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Stock-Specific Migration Timing of Adult Spring–Summer Chinook Salmon in the Columbia River Basin

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Abstract.—An understanding of the migration timing patterns of Pacific salmon *Oncorhynchus* spp. and steelhead *O. mykiss* is important for managing complex mixed-stock fisheries and preserving genetic and life history diversity. We examined adult return timing for 3,317 radio-tagged fish from 38 stocks of Columbia River basin spring–summer Chinook salmon *O. tshawytscha* over 5 years. Stock composition varied widely within and between years depending on the strength of influential populations. Most individual stocks migrated at similar times each year relative to overall runs, supporting the hypotheses that run timing is predictable, is at least partially due to genetic adaptation, and can be used to differentiate between some conspecific populations. Arrival timing of both aggregated radio-tagged stocks and annual runs was strongly correlated with river discharge; stocks arrived earlier at Bonneville Dam and at upstream dams in years with low discharge. Migration timing analyses identified many between-stock and between-year differences in anadromous salmonid return behavior and should aid managers interested in protection and recovery of evolutionarily significant populations.

The Columbia River drains more than 673,000 km^2 in seven U.S. states and British Columbia, and was historically one of the most productive rivers for anadromous salmon *Oncorhynchus* spp. and steelhead *O. mykiss* in the world (Chapman 1986; Nemeth and Kiefer 1999). Major declines in wild Columbia River basin salmonids have been attributed to habitat degradation and loss, excessive harvest, hatchery propagation, water diversion, and development and operation of main-stem hydroelectric dams (Raymond 1988; National Research Council 1996). Twelve Columbia River basin salmon and steelhead runs are currently protected under the U.S. Endangered Species Act (ESA); three of these runs are listed as endangered (NMFS 2000). Spring–summer Chinook salmon *O. tshawytscha* listed as threatened include the Snake River evolutionarily significant unit (ESU), the lower Columbia River ESU, and the upper Willamette River ESU; the upper Columbia River spring Chinook salmon ESU is endangered.

Columbia River basin ESUs cover large geographic areas, and each ESU contains a hierarchy of Chinook salmon subpopulations whose boundaries and conservation status were delineated by the National Marine Fisheries Service (NMFS) (Myers et al. 1998). Each ESU includes distinct populations (or metapopulations) that are reproductively isolated from conspecific populations and that represent an important evolutionary component of the species (Waples 1991). As defined, reproductive isolation between ESUs need not be absolute, but should be strong enough that genetic differences occur at evolutionary time scales. Metapopulations at the ESU level include many populations linked by genetic exchange within shorter ecological time scales (Cooper and Mangel 1999), and each population can include multiple locally adapted stocks within a watershed (Nehlsen et al. 1991; Emlen 1995). Within this population framework, differentiation between and protection of intraspecific groups are critical for maintaining genetic diversity and for recovery of both small-scale assemblages (i.e., local stocks) and broader ESU-level populations (National Research Council 1996; Policansky and Magnuson 1998).

Management of Columbia River basin spring–summer Chinook salmon ESUs and their hierarchy of subpopulations and stocks is particularly com-

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