



Wild Trout and Salmon Genetics Laboratory
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Ladd:

The paired interspersed nuclear DNA elements (PINE) technique has been used to analyze DNA from the following trout samples:

Summary of results.

Sample #	Water Name/Location/Collection Date/ Collector	^a N	^b # markers	^c Species ID	^d Power (%)	^e % WCT	^f Individuals
2978	Sixmile Creek lower 15N22W12 middle 8/5/2002 upper Ladd Knotek	5 10 12	R6Y4 R6Y4 R6Y4	WCT X RBT WCTXRBT,WCT WCT	 R77Y60	71X29 100	xx
2979	Roman Creek 8/6/2002 Ladd Knotek	26	R6Y4	WCT X RBT		96.5X3.5	xx
2988	Allen Creek 12N18W24 8/7/2002 Ladd Knotek	27	R6Y4	WCT	R96Y89	100	xx

^aNumber of fish successfully analyzed. If combined with a previous sample (Indicated in "Location" column), the number indicates the combined sample size. If present, the number in () is the average number of individuals successfully analyzed per locus (some individuals do not amplify for all marker loci).

^bNumber of markers analyzed that are diagnostic for the non-native species (R=rainbow trout, W=westslope cutthroat trout, Y=Yellowstone cutthroat trout).

^cCodes: WCT = westslope cutthroat trout (*Oncorhynchus clarki lewisi*); RBT = rainbow trout (*O. mykiss*); YCT = Yellowstone cutthroat trout (*O. clarki bouvieri*). Only one species code is listed when the entire sample possessed alleles from that species only. However, it must be noted that we cannot definitively rule out the possibility that some or all of the individuals are hybrids. We may not have detected any non-native alleles at the loci examined because of sampling error (see Power %). Species codes separated by "x" indicate hybridization between those species.

^dNumber corresponds to the percent chance we have to detect 1% hybridization given the number of individuals successfully analyzed and the number of diagnostic markers used. For example, 25 individuals are required to yield a 95% chance to detect 1% hybridization with rainbow or an 87% chance to detect 1% hybridization with Yellowstone cutthroat trout into what once was a westslope cutthroat trout population. Not reported when hybridization is detected.

^eIndicates the genetic contribution of the hybridizing taxa in the order listed under c to the sample assuming Hardy-Weinberg proportions. This number is reported if the sample appears to have come from a hybrid swarm. That is, a random mating population in which species markers are randomly distributed among individuals.

^fIndicates number of individuals with genetic characteristics corresponding to the species code column when the sample can be analyzed on the individual level. This occurs when marker alleles are not randomly distributed among individuals and hybridization appears to be recent and/or if the sample appears to consist of a mixture of populations.

Methods and Data Analysis

The PINE technique uses short synthetically made segments of DNA called primers, in pairs, to search for relatively small segments of organismal DNA flanked by particular, often viral, DNA inserts. During the polymerase chain reaction (PCR), the primers bind to the ends of the inserts and many copies of the organismal DNA between the primers are made. While the DNA from some organisms may have two appropriately spaced inserts to which the primers can attach, the DNA from other organisms may have only one or none of the appropriately spaced inserts in particular regions. During PCR we will fail to copy DNA in the latter two cases. Thus, the PINE technique coupled with PCR is used to search for evidence of genetic variation based on the presence or absence of particular DNA fragments. The fragments are labeled by the primers used to produce them and their length in terms of the number of nucleotides in the fragment.

The fragments are made using dye labeled nucleotides and after PCR are separated from each other via electrophoresis in polyacrylamide gels. Smaller fragments move through the gels at a faster rate than larger fragments. The use of dye labeled nucleotides allows one to visualize the position of the fragments in the gels after electrophoresis using a spectrophotometer and the size of the fragments is determined by comparison to the position of synthetic fragments of known size that were also migrated into the gel.

When DNA from westslope cutthroat trout, *Oncorhynchus clarki lewisi*, and rainbow trout, *O. mykiss*, is compared with PINE analysis and three different pairs of primers seven fragments are characteristic of westslope cutthroat trout and six fragments are usually characteristic of rainbow trout (Table 1). Likewise, when DNA from westslope and Yellowstone cutthroat trout, *O. c. bouvieri*, is compared using the same procedure one fragment is characteristic of westslope cutthroat trout and four fragments are characteristic of Yellowstone cutthroat trout (Table 1).

Fragments produced from the DNA of one taxon and not another are commonly termed diagnostic or marker loci because they can be used to help determine whether a sample came from a non-hybridized population of one of the taxa or a population in which hybridization between them has or is occurring. Individuals from a non-hybridized population will possess fragments characteristic of only that taxon. In contrast, since half the DNA of first generation hybrids comes from each of the parental taxa the DNA from such individuals will yield all the fragments characteristic of the two parental taxa. In later generation hybrids, the amount and particular regions of DNA acquired from the parental taxa will vary among individuals. Thus, DNA from later generation hybrid individuals will yield only a subset of the parental fragments and the particular subset will vary among individuals. In a sample from a random mating hybrid swarm, that is a population in which the genetic material (i.e. fragments) of the parental taxa is randomly distributed among individuals such that essentially all of them are of hybrid origin, the frequency of the fragment producing allele from the non-native taxon is expected to be nearly equal among the diagnostic loci since their presence can all be traced to a common origin or origins. Thus, if a sample contains substantial variation at only a single marker locus where the presence of the fragment is usually characteristic of a non-native taxon and lacks such fragments at all other markers this is probably not indicative of hybridization. Rather, it much more likely represents the existence of genetic variation for the presence or absence of the fragment within this particular population of the native taxon.

An important aspect of PINE marker loci is that individuals homozygous for the presence allele (pp) or heterozygous (pa) will both yield the fragment. That is, p is dominant to a . Thus, in order to estimate the genetic contribution of the native taxon to a hybrid swarm we concentrate on the marker loci at which the p allele is characteristic of the non-native taxon. Furthermore, we must assume that genotypic distributions in the population reasonably conform to expected random mating proportions. Under this assumption the frequency of the native a allele is approximately the square root of the frequency of individuals in the population lacking the

fragment (*aa*). The frequency of the non-native allele then is one minus this value. We focus on the *p* alleles characteristic of the non-native taxon because with low levels of hybridization it is the presence of these alleles that are likely to provide evidence of hybridization. With low levels of hybridization, it is likely all individuals in the sample will genotypically be *pp* or *pa* where the *p* allele is characteristic of the native taxon. Thus, like in non-hybridized populations all individuals in the sample will yield the fragment providing no evidence of hybridization.

Failure to detect evidence of hybridization in a sample does not necessarily mean the population is non-hybridized because there is always the possibility that we would not detect evidence of hybridization because of sampling error. In order to assess the likelihood the population is non-hybridized, we determine the chances of not detecting as little as a one percent genetic contribution of a non-native taxon to a hybrid swarm. This is simply 0.99^{2NX} where *N* is the number of fish in the sample and *X* is the number of marker loci where the *p* allele is characteristic of the non-native taxon.

In samples showing evidence of hybridization, that is; fragments characteristic of a non-native taxon were detected at two or more marker loci, we used two approaches to determine if the population appeared to be a hybrid swarm. First, contingency table chi-square analysis was used to test for heterogeneity of allele frequencies among the marker loci. Next, we compared the observed distribution of the number of loci per individual at which non-native fragments were detected to the expected random binomial distribution based on the estimated native and non-native genetic contributions to the population. If both analyses were non-significant we concluded the population came from a hybrid swarm.

Heterogeneity of allele frequencies among marker loci can arise in very old hybrid swarms as the frequencies over time diverge from each other due to genetic drift. In this case, however, the non-native fragments will still be randomly distributed among individuals.

There are two likely reasons why a non-random distribution of non-native fragments may be observed among individuals in a sample. It may contain individuals from genetically divergent populations with different amounts of hybridization or hybridization may have only recently occurred in the population. Based on genetic data alone, these two situations will generally be difficult to distinguish from each other. Regardless of the explanation, when the non-native fragments are not randomly distributed among individuals in a sample estimating a mean level of hybridization has little, if any, biological meaning and, therefore, is often not estimated.

Results and Discussion

Sixmile Creek 2978

This sample consists of fin clips taken from fish collected from three locations in Sixmile Creek: upper (*N*=12), middle (*N*=10), and lower (*N*=5). Each location was greater than one mile away from the adjacent one and there are no known barriers between locations.

Considering all the locations, PINE fragments characteristic of rainbow trout were detected at all six diagnostic loci analyzed between this fish and westslope cutthroat trout. The allele frequencies at the diagnostic loci, however, were statistically heterogeneous (contingency table chi-square; $P<0.001$) among the locations. Thus, each location was treated as a separate sample in the subsequent analyses.

PINE fragments characteristic of rainbow trout were detected at five diagnostic loci in the lower sample. The allele frequencies were statistically homogeneous ($P>0.05$) among the diagnostic loci and the rainbow trout fragments appear to be randomly distributed ($P>0.50$) among the fish in the sample. The lower portion of Sixmile Creek, therefore, appears to contain a westslope cutthroat-rainbow trout hybrid swarm in which essentially all fish are of hybrid origin.

In the middle sample, PINE fragments characteristic of rainbow trout were detected at three diagnostic loci. Although the allele frequencies were statistically homogeneous ($P>0.05$) among the diagnostic loci, the rainbow trout fragments were not randomly distributed ($P<0.05$) among the fish in the sample. In contrast, they were detected in just three fish with one possessing rainbow trout markers at three loci, another at two loci, and the other at one locus. These results suggest the middle portion of the stream contains a mixture of non-hybridized westslope cutthroat trout and hybrids between westslope cutthroat and rainbow trout.

The fish definitely of hybrid origin in the middle portion of the stream, on the average, possess rainbow trout markers at fewer diagnostic loci (2.00) than those in the lower portion of the stream (3.25). This suggests that the hybrid fish in the middle portion of the stream are not simply migrants from the lower reach. Rather they appear to be progeny of westslope cutthroat trout and hybrid migrants from the lower reach. Thus, it appears that hybridization with rainbow trout is moving upstream in Sixmile Creek.

Although the middle portion of the stream most likely contains some non-hybridized westslope cutthroat trout, reliably identifying them on an individual basis will be problematic. It will require data from numerous diagnostic loci. Thus, from a practical perspective this stream reach should simply be considered to contain hybridized fish.

PINE fragments characteristic of only westslope cutthroat trout were detected in the upper sample. Because of the small sample size, the conclusion that this stream reach contains a non-hybridized westslope cutthroat trout population is somewhat tenuous. We have only a 77% chance of detecting as little as one percent hybridization with rainbow trout and a 60% chance of detecting as little as one percent hybridization with Yellowstone cutthroat trout. Although the genetic status of the trout in the upper reach is somewhat uncertain, the conservative approach would be to consider them to be non-hybridized westslope cutthroat trout. Furthermore, since hybridization with rainbow trout appears to be moving upstream in Sixmile Creek and there appears to be no barriers between sample locations the continued genetic integrity of the fish in the upper reach should be considered to be in jeopardy.

Roman Creek 2979

This sample consists of fin clips taken from fish collected from two locations in Roman Creek: upper ($N=17$) and lower ($N=9$). Considering both samples, PINE fragments characteristic of both westslope cutthroat and rainbow trout were detected at four of the six diagnostic loci between these fishes that were analyzed. The frequency of rainbow trout markers did not significantly differ (contingency table chi-square; $P>0.10$) between the fish collected from the two locations so they were combined into a single sample in the subsequent analyses.

The frequency of rainbow trout alleles in the sample was statistically homogeneous ($P>0.10$) among the diagnostic loci and the rainbow trout markers appear to be randomly distributed ($P>0.05$) among the fish in the sample. Thus, this population appears to be a westslope cutthroat-rainbow trout hybrid swarm in which essentially all fish are of hybrid origin.

Allen Creek 2988

PINE fragments characteristic of only westslope cutthroat trout were detected in the sample. With the 27 fish in the sample, we have a 96% chance of detecting as little as one percent hybridization with rainbow trout and an 89% chance of detecting as little as one percent hybridization with Yellowstone cutthroat trout. This population, therefore, is very likely non-hybridized westslope cutthroat trout.

Sincerely,

Ben Wright
Robb Leary

TABLE 1

Diagnostic PINE markers for westslope cutthroat, Yellowstone cutthroat, and rainbow trout. **X** indicates the fragment is present in the particular taxon.

<u>Markers</u>	<u>Yellowstone</u>	<u>Westslope</u>	<u>Rainbow</u>
Hpa1 5'/Hpa1 3'			
232	x		
153		x	
72	x	x	
70			x
69	x	x	
66			x
Fok1 5'/Tc1			
369			x
366	x	x	
230			x
159	x		
138	x		
110		x	
Hpa1 5'/33.6+2			
395			x
388	x	x	
266			x
248	x		
148	x	x	