Population-specific escapement of Columbia River fall Chinook salmon: Tradeoffs among estimation techniques

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A B S T R A C T
In the multi-stock Columbia River system, managers estimate fall Chinook salmon, Oncorhynchus tshawytscha (Walbaum), escapements using various combinations of spawning ground surveys, harvest data and fish counts at dams and hatcheries. Our objectives were to improve upon the traditional methods, and to evaluate trade-offs among methods. Using data from radio-tagged (n = 4421) and PIT-tagged (n = 1950) adult salmon over eight years, we applied a mark-recapture model and estimate population-specific escapements, both aggregating data within year and stratifying them by week. Mark-recapture estimates differed between estimation techniques and from estimates generated using traditional methods. Stratifying data by week measured escapement estimate uncertainty more reasonably than aggregating data within year. Radiotelemetry provided better spatial resolution among populations for tributary spawners whereas PIT tags provided low-cost, easily replicated estimates using an existing detection system. Mark-recapture techniques had several advantages over current practices: quantifying uncertainty, transparent methods and reduced sensitivity to survey biases.

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1. Introduction

Adult escapement estimates for anadromous Pacific salmonids (Oncorhynchus spp.) are used to assess a variety of management and conservation objectives. These include monitoring population status and trends (Baker et al., 1996), developing life-cycle survival models (Kareiva et al., 2000; McClure et al., 2003), evaluating restoration and recovery efforts (e.g., Peters et al., 2001), and forecasting adult returns (e.g., Hyun et al., 2005, 2012b). Escapement data are perhaps most frequently used to manage fisheries, especially in mixed-stock river systems where robust populations are intermingled with populations of conservation concern (e.g., Knudsen, 2000; Good et al., 2007). The accuracy and precision of salmonid escapement estimates differ widely among estimation techniques and it is important to understand the strengths, biases, and sources of uncertainty in each approach. Most methods are constrained by some combination of available resources (e.g., personnel, time, equipment), characteristics of the enumeration site (e.g., depth, turbidity, accessibility), salmon behaviors (e.g., immigration and emigration timing, residence time, prespawn mortality), and study design (e.g., sampling intervals and tag recovery likelihood). The importance of these factors varies among methods and information requirements. For example, widely used visual surveys across a geographic sampling frame like redd counts (hereafter “surveys”) can be cost effective, but are sensitive to weather, river conditions, and among-observer differences (Chapman et al., 1986; Jones et al., 1998; Groves and Chandler, 1999; Dunham et al., 2001; Holt and Cox, 2008). Direct enumeration (hereafter “counts”), such as at passage constrictions like weirs, fences, or dam fishways is generally considered more reliable than visual methods. However, installation and maintenance can be cost-prohibitive and count data are also subject to errors. These include unmonitored upstream or downstream passage events (Dauble and Mueller, 2000; Boggs et al., 2004) and the counting biases associated with fish density, separation among populations (Murdoch et al., 2010), timing effects (Halborn et al., 1999; Parken et al., 2003), and fallback and reascension at count stations (Boggs et al., 2004). Mark-recapture studies have important statistical advantages over many survey and enumeration approaches, including the ability to quantify uncertainty in escapement estimates (Lebreton et al., 1992; Schwarz and Seber, 1999). However, mark-recapture estimates can be sensitive to

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