The effect of modulating ration and dietary lipid on growth, smolting and early male maturation in yearling Umatilla River fall Chinook salmon

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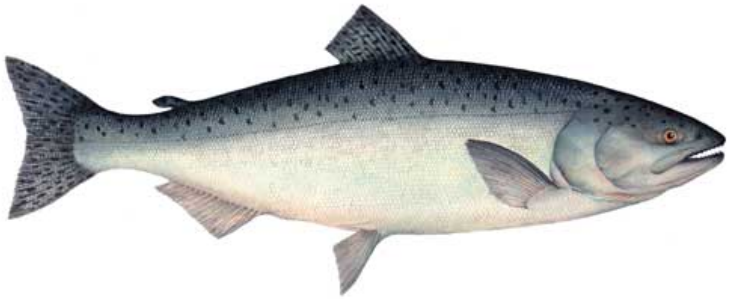
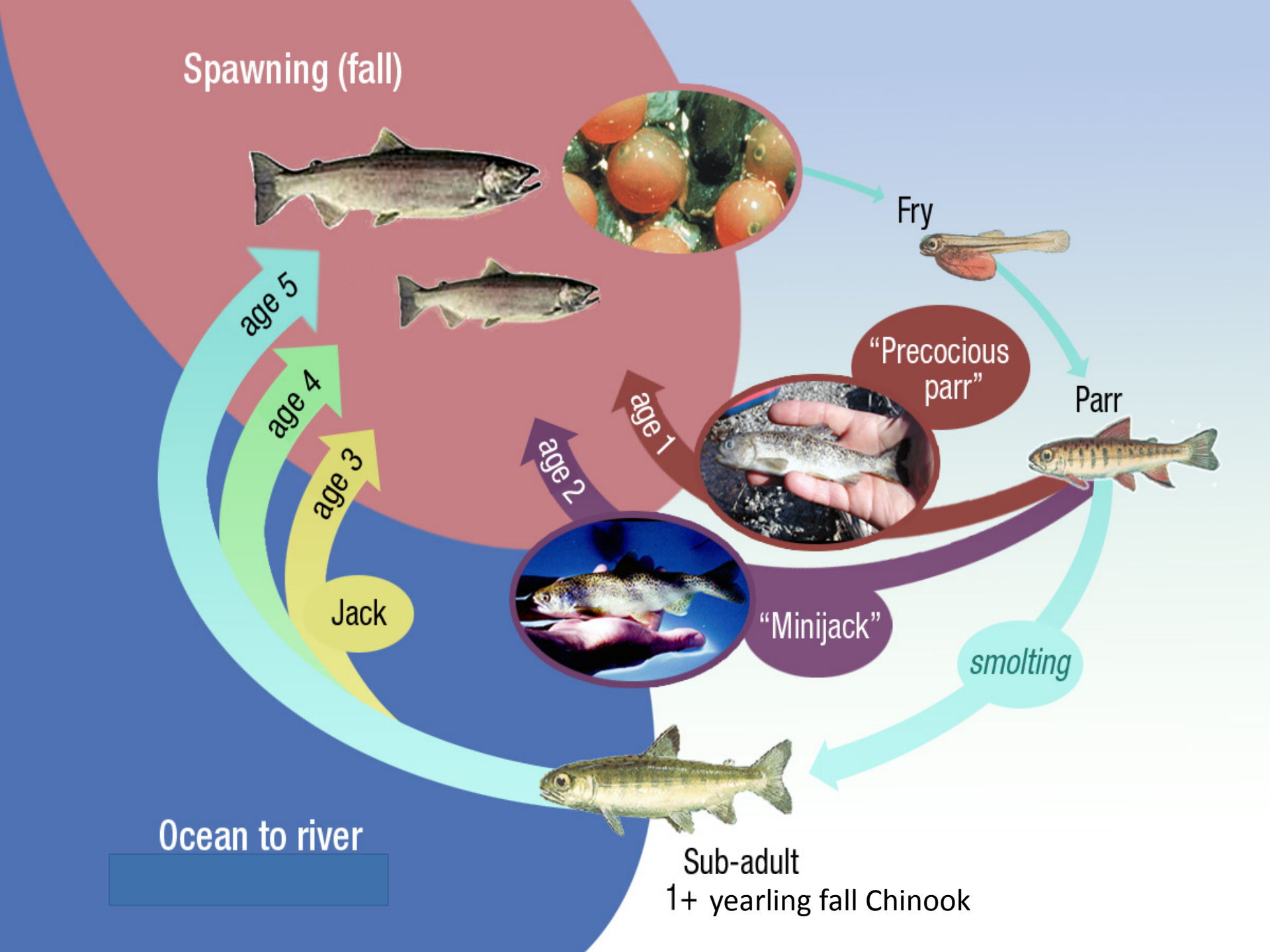


Chinook Salmon
Onchorhynchus tshawytscha


Spawning (fall)
Fry
Parr
"Precocious parr"
age 1
age 2
age 3
age 4
age 5
Jack
"Minijack"
smolting
Ocean to river
Sub-adult
1+ yearling fall Chinook

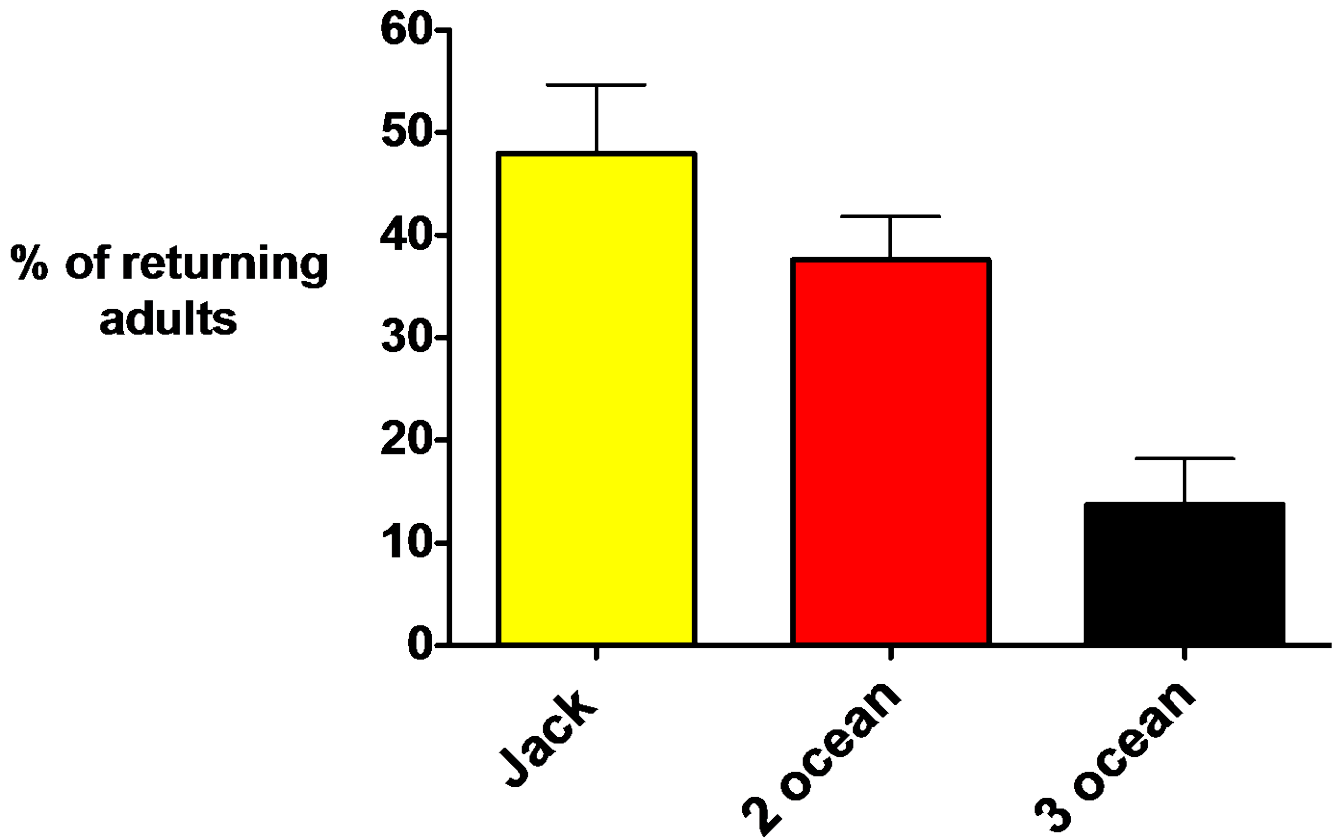
2002 -2009 Yearling Fall Chinook salmon Releases throughout the Columbia/Snake

- 10,996,006 fish released = Avg. 1,374,501/year
- 258,595 PIT-tags Implanted
- 6,478 PIT-tags detected in Bonneville Dam adult ladder

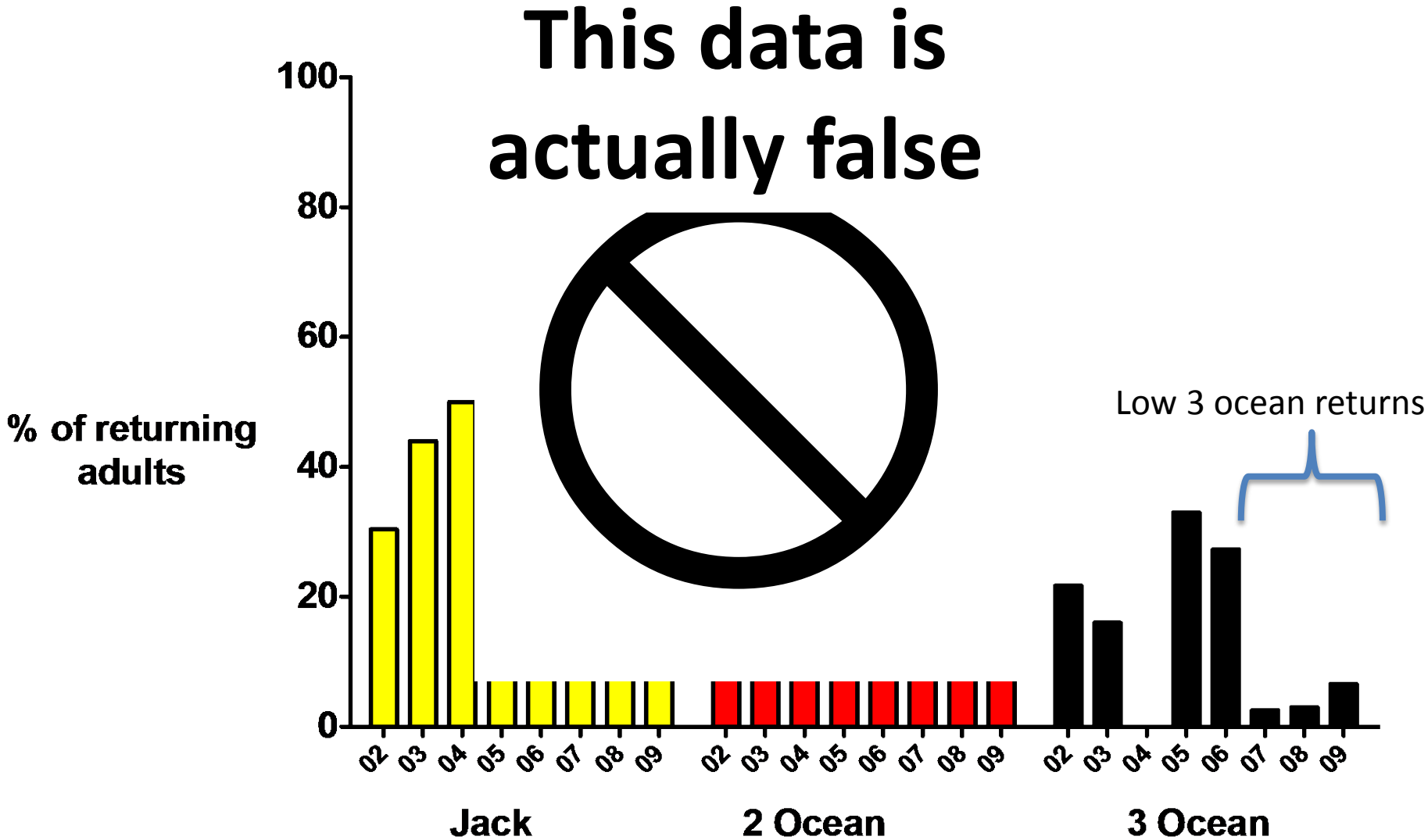
2.5% SAR

Passive integrated transponder tag = PIT tag

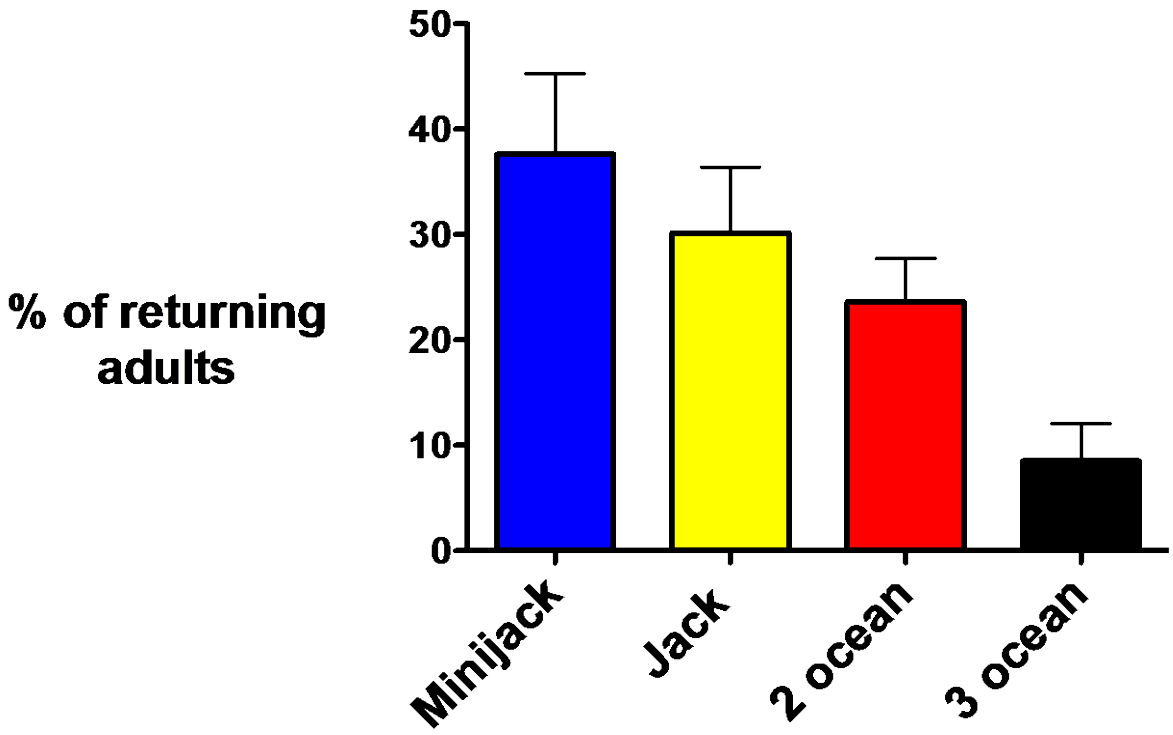
Almost 50% of the yearling reared fall Chinook salmon returning to Bonneville from 2002 to 2009 were Jacks

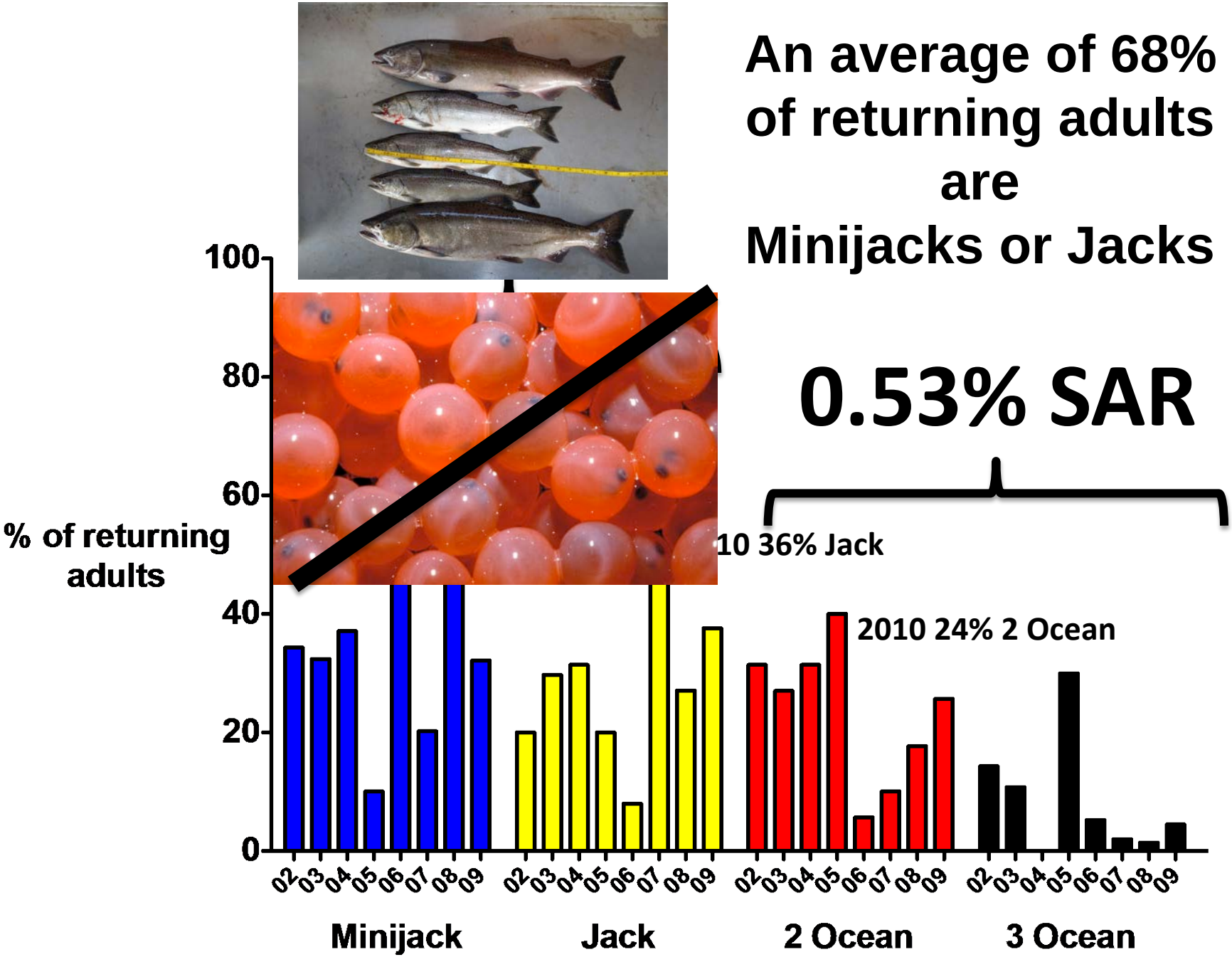


Jack returns have been especially high in recent release years

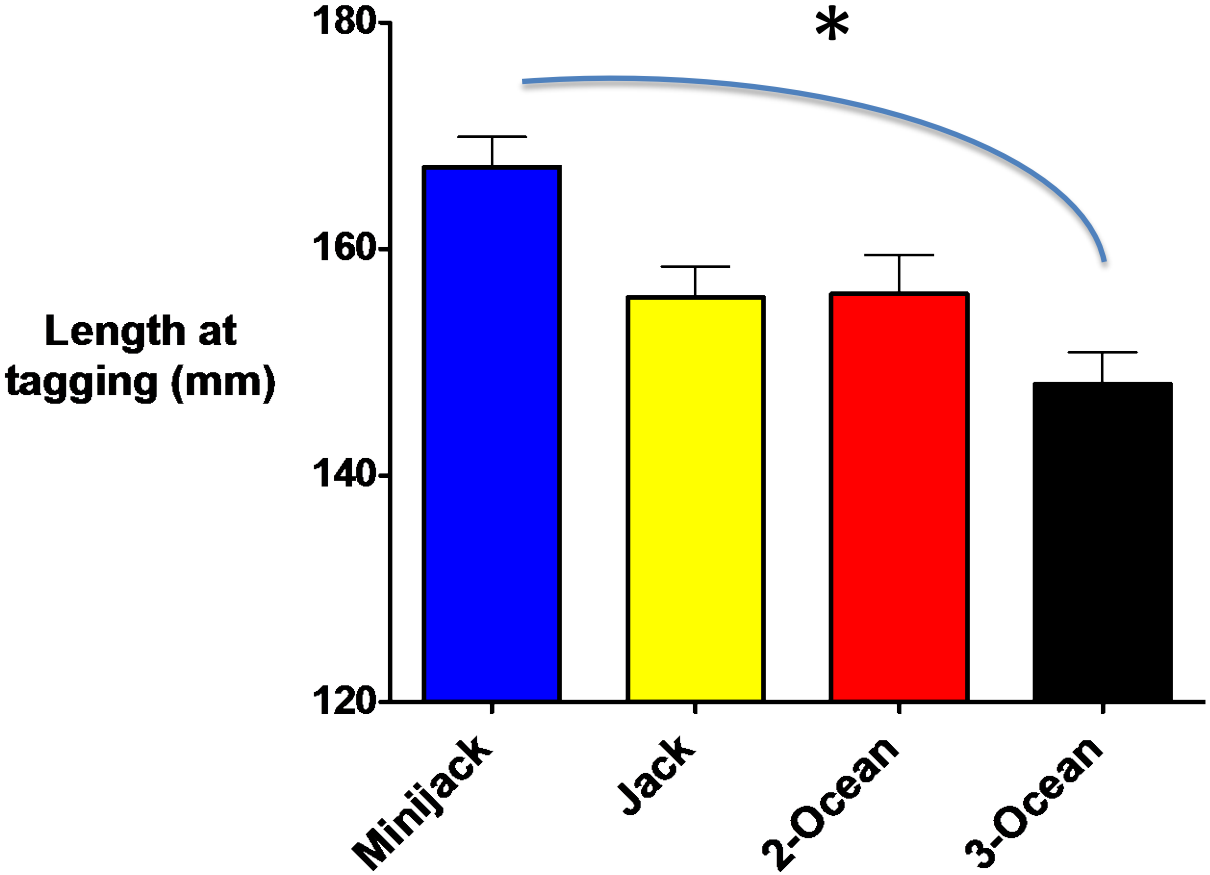


The greatest proportion of returning yearling fall Chinook salmon from 2002 to 2009 are actually *minijacks*




An average of 68% of returning adults are Minijacks or Jacks
0.53% SAR
% of returning adults
100
80
60
40
20
0
10 36% Jack
2010 24% 2 Ocean
02 03 04 05 06 07 08 09
Minijack
Jack
2 Ocean
3 Ocean

The larger the fish at tagging, the earlier the age at maturity



Questions to ponder

- **Is the yearling rearing strategy for fall Chinook salmon producing the desired result regarding recovery, recreation and harvest? Not all SAR's are created equal (i.e. Minijack vs. 3 Ocean).**

- **Is the yearling strategy best suited to a modern highly impounded, predator filled Snake/Columbia River? See Conner et al. 2005**

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[Article]

Two Alternative Juvenile Life History Types for Fall Chinook Salmon in the Snake River Basin

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Both wild and hatchery 0-age Snake R. fall Chinook salmon show a significant tendency to express a yearling freshwater life-history

Abstract.—Fall Chinook salmon *Oncorhynchus tshawytscha* in the Snake River basin were listed under the Endangered Species Act in 1992. At the time of listing, it was assumed that fall Chinook salmon juveniles in the Snake River basin adhered strictly to an ocean-type life history characterized by saltwater entry at age 0 and first-year wintering in the ocean. Research showed, however, that some fall Chinook salmon juveniles in the Snake River basin spent their first winter in a reservoir and resumed seaward movement the following spring at age 1 (hereafter, reservoir-type juveniles). We collected wild and hatchery ocean-type fall Chinook salmon juveniles in 1997 and wild and hatchery reservoir-type juveniles in 1998 to assess the condition of the reservoir-type juveniles at the onset of seaward movement. The ocean-type juveniles averaged 112–139 mm fork length, and the reservoir-type juveniles averaged 222–224 mm fork length. The large size of the reservoir-type juveniles suggested a high potential for survival to salt water and subsequent return to freshwater. Scale pattern analyses of the fall Chinook salmon spawners we collected during 1998–2003 supported this point. Of the spawners sampled, an overall average of 41% of the wild fish and 51% of the hatchery fish had been reservoir-type juveniles. Males that had been reservoir-type juveniles often returned as small ''minijacks'' (wild, 16% of total; hatchery, 40% of total), but 84% of the wild males, 60% of the hatchery males, and 100% of the wild and hatchery females that had been reservoir-type juveniles returned at ages and fork lengths commonly observed in populations of Chinook salmon. We conclude that fall Chinook salmon in the Snake River basin exhibit two alternative juvenile life histories, namely ocean-type and reservoir-type.

Questions to ponder

1. Is the yearling rearing strategy for fall Chinook salmon producing the desired result regarding recovery, recreation and harvest? Not all SAR's are created equal (i.e. Minijack vs. 3 Ocean).

1. Is the yearling strategy best suited to a modern highly impounded, predator filled Snake/Columbia River? See Conner et al. 2005

2. **If the answer to #2 is yes……then……. How can we optimize survival while minimizing alterations to life-history?**

Variation in Age of Male Maturity

Mature male salmon

Factors Affecting Age of Maturation

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

Growth & Body energy stores

The Hatchery environment can significantly influence age of maturation

Two key factors that numerous studies have shown can be manipulated in the hatchery to affect salmon life-history

- **Growth rate / size in the first year**
- **Dietary lipid level**

Umatilla River Yearling URB fall Chinook Salmon Supplementation program

"The primary goal of the Umatilla River fall Chinook program is to reintroduce fall Chinook for harvest in the Umatilla and Columbia rivers while rebuilding and maintaining adequate hatchery and natural production." Umatilla Fall Chinook HGMP

Program Issues

- **Low 2 and 3-Ocean returns**
- **High minijack rates (Since 2002 56% of returning adults have been minijacks)**

Experimental Design

- Four year rearing study

brood years	2010 - 2013
released in	2012 - 2015
adults return	2012 - 2018

- 4 Treatments

60,000 Hi Fat Hi Ration (Std.)	60,000 Hi Fat Lo Ration	60,000 Lo Fat Hi Ration	60,000 Lo Fat Lo Ration

- Rangen feed with 19% or 11 % lipid and High (Std.) vs. Low ration from ponding to Dec. 1 of year 2 then all fish on High Fat / High Ration until release.

- Monitor growth/size, body lipid, smolting, early male maturation

- Monitor post-release performance (20,000 CWT + 2,000 PIT-tags per treatment per year).

Rearing Regime

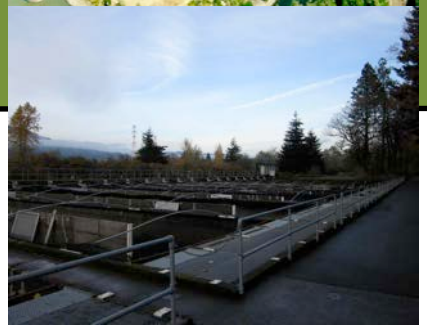
3. In early February differentially tagged smolts trucked back to an acclimation pond on Umatilla R.

Experimental Subgroup

4. In April smolts are released

Umatilla R.

Bonneville Hatchery



1. Returning adults are collected for gametes at Three Mile Falls Dam on the Umatilla River

2. Juveniles are reared at Bonneville Hatchery under a yearling 2x2 regime manipulating dietary fat and ration

Sampling

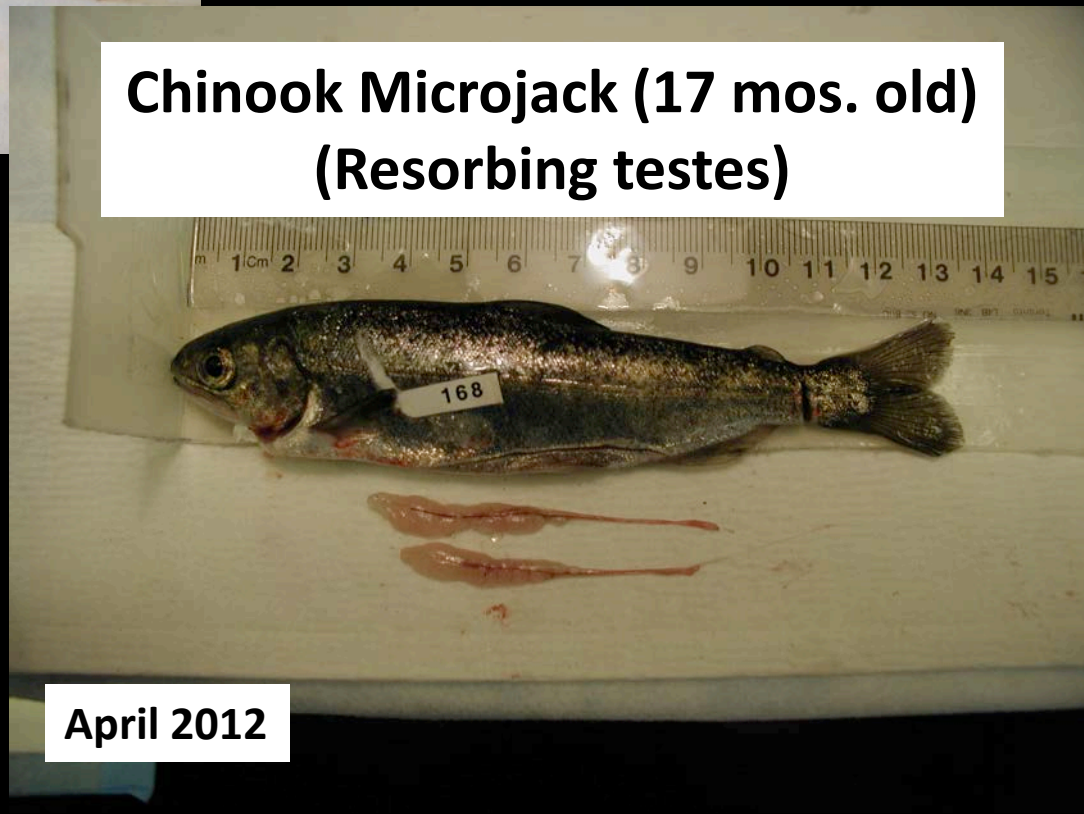
(monthly Sept.-Apr)

- **Random grab of 25 fish/ treatment**
- **Measure length, weight, condition factor, sex**
- **Collect gill tissue for Na+/K+-ATPase activity (salt pump-smolt indicator)**
- **Collect carcasses for body fat determination**
- **At the time of release in spring measure 300 fish from each treatment for early male maturation (microjacks and minijacks) via morphology and plasma 11-ketotestosterone levels**

How do we ID an age-1 microjack?

Chinook Microjack (12 mos. old)
(Running)

Nov. 2011

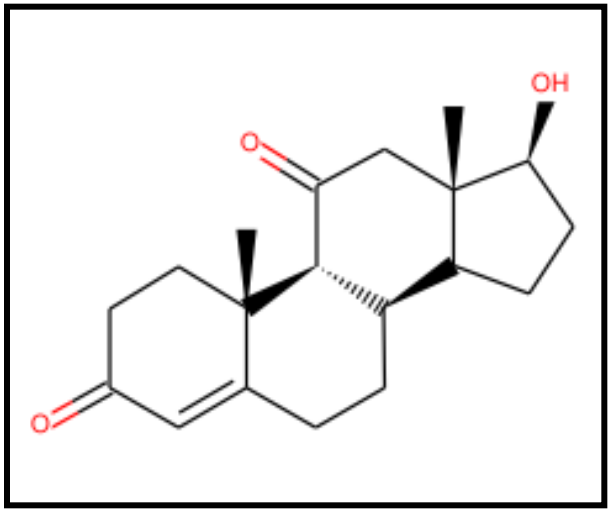


Chinook Microjack (17 mos. old)
(Resorbing testes)

April 2012

How do we ID an age-2 minijack?

Plasma 11-ketotestosterone (11-KT)



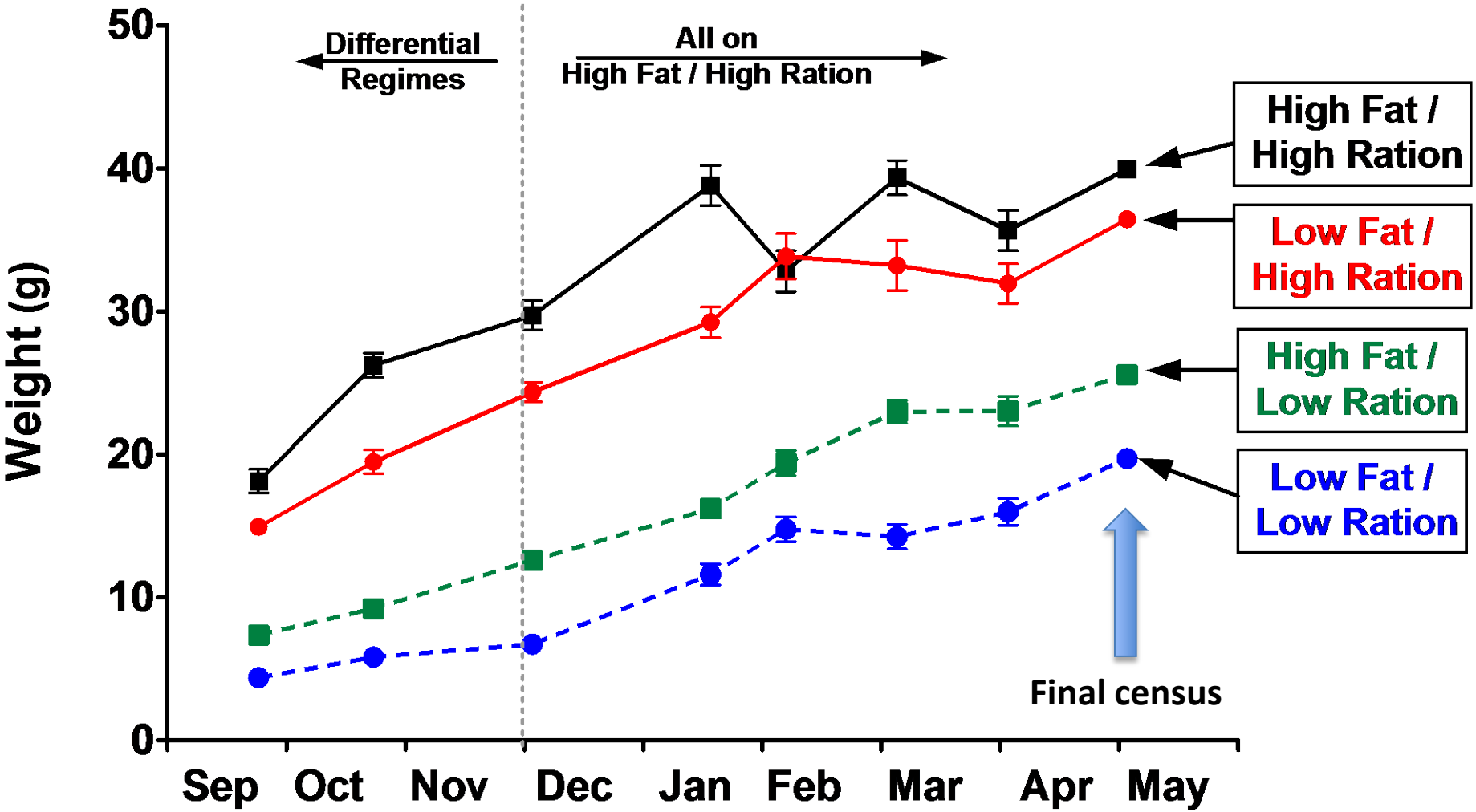
- **Major androgen in teleost fish**
- **Regulates spermatogenesis**
- **This hormone tells us which male fish are minijacks**

see Larsen et al. 2004 TAFS

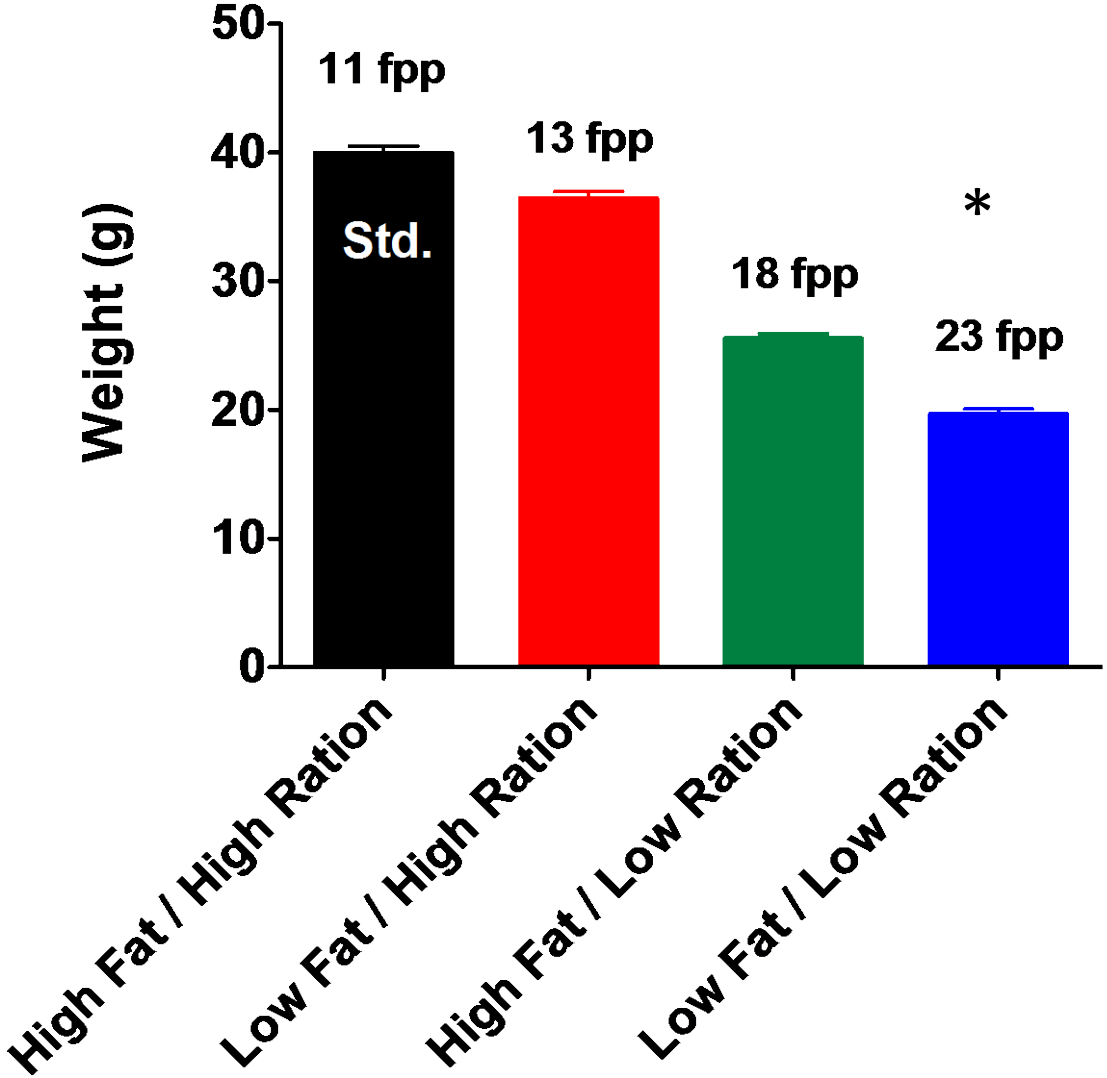
Results

Size and Fat

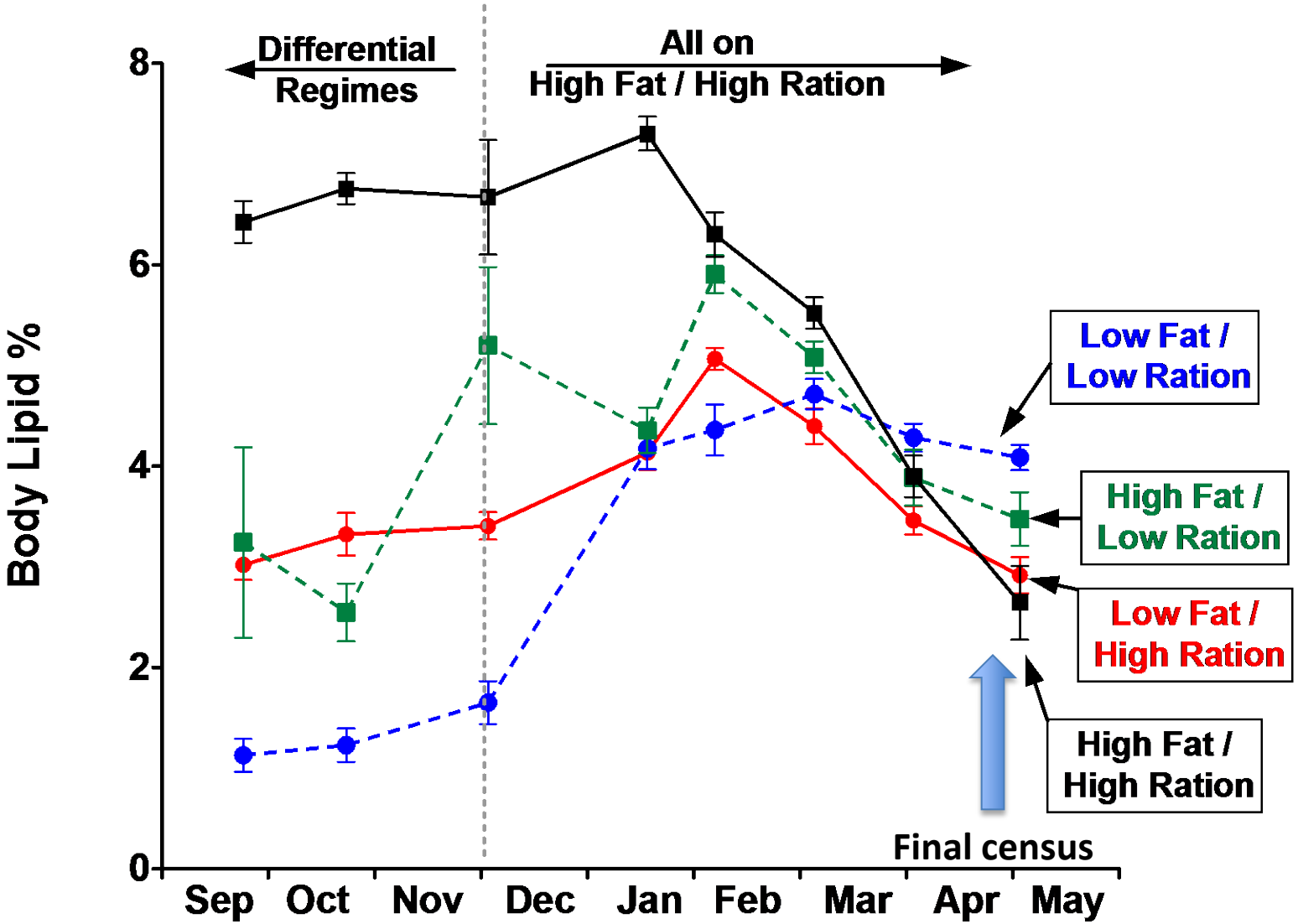
Growth rates and rank order of treatments were consistent throughout the study



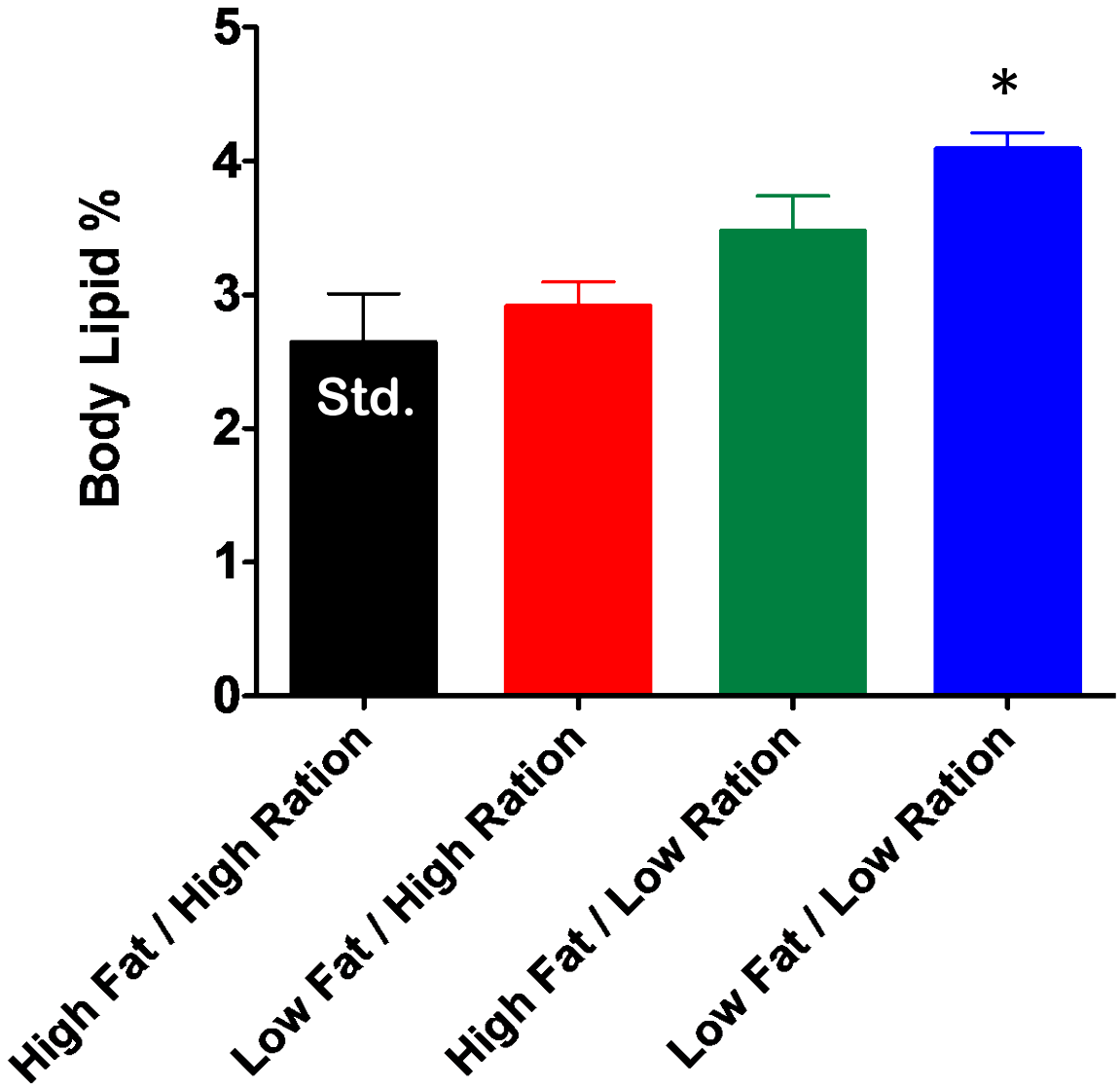
Size at release is highest in the High Fat / High ration treatment and lowest in the Low Fat / Low Ration treatment



Lipid levels clearly reflect treatments in autumn, peak in winter, then all decrease with smolting



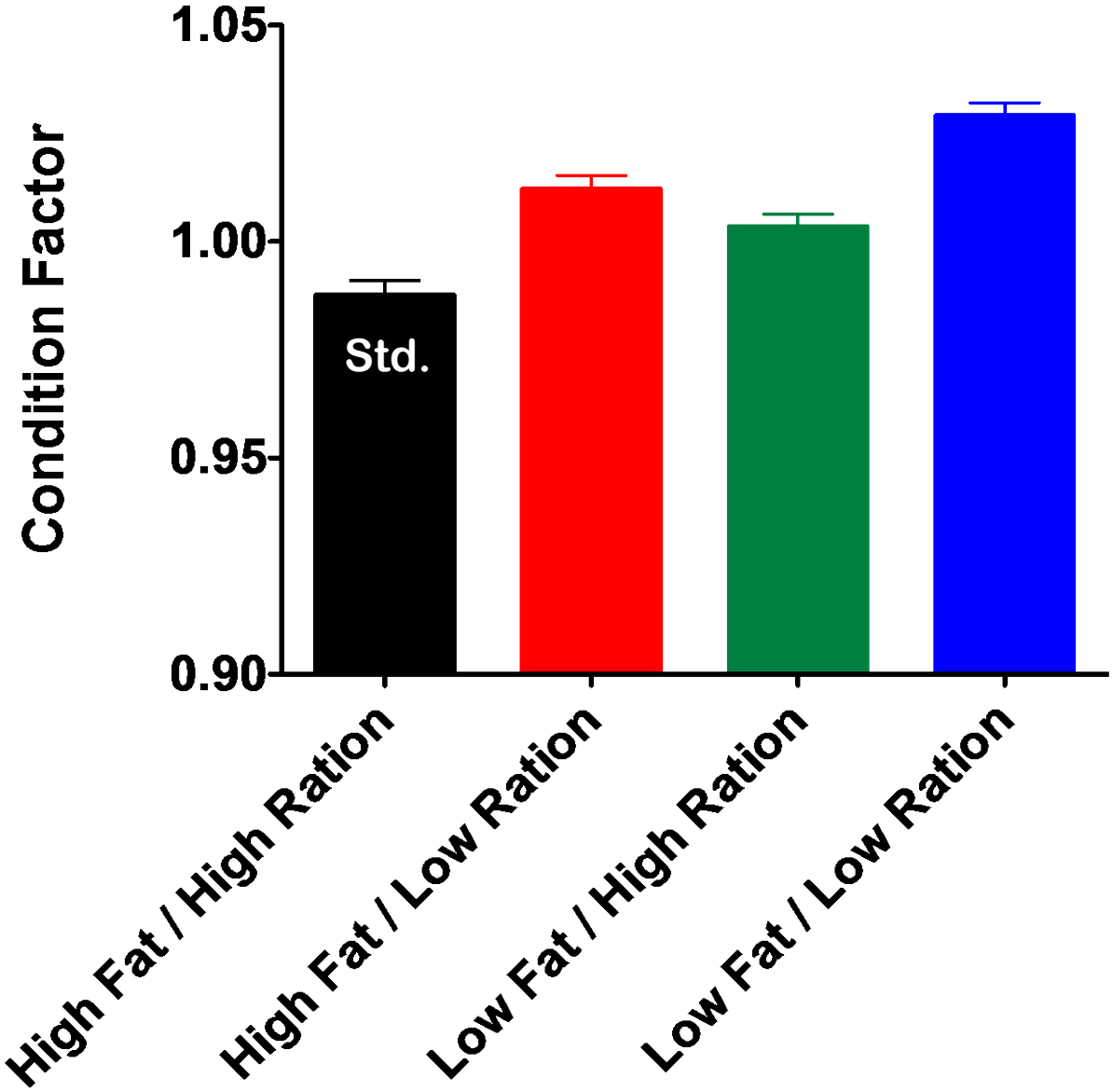
Lipid stores at release are lowest in the High Fat / High Ration and highest in the Low Fat / Low Ration treatment



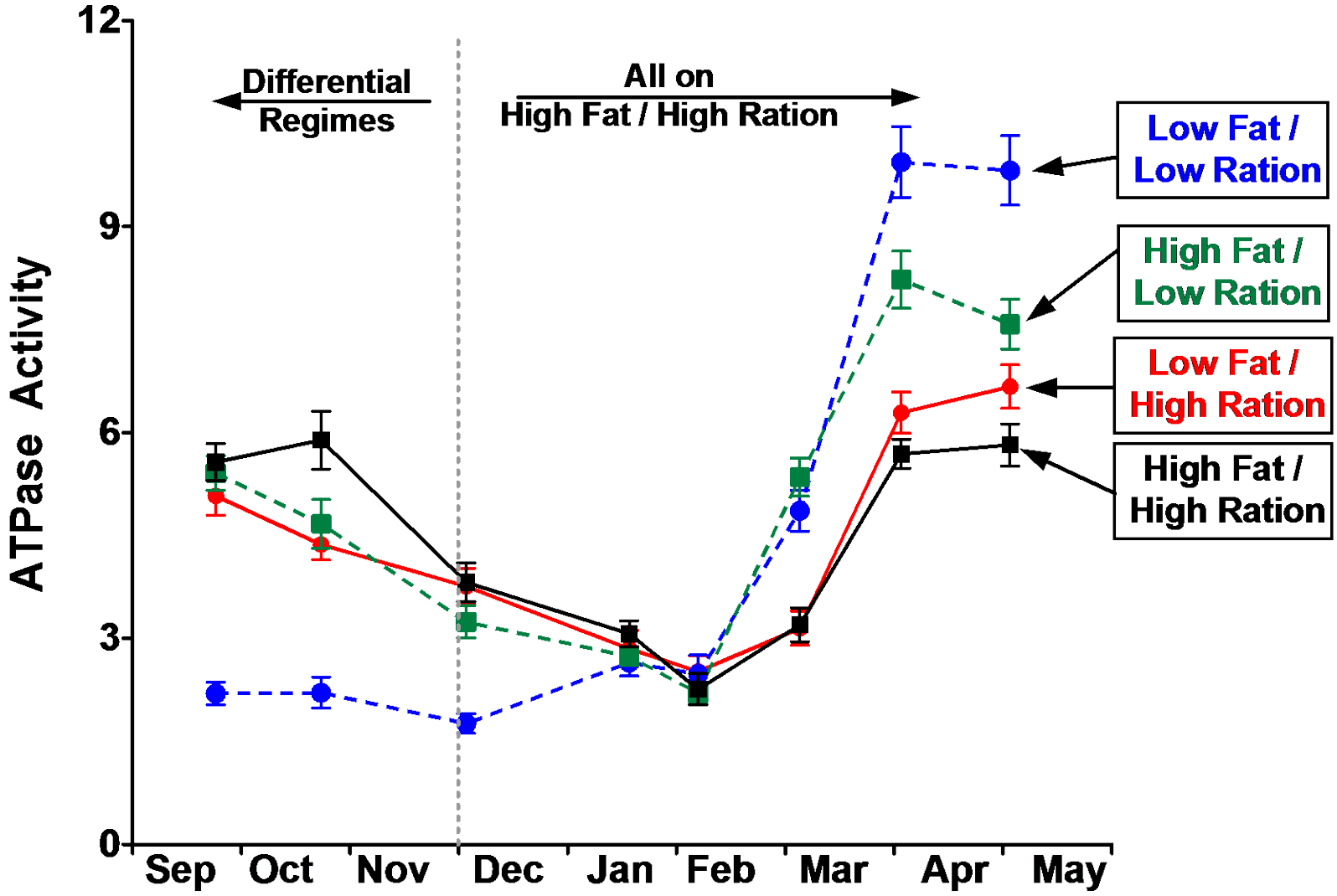
Results

Smolt development

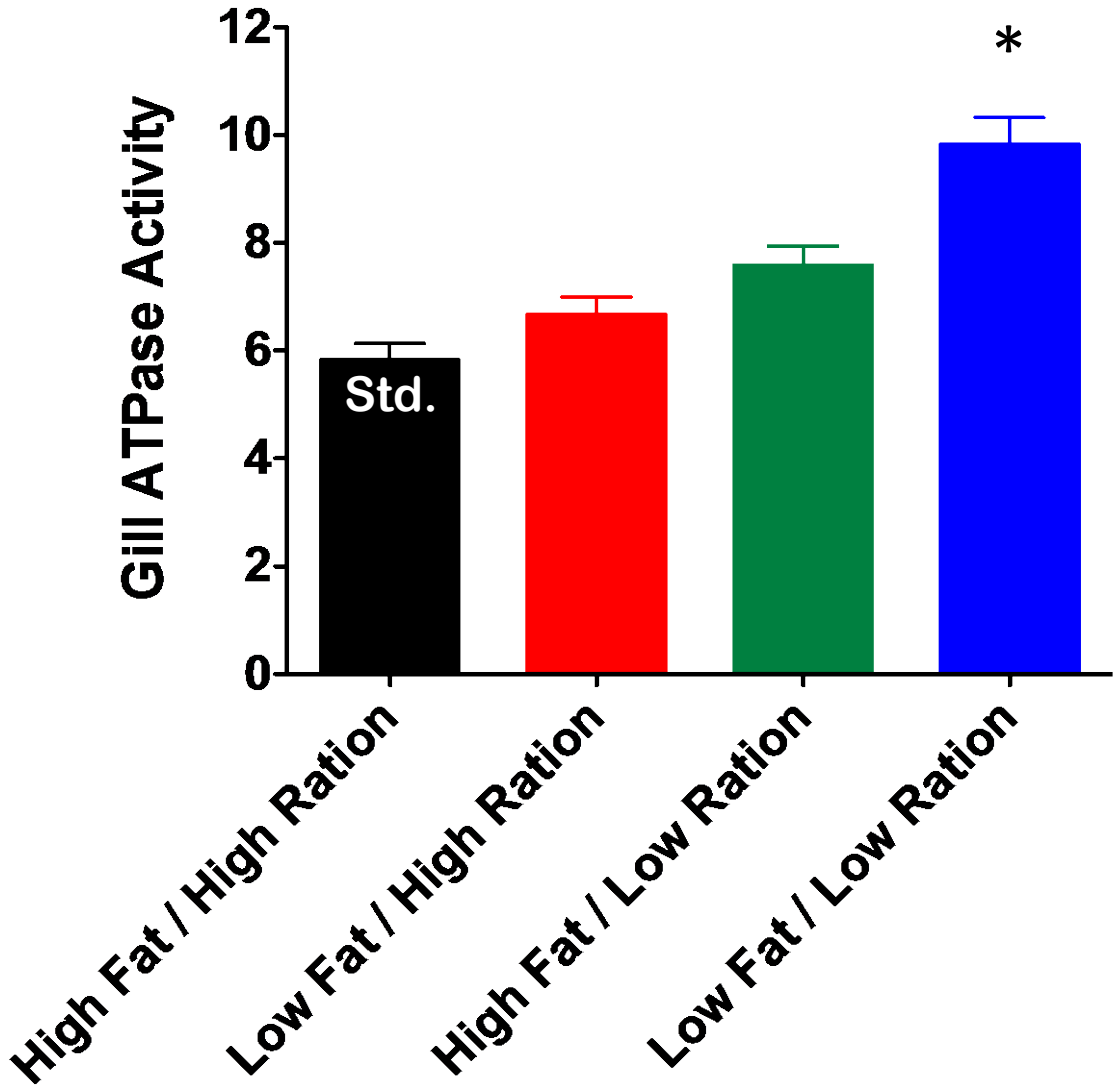
K at release is lowest in the High Fat / High Ration and highest in the Low Fat / Low Ration treatment



The Low Fat / Low Ration fish did not smolt in the fall, but had the highest levels at release

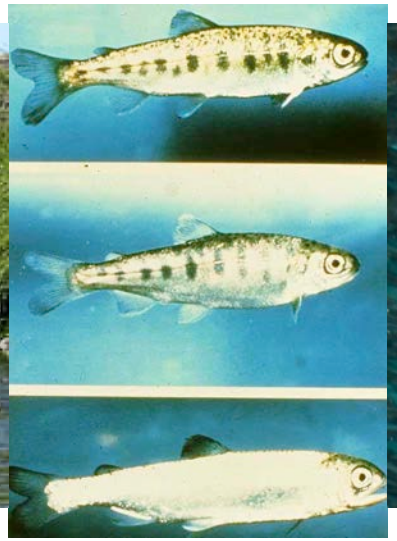


Gill ATPase activity at release is lowest in the High Fat / High Ration and highest in the Low Fat / Low Ration treatment



A word about smolting in the fall

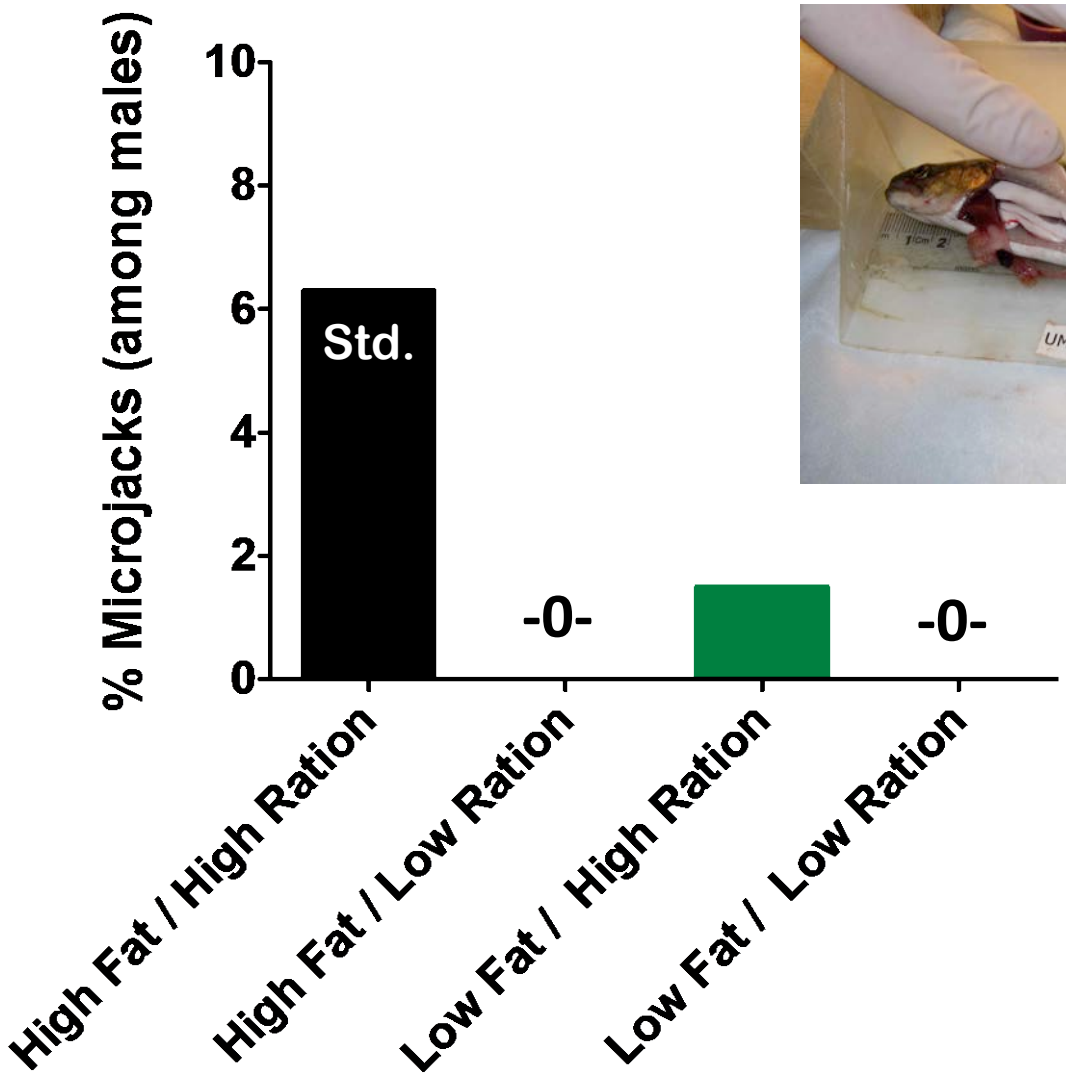
- **Smolting is a stressful physiological process**
- **During smolting the immune system is suppressed opening up the opportunity for pathogen outbreaks**
- **It may be more ideal to undergo smolting in a low density river than a high density raceway (i.e. Low Fat / Low Ration)**



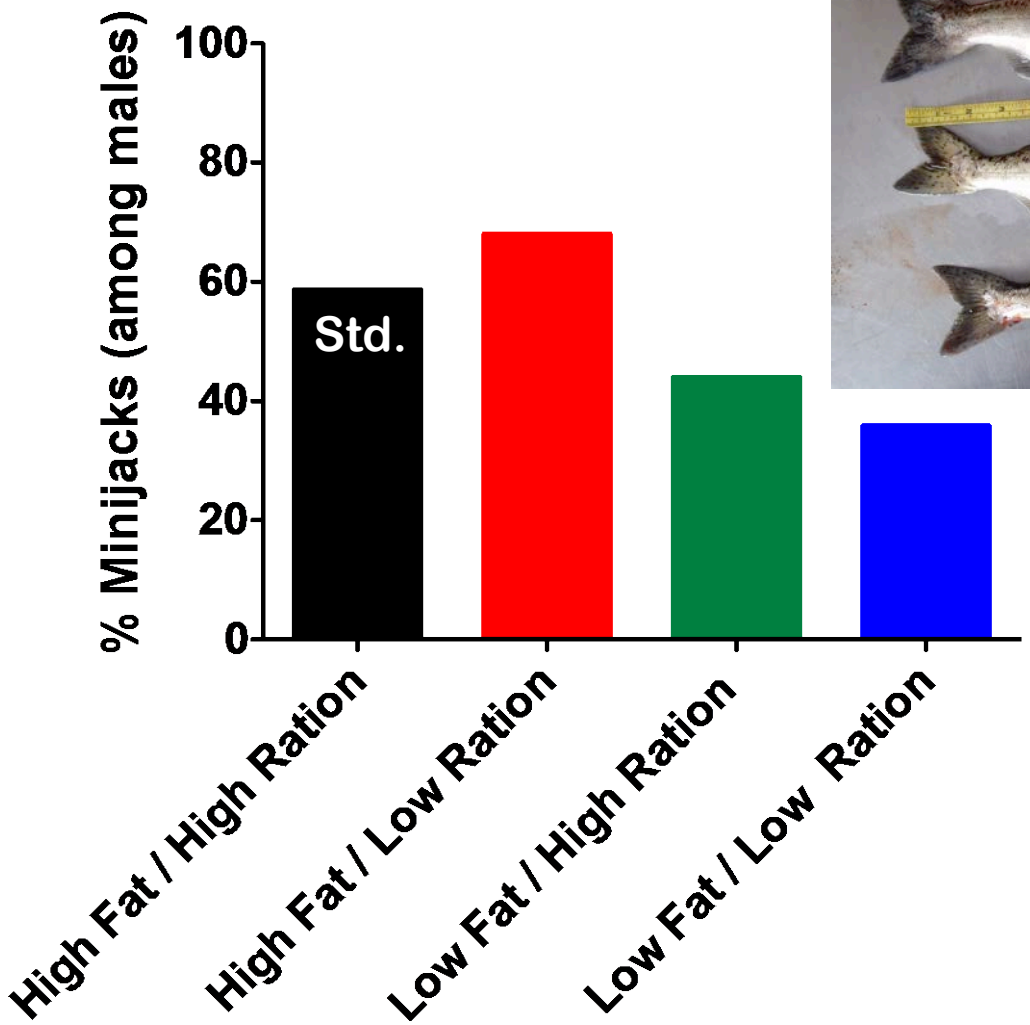
Results

Early Male Maturation

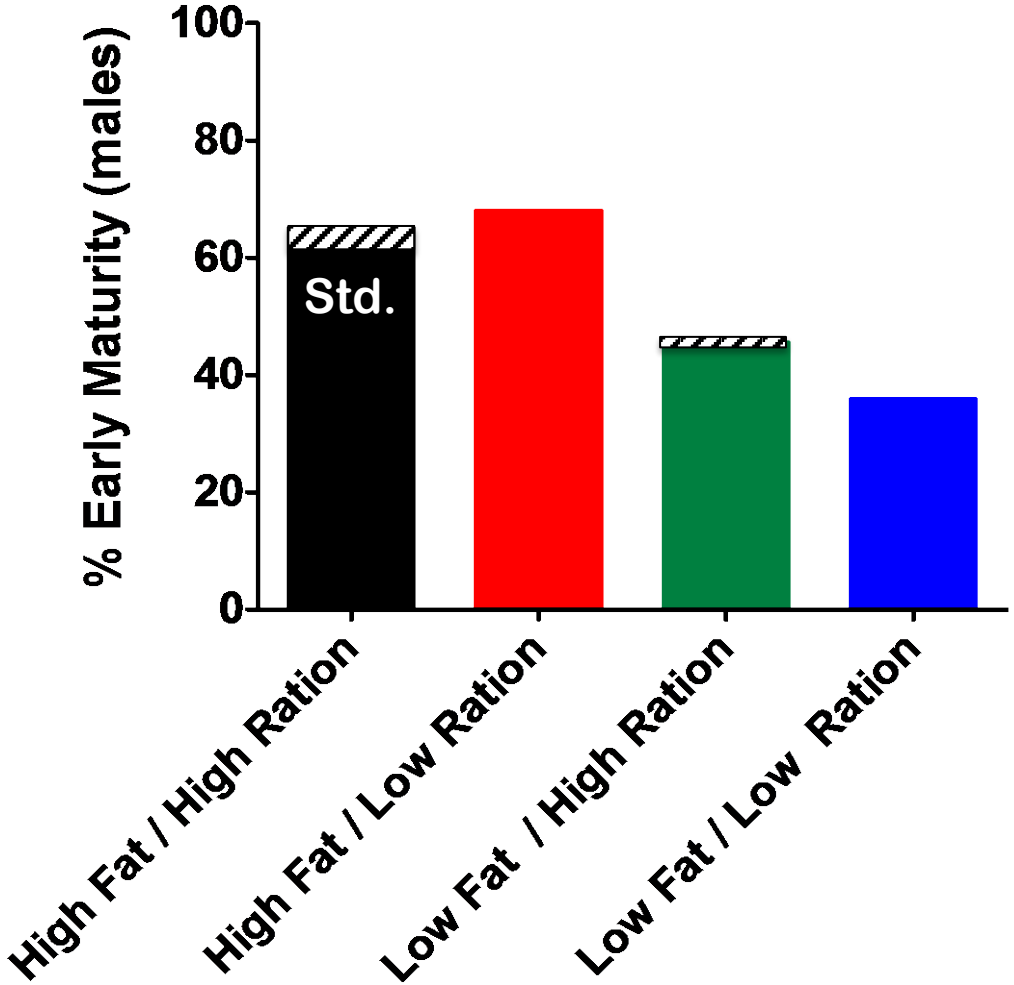
6 % of the High Fat / High Ration (Standard) males matured as age-1 microjacks

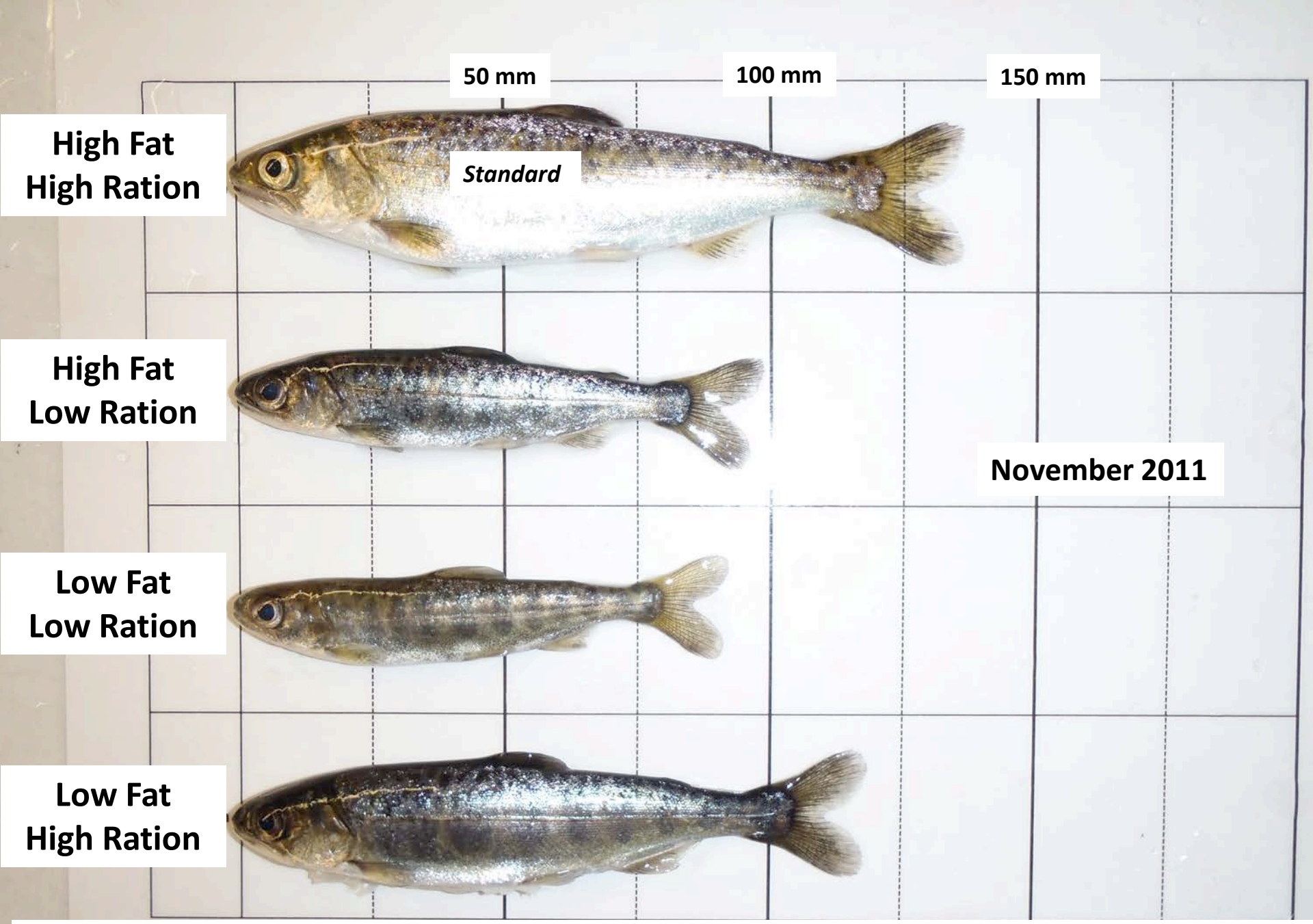


Minijack rates ranged from 36% (Low Fat / Low Ration) to 68% (High Fat / Low Ration)

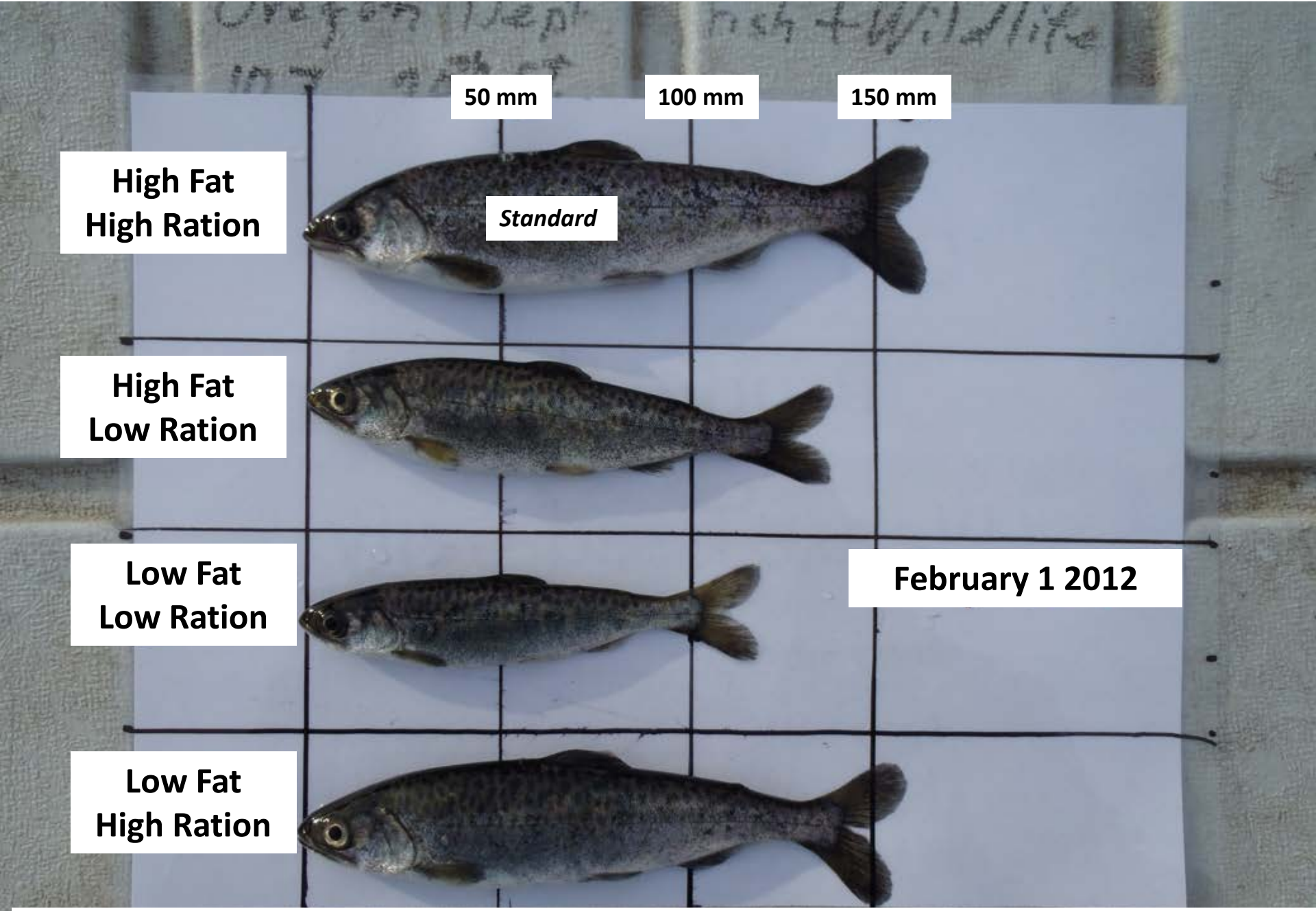


Adding together microjacks and minijacks provides the best measure of early male maturation

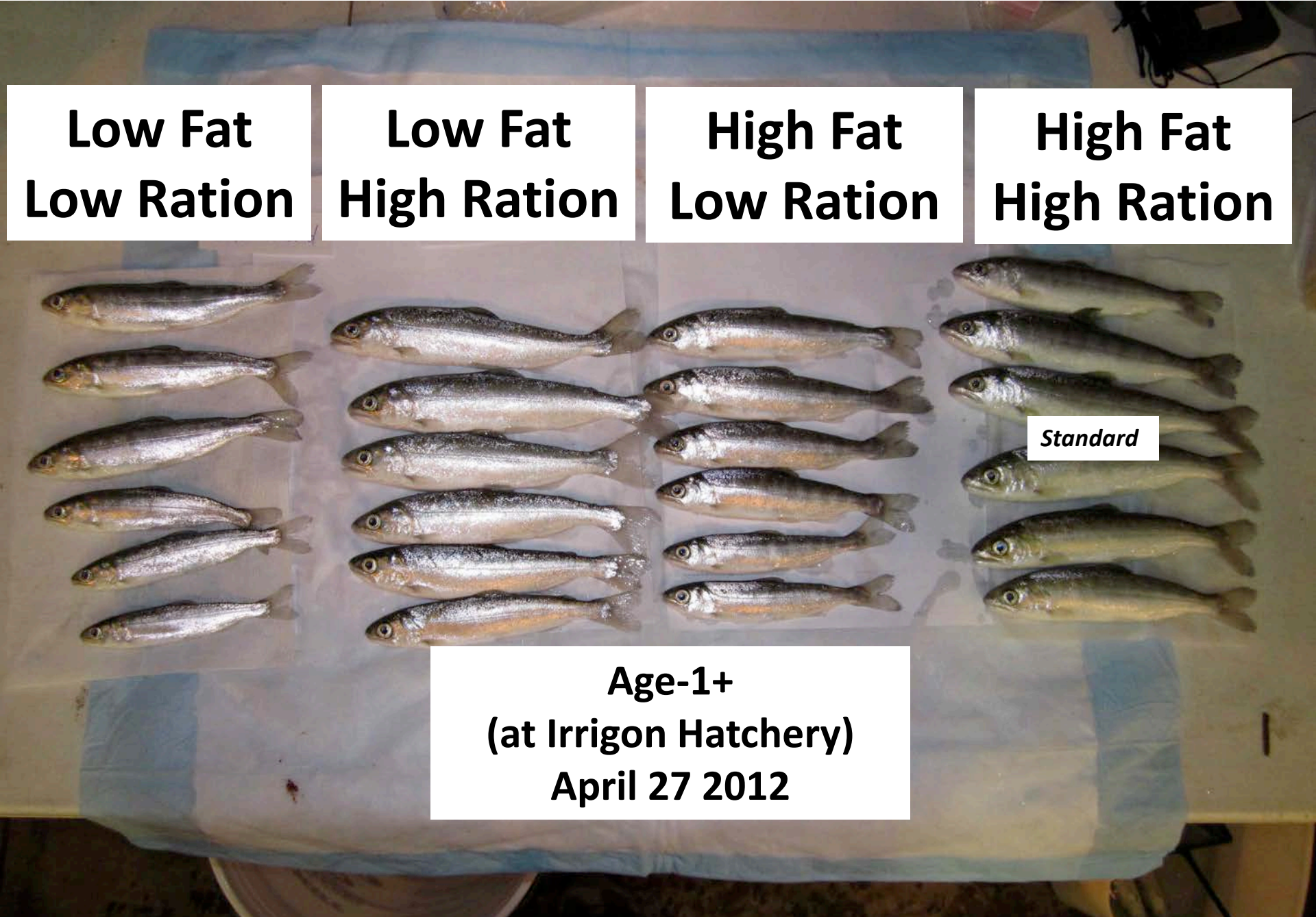




After a year of differential rearing at Bonneville Hatchery



Right before transfer to the acclimation site



Near the time of smolt release

Conclusions

- **High SAR's are misleading in yearling fall Chinook programs.**
- **Dietary lipid and ration were successfully manipulated in the Umatilla production program.**
- **The standard rearing regime produced a <u>bigger</u> smolt.**
- **The Low Fat / Low ration regime *may* have produced a <u>better</u> smolt.**
- **Early male maturation rates were very high, especially the High Ration treatments.**
- **The best regime will be the one that wins the battle of tradeoffs between predator avoidance, smolt development, and early male maturation.**
- **Adult survival *and demographics* will provide the ultimate measure of success…….stay tuned.**

Acknowledgements

- Confederated Tribes of the Umatilla Indian Reservation
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