RRS Project Review

Project ID: 1989-096-00[1]

Title: Genetic Monitoring and Evaluation (M&E) Program for Salmon and Steelhead

Short Description: Initiated in 1989, this study monitors genetic changes associated with hatchery propagation in multiple Snake River sub-basins for Chinook salmon and steelhead; Little Sheep Creek (Imnaha Basin) for steelhead, and Catherine Creek, Lostine River, and the Upper Grande Ronde for Chinook salmon. It also derives estimates of reproductive success for individual families and groups of fish. The study has two components: gene frequency monitoring over time, and reproductive success in hatchery and wild fish. Results should aid in addressing critical uncertainty and genetic risk associated with the use of supplementation in recovery.

Sponsor: NOAA / ODFW

BiOp association: 2008 FCRPS

RPA 62.5 Investigate feasibility of genetic stock id techniques,
RPA 63.1 Measure effect of safety-net & conservation hatchery programs
RPA 64.1 Estimate relative reproductive success (RSS) of hatchery
RPA 64.2 Determine if artificial production contributes to recovery

Is this an Accord project? No

Budget (2008 to present):

BPA		Total	$ 4,569,415 (M&E = $4,008,614)
		FY16	$ 488,167
Cost share			
	NOAA		$ 367,527 (2009-2014)
	Pacific Salmon Commission		$ 38,000 (2008-2009)

Proposal from last Categorical Review:

https://www.cbfish.org/Proposal.mvc/Summary/RMECAT-1989-096-00

Most recent Council recommendation:

https://www.cbfish.org/Assessment.mvc/CouncilRecommendationAssessmentSummary/Assessment/1989-096-00-NPCC-20110125

**Sponsor has not addressed Council/ ISRP qualifications to date (August 2016) – the results report and recommendation of future work, outcome of Lower Snake Comp Review process, and the hatchery

[1]This is not one of the six exclusively RRS projects, but it has RRS linkages.

effects evaluation process described in programmatic recommendation #4 were due by the end of CY2014 – this remains an outstanding issue.

Date of most recent annual report available on Pisces/cbfish? January 2016, "Monitor and Evaluate the Genetic Characteristics of Supplemented Salmon and Steelhead" https://pisces.bpa.gov/release/documents/DocumentViewer.aspx?doc=P148017

Short summary of project reporting compliance: This project involves two agencies, each with their own contract(s), working collaboratively. A single, joint authored annual report is generated for the contract period. Contract management and project performance for each agency has been excellent. To date, at least 13 peer-reviewed scientific papers have been published using information from this project.

Summary of the scope of the project as it was reviewed by Council: Initiated in 1989, this study monitors genetic changes associated with hatchery propagation in multiple Snake River sub-basins for Chinook salmon and steelhead. It also derives estimates of reproductive success for individual families and groups of fish.

The information obtained from this study directly addresses a critical knowledge gap identified by comanagers, that is, under what conditions does hatchery supplementation provide a sustained contribution to natural production? This type of monitoring work is now an essential part of hatchery reform and the goal of using widespread hatchery propagation in recovery of natural populations. This study was designed as a two-tiered approach: gene frequency monitoring over time (Tier 2), and a direct examination of reproductive success (RS) in hatchery and wild fish (Tier 3). Tier 2 sites use changes in gene frequencies through time in hatchery, natural and wild Chinook salmon and steelhead populations to evaluate the genetic effects of hatchery supplementation on a broad geographic scale. Tier 3 sites involve direct measures of the relative reproductive success of hatchery fish spawning in the wild by using parentage analysis to construct pedigrees (see study sites below). These methods were explained in detail in the proposal recommended and approved by the ISRP, BPA, and the NPCC.

Summary of the scope of the project now: Scope has not appreciably changed since the last review.

Has the scope of this project changed significantly since it was reviewed? No

ISRP/AB Critical Uncertainties Appendix D review:

http://www.nwcouncil.org/media/7149871/isabisrp2016-1appendixd.pdf#page=107

Comments: Since its inception in 1989, this project has made and continues to make significant contributions toward increasing understanding of the potential effects of hatchery programs on the genetic structure of adjacent conspecific populations and in supplemented populations. Another important finding of this study is that RRS research based on juveniles may be comparable and statistically more robust than adults. Results show cases where hatchery fish seem to have contributed to natural production and cases where the genetic effects of the hatchery supplementation are less apparent. Detection of long-term trends in genetic diversity requires time series that are decades long and may need to continue as long as salmon populations are not self-sustaining.

Questions to all project sponsors with RRS studies:

- How does this project inform (1) the Council's Research Plan and (2) the Council's Fish and Wildlife Program objectives?
- Can any results from this study be extrapolated to other geographic locations or other populations?
- How does the Idaho Supplementation Study inform this project?
- Does this project have any of the following elements:
  - (a) A scientific question
  - (b) A hypothesis
  - (c) A specific time frame within which to answer the question posed
- How was it determined which species or geographic area to study?
- How does this effort work or collaborate with other RRS projects on aspects of the study (methodology, data and conclusions)?
- How does density dependence factor in to this study moving forward?

Questions relative to this project:

- Is the Tier 3 work, RRS, complete? If not, when is it anticipated to reach completion?
- The ISAB remarks that this project has made "significant contributions" toward increasing the understanding of potential effects of hatchery programs. What are those "significant contributions?"
- How long is it anticipated to confirm the finding that RRS based on smolt production is comparable to RRS based on adult returns?
- What are the major findings after 27 years of this research?
- The Council recommendations regarding this project have not been addressed-what is the plan for addressing them?

Monitor and evaluate characteristics of supplemented salmon and steelhead

BPA Project # 1989-096-00

RRS Project Workshop
Portland, OR
October 13, 2016

Ewann Berntson, Paul Moran and Robin Waples

Conservation Biology Division, Northwest Fisheries Science Center

NOAA Fisheries

Project Goals

Provide evidence of risks/benefits of hatchery supplementation on both targeted and non-targeted populations

- What is the nature and extent of genetic change over time in supplemented and unsupplemented populations?
- What is RRS of supplementation fish spawning in nature?
- How does estimated RRS correlate with measures of productivity?

Addressing critical uncertainties in supplementation, recovery, and conservation genetics

Why is long-term monitoring necessary?

- Year-to-year variability
  - In-river conditions
  - Out-of-basin conditions
  - Adaptive management practices
  - Resulting RRS
- Hatchery effects may increase with time/exposure
- Heritability questions

Relevance to Council's Research Plan (2006)

Direct

- Hatcheries/Artificial Production: Supplementation
  - CU #3: Demographic benefit to natural-origin fish from the natural spawning of supplementation adults?
  - CU #4: Changes in natural spawning fitness of integrated (supplemented) populations as relates to management rules?

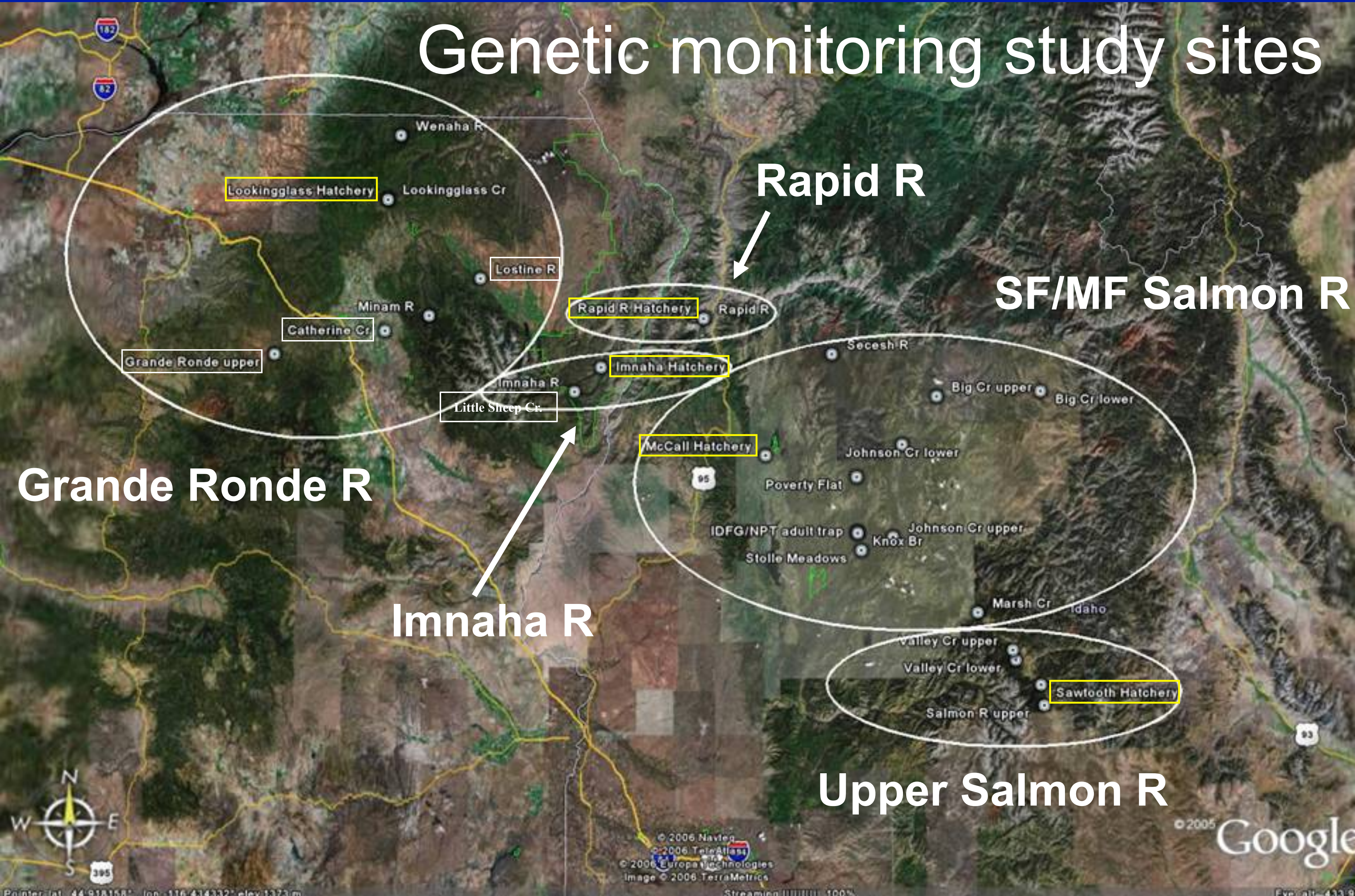
Indirect

- Hatcheries/Artificial Production: All Hatcheries
  - CU #6: Relationship between basinwide hatchery production and the survival and growth of naturally produced fish?
- Population Structure and Diversity
  - CU #2: Impact of artificial production and supplementation on restoration of an ecologically functional metapopulation structure?
  - CU #3: Relationship between genetic diversity and ecological and evolutionary performance? Does loss of diversity reduce the resilience of remaining populations?

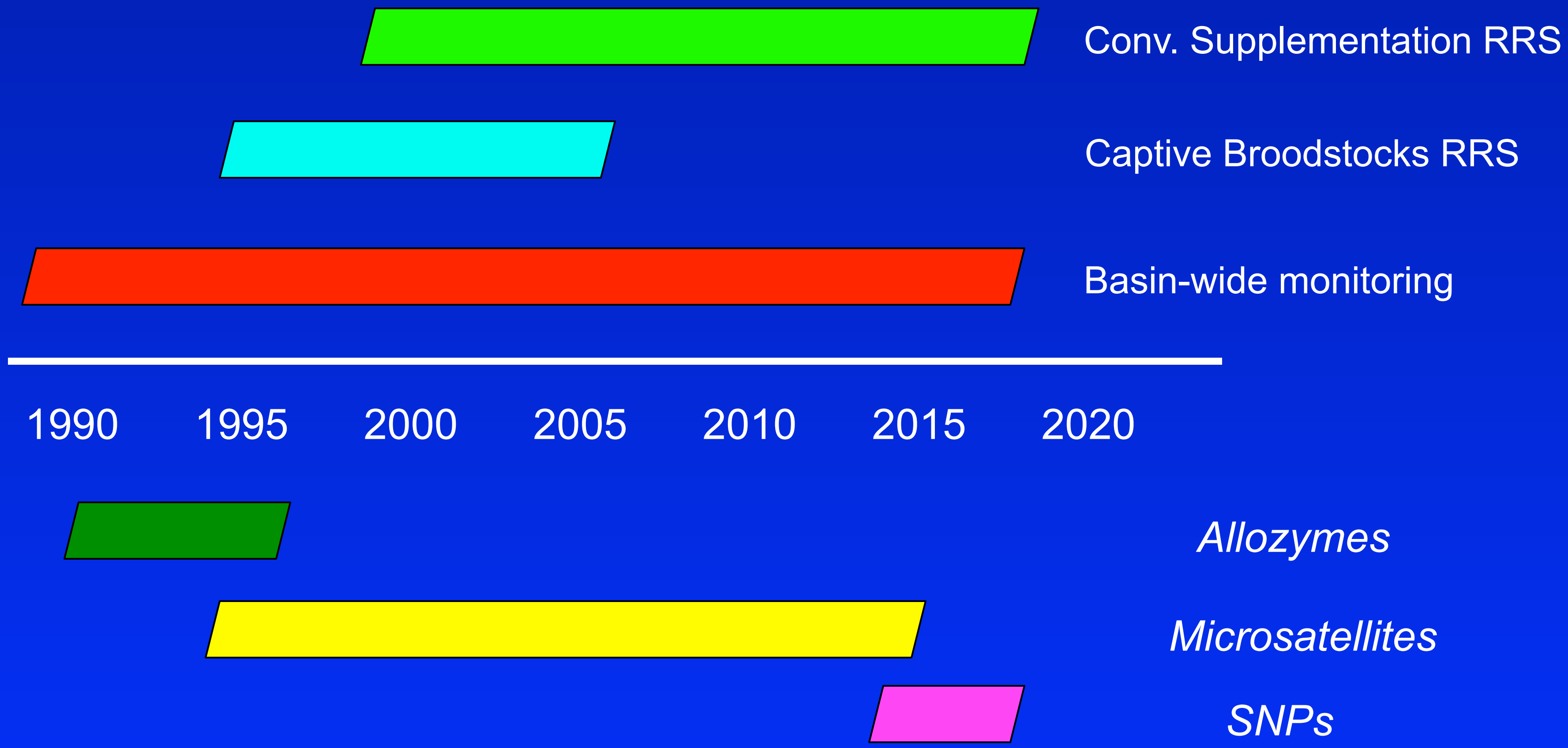
Relevance to Council's Fish and Wildlife Program's goals and objectives (2014)

- Theme 2: Ensure species survival by promoting abundance, diversity and adaptability
  - Restoring healthy, self-sustaining natural-origin anadromous fish
  - Encouraging biologically diverse species that are resilient to environmental variability
  - Achieving delisting and recovery criteria for ESA-listed species in the BiOP

Genetic monitoring study sites



Evolution of a Project



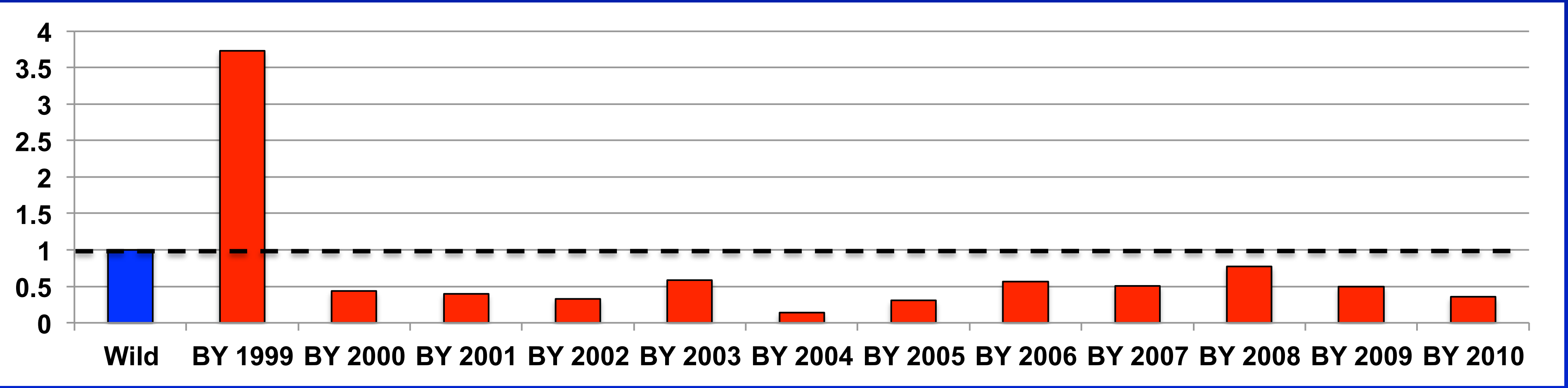
Relationships to other regional projects

- **NE Oregon**
  - Early Life History of GR Basin Chinook (ODFW)
  - GR Chinook Captive Broodstock program (ODFW, NPT, LSRCP, NOAA)
  - Smolt migration characteristics—Fish Passage Center monitoring program
- **Idaho**
  - Idaho Supplementation Studies (NPT, SBT, IDFG)
  - Monitoring migrations of Chinook smolts (NOAA)
  - Integrated status and effectiveness monitoring program (ISEMP)
- **Basin-wide**
  - Contributing to ongoing baseline projects (microsats, SNPs)
  - Various requested collaborations—whirling disease, BKD, mouth tumors, outplanting effectiveness, etc.

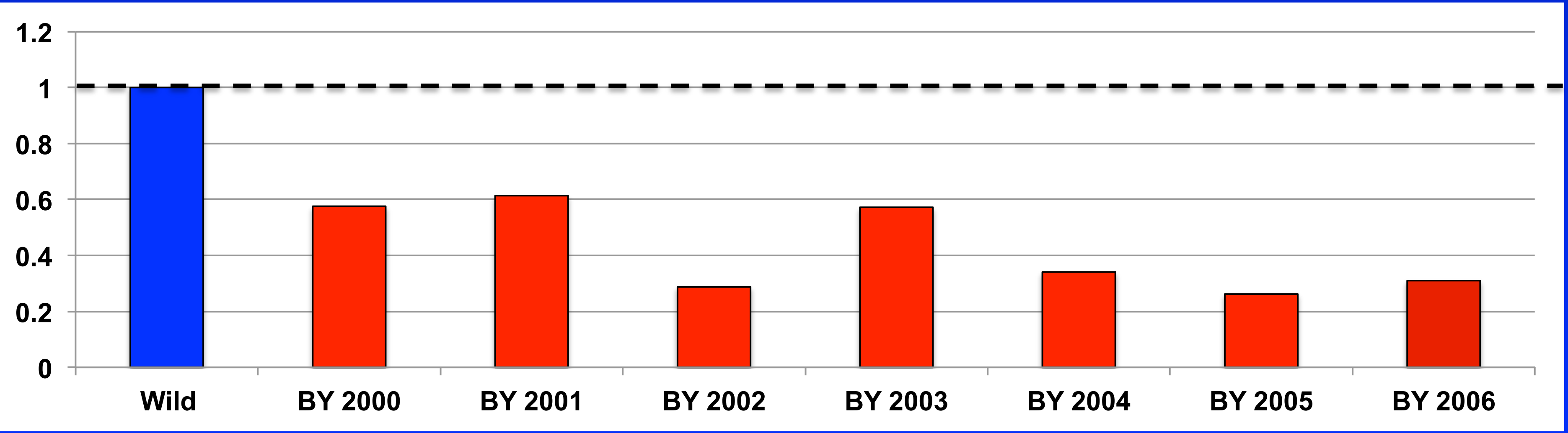
Major Accomplishments

- Publication of 35 peer-reviewed papers, excellent reporting record, local/national presentations
- Annual sampling ~3 decades, multiple basins
- Documented lowered RRS in supplementation hatchery systems
  - Two species, two rivers
  - Accompanying ecological data
- Hypothesized potential mechanisms behind reduced RRS
- Characterized genetic structure/connectivity of hatchery and wild Chinook and steelhead in Grande Ronde and Salmon River basins

Little Sheep Creek Steelhead

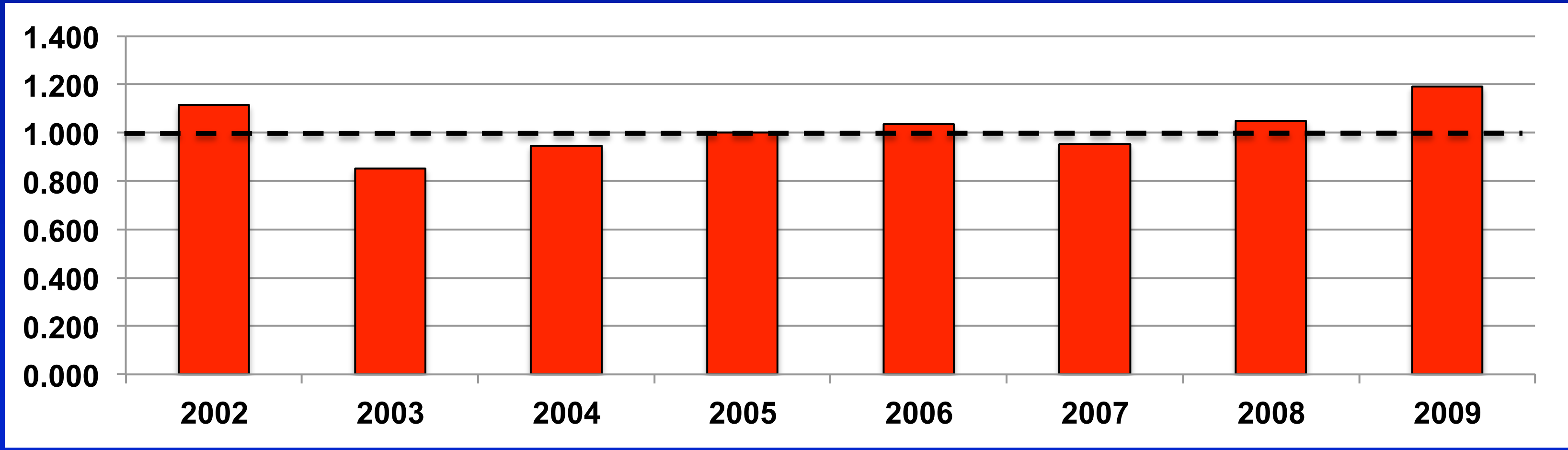


Adult-to-juvenile, Geomean = 0.49 (all years)
= 0.41 (2000-2010)

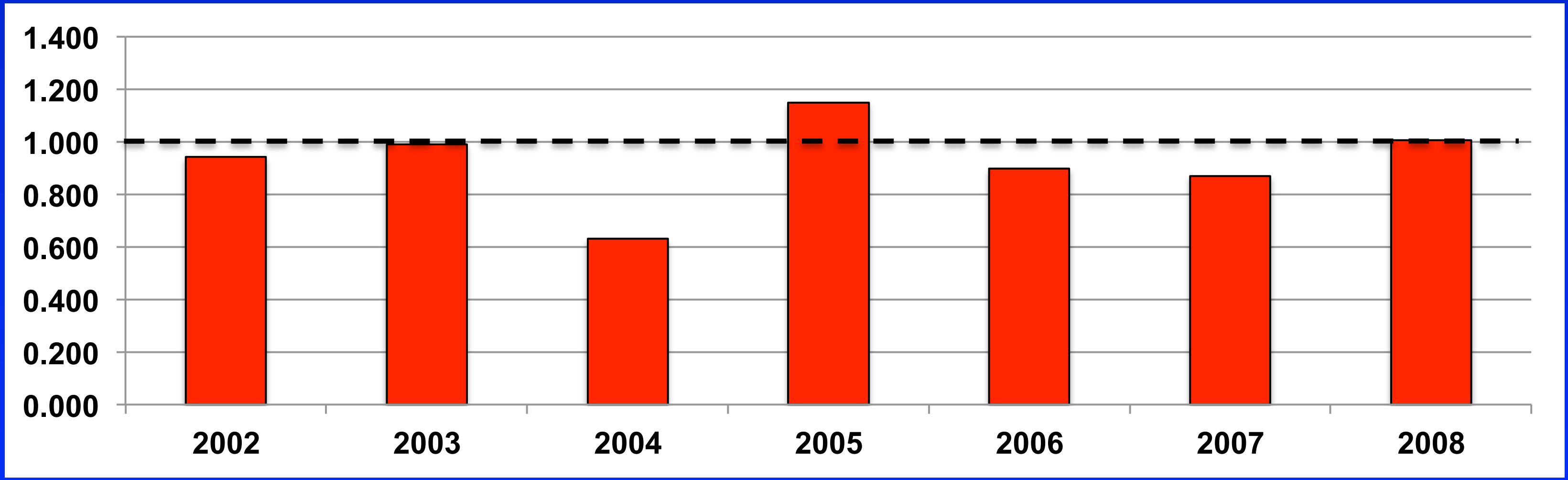


Adult-to-adult, Geomean = 0.40

Catherine Creek Chinook RRS



Adult-to-juvenile, Geomean = 0.99

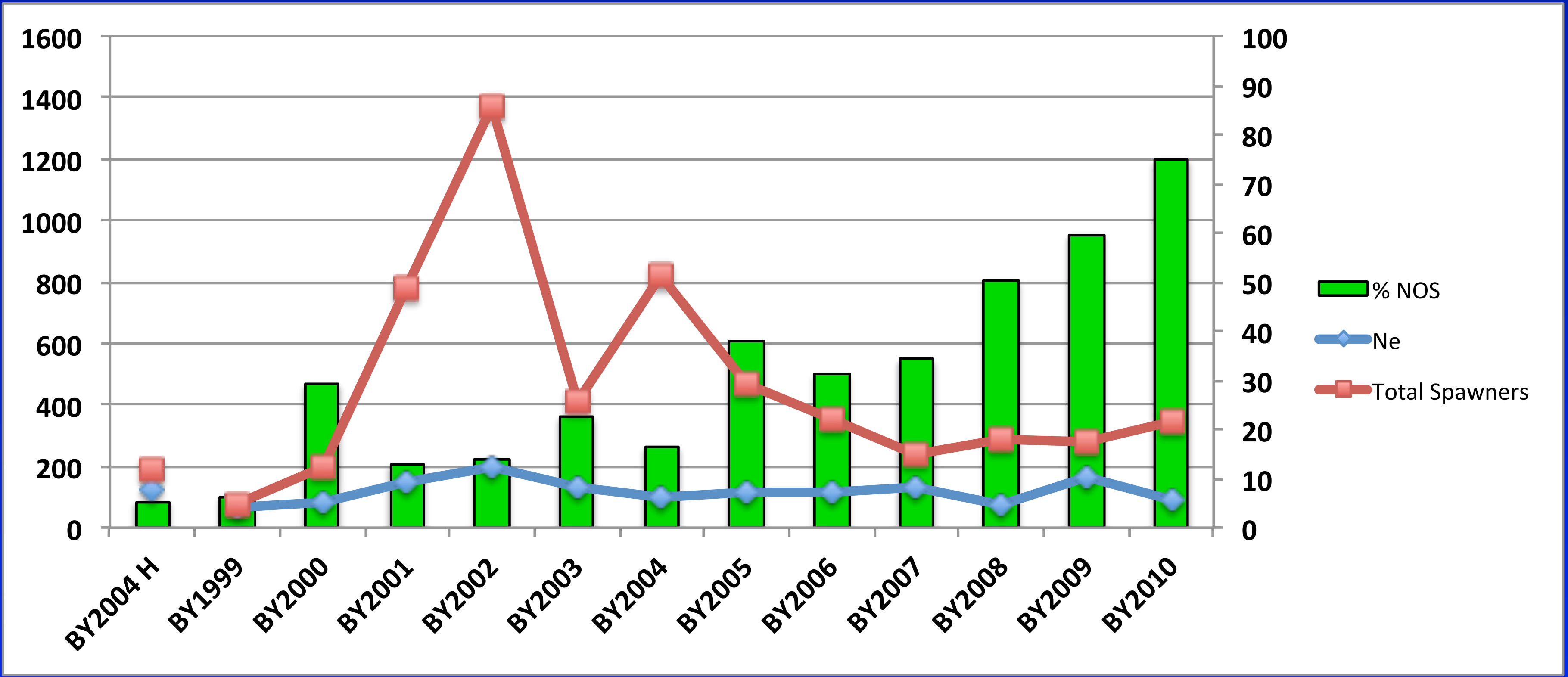


Adult-to-adult, Geomean = 0.89

Density dependence

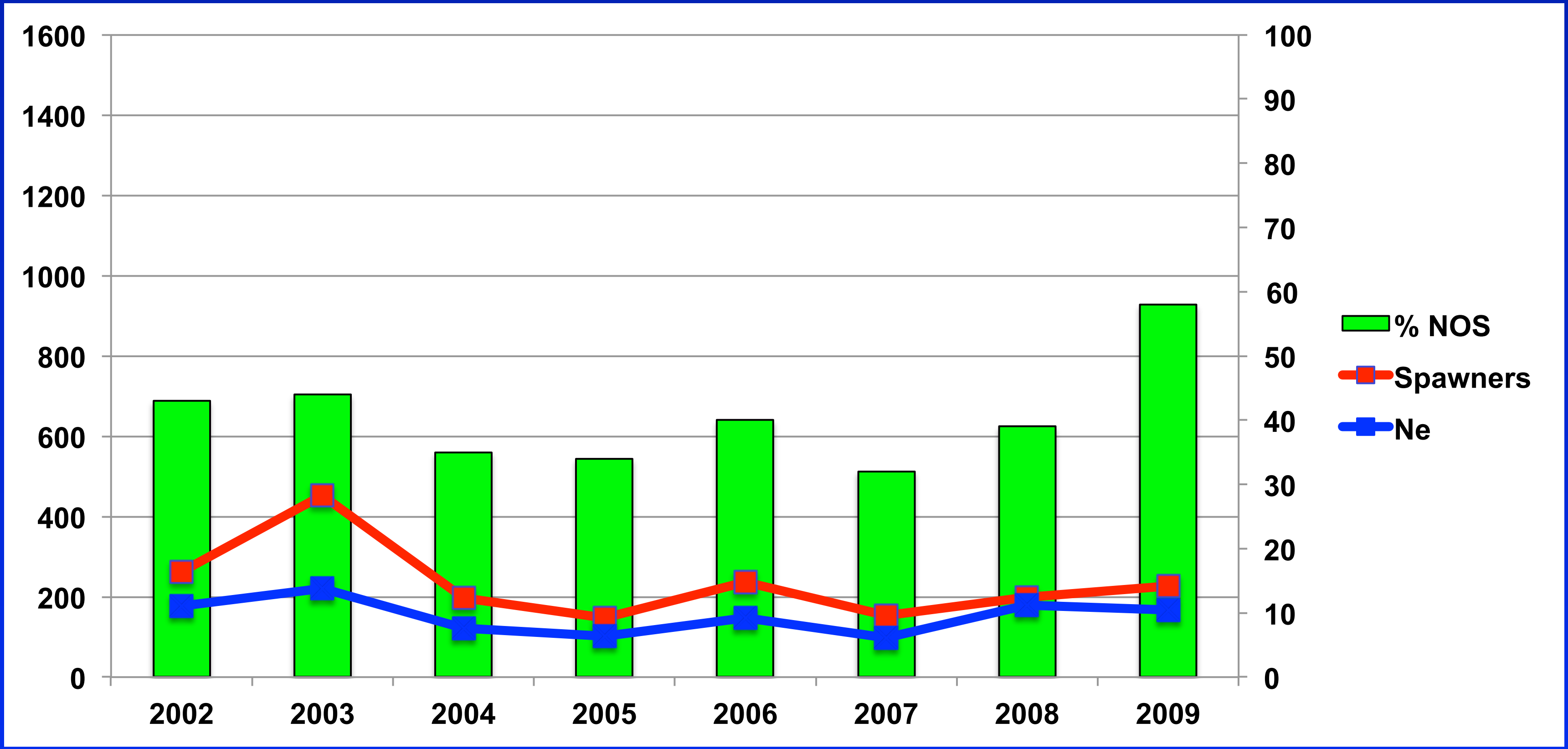
- Same-sex competition was a factor in Little Sheep Cr.
  - Not evident for overall density
  - Females more negatively impacted
  - Move acclimation sites higher in system?
- 2005 change in spawner densities
  - Reduced number of adults passed
  - Goal of 50% NOS

Little Sheep Creek



- Stable N_e despite fluctuating census, pNOS
- N_e similar in hatchery vs. stream
- Monitoring effect of weir change (BY 2005)

Catherine Creek



- N_e varies similarly to census
- Overall higher pNOS, lower census than Little Sheep

Next Steps

- Link to productivity/abundance in streams and controls
- Alternate acclimation sites in Little Sheep Creek
- Epigenetic factors
- Heritability/selection coefficients of reduced RRS
- Differences from other supplementation systems

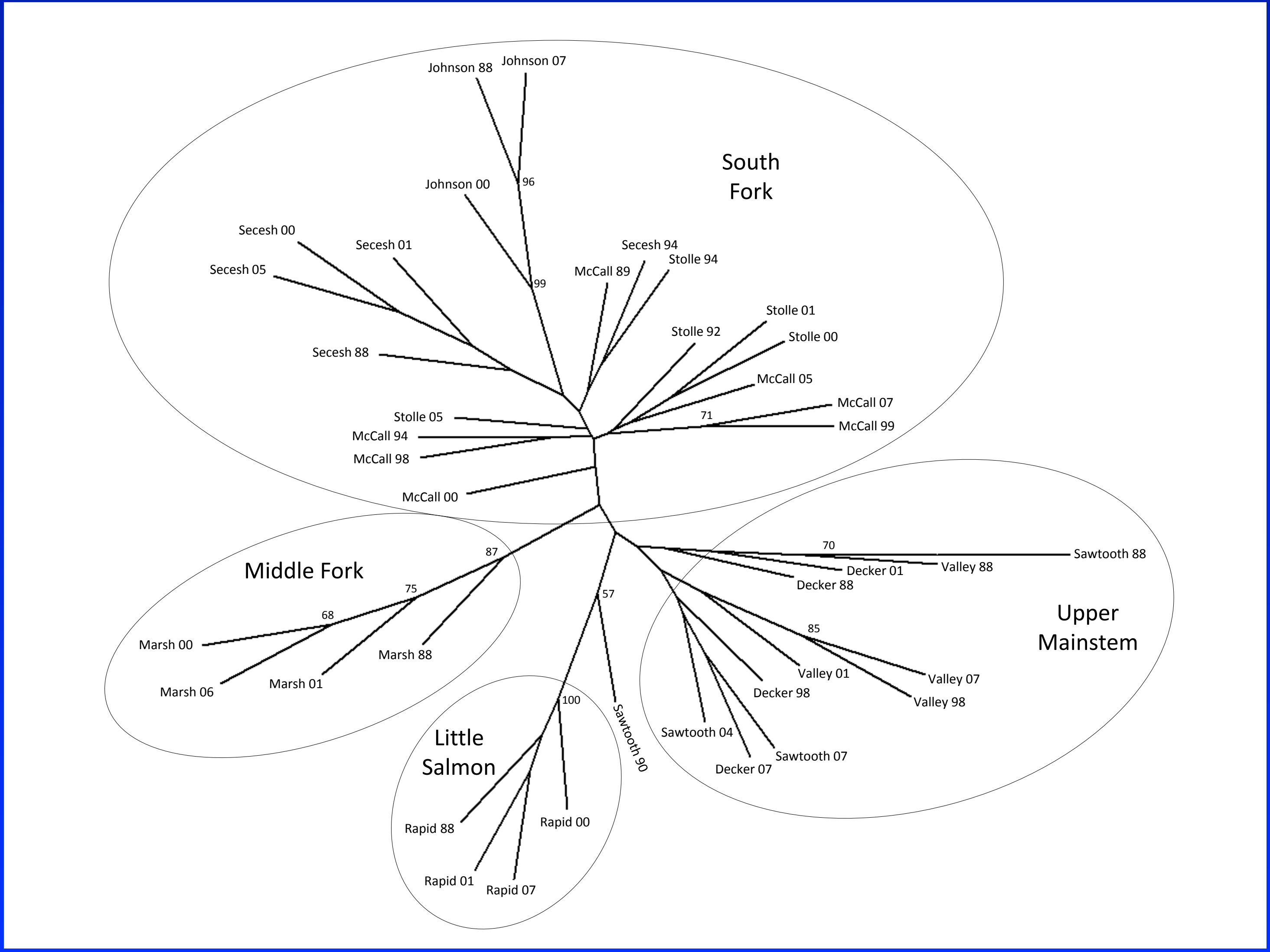
Long-term Datasets, Broad-Scale Monitoring

- Substantial year-to-year variability in-river conditions, out-of-basin conditions, spawner abundances, RS
- Longer exposure to hatchery conditions = greater effects?
- Small differences in RS over time can yield large effects on populations
- Multiple generations critical to understanding/improving supplementation
- We respond to RPA's, Critical Uncertainties, co-managers

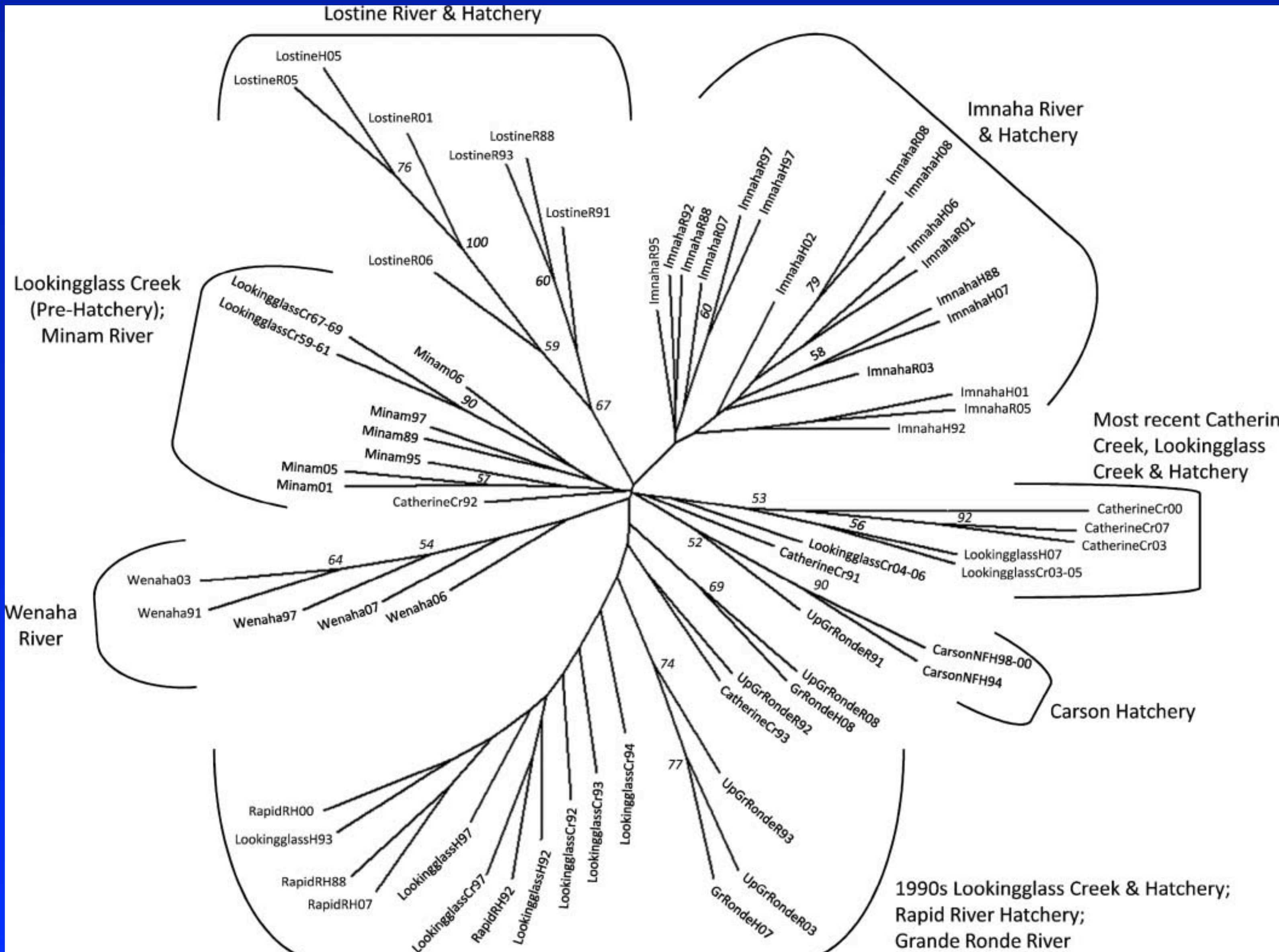
Hypotheses:

- H_O: Supplementation fish successfully target intended streams
  - H_A: Supplementation fish do not exhibit high fidelity to streams of origin; genetic signals can be detected in multiple non-target streams.
- H_O: Measures of diversity in the Snake Basin have remained stable over time throughout supplementation
  - H_{A1}: Diversity in supplementation streams has increased
  - H_{A2}: Diversity in supplementation streams has decreased
  - H_{A3}: Patterns of diversity in control streams mirror supplementation streams
- H_O: Hatchery-origin supplementation fish have equal RS to natural-origin fish when spawning naturally
  - H_A: Hatchery-origin fish have lowered RRS

Structure in Salmon River Chinook populations



Grande Ronde Chinook populations



Little Sheep Creek Pre/Post 2005 RRS

Year	# spawners	pNOB	Ad-juve	Ad-ad
2000	79	6	0.48	0.61
2001	199	29	0.39	0.52
2002	1370	14	0.24	0.29
2003	409	23	0.47	0.57
2004	819	17	0.21	0.31
2005	464	38	0.32	0.3
2006	354	30	0.48	0.2
2007	240	34	0.52	0.4
2008	291	48	0.59	0.71
2009	283	56	0.39	
2010	346	71	0.37	
2011	307	70	0.77	
2012	241	54	0.46	
	Geomean	**pre-2005**	**0.34**	**0.44**
		post-2005	**0.47**	**0.36**

msats

SNPs

GLM analysis--steelhead

- Considered effects and interactions of sex, **origin**, return date, **length**, **density**, **spawning site**
- Hatchery fish = lower RRS
- Larger fish = higher RRS
- Lower RRS with more same-sex competitors, particularly hatchery fish
  - Wild fish better able to compete with higher numbers of same-sex competitors?
  - Wild fish able to spawn in better habitat?

Peer-reviewed papers—
13 since 2006

- Waples, R. S. 2006. A bias correction for estimates of effective population size based on linkage disequilibrium at unlinked gene loci. Conservation Genetics 7(2):167-184.
- Narum, S.R., S. Boe, P. Moran, and M. Powell. 2006. Small scale genetic structure and variation in steelhead of the Grande Ronde River, Oregon, U.S.A. Trans. Amer. Fish. Soc. 135:979–986.
- Moran, P., D.J. Teel, E.S. HaHood, J. Drake, S. Kalinowski. 2006. Standardizing multi-laboratory microsatellite data in Pacific salmon: An historical view of the future. Ecol. Freshwater Fish 15:597-605.
- Narum, S.R., D. Hatch, A.J. Talbot, P. Moran, and M.S. Powell. 2007. Conservation of iteroparous salmonids in complex mating systems and influence on effective population size. J. Fish Biol. 72:45-60.
- Seeb, L.W., A. Antonovich, M.A. Banks, T.D. Beacham, M.R. Bellinger, M. Campbell, N.A. Decovich, J.C. Garza, C.M. Guthrie III, P. Moran, S.R. Narum, J.J. Stephenson, K.J. Supernault, D.J. Teel, W.D. Templin, J.K. Wenburg, S.F. Young, C.T. Smith. 2007. Development of a standardized DNA database for Chinook salmon. Fisheries 32:540-552.
- Narum, S.R, M. Banks, T. Beacham, R. Bellinger, M. Campbell, J. DeKoning, A. Elz, C. Guthrie, C. Kozfkay, K. Miller, P. Moran, R. Phillips, L. Seeb, C. Smith, K. Warheit, S. Young, and J.C. Garza. 2008. Differentiating Chinook salmon populations at broad and fine geographic scales with microsatellites and SNPs. Molec. Ecol. 17:3464-3477.
- Paquin, M.M., J.M. Meyers, H. Pollard, R.M. Carmichael, and P. Moran. 2008. Steelhead Hatchery Legacy: Hatchery and Wild Population Genetic Structure in the Snake River Basin. Cons. Genet. *In revision*.
- Grim, K.C., M.J. Wolfe, M. Edwards, J. Kaufman, S. Onjukka, P. Moran, and J.C. Wolf. 2009. Epizootic ameloblastomas in Chinook salmon (Oncorhynchus tshawytscha) of the northwestern United States. Vet. Path 46(4):622-635.
- Stephenson, J.J., M.R. Campbell, J.E. Hess, C. Kozfkay, A.P. Matala, M.V. McPhee, P. Moran, S.R. Narum, M.M. Paquin, O. Schlei, M.P. Small, D.M. Van Doornik, J.K. Wenburg. 2009. A centralized model for creating shared, standardized, microsatellite data that simplifies inter-laboratory collaborations. Cons. Genet. 10:1145-1149.
- Berntson, E.A., R.W. Carmichael, M.W. Flesher, E.J. Ward and P. Moran 2011. Diminished reproductive success of steelhead from a hatchery supplementation program (Little Sheep Creek, Imnaha Basin, Oregon). TAFS 140:685-698.
- Blankenship, S.M., M.R. Campbell, J.E. Hess, M.A. Hess, T.W. Kassler, C.C. Kozfkay, A.P. Matala, S.R. Narum, M.P. Small, J.J. Stephenson, K.I. Warheit and P. Moran. 2011. Major lineages and metapopulations in Columbia River *Oncorhynchus mykiss* are structured by dynamic landscape features and environments. TAFS 140:665-684.
- Van Doornik, D. M., R. S. Waples, M. C. Baird, P. Moran, and E. A. Berntson. 2011. Genetic monitoring reveals genetic stability within and among threatened Chinook salmon populations in the Salmon River, Idaho. NAJFM 31:96-105.
- Van Doornik, D. M., D. L. Eddy, R. S. Waples, S. J. Boe, T. L. Hoffnagle, E. A. Berntson, and P. Moran. 2013. Genetic monitoring of threatened Chinook salmon populations: estimating introgression of nonnative hatchery stocks and temporal genetic changes. NAJFM 33:693-706.