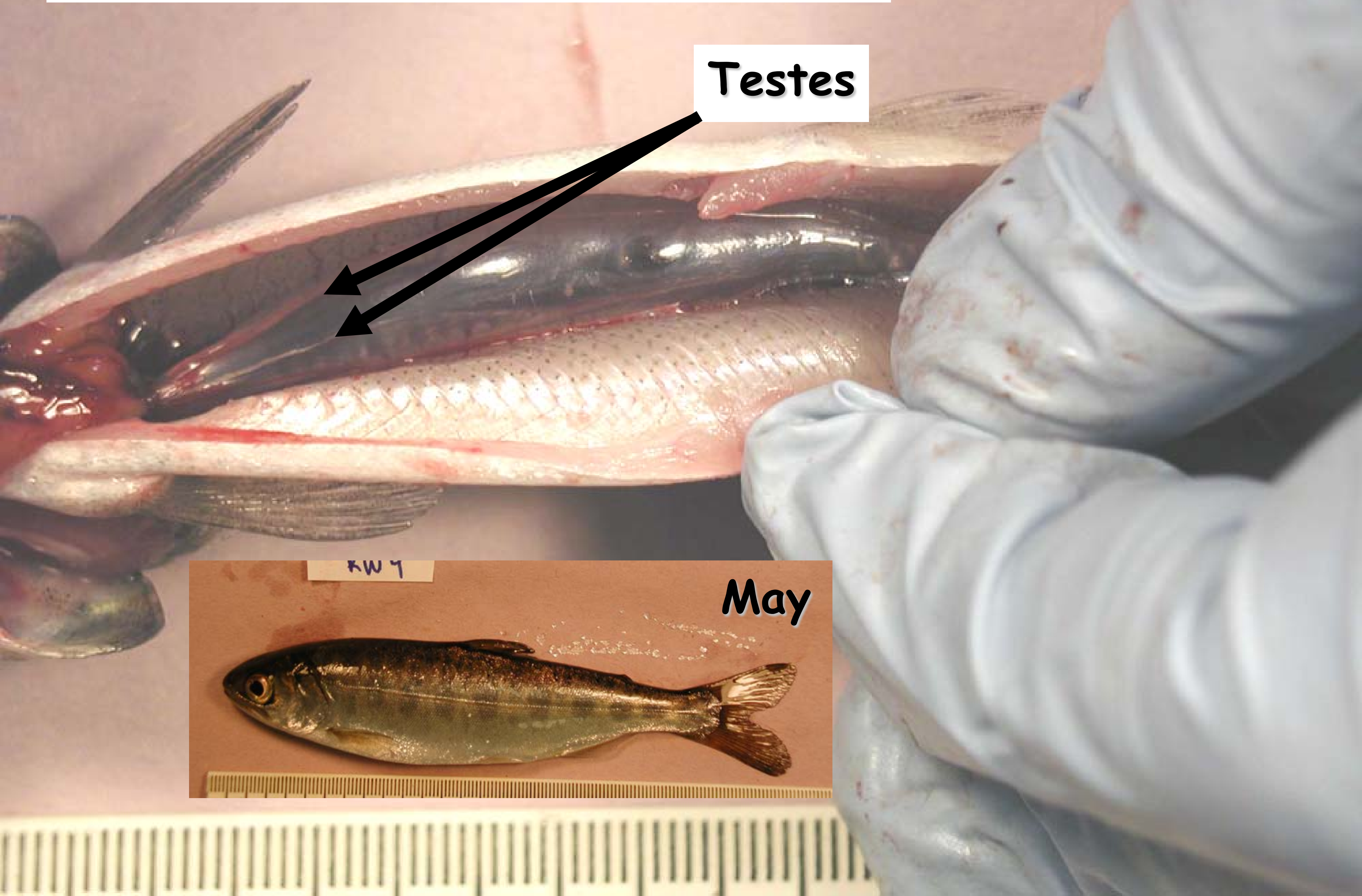
BY	Release #	% of males	# Minijacks
1997	386,048	44%	84,931
1998	589,683	72%	211,107
1999	758,789	50%	189,697
2000	834,285	37%	153,508
2001	370,236	52%	95,520

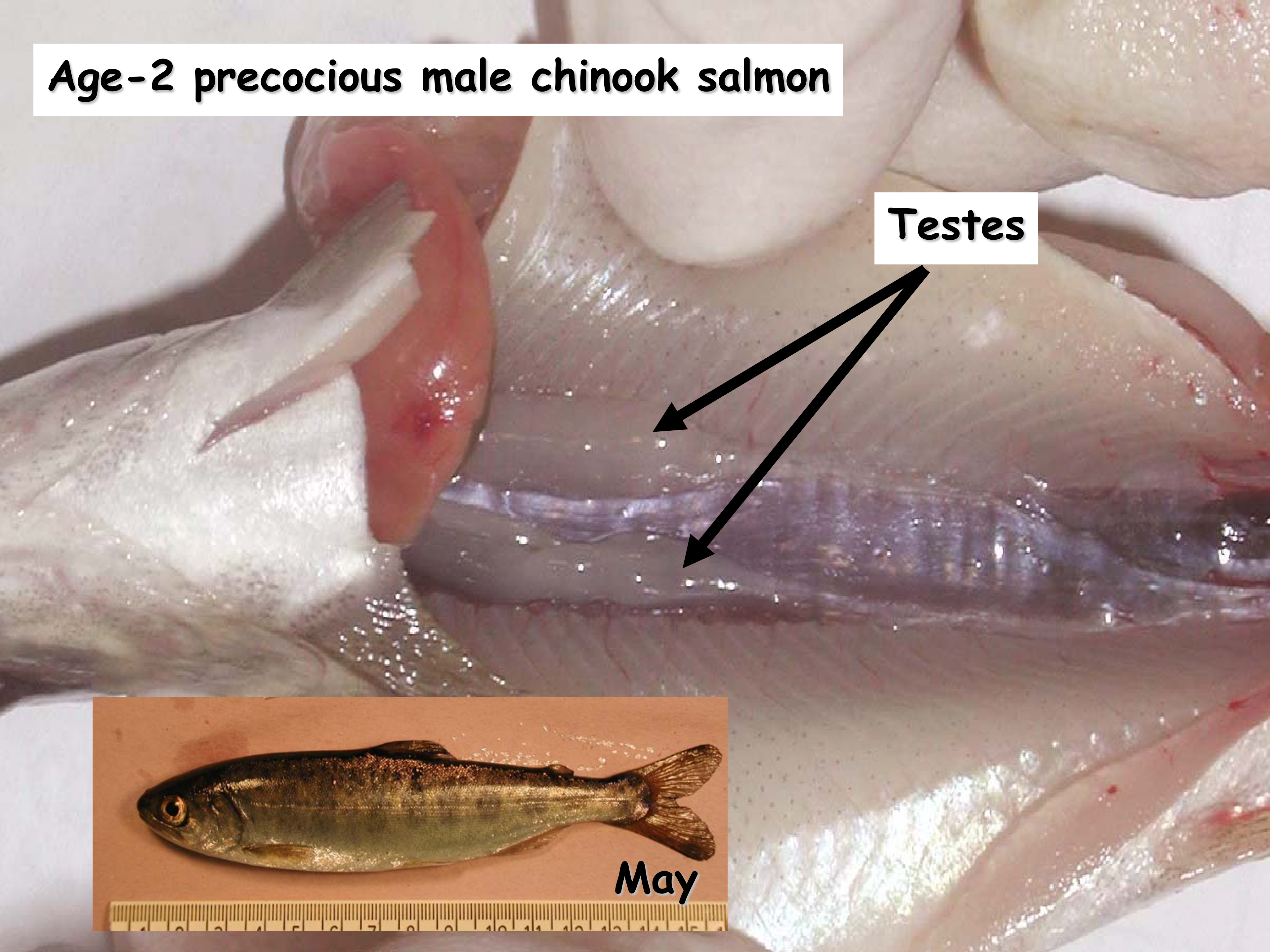
Avg. 50%

Larsen, D.A., Beckman, B.R., Cooper, K.A., Barrett, D., Johnston, M., Swanson, P., and Dickhoff, W.W. (2004). Assessment of high rates of precocious male maturation in a spring Chinook salmon supplementation hatchery program. Transactions of the American Fisheries Society. 133, 98-120.

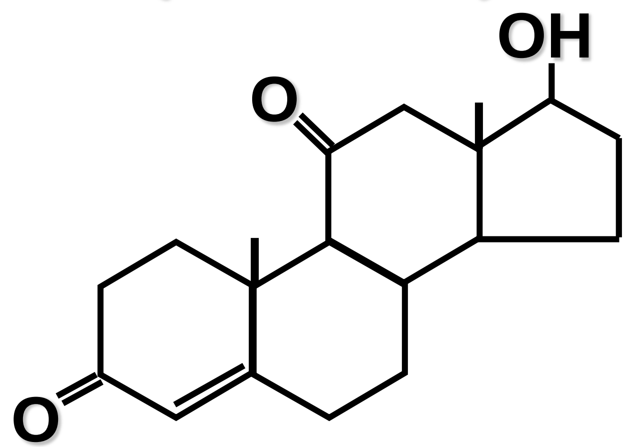
How do we assess precocious male maturation?

Age-2 immature male chinook salmon



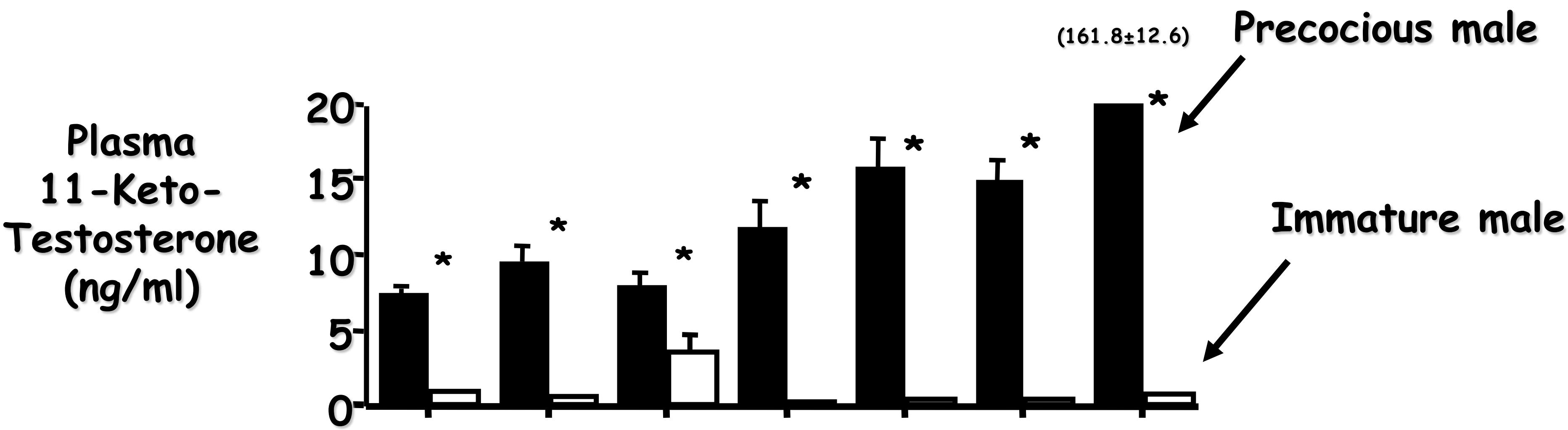

Age-2 precocious male chinook salmon
Testes
May

Plasma 11-ketotestosterone (11-KT)



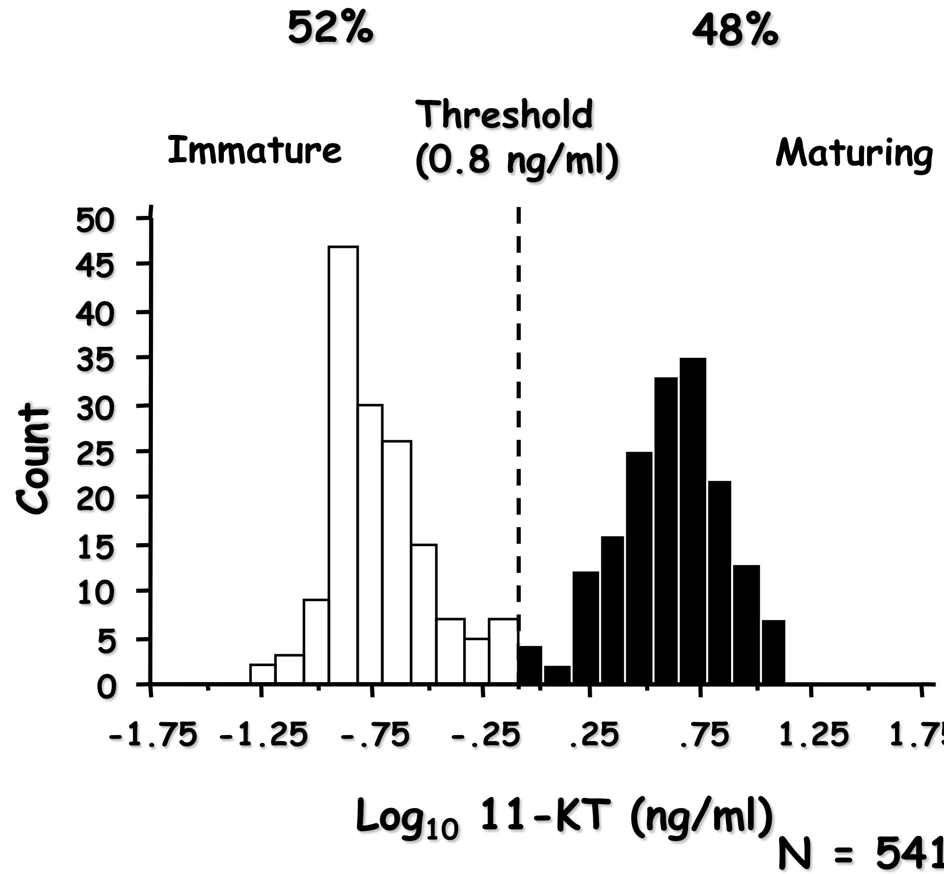
- Major androgen in teleost fish
- Instrumental in the regulation of spermatogenesis

Laboratory based studies have clearly established that 11-ketotestosterone (11-KT) is significantly elevated in precocious males approximately 9 months prior to maturation



(Campbell et al. 2004)

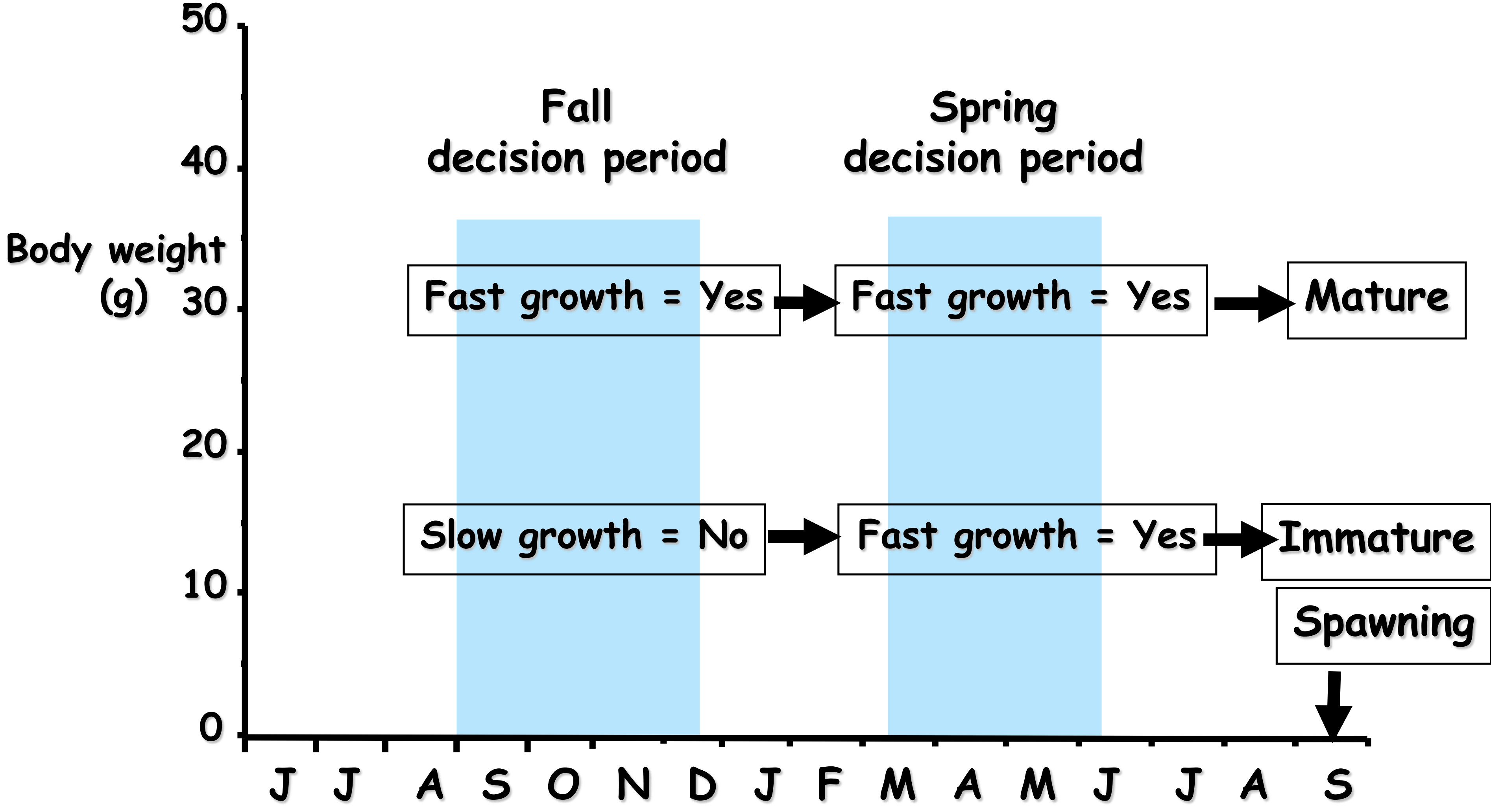
Every March the Yakima Chinook are screened for pathology just prior to volitional release



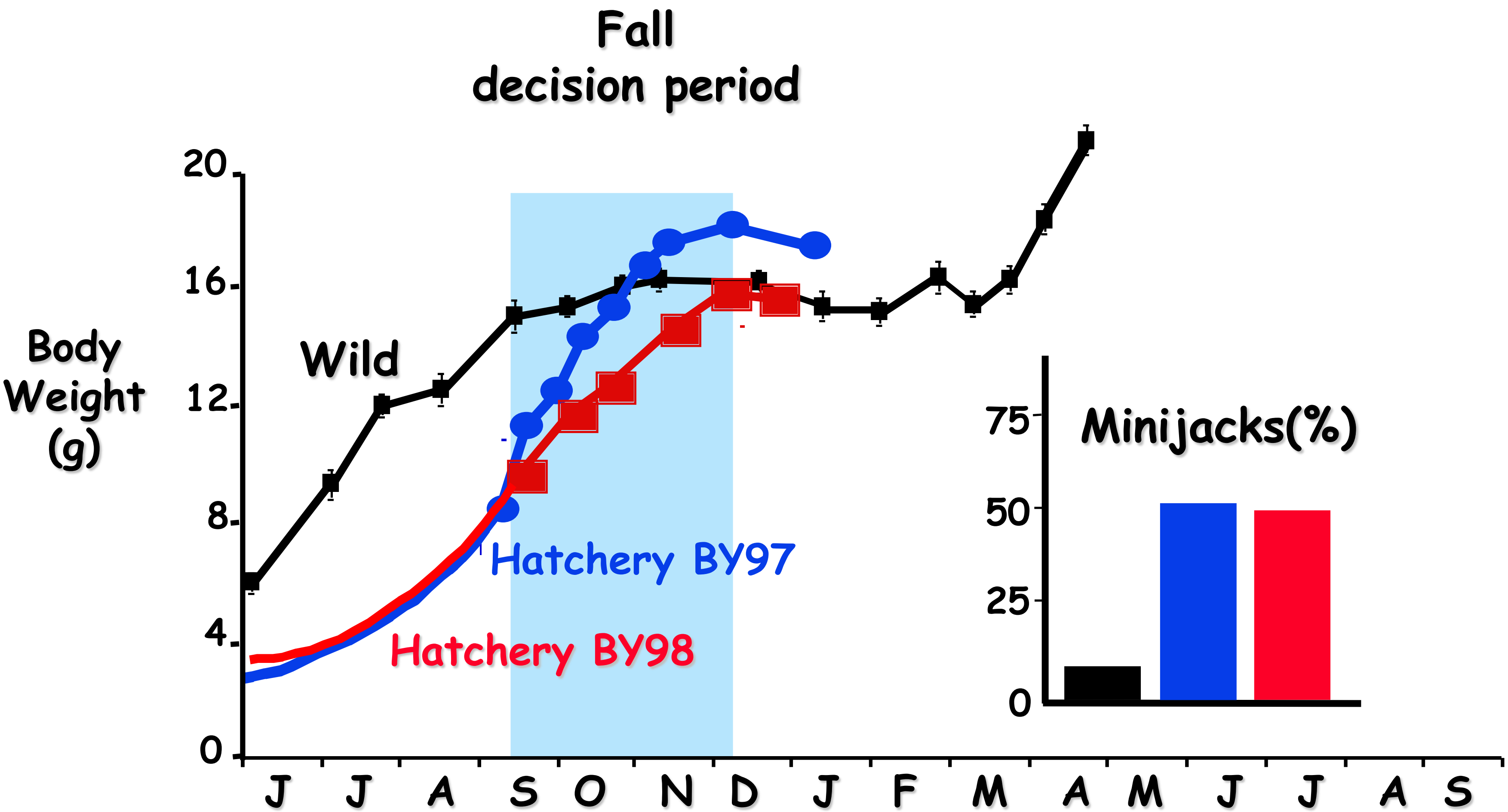
Consequences of high levels of precocious maturation

- Ecological impacts
- Genetic impacts
- Increased straying
- Skewed gender ratio
- Loss of adult producti

Critical periods for maturation decision – based on body size/growth rate



Comparison of wild and hatchery growth and minijack rates



Lab scale studies:

- Autumn Growth Rate
- Body size

*Significant time and effort provided by CESRF staff.

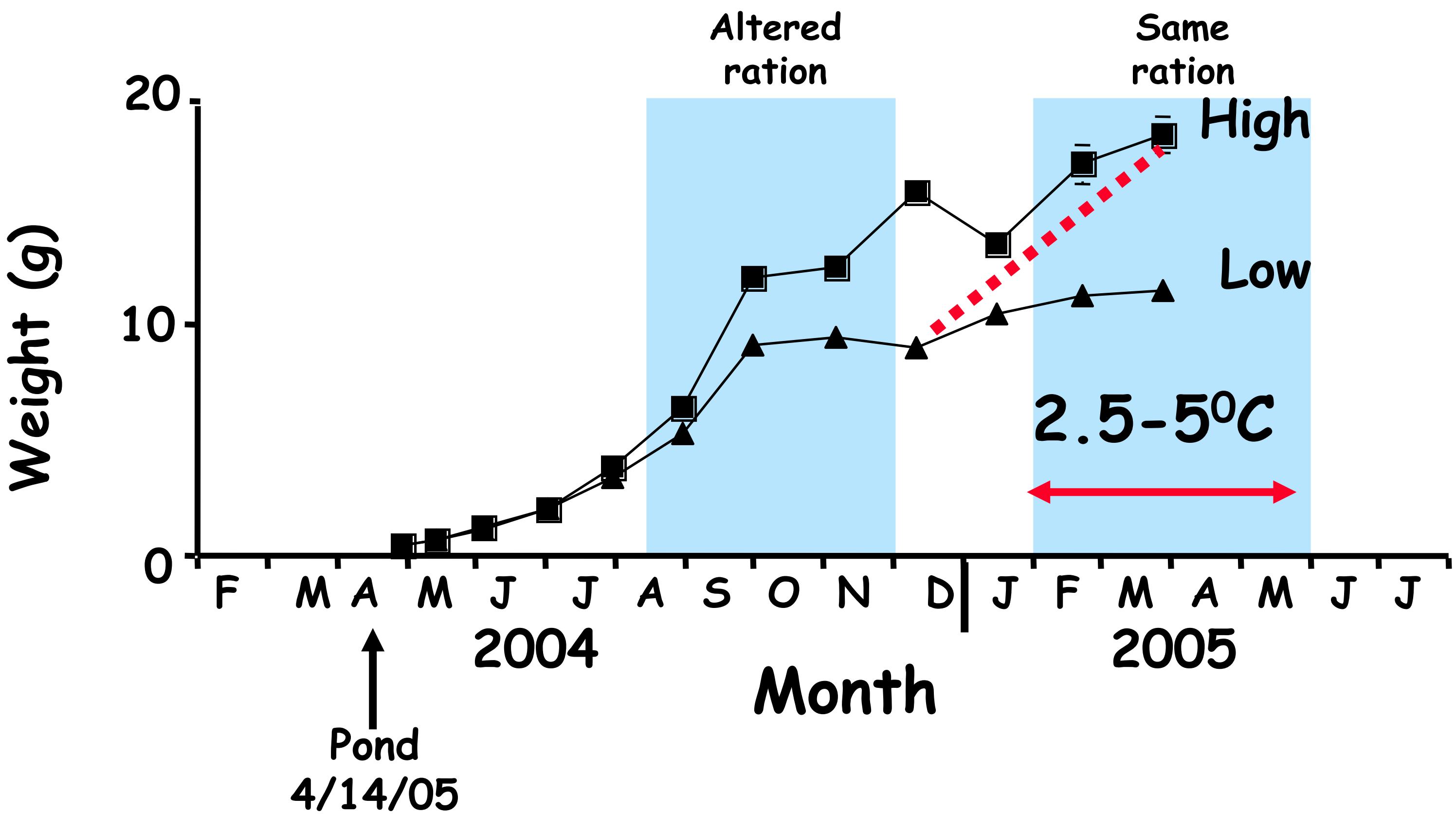
Larsen, D.A., Beckman, B.R., Strom, C.R., Parkins, P.J., Cooper, K.A., Fast, D.E., and Dickhoff, W.W. (In press). Growth modulation alters the incidence of early male maturation and physiological development of hatchery reared spring Chinook salmon: a comparison with wild fish. Transactions of the American Fisheries Society.

Results from this study provided the basis for production scale rearing regimes (BY 2002-2004)

Goals of production experiment

- **Maintain healthy physiological and behavioral condition of smolts**
- **Reduce minijack rates to conform with the wild fish template.**
- **Reduce potential ecological, genetic, demographic effects of high minijack rates.**
- **Obtain critical information regarding growth, size and SAR**
- **Use adaptive management to modify rearing regimes as more data becomes available**

Growth rate was adjusted via ration (BY 2002-2004)



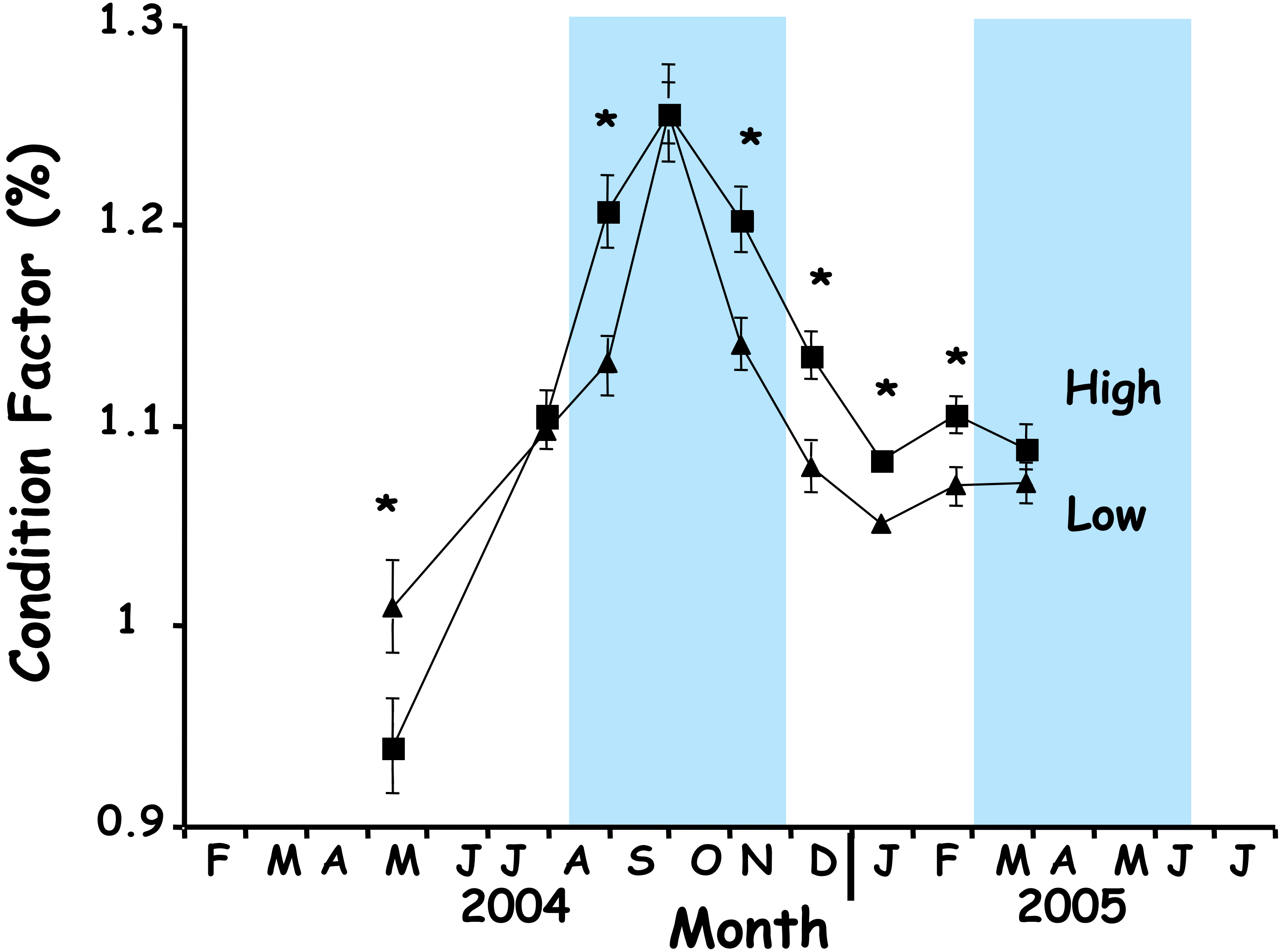
Results, to date, after three years

- Physiology
- Behavior
- Minijack rate
- Survival

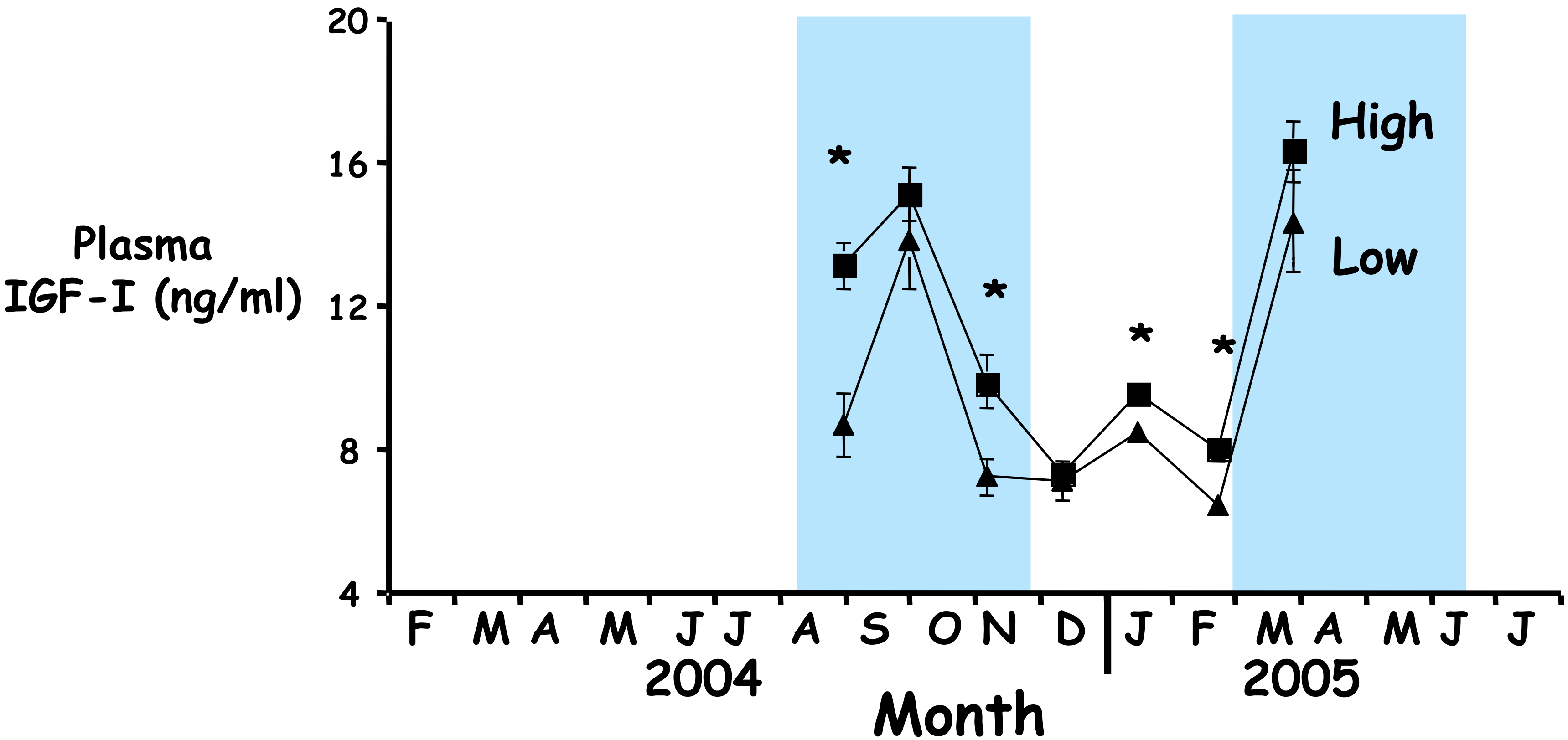
Results, to date, after three years

- **Physiology**
- **Behavior**
- **Minijack rate**
- **Survival**

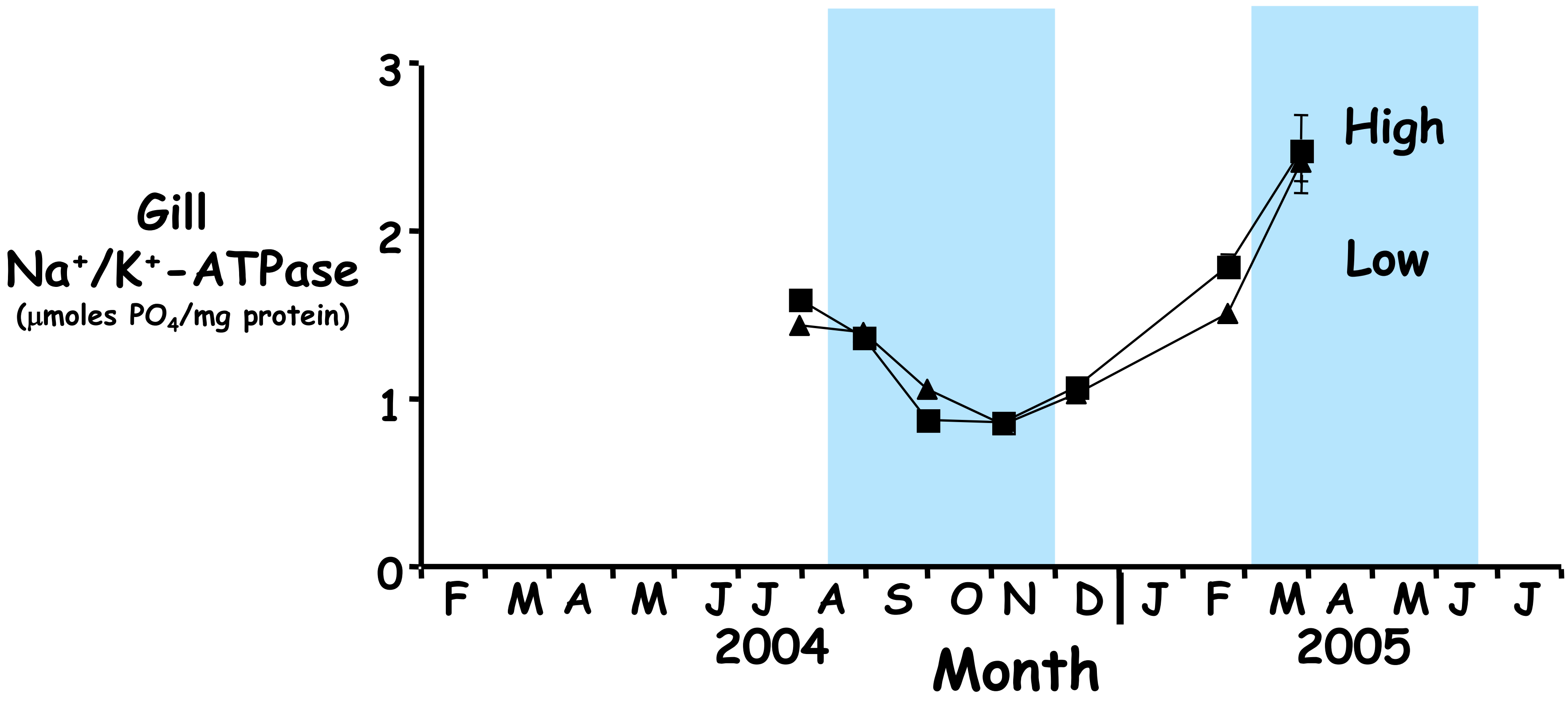
Condition factor is similar between treatments



Plasma IGF-I (growth regulating hormone) pattern is similar between treatments



Gill Na^+/K^+-ATPase activity (smolt indicator) is identical between treatments



Summary-Physiological Comparison

- With the exception of growth rate and release size, Low and High treatments are physiologically similar

Results, to date, after three years

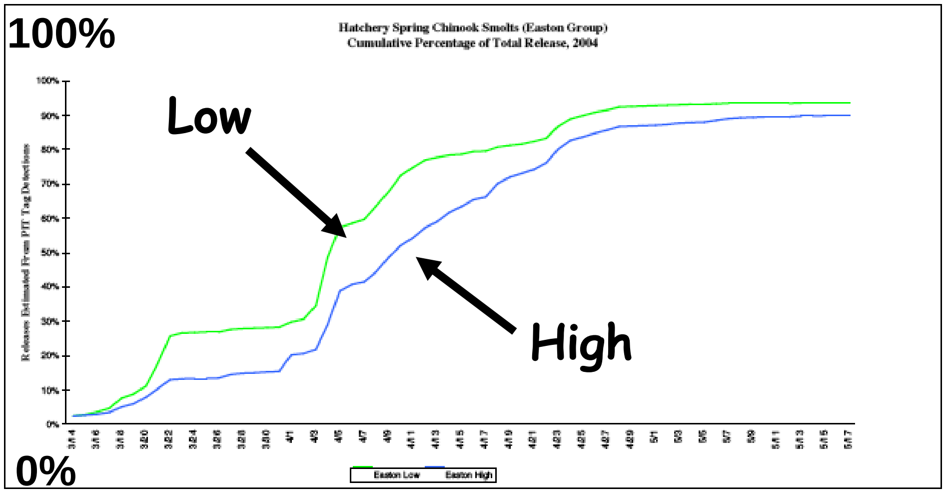
- Physiology
- **Behavior**
- Minijack rate
- Survival

Juvenile Outmigration Brood Year 2002

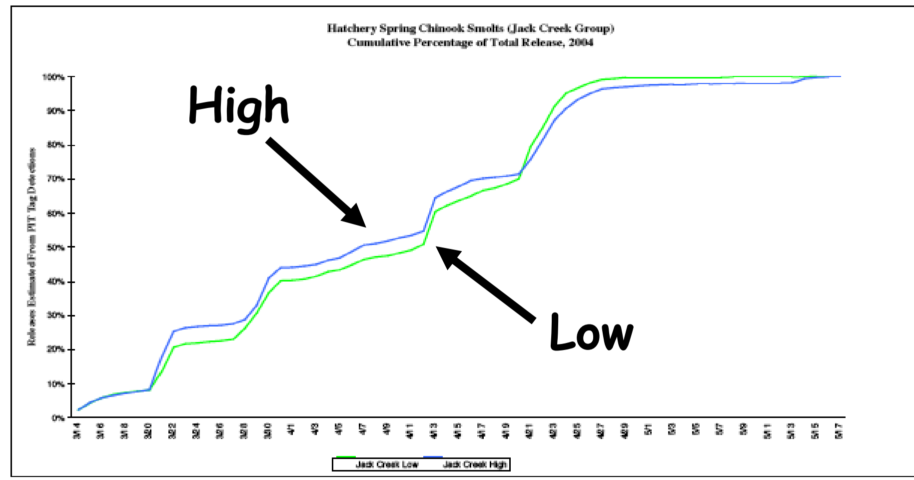
Earlier Volitional Migration

2 Low, 1 High

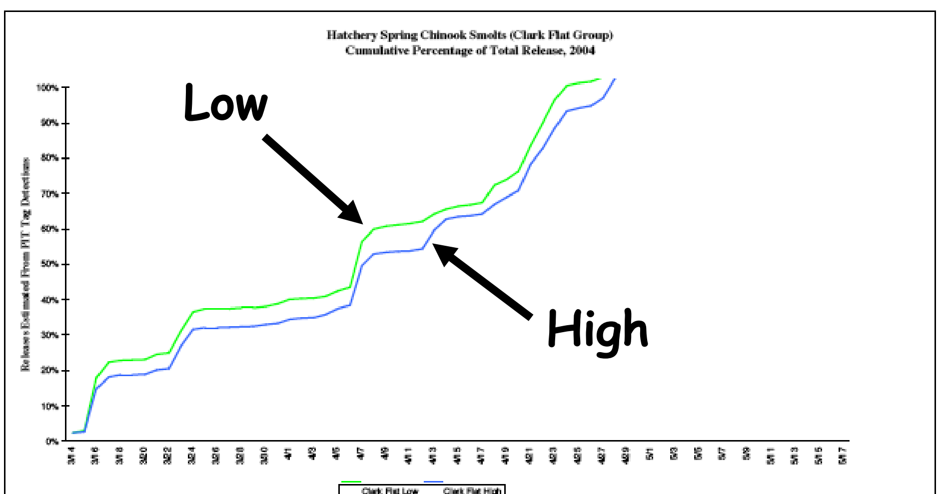
Easton



Jack Creek



Clark Flat



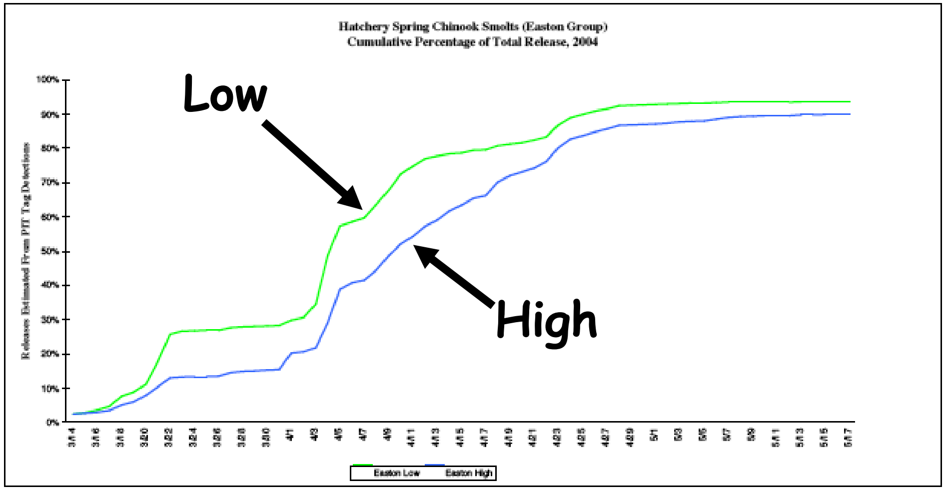
Data courtesy YKFP

Juvenile Outmigration Brood Year 2003

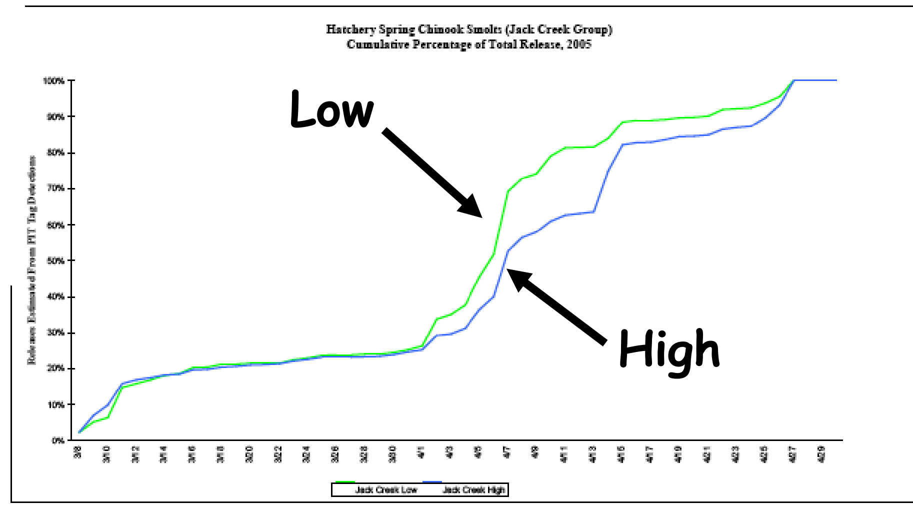
Earlier Volitional Migration

3 Low

Easton



Jack Creek



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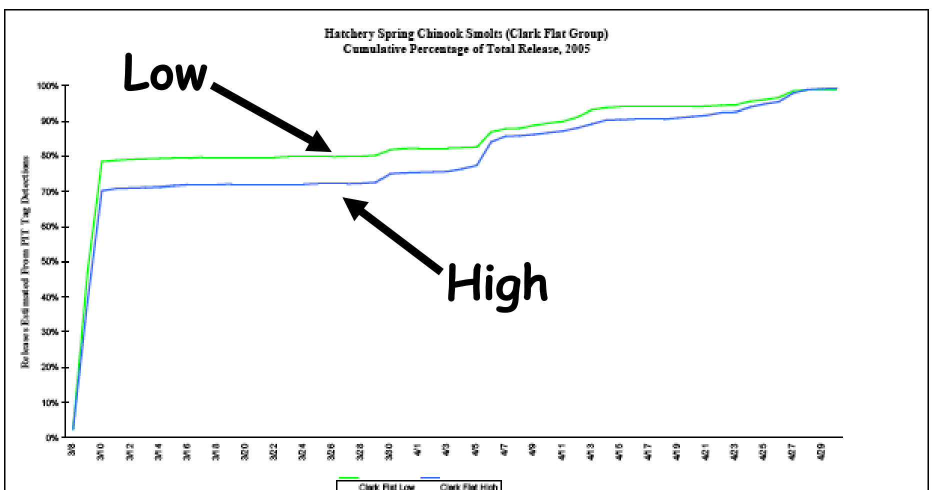


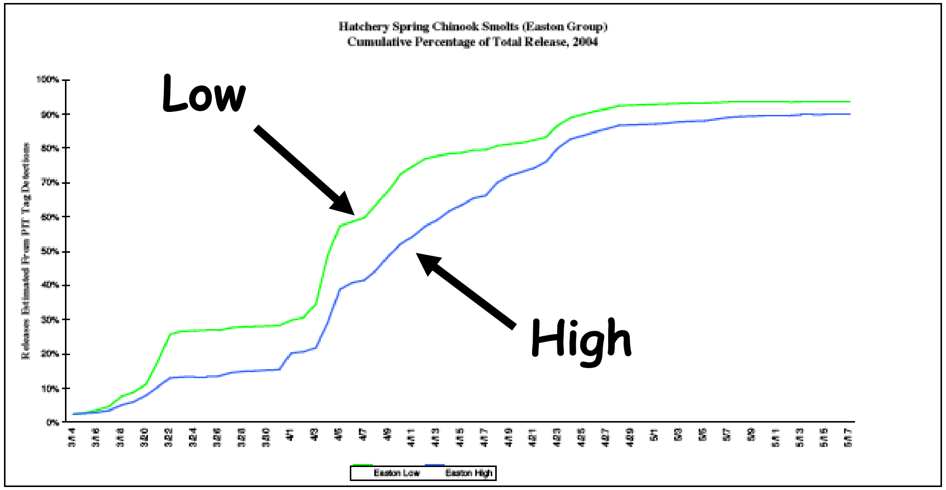
Data courtesy YKFP

Juvenile Outmigration Brood Year 2004

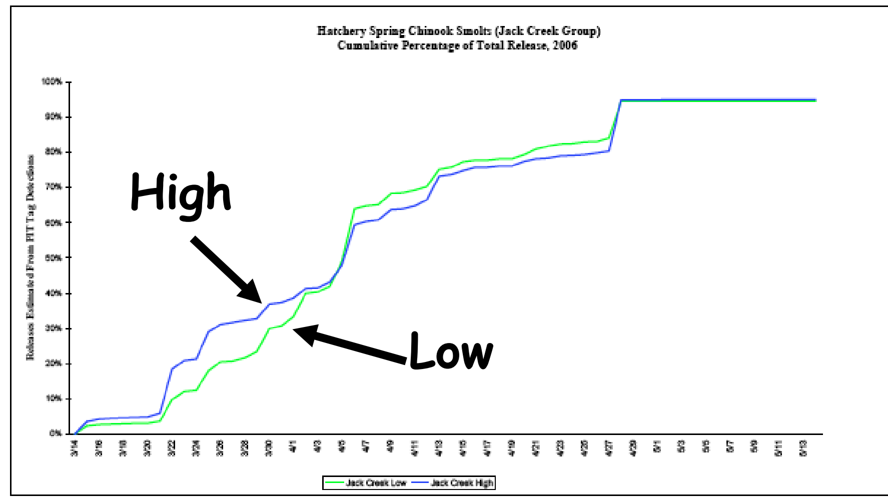
Earlier Volitional Migration

2 Low, 1 High

Easton



Jack Creek



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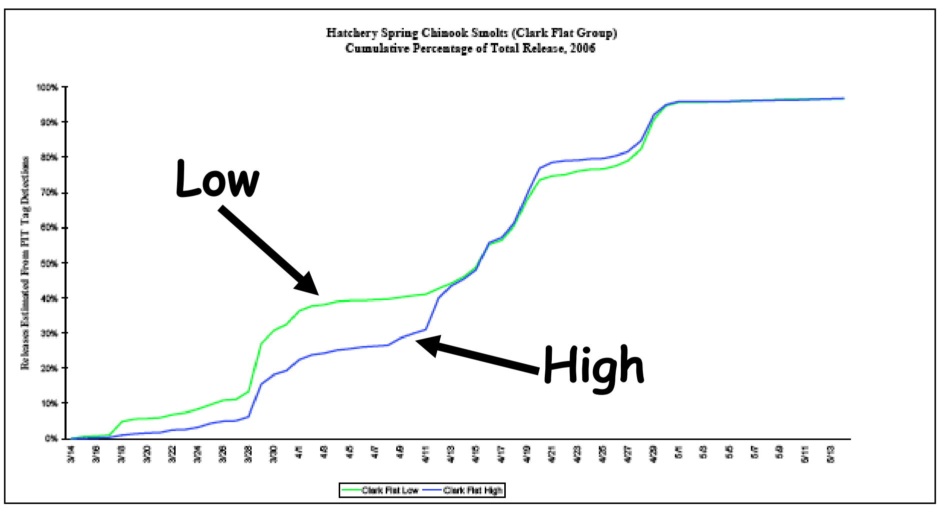


Data courtesy YKFP

Summary Behavior Comparison

- 7 of 9 (Yr. x acc. site) comparisons found Low treatment migrated from acclimation sites earlier than High treatment.

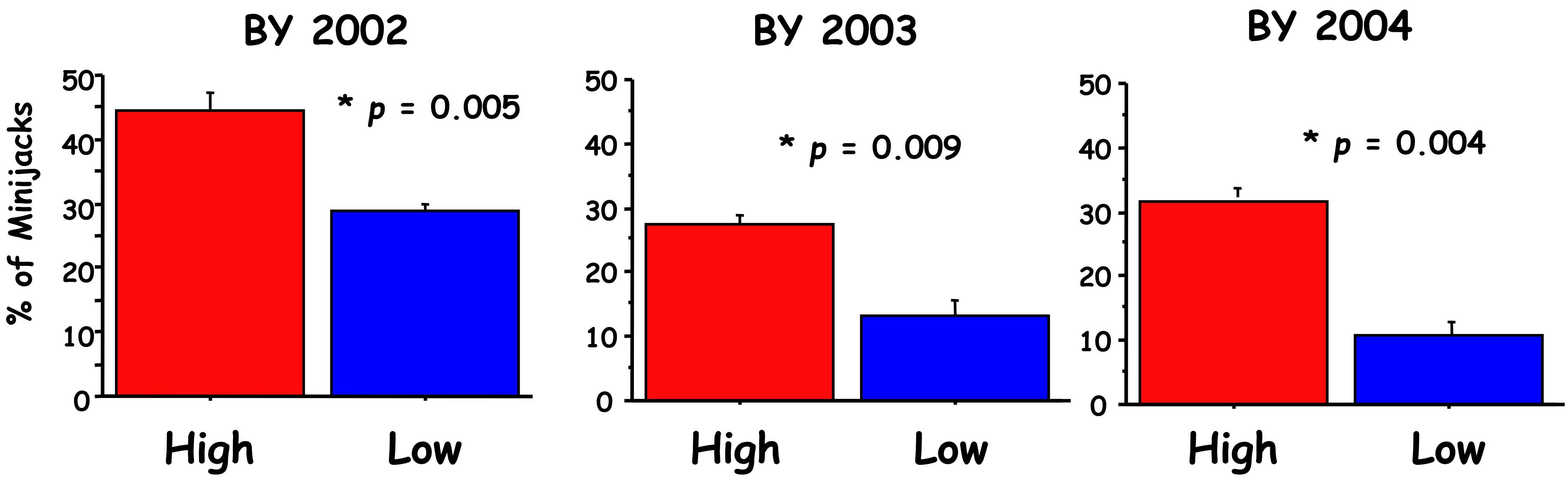
- Volitional migration behavior of Low Trt. is not delayed

- Slower migration of High Trt.may be reflection of higher proportion minijacks

Results, to date, after three years

- Physiology
- Behavior
- **Minijack rate**
- Survival

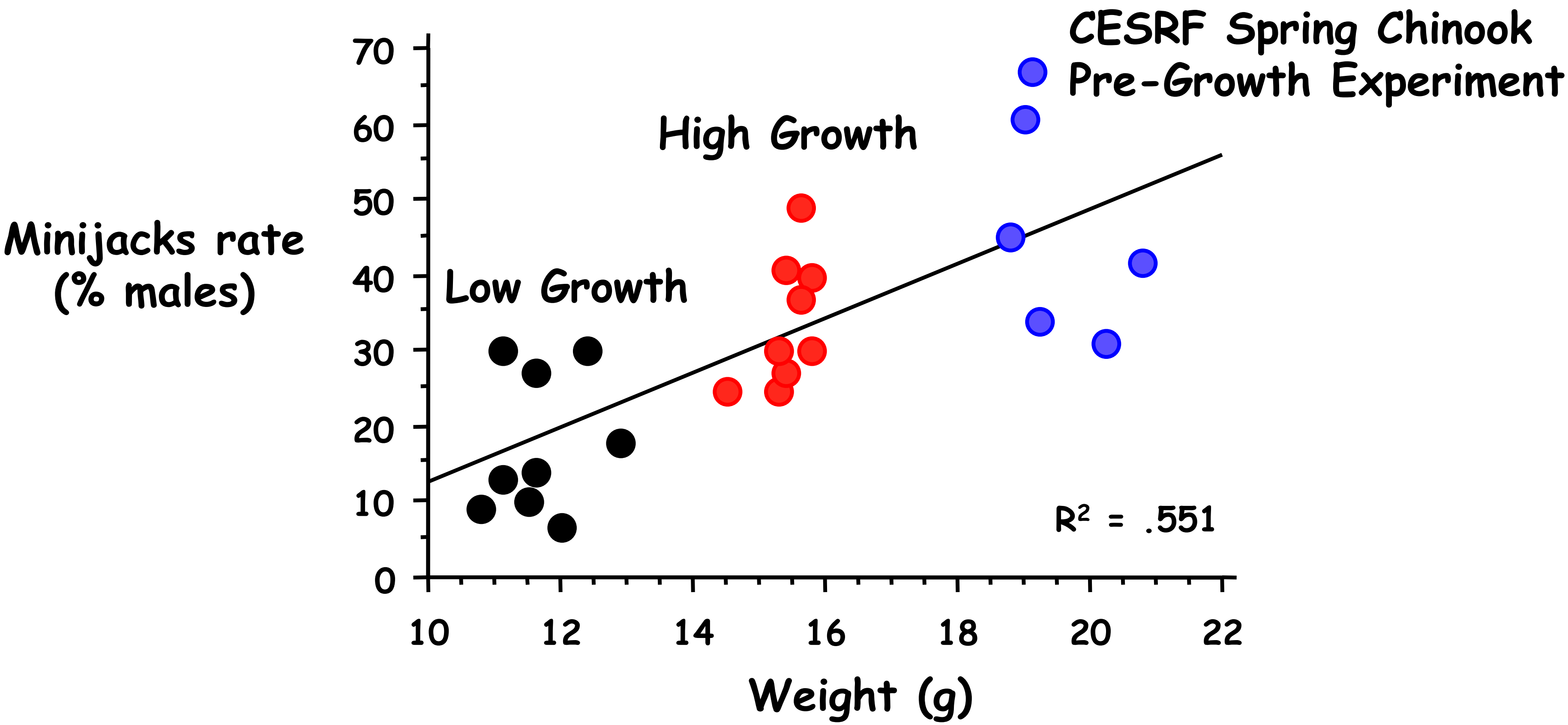
Minijack rates before release are consistently lower in the Low growth Trt. (all sites combined)



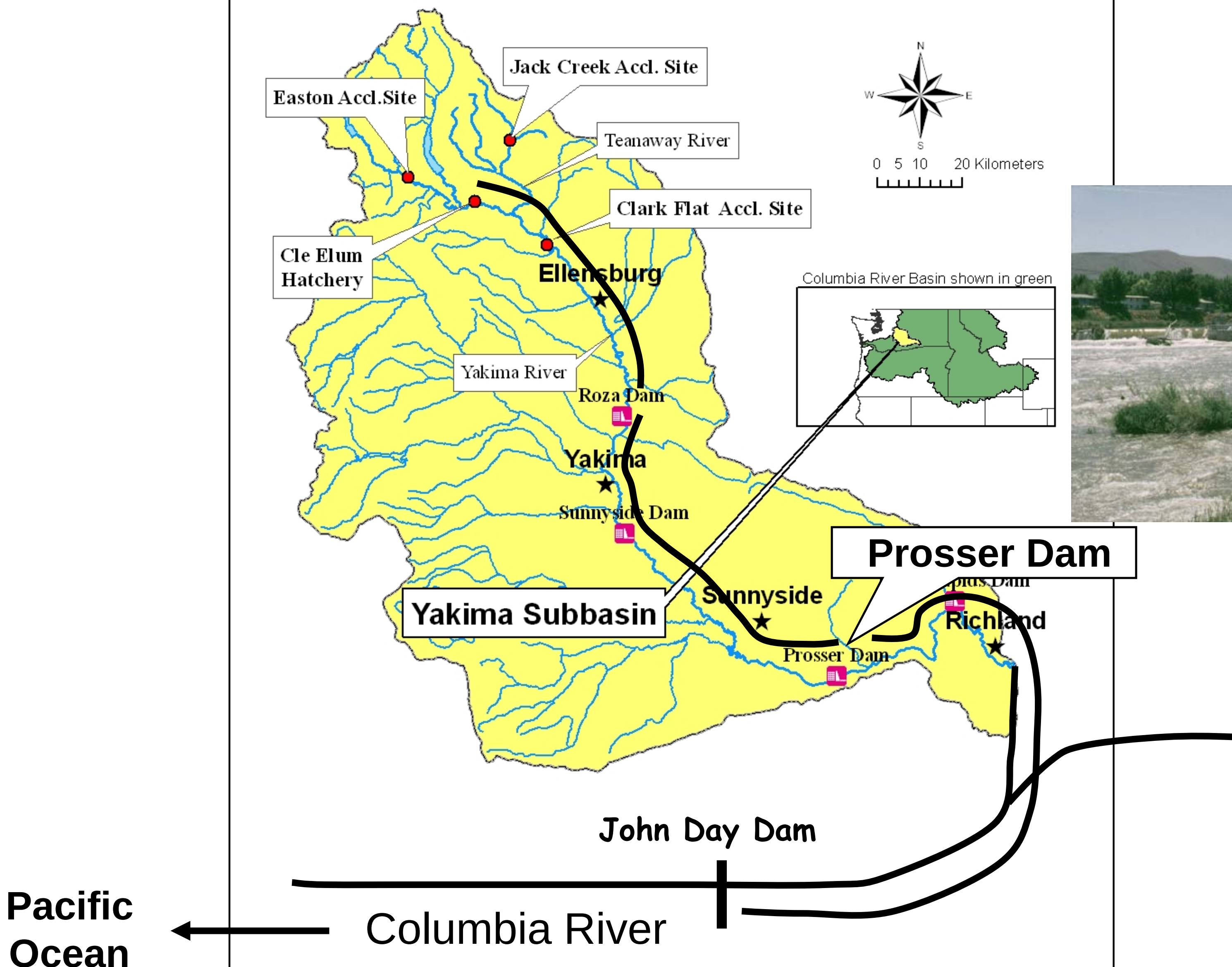
F:M	F:M	F:M	F:M	F:M	F:M
53:47	49:51	53:47	48:52	51:49	50:50

The bigger they are at release, the higher the minijack rate

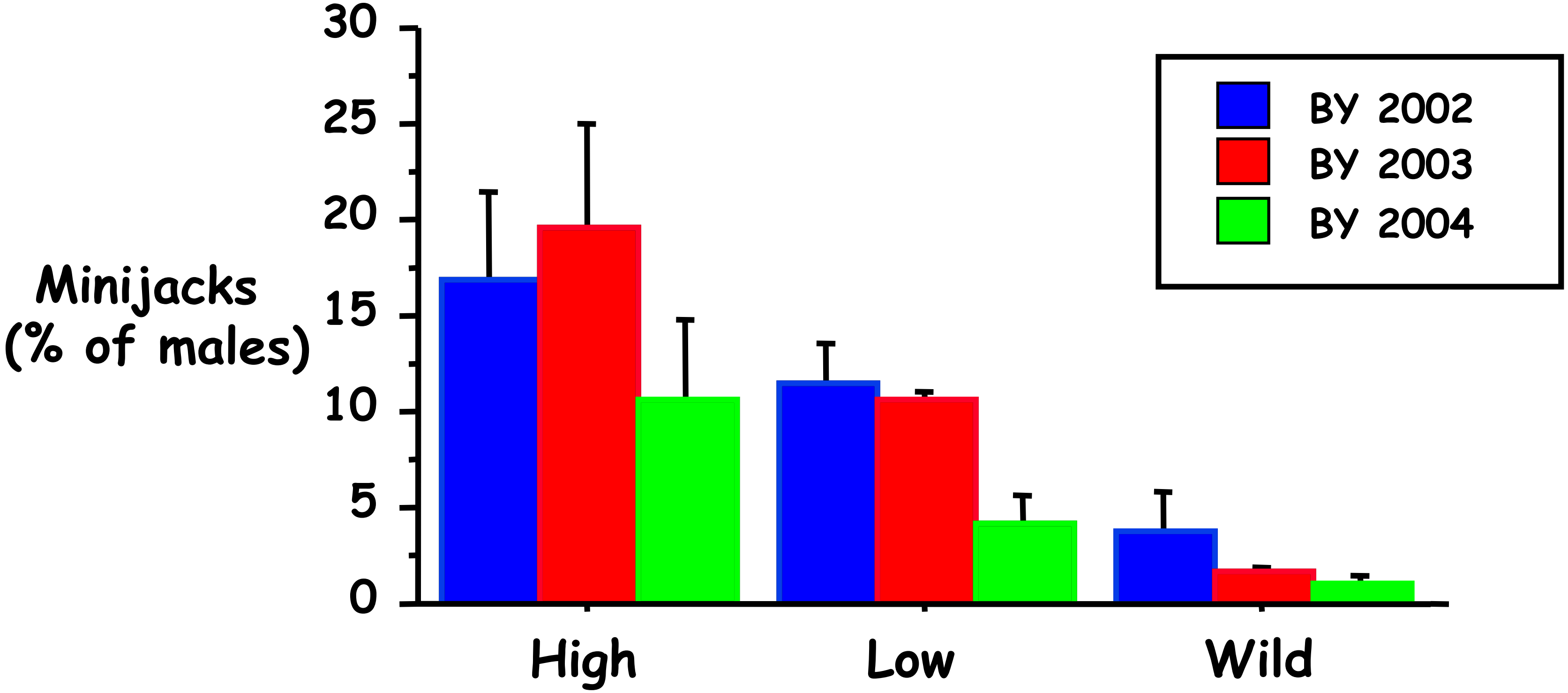
(BY X acc.site, BY 2000-BY 2004)



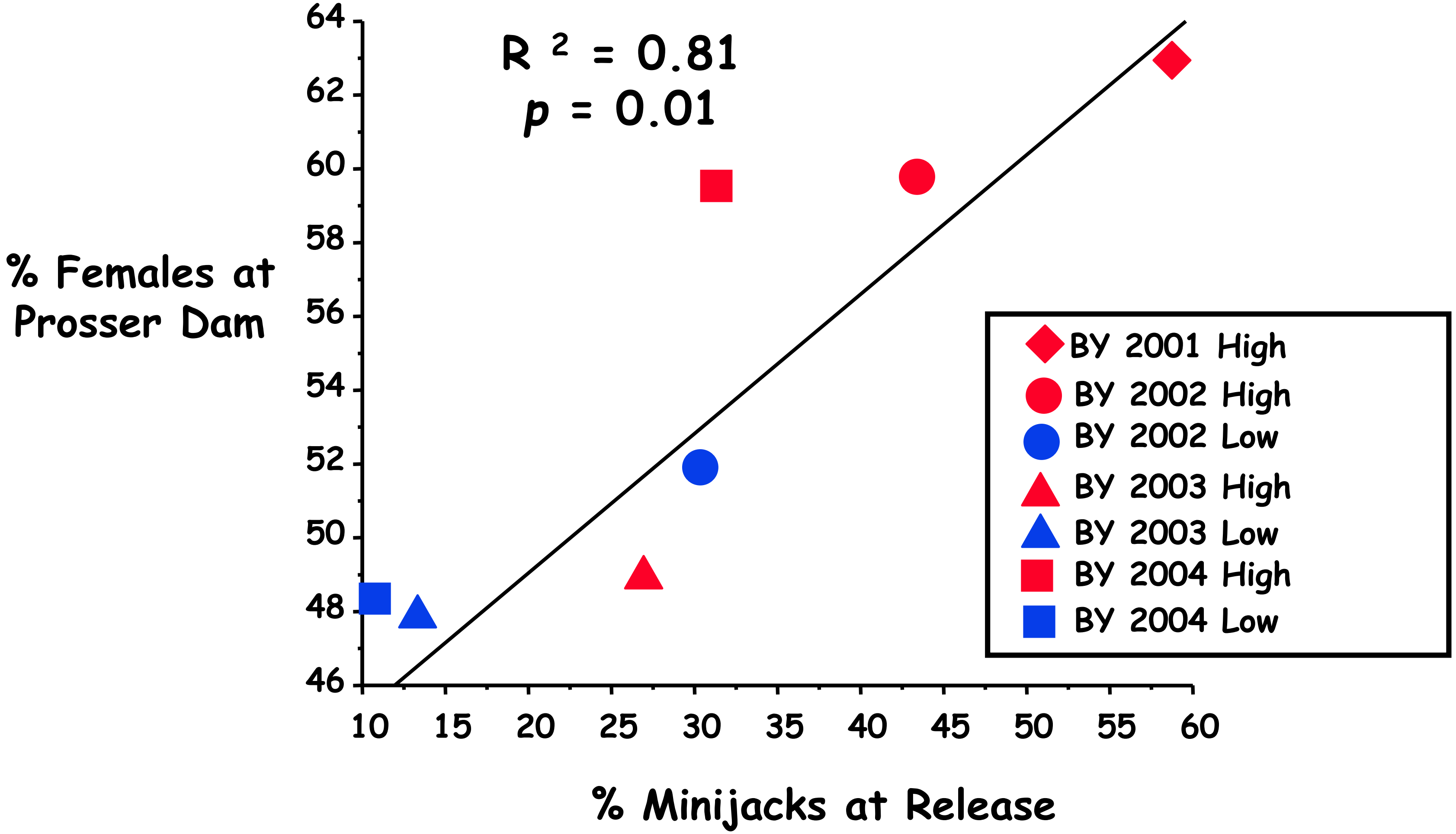
The Yakima River Basin



Minijack rates of migrating hatchery (High and Low Trt.) and wild fish are different



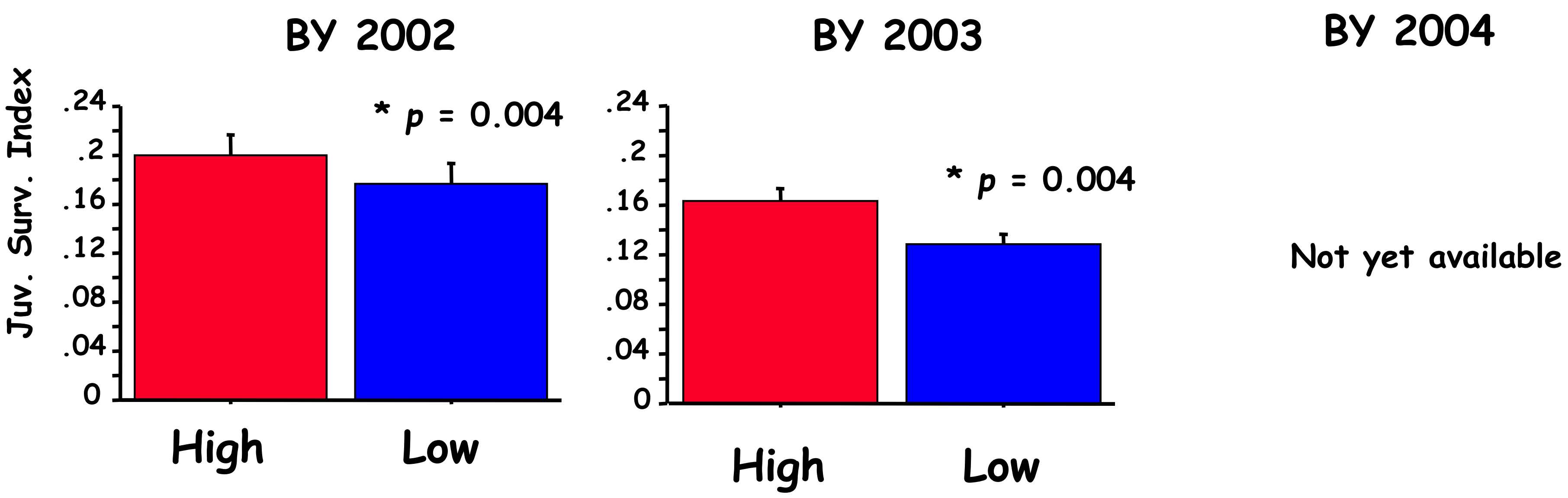
Higher minijack rates at time of release correlate with gender ratios skewed in favor of females during smolt migration



Results, to date, after three years

- Physiology
- Behavior
- Minijack rate
- **Survival**

Juvenile Survival Index to McNary Dam is lower for the Low growth fish

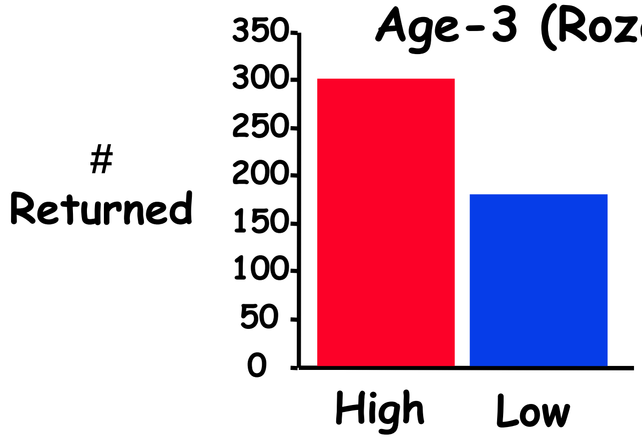


Modified from Neeley 2004, 2005

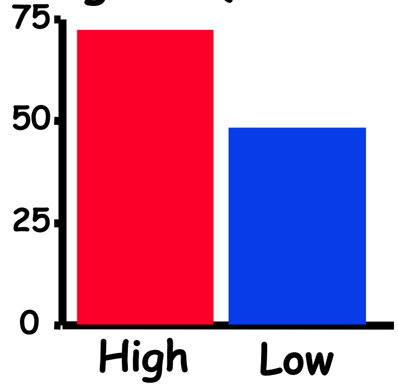
Adult Return, to date, is lower for Low Growth Trt.

BY 2002

Age-3 (Roza)



Age-4 (Bonn.PIT-tags)



Age-5

2007

BY 2003

Age-3 (Bonn. PIT-tags)

2006
PIT-tags: 2 High, 1Low

Age-4

2007

Age-5

2008

BY 2004

Age-3

2007

Age-4

2008

Age-5

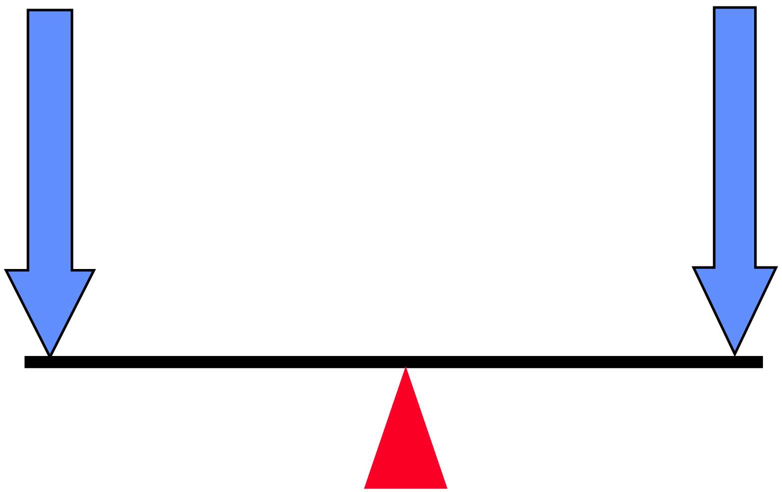
2009

Goals of production experiment

- **Maintain healthy physiological and behavioral condition of smolts**
- **Reduce minijack rates to conform with the wild fish template.**
- **Reduce potential ecological, genetic, demographic effects of high minijack rates.**
- **Obtain critical information regarding growth, size and SAR**
- **Use adaptive management to modify rearing regimes as more data becomes available**

Lower Growth Rate/Cold spring H_2O temp.
=
Small body size
=
Lower survival

Lower Growth Rate
=
Lower Minijack Rate



Henderson, M. A., and A. J. Cass. (1991). Effect of **smolt size on smolt-to-adult survival** for Chilko Lake sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences 48:988-994.

Martin, R. M. and A. Wertheimer. (1989). Adult production of Chinook salmon reared at different densities and released as two **smolt sizes**. Progressive Fish-Culturist 51:194-200.

Ward, B. R. and P. A. Slaney. (1988). Life history and smolt-to-adult survival of Keogh River steelhead trout (*Oncorhynchus mykiss*) and the relationship to **smolt size**. Canadian Journal of Fisheries and Aquatic Sciences 45:1110-1122.

Ward, B.R., P. A. Slaney, A. R. Facchin, and R. W. Land. (1989). **Size-biased survival** in steelhead trout (Oncorhynchus mykiss): back-calculated lengths from adults' scales compared to migrating smolts at the Keogh River, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:1853-1858.

Virtanen, E., L. Soderholm-Tana, A. Soivio, L. Forsman, and M. Muona. (1991). Effect of physiological condition and smoltification **status at smolt release** on subsequent catches of adult salmon. Aquaculture 97:231-257.

Question

How do we produce large fish that still grow slow in the autumn maturation initiation period?

Proposed experimental rearing regime