

Regurgitation Rates of Intra-gastric Radio Transmitters by Adult Chinook Salmon and Steelhead during Upstream Migration in the Columbia and Snake Rivers

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Abstract.—Regurgitation rates for radio tags gastrically implanted into adult salmon *Oncorhynchus* spp. and steelhead *O. mykiss* are difficult to estimate in the wild because most fish are never recaptured to allow inspection of secondary tags. During 1996–2000, 9,006 Chinook salmon *O. tshawytscha* and steelhead with both radio tags and secondary tags were released near Bonneville Dam on the Columbia River (Washington–Oregon), and 1,764 fish were recaptured in mid-migration 460 km upstream on the lower Snake River. Minimum annual regurgitation rates ranged from 0.4% to 10.9% for spring–summer Chinook salmon (pooled rate = 3.0%; $n = 838$), from 3.5% to 4.3% for steelhead (pooled rate = 4.0%; $n = 881$), and from 0% to 5.6% for fall Chinook salmon (pooled rate = 2.2%; $n = 45$). Fish that lost transmitters retained them a median of 7 d (average = 14.1 d) before regurgitation, and a majority of losses occurred in the lower Columbia River. Transmitter retention was improved by placing rubber bands or a ring of surgical tubing around part of each tag.

Radiotelemetry is increasingly used to monitor adult salmonid *Oncorhynchus* spp. migration rates, habitat preferences, behavior at dams, escapement, distribution within a drainage, and survival to spawning areas (Laughton 1991; Schreck et al. 1994; Hockersmith et al. 1995; Stuehrenberg et al. 1995; Pahlke 1997; Bjorn et al. 1998, 2000a, 2000b; Smith et al. 1998; Gowans et al. 1999). Most of the recent telemetry studies of adult salmon and steelhead *O. mykiss* have used intra-gastric tagging, which does not require surgery and has reduced fish handling and recovery times. A weakness of this method is that some fish regurgitate their transmitters, and regurgitation rates are difficult to measure because the fate of these fish is often unknown or ambiguous (Pahlke and Bernard 1996). Mistaking regurgitated transmitters for deaths or other losses—or vice versa—could bias research results in several ways. For example, a “stationary” transmitter that can be detected but not recovered by researchers could be either a regurgitated transmitter or one still present in the carcass of a fish that died. Similarly, transmitters discarded from fish recaptured in fisheries could, when subsequently found, be misidentified as regurgitated. Either mistake could result in inaccurate

rate survival or escapement estimates or other misinterpretations of data.

The best opportunities for calculating transmitter regurgitation and retention rates are with fish recaptured in cooperative fisheries (Smith et al. 1998), at hatcheries or traps (Bjorn et al. 1998), or from spawning grounds. Secondary tags or markers are required in all cases to allow identification of fish that lose transmitters. Our telemetry study of adult salmonids in the Columbia River basin provided a unique opportunity to evaluate transmitter regurgitation rates. We were able to tag a large number of fish at Bonneville Dam (the first hydroelectric project encountered by adult migrants in the Columbia River) and later recapture and inspect the fish at Lower Granite Dam, 460 km upstream in the Snake River. Our objectives for this paper were to calculate regurgitation rates for adult Chinook salmon *O. tshawytscha* and steelhead, estimate tag retention time for fish that regurgitated transmitters, and evaluate whether tag retention could be increased by adding rubber bands or surgical tubing to transmitters.

Methods

As part of a large-scale study of adult salmon and steelhead migrations in the Columbia River basin (Bjorn et al. 2000a, 2000b), fish were trapped at the adult fish facility adjacent to the Washington-shore fish ladder at Bonneville Dam (river kilometer [rkm] 235 from the Columbia River mouth) as they migrated upstream to natal streams or hatcheries (Figure 1). Over the four

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