The Origins of Lake Washington Sockeye Salmon: What Can Genetic Data Tell Us?

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Currently, four well-established populations of sockeye salmon (*Oncorhynchus nerka*) spawn in the Lake Washington basin. These include beach spawners (primarily at Pleasure Point), and populations spawning in the Cedar River, Issaquah Creek, and the Sammamish River tributaries (principally Bear Creek). The origin of the Bear Creek population (*i.e.*, native or non-native) is uncertain. Historical records of sockeye in Bear Creek are limited, and the genetic data, though suggestive of a native origin, are not conclusive.

Early reports (Evermann and Meek 1898; Rathbun 1900; Evermann and Goldsborough 1907) indicate that *O. nerka* spawned in Lake Washington's tributaries at the turn of the century. Most of these reports are now believed to be of kokanee, the nonanadromous form of *O. nerka* (Shaklee *et al.* 1996). The presence of kokanee suggests that anadromous sockeye must have inhabited the basin at some time in the past (Wood and Foote 1996), perhaps even in the early 1900's. Nonetheless, these populations may not have survived the dramatic changes to the watershed following the 1916 completion of the Lake Washington ship canal, which permanently dried the lake's former outlet (the Black River, a tributary of the Duwamish) and established the Ship Canal as the watershed's only link to the Pacific. Such changes might reasonably have had negative impacts on any contemporary, anadromous sockeye populations, and, indeed, the few historical records from that period suggest that anadromous sockeye were not present in the Lake Washington drainage during the 1920's and '30's (Cobb 1927; Rounsefell and Kelez 1938). This suggests that sockeye inhabiting the basin today descended entirely from introduced fish from Baker Lake and/or Cultus Lake between 1937 and 1954 (Table 1). Four years after the 1937 plantings an estimated 9,099 sockeye returned to Issaquah Creek, 400 returned to the Cedar River, and only two were caught in a rack across Bear Creek (Royal and Seymour 1940). In all subsequent years, sockeye were observed returning to Issaquah Creek (Kolb 1971).

Based on historical records the Cedar River and Issaquah Creek populations were most likely established from Baker Lake transplants. This inference is borne out by the genetic similarity of those three populations (Hendry *et al.* 1996; Seeb and Wishard 1977). The Bear Creek population, on the other hand, exhibits allele frequencies at some allozyme loci that are quite distinct from those in either Baker or Cultus Lake. Hendry *et al.* (1996) suggest that Bear Creek sockeye descended from a remnant native population. Assessing the level of confidence in such an inference is difficult, but may be done in the context of a statistical, hypothesis-testing framework.

With genetic data it is not possible to directly confront the hypothesis that the Bear Creek population descended from "native" fish. Instead, one must rely on a process of elimination, demonstrating that the other possibilities are implausible. In this case, that means testing whether the allele frequencies in Bear Creek are so different from those in either Baker Lake or Cultus Lake, that it is improbable that Bear Creek sockeye descended exclusively from either of those two possible source populations. A likelihood-ratio approach which accounts both for sampling error and for random genetic drift allows such a test. The most fundamental result is that if the Bear Creek population were founded by the Baker Lake transplants, its population size would have had to remain very small for many years to generate the observed level of genetic divergence from Baker Lake. However, since very little is known about the historical, genetically effective population size of the Bear Creek population, one cannot completely exclude the possibility that Bear Creek sockeye descended from the Baker Lake transplants. For a complete description of the statistical procedures and the results see Anderson (1998).

This result cannot be taken as evidence that Bear Creek sockeye are *not* of native origin. Rather it is a reflection of the considerable difficulty involved in making inferences of this type with genetic data—especially if one demands levels of statistical significance common in other fields of science. However, the genetic data do indicate that Bear Creek sockeye form a population distinct from the others in the lake. They also possess a number of life-history traits which distinguish them from the other Lake Washington stocks (Hendry and Quinn 1997). Whether or not they are of native origin, the sockeye in Bear Creek have been successful in growing from what must have been a very small population size in the 1940's, to a population which has seen some impressively large returns in recent years. As such they are of considerable management and conservation interest.

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Table 1: Transplants of sockeye salmon into the Lake Washington drainage basin (taken from Hendry 1995). Transplants from Baker Lake were taken from the U.S. Bureau of Fisheries Hatchery on Grandy Creek (Royal and Seymour 1940). Transplants from Cultus Lake (on the Chilliwack River, a tributary of the Fraser) probably originated from beach spawning populations in the lake (Woodey 1966).

Year	*Receiving Waters*	*Number (1,000's)*	*Age*	*Planted From*
1917[a,d]	Lk. Washington	20	fry	Unknown
1937[a,b,c]	Bear Creek	576	fry	Baker Lake
1937[a,b,c]	Cedar River	656	fry	Baker Lake
1937[a,b,c]	Issaquah Creek	1,257	fry	Baker Lake
1942[b]	Lk. Washington	41	fingerling	Baker Lake
1943[a,b]	Cedar River	227	fingerling	Baker Lake
1943[a,b]	Issaquah Creek	254	fingerling	Baker Lake
1944[b]	Cedar River	54	yearling	Baker Lake
1944[a,b]	Issaquah Creek	42	yearling	Baker Lake
1944[a,b]	North Creek	24	fingerling	Cultus Lake
1945[b]	Cedar River	32	yearling	Baker Lake
1950[b]	Issaquah Creek	6	fingerling	Cultus Lake
1954[b]	Issaquah Creek	54	yearling	Cultus Lake

Sources:
[a]Woodey (1966)
[b]Kolb (1971)
[c]Royal and Seymour (1940)
[d]State of Washington Department of Fisheries and Game (1919)