Use of otoliths to identify river and hatchery of origin of California Central Valley Chinook salmon in the ocean fishery: potential application to Klamath River Chinook salmon

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SUMMARY:

Ocean harvest models aim to quantify impacts of fishing mortality in the marine environment, with specific mandates to manage the overall resource to minimize impacts on endangered or threatened populations. This creates a particular challenge for managing salmonid resources, given that few tools exist to determine the extent of movement or mixing of stocks in a common marine environment, especially when populations differ significantly in size (McKinnell et al. 1997, PFMC 2001). Current use of coded wire tags provides limited insight into the role of individual natal sources to Chinook salmon population dynamics due to small numbers of tagged fish and even fewer recoveries (<10% of hatchery releases and far fewer wild fish are tagged).

We developed novel techniques to determine whether otoliths (fish earbones) can be used as natural population markers to identify individual sources of salmon from the fall-run California Central Valley (CCV) in adults caught in the ocean fishery. Our research shows that otolith microstructure and geochemical composition provide discrete tags for determining production source (hatchery vs. wild) and individual hatchery and stream-of-origin for adult Chinook salmon. Hatchery and wild individuals can be distinguished with 90% correct classification based on differences in otolith microstructure (width and variability of daily growth bands and distinctness of exogenous feeding check) formed during early growth in hatcheries or wild rearing environments. Growth rates of fish reared in hatcheries are greater and less variable than those of wild fish resulting in the physical banding pattern in otoliths that is diagnostic between the two production types. A less distinct exogenous feeding check is deposited on otoliths of hatchery fish because hatchery fish are fed supplemental food prior to depleting maternal yolk, which results in a smooth transition to exogenous feeding and no disruption of otoliths growth. Sr isotopes ($^{87}Sr/^{86}Sr$) in fish from the ten natural spawning rivers in the CCV are significantly different from one another and can be used to identify the natal origin of wild adults with 95% accuracy. In addition, Sr isotopes ($^{87}Sr/^{86}Sr$) are distinct among juveniles from each of the five hatcheries and these distinctive markers are identifiable in otoliths from adults captured in the ocean fishery. This match between natal sources and otolith signatures in ocean-caught adults was ground-truthed by examining otoliths of adults that had been tagged with coded wire at their natal tributary.

We are using these techniques to identify the origin of fishes caught in the ocean fishery to determine whether some river/ hatchery sources are contributing disproportionately to the fishery, which has direct implications for targeting restoration efforts on critical salmon habitat and quantifying the role of hatcheries in supplementing natural populations. A spatial analysis of our mixed-stock fishery data indicates that fish caught in schools from Bodega Bay south to Monterey Bay during salmon fishing season are comprised of fish from all potential wild and hatchery sources. These results confirm current ocean harvest models, which assume that fish from the 15 potential spawning sources in the Central Valley are mixed in the ocean fishery at the scale of regions and schools. A similar study can be conducted in the Klamath-Trinity system to determine if otolith microchemistry and microstructure can be used to identify individual sources of fish. The results from that study in conjunction with information already derived for Central Valley Chinook salmon have the potential to identify the stock origin (Central Valley versus Klamath-Trinity) as well as individual rivers and hatcheries for both stocks of fish caught in the ocean. Analyses of these data could elucidate movement patterns, spatial structure, and how different source populations contribute to fisheries distributed along the coast to aid in sustainable management.

TECHNIQUE BACKGROUND:

The chemical and isotopic composition of the otoliths has been used in a variety of ways to aid in stock identification of fish populations. Otoliths are formed by the daily deposition of a layer of a calcium carbonate and protein matrix. Because ninety percent of the calcium carbonate and trace elements that comprise otolith material is derived from surrounding water, the chemical and isotopic composition of otoliths provides a signature map of specific water masses. In California, volcanic rock dominates the Cascade Mountain range to the north, while older granitic rock is widespread along the western slope of the Sierra Nevada mountain range. The north-to-south gradient in rock type and age produces a trend of low strontium isotopic ratios in the north to high values in the south. The watershed of the major salmon-spawning rivers drain across these different geologic formations, transferring the natural isotopic markers to the otoliths of the fish in the rivers. Otoliths serve as a permanent record of the natal rearing environment. To identify hatchery fish from wild fish that co-occur on the same rivers and therefore are predicted to reflect similar isotopic chemistry, we developed additional population markers using otolith microstructure.

Otolith microstructure, the pattern in concentric bands in otoliths has also been used in stock identification especially when growth rates among populations are known to occur. Like tree rings, otoliths provide a record of age and growth in fishes and therefore can be used in juvenile salmon to record growth rates during the life of the fish. Environmental factors that effect fish growth such as temperature, photoperiod, stress, developmental changes and food resources have been demonstrated to influence otolith microstructure (Campana and Neilson 1985). Otolith microstructure was used to discriminate between hatchery and wild Chinook salmon in British Columbia based on wider and less variable increment widths found in hatchery produced individuals (Zhang et al. 1995). The potential differences in rearing environments between hatcheries and natural rivers, with hatcheries providing a more constant and abundant feeding environment, may contribute to differences in microstructure between production sources.

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