

Population Genetics of *Oncorhynchus mykiss* in the California Central Valley

John Carlos Garza & Devon Pearse
Molecular Ecology & Genetic Analysis Team
Southwest Fisheries Science Center



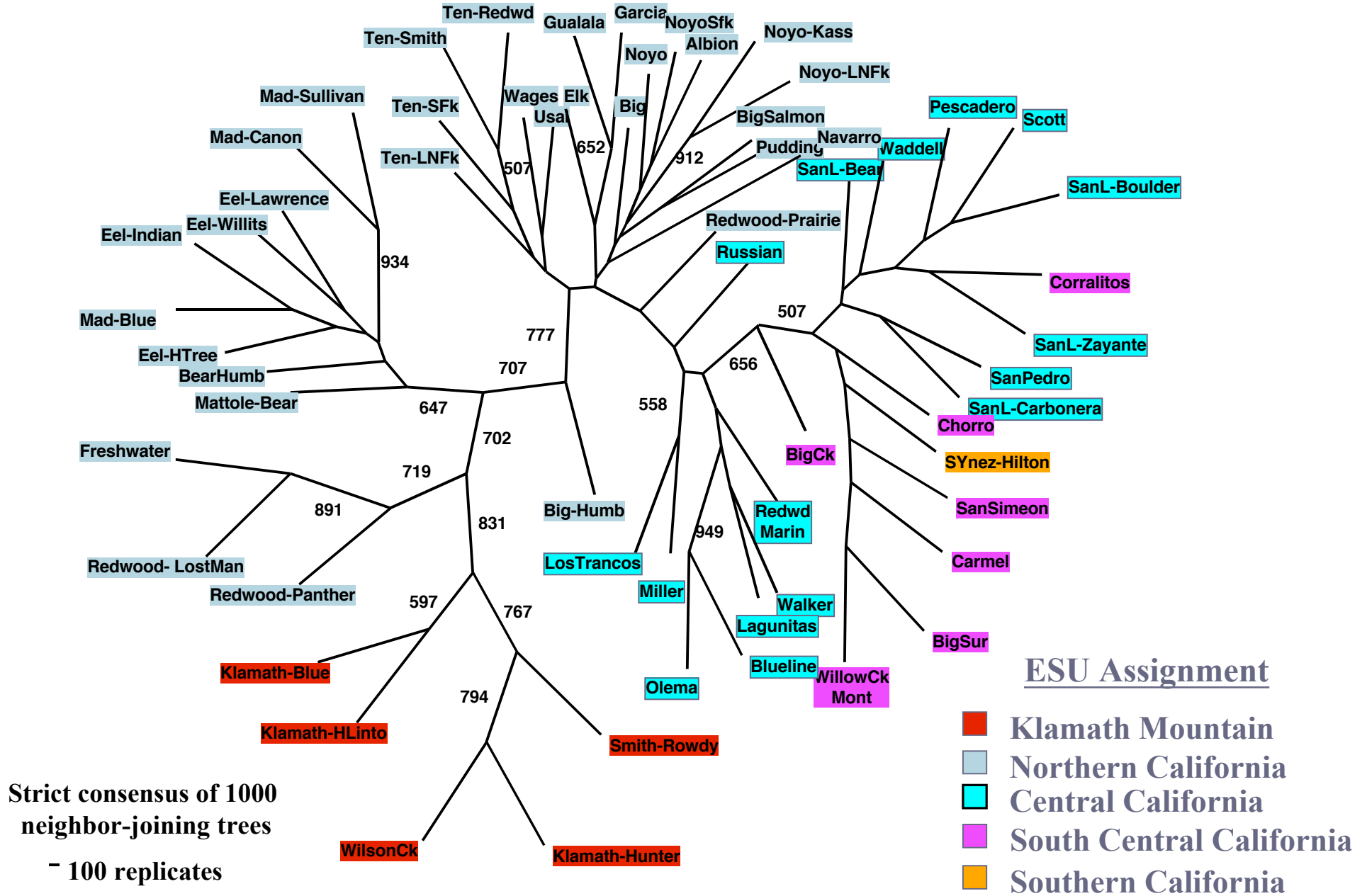
Pacific Coast Steelhead Meeting, March 10, 2010

Coastal CA Steelhead Population Structure

- “Snapshot” of population structure from 60 sites, 40 basins in all five Coastal CA ESUs
- ~4500 juvenile fish non-lethally sampled from 5 sections/site
- Samples collected June-Oct. 2001
- Avg. of 66 fish/site analyzed
- Data from 18 microsatellite loci
- ~132,000 allele copies, 540 unique alleles sampled.



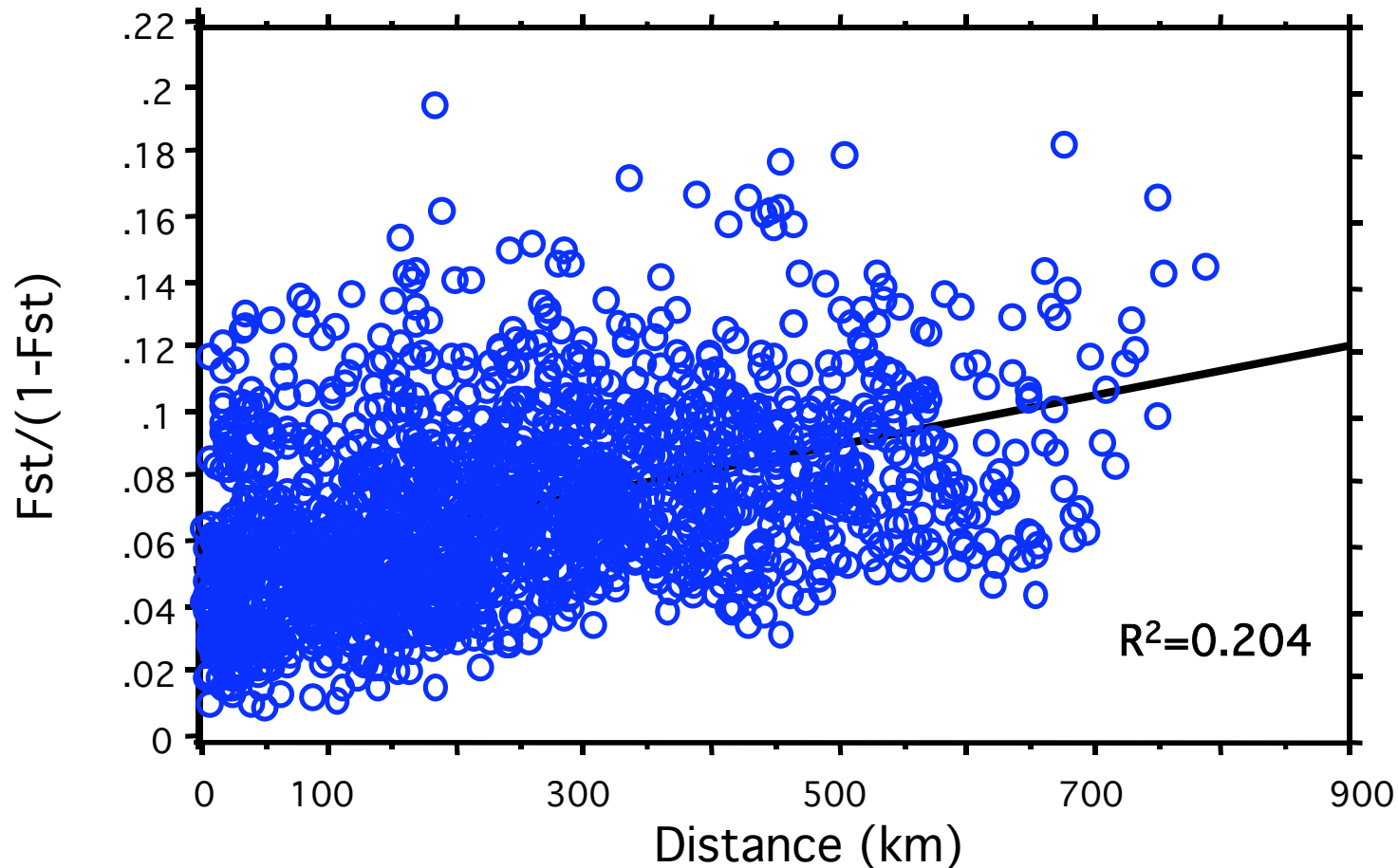
Steelhead Bootstrap Consensus Tree



Isolation by distance

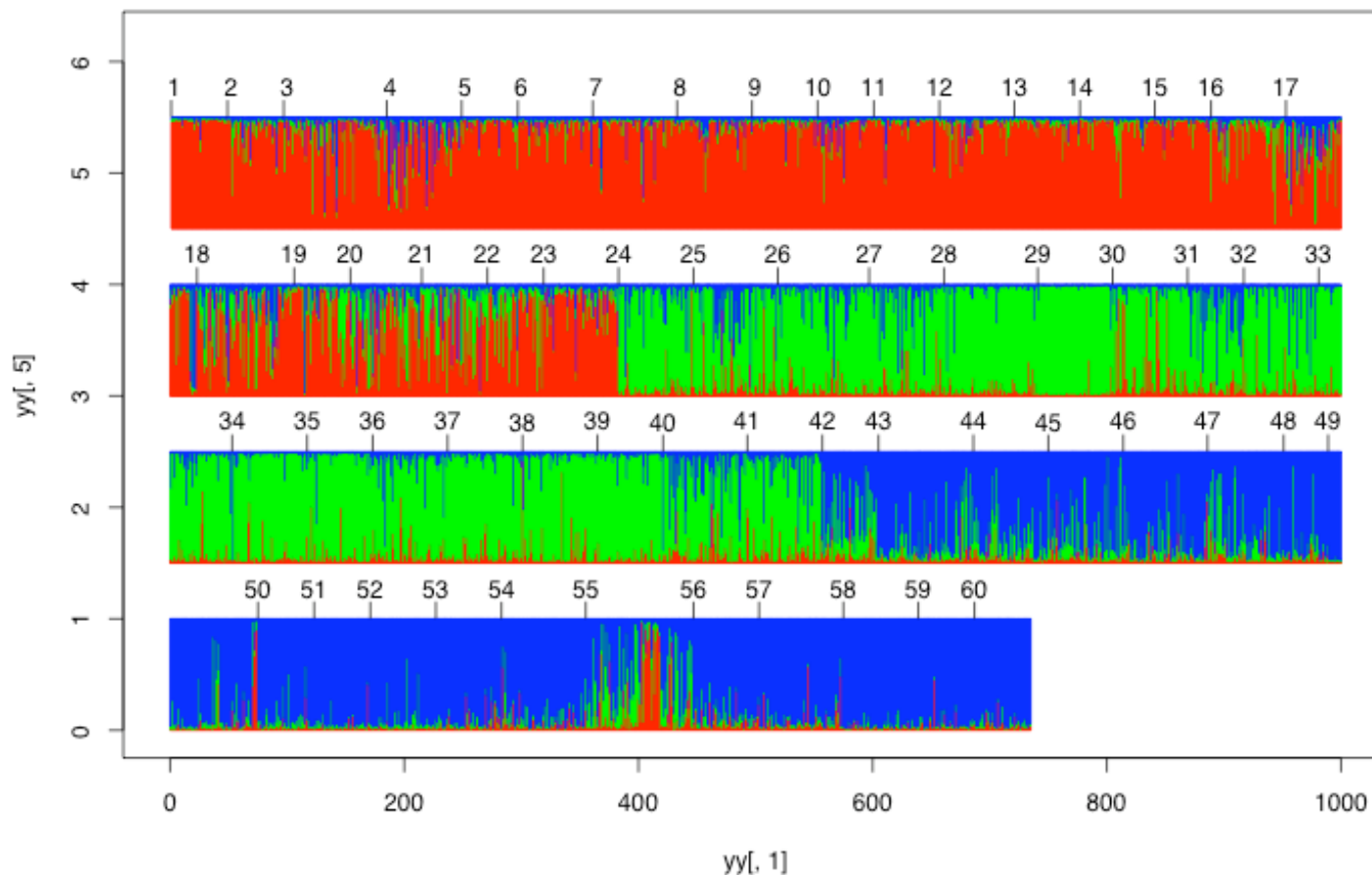
Regression of genetic distance [$F_{st}/(1-F_{st})$] on geographic distance for 59 steelhead trout populations in coastal California.

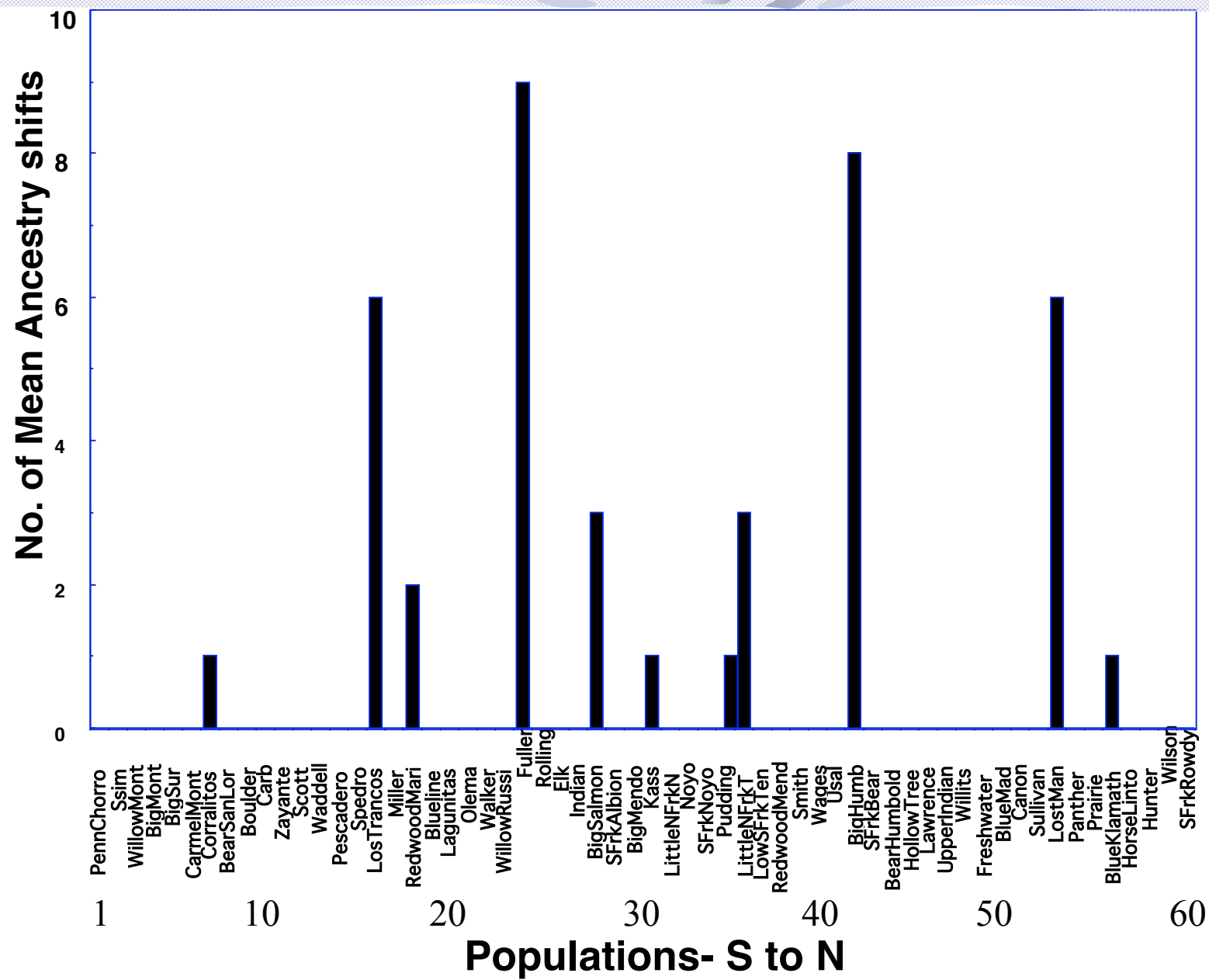
Geographic distance explains about 20% of the variation in genetic distance

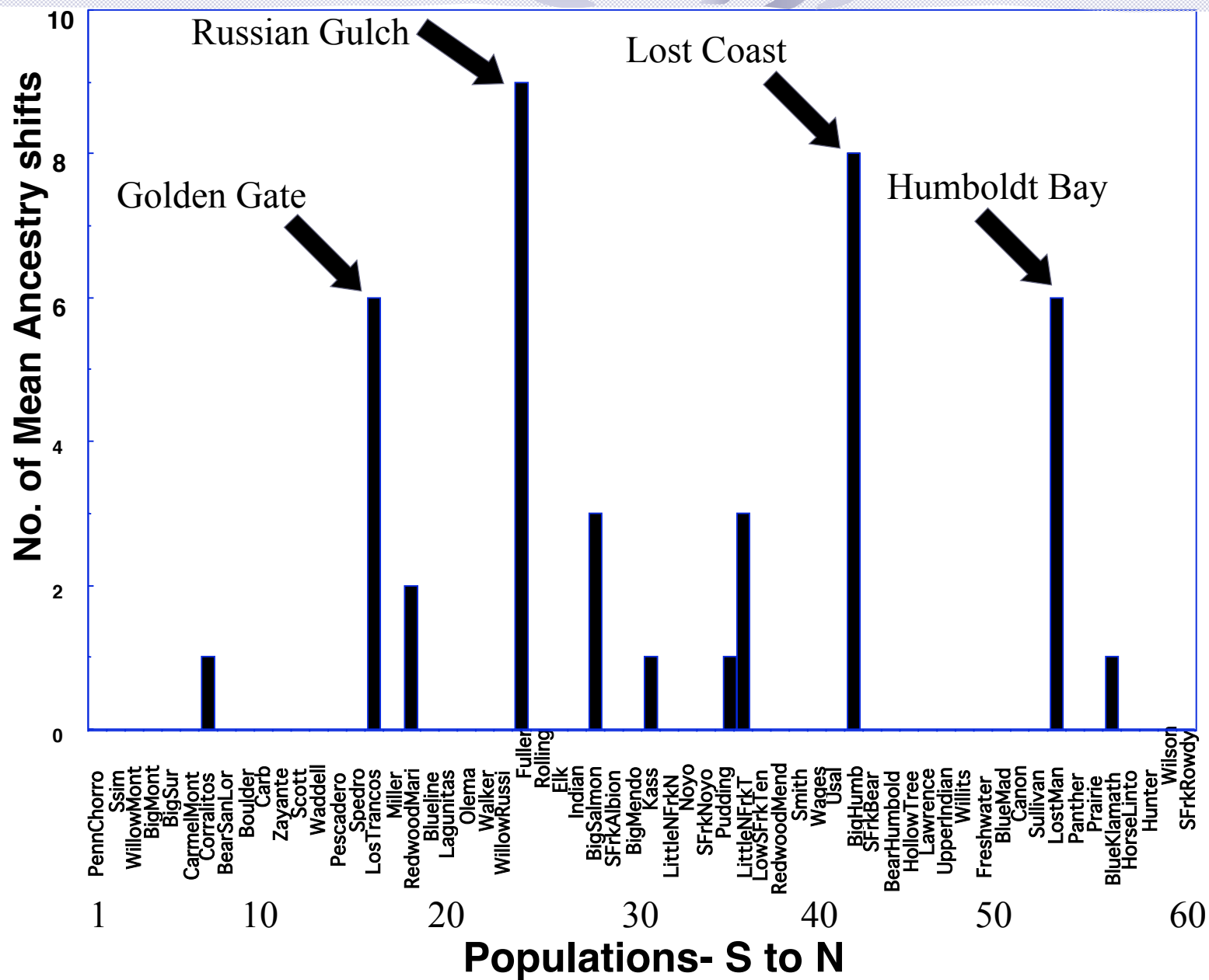


Steelhead Population Structure Assignment Tests

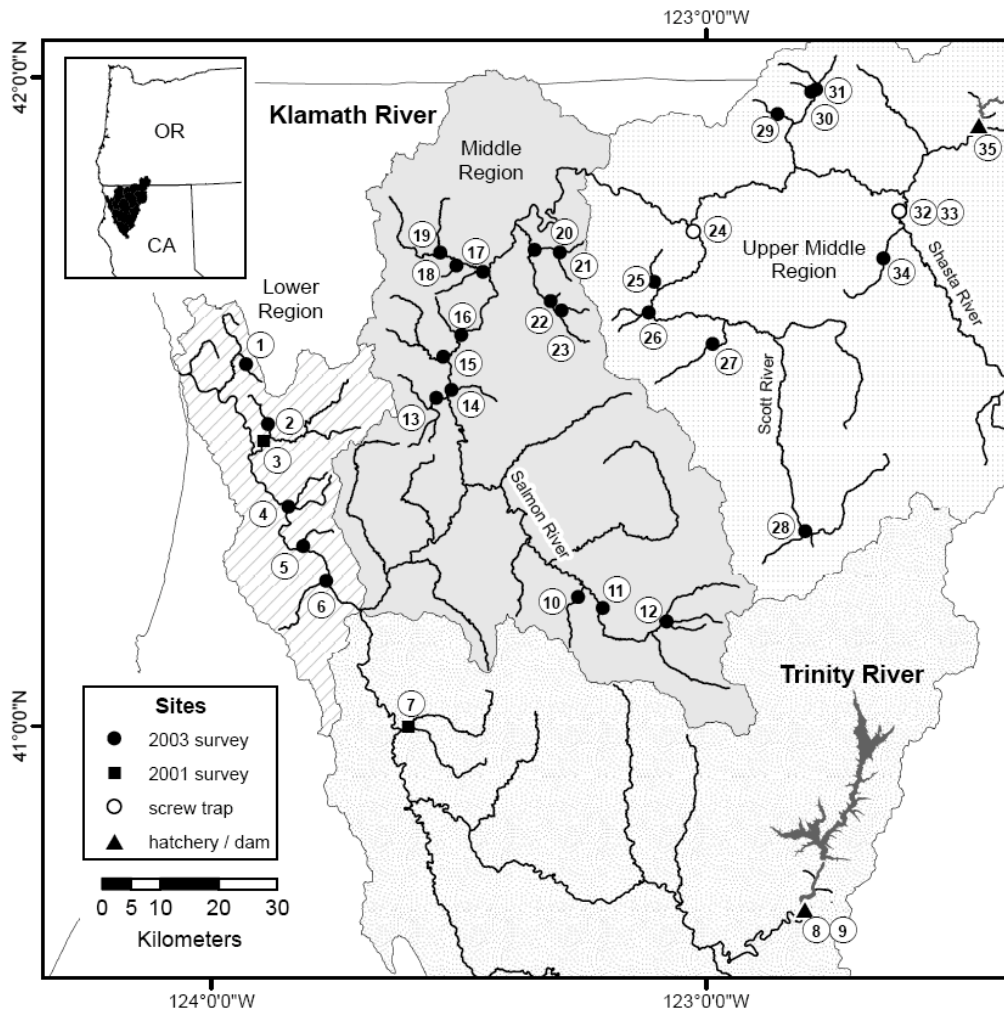
Results for K = 3





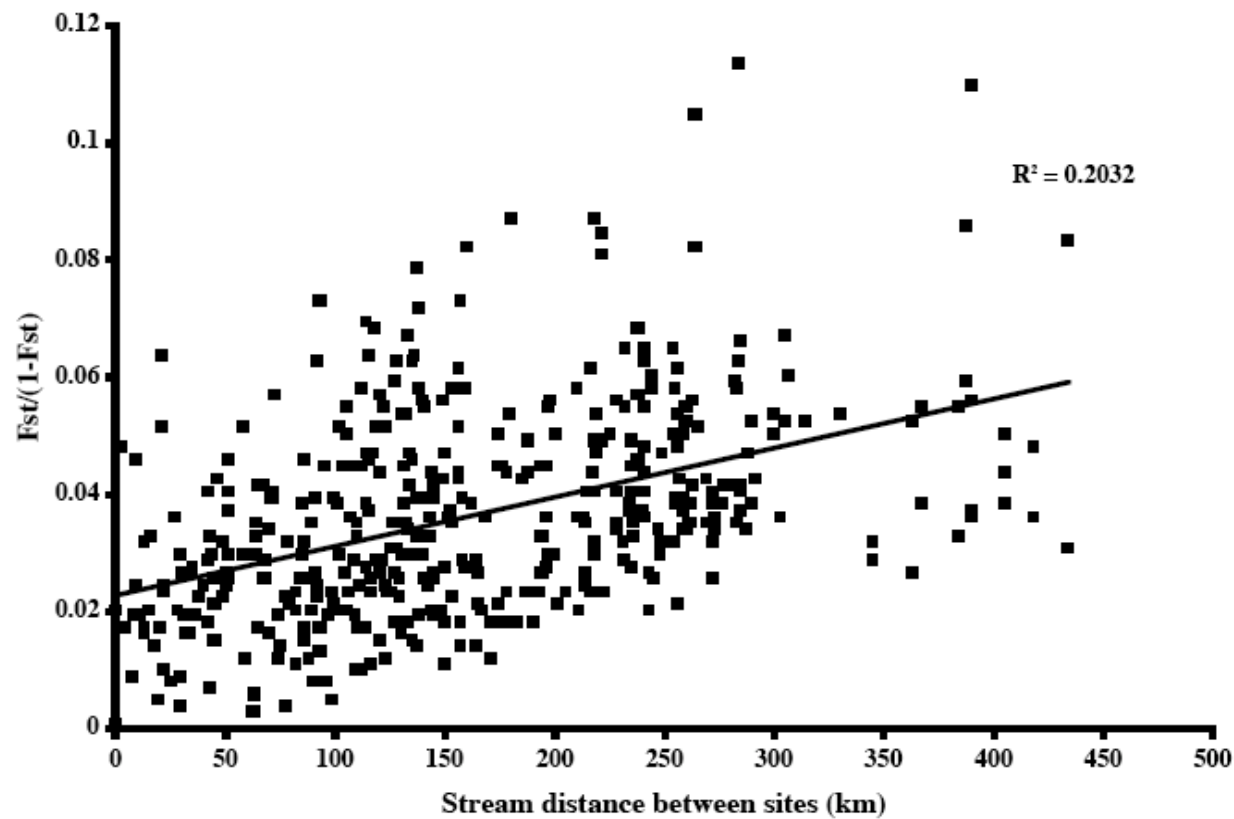


Population genetics of steelhead (*Oncorhynchus mykiss*) in the Klamath River



from Pearse et al., 2007

Isolation-by-distance of steelhead (*Oncorhynchus mykiss*) in the Klamath River



from Pearse et al., 2007

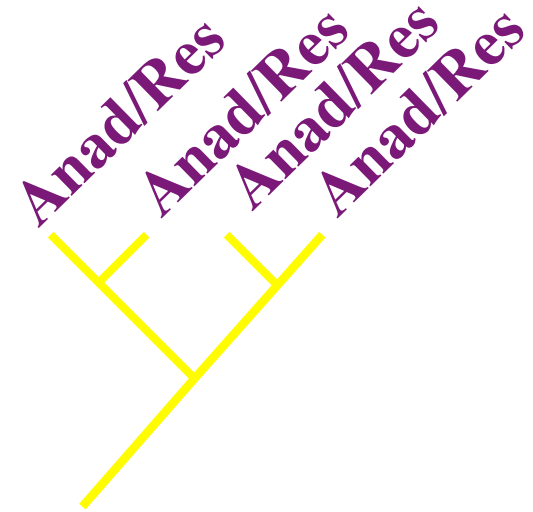
What are the possible population genetic patterns in *O. mykiss*?



Reciprocal
monophyly



Convergence

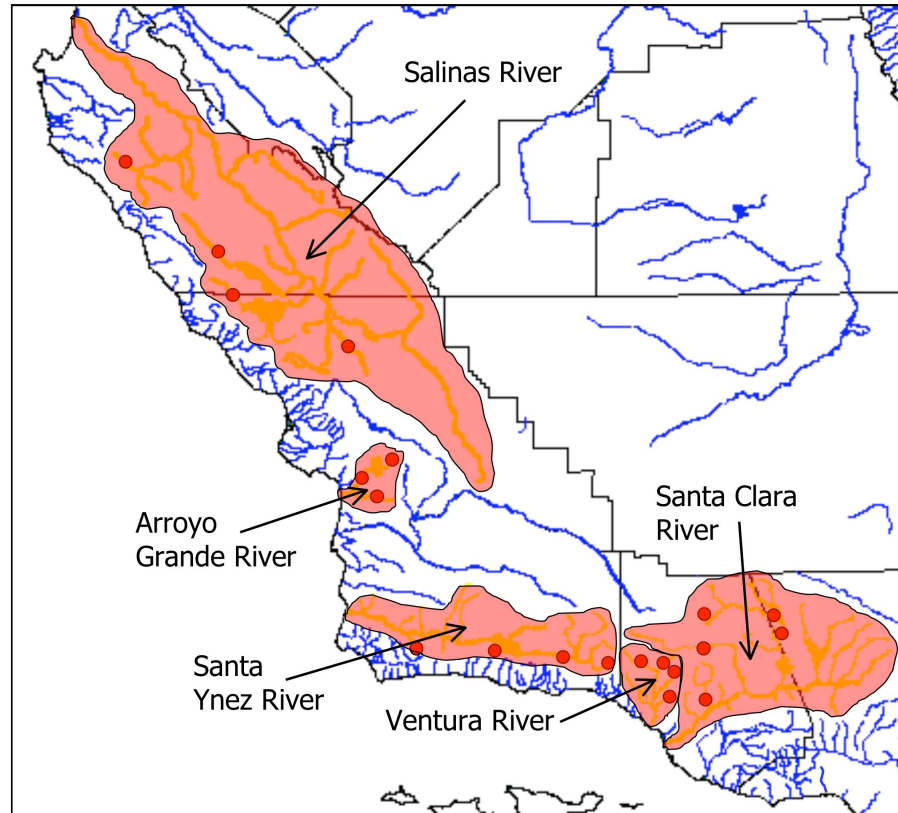


Phenotypic
plasticity

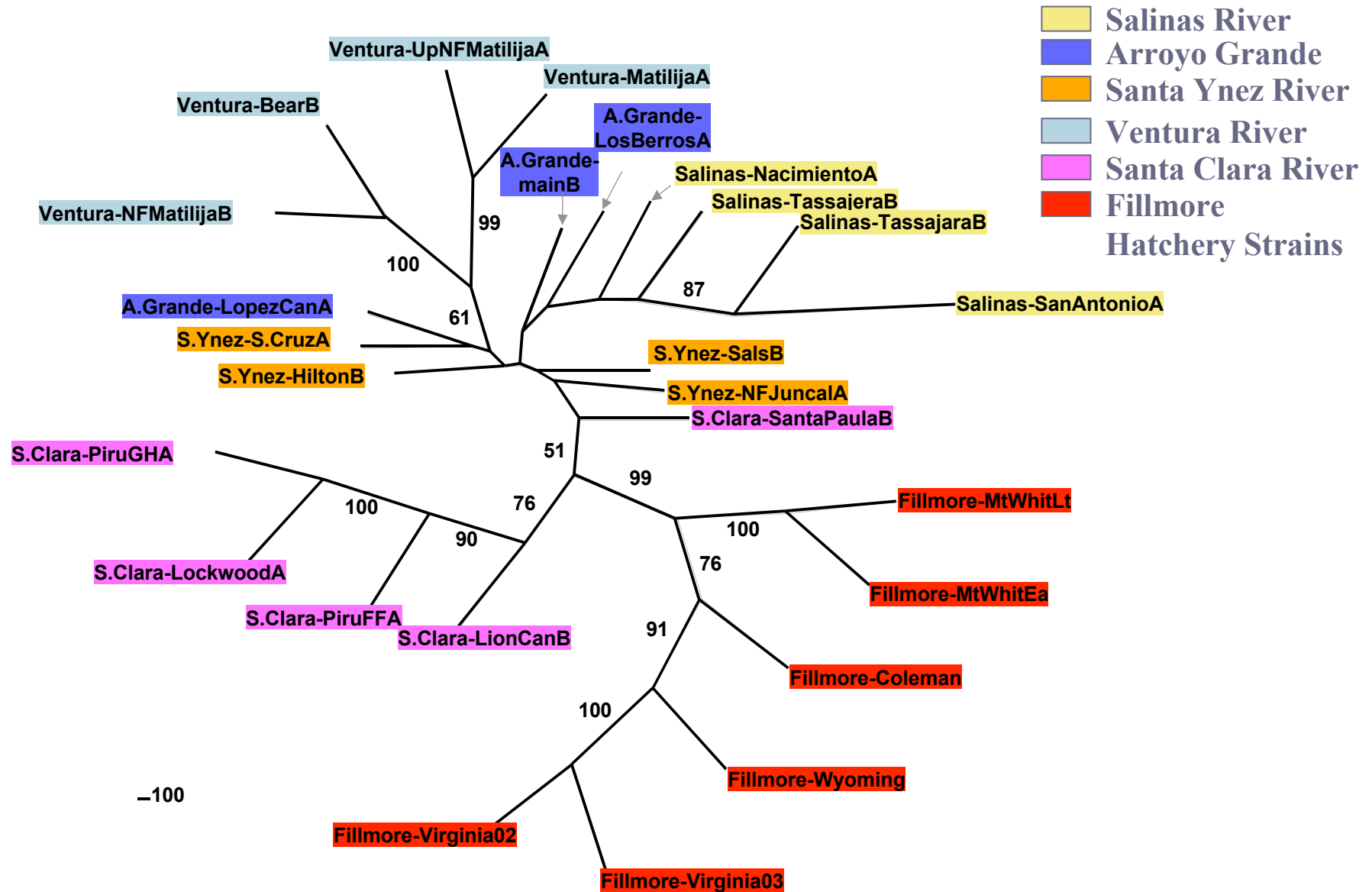
**What is the effect of natural or artificial barriers?
What might be the influence of stocking?**

Southern California Trout Population Structure

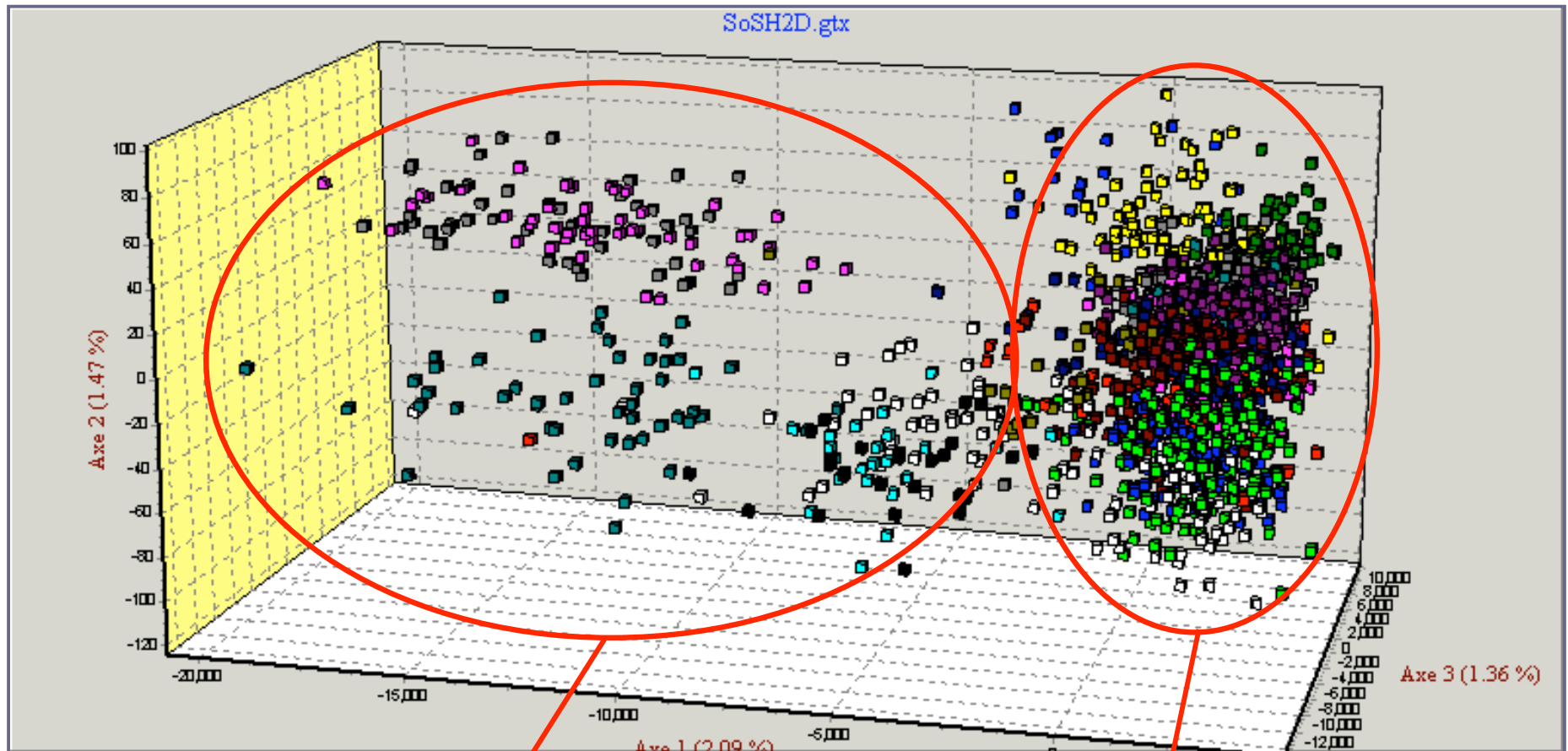
- Extension of population structure study to South-Central & Southern CA.
- Five basins with sampling above and below dams.
- Small numbers from further south
- All strains of rainbow trout used in stocking also sampled
- ~1900 juvenile fish sampled non-lethally w/ standardized protocol.
- Data from same 18 microsatellite loci.



Consensus chord distance tree with bootstrap support (10,000 replicates)



Factorial Correspondence Analysis



Fillmore Hatchery

Southern Steelhead



Summary:

- Steelhead divergence consistent with isolation-by-distance at many scales.
- Genetic analyses of *O. mykiss* from multiple coastal South-Central CA rivers generally show little or no effect of stocking above dams.
=> “native” genotypes persist.

Extension of population structure work to Central Valley *O. mykiss* populations

- Pairs of populations sampled above and below dams.
- All major hatchery rainbow trout strains also included
- Eleven subbasins sampled. Total of >1500 fish.
- Same 18 microsatellites as in previous work.





Dams
Within Jurisdiction
of the
State of California



Central Valley *O. mykiss* Population Genetics Study Summary Statistics

Sub-basin	Population	Age/strain	Sample size	Unbiased Hz	Obs Hz	Allelic Richness	No Alleles	Linkage DisEq
American	Lower	Juveniles	19	0.6991	0.6731	7.59	7.82	3.7
American	Middle	Mixed residents	60	0.7190	0.6563	7.98	11.00	8.1
American	North	Mixed residents	51	0.6722	0.6473	6.58	8.83	4.1
American	Nimbus	Juveniles/adults	102	0.7113	0.6607	8.36	12.82	46.3
Battle	Coleman	Anadromous adults	180	0.7200	0.6991	9.00	15.44	6.6
Butte	Main	Below-Mixed	52	0.7288	0.7064	8.63	12.39	5.2
Calaveras	Main	Below-Mixed	48	0.7012	0.7010	7.40	9.50	3.3
Deer	Main	Below-Mixed	46	0.7371	0.7162	9.32	13.06	2.6
Feather	Upper	Mixed residents	52	0.7123	0.6296	8.39	11.94	9.8
Kings	Upper	Mixed residents	59	0.6686	0.6434	7.22	9.83	66.7
McCloud	ButcherKnife/Claiborne Cks	Mixed residents	54	0.6661	0.5939	6.67	8.78	42.5
Stanislaus	Lower	Below-Mixed	92	0.7226	0.7023	8.29	12.56	8.5
Stanislaus	Upper	Mixed residents	52	0.6893	0.6360	7.89	11.33	10.5
Tuolumne	Lower	Below-Mixed	127	0.6980	0.6545	7.01	10.44	30.1
Tuolumne	Upper	Mixed residents	47	0.7170	0.6379	7.76	10.94	5.9
Yuba	Lower	Below-Mixed	107	0.7145	0.6864	8.43	13.17	7.8
Yuba	Upper	Mixed residents	51	0.7077	0.6657	7.79	10.94	20.3
American	American River Hatchery	Eagle-Juveniles	50	0.5957	0.5904	4.51	5.24	13.3
American	AmericanRH/HotCreekH	Coleman-juvenile	85	0.6050	0.5860	5.31	7.22	7.5
American	American River Hatchery	Moccasin-Juveniles	55	0.6122	0.5820	4.89	5.65	11.8
American	American RH/MtShastaH	MtShasta-Juveniles	120	0.5978	0.5648	4.51	6.28	7.5
Hot Creek	Hot Creek Hatchery	Junction Kamloops	50	0.6112	0.5872	5.88	7.59	6.7
Total			1559					

Central Valley *O. mykiss* Population Genetics Study Summary Statistics

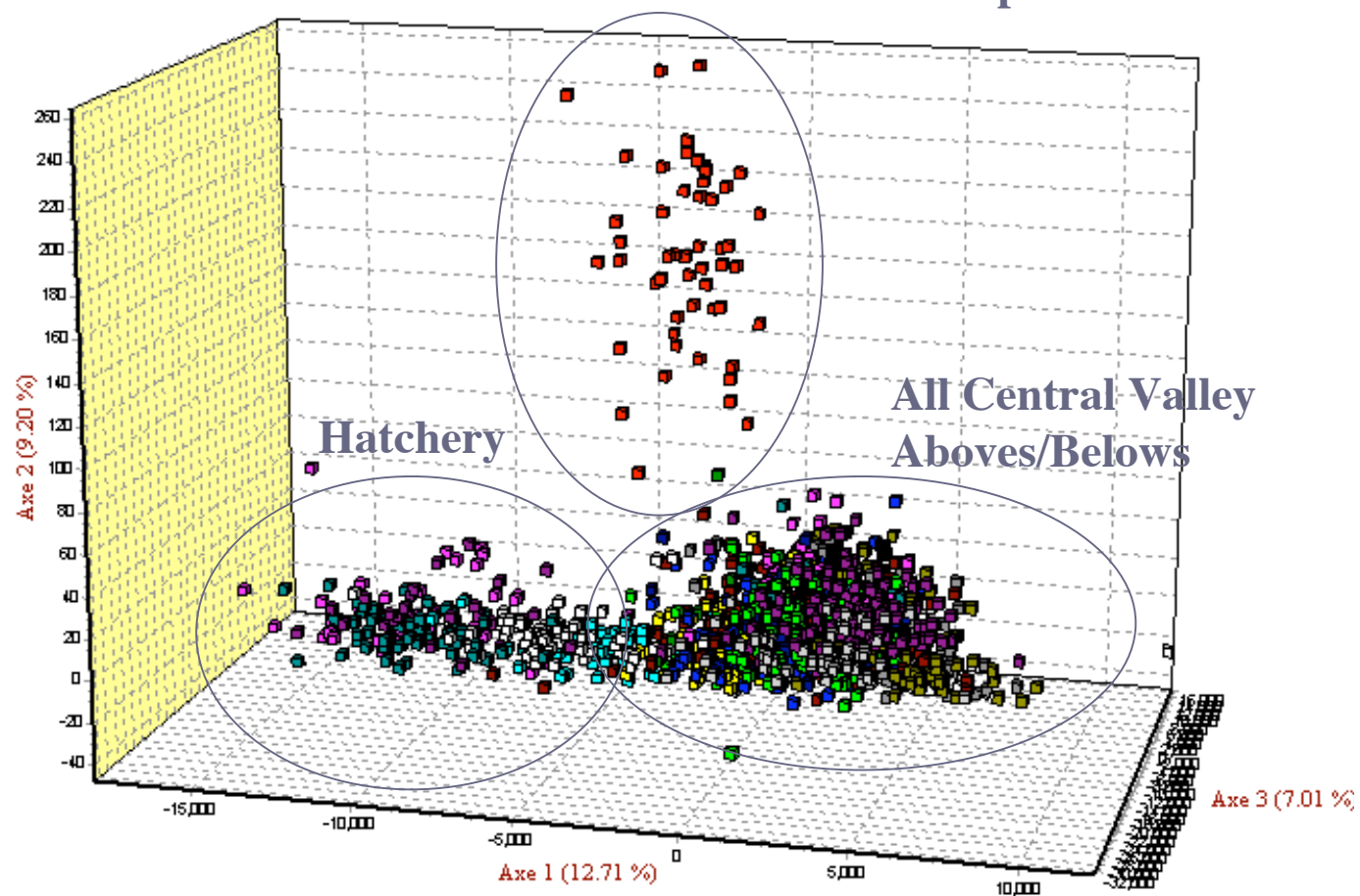
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American	North	Mixed residents	51	0.6722	0.6473	6.58	8.83	4.1
American	Nimbus	Juveniles/adults	102	0.7113	0.6607	8.36	12.82	46.3
Battle	Coleman	Anadromous adults	180	0.7200	0.6991	9.00	15.44	6.6
Butte	Main	Below-Mixed	52	0.7288	0.7064	8.63	12.39	5.2
Calaveras	Main	Below-Mixed	48	0.7012	0.7010	7.40	9.50	3.3
Deer	Main	Below-Mixed	46	0.7371	0.7162	9.32	13.06	2.6
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Tuolumne	Lower	Below-Mixed	127	0.6980	0.6545	7.01	10.44	30.1
Tuolumne	Upper	Mixed residents	47	0.7170	0.6379	7.76	10.94	5.9
Yuba	Lower	Below-Mixed	107	0.7145	0.6864	8.43	13.17	7.8
Yuba	Upper	Mixed residents	51	0.7077	0.6657	7.79	10.94	20.3
American	American River Hatchery	Eagle-Juveniles	50	0.5957	0.5904	4.51	5.24	13.3
American	AmericanRH/HotCreekH	Coleman-juvenile	85	0.6050	0.5860	5.31	7.22	7.5
American	American River Hatchery	Moccasin-Juveniles	55	0.6122	0.5820	4.89	5.65	11.8
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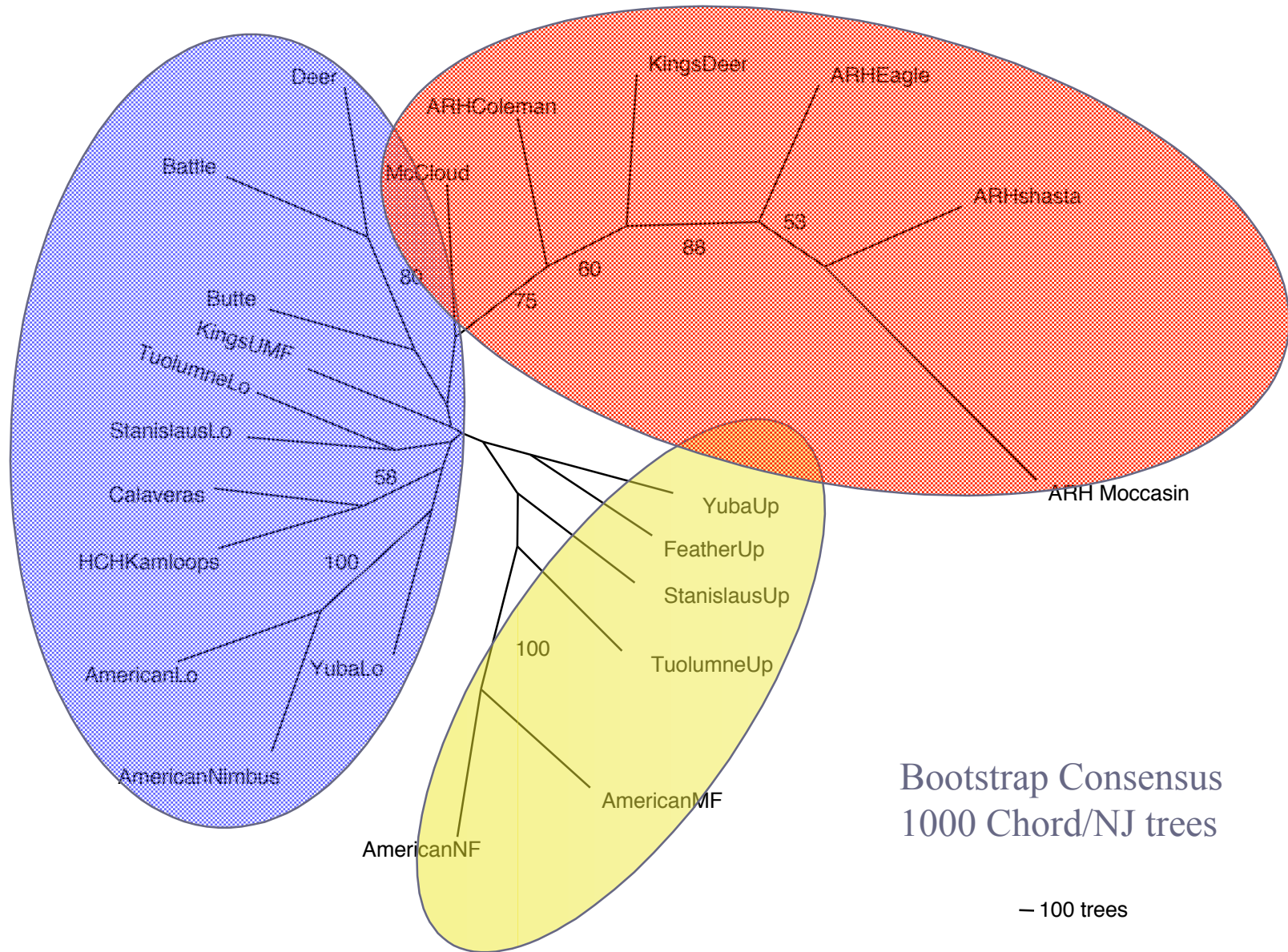
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Yuba	Lower	Below-Mixed	107	0.7145	0.6864	8.43	13.17	7.8
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Factorial Correspondence Analysis

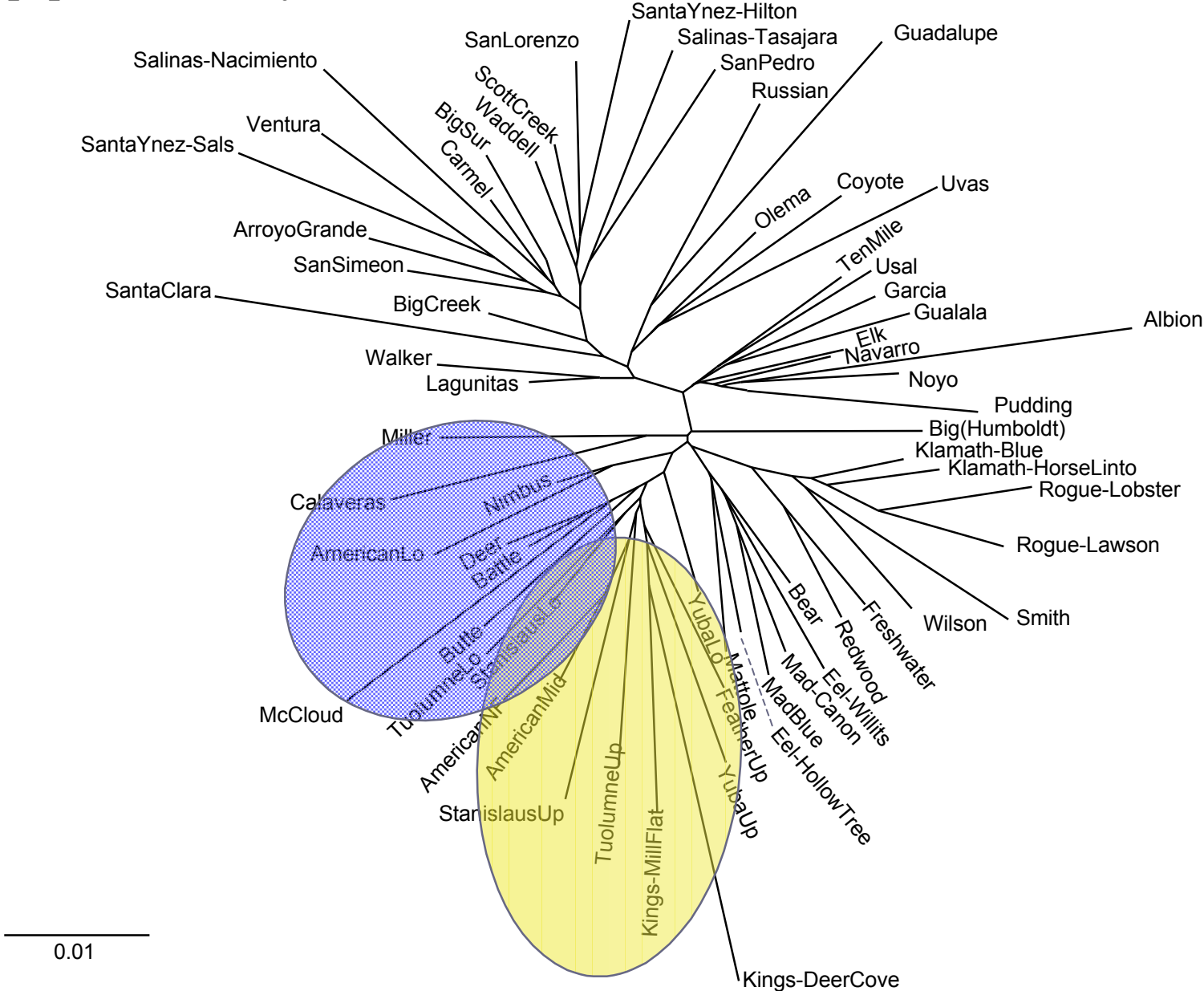
Kamloops



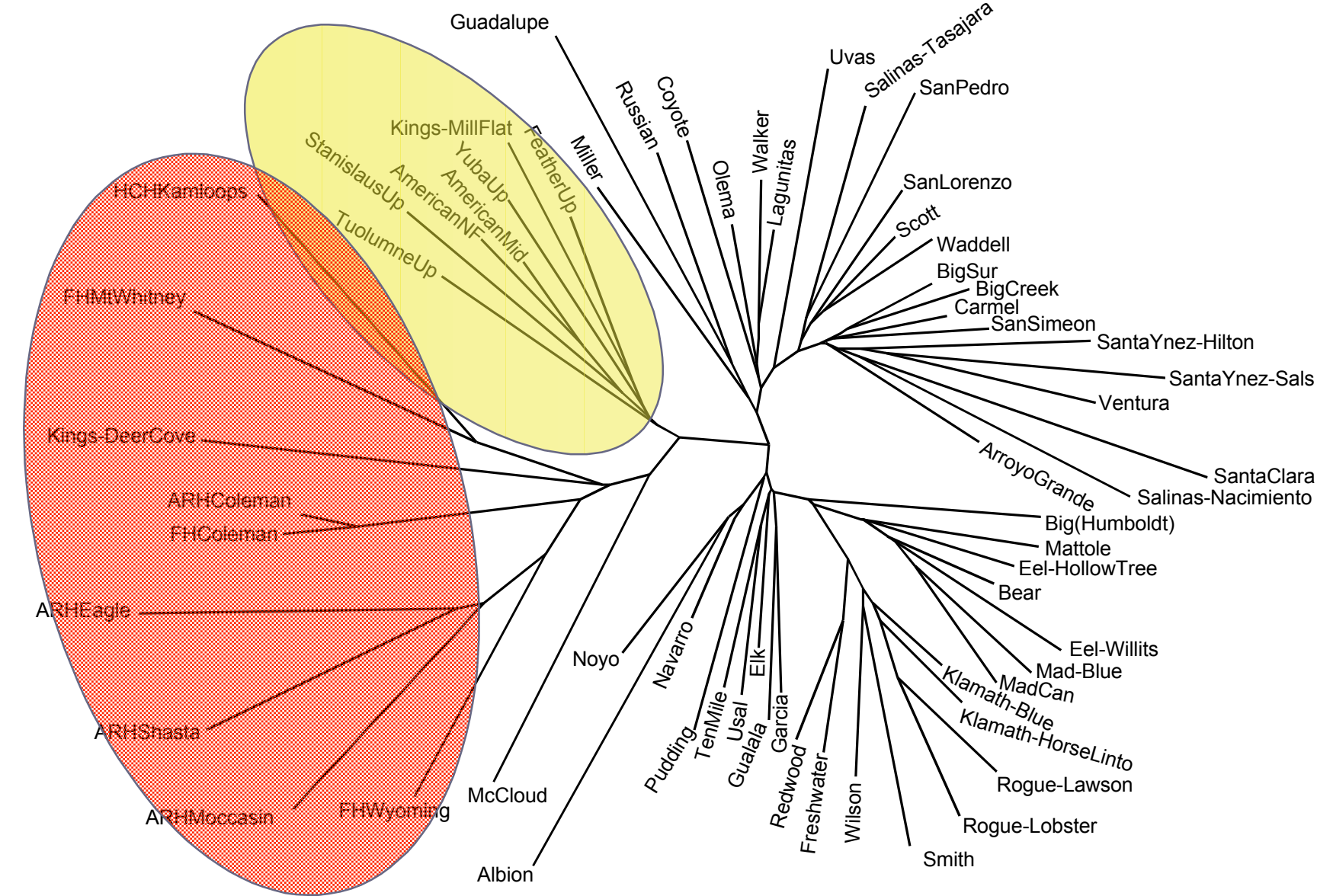
CV *O. mykiss* with Kings split and Stanislaus non-hatchery



All CV pops, no hatchery strains

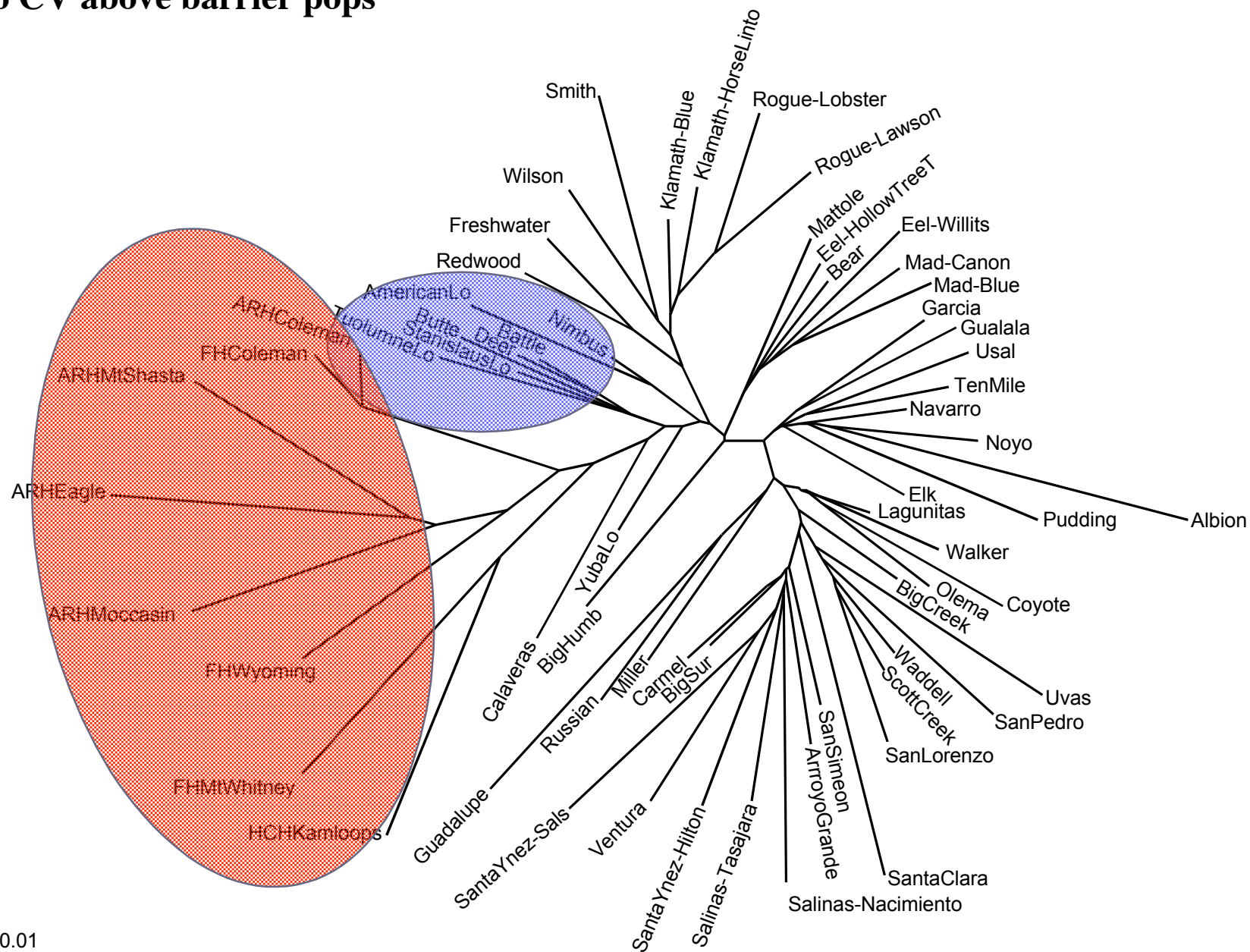


No CV below barrier pops



0.01

No CV above barrier pops



Ancestry and Size of *O. mykiss* at Nimbus

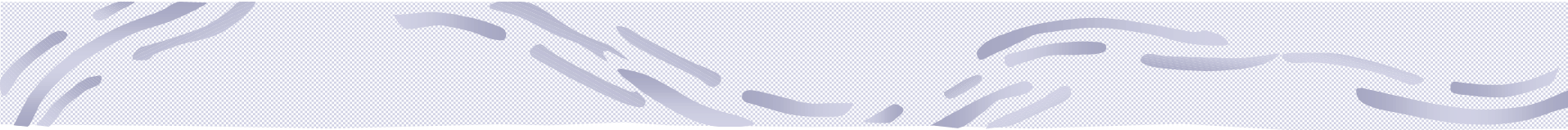
Size-FL (mm)	Assigned pop-1	Probability	Assigned pop-2	Probability
315	MtShasta	100		
360	MtShasta	100		
445	Moccasin	100		
505	MtShasta	100		
550	AmLo	99.232	TuolLo	0.397
550	Moccasin	100		
550	Moccasin	100		
560	StanLo	96.273	YubaUp	3.688
560	StanLo	89.765	Nimbus	9.127
565	MtShasta	100		
585	AmLo	95.29	Nimbus	4.696
590	Nimbus	99.978	Cala	0.021
590	Nimbus	61.88	YubaLo	37.664
630	MtShasta	99.999	Moccasin	0.001
630	MtShasta	100		
640	Battle	99.886	Butte	0.08
660	Nimbus	92.765	AmLo	7.229
660	Nimbus	96.109	AmLo	3.075
685	Nimbus	98.282	StanLo	1.636
690	MtShasta	97.978	Eagle	2.018
700	AmLo	69.723	Nimbus	15.561
700	Nimbus	99.999	YubaLo	0.001
710	Nimbus	99.138	AmLo	0.794
720	Nimbus	99.999	AmLo	0.001
735	YubaLo	79.1	Nimbus	20.684
740	Nimbus	90.124	AmLo	9.876
740	Nimbus	88.46	AmLo	11.54
760	Nimbus	99.999	AmLo	0.001
770	Nimbus	97.271	AmLo	2.728
800	Nimbus	99.998	StanLo	0.002
810	Nimbus	98.756	AmLo	1.232

Hatchery fish



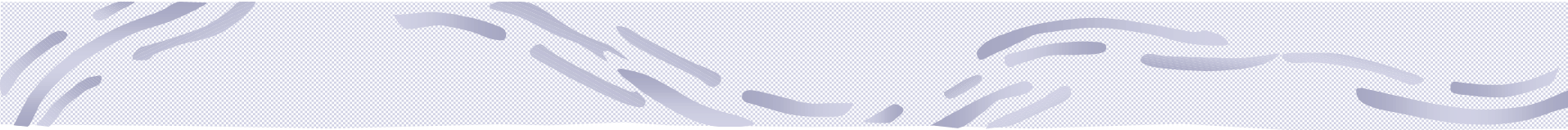
Central Valley *O. mykiss* Conclusions

- Genetic structure of *O. mykiss* populations in California not generally consistent with ESU/DPS boundaries
 - Coastal and Central Valley *O. mykiss* populations are structured , but little evidence of recent reproduction by hatchery trout in either place
 - Populations above & below dams in the same sub-basin not most closely related.
 - Populations above dams are more closely related to each other and populations below dams also more closely related
 - Most likely explanation is that most above dam populations relatively intact ancestry, whereas below dam populations introgressed from Eel River and, possibly, hatchery rainbow trout stocks.
 - Large fish returning to Nimbus Hatchery 1/3 hatchery trout ancestry
 - Above dams, variable structure: American NF & MF, one population; Kings-Deer Cove & Upper Mill Flat Creeks, highly distinct.
- 



Central Valley *O. mykiss* Next Steps

- Populations to add to phylogeographic analysis
 - Merced River: samples-25 above, 25 below
 - Feather River, below: 10
 - Mokelumne River:
 - Thomes Creek
 - Clear Creek
 - Stoney Creek
 - Others?
 - New genes to add to phylogeographic analysis
 - 144 new SNPs developed by MEGA Team
 - Ancestry informative haplotype markers
 - Intergenerational genetic tagging
 - Measure migration between subbasins
 - Measure relative reproductive success of hatchery vs wild
- 



Acknowledgements

- Alicia Abadia
- George Edwards
- Celeste Gallardo
- Libby Gilbert-Horvath
- Michael Lacy
- Andy Martinez
- Edith Martinez
- Katie Perry

Other collaborators who helped in sample collection.

