Effect of Broodstock Age on Precocial Maturation of Male Chinook Salmon Smolts - Minijacks

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- Substantial hatchery production of salmon and steelhead for harvest augmentation and/or for supplementation of depressed natural populations
- However, hatchery returns include high proportions of less desirable (small) age 3 jack males – associated with accelerated growth in hatchery
- Studies also indicate that that age at maturity is a heritable/genetic trait
- Believed that hatchery production associated with general shift in age structure towards smaller younger salmon/steelhead returns
- Conference on Age and Size at Maturity of Chinook Salmon and other Pacific Salmonids, May 17-19, 2011, Portland OR

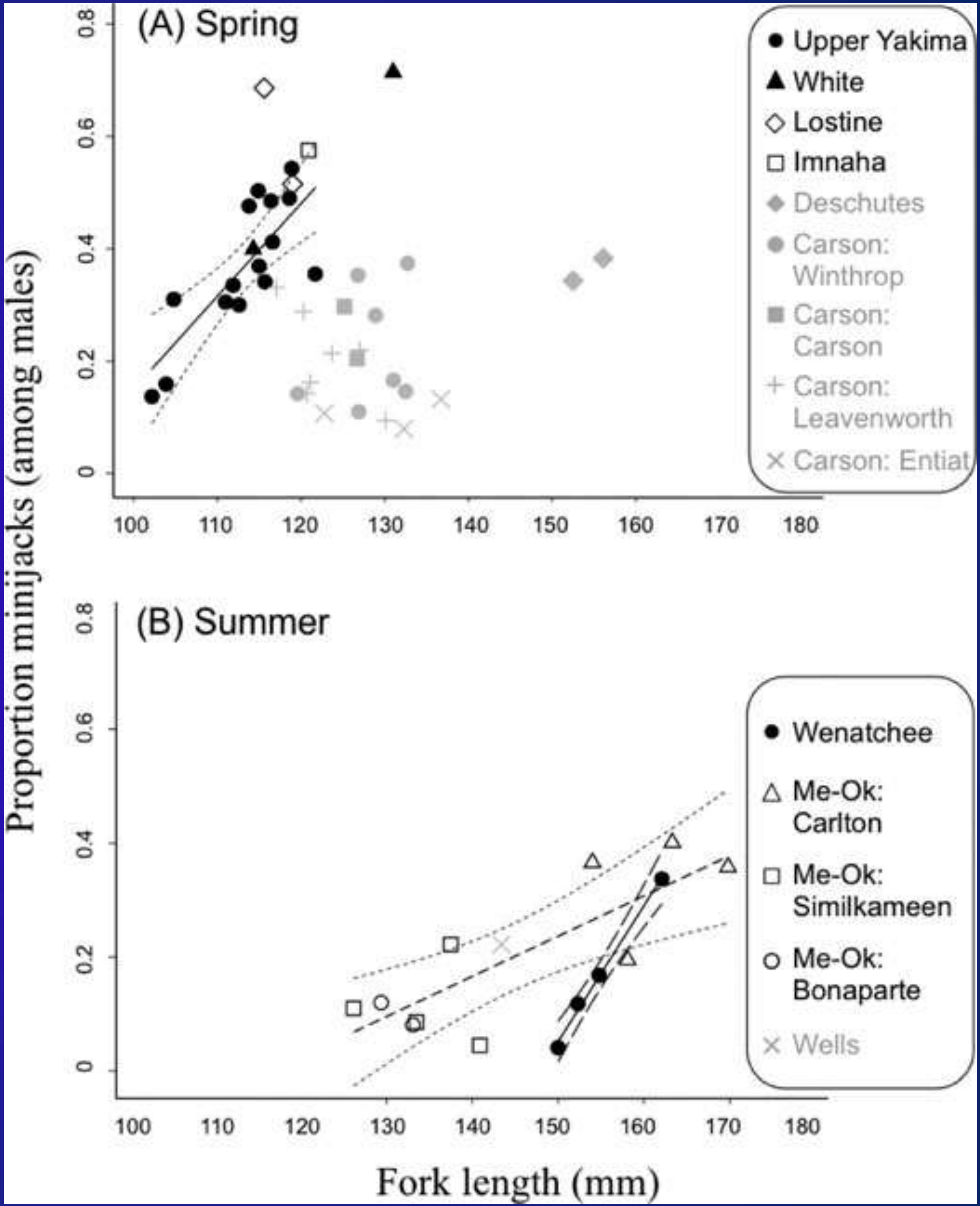
Broodstock management

- The "old way" was to spawn larger females with limited numbers of the biggest (oldest) bucks
- Then, geneticists insisted random mix of sizes/ages (including jacks, 5-10%), 1:1 matings, etc. to preserve genetic diversity within stocks
- But, mating is not random nor 1:1 in nature, with older larger fish being more successful
- And, in light of age structure trend in adult returns, currently (unofficial?) move back towards limiting jacks and favoring older/larger broodfish

- **Besides increased jack returns, hatcheries also produce sexually maturing (age 2) male smolts - minijacks**
- **Minijacks do not grow to adult (or even jack) size and do not contribute to fisheries, nor to natural spawning**
- **Therefore, minijacks represent a substantial economic and management loss to hatchery programs, i.e., if male smolt minijack rate = 50%, is "equivalent" (relative to mgt. objectives) to 25% mortality of released smolts...**

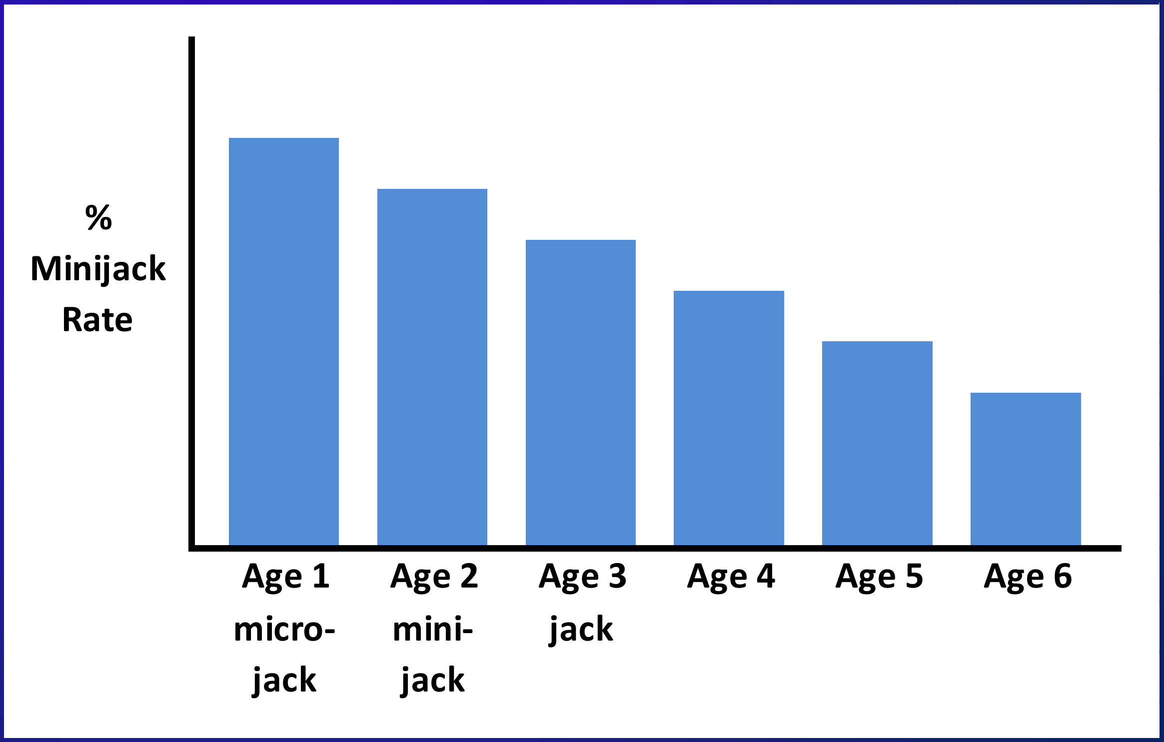
- **Rate of minijack production associated with high growth and lipid levels of parr during fall-winter period prior to smoltification**
- **Strong correlation of smolt size at release and minijack rate**
- **But, minijack rates also vary across stocks/hatchery programs – inferring genetic influence on minijack rate**

Harstad et al. 2014 Variation in minijack rate among hatchery populations of Columbia River Basin Chinook Salmon. TAFS 143:768-778.



- ... So, if adult age at maturity is a heritable trait, and older larger broodstock will return older larger progeny,
- And, if minijack rate has a heritable basis,
- Will use of older larger broodstock also reduce minijack rate?

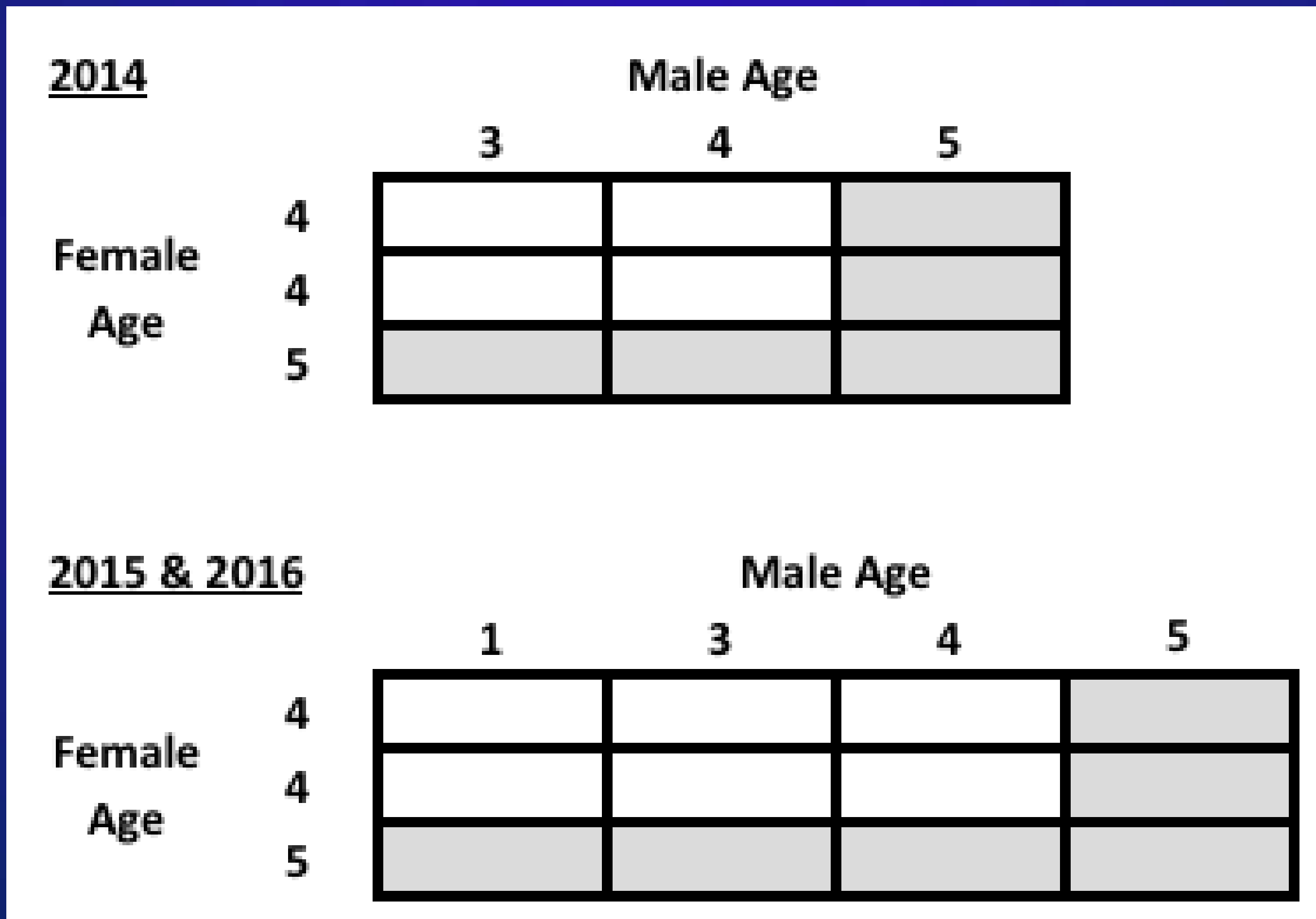
i.e.,



Study Design:

- We initiated a 3-broodyear (2014, 2015 and 2016) study to measure the "Effect of Parent Age on Rate of Minijack Production Among Male Progeny of Spring Chinook"
- Study conducted at the Cle Elum Supplementation Research Facility (CESRF), Cle Elum WA, managed by the Yakama Nation
- CESRF broodstock = 100% natural origin (no hatchery influence on age at maturation)
- Funding from BPA through CRITFC Accords Project 2009-009-00

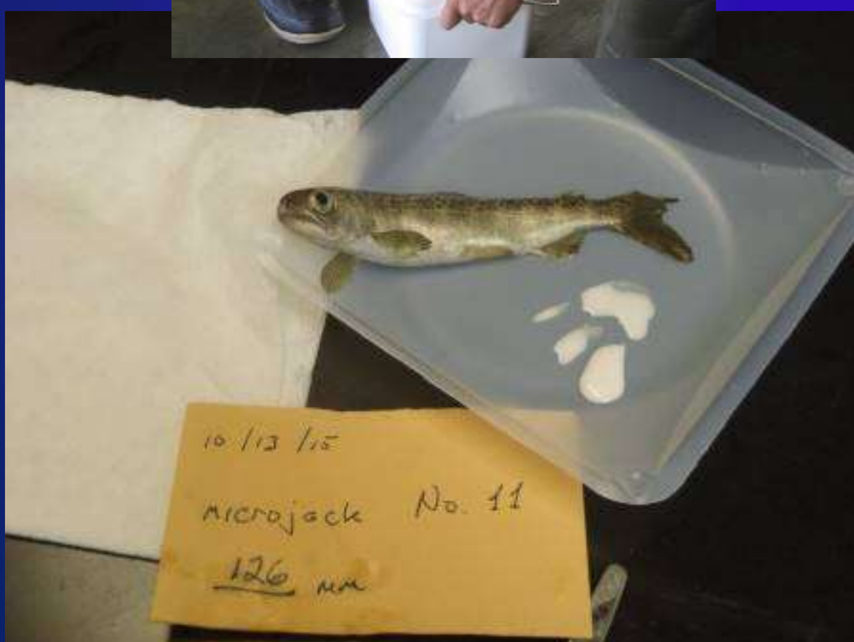
• **Produce factorial/matrix matings (approx. 200 eggs/mating) with female and male broodfish of different ages (age 1 = precocious parr/microjack):**



- Rear fry to swim-up
- Collect 50 fry per mating, pool into common raceway, and rear to smolt stage
- in April (concurrent with CESRF smolt release time) sacrificed study fish - length, weight, sex ID
- Then, blood and tissue (fin clip) sample from males
- Perform plasma 11-ketotestosterone (11-KT) assays (Dept. of Biology, Univ. of Idaho)
- Frequency distribution analysis of 11-KT to categorize individual smolts: low 11-KT (non-maturing) and high 11-KT (maturing minijack)

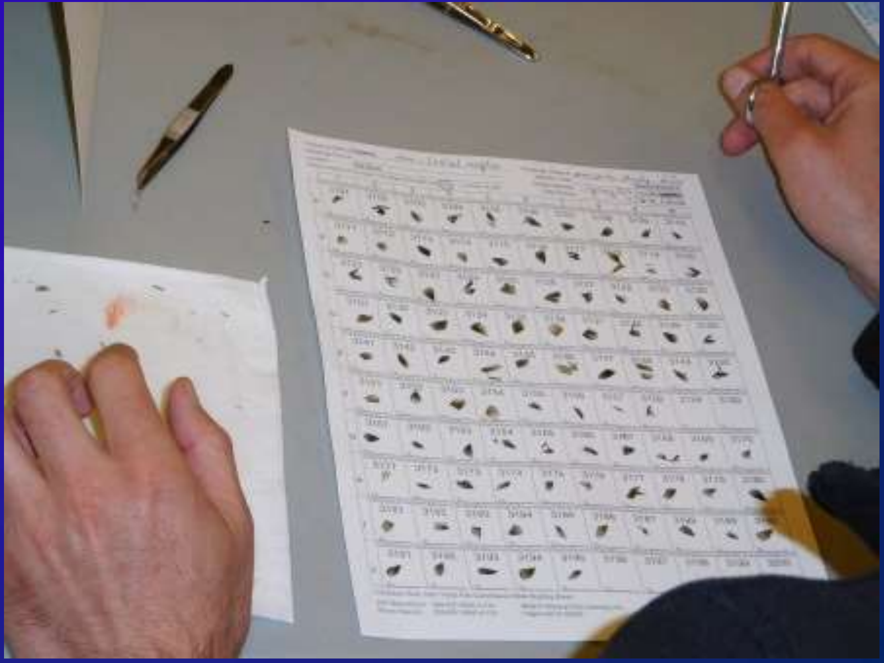
- Extract DNA from fin tissue (CRITFC Molecular Genetics Laboratory – Hagerman Fish Culture Experiment Station, Hagerman ID)
- Genotype for standardized SNP panel, and perform parentage analysis
- Identify full-sibling male progeny groups
- Calculate % minijacks within each progeny group
- Analyze minijack rates across cross types for effect of female and male parent age




10/13/15
microjack No. 11
126 mm



Made in U.S.A. by Wildco®



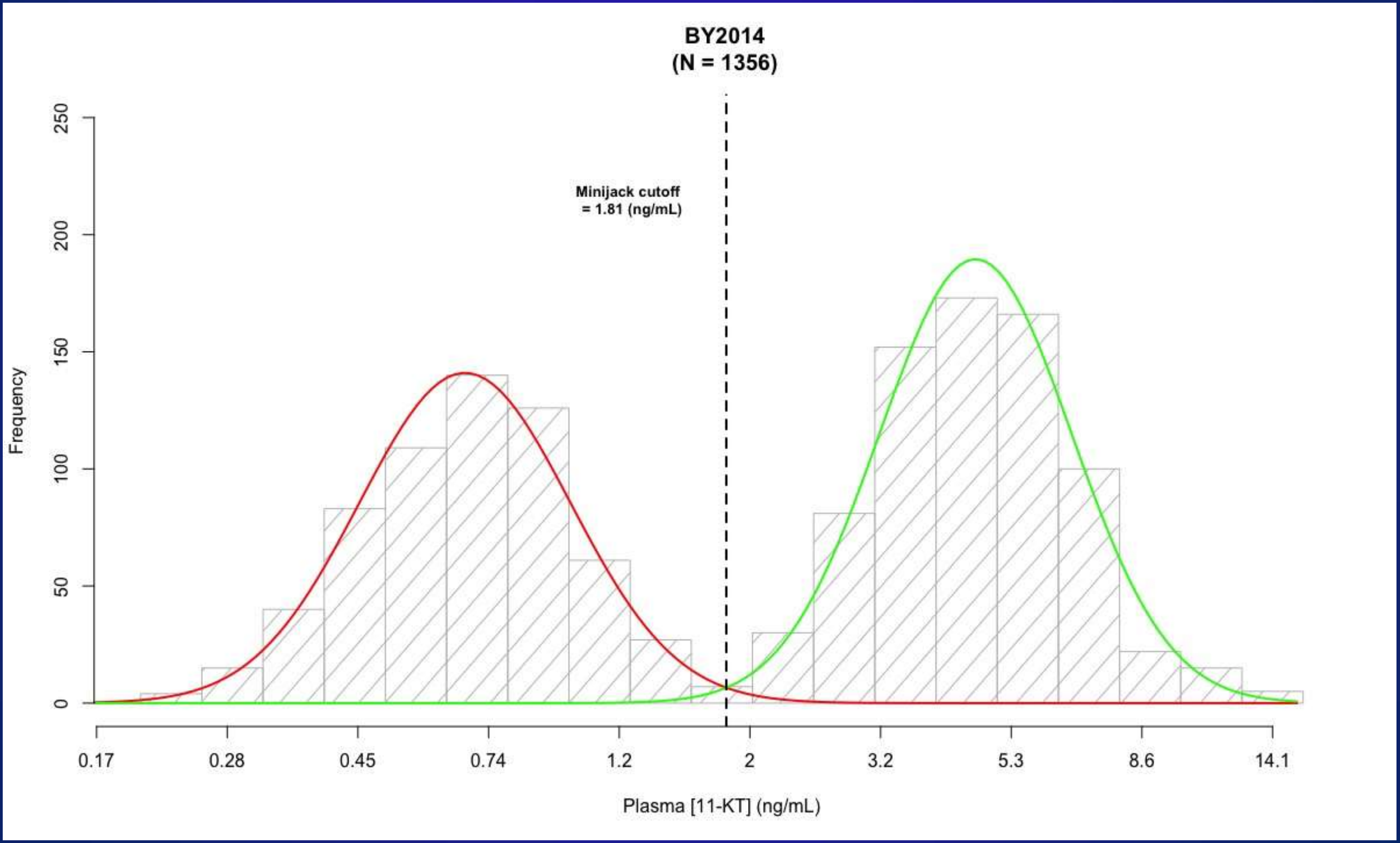

VIEW


US Kelt

RESULTS – By 2014 and BY2015

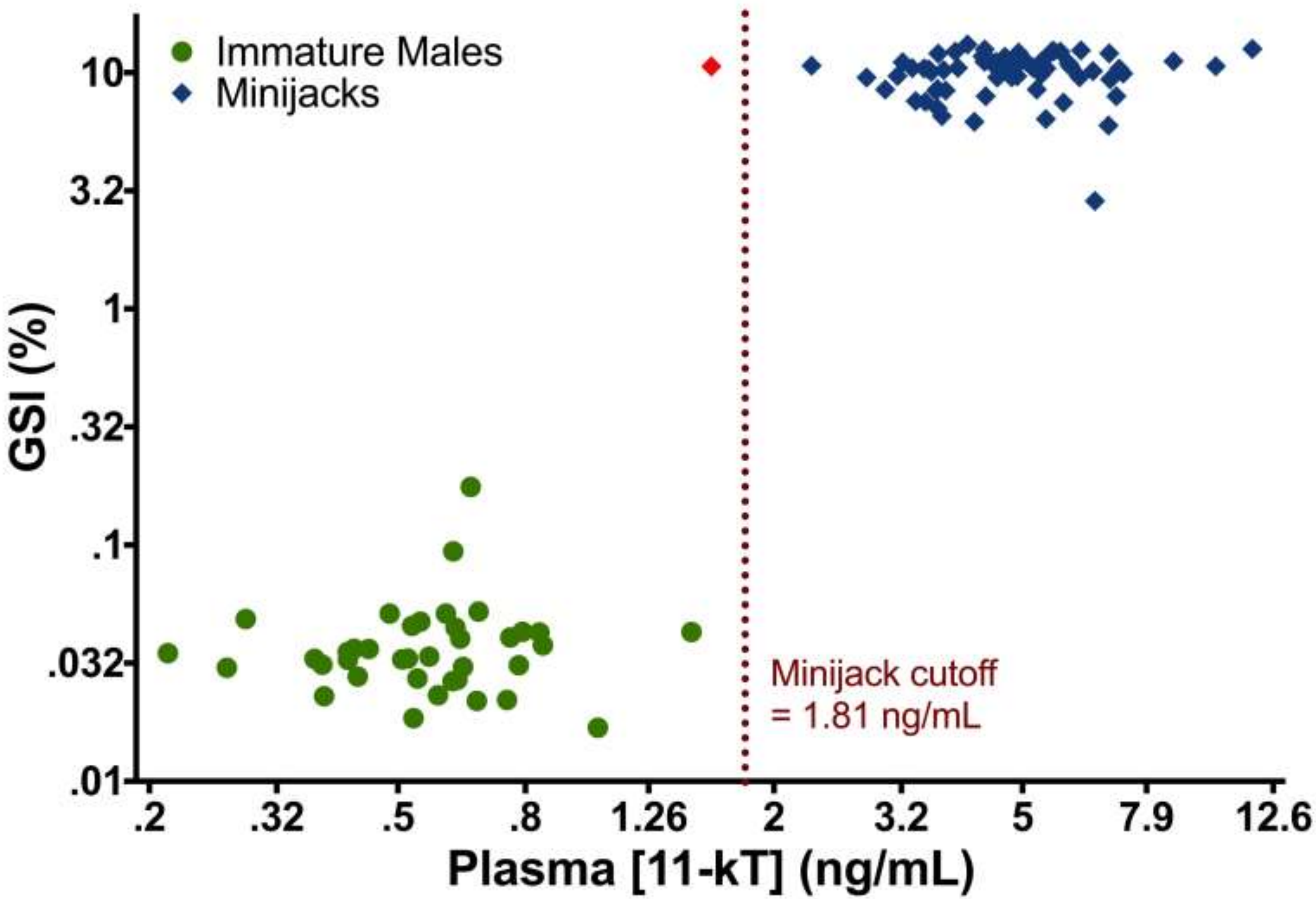
- April 11-KT measures distinctly bimodal – smolts exhibited low 11-KT (normal non-maturing), or high 11-KT (maturing minijack)
- Subset of BY 2014 smolts non-lethally sampled in April 2016, PIT tagged and returned to raceway, reared until Sept 2016 (spawning season)
- Medeiros et al. poster NWFCC 2016 - 101 surviving males; April 11-KT for 100 (99%) correctly predicted Sept maturation status
- Confirmation that April 11-KT reliably predicts individuals as a minijack versus non-maturing smolt

Distinct separation between low 11-KT (non-maturing smolts) and high 11-KT (maturing minijacks)



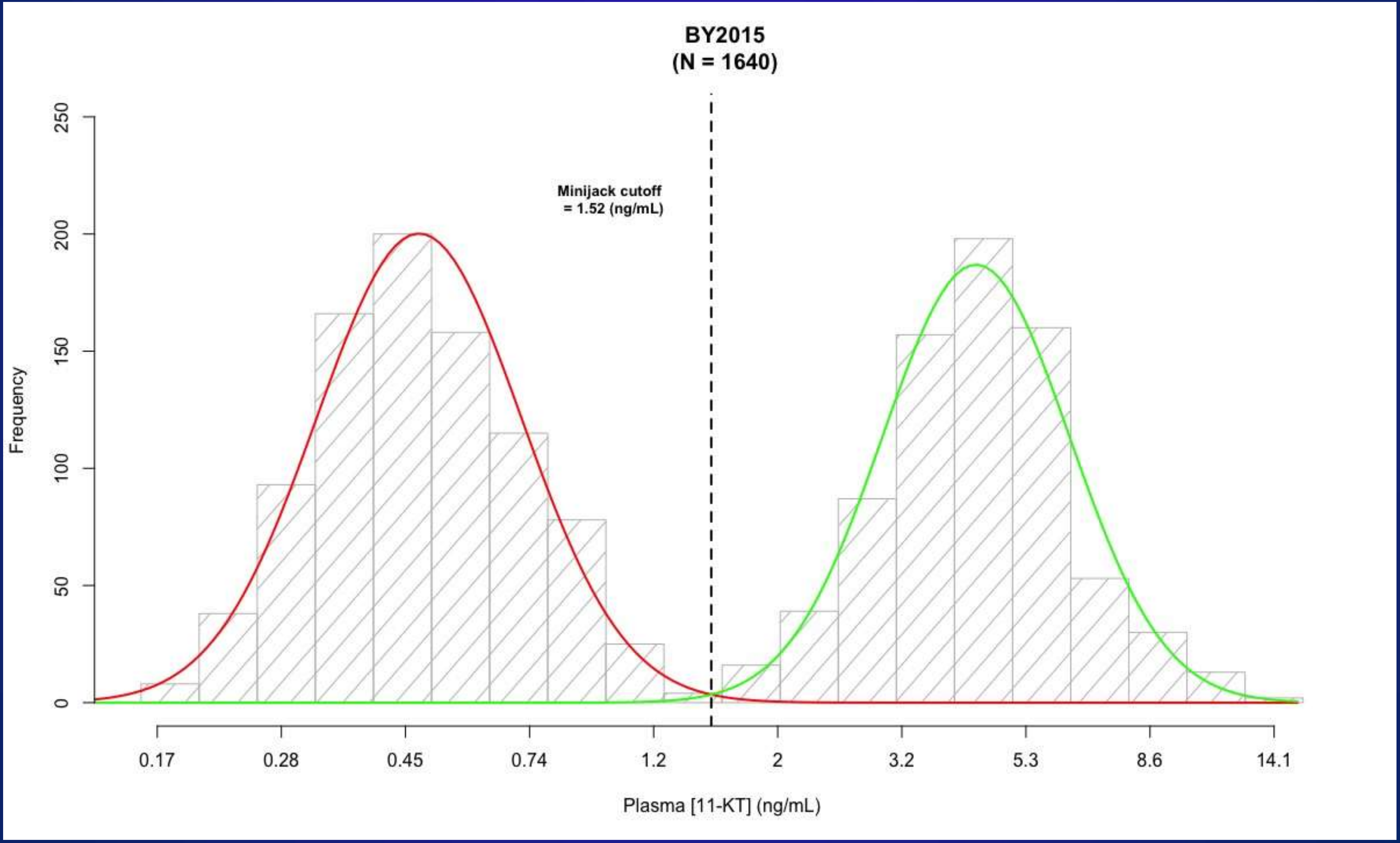
April 11-KT vs September GSI

(BY2014 Surviving Non-Lethally Sampled Males)



Minijack (FL - 22 cm; 8½")

BY 2015 – also clear distinction between low 11-KT and high 11-KT



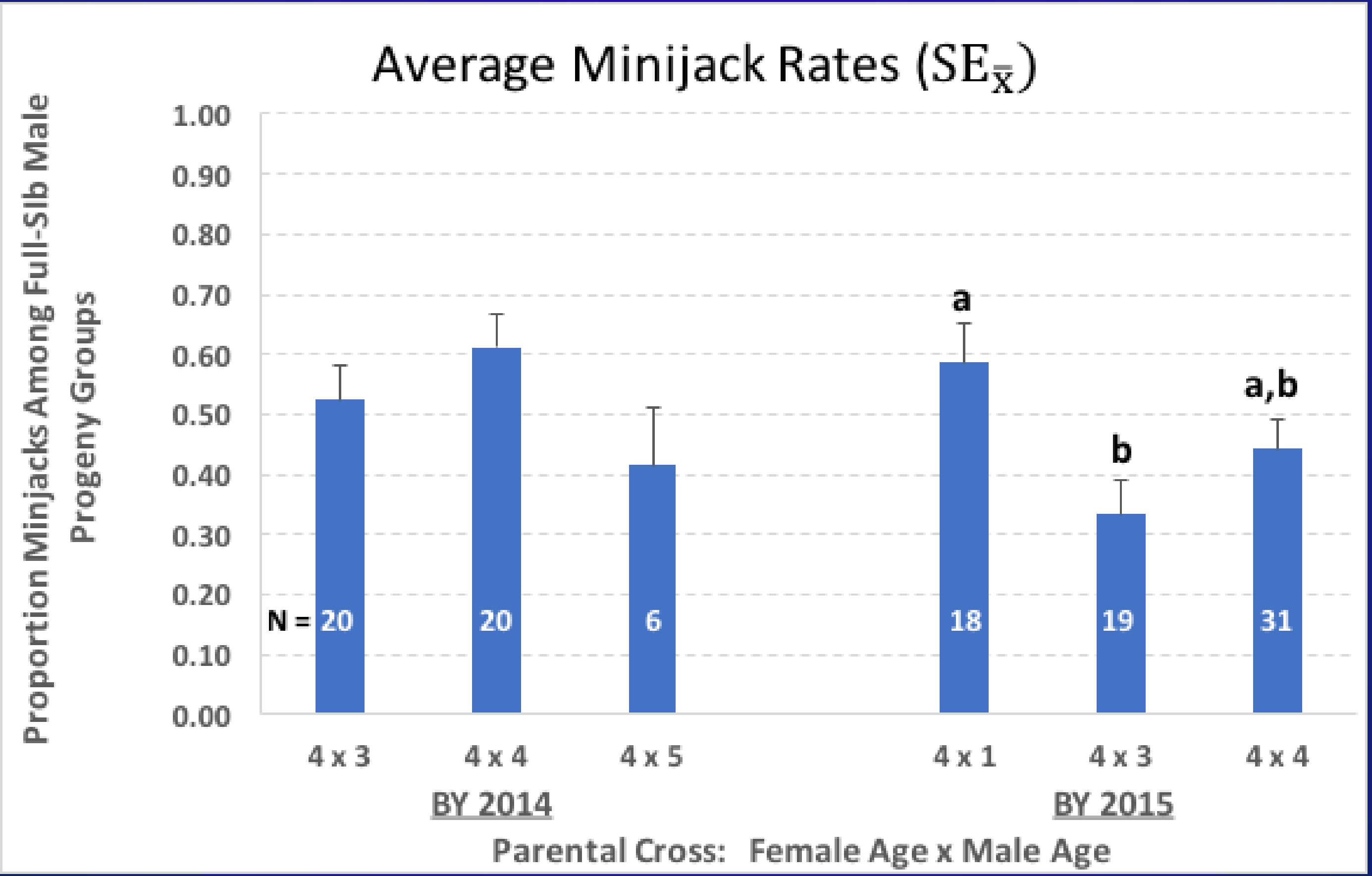
RESULTS

% minijacks per male progeny group (n≈20/group)

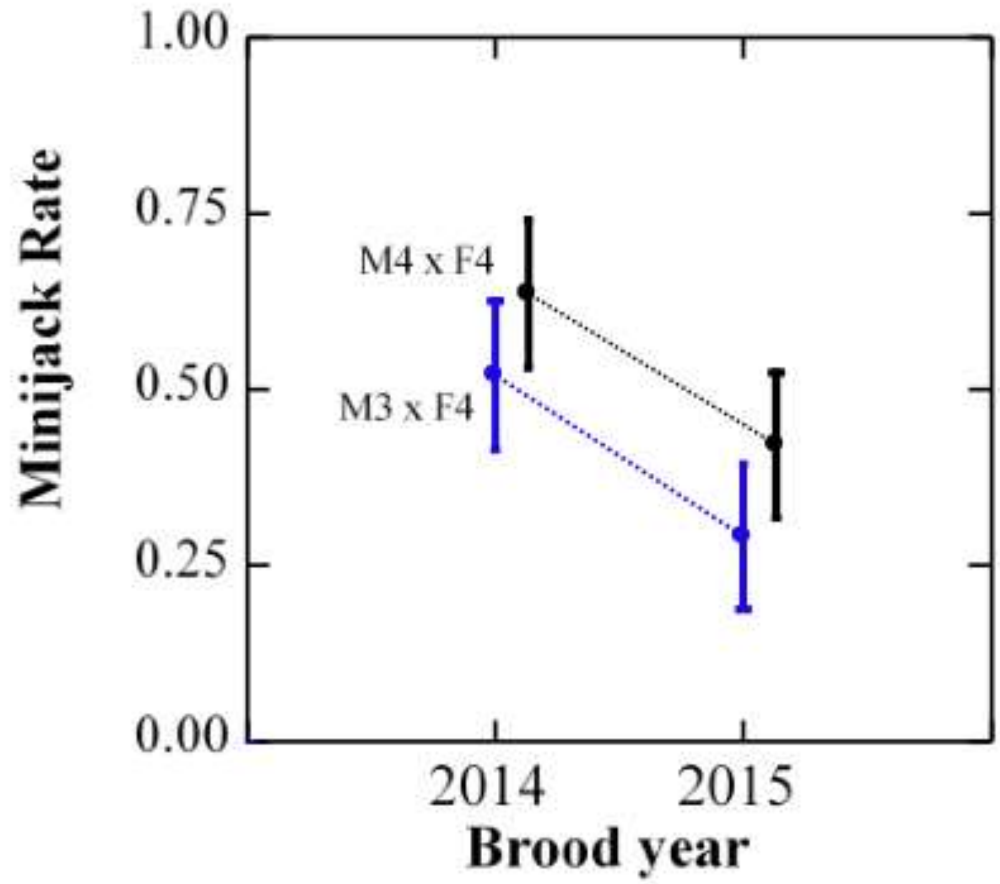
	BY 2014 minijack rates			BY 2015 minijack rates			
	4x3	4x4	4x5	4x1	4x3	4x4	
	0.13	0.17	0.04	0.00	0.00	0.00	0.52
	0.18	0.17	0.25	0.19	0.04	0.04	0.53
	0.22	0.23	0.41	0.26	0.05	0.05	0.55
	0.25	0.27	0.55	0.39	0.08	0.06	0.56
	0.30	0.45	0.56	0.48	0.13	0.14	0.61
	0.32	0.53	0.68	0.48	0.15	0.17	0.64
	0.38	0.57		0.48	0.19	0.17	0.65
	0.44	0.59		0.55	0.23	0.18	0.73
	0.50	0.62		0.55	0.32	0.25	0.74
	0.52	0.64		0.56	0.35	0.27	0.78
	0.58	0.65		0.60	0.35	0.27	0.84
	0.60	0.68		0.70	0.40	0.29	0.85
	0.60	0.69		0.83	0.41	0.31	0.85
	0.61	0.75		0.87	0.43	0.36	1.00
	0.67	0.76		0.88	0.44	0.40	
	0.77	0.79		0.91	0.57	0.43	
	0.79	0.86		0.91	0.70	0.50	
	0.81	0.91		0.95	0.71		
	0.85	0.94			0.80		
	1.00	0.95					
Average	0.50	0.59	0.42	0.59	0.33	0.44	
StDev	0.25	0.25	0.23	0.27	0.24	0.28	
Number	20	20	6	18	19	31	

BY 2014 – no difference in minijack rate for progeny of age 3, 4 or 5 male parents crossed to age 4 females

BY 2015 – minjack rate significantly higher for progeny of microjack male relative to age 3 jack male parents; progeny of age 4 male parents intermediate



ANOVA for BY 2014 and 2015 data combined – minijack rates significantly different: 4x3 < 4x4



- **Possible maternal effects? (e.g., differences within age 4 females for length/weight, egg/fry size)**
- **Paired t-tests for age 3 and age 4 males crossed to the same age 4 female:**

BY 2014 Paired t-tests female crossed to an age 3 and an age 4

4x3	4x4	diff
0.524	0.909	-0.385
0.579	0.750	-0.171
0.696	0.762	-0.066
0.833	0.955	-0.121
1.000	0.615	0.385
0.500	0.174	0.326
0.808	0.636	0.171
0.176	0.174	0.003
0.769	0.450	0.319
0.176	0.227	-0.051
0.769	0.941	-0.172
0.609	0.565	0.043
0.250	0.690	-0.440
0.438	0.857	-0.420
0.375	0.792	-0.417
0.125	0.690	-0.565
0.320	0.857	-0.537
0.222	0.792	-0.569
0.600	0.654	-0.054
0.300	0.273	0.027
0.846	0.588	0.258

t-Test: Paired Two Sample for Means

	4x3	*4x4*
Mean	0.520	0.636
Variance	0.068	0.061
Observations	21	21
Pearson Correlation	0.272	
Hypothesized Mean Difference	0	
df	20	
t Stat	-1.734	
P(T<=t) one-tail	0.049	
t Critical one-tail	1.725	
P(T<=t) two-tail	0.098	
t Critical two-tail	2.086	

BY 2015 Paired t-tests – female crossed to an age 3 and an age 4

4x3	4x4	Diff.
0.318	0.364	*-0.045*
0.318	0.273	*0.045*
0.000	0.050	*-0.050*
0.000	*0.000*	*0.000*
0.077	*0.038*	*0.038*
0.231	0.313	*-0.082*
0.412	*0.842*	*-0.430*
0.412	0.500	*-0.088*
0.400	0.852	*-0.452*
0.400	0.611	*-0.211*
0.150	0.55	*-0.400*
0.190	*0.636*	*-0.446*
0.704	*0.560*	*0.144*
0.706	*0.273*	*0.433*
0.348	*0.250*	*0.098*
0.130	*0.174*	*-0.043*
0.429	*0.136*	*0.292*
0.053	*0.400*	*-0.347*
0.444	*0.846*	*-0.402*
0.037	*0.652*	*-0.615*
0.348	*0.524*	*-0.176*
0.291	0.421	

t-Test: Paired Two Sample for Means

	4x3	*4x4*
Mean	0.291	0.421
Variance	0.042	0.071
Observations	21	21
Pearson Correlation	0.370	
Hypothesized Mean Difference	0	
df	20	
t Stat	-2.215	
P(T<=t) one-tail	0.019	
t Critical one-tail	1.725	
P(T<=t) two-tail	0.039	
t Critical two-tail	2.086	

Recommendations to reduce minjack production?

- Do not use microjacks as male broodstock (duh!)
- Use more age 5 fish? – maybe, but insufficient data
- Jack broodstock yield <u>fewer</u> minijacks than age 4 males, therefore use more jacks... (huh?)
- Likely most effective option – growth manipulation in fall-winter period prior to smoltification
- BUT, what other genetic factors are behind the <u>very</u> wide variation in minijack rate within cross-types, and how are they interacting with spawner age ... ???
- Combined analysis for all 3 broodyears in study will follow sampling of BY 2016 smolts in April 2017