

The Effect of 1.5-Length and Double-Length Coded Wire Tags on Coho Salmon Survival, Growth, Homing, and Electronic Detection

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Abstract.—We compared 1.6-mm and 2.2-mm coded wire tags (CWTs) of a new composite to the original 1.1-mm CWTs by examining (1) tag detectability, (2) rates of adult returns, and (3) growth in coho salmon *Oncorhynchus kisutch*. We found that coho salmon tagged with the larger CWTs returned in numbers similar to salmon with the smaller CWTs. The sizes of returning adults and rates of successful homing were not different between fish with the new and old tags. Based on CWT recoveries, we estimate that of the adults returning, 99.98% successfully returned to their hatchery of release. Samplers using wands and R9500 tunnel detectors recovered 99.93% and 100% of the tags, respectively. Tag length and wire composition had little bearing on electronic detection; however, coho salmon adults in our study returned at relatively small sizes (mean fork length, <50 cm). Other studies with larger salmonids have shown lower electronic detection rates. Study results suggest that larger CWTs will not compromise coho salmon survival, growth, or homing, provided the fish have a snout target area of sufficient size to accommodate the CWT.

In 1990, Johnson reported that the coded wire tag (CWT; as described in Jefferts et al. 1963), in conjunction with the visually detectable adipose fin mark, was the most widely used stock identification technique for *Oncorhynchus* spp. on the west coast of North America. However, by 1995 there were competing uses for the adipose fin mark. The Washington State legislature mandated (Revised Code of Washington 75.08.510) that all hatchery coho salmon *Oncorhynchus kisutch* be visually identified for the purpose of selective fisheries (i.e., fisheries that could target just the hatchery fish with limited bycatch of other stocks). Furthermore, the National Marine Fisheries Service was requiring hatchery fish to be marked as a means of differentiating wild fish from hatchery fish due to listings under the Endangered Species Act (Weitkamp et al. 1995)

Some scientists feared the coastwide CWT database maintained by the Pacific States Marine Fisheries Commission (PSMFC; Johnson 1990) would be compromised by large releases of adipose-clipped coho salmon not carrying CWTs. The most reasonable solution was to determine whether CWTs could be recovered exclusively through the use of electronic detection equipment that detects the magnetic field of a CWT. If CWTs could be effectively detected electronically, then adipose fin

clips could be used alternatively for the purpose of selective fisheries.

In the late 1980s, Northwest Marine Technology (NMT) developed a handheld electronic CWT detector, or wand (Figure 1), for field sampling of CWTs. This wand was capable of detecting, at a distance of 2.0 cm, a 1.1-mm CWT cut from the wire used at that time (hereafter “original wire”). Northwest Marine Technology believed that electronic detection distances could be enhanced by increasing tag length and by modifying the existing wire composition to increase magnetic moment (hereafter, “improved wire”). After developing the improved wire, trials conducted by NMT showed that the wand detection distance for a 1.6-mm CWT was increased to 3.0 cm and a 2.2-mm tag was increased to 4.1 cm (P. Ekstrom, Northwest Marine Technology, personal communication).

There is evidence in the fisheries literature that Pacific salmon use both magnetic (Quinn and Groot 1983) and olfactory cues (Dittman and Quinn 1996; Dittman et al. 1996) for imprinting and homing. The suggestion to change the magnetic properties of CWT wire raised concerns that coho salmon might survive at lower rates and that adults would be more likely to stray. A larger CWT might also increase the likelihood of olfactory nerve damage (Morrison and Zajac 1987) that might lead to increased straying. The two objectives of our research were to (1) determine whether longer CWTs cut from the improved wire reduced survival, growth, or homing of hatchery coho

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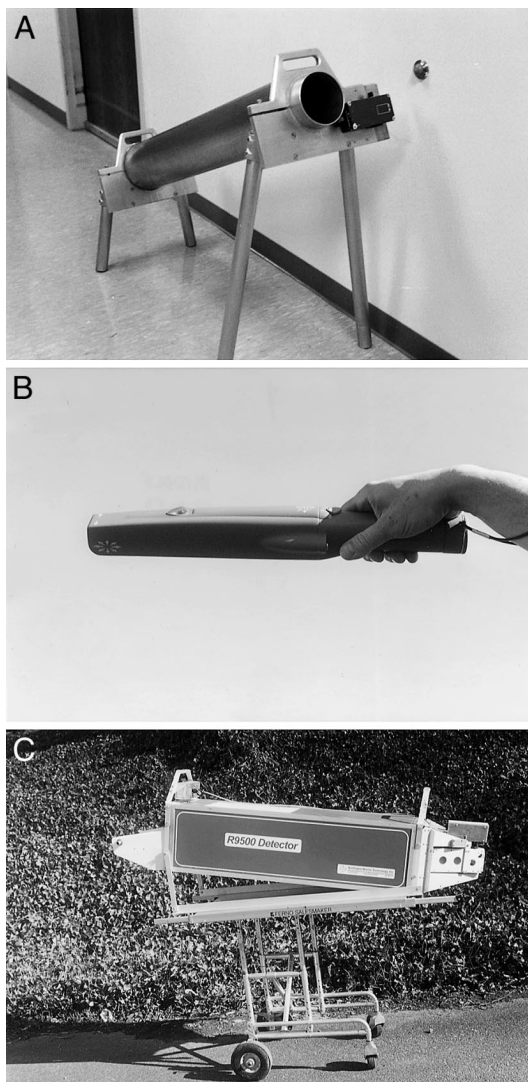


FIGURE 1.—Electronic coded wire tag detection equipment evaluated during this study. The top photograph shows the omnidirectional detector (15 cm in inside-tube diameter $\times$ 100 cm long), the middle photograph shows the wand (42 cm long $\times$ 7 cm in diameter), and the bottom photograph shows the R9500 detector (39 cm wide $\times$ 30 cm high $\times$ 105 cm long, with inside-tunnel dimensions 10 cm $\times$ 20 cm).

salmon compared with fish tagged with 1.1-mm CWTs cut from original wire; and (2) evaluate changes made to improve CWT detection in returning adults.

Methods

Coho salmon in this study were released from two Washington Department of Fish and Wildlife

(WDFW) hatcheries located on river systems that flow into Puget Sound, Washington. George Adams Hatchery is located on Purdy Creek, a tributary to the Skokomish River that is 8 km upriver from the Skokomish River mouth, which is at the southern end of Hood Canal. Voights Creek Hatchery is located on a tributary to the Puyallup River, 29.9 km upriver from the Puyallup River mouth at Tacoma, Washington. Adult coho salmon have historically returned to both facilities as age-3 fish from September through November. Returning fish are captured using weirs, and eggs are collected and fertilized to propagate each stock.

Evaluating 1.1-mm and 2.2-mm CWTs.—A study to compare the relative survival and growth of coho salmon tagged with 1.1-mm versus 2.2-mm CWTs was conducted using the 1992 brood year at George Adams Hatchery. The two groups were tagged following standard WDFW tagging procedures (Schurman and Thompson 1990). Study fish were 12 months old and averaged 11.5 cm in fork length at tagging during March 1994. One group of 45,100 coho salmon was given an adipose fin clip and tagged in the snout with a 1.1-mm original CWT. The other group of 44,700 fish was given the same clip and tagged with a 2.2-mm improved CWT. Groups were tagged simultaneously from the same raceway to ensure random group assignment but were given a unique tag code. Random samples of approximately 2,000 fish from each group were held in separate pens for 21 d to estimate tag loss. After tagging, both groups were held in the same raceway until July 1994 when they were released at a mean length of 17.1 cm.

Evaluating 1.1-mm and 1.6-mm CWTs.—A study to compare the relative survival and growth of coho salmon tagged with 1.1- and 1.6-mm CWTs was conducted using the 1993 brood year at Voights Creek Hatchery. At the time of tagging (February 1995) the 11-month-old coho salmon averaged 9.6 cm. A total of 20,600 fish were injected in the snout with 1.1-mm original CWTs. The second group of 20,400 was tagged with 1.6-mm improved CWTs. Groups were tagged simultaneously from the same raceway to ensure random group assignment. Neither group was adipose-fin-clipped, but both groups were given unique tag codes. Because we planned to evaluate the performance of CWT detectors when adults returned, we did not want a missing adipose fin clip to influence sampler behavior (i.e., wand samplers might spend more time searching for a CWT in an adipose-clipped salmon compared with an un-

clipped fish). After being held in the same raceway, study groups were released during May 1995 at a mean length of 12.3 cm.

Detecting CWTs in returning adults.—Adults lacking adipose fins that returned to the George Adams Hatchery in autumn 1995 were measured (cm) and sampled for a CWT with a wand. When the wand failed to detect a CWT, the fish's snout was removed and passed through an NMT omnidirectional CWT detector (Figure 1). Before field use, we tested the accuracy of the omnidirectional detector by sampling 200 snouts of adipose-clipped adult salmon, of which an unknown proportion contained CWTs. These snouts were later X-rayed and results were compared. These evaluations showed that the omnidirectional detector found all of the CWTs during both 1995 and 1996. It follows that when a CWT was not detected with the omnidirectional detector, we assumed the snout contained no CWT. After electronic sampling, snouts were removed and placed in numbered plastic bags. The result of the electronic sampling for each fish (i.e., CWT detected by the wand or omnidirectional detector) was recorded on the individual snout label. Snouts were sent to the WDFW Coded Wire Tag Recovery Laboratory in Olympia, Washington, where the tags were excised, decoded, and recorded in the PSMFC database.

About half of the coho salmon returning to Voights Creek Hatchery in 1996 were screened for CWTs with a wand; the other half were passed through an R9500 rectangular detector (Figure 1). The R9500 is used to scan whole salmon for CWTs and was designed for rapid sampling of large numbers of adults at commercial plants and hatchery racks. Snouts of adipose-clipped coho salmon that tested negative for a CWT with either the wand or the R9500 were removed and passed through the omnidirectional detector. Electronic sampling results were recorded for each individual snout label.

By recording the results of electronic sampling for individual fish, we were able to calculate the rate of successful detection by CWT length and detector type. For each comparative study, we used chi-square tests of homogeneity in 2×2 contingency tables to test the null hypothesis ($\alpha = 0.05$) that successful tag detection rates for each detector did not vary between the two CWT lengths.

In both evaluations, we used chi-square tests, the null hypothesis being that adults returned in proportion to the number released as juveniles. Using a *t*-test, we tested the null hypothesis that coho salmon tagged with 1.1-mm CWTs returned

TABLE 1.—Number (proportion in parentheses) of marked juvenile coho salmon released in 1994, number of coded wire tags (CWTs) recovered, and mean length of marked adults returning to George Adams Hatchery in 1995. One group of fish was tagged with 1.1-mm original-wire CWTs, the other group with 2.2-mm improved-wire CWTs.

CWT length (mm)	Number with CWTs		Mean length ± SD (cm)
	Released	Recovered	
1.1	45,100 (0.497)	937 (0.511)	47.8 ± 4.6
2.2	44,700 (0.503)	898 (0.489)	47.8 ± 4.9

at the same mean size as fish tagged with longer CWTs.

We queried the PSMFC database for CWTs to compare levels of straying for the two George Adams Hatchery study groups. This database includes information on hatchery rack and stream survey CWT recoveries from Washington, Oregon, and British Columbia. Because the Voights Creek Hatchery coho salmon were released without adipose clips, they were not collected by other CWT samplers.

Placement of CWTs.—Before tag excision, samples of 113 snouts containing CWTs from George Adams Hatchery were X-rayed (both dorsoventrally and laterally) to score tag placement. Tag placement was scored as good if the CWT was positioned entirely in a fish's tag target area (as defined by NMT 1990), and bad if not entirely inside the target area. This target area is located on the axis of the snout, anterior to the eye, and is composed of muscle, cartilage, adipose, and fibrous tissue underlying the dermis. One biologist, provided with a schematic and a definition of the tag implantation site, scored all X-rays. Using a 2×2 contingency table, we tested the null hypothesis that the number of snouts classified with good and bad CWT placement did not vary significantly between coho salmon tagged with 1.1- and 2.2-mm CWTs.

Results

Comparison of 1.1-mm versus 2.2-mm CWTs

A total of 937 coho salmon with 1.1-mm and 898 with 2.2-mm CWTs were recovered from returns to the George Adams Hatchery during autumn 1995 (Table 1). The observed returns between the two groups did not significantly differ ($\chi^2 = 1.47$, $df = 1$, $P = 0.22$) from expected returns adjusted for numbers released. The mean size of returning adults tagged with 1.1-mm (47.8 ± 4.6 cm [$\pm$ SD]) and 2.2-mm CWTs (47.8 ± 4.9

TABLE 2.—Number (proportion in parentheses) of marked juvenile coho salmon released in 1995, number of coded wire tags (CWTs) recovered, and mean length of marked adults returning to Voights Creek Hatchery in 1996. One group of fish was tagged with 1.1-mm original-wire CWTs, the other group with 1.6-mm improved-wire CWTs.

CWT length (mm)	Number with CWTs		Mean length ± SD (cm)
	Stocked	Recovered	
1.1	20,400 (0.502)	853 (0.504)	45.9 ± 5.0
1.6	20,200 (0.498)	839 (0.496)	45.7 ± 4.8

cm) did not differ significantly ($t = -0.04$, $N = 1,831$, $P = 0.48$).

The search of the PSMFC coastwide CWT database yielded recovery of one 2.2-mm CWT at Hood Canal Hatchery. The Hood Canal Hatchery is located 6 km north of the George Adams Hatchery on the same side of Hood Canal inlet. The trap at Hood Canal Hatchery is an “zero-return” trap, meaning the trap is inundated with seawater at high tide, but at low tide the trap prevents movement of fish back to Hood Canal.

Comparison of 1.1-mm versus 1.6-mm CWTs

During the autumn of 1996, 853 coho salmon with 1.1-mm and 839 with 1.6-mm CWTs were recovered at the Voights Creek Hatchery (Table 2). The number of observed returns for each tag group did not differ significantly ($\chi^2 = 0.02$, $df = 1$, $P = 0.88$) from expected returns. The mean size of adults tagged with 1.1-mm CWTs (45.9 ± 5.0 cm) did not significantly differ ($t = -0.76$, $N = 1,688$, $P = 0.22$) from the mean size of fish tagged with 1.6-mm CWTs (45.7 ± 4.8 cm).

Detection of CWTs in Adult Returns

A total of 1,835 CWTs were recovered by electronic sampling at George Adams Hatchery (Table 3). The wand detected 99.89% of the 1.1-mm CWTs and 100% of the 2.2-mm CWTs. Only one additional 1.1-mm CWT was recovered using the omnidirectional detector. The proportions of CWTs successfully detected using the wand did not significantly differ ($P > 0.99$) between 1.1- and 2.2-mm CWTs.

A total of 1,688 CWTs were recovered using electronic detectors at Voights Creek Hatchery (Table 2). The wand successfully detected 439 (99.77%) of the 1.1-mm CWTs and 440 (100%) of the 1.6-mm CWTs. The R9500 rectangular detector detected all the 1.1- and 1.6-mm CWTs. Differences in successful tag recovery rates of the two

TABLE 3.—Electronic detection of coded wire tags (CWTs) in coho salmon at George Adams and Voight Creek hatcheries by the wand and R9500 tag detectors (see Figure 1).

CWT length (mm)	Wand		R9500	
	CWT detected	CWT missed	CWT detected	CWT missed
George Adams Hatchery, 1995				
1.1	936	1		
2.2	898	0		
Voight Creek Hatchery, 1996				
1.1	439	1	412	0
1.6	426	0	410	0

tag lengths did not significantly differ ($P > 0.99$) between detectors.

Placement of CWTs

The X-rayed snouts from adults returning to George Adams Hatchery (Table 4) showed good tag placement in 92% of the 1.1-mm CWT group ($N = 63$) and 94% of the 2.2-mm CWT group ($N = 50$). These differences were not statistically significant ($P > 0.95$), suggesting that coho salmon at a mean length of 11.7 cm at the time of tagging have a CWT target area of sufficient size to accommodate a 2.2-mm CWT.

Discussion

This study demonstrates that the handheld wand and R9500 tunnel detector can reliably detect CWTs in coho salmon. Therefore, we believe that adipose fin removal is not a prerequisite for CWT recovery in *Oncorhynchus* spp. of a size similar to those used in our study (mean length, 47.8 cm; range, 30–75 cm).

Although electronic detection of CWTs was successful, it is important to note that the adults returning to both Voights Creek and George Adams hatcheries were smaller (<50 cm mean length) than adults from other coho salmon stocks. Vander Haegen et al. (2002) showed a bias towards wand

TABLE 4.—Number (proportion in parentheses) of 1.1-mm and 2.2-mm coded wire tags (CWTs) placed in snouts of coho salmon at George Adams Hatchery. Using X-rays, tag placement was scored as good if the CWT was found entirely inside the tag target area and bad if any portion of the CWT was outside the target area.

CWT length (mm)	Tag placement	
	Good	Bad
1.1	58 (0.92)	5 (0.08)
2.2	47 (0.94)	3 (0.06)

nondetection of CWTs in larger chinook salmon *O. tshawytscha* and coho salmon. Vander Haegen reported detection rates of 95.5% (1.6-mm CWTs) for coho salmon having a mean length of 63.7 cm and 90.6% (1.1-mm CWTs) for chinook salmon averaging 77.8 cm. Managers concerned with high CWT detection rates in larger coho salmon, chinook salmon, and steelhead trout *O. mykiss* should consider implanting 1.6- or 2.2-mm CWTs because larger tags can be detected at greater distances with the wand than can 1.1-mm CWTs.

Although several researchers have reported using wands to recover CWTs (Bonar et al. 1997; Hale and Gray 1998; Isely and Tomasso 1998; Schram et al. 1999), this is one of the first studies documenting their effectiveness. Failure to detect tagged specimens when sampling animals for tags can lead to biased estimates of population size (Ricker 1975) and survival (Brownie et al. 1985). In our study, the wand detector successfully detected 99.93% of the CWTs in adult coho salmon snouts. These results suggest that the wand can be a robust CWT recovery tool for similar fisheries applications.

Our study also indicates that longer CWTs can be applied without impairing the survival, growth, and homing of coho salmon (relative to the effects of using the original-length tag). We encourage other salmon researchers to evaluate 1.6- and 2.2-mm CWTs in chinook salmon and steelhead trout of sufficient size.

The potential for a magnetized CWT to interfere with salmon homing has been a topic of debate among salmon researchers. Quinn and Groot (1983) used experimental tanks to show that most untagged fry of chum salmon *O. keta* aligned in a direction appropriate for seaward migration, and that insertion of standard-length CWTs into fry (mean length = 51 mm) had little effect on orientation preference. Habicht et al. (1998) evaluated the effects of 0.5-mm CWTs on straying rates in pink salmon *O. gorbuscha* from Prince William Sound, Alaska. They reported that in 1 of 2 brood years, adults that successfully homed had significantly fewer CWTs in critical areas (near olfactory organs and nerves) than did those that strayed.

Of 3,258 total CWT recoveries in our study, 99.98% were from adults that successfully homed. We also found that insertion of larger CWTs with greater magnetic moments did not cause increased straying. Hard and Heard (1999) reported that CWT recoveries from chinook salmon of Little Port Walter, Alaska, indicated little straying over a 9-year period. We conclude that coded wire tag-

ging does not appear to cause straying in salmon, provided the fish have a target area of sufficient size to accommodate the CWT.

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