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[Communication]

Comparing Two Methods Used to Mark Juvenile Chinook Salmon: Automated and Manual Marking

DAVID M. HAND,* WILLIAM R. BRIGNON, DOUGLAS E. OLSON, AND JESSE RIVERA
U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, 1211 Southeast Cardinal Court, Suite 100, Vancouver, Washington 98683, USA

Abstract.—Hatcheries in the U.S. Pacific Northwest are increasingly implementing programs that use an adipose fin clip and coded wire tag to mark a large number of juvenile salmonids *Oncorhynchus* spp. Traditionally, fin-clipping and tagging were done by hand, but the need to mass-mark large numbers of fish has led to the development of an automated tagging trailer system (Northwest Marine Technology, Inc.). We compared the adipose fin clip quality, coded wire tag retention, and injury rates of juvenile stream-type spring Chinook salmon *O. tshawytscha* marked and tagged at automated and manual tagging trailers at Warm Springs National Fish Hatchery (NFH) and Carson NFH, two hatcheries located in the Columbia River basin. Clip quality (99% good clips), tag retention (>98%), and injury rates (<7%) were similar between the two types of trailers at Carson NFH, where the manual markers had several years' experience clipping and tagging fish. At Warm Springs NFH, where the majority of manual markers had no previous experience, injury rates were similar (<14%) but the fish marked and tagged in the automated trailer had significantly higher clip quality (95% good clips) and tag retention (98%) than those marked and tagged in the manual trailer (70% good clips, 87% retention), where the clip quality and tag retention were poorest during the first day of tagging. Our results show that automated and manual trailers can perform similarly with regard to fin clip quality, tag retention rate, and injury rate when staffed by experienced markers. We recommend focusing efforts on training and quality control during the initial days of tagging and incorporating postmarking clip quality and coded wire tag retention sampling into all marking programs.

Marking and tagging fish populations is an important component of many fishery management and evaluation programs (Hilborn et al. 1990). Removal of fins, or fin clipping, has been used to mark groups of salmonids (Wertheimer et al. 2002), and before the 1970s was the standard marking method for fish stock identification (Johnson 2004). In the U.S. Pacific Northwest, coded wire tags (Elrod and Schneider 1986) have been used for over 30 years to mark Pacific salmon *Oncorhynchus* spp. and steelhead *O. mykiss* for fishery management and evaluation purposes (Zhou 2002). Currently, over 50 million juvenile salmonids with a coded wire tag are released on an annual basis along the Pacific coast (Johnson 2004). Traditionally, an adipose fin clip was used to externally mark salmon and steelhead tagged with a coded wire tag so that these fish were readily identifiable upon adult recapture (Johnson 2004). More recently, the use of the adipose fin clip has been expanded to allow for selective fisheries, where marked fish, typically of hatchery origin, are selectively harvested while unmarked fish are released (Zhou 2002). In 2003, the U.S. Congress mandated the mass-marking of all salmon and steelhead produced at federally funded or operated fish hatcheries (Consolidated Appropriations Resolution of 2003). Several states are also moving forward with comprehensive mass-marking programs (Johnson 2004). The mass-marking supports selective fisheries, which target harvest of hatchery fish while reducing harvest rates on naturally spawned populations of conservation concern. Mass-marking also assists with broodstock management and monitoring wild and hatchery fish (Olson et al. 2004).

Throughout the 1980s and 1990s, the majority of coded-wire-tagging and adipose fin-clipping of Pacific salmonids was accomplished by manually clipping the fin with a pair of scissors and inserting a coded wire tag using a tag injector. The need to mass-mark large numbers of fish led to the development of dedicated mobile units that could be transported to various locations to mark and tag fish efficiently (Schurman and Thompson 1990). These mobile units, or tagging trailers, were initially designed so that a crew of up to 10 markers could manually fin-clip and coded-wire-tag fish. A newer, automated tagging trailer, called the AutoFish SCT (Northwest Marine Technology, Inc.), has been developed that sorts the fish, clips the adipose fin, and inserts a coded wire tag automatically with minimal human handling and anesthetic (Hammer and Blankenship 2001). Both manual and automated tagging trailers are in use today.

Tag retention and fin clip quality are a critical component of most marking programs. Tag loss can affect final estimates of coded wire tag groups and needs to be accounted for as part of any evaluation (Blankenship 1990; Ando et al. 2004). Similarly, the

* Corresponding author: david_hand@fws.gov

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number of fish marked should be adjusted downward based on an estimation of adipose fin clip quality (Thompson and Blankenship 1997). Several studies have shown that the retention rate of coded wire tags in fish tagged manually can exceed 95% under ideal tagging circumstances (Ostergaard 1982; Elrod and Schneider 1986; Blankenship 1990; Hale and Gray 1998). Adipose fin clip quality of juvenile fish marked manually has not been as well documented. Peltz and Miller (1990) found that up to 8.2% of pink salmon *O. gorbuscha* fry did not receive a valid adipose clip when marked by hand, while Elrod and Schneider (1986) looked at four year-classes of adult lake trout *Salvelinus namaycush* and estimated between 0.2% and 6.8% of the fish did not receive an adipose clip during the initial manual marking process.

We are unaware of any peer-reviewed published literature looking directly at the fin clip quality or tag retention rates of fish marked and tagged using an automated trailer. Therefore, the objective of this study was to compare the coded wire tag retention rate and adipose fin clip quality of juvenile stream-type spring Chinook salmon *O. tshawytscha* marked and tagged in an automated trailer with fish marked and tagged in a manual trailer. In addition, concerns from hatchery personnel about potential external injuries to fish resulting from marking and tagging procedures (Mike Paiya, U.S. Fish and Wildlife Service, personal communication) led us to compare the injury rates of fish marked using automated and manual methods.

Methods

For this evaluation, juvenile spring Chinook salmon were fin-clipped and coded-wire-tagged at two fish hatcheries in the Columbia River basin, Warm Springs National Fish Hatchery (NFH) and Carson NFH. The primary purpose of both hatcheries is to produce spring Chinook salmon for harvest. At each hatchery, adult spring Chinook salmon are spawned in late August or early September, fertilized eggs are incubated until hatch-out in early January, and fish are then placed into hatchery raceways. Fish are reared in the raceways for up to 15 months before being released as downstream-migrating smolts. As part of each hatchery's standard monitoring and evaluation program, all fish are externally marked and a portion of each hatchery's release is coded-wire-tagged during the spring of their first year. We evaluated the fin-clipping and tagging at each hatchery using both manual and automated methods. A pair of marking and tagging trailers, one designed for manually marking and tagging fish and one AutoFish SCT automated trailer (Northwest Marine Technology, Inc., Shaw Island, Washington), were operated concurrently at each hatchery. A schematic of the fin-clipping, coded-wire-tagging, and sampling design is shown in Figure 1.

Warm Springs NFH.—At Warm Springs NFH, all production fish (up to 750,000 juveniles per year) are coded–wire-tagged and adipose-fin-clipped before release. For this study, brood year 2005 juvenile spring Chinook salmon were marked with fin clips and coded wire tags between May 4 and May 17, 2006. Approximately 25,000 juveniles were fin-clipped, tagged, and then placed into each of 20 raceways. Each raceway was assigned an individual coded wire tag code. Ten raceways contained fish that were clipped and tagged using a manual trailer and 10 raceways contained fish that were clipped and tagged using an automated trailer. The large number of fish that were fin-clipped and tagged at Warm Springs NFH also allowed us to look at the variation of fin clip quality and coded wire tag retention over time. The majority of people (markers) working in the manual trailer at Warm Spring NFH in 2006 had no previous experience fin-clipping and tagging fish. An experienced tagging trailer supervisor from the U.S. Fish and Wildlife Service's marking program provided the markers with an overview of the tagging and marking process and showed the markers how to fin-clip and coded-wire-tag fish before the tagging process began.

Carson NFH.—At Carson NFH, all spring Chinook salmon (approximately 1.1 million juveniles per year) are adipose-fin-clipped as part of normal hatchery production, but only 75,000 fish from each year's production receive a coded wire tag. For this evaluation, spring Chinook salmon juveniles from brood year 2007 were tagged and fin-clipped on April 25, 2008. Approximately 25,000 juveniles were marked and tagged using a manual trailer and 50,000 juveniles were marked and tagged using an automated trailer. Fish distributed to the manual trailer were collected from a different rearing pond than fish distributed to the automated trailer. Marking and tagging at Carson NFH followed the same procedures as at Warm Springs NFH. The manual markers at Carson NFH each had several years of previous experience fin-clipping fish, and the majority had several years experience applying coded wire tags to fish.

Fin-clipping and coded-wire-tagging process.—During the fin-clipping and tagging process, fish were netted out of holding raceways by experienced fish handlers and transferred to either the manual or automated trailer as needed. Once fish were transferred to the manual trailer, adipose-fin-clipping and tagging proceeded according to standard protocols described by Schurman and Thompson (1990). Experienced trailer supervisors prepared the trailers by selecting head

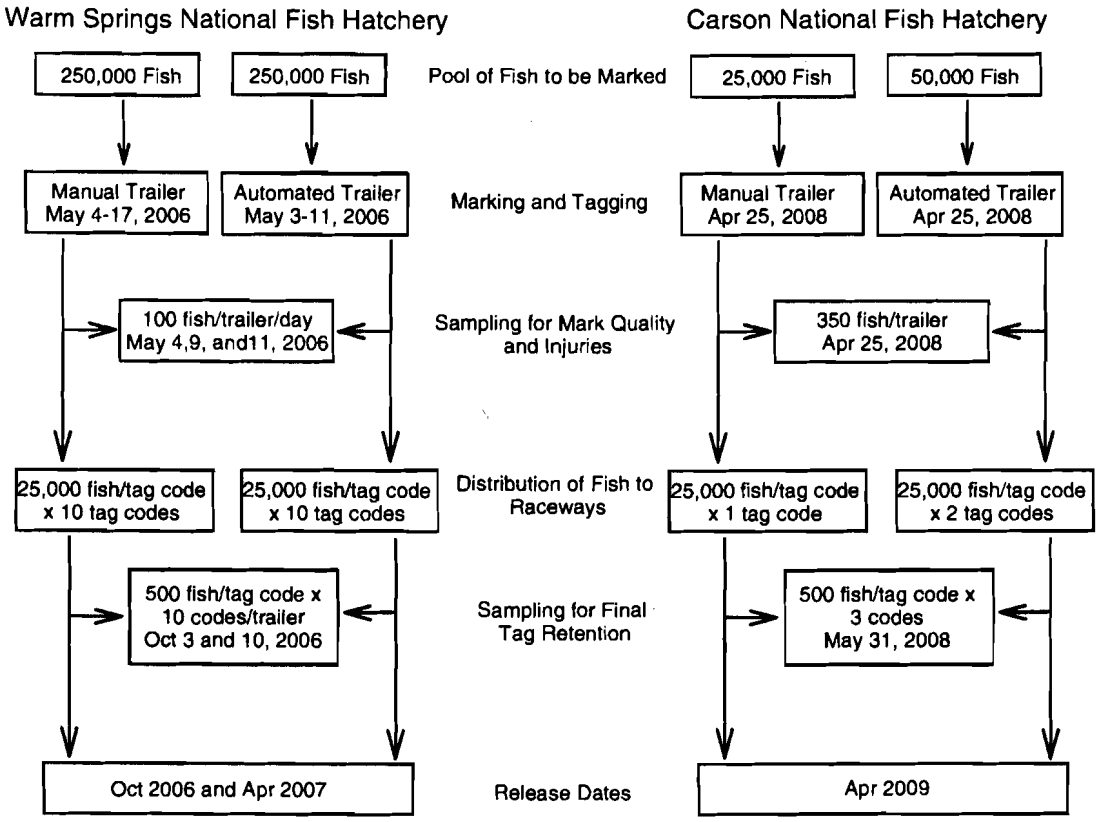

FIGURE 1.—Schematic of fin-clipping, coded-wire-tagging, and sampling design at Warm Springs and Carson National Fish Hatcheries.

molds for the coded wire tag injectors, ensuring that the tagging and clipping equipment was in good condition, and preparing the tagging and clipping stations for the marking crew. A crew of 8–10 markers then began the marking and tagging process. Each marker would anesthetize approximately 20–40 fish at a time in a tub containing approximately 105 mg/L of MS-222 (tricaine methanesulfonate) in water. Once the majority of fish lost equilibrium, the marker would then clip the adipose fin of each fish using a pair of scissors and insert a coded wire tag into the fish using a Mark IV tag injector (Northwest Marine Technology, Inc.). Fish were then passed through a quality control device (Northwest Marine Technology, Inc.) that verified the presence of a coded wire tag. Fish without a coded wire tag were shunted into a holding container where the marker could retag the fish. Fish with a coded wire tag were then sent via pipes to the hatchery raceways. No quality control device for fin clip quality was used in the manual trailers. Once tagging and marking began, the trailer supervisor periodically checked the tag retention and fin clip quality by sampling fish at the outflow pipe of the trailer. If tag retention was low or clip quality was poor, the supervisor would notify the markers and provide additional training as needed.

Experienced trailer supervisors also prepared the automated trailers for fin-clipping and tagging. Once the automated trailer was prepared, fish were transferred to it and placed into a holding tank located near the front of the trailer. From the holding tank, fish were pumped into a volitional entry sorter where a proprietary video-imaging device (Northwest Marine Technology, Inc.) measured their lengths and sent them to one of six processing lines. Each processing line was set up to coded-wire-tag and fin-clip a specific size range of fish. From each processing line, fish volitionally swam into a set of foam padded plates that held the fish in place while another video-imaging device verified the proper placement of the fish and an automated clipping device removed the adipose fin. While the fin was being clipped, a tag injector inserted a coded wire tag into the fish's snout. The video imager then verified that a majority of the adipose fin was clipped, and a quality control device verified the

presence of a coded wire tag. Fish that were rejected by failing one or both verifications were diverted to holding containers at each line. A marker collected rejected fish from the holding containers, anesthetized the fish using MS-222, and then clipped the adipose fin, inserted a coded wire tag, or clipped and tagged the fish in the same manner as in the manual trailer. Typically, less than 5% of fish are rejected by the automated system (J. Rivera, unpublished). All tagged and clipped fish were then sent via pipes to the hatchery raceways. At each hatchery, the average number of fish that were clipped and tagged per hour was estimated by dividing the total number of fish processed by the total number of hours each trailer was in operation.

Injury and fin clip quality.—For the injury and fin clip quality evaluation portion of this study, a fish collector and a fish evaluator were designated before the marking and tagging at each hatchery. The same collector was used at both hatcheries but a different fish evaluator was designated at Warm Springs NFH and Carson NFH. Although the two-person crew was different at each hatchery, the same crew was used for the duration of each evaluation at the respective hatcheries and protocols for injury and fin clip evaluation were identical. At each hatchery, the fish collector flipped a coin to select the trailer type, manual or automated, from which to collect fish. The collector then collected 20–60 fish from the outflow pipe of the selected trailer, placed them in a 19-L (5 gal) bucket filled with water, and transported them to the fish evaluator. The fish evaluator was located in a room away from the marking trailers and had no knowledge of the type of trailer from which the fish had come. Once the fish were delivered to the evaluator, they were anesthetized using MS-222, measured for fork length (FL), and visually examined for injuries and fin clip quality. Once the visual examination was complete, fish were returned to the appropriate raceways and the fish collector then flipped a coin and repeated the sampling process until the desired number of fish was sampled from each trailer type. At Warm Springs NFH, fin-clipping and tagging occurred over approximately a 2-week time frame. Sampling for injuries and fin clip quality was subdivided into an early (May 4), middle (May 9), and late (May 11) time period. One hundred fish from each trailer type were sampled during each time period, except during the late period where a counting error resulted in a 96-fish sample from the automated trailer. At Carson NFH, all fin-clipping and tagging occurred during a single day. All sampling for injuries and fin clip quality took place on April 25, 2008, with a sample size of 350 fish from each trailer type.

Injuries and fin clip quality rankings were assigned to each fish based on visual observations by the evaluator according to pre-established guidelines. The evaluator looked specifically at the head region (eye, operculum, and top of head), body, and fins. A fish was classified as injured if bruising or discoloration, descaling, indentations, bulges, or split or frayed fins were visible. Injuries that were clearly not the result of the tagging or fin-clipping procedure, such as skeletal deformation or fungus growth, were noted but not recorded as injuries. Adipose fin clip quality was rated as either being good (≥75% of the adipose fin was removed) or poor (<75% of the adipose fin was removed; Figure 2). If a fish received a deep fin clip, identified as a deep gouge in the skin tissue around the adipose fin area, the clip was classified as good and the presence of the gouge was noted as an injury.

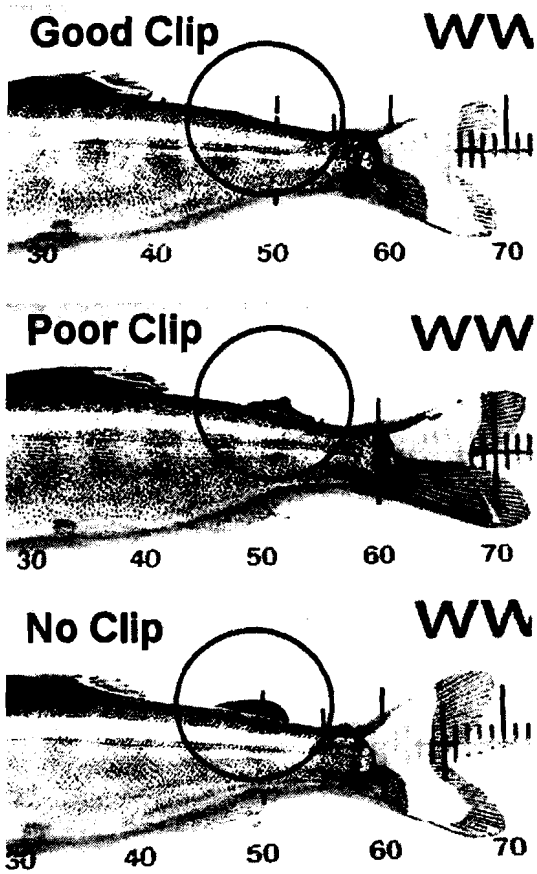

FIGURE 2.—Examples of good, poor, and no adipose fin clips. The area of the adipose fin is enhanced to improve visual clarity. Poor clips and no clips were grouped together for clip quality analysis. The numbers along the scale are millimeters.

TABLE 1.—Mean fork length (mm) of juvenile spring Chinook salmon evaluated for injuries and clip quality at Warm Springs National Fish Hatchery (NFH) in 2006 and Carson NFH in 2008. The trailer is the type of trailer used to fin-clip and coded-wire-tag fish. The mean length at Carson NFH differed between methods (*t*-test: $P < 0.001$).

	Warm Springs NFH			Carson NFH		
Trailer	*N*	Mean length	SD	*N*	Mean length	SD
Manual	300	66.6	3.9	350	66.9	2.9
Automated	296	67.1	3.4	350	70.1	2.9

Coded wire tag retention evaluation.—Final estimates of coded wire tag retention are typically done at least 29 d after tagging to account for tags lost after tagging (Blankenship 1990). At Warm Springs NFH, coded wire tag retention for each of the 20 coded wire tag groups was estimated 5 months after tagging, on October 3 and 10, 2006. Approximately 500 fish were netted from each tag group, anesthetized using MS-222, and scanned for the presence of a coded wire tag using a V-detector (Northwest Marine Technology, Inc.) that detects small changes in the magnetic field caused by the presence of a coded wire tag. The numbers of fish with and without a coded wire tag were recorded for each tag group. A total of 5,390 fish from the manual trailer and 5,173 fish from the automated trailer were sampled for the presence of a coded wire tag at Warm Springs NFH. At Carson NFH, fish with unique coded wire tag codes were mixed with fish with only the adipose fin clipped into several hatchery raceways. Therefore, approximately 500 fish from each of the three coded wire tag groups were collected from the trailer outflow during tagging for coded wire tag retention estimates. These fish were held separately in tanks inside the hatchery building and were provided standard care for 30 d after tagging. Coded wire tag retention was then estimated for each tag group following the same procedures as at Warm Springs NFH; a total of 513 fish from the manual trailer and 1,055 fish from the automated trailer were sampled for coded wire tags.

Data analysis.—All data were analyzed by treatment (trailer type) at each hatchery. Mean FLs of fish sampled for injuries and fin clip quality were compared using two sample *t*-tests. The number of injuries and fin clip quality of fish tagged in each trailer were compared using the Fisher exact test. Tag retention rates were compared using a chi-square test. The effect of time period on fin clip quality at Warm Springs NFH was examined using a 2×3 contingency table with time period as the rows and clip quality as the columns. Chi-square analysis of 2×2 contingency tables was used to test whether there was a significant difference in clip quality within periods and between methods. All statistical tests were conducted at the $\alpha = 0.05$ significance level.

Results

At Warm Springs NFH, approximately 3,000 fish per hour in the manual trailer and 5,400 fish per hour in the automated trailer were fin-clipped and coded-wire-tagged. At Carson NFH, the markers in the manual trailer fin-clipped and coded-wire-tagged approximately 3,600 fish per hour compared with the automated trailer, which clipped and tagged 6,800 fish per hour.

Injury and Fin Clip Quality

The mean FLs of spring Chinook salmon sampled from the manual and automated trailers were not significantly different at Warm Springs NFH, but at Carson NFH fish from the manual trailer were smaller than fish from the automated trailer (Table 1). Injury rates, fin clip quality, and tag retention rates of fish from the two trailer types at each hatchery are shown in Table 2. Injury rates did not differ between methods at Warm Springs NFH ($P = 0.371$) or at Carson NFH ($P = 0.510$). All of the injuries at each hatchery were classified as minor except for two fish sampled from the automated trailer at Carson NFH that had major injuries to the head area that were potentially life-

TABLE 2.—Injury rate and adipose fin clip quality of juvenile spring Chinook salmon marked by two tagging methods at Warm Springs National Fish Hatchery (NFH) in 2006 and Carson NFH in 2008. The values are numbers of fish, with percentages in parentheses. Injury rate and clip quality were compared between methods at each hatchery using the Fisher exact test; ns = not significant.

Hatchery and trailer type	Injured	Not injured	*P*	Good clip	Poor clip	*P*
Warm Springs NFH						
Manual	31 (10)	269 (90)	ns	209 (70)	91 (30)	<0.001
Automated	38 (13)	258 (87)		281 (95)	15 (5)	
Carson NFH						
Manual	17 (5)	333 (95)	ns	345 (99)	5 (1)	ns
Automated	22 (6)	328 (94)		347 (99)	3 (1)	

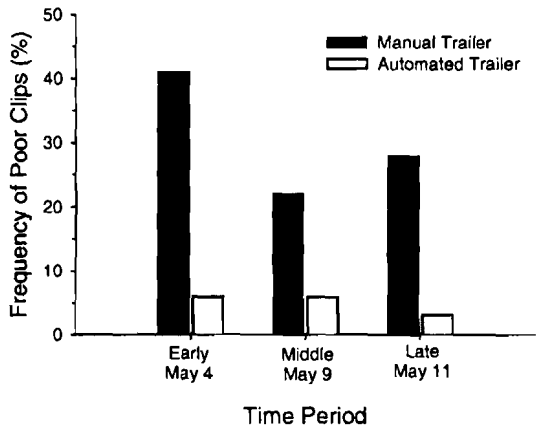

FIGURE 3.—Frequency of poor adipose fin clips in juvenile spring Chinook salmon handled at two types of tagging trailers at Warm Springs National Fish Hatchery at two periods in 2006. A poor clip had less than 75% of the adipose fin removed. The number of fish examined during each time period was 100 for each trailer except for the automated trailer in the late period, for which 96 fish were examined. For fish clipped manually, the number of poor clips differed by time period ($P = 0.013$). Within time periods, the number of poor clips differed between trailers (early, $P < 0.001$; middle, $P < 0.001$; and late, $P < 0.001$).

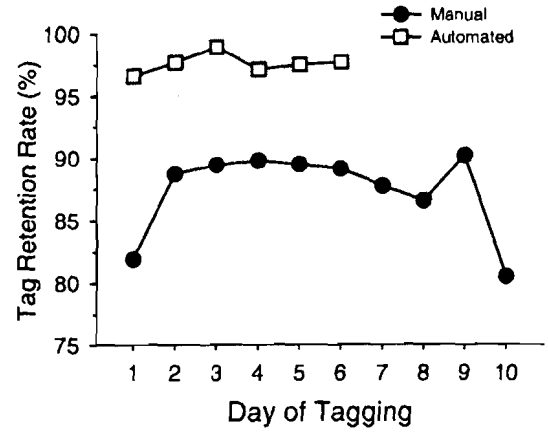

FIGURE 4.—Coded wire tag retention rates, by day of tagging, for juvenile spring Chinook salmon tagged at a manual and an automated trailer at Warm Springs National Fish Hatchery in 2006. Tagging took place during weekdays only; day 1 of tagging was May 4 and day 10 was May 17. Each trailer tagged approximately 250,000 fish in total; an average of approximately 3,000 fish/h were tagged in the manual trailer and 5,400 fish/h in the automated trailer.

threatening. A significant difference ($P < 0.001$) in adipose fin clip quality was observed between fish clipped in the two trailers at Warm Springs NFH; 30% of the fish from the manual trailer and just over 5% of the fish sampled from the automated trailer had poor clips. Five fish from the manual trailer and 11 fish from the automated trailer had noticeable gouges in the area of the adipose fin clip. Fin clip quality varied by time period in the manual trailer ($P = 0.013$) but not in the automated trailer ($P = 0.852$). Clip quality in the manual trailer was poorest during the early time period (Figure 3). Within each time period the incidence of poor clips was higher in the manual trailer than in the automated trailer (early $P < 0.001$, middle $P < 0.001$, late $P < 0.001$). At Carson NFH, a total of six fish, all from the automated trailer, had gouges. No differences in adipose fin clip quality were observed between trailers at Carson NFH; 1% of the fish from each trailer had poor clips.

Coded Wire Tag Retention Evaluation

Tag retention differed ($P < 0.001$) between the manual trailer (87%) and the automated trailer (98%) at Warm Springs NFH, while at Carson NFH tag retention exceeded 98% in both trailers and did not differ ($P = 0.34$). At Warm Springs NFH, the coded wire tag retention rate for fish tagged in the manual trailer was lowest during the first day of tagging, increased and leveled out during the next 8 d of tagging, and then dropped precipitously on the last day of tagging (Figure 4). Coded wire tag retention rates for fish tagged in the automated trailer were not as variable and remained above 96% for the duration of tagging.

Discussion

We found that manual and automated tagging trailers performed similarly with regard to injury rates at Warm Springs NFH, but differed with regard to tag retention and clip quality. At Carson NFH the manual and automated trailers performed similarly with regard to all three metrics measured. Fish distributed to the manual trailer at Carson NFH came from a different rearing pond than those that were distributed to the automated trailer, resulting in a difference in FLs. Given the small (<4 mm) difference in FLs and the similar performance between the two types of trailers at Carson NFH that we observed, the length difference did not appear to affect the results of this study. The differences in performance of the manual trailer at the two hatcheries were probably the result of differences in marker experience. At both hatcheries an experienced trailer supervisor prepared the manual trailers for clipping and tagging. The majority of markers at Warm Springs NFH had no previous experience clipping and tagging fish while all of the markers at Carson NFH had at least 1 year of experience. Coded wire tag retention depends on proper placement of the tag in the fish's snout (Ostergaard 1982), and we suspect that

inexperienced markers are more likely to remove the fish from the tag injector too quickly or misalign the fish in the head molds for tagging.

Several studies have shown coded wire tag retention rates increase with marker experience (Ostergaard 1982; Elrod and Schneider 1986; Blankenship 1990). The increase in tag retention rates for fish tagged in the manual trailer at Warm Springs NFH after the first day of tagging indicates markers became more proficient at tagging as time went on, although tag retention never exceeded 90%. The precipitous drop in tag retention rates experienced between day 9 and day 10 (last day) of tagging in the manual trailer may be attributable to the size of fish that were tagged on the last day. Manual trailers typically use one size head mold for all fish. Fish clipped and tagged on the 10th day were the last fish to be netted out of the holding raceway and we suspect that the size variation of these fish was greater than for fish from previous days. The single-sized head mold used in the tag injectors might have been too big for smaller fish and too small for larger fish, which may have accounted for some of the poor tag retention.

Retention of coded wire tags is critical to many management and evaluation programs (Elrod and Schneider 1986). While tag loss can be adjusted for in survival and harvest estimates by conducting tag retention estimates before juvenile release (Blankenship 1990), high tag loss may require more fish to be tagged and increase overall tagging costs. Tag loss may also affect fishery management operations. For example, at Warm Springs NFH, an automated passage system is used that detects the presence of coded wire tags in returning hatchery adults and diverts those adults into a holding pond while allowing wild, untagged adults upstream into the spring Chinook salmon spawning grounds (Olson et al. 2004). High coded wire tag loss can lead to large numbers of hatchery fish being allowed onto the wild spawning grounds.

The temporal pattern in fin clip quality of fish processed in the manual trailer at Warm Springs NFH was similar to the temporal pattern we observed in tag retention rates in that trailer. Fin clip quality improved after the first day of marking, but over 20% of the fish continued to receive a poor clip even in the later marking period. In comparison with the poor clip quality we observed at Warm Springs NFH, a group of experienced markers was able to achieve high tag retention rates (>95%) and good fin clip quality at Carson NFH. Poor adipose fin clip quality can affect harvest management and population estimates. Thompson and Blankenship (1997) found that 23% of coho salmon *O. kisutch* given incomplete adipose fin clips as juveniles completely regenerated the fin by the adult return stage. Hatchery fish that have a regenerated adipose fin, or never received a fin clip, would not be available for harvest under many selective fishery management regimes. These fish may also be mistaken for wild fish in spawning surveys, video counting, run reconstructions, and population estimates. We found that clip quality can vary substantially when clipped manually. We recommend that clip quality sampling be conducted for all marking programs so that estimates of the number of hatchery fish in a population can be adjusted for.

When marking and tagging large numbers of fish it is desirable to achieve the highest mark quality and tag retention possible in the most efficient manner that has the least effect on the fish. We found that an automated trailer and a manual trailer operated by experienced markers and experienced trailer supervisors performed similarly with regard to coded wire tag retention and adipose fin clip quality. Both methods also resulted in low injury rates to the fish. When fin-clipping and tagging fish manually, we recommend focusing efforts on training and quality control during the first few days of fin-clipping and tagging, especially when inexperienced markers and taggers are employed. When deciding which method to use for a mass-marking program, factors such as cost, speed of marking and tagging, the effects of anesthetic on fish, and the long-term effect on survival should be considered in addition to the experience level of the available personnel.

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References

Ando, D., M. Nagata, T. Kitamura, and Y. Shinriki. 2004. Evaluation of loss rate of coded wire tags implanted into

adipose eye tissue of masu salmon *Oncorhynchus masou* and effect on growth of tagged salmon. Fisheries Science 7:524–526.

Blankenship, H. L. 1990. Effects of time and fish size on coded wire tag loss from Chinook and coho salmon. Pages 237–243 *in* N. C. Parker, A. E. Giorgi, R. C. Heidinger, D. B. Jester, E. D. Prince, and G. A. Winans, editors. Fish-marking techniques. American Fisheries Society, Symposium 7, Bethesda, Maryland.

Consolidated Appropriations Resolution of 2003. U.S. Statutes at Large 108:11–554.

Elrod, J. H., and C. P. Schneider. 1986. Evaluation of coded wire tags for marking lake trout. North American Journal of Fisheries Management 6:264–271.

Hale, R. S., and J. H. Gray. 1998. Retention and detection of coded wire tags and elastomer tags in trout. North American Journal of Fisheries Management 18:197–201.

Hammer, S. A., and H. L. Blankenship. 2001. Cost comparison of marks, tags, and mark-with-tag combinations used in salmonid research. North American Journal of Aquaculture 63:171–178.

Hilborn, R., C. J. Walters, and D. B. Jester. 1990. Value of fish marking in fisheries management. Pages 5–7 *in* N. C. Parker, A. E. Giorgi, R. C. Heidinger, D. B. Jester, E. D. Prince, and G. A. Winans, editors. Fish-marking techniques. American Fisheries Society, Symposium 7, Bethesda, Maryland.

Johnson, J. K. 2004. Regional overview of coded wire tagging of anadromous salmon and steelhead in northwest America. Pacific States Marine Fisheries Commission, Portland, Oregon.

Olson, D. E., B. Spateholts, M. Paiya, and D. E. Campton. 2004. Salmon hatcheries for the 21st century: a model at Warm Springs National Fish Hatchery. Pages 585–602 *in* M. J. Nikum, P. M. Mazik, J. G. Nickum, and D. D. MacKinlay, editors. Propagated fish in resource management. American Fisheries Society, Symposium 44, Bethesda, Maryland.

Ostergaard, D. E. 1982. Retention of coded wire tags in lake trout. Progressive Fish-Culturist 44:162.

Peltz, L., and J. Miller. 1990. Performance of half-length coded wire tags in a pink salmon hatchery marking program. Pages 244–252 *in* N. C. Parker, A. E. Giorgi, R. C. Heidinger, D. B. Jester, E. D. Prince, and G. A. Winans, editors. Fish-marking techniques. American Fisheries Society, Symposium 7, Bethesda, Maryland.

Schurman, G. C., and D. A. Thompson. 1990. Washington Department of Fisheries mobile tagging units: construction and operation. Pages 232–236 *in* N. C. Parker, A. E. Giorgi, R. C. Heidinger, D. B. Jester, E. D. Prince, and G. A. Winans, editors. Fish-marking techniques. American Fisheries Society, Symposium 7, Bethesda, Maryland.

Thompson, D. A., and H. L. Blankenship. 1997. Regeneration of adipose fins given complete and incomplete clips. North American Journal of Fisheries Management 17:467–469.

Wertheimer, A. C., J. F. Thedinga, R. A. Heintz, R. F. Bradshaw, and A. G. Celewycz. 2002. Comparative effects of half-length coded wire tagging and ventral fin removal on survival and size of pink salmon fry. North American Journal of Aquaculture 64:150–157.

Zhou, S. 2002. Uncertainties in estimating fishing mortality in unmarked salmon in mark- selective fisheries using double-index-tagging methods. North American Journal of Fisheries Management 22:480–493.