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Effect of Smolt Length at Release on Adult Returns of Hatchery-Reared Winter Steelhead

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Abstract.—Smolts of hatchery-reared steelhead *Oncorhynchus mykiss* were tagged by length-group and released in 1983 and 1984 on the Cowlitz River, Washington. Recovery of adults was significantly greater for smolts 190 mm and larger compared with returns of smaller fish.

Size at release is known to influence survival of hatchery-reared anadromous salmonids. However, there are few size-at-release studies for hatchery steelhead *Oncorhynchus mykiss* available in the literature. Larson and Ward (1955) and Wagner et al. (1963) compared survival in groups of smolts in which lengths overlapped and possibly obscured results. Tipping et al. (1995) evaluated emigration rates of hatchery steelhead smolts segregated by 10-mm fork length increments and found that smolts 190–199 mm long were more successful than smaller fish and that emigration rates did not increase for smolts 200 mm and larger, although the effect of emigration rate on adult returns was not determined. The target size of hatchery steelhead in Washington State has been 75–90 g, which corresponds to lengths of about 195–210 mm, considerably greater than lengths for wild steelhead (155–165 mm; Loch et al. 1988). In the present study I compared adult recoveries of hatchery steelhead to smolt length at release.

This study was conducted on the Cowlitz River, a lower Columbia River tributary in Washington. The upstream anadromous terminus of the Cowlitz River is at the Cowlitz Salmon Hatchery (river kilometer [rkm] 78, as measured from the confluence with the Columbia River). The steelhead smolts were reared and released from the Cowlitz Trout Hatchery (rkm 67). For 1980–1992 releases, about 1.8% of hatchery winter steelhead smolts were subsequently harvested as adults by Cowlitz River recreational anglers (author, unpublished data).

In late April 1983 and 1984, 4,000 and 4,985, respectively, hatchery winter steelhead smolts emigrating from rearing ponds at the Cowlitz Trout Hatchery were anesthetized with MS-222 (tricaine methanesulfonate), measured for fork length to the nearest millimeter, and tagged with a small (35-mm) numbered Floy anchor tag inserted at the dorsal fin base. Fish from 160 to 219 mm long were grouped in 10-mm length intervals; fish 220 mm and larger were considered as another group. In 1983, smolts 220 mm and larger averaged 226.4 mm and ranged up to 265 mm; in 1984, smolts 220 mm and larger averaged 229.8 mm and ranged up to 273 mm. After the fish were tagged, they were released into the Cowlitz River.

Tags from returning adult steelhead were recovered in the recreational fishery through angler contacts and signs posted at popular Cowlitz River fishing areas. Additional tagged fish were recovered in traps at the Cowlitz Trout and Cowlitz Salmon hatcheries. The first tag recoveries were in the winter of 1984–1985; data collection was completed in 1988. Chi-square analysis ($P = 0.05$) was used to compare return rates from each length interval to all other length intervals within each year of release and for both years combined. In addition, chi-square was used to compare recoveries from smolts less than 190 mm to those equal to or greater than 190 mm.

Forty-four tags were recovered for each year of release for an average adult recovery rate of 1%. Most tags (52.3%) were recovered when fish returned after 2 ocean-years, 46.6% after 3 ocean-years, and 1.1% after 4 ocean-years. The recreational fishery provided 55.7% of tag recoveries; the rest were from fish trapped at the hatcheries.

Return rates appeared to increase with smolt size; an average of 0.3% of smolts less than 190 mm were recovered, compared with 1.3% of fish larger than 190 mm (Table 1), a significant difference ($P < 0.001$) in both years ($\chi^2 = 18.19$ in 1983, $\chi^2 = 8.00$ in 1984). For both years, there were no significant differences in tag recoveries for fish 190 mm and larger, except for the significantly lower return of the 1984 release of 200–209-mm smolts.

Although sample sizes were small, smolt length did not appear to influence steelhead age at ma-

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TABLE 1.—Number of hatchery-reared steelhead smolts tagged and adult returns by smolt length. Within a column, adult return rates without a letter in common are significantly different ($P \leq 0.05$); NA = not applicable.

Smolt length (mm)	1983 release		1984 release		1983 and 1985 combined	
	Number tagged	Adult returns (%)	Number tagged	Adult returns (%)	Number tagged	Adult returns (%)
160–169	569	0 (0.0) w	0	NA	569	0 (0.0) y
170–179	625	5 (0.8) yx	0	NA	625	5 (0.8) z
180–189	625	1 (0.2) xw	942	1 (0.1) x	1,567	2 (0.1) y
190–199	572	8 (1.4) zy	968	9 (0.9) zy	1,540	17 (1.1) z
200–209	570	13 (2.3) z	1,030	3 (0.3) yx	1,600	16 (1.0) z
210–219	625	8 (1.3) zy	942	15 (1.6) z	1,567	23 (1.5) z
≥220	414	9 (2.2) zy	1,103	16 (1.5) z	1,517	25 (1.6) z
Total	4,000	44 (1.1)	4,985	44 (0.9)	8,985	88 (1.0)

turity: 57% of adults ($N = 7$) from smolts less than 190 mm, 50% of adults ($N = 56$) from 190–219-mm smolts, and 56% of adults ($N = 25$) from smolts greater than 220 mm returned after 2 ocean-years.

This experiment suggests that hatchery steelhead smolts should be at least 190 mm in length at release; this information may help managers optimize steelhead return rates while considering production costs. Feed costs for 205-mm, 215-mm and 225-mm smolts are about 16%, 33%, and 55%, respectively, more than for 195-mm smolts (assumes feed cost of US$0.77/kg and feed conversion at 1.3:1), but adult returns for these sizes were not significantly greater than for 190–199-mm smolts. However, mean length at release should exceed 190–199 mm to account for a normal length distribution in a population. The target release length will depend on the population length variation and the percent of the population desired to be greater than 190 mm. Ward and Slaney (1988) reported that large wild steelhead smolts had higher adult survival than small smolts.

Releasing hatchery steelhead smolts at lengths that optimize adult returns may also reduce interactions among wild salmonids by nonmigrating hatchery steelhead. Tipping et al. (1995) found that only 62.4% of 146–169-mm smolts were trapped 4.7 km downstream while 83.7% of smolts greater than 190 mm successfully emigrated.

A limitation of this study is the potential bias by possible length-related tag mortality or tag retention. However, recent research supports these findings. Tipping et al. (1995) found similar length-influenced results for emigration rates of hatchery steelhead marked with visible implant tags. In addition, a length-at-release experiment that used small Floy tags with smolts of sea-run cutthroat trout *O. clarki* (Tipping 1986) was repeated with visible implant tags (Tipping and Blankenship 1993), and both experiments showed similar length-related adult survivals. This would suggest that length-related tag mortality or tag retention was similar within the size-range of fish tagged.

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