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Understanding anadromous behavior through time using salmonid vertebrae microchemistry

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In North America, the restoration of salmonid populations depends on knowledge of life-history behaviors prior to their decline following European colonization. The microchemistry of otoliths from samples at archaeological sites and in museum collections can provide information for studying the dynamics of salmonid populations in the past. Otoliths, however, are rarely preserved or recovered during excavations. Vertebrae are recovered more often from archaeological sites, and like otoliths, contain growth banding structures. Our study examines whether vertebrae microchemistry can be used in place of otolith microchemistry to study past patterns of salmonid migration. Here, we present an approach for understanding salmonid life histories using vertebrae microchemistry collected using the laser ablation split-stream (LASS) method. We demonstrate that microchemical records of otoliths and vertebrae are broadly correlative in samples from three modern salmonid species in the Skagit and Snake Rivers. Variation of $^{87}Sr/^{86}Sr$, and inverse behavior of Ba/Ca and Sr/Ca, across transects of *Oncorhynchus nerka* and *O. mykiss* vertebrae record the migration of these fish from freshwater ($^{87}Sr/^{86}Sr_{(O.\ nerka)}$: 0.708; $^{87}Sr/^{86}Sr_{(O.\ mykiss)}$: 0.711) into the ocean ($^{87}Sr/^{86}Sr$: 0.709). Variation of $^{87}Sr/^{86}Sr$ and Sr/Ca is less apparent in *O. tshawytscha*, indicating primary chemical signatures may be overprinted during the later marine stage of life in species that quickly migrate to the ocean before ossification is complete. However, *O. tshawytscha* vertebrae have high Ba/Ca signatures (>0.12) early in life, possibly recording pre-migration residence in freshwater; this suggests the behavior of Ba and Sr may be decoupled before ossification. We compare these results with vertebrae from an archaeological site on the Skagit River, WA, USA. Skagit River vertebrae have largely uniform Sr/Ca (0.4-0.6) and marine $^{87}Sr/^{86}Sr$ (~0.709) values, but variable Ba/Ca (0.1-1.2) values, which may reflect freshwater residence early in life and interactions with localized Ba-rich zones later in life while in the open ocean. Our results indicate salmonid vertebrae microchemistry can be used to study migration and anadromy. In archaeological studies, this tool can potentially provide a deep-time perspective on the life histories of salmonid populations when otoliths are unavailable.