Genetic Analysis of Hatchery Steelhead from the Central Valley Reveals Patterns of Reproduction and Migration

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Genetic Analysis of Central Valley Hatchery Steelhead

-Intergenerational genetic (parentage-based) tagging (PBT) is especially useful in steelhead because of iteroparity and lack of coded wire tagging.

-California Hatchery Scientific Review Group (2012) recommended genetic tagging for all steelhead programs in California.

-In combination with genetic stock identification (GSI), PBT is helping us to better understand biology of hatchery-origin steelhead in California.

-Interagency collaboration: NOAA/UCSC, CDFW, BOR, CDWR, USFWS

- -CDFW collects and archives samples
- -NOAA SWFSC performs laboratory and inferential analyses
- -BOR and CDWR provide funding.

Genetic Analysis of Central Valley Hatchery Steelhead

Logistics

-Collection of tissue samples from all steelhead broodstock from the Mokelumne River, Nimbus, Feather River and Coleman hatchery programs for 2011-14 spawn years

-Genotype all samples with 95 SNP markers (and sex ID) markers

-Use genotypes to establish parent database for recovery of genetic tags in subsequent years through pedigree reconstruction

-Estimate rates of migration between Central Valley steelhead programs and introgression of trout using assignment tests (GSI)

-Estimate inbreeding in all hatchery programs

-Identify parents of returning adults to estimate age structure, variance in family size and trait inheritance.

Genetic Analysis of Central Valley Hatchery Steelhead

Sampling and broodstock numbers

Hatchery program	Number of samples	Number of samples from 2011	2012	2013	2014	Mean
Coleman	3584	929	851	896	879	889
Feather River	4440	638	756	1512	1500	1102
Nimbus	1536	500	293	410	327	383
Mokelumne River	650	207	205	49	186	162
Total	10210	2274	2105	2867	2892	2892

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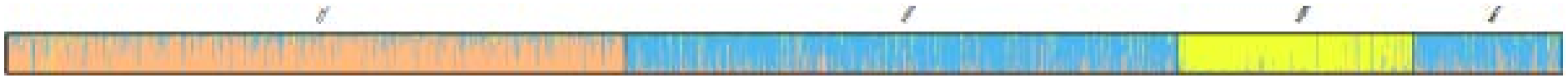
Bayesian analysis of ancestry in steelhead broodstock



Coleman Feather Nimbus Mokelumne

Three populations hypothesized: k = 3

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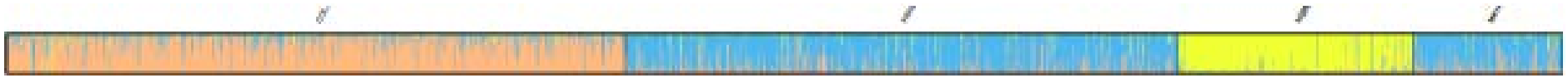
Bayesian analysis of ancestry in steelhead broodstock



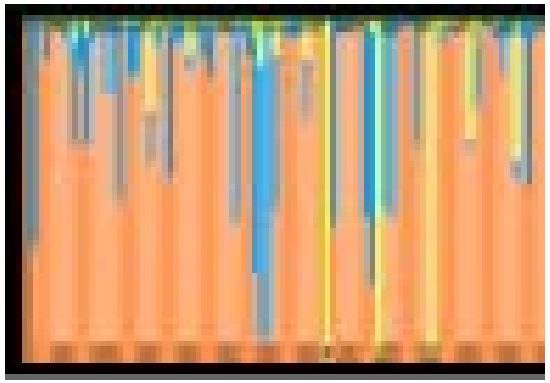
Coleman Feather Nimbus Mokelumne

Three populations hypothesized: k = 3

Non-native Nimbus broodstock most different

Intergenerational Genetic (Parentage-based) Tagging of Central Valley Steelhead Hatchery Stocks

Bayesian analysis of ancestry in steelhead broodstock



Coleman
Three populations hypothesized: k = 3

Can be used to directly identify migrants

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Estimated migration between steelhead programs 2011-14

	Coleman	Feather and Mokelumne	Nimbus
Coleman	2177	27	4
Feather	97	2278	1
Nimbus	0	15	1365
Mokelumne	19	261	1

Only fish with assignment probabilities (Q-values) > 0.9 reported.

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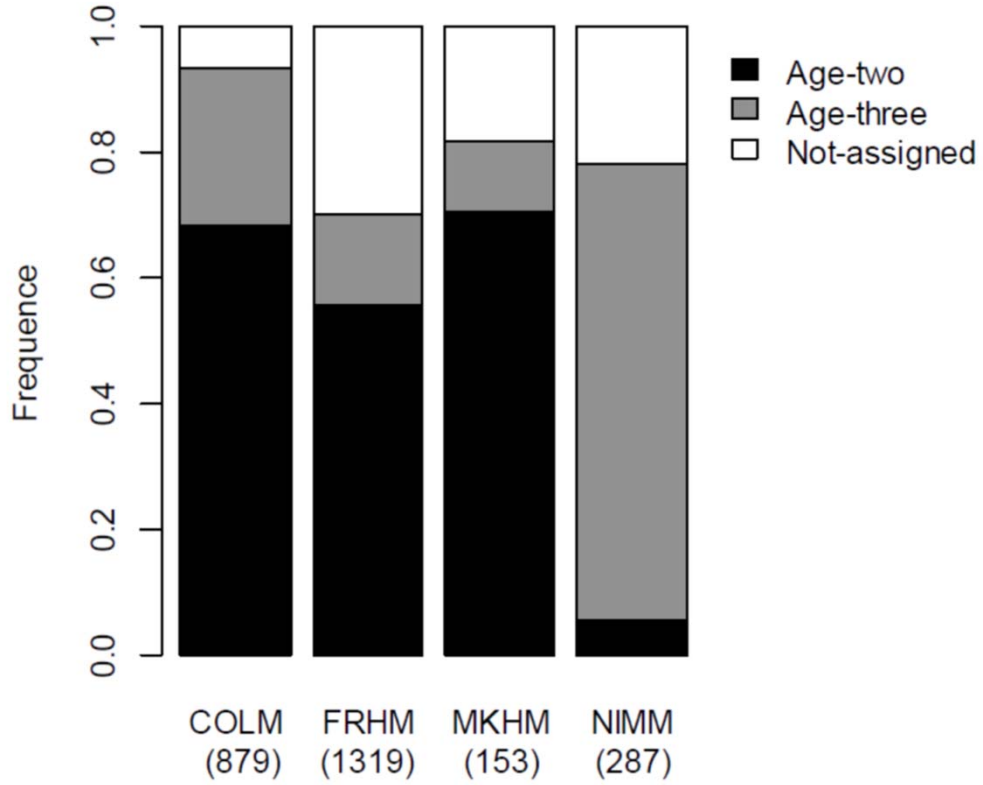
Age structure of hatchery broodstock/returns
Pedigree reconstruction

2014



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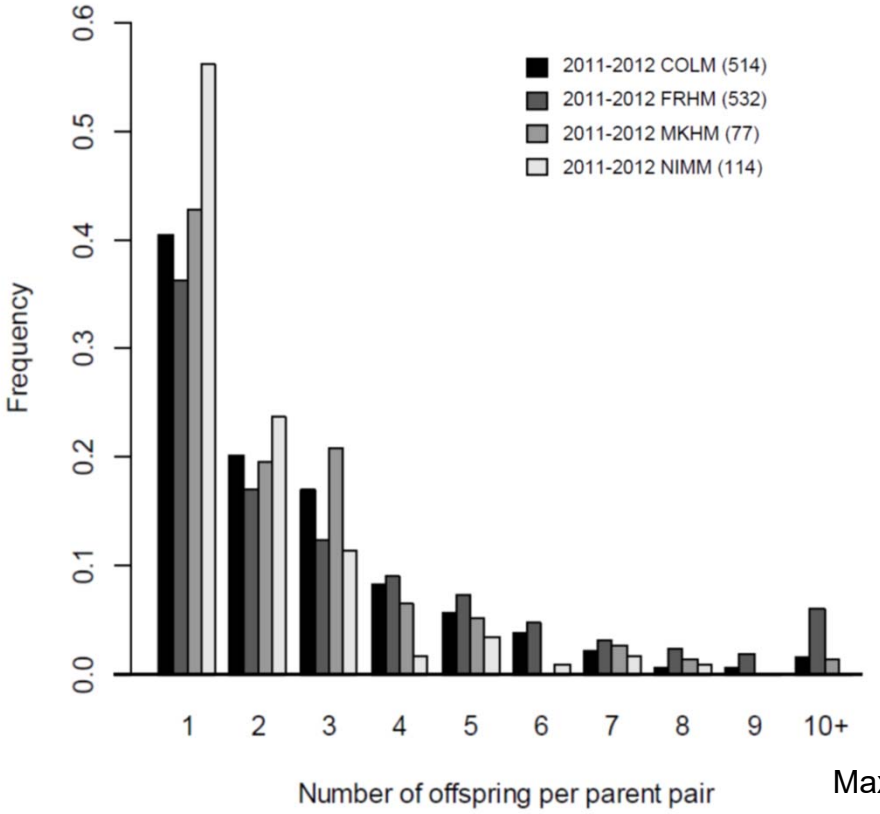
Relative reproductive success/returning adult progeny

Over half of fish used as broodstock have at least one sibling also used as broodstock



Max. = 27

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Repeat spawning
Matching samples analysis

	Spawn year			
Hatchery program	2011	2012	2013	2014
Coleman	1 (0.1%)	0 (0%)	2 (0.2%)	0 (0%)
Feather River	102 (21.2%)	103 (16.3%)	291 (22.4%)	163 (12.1%)
Nimbus	9 (4.3%)	1 (0.4%)	7 (14.3%)	23 (12.4%)
Mokelumne River	35 (8%)	7 (2.4%)	6 (1.5%)	35 (12.2%)

In parentheses is the proportion of all matings in which a reused male spawned

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Iteroparity

Matching samples analysis

Hatchery program	Spawn year 2012	2013	2014
Coleman	33 (3.88%)	18 (2.01%)	36 (4.1%)
Feather River	26 (3.98%)	30 (2.56%)	73 (5.53%)
Nimbus	1 (0.39%)	0 (0%)	0 (0%)
Mokelumne River	11 (5.39%)	0 (0%)	3 (1.96%)

Iteroparous fish strongly biased towards females.

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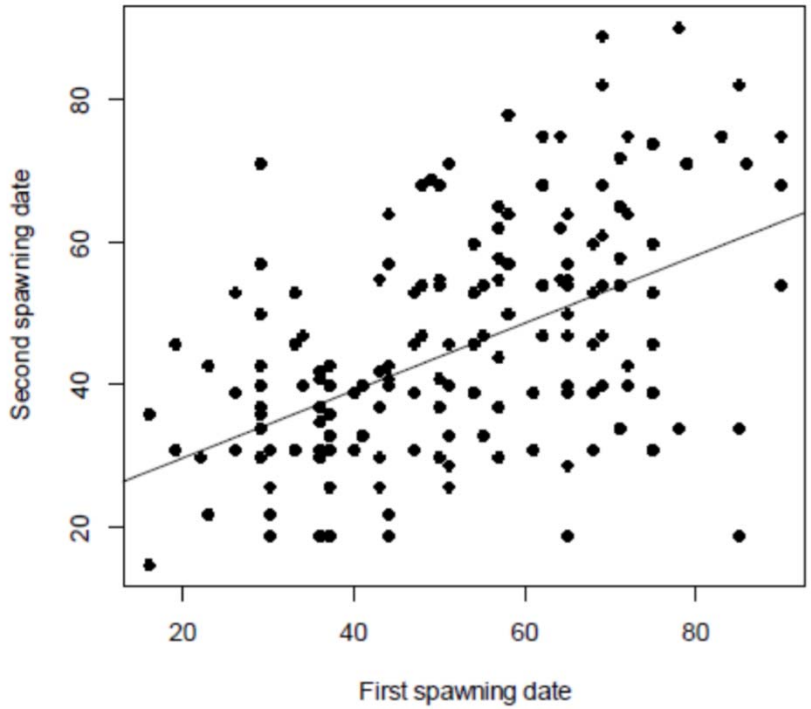
Iteroparity and repeat spawning

Matching samples analysis

Correlation between 1st and 2nd spawn dates for iteroparous fish

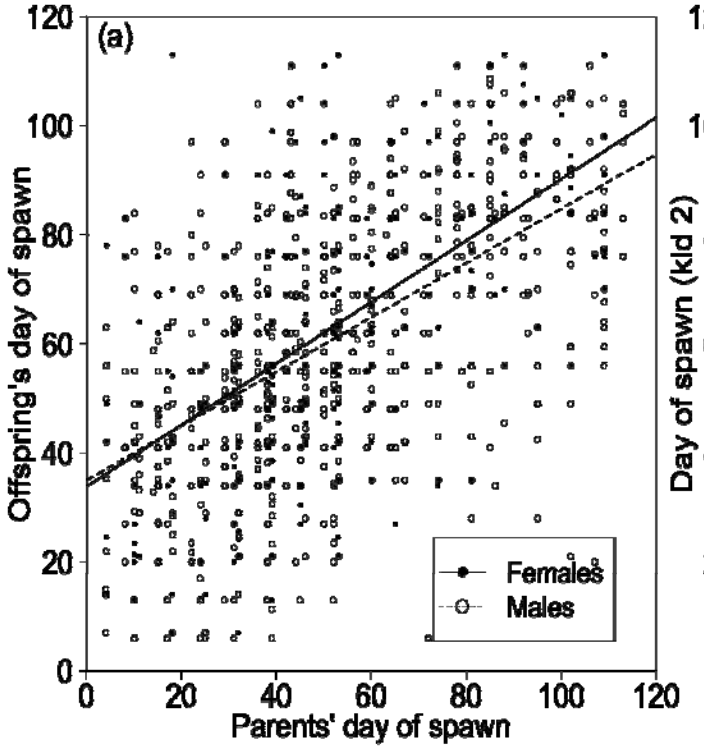
R^2=0.31



Heritability of Spawn Timing

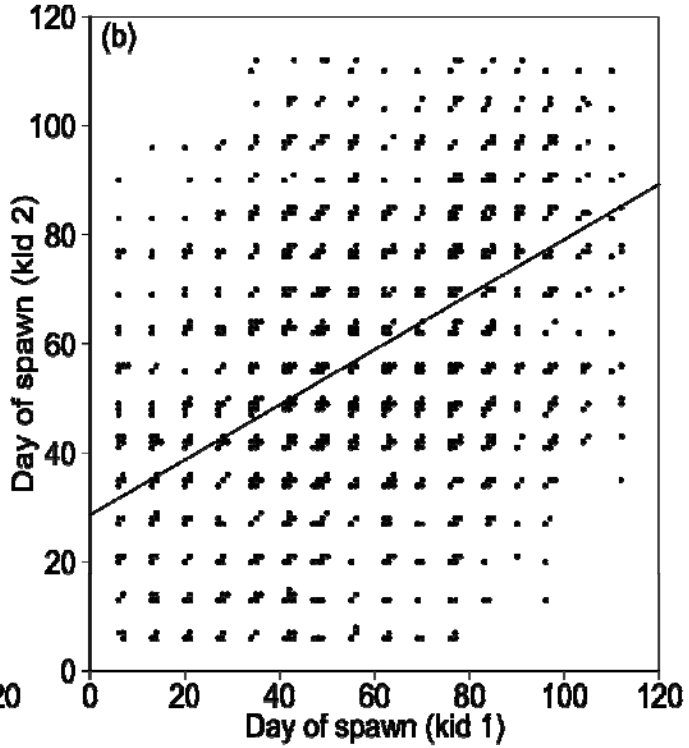
Russian River Steelhead Hatchery Stocks

Parent/Offspring



h_2=0.512

Sibling/Sibling



h^2=0.545

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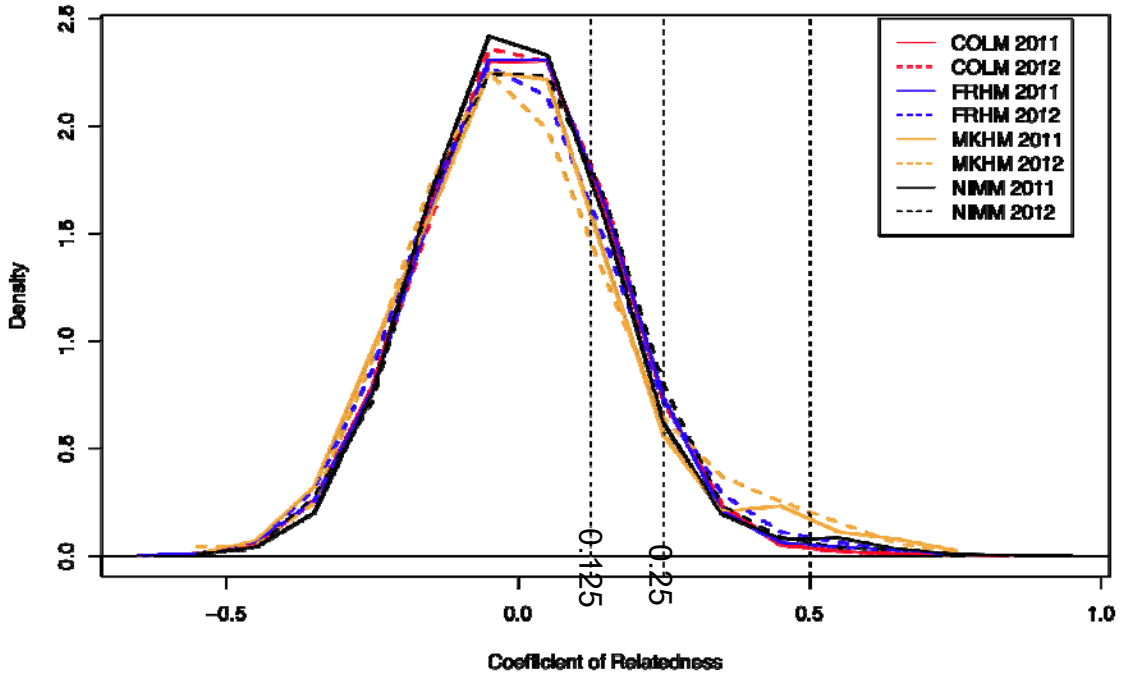
Inbreeding in hatchery mating

Distribution of coefficient of relatedness for matings estimated by randomly pairing fish spawned on same day.

Rxy=0.5 for full sibs

Rxy=0.25 for half sibs

Rxy=0.125 for cousins



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	Percentage of inbred matings at		
	Rxy>0.5	Rxy>0.25	Rxy>0.125
Coleman 11	0.3	6	21.8
Coleman 12	0.3	5.8	21.9
Feather 11	0.7	6.1	22
Feather 12	0.9	7.7	22.1
Nimbus 11	1.3	6.1	20.8
Nimbus 12	0.6	7.3	24
Mokelumne 11	2.2	8.7	21.2
Mokelumne 12	2.3	11.2	23.3

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Feather 12	0.9	7.7	22.1
Nimbus 11	1.3	6.1	20.8
Nimbus 12	0.6	7.3	24
Mokelumne 11	2.2	8.7	21.2
Mokelumne 12	2.3	11.2	23.3

Thrower and Hard (2008) Found a huge reduction in marine survival of steelhead from Rxy=0.5

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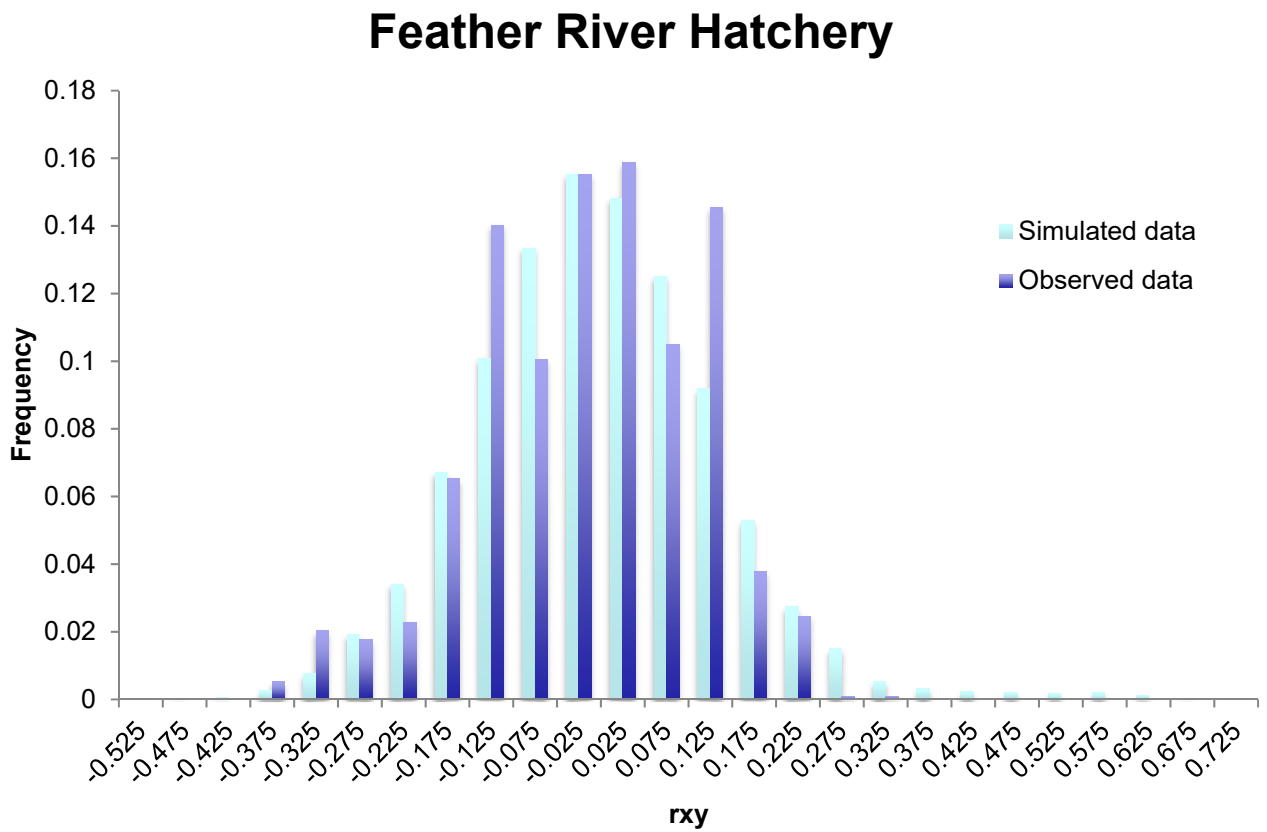
Inbreeding in hatchery mating

Clear signal of inbred matings not producing anadromous adult returns



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Conclusions

-Feather River and Mokelumne River hatchery stocks are very similar, not concordant with ESA listing: ongoing migration

-Iteroparity rates are similar to those in other hatchery stocks. Nimbus exception with almost no iteroparous individuals

-High heritability of run timing in all stocks: less than in Russian River

-Male reuse continues to be an issue in most programs: reducing diversity

-Age structure of Nimbus different from all others: dominated by age 3 fish

-Extensive family structure: over half of spawners have at least one sibling who also is a spawner-high variance in reproductive success

-Inbreeding likely causing some mortality.

Acknowledgements

SWFSC/UC Santa Cruz

- Alicia Abadía-Cardoso
- Eric Anderson
- Vanessa Apkenas
- Cassie Columbus

Other agencies

- Lea Koerber
- Josh Israel
- Rob Titus
- BOR and DWR funding