Dispersal of Hatchery-Reared Chinook Salmon Parr following Release into Four Idaho Streams

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Abstract.—Repeated snorkel surveys were used to observe dispersal of parr of hatchery-reared chinook salmon Oncorhynchus tshawytscha from release sites in four mountain streams during 1994. The distribution of hatchery chinook salmon released in two streams at multiple sites was compared with the distribution of hatchery fish released in two streams at single release sites. Hatchery chinook salmon parr remained concentrated within 1.5 km of release sites through summer, but they were more evenly distributed in streams where multiple release sites were used. Densities of hatchery fish remained relatively stable following release, although there was a trend of gradual declining densities through summer and early fall.

Most hatchery-reared Pacific salmon and steelhead Oncorhynchus spp. produced in the Pacific Northwest are released in the spring as smolts that are ready to migrate to the ocean. Smolts are typically released directly from hatcheries with the intent that the adults will return to the hatchery in the future to be used as broodstock. Increasingly, hatchery fish have been also been used to supplement or reestablish natural salmonid stocks. In those cases, juveniles are released as smolts or presmolts into distant streams with the hope that the adult salmon will return and spawn. In such supplementation programs, juvenile salmonids are typically released from trucks or aircraft at one or two sites in target streams, and although salmonids at or near the smolt stage tend to disperse downstream quickly following release, it appears that presmolts and parr, expected to rear in streams for extended periods before migrating, tend to remain concentrated near release sites (Horner 1978; Egglisnaw and Shackley 1980; Cresswell 1981; Wentworth and LaBar 1984; Hume and Parkinson 1987; Seelbach 1987; Richards and Cernera 1989). If so, survival of these hatchery fish could suffer from intraspecific competition for limited resources and by attracting predators. The situation is further complicated if target streams contain natural fish populations.

Hatchery salmonids vary behaviorally and genetically from naturally produced conspecifics (Vincent 1960; Fenderson et al. 1968; Reisenbichler and McIntyre 1977; Sosiak et al. 1979; Bachman 1984; Chilcote et al. 1986; Leider et al. 1986; Swain and Riddell 1990; Hindar et al. 1991; Mesa 1991; Waples 1991). For example, hatchery fish are typically larger and more aggressive than same-aged natural conspecifics (Vincent 1960; Fenderson et al. 1968; Swain and Riddell 1990; Mesa 1991; Peery 1995), and when released in large numbers, they may have a short-term competitive advantage over existing natural fish (e.g., Chilcote et al. 1986; Nickelson et al. 1986). But longer-term (parr-to-smolt and smolt-to-adult) survival rates for hatchery fish tend to be lower than for their natural counterparts (Miller 1954, 1958; Flick and Webster 1964; Mason et al. 1967; Flick and Webster 1976; Fraser 1981; Erskine and Haase 1983; Piggins and Mills 1985; Hume and Parkinson 1987). So, a supplementation stocking program could result in lower survival for the existing natural populations and recently introduced hatchery fish alike. More information is needed on the behavior and dispersal patterns of hatchery-reared salmonid parr in streams if their release is to be an effective strategy for supplementing and reestablishing depleted natural stocks of salmon and steelhead in the Pacific Northwest. In this study, we monitored the dispersal of parr of hatchery chinook salmon Oncorhynchus tshawytscha after their release into four Idaho streams. We compared the relative distribution of the hatchery chinook salmon released at a single site and at multiple sites within streams.

Methods

Hatchery chinook salmon parr were released into Pete King, Squaw, White Sands, and Big Flat creeks, tributaries of the Lochsa River in the Snake

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River basin (Figure 1). Chinook salmon parr used during this study were reared and released by personnel from the Idaho Department of Fish and Game, Clearwater Hatchery, Ahsahka, Idaho.

Study area.—Pete King Creek is a fourth-order stream near the confluence of the Lochsa and Selway rivers. The study area in Pete King Creek was the lower 5.2 km (approximately 29,000 m²), which had a gradient of 3.0% (elevation of 450–585 m). The most abundant resident fish were subadult rainbow trout, steelhead (anadromous rainbow trout), and cutthroat trout \( O. clarki \). Squaw Creek is a fourth-order stream approximately 90 km upstream from Pete King Creek, near Powell, Idaho. In Squaw Creek, the study area was the lower 5.4 km (approximately 33,000 m²), which had a gradient of 2.3% (elevation, 975–1,085 m). Adult and subadult rainbow trout, steelhead, cutthroat trout, and bull trout \( Salvelinus confluentus \) were abundant in Squaw Creek. The study area on White Sands Creek began about 21 km upstream from its mouth and extended upstream about 5 km (approximately 62,000 m²). The study area was predominately low gradient (1.9%; elevation, 1,439–1,506 m) and was dominated by pools and glides. Resident trout (rainbow trout and possibly cutthroat trout) were only occasionally observed in White Sands Creek during this study. Big Flat Creek is a second-order tributary of White Sands Creek, starting at about stream km 22.5 (from the mouth of White Sands Creek). The study area in Big Flat Creek was the lower 5.7 km of the stream (approximately 49,000 m²), which had an average gradient of 1.7% (elevation, 1,475–1,573 m). Just downstream from the confluence of White Sands and Big Flat creeks, the stream gradient increased substantially as the creek passed through a steep-walled canyon. Squaw and Pete King creeks were accessible by road, and hatchery releases were made with tanker trucks. White Sands and Big Flat creeks were in a roadless area at the headwaters of the Lochsa River. At these sites, hatchery salmon were stocked by helicopter with a drop bucket.

Releases.—Chinook salmon parr released during this study were expected to rear in study streams during summer, overwinter, and migrate to the ocean as age-1 smolts in the spring of 1995. In 1994, hatchery fish were released at single sites in Pete King and Big Flat creeks and at multiple sites in Squaw and White Sands creeks (Table 1). On 5 July 1994, 12,000 chinook salmon parr were released from a tanker truck into Pete King Creek, 4.2 km upstream from the mouth of the stream. On the same day, 12,000 parr were divided among
Table 1.—Stream, date of release, number of hatchery chinook salmon parr released, and the number, mean length, width, and depth of snorkel sites used in the four streams during 1994. Values in parentheses are standard deviations.

<table>
<thead>
<tr>
<th>Creek</th>
<th>Release date</th>
<th>Number released</th>
<th>Number of sites</th>
<th>Average snorkel site (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>Squaw</td>
<td>5 Jul</td>
<td>12,000</td>
<td>14</td>
<td>20.2 (3.5)</td>
</tr>
<tr>
<td>Pete King</td>
<td>5 Jul</td>
<td>12,000</td>
<td>12</td>
<td>18.7 (6.8)</td>
</tr>
<tr>
<td>White Sands</td>
<td>6 Jul</td>
<td>80,000</td>
<td>12</td>
<td>17.1 (4.4)</td>
</tr>
<tr>
<td>Big Flat</td>
<td>7 Jul</td>
<td>40,000</td>
<td>11</td>
<td>22.0 (6.6)</td>
</tr>
</tbody>
</table>

three sites in Squaw Creek: 2.2 km, 3.1 km, and 4.6 km upstream from the stream mouth. In White Sands Creek, 80,000 hatchery parr were released on 6 July via a helicopter drop throughout a 3.5-km section of stream ranging from 22.5 to 26 km upstream from the mouth of the creek. In Big Flat Creek, 40,000 parr were released on 7 July by helicopter into a single pool 5.7 km upstream from the confluence with White Sands Creek. Fish released in 1994 averaged 76.4 mm fork length (95% confidence interval [CI], ±1.5 mm) and 5.0 g (±0.3 g) in weight at the time of release.

Snorkel surveys.—Snorkel transects were established at 14 locations in Squaw Creek, 12 in Pete King Creek, 12 in White Sands Creek, and 11 in Big Flat Creek. Transects were established at approximately 0.5-km intervals, starting at the release sites in Pete King and Big Flat creeks and at the furthest upstream release areas in Squaw and White Sands creeks, and proceeding downstream. Additional transects were used in each stream, one each about 0.5 km upstream and downstream from release sites. The exception was in White Sands Creek, where no specific release sites were used and so transects were placed at approximate 0.5-km intervals throughout the study area. Intervals between transect sites were estimated through vehicle odometer readings while driving on logging roads adjacent to Squaw and Pete King creeks and by pacing on White Sands and Big Flat creeks. Transects varied in length (Table 1) and, when possible, contained a well-defined pool bounded by upstream and downstream riffles. During a survey, we entered the stream at the downstream end of a transect and worked upstream while counting the number of hatchery chinook salmon and resident fish. Snorkel surveys were conducted from about 0900 hours until about 1500 hours to encompass the warmest and brightest portion of the day. Data were recorded by a person on the streambank or by the observer writing on slates while underwater. Transect lengths and average stream widths were measured (Table 1) and used to calculate areas, from which fish densities (fish/m²) were determined. Eight snorkel surveys were completed in each stream: one before release of the hatchery fish, and then 24 h and 1, 2, 4, 6, 9, and 12 weeks following release dates (5 July to 2 October 1994).

The distribution of hatchery fish in the four streams and over time was compared visually by graphing mean fish densities by transect location and date. Fish densities were also compared between the two release strategies (single versus multiple release sites) and by date using a two-way analysis of variance (ANOVA; SAS Institute 1990). Analysis was limited to data collected from eight snorkel transects from each stream that had similar distances from the single release sites in Pete King and Big Flat creeks or from the furthest upstream release areas in Squaw and White Sands creeks. These sites were roughly 0.1 km upstream from and 0.0, 0.5, 1.0, 1.5, 2.0, 3.0, and 4.0 km downstream from the furthest upstream release points or areas. Values used in analysis were fish densities averaged over the eight transect sites from each stream and for each survey date, excluding the initial survey that was completed before release of fish.

The downstream movement of hatchery parr soon after their release was monitored by using temporary weirs and traps in Squaw and Pete King creeks. Weirs were placed near the mouths of the two creeks and consisted of panels of 6.4-mm-mesh hardware cloth stretched diagonally across the width of the streams, terminating in live-box traps. Traps were checked every 1–2 h during a 5-d period following the release of the hatchery parr. Fish collected in the traps were identified, enumerated, and then released downstream of weirs. Emigration was not monitored with traps in White Sands and Big Flat creeks because of the remoteness of the sites.

Summer growth of hatchery parr in the four streams was monitored using minnow traps baited with commercial fish-egg bait. Hatchery parr were collected from Pete King and Squaw creeks on 3–4 August 1994, 29–30 d after their release, and from Big Flat and White Sands creeks on 16 September.
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FIGURE 2.—Densities of hatchery chinook salmon parr observed in the four streams through the study. Release sites are indicated by arrows along the x-axis.

1994, 71–72 d following release. We measured fork lengths to the nearest millimeter with a small measuring board and weights to the nearest 0.1 g with a battery-operated digital scale. Average weights of fish collected were compared for the two pairs of samples (Pete King Creek versus Squaw Creek and Big Flat Creek versus White Sands Creek) by \( t \)-tests; results were considered significant at the alpha = 0.05 level.

Results

No hatchery chinook salmon from previous years’ releases were observed in the four streams before stocking fish in the summer of 1994. A chinook salmon redd with an attending female was observed in the first (furthest downstream) transect site in Big Flat Creek in the fall of 1993, and natural age-0 chinook salmon were observed at that site during the spring of 1994. Some natural chinook salmon parr were observed in White Sands Creek downstream from the confluence with Big Flat Creek during the summer. No other natural chinook salmon were found in the study area during 1994.

Throughout the study period, hatchery chinook salmon were found in highest concentrations at or near release sites (Figure 2), mainly in pools. Mean densities of hatchery parr were higher in the two streams in which single release sites were used, averaging 0.83 fish/m² (95% CI, 0.17 fish/m²) in Pete King and Big Flat creeks and 0.43 fish/m² (±0.20 fish/m²) in Squaw and White Sands creeks over the entire study period (ANOVA, \( P = 0.0008 \); Figure 3). Densities declined through the summer, from 1.14 fish/m² (±0.42 fish/m²) 1 d after their release to 0.48 fish/m² (±0.38 fish/m²) 12 weeks after release in Pete King and Big Flat creeks and from 0.89 fish/m² (±1.32 fish/m²) to 0.22 fish/m² (±0.13 fish/m²) in Squaw and White Sands creeks, but the change was not statistically significant (\( P = 0.2685 \)) nor was the interaction between release strategy and date (\( P = 0.6455 \); Figure 4). The fewest hatchery parr were observed on days when the water temperatures at transect sites averaged around 10°C or cooler, towards the end of the study.

Some hatchery chinook salmon parr emigrated from Squaw and Pete King creeks soon after their
release in 1994, predominately at night. In Squaw Creek, hatchery parr were collected during the first, second, and third nights after release. By the fourth night, movement out of Squaw Creek had dropped to near zero. In all, 277 hatchery parr were collected over the 5-d trapping period, or 2.3% of the hatchery fish released into the stream. Hatchery parr were collected in the trap at Pete King Creek on the second and third nights after release, but their movement had ceased by the forth night. In all, 72 hatchery parr were collected in the Pete King Creek trap over the 5-d trapping period, or 0.6% of the fish released into the stream. A rainstorm increased streamflow during the trapping period, allowing water to pass around one end of the weir in Pete King Creek at times.

Hatchery chinook salmon parr averaged 76.4 mm FL (±1.5 mm) and 5.0 g (±0.3 g) in weight when released into the four streams on 5 July. On 3–4 August, 29 and 30 d after release, the hatchery parr collected from Pete King Creek averaged 5.0 g (±0.3 g, N = 23), and those from Squaw Creek averaged 6.6 g (±0.9 g; N = 28; t-test, P = 0.0122). Water temperatures during this period averaged 12.5°C (SD = 0.2) in Squaw Creek and 16.9°C (SD = 0.2) in Pete King Creek. On 16 September, 71 and 72 d after their release, hatchery parr collected from Big Flat Creek averaged 4.0 g (±0.2 g; N = 41), while those collected from White Sands Creek averaged 5.7 g (±0.4 g; N = 39; t-test, P < 0.001). Water temperatures recorded at the time of the snorkel surveys averaged 11.3°C (SD = 2.7) in White Sands Creek and 12.0°C (SD = 1.4) in Big Flat Creek through September.

**Discussion**

Mean densities of the hatchery chinook salmon parr were lower when released at multiple sites. Reduced fish densities in the immediate release areas potentially improved the use of the rearing habitat by spreading the parr throughout streams.

Weights of hatchery chinook salmon parr re-
captured during the summer were higher in creeks where multiple release sites were used; however, the small number of fish recaptured makes drawing conclusions difficult. Growth rates were unrelated to temperature conditions in the four streams. Differences in size of recaptured fish would result if some fish lost weight or, possibly, if some of the larger fish left the streams in response to higher densities in Big Flat and Pete King creeks. Freshwater survival of juvenile salmon is thought to be density dependent (Ricker 1954; Bjornn 1978; Gee et al. 1978; Symons 1979), and the growth and survival of hatchery salmonids has been shown to be inversely related to stocking densities (Mortensen 1977; Egglishaw and Shackley 1980; Sekulich 1980; Hume and Parkinson 1987; Whalen and LaBar 1994; McMenemy 1995). We believe the summer growing conditions for the hatchery chinook salmon parr were improved by spreading the hatchery releases over multiple sites.

During a the 5-d period following release, 2.3% and 0.6% of the hatchery parr were collected near the mouths of Squaw and Pete King creeks. The value for Pete King Creek may be an underestimate of the initial emigration because a gap in the temporary weir may have allowed fish to bypass the trap. In either case, it appears that no more than 2.3% of the hatchery fish left the study streams soon after release. The 1-d difference in appearance of hatchery parr at the downstream traps in Squaw and Pete King creeks in 1994 was probably due to the difference in the distance the parr had to travel from the release sites in the two streams. The release site in Pete King Creek was 4 km upstream from the trap, while the furthest downstream release site in Squaw Creek was 2 km from the trap.

Hatchery parr that remained in the study streams during summer were found in highest densities within 1.5 km downstream of the release sites, even when multiple release sites were used. Richards and Cernera (1989) also observed that hatchery chinook salmon stocked into the Yankee Fork of the Salmon River, Idaho, remained concentrated within 2 km of the release sites, and other researchers have reported the tendency for hatchery salmonids to remain concentrated near stocking areas (Horner 1978; Egglishaw and Shackley...
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1980; Cresswell 1981; Wentworth and LaBar 1984; Hume and Parkinson 1987; Seelbach 1987). Minimum dispersal from the point of origin may not be a unique behavior of hatchery fish. Richards and Cernera (1989) reported that peak concentrations of natural age-0 chinook salmon were found in the Yankee Fork of the Salmon River in areas associated with the highest densities of redds constructed the previous fall. However, Sekulich (1980) observed that hatchery chinook salmon tended to remain longer at release sites than transplanted natural chinook salmon when both were released into an Idaho stream.

When dispersion did occur, it was downstream, rather than upstream. However, in three of the four streams, upstream movement appeared to be blocked by barriers that physically inhibited ascent of the small fish. In White Sands Creek, the location of the furthest upstream release site was unknown, so the extent of upstream dispersal by fish could not be determined.

After the initial pulse of emigration, hatchery parr densities in the four study streams remained relatively stable, with abundance declining only gradually through the summer. The decline in fish densities through summer may have been caused by fish spreading to stream areas between transect sites, emigration, mortality, and predation. Predation by resident fish is thought to have a significant effect on survival of hatchery salmonids (McCrimmon 1954; Mills 1969; Horner 1978; Kennedy and Strange 1986; Beamish et al. 1992). During several of the snorkel surveys we observed trout chasing and, in one case, catching hatchery salmon. This was most often observed in the larger pools in Squaw Creek where groups of hatchery parr were in close proximity to larger rainbow trout, steelhead, cutthroat trout, and bull trout. Fish densities were lowest during fall (September and October) when daytime water temperatures were near or below 10°C. At low water temperatures, juvenile salmonids seek refuge within the bottom substrate (Chapman and Bjornn 1969; Bjornn 1971; Cunjak 1988; Taylor 1988) and this cover-seeking behavior may have made it appear that densities had dropped, when in fact the fish were still present in the streams. A special effort was made to search for fish concealed among the cobble and boulder substrate during the fall snorkel surveys, but few additional fish were found. It is also possible that the decline in fish densities in the fall resulted from fish emigrating from the study streams into the larger river downstream in search of more hospitable overwintering habitat.

This fall out-migration may have been triggered by declining water temperatures or by the shortening of the photoperiod (Bjornn 1971).

Natural chinook salmon were observed at only one site during the study. In fall 1993, a redd was made by a female chinook salmon within the first snorkel site just upstream from the mouth of Big Flat Creek. On 3 July 1994 (before the hatchery releases) several hundred chinook salmon fry (1.87 fish/m²) were observed at this site, but no natural fry were observed at either upstream or downstream locations. The natural chinook salmon fry were found mainly at the stream margins near undercut banks and instream brush habitat. Those natural fry closer to midstream remained near the bottom cobble and gravel substrate. One week later, the density of natural fish at this site had decreased to 1.03 fish/m². Through July and August, the density of the natural fry declined gradually to 0.81 fish/m²; and by 2 October, the density was 0.5 fish/m². From the limited observations made on the natural chinook salmon at this one site, it appeared that dispersal of natural chinook salmon from the point of emergence may follow a similar pattern as observed for hatchery parr from a single-point release.

In general, the dispersal of hatchery chinook salmon parr following their release into the four study streams occurred in three stages. The first stage was an initial pulse of hatchery parr that moved downstream and out of the study streams soon after release. The hatchery parr that did not disperse only a short distance (1.5 km or less) downstream from release sites, where they remained through summer. Densities of hatchery fish in the study streams declined slowly through summer as the fish either dispersed further throughout the streams, emigrated, or died from natural causes. The third stage was characterized by lower fish densities caused by movement from the study streams during fall or by cover-seeking behavior by the small fish as water temperatures cooled. During a supplementation program, stocking strategies can have the greatest influence on the first and second stage of the hatchery fish dispersal pattern. Most of the small parr (5.0 g in this study) we released remained within the target streams, which reduced any potential impacts the hatchery fish may have had at downstream locations. Spreading the hatchery fish through the target stream by using multiple release sites should improve summer rearing conditions for the hatchery fish and reduce the potential harmful effects to natural fish near release areas. Based on our
observation, a distance of at least 1.5–2 km between release areas would produce the best distribution of fish in release streams.

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