

# Central California Steelhead THEN & NOW: Changes in patterns of genetic diversity

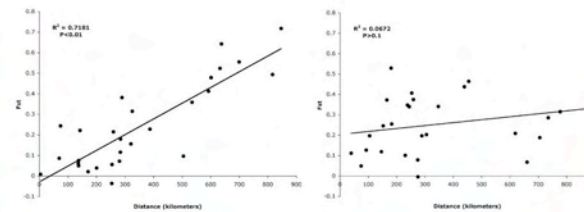


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Steelhead trout (*Oncorhynchus mykiss*; formerly *Salmo irideus* or *S. gairdneri*) are anadromous salmonids native to western North America. Due to their recreational fishing values, millions of hatchery-bred juvenile trout have been released in coastal California streams over the last 100 years. Their impact is the subject of debate, but most on remaining native populations in California are in decline due to dam construction and habitat degradation and are listed under the Endangered Species Act, (Busby et al. 1996; NMFS 2006).

## Approach

Population samples of steelhead collected by Stanford University professor J. O. Snyder in 1897 and 1909 from eight populations in five central California rivers (see map) provided the opportunity to evaluate the genetic composition of current populations relative to their native ancestral stocks. We extracted DNA and sequenced the mtDNA control region of 180 individuals. For comparison, 208 individuals collected between 1998 and 2004 from approximately the same locations were also sequenced. If hatchery practices and other anthropogenic causes have not greatly affected these steelhead populations, then population genetic statistics estimated from historical and modern populations should be similar.



**THEN** **NOW**

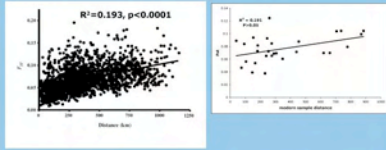
Correlations between genetic and geographic distance in historical and modern *O. mykiss* in central California, based on mtDNA haplotype frequencies. These relationships are consistent regardless of genetic or geographic metric used, and the historical correlation remains significant even when the most distant population, South Fork Eel River, is removed.



Iron Gate Dam, Klamath River

## MtDNA vs. microsatellite data

The lack of a significant IBD based on mtDNA in the modern collections is consistent with previous data from 18 nuclear microsatellite markers in 60 coastal California steelhead populations which show a low but significant correlation between genetic divergence and geographic distance (below left). This correlation remains significant when only data from the eight historical collection locations are included ( $r^2=0.193$ ,  $p<0.05$ ; below right), but is again much weaker than that seen in the historical mtDNA data. Thus, modern IBD estimated from both mitochondrial and nuclear DNA data is greatly reduced compared with historical mtDNA, indicating that the natural genetic patterns present in steelhead have been significantly altered in the modern collections relative to the historical samples.



## Observed mtDNA haplotypes in Historical, modern, and hatchery trout.

	A	B	C	D	E	F	G	H	I	J	K	Other	n
<b>Historical</b>													
SFE	27	0	2	0	0	0	0	0	0	0	0	0	2
COF	5	0	8	0	1	0	0	0	0	0	0	0	4
SLO	11	0	13	0	16	0	0	0	0	0	0	0	3
PAJ	2	0	3	0	5	2	6	0	0	0	0	0	5
PAL	2	0	0	0	2	2	6	0	0	0	0	0	3
SAS	2	0	5	0	16	6	2	0	0	0	0	0	5
SSA	4	0	4	1	7	0	0	0	0	0	0	0	4
SMC	0	2	4	0	15	0	0	0	0	0	0	0	3
Total(Mean)	53	2	39	1	63	10	14	0	0	0	0	1	83(33) (2,20)
<b>Modern</b>													
SFE	15	5	4	0	0	0	0	0	0	0	0	0	3
COF	9	0	18	0	4	0	0	0	0	0	0	0	3
SLO	15	0	7	0	8	0	2	0	0	0	0	0	4
PAJ	3	0	7	0	3	1	2	0	0	0	0	0	5
PAL	0	12	9	0	11	0	0	0	0	0	0	0	3
SAS	11	0	0	0	18	0	0	0	0	0	0	0	2
SSA	0	14	0	0	8	0	0	0	0	0	0	0	2
SMC	0	16	1	0	0	0	4	1	0	0	0	0	4
Total(Mean)	53	47	46	0	52	1	8	1	0	0	0	0	73(25) (1,92)
<b>Hatcheries</b>													
SFE	37	0	0	0	0	0	0	0	0	0	0	0	1
KSM	11	0	0	0	0	0	0	13	0	0	0	0	2
TRH	6	0	0	0	0	0	5	0	0	0	0	0	2
VR	20	0	1	0	0	0	0	0	0	0	0	0	2
COL	6	0	9	0	0	0	0	0	0	0	0	0	3
WHT	4	0	19	0	0	0	0	0	0	0	0	0	2
EAG	24	0	0	0	0	0	0	0	0	0	0	0	1
Total(Mean)	108	0	29	0	0	0	5	0	13	8	0	0	51(18) (0,77)

## Results

• There was a strong and highly significant correlation between genetic and geographic distances in the historical populations ( $R^2=0.72$ ,  $p<0.01$ ; THEN) but no relationship in the modern populations ( $R^2=0.07$ , n.s.; NOW).

• We found no correlation between the genetic differentiation, as measured by  $F_{ST}$ , among pairs of historical populations and that in their modern counterparts ( $R^2=0.0083$ , n.s.).

• Genetic differentiation among the cluster of streams tributary to Monterey Bay has more than doubled (mean pairwise  $F_{ST}$ : historical=0.11, modern=0.25; paired t-test,  $p<0.05$ ).



Extensive trout planting, statewide



Matijita Dam, Ventura River

## Conclusions

These results indicate that a formerly strong natural pattern of genetic differentiation proportional to geographic distance has been erased in ESA-listed central California steelhead populations, presumably due to habitat alterations and dam construction, along with extensive planting of hatchery trout over the past century.

## Acknowledgements

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