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# A Comparison of Trap Efficiencies for Wild and Hatchery Age-0 Chinook Salmon

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*Abstract.*—Trap efficiencies for captured wild and hatchery age-0 chinook salmon *Oncorhynchus tshawytscha* migrating from the South Umpqua River, Oregon, were compared at three trap positions within a pool, where water velocities were relatively high, medium, or low, to determine if differences existed in the capture rates of these two groups of fish. Mean trap efficiencies for wild chinook salmon ranged from 23 to 27% and did not differ significantly among the three trap positions. In contrast, trap efficiencies for hatchery fish ranged from 1 to 26%, and these fish were captured at significantly lower rates when the trap was positioned in areas of lower-velocity water. Trap efficiencies were similar for wild and hatchery fish when the trap was in high-velocity water but differed significantly when the trap was in slow water. Our observations indicated that differences in the behavior of wild and hatchery fish accounted for the differing capture efficiencies. These findings suggest that trap efficiencies should be estimated independently for wild and hatchery fish until it is empirically demonstrated that the respective efficiencies are similar.

Estimates of trap efficiency are often used in the estimation of migratory salmon smolt populations (Seelbach et al. 1985; Dambacher 1991; Zafft 1992). Because different species exhibit different migratory behavior (Groot and Margolis 1991), estimates of trap efficiency generally vary between species (Seelbach et al. 1985) and among fish sizes within a species (Dambacher 1991). Ricker (1975) suggested that similar capture rates among species are unlikely, and he also stated that capture rates of hatchery fish should not be used as an estimate of wild fish capture rates.

Nevertheless, because many stocks of salmonids are currently threatened or in decline (Nehlsen et al. 1991), the possibility of using a surrogate species (Ward et al. 1990) or hatchery-reared fish of the same species (Leider et al. 1986) to estimate trap efficiency for a diminished stock can seem attractive. In this context, we evaluated trap efficiencies for wild and hatchery age-0 chinook salmon *Oncorhynchus tshawytscha*. Our objectives were to determine if capture efficiencies were similar for the two groups and if they were not similar, to detect reasons for the difference.

## Methods

A rotary smolt trap (constructed by EG Solutions, Eugene, Oregon) was used to capture migrating wild and hatchery age-0 chinook salmon as they left the South Umpqua River, Oregon. The trap was 10 km above Tiller and approximately 300 river kilometers from the Pacific Ocean. The upstream orifice of the rotating drum was 2.43 m in diameter, and slightly less than one-half the opening was submerged to capture migrating smolts. Water entering this rotary trap deflected off helical structures within the drum, forcing the drum to rotate; thus the drum rotated faster in higher-velocity water than in lower-velocity water. The helical structures within the drum also made it impossible for the fish to escape entrapment if they remained within the drum for more than half a rotation. All captured fish were retained in a livewell, 1.2 m long × 0.9 m wide × 0.4 m deep, at the back of the trap.

The trap was deployed in a pool immediately downstream from a higher-gradient riffle. A cable system held the trap within the current and allowed it to be moved (from shore) most places within the pool. Trap efficiencies were determined at three positions: (1) head—at the head of the pool where current was strongest and the rotary drum turned an average of 3.05 rotations/min; (2) middle—5 m back from the head of the pool where the drum turned an average of 2.37 rotations/min, and (3) foot—10 m back from the head of the pool where velocities were the lowest and drum speed averaged 1.40 rotations/min. The trap was in the thalweg at all three positions.

The sequence of trap positions (head, middle, or foot) was randomly determined with the constraint that the trap be fished 1 d at all three positions within a 3 d period. We conducted trials for 9 d, so the trap was operated at all three positions three times.

On May 29, 1992, approximately 90,000 adipose-clipped, hatchery-reared, age-0 chinook salm-

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TABLE 1.—Estimated trap efficiencies for wild and hatchery age-0 chinook salmon. Ratios in parentheses are the number of marked fish recaptured/number of marked fish in the group; CI is confidence interval.

| Trap position in pool (recapture date) | Wild fish trap eficiency | | Hatchery fish trap efficiency | |
|---|---|---|---|---|
| | Estimate | 95% CI | Estimate | 95% CI |
| Foot (May 31) | 20% (6/30) | 5–33% | 1% (2/310) | ≈0–2% |
| Middle (Jun 2) | 25% (4/16) | 2–44% | 5% (13/274) | 2–7% |
| Head (Jun 1) | 33% (12/36) | 17–48% | 29% (71/242) | 23–35% |
| Foot (Jun 3) | 26% (7/27) | 8–41% | 1% (2/228) | ≈0–2% |
| Middle (Jun 4) | 21% (3/14) | ≈0–41% | 6% (4/67) | ≈0–12% |
| Head (Jun 5) | 13% (2/16) | ≈0–28% | 22% (38/174) | 16–28% |
| Foot (Jun 8) | [a] | | 8% (6/73) | 2–14% |
| Middle (Jun 7) | [a] | | 12% (20/165) | 7–17% |
| Head (Jun 6) | [a] | | 37% (66/179) | 29–46% |
| | | **Weighted averages**[b] | | |
| Foot | 23% (13/57) | 11–33% | 1% (4/538) | ≈0–2% |
| Middle[c] | 23% (7/30) | 7–38% | 5% (17/341) | 3–7% |
| Head | 27% (14/52) | 14–38% | 26% (109/416) | 22–30% |

[a] Insufficient data; fewer than two marked fish recaptured.
[b] Weighted averages apply only to dates for which sufficient data are available for both wild and hatchery fish (May 31–Jun 5).
[c] Trap efficiencies differed significantly (binomial test, $P < 0.05$) between wild and hatchery fish at the middle location. The apparent overlap in confidence intervals is due to rounding errors.

on (parent stock: North Umpqua River) were released 25 km upstream of the trap site. This group of fish was used in the estimation of trap efficiencies for hatchery fish. Wild fish trap efficiencies were determined for age-0 chinook salmon captured during their natural migrations.

Beginning May 30, the day after hatchery-reared fish were released, fish captured in the smolt trap were sorted by hatchery or wild origin, measured for fork length, and given a day-specific caudal fin mark (dorsal or ventral clips or notches). Processing of fish began at 0800 hours each day. After they were processed, marked fish were transported 400 m upstream and placed in a pen where they were held until 1300 hours, at which time all fish were released. While fish were held in the pen, the trap was moved to the position it was to be fished during the next 24 h. Only caudally unmarked fish trapped during the previous 19 h were marked for the next trial. Previously marked and recaptured fish were released below the trap.

Trap efficiencies were estimated independently for hatchery and wild fish as the ratio of marked fish recaptured at a specific trap position to the total number of marked hatchery or wild fish released the previous afternoon. Because trap efficiency could be affected by trap position, only fish captured during the 19 h after release (1300–0800 hours) were used to determine capture efficiency for that trap position. More than 95% of all recaptures (97.1% for wild fish and 96.4% for hatchery fish) occurred during the first 19 h, so estimates of trap efficiencies were probably not affected by fish that failed to migrate immediately. Confidence intervals for trap efficiencies were calculated directly from the binomial distribution (Dowdy and Wearden 1983).

We then tested two hypotheses: (1) trap efficiencies did not differ significantly among trap positions for either hatchery or wild fish; (2) trap efficiencies did not differ significantly between hatchery and wild fish at any trap position. Statistical comparisons among positions and between hatchery and wild fish were based on the binomial distribution (Dowdy and Wearden 1983).

Because any differences in trap efficiency were likely the result of differences in the two groups' migration behavior (Ricker 1975), we examined timing of fish movement and fish size to see if these factors were influential. Diel movement patterns were examined by comparing the numbers of marked and unmarked fish within the live-well in the evening (2000 hours) with those in the live-well the following morning (0800 hours). Numbers of fish in the live-well, by origin, were estimated visually (mean value of six or seven counts) each evening by a swimmer wearing a mask and snorkel. Live-well counts were augmented by daytime underwater observation of fish behavior. Sizes of fish measured each morning were compared with Student's $t$-tests.

## Results

Trap efficiencies estimated for wild fish were similar among all three trap positions (Table 1). In contrast, efficiencies for hatchery fish differed significantly ($P \leq 0.05$) between trap positions, being higher at the middle position than at the foot position and much higher at head position (where water velocity was greatest) than at the other two.

Mean trap efficiencies differed between wild and hatchery fish ($P \leq 0.05$) at the middle and foot positions but not at the head position (Table 1). At the foot position, mean trap efficiency was 20 times greater for wild fish than for hatchery fish.

Evening checks of the trap's live-well revealed few wild chinook salmon (marked or unmarked) but many hatchery fish (marked and unmarked). In most instances (eight of nine trials) the estimated number of marked hatchery fish within the trap at 2000 hours was at least 75% of the total number of marked hatchery fish counted within the trap the next morning. In contrast, evening live-well checks revealed only two marked and four unmarked wild fish during the 9 d study. These observations suggest that hatchery fish moved downstream during daylight hours whereas wild fish moved mainly at night.

Underwater observations at the mouth of the rotary trap during daylight (1300–2000 hours) indicated that hatchery fish commonly avoided the trap in areas of low and medium water velocity. Hatchery fish exited the upstream riffle with their heads facing the current. When the trap was positioned at the head of the pool, these fish were captured while they were still oriented upstream. When the trap was set in the middle or the foot of the pool, out of the turbulent flow, the fish had reversed their orientation and begun to actively swim downstream before they encountered the trap. It was in their downstream orientation that hatchery fish were observed avoiding the trap.

Wild fish were not seen in their approaches to the trap. Most of them migrated at night, and consistent trap efficiencies for wild fish suggest that trap avoidance by wild fish is not a problem at low light levels.

Hatchery fish averaged 78.7 mm ($N$ = 1,551) in fork length whereas wild-reared fish averaged 66.6 mm ($N$ = 163), a significant difference ($P < 0.05$). Their size advantage might have made hatchery fish better able than wild fish to avoid capture regardless of migration timing.

## Discussion

Hatchery age-0 chinook salmon in the South Umpqua River were captured far less efficiently than wild salmon at some trap locations within a pool. If trap efficiencies for hatchery fish in low or medium velocity waters had been applied to wild fish, efficiencies for wild fish would have been greatly underestimated. The differences in the trap efficiency between hatchery and wild fish were probably related to diel migration timing and water velocity, and possibly to fish size.

Because hatchery fish migrated during daylight hours when few wild fish did, one assumption implicit to estimation and application of trap efficiencies was violated: that both groups have similar behavior (Ricker 1975). Cramer et al. (1992) also found that time of day influenced capture rates of age-0 hatchery chinook salmon, which varied from 1.6% when marked fish were released during the day to 26% when they were released during the night. In contrast, trap efficiencies for wild age-0 chinook salmon, which migrate primarily at night (Hartman et al. 1982; McMenemy and Kynard 1988; Zafft 1992), will probably not be affected by release time. Cramer et al. (1992) suggested that marked fish be released at dusk. This practice, however, could lead to overestimates of relevant efficiency if some unmarked fish migrate during the day, when trap efficiencies may be lower.

In our trials, trap efficiencies for wild and hatchery fish were similar only where water velocity was so high that fish migrating during the day were unable to avoid capture. A water velocity sufficiently greater to prevent fish from avoiding capture likely varies both among and within salmonid species (Seelbach et al. 1985; Dambacher 1991). Trap positions that minimize avoidance behavior should be determined for each species at each trapping location. If a trap cannot be positioned in strong current, trap efficiencies should be independently estimated for hatchery and wild fish—at least until their similarity is determined empirically. When trap efficiencies of wild and hatchery fish must be estimated collectively (e.g., when hatchery fish are unmarked) traps placed in slow currents may give misleading results.

Our study was limited in scope, but our results indicate that care must be taken if trap efficiencies generated with hatchery fish are to be applied to wild fish. We suggest that until there is site-specific evidence that indicates wild and hatchery fish have similar trap efficiencies, estimates of trap efficiency for these two groups should be calculated independently.

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