Hatchery rearing duration effects on reproductive behavior and breeding success of steelhead trout

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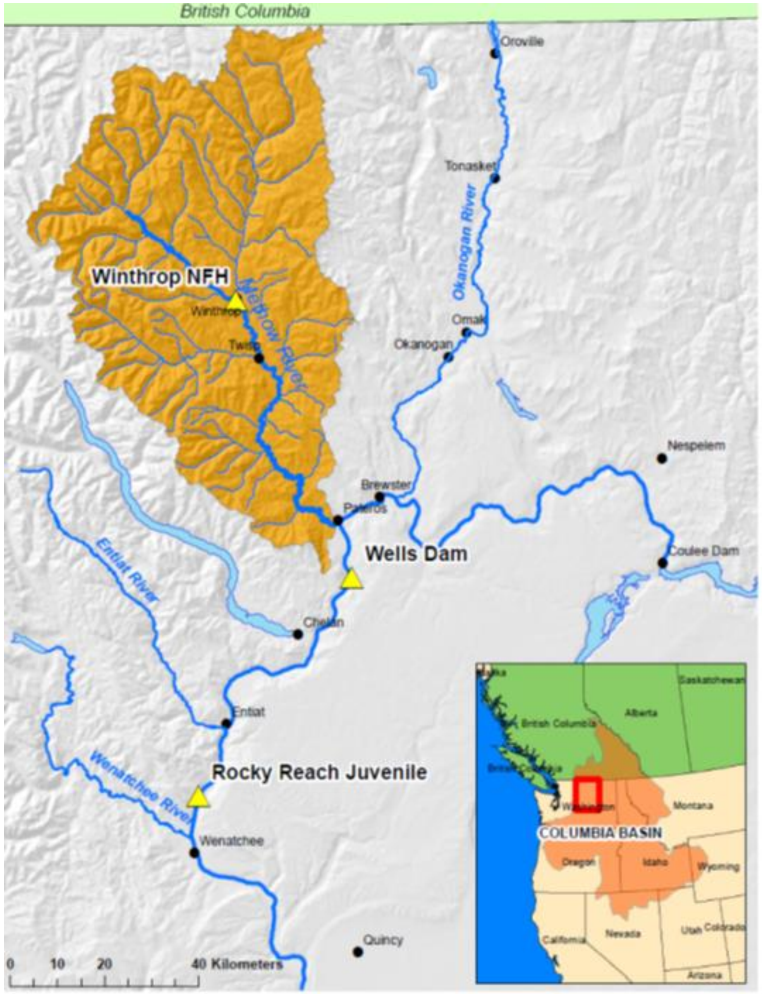
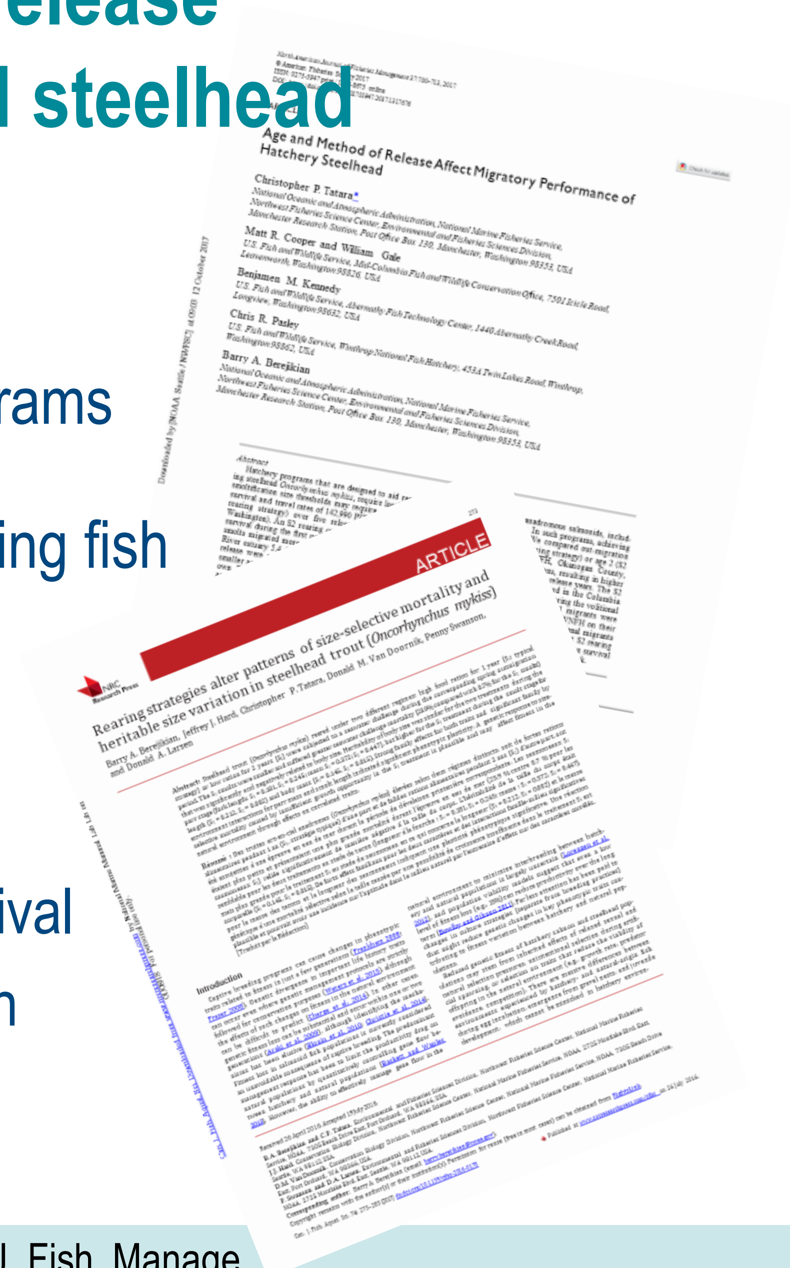
US Fish and Wildlife Service, Winthrop National Fish Hatchery



Age-at release effects on post-release performance of hatchery reared steelhead

- Age-1 release (S1)
  - Most hatchery programs
  - Challenging for local broodstock programs and cold rearing temperatures
  - High residualism rates in slower growing fish

- Age-2 release (S2)
  - Can reduce size-selective mortality
  - Can improve migration speed and survival
  - Residualism from early male maturation



Tatara et al. (2017) N. Am. J. Fish. Manage.
Berejikian et al. (2017) Can. J. Fish. Aquat. Sci

Objectives

- Estimate the effects of hatchery rearing duration (S1 vs S2) on breeding success
- Estimate the breeding success of precociously mature male parr from S2 programs
- Identify mechanisms causing variation in breeding success
- Examine implications of different rearing strategies on hatchery and natural populations

Measuring breeding success

Spawning studies at Winthrop NFH

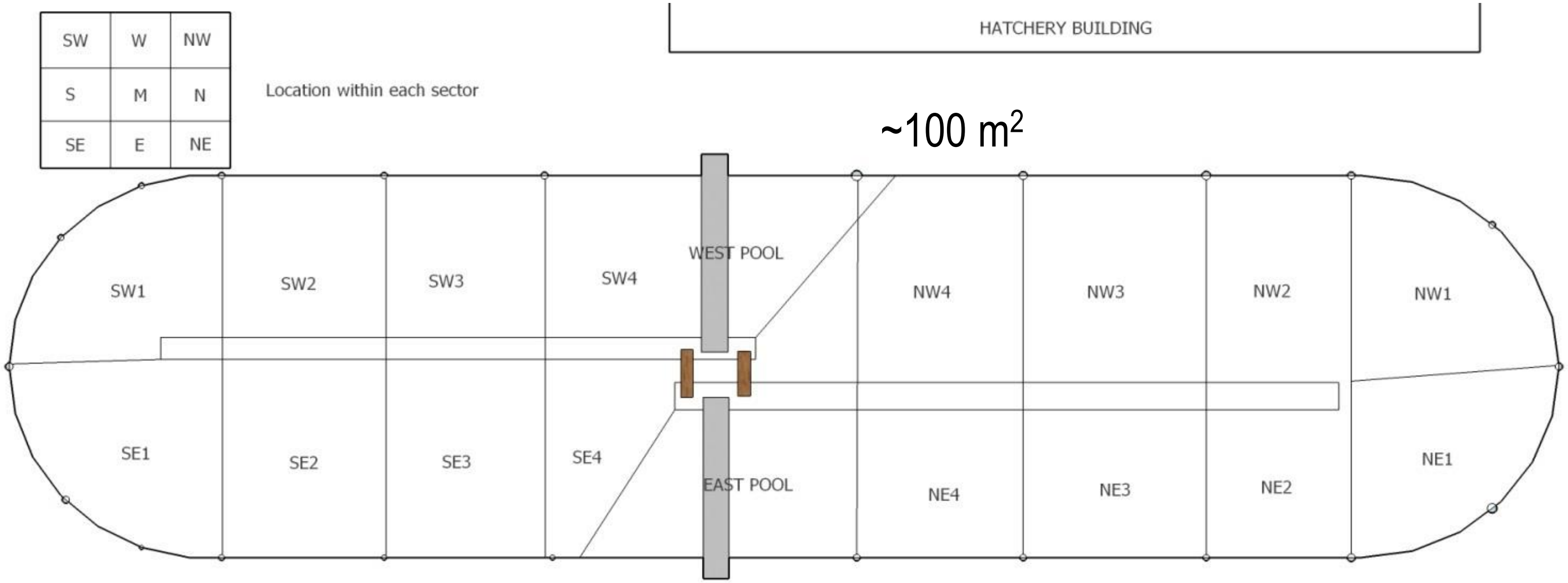


Image: Michael Humling

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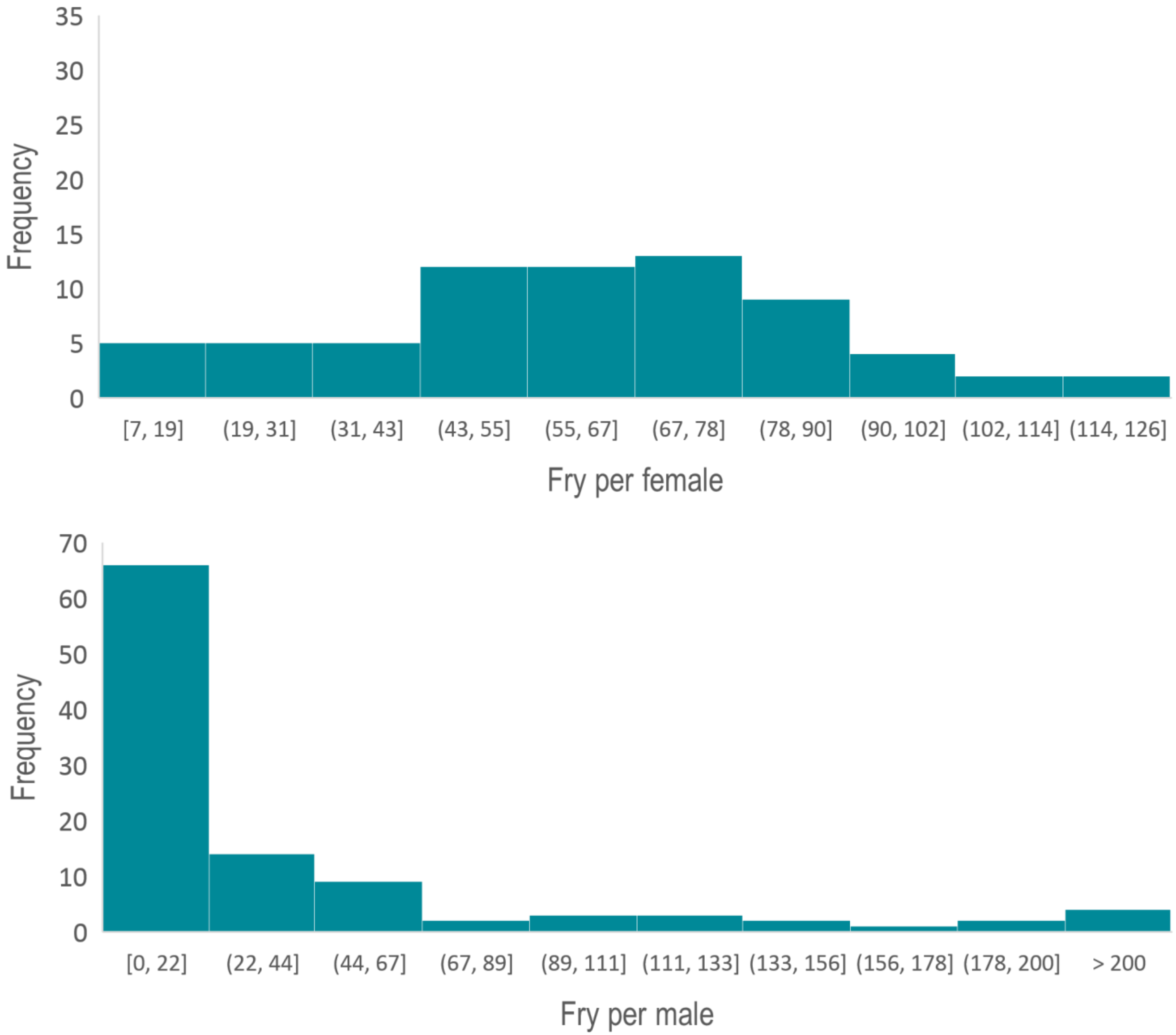
Experimental Design

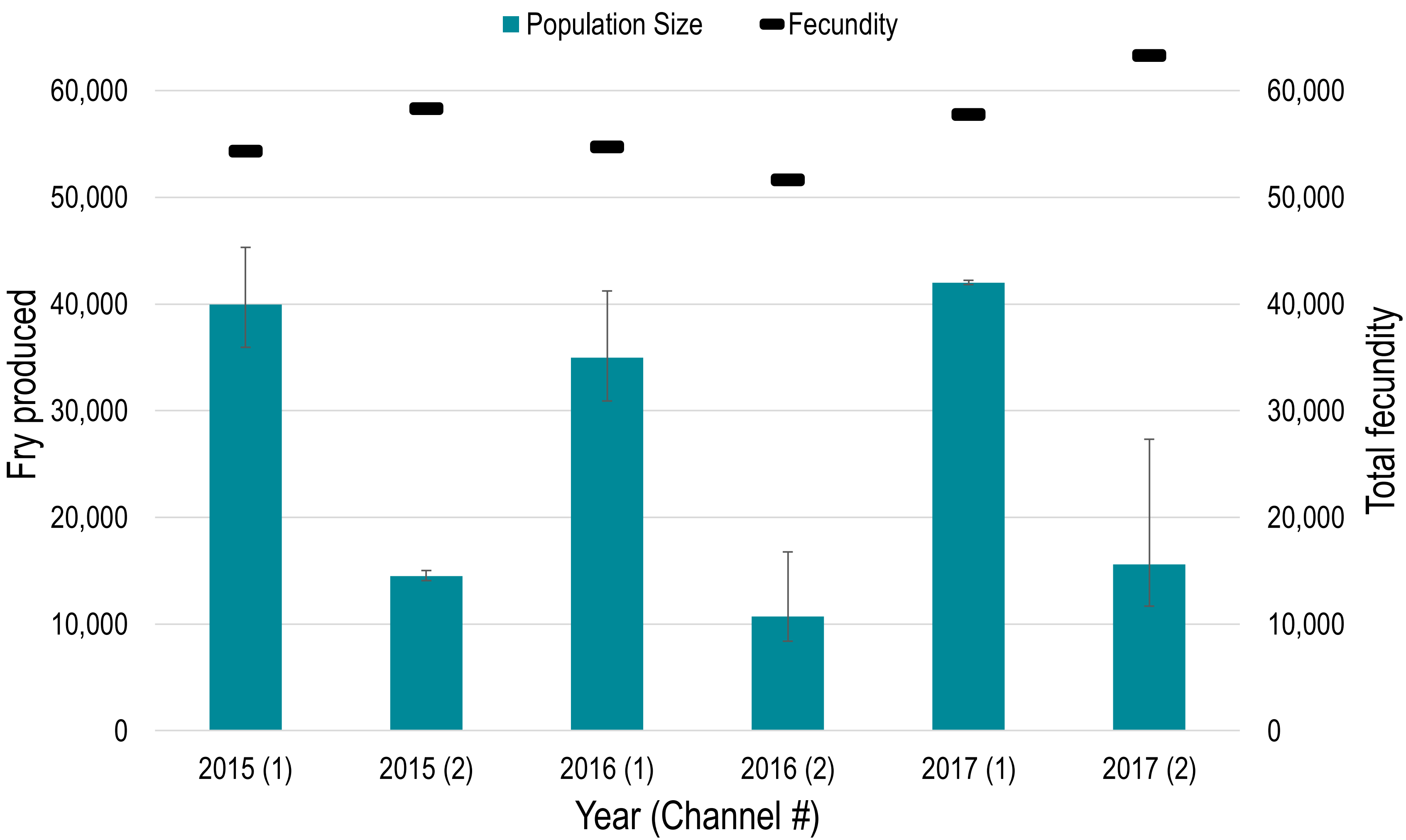
- Six breeding populations
  - Two stream channels stocked 1 week apart
  - Reflects natural spawn timing
  - Three years (2015-2017)
- 11-13 males & females in each breeding population
  - Approx. equal numbers of S1 & S2 adult steelhead (males skewed towards S1)
  - 6 mature S2 parr into each breeding population
  - Unique external tag
  - Fin clip for pedigree analysis

Observe and quantify behavior (dawn to dusk)

Fry produced per female (top) and male (bottom)

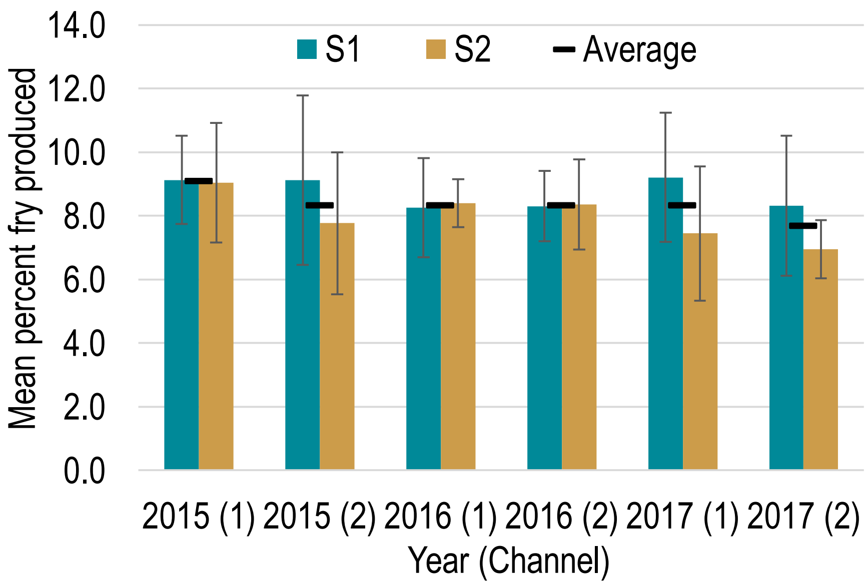


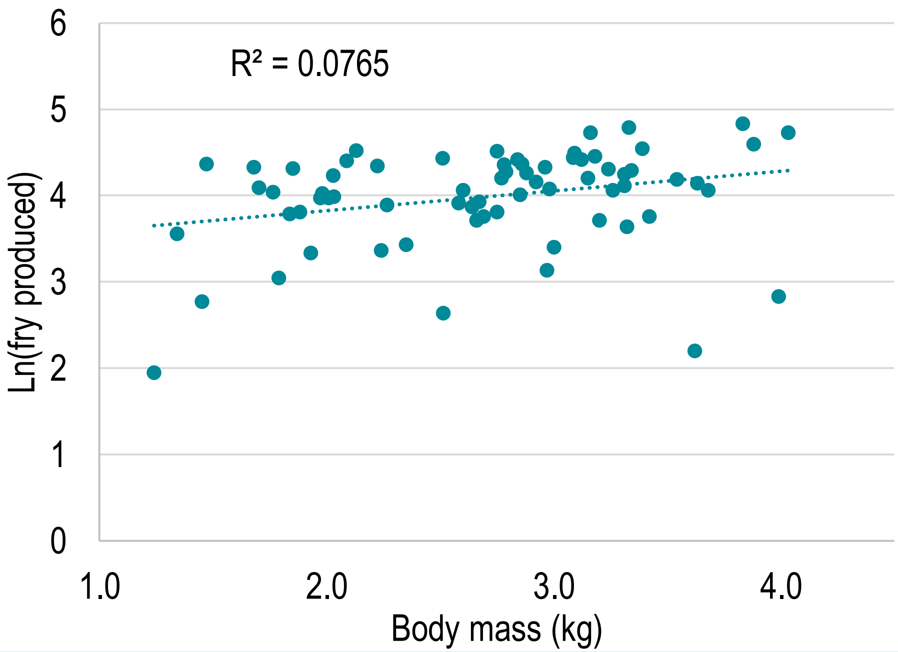
Female offspring production and fecundity



Female breeding success

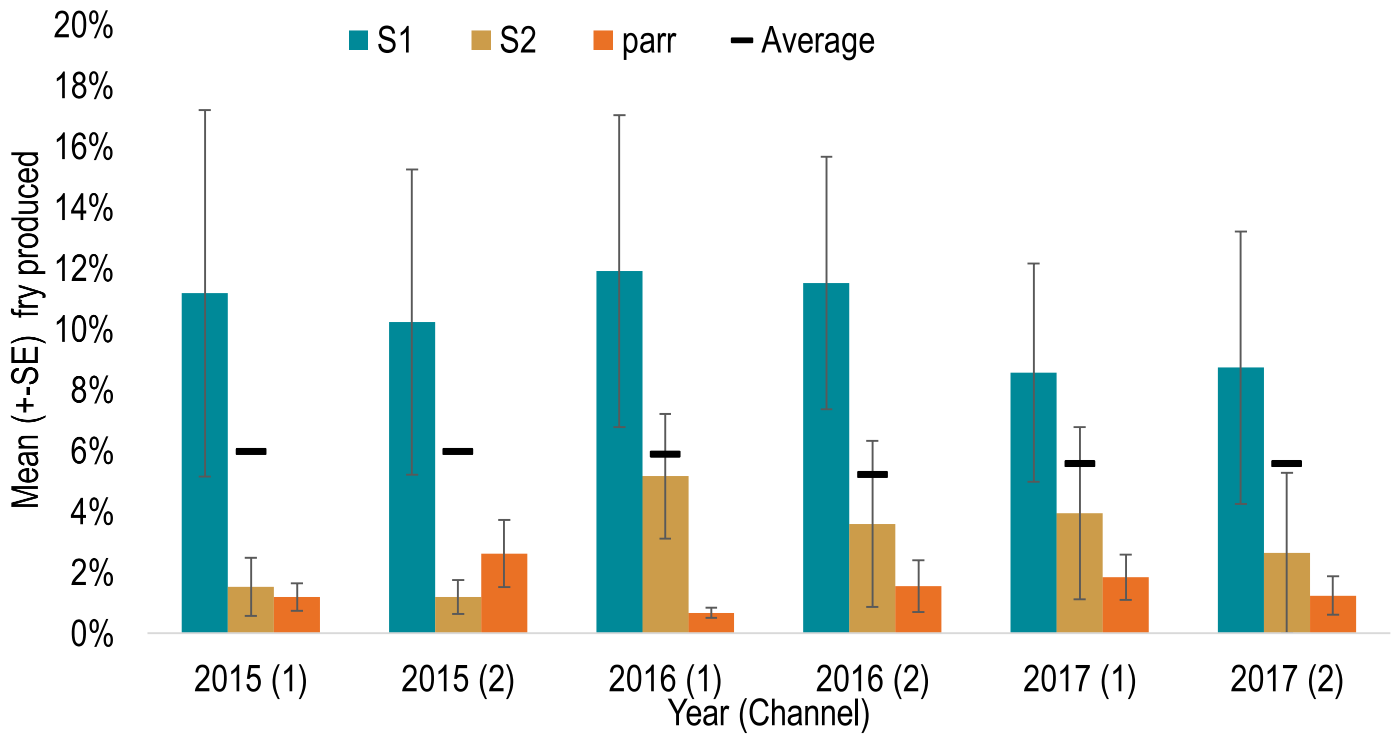
Analysis of Covariance					
Effect	Type III SS	df	Mean Squares	F-Ratio	p-Value
Rear Type	0.038	1	0.038	0.120	0.730
Body Mass	1.702	1	1.702	5.413	0.023
Error	20.757	66	0.314		





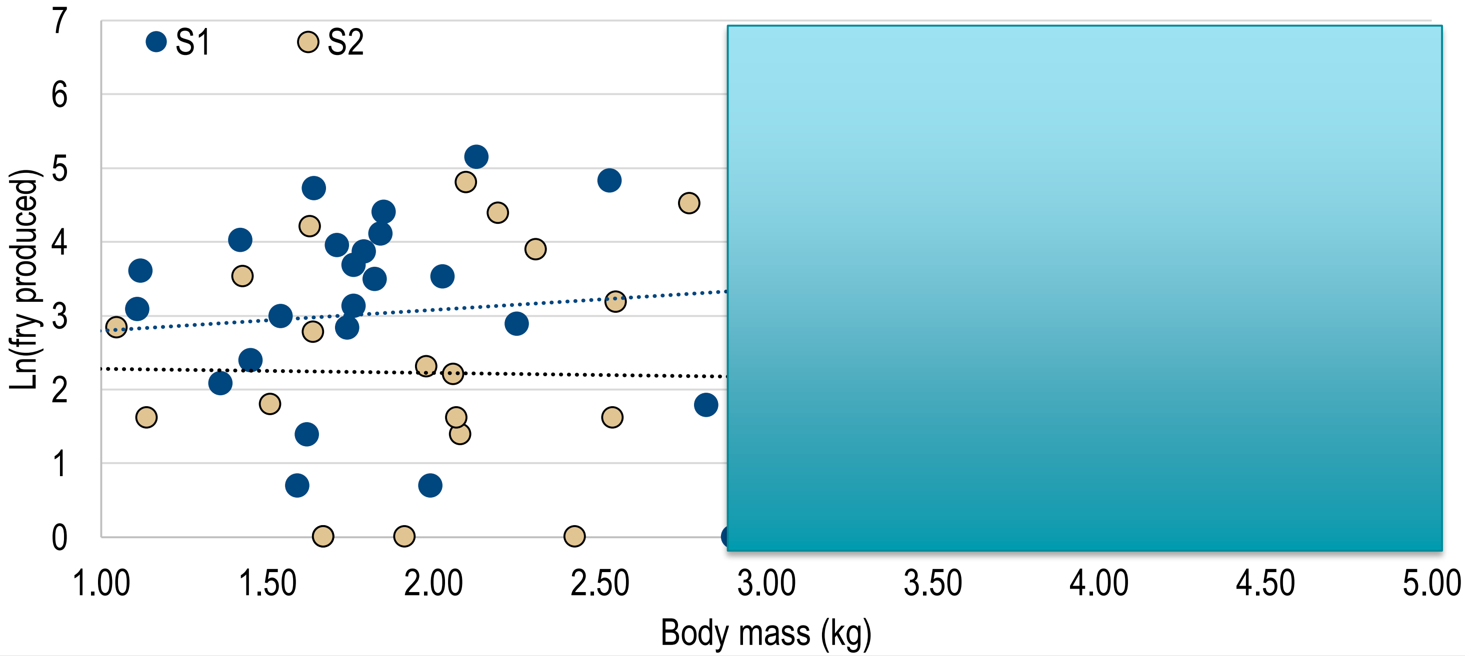
Male breeding success (S1, S2, parr)

Analysis of Variance (S1, S2, Parr)					
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Rear type	**45.760**	**2**	**22.880**	**9.782**	**0.000**
Error	240.917	103	2.339		



Male breeding success (S1, S2 only) ANCOVA

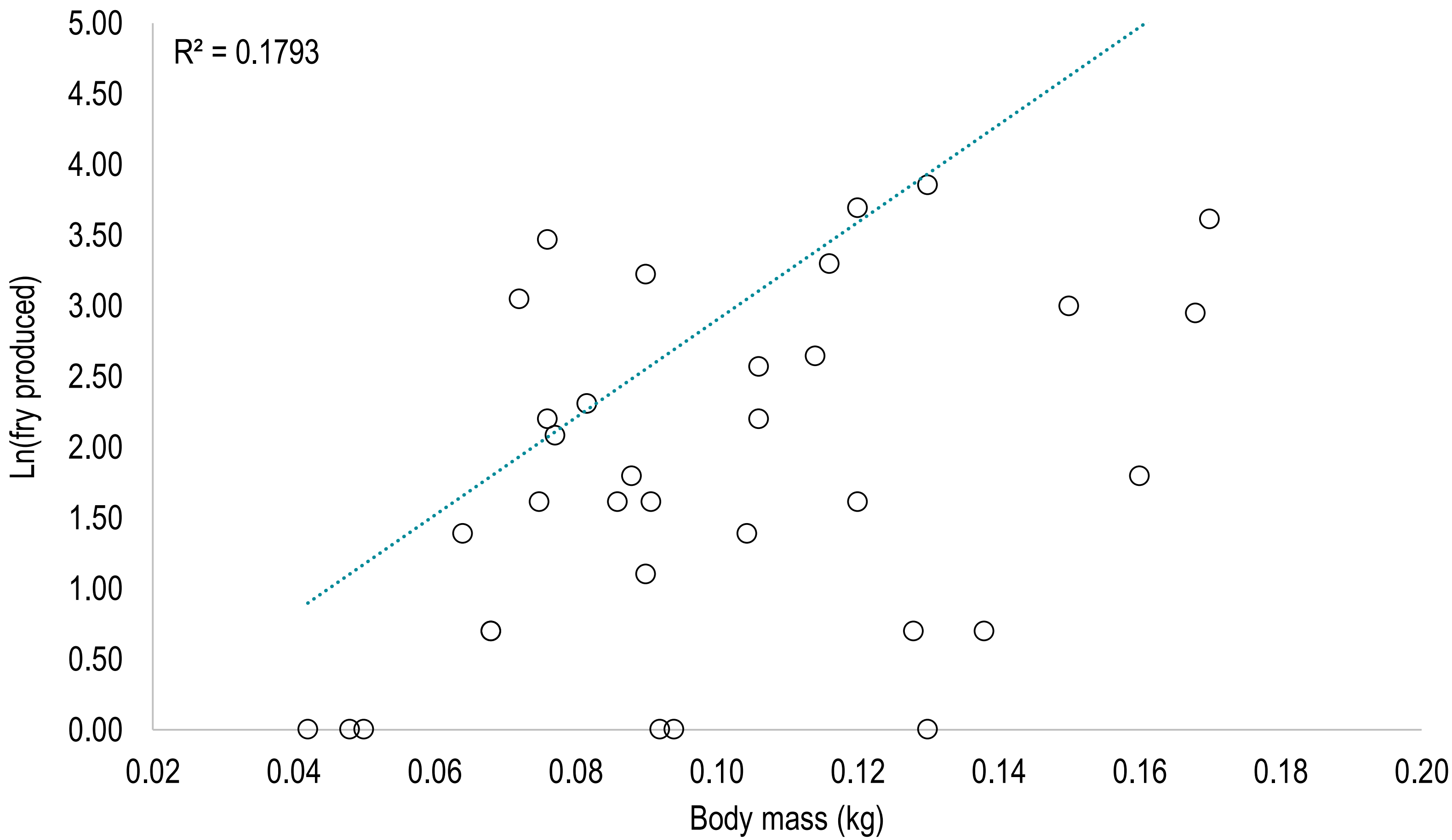
Analysis of Variance (S1, S2)	Covariate = body mass				All males
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Rear type	**13.67**	**1**	**13.67**	**4.900**	**0.030**
Body mass	2.77	1	2.77	0.995	0.322
Error	186.92	67	2.79		



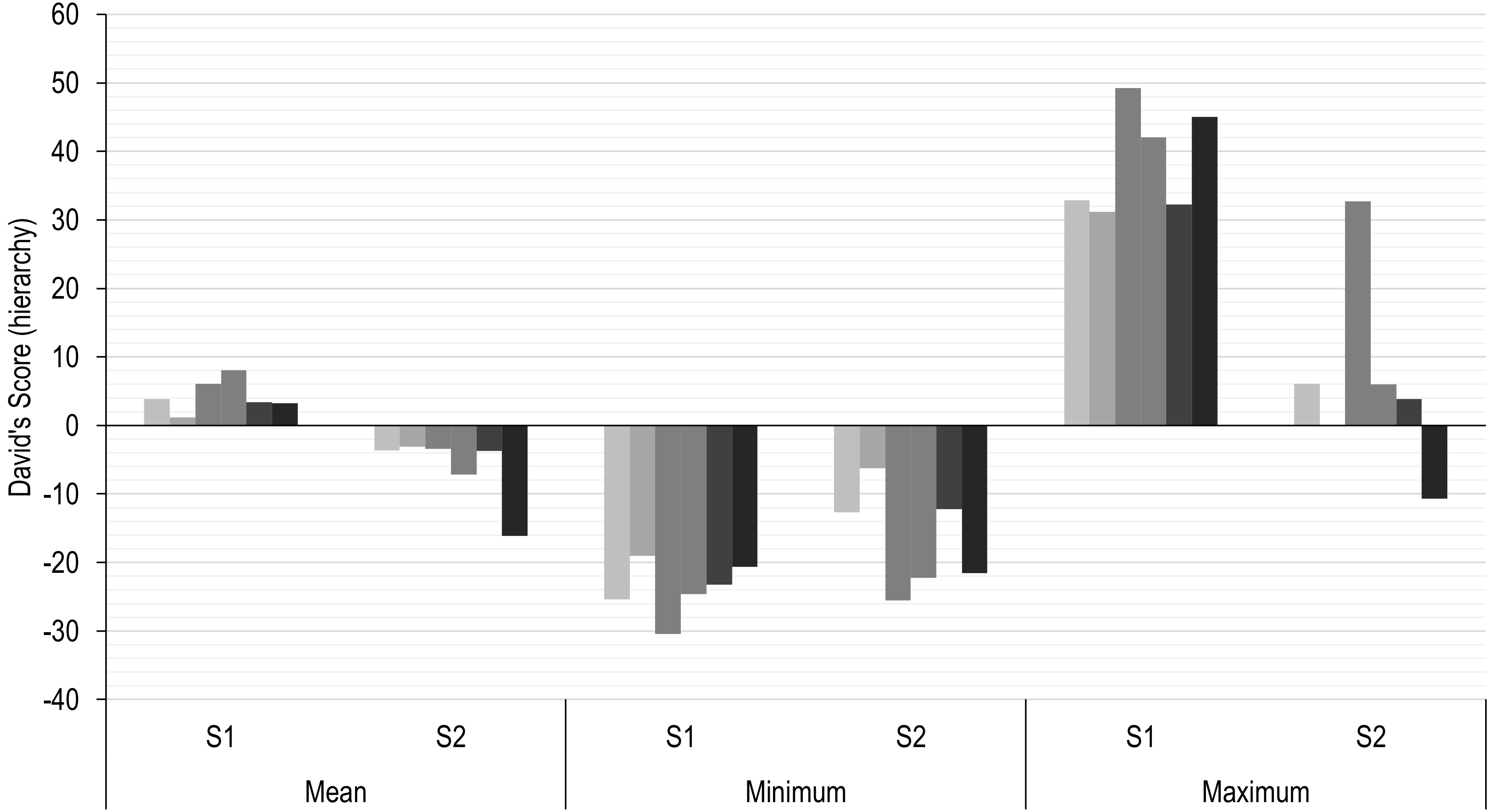
Male breeding success ANCOVA (S1 and S2 < 2.8 kg)

Analysis of Variance (S1, S2)	Covariate = body mass			Males < 2.8 kg	
Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Rear type	**11.27**	**1**	**11.27**	**5.778**	**0.021**
Body mass	3.35	1	3.35	1.719	0.197
Error	76.08	39	1.95		

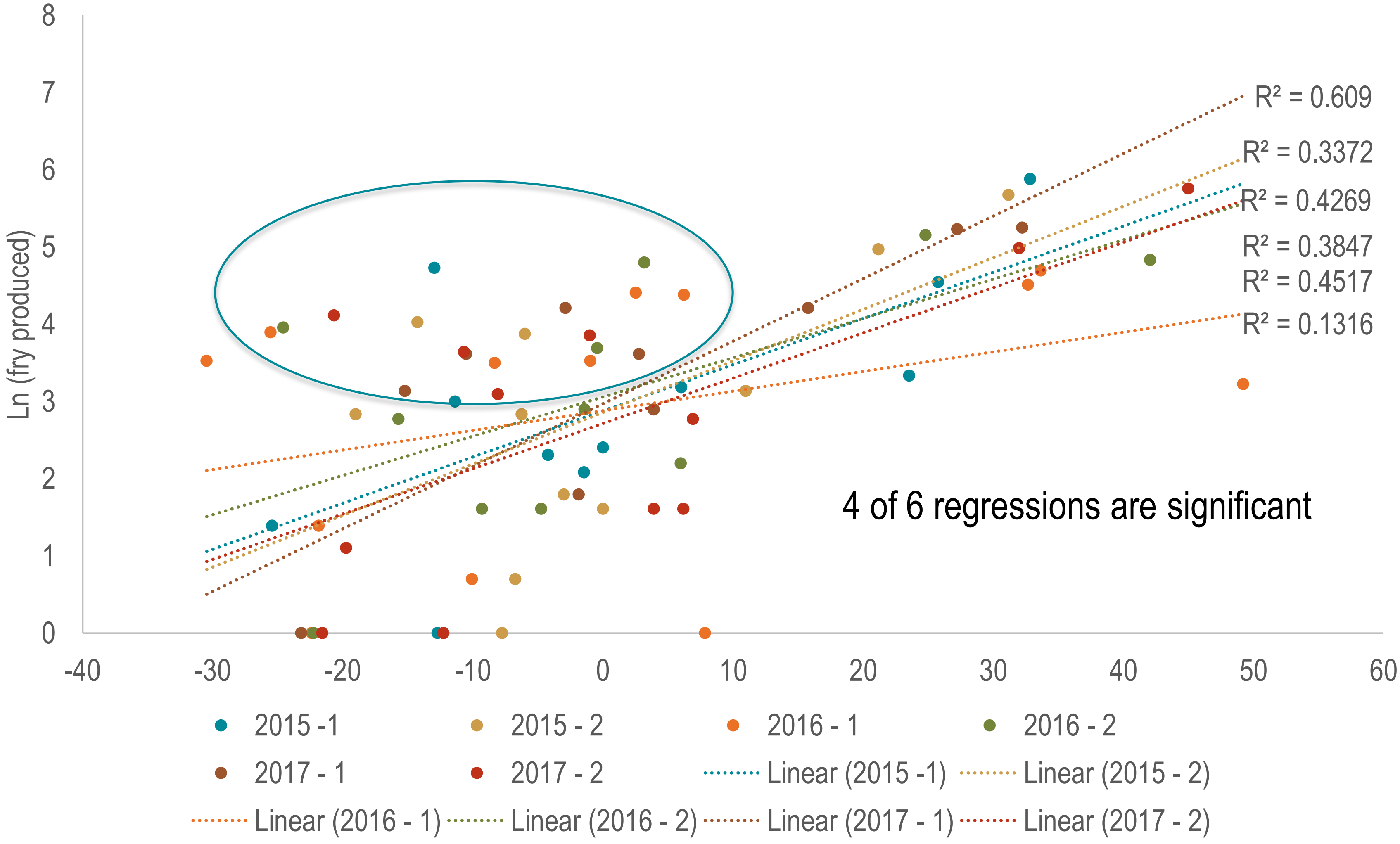
Male body size vs breeding success(parr only)



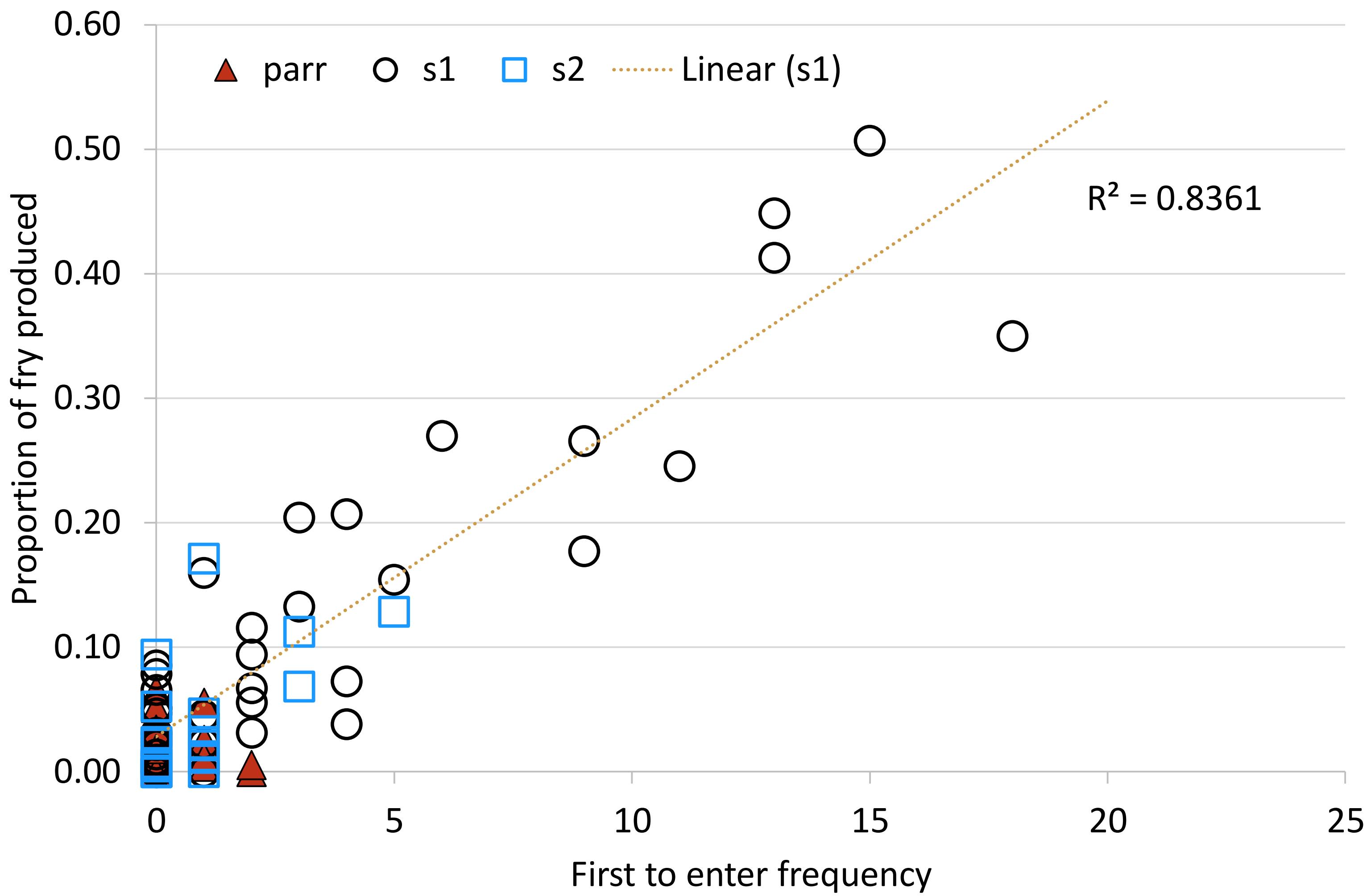
Male dominance hierarchies



Dominance vs fry production (by breeding group)



First to enter nest at time of spawning



Sex-bias in relative fitness estimates?

Species	Male RRS		Female RRS	Comments	Reference
Atlantic salmon	0.51	<	~1.0	Breeding success	Fleming et al. 1997
Chinook salmon	0.32	<	0.51	Adult to juvenile	Williamson et al. 2010
Chinook salmon	0.64	<	1.00	Lifetime	Hess et al. 2012
Chinook salmon	0.48	<	1.2	Adult to Juvenile	Sard et al 2015
Chinook salmon	0.83	<	1.48	Lifetime	Anderson et al 2012
Steelhead	0.60	<	0.63	Lifetime H_{hw} v. H_{ww}	Araki et al. 2007
Steelhead	0.31	<	0.42	Lifetime W_{hh} v. W_{ww}	Araki et al. 2009
Steelhead	**0.60**	<	**1.15**	**Adult to juvenile (nn broodstock)**	**Ford et al. 2016**
Steelhead	0.32	<	0.50	Adult to juvenile (hn broodstock)	Ford et al. 2016
Steelhead	0.14	>	0.13	Adult to juvenile (hh broodstock)	Ford et al. 2016
Coho salmon	0.62	<	0.82	Breeding success	Fleming and Gross 1993
Coho salmon	0.62	<	0.84	Lifetime	Theriault et al. 2011
Chum salmon	0.99	>	0.73	Adult to juvenile	Berejikian et al. 2009
Chinook salmon	1.1	>	1.0	Lifetime H_{hh} v. H_{ww}	Ford et al. 2012
Coho salmon	0.97	>	0.74	Lifetime	Ford et al. 2006
Steelhead	0.48	>	0.40	Lifetime	Berentson et al. 2011

Summary

- Female breeding success
  - Somewhat influenced by body size and fecundity
  - Similar between S1 and S2
  - Up to 73% of eggs converted to fry
  - Productivity should be unaffected by rearing strategy

- Male breeding success
  - Success highly skewed towards a few of the larger males
  - Otherwise body size has little influence
  - S1 > S2; possibly influenced by competitive asymmetries
  - Precocious males contribute substantially (~10% of the fry produced)

Acknowledgements

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