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Factors Influencing Retention of Visible Implant Tags by Westslope Cutthroat Trout Inhabiting Headwater Streams of Montana

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Abstract.—Retention of visible implant (VI) tags by westslope cutthroat trout *Oncorhynchus clarki lewisi* inhabiting 20 reaches of 13 isolated headwater tributary drainages in Montana was evaluated during 1993 and 1994. In 1993, 2,071 VI tags were implanted in westslope cutthroat trout (100–324 mm fork length) and adipose fins were removed as a secondary mark to evaluate tag retention. Of 348 westslope cutthroat trout recaptured during the year they were tagged, 201 (58%) had retained their tags. Of 616 westslope cutthroat trout recaptured the year after tagging, 355 (58%) had retained their tags. Logistic regression analyses indicated that fish length was the most significant variable that positively influenced tag retention. Other significant variables were wetted width and channel gradient of the stream in which fish were tagged and quality of tag insertion (rated at time of tagging). Fish condition did not significantly improve deviance performance of logistic regression models that included fork length and tag insertion quality. Neither slopes nor intercepts of $\log_{10}$(length)–$\log_{10}$(weight) regressions were significantly different ($P >$ 0.10) between fish that retained tags and fish that lost them. Fish condition was not significantly different ($P > 0.951$; analysis of covariance) between previously tagged and untagged westslope cutthroat trout after differences between drainages and years were accounted for. We found no significant differences in slopes ($P > 0.50$) or intercepts ($P > 0.05$) of $\log_{10}$(length)–$\log_{10}$(weight) regressions between previously tagged and untagged fish. However, for 11 drainages where comparisons could be made, we found significant differences ($P < 0.05$) in length–weight regression slopes between previously tagged and untagged fish for one drainage and in regression intercepts for an additional three drainages. Ninety-five percent of all tags were readable at recapture. A logistic regression model predicted that tag retention would be 75% or higher for westslope cutthroat trout 155 mm FL or larger if tag insertion quality was good. In spite of relatively poor tag retention (<75%) by smaller (<155 mm) westslope cutthroat trout, VI tags were a valuable tool to assess movements of those fish retaining tags.

Fish researchers and managers mark fish to obtain information on abundance, movements and migration, age and growth, mortality, behavior, exploitation rates, and stocking success (McFarlane et al. 1990). Evaluating retention of marks is important in any mark–recapture study (e.g., Nielsen 1992). Haw et al. (1990) developed an alphanumerically coded visible implant (VI) tag that can be inserted just beneath clear tissue, usually behind the eye, and read when the fish is recaptured. Because they are small, VI tags can be used to uniquely identify small fish without sacrificing the fish to recover the tag. In initial tests of VI tags by Haw et al. (1990), only 1 of 42 tagged rainbow trout *Oncorhynchus mykiss* (mean total length, TL, 158 mm) lost a tag during 22 weeks in a hatchery environment.

Visible implant tag retention has been positively related to fish size or age for Atlantic salmon *Salmo salar* (Kincaid and Calkins 1992), brook trout *Salvelinus fontinalis* (Bryan and Ney 1994), and brown trout *Salmo trutta* (Niva 1995). McMahon et al. (1996, this issue) suggest that environmental

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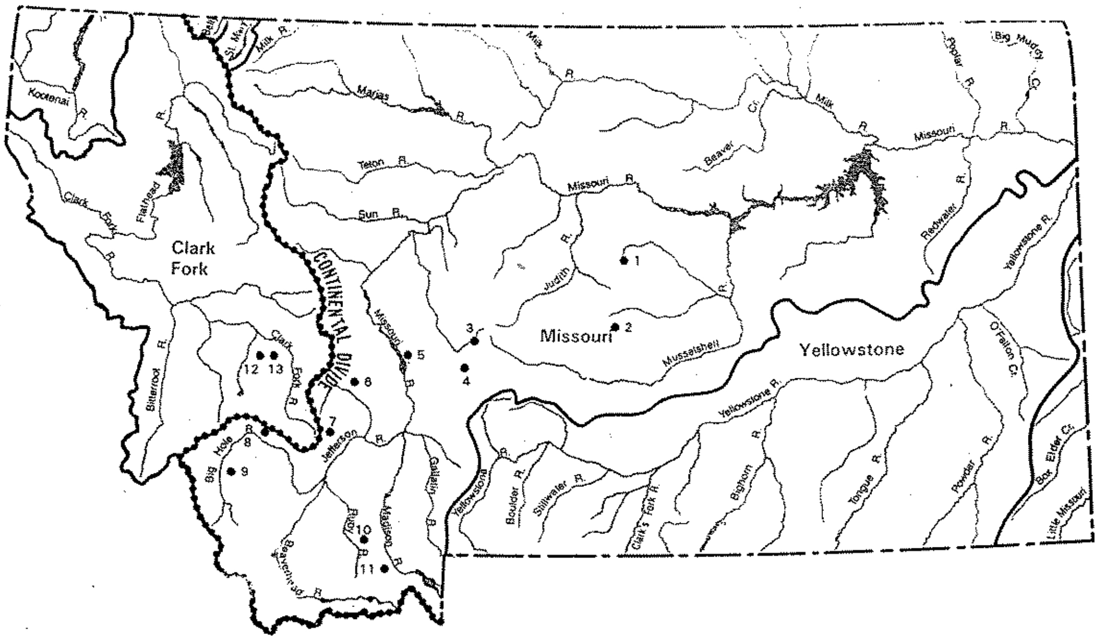

FIGURE 1.—Map (modified from Holton 1990) of major drainages in Montana showing sample locations (●) where retention of visible implant tags in westslope cutthroat trout was assessed. Numbers next to locations correspond to numbers in parentheses by stream names in Table 1.

conditions may also affect tag retention, because rainbow trout have shown poorer retention in the wild than in a hatchery. We needed to document the retention of VI tags as part of a study to estimate mortality and movement of small (100–320 mm fork length, FL) westslope cutthroat trout *Oncorhynchus clarki lewisi* inhabiting headwater streams of Montana. We wanted to determine what factors influence tag loss and to test if VI tags adversely affect the condition of tagged fish.

Methods

Visible implant tag retention by westslope cutthroat trout was assessed in 20 reaches within 11 tributary drainages of the upper Missouri River and two tributary drainages of the upper Clark Fork River, Montana (Figure 1). These reaches were characterized by low-flow wetted widths of 1.5–3.6 m, water conductivities of 57–649 μS, elevations of 1,320–2,570 m, and gradients of 1–11% (Table 1). Westslope cutthroat trout in sampled populations exhibited little evidence of introgression with either rainbow trout or Yellowstone cutthroat trout *O. c. bouveri* based on external morphometric characteristics and electrophoretic testing (Salmon and Trout Genetics Laboratory, University of Montana, unpublished data).

Fish were captured by using a Smith-Root BP-15 backpack electrofisher set at 40 mHz pulse with a pulse width of 1 ms. Voltages were set from 400 to 800 V. These settings were used to maximize capture efficiency while minimizing risk of injuring fish (W. Fredenberg, U.S. Fish and Wildlife Service, personal communication). All captured fish were anesthetized with MS-222 (tricaine), measured to the nearest millimeter (FL), and weighed to the nearest gram. Condition factors (weight·10^5/length^3) were calculated for individual fish (Anderson and Gutreuter 1983).

All westslope cutthroat trout from 120 mm to the largest fish captured (324 mm) and a few between 100 and 120 mm were tagged with individually coded alphanumeric VI tags as described by Haw et al. (1990) and Kincaid and Calkins (1992) (Figure 2). A minimum fish length of 150 mm (TL) is recommended by the manufacturer to obtain reasonable tag retention (P. Bergman, Northwest Marine Technology, personal communication); however, we were interested in obtaining information on movements and retention of tags for smaller fish. We implanted 2,071 rectangular, plastic laminate tags (2.5 mm × 1.0 mm × 0.1 mm thick) with a white code on a black background in 1993. Most fish were tagged behind the left eye, where

TABLE 1.—Physical features of streams (map location numbers in parentheses) where westslope cutthroat trout were tagged with visible implant tags during 1993 and recaptured during 1993 and 1994. "Model sample size" refers to number of fish tagged in each reach; "NA" means data are not available.

Stream and reach (map number)	Rosgen type[a]	Mean temperature (°F)	Mean conductivity (μS)	pH	Mean wetted width (m)	Length with cutthroat trout (km)	Elevation range (m)	Mean channel gradient (%)	Number of tags out	Model sample size
Collar Gulch (1)	B2	6.4	206	8.3	2.0	2.7	1,450–1,550	3.6	232	134
Cottonwood (Ruby) (10)	A3	8.2	NA	NA	2.2	5.8	2,260–2,540	4.8	71	20
Geyser	A3	6.7	447	8.6	1.6	1.6	2,460–2,570	6.7	305	79
Cottonwood (Smith) (4)	B1	8.5	131	8.4	2.5	0.6	1,830–1,850	4.1	89	88
East Fork	A3	9.4	57	8.1	1.5	3.0	1,850–2,190	11.4	25	0
West Fork	A3	11.7	126	8.2	2.5	2.8	1,850–2,110	6.4	333	124
Douglas (12)	A2	5.3	245	8.9	3.0	1.1	1,570–1,630	5.5	81	26
North Fork	B2	7.1	253	8.7	1.5	3.1	1,650–1,790	4.7	152	39
Half Moon (2)	A2	12.3	333	8.7	3.0	7.3	1,710–2,010	4.2	11	0
Halfway (7)										
Reach 1	A3	9.1	74	8.9	1.8	3.7	1,830–2,195	10.4	51	25
Reach 2	B3	11.0	72	8.5	1.5	4.1	2,195–2,290	4.6	142	48
Jerry (8)	A3	7.7	160	8.9	2.5	2.8	2,100–2,220	4.4	95	28
Delano	A3	4.5	180	8.7	1.2	1.9	2,120–2,260	7.1	87	43
Mcvey (9)	B3	5.4	78	8.7	1.5	2.3	1,860–1,940	3.4	66	13
Muskrat (6)	A2	7.8	NA	NA	3.6	2.2	1,570–1,700	5.5	18	0
North Fork Deadman (3)	A3	6.3	254	8.6	1.7	2.5	1,960–2,130	6.8	5	0
North Fork Gold (13)										
Reach 1	B3	6.8	178	8.4	2.0	2.5	1,880–1,950	1.2	76	14
Reach 2	B3	6.4	157	8.5	2.3	2.2	1,950–2,010	4.0	26	2
Soap (11)	A3	6.2	81	8.2	2.5	3.9	1,910–2,170	6.6	166	58
White's Gulch (5)	B3	11.6	649	8.2	1.5	4.6	1,320–1,470	3.3	38	29

[a] Rosgen channel types are based on Rosgen (1994).

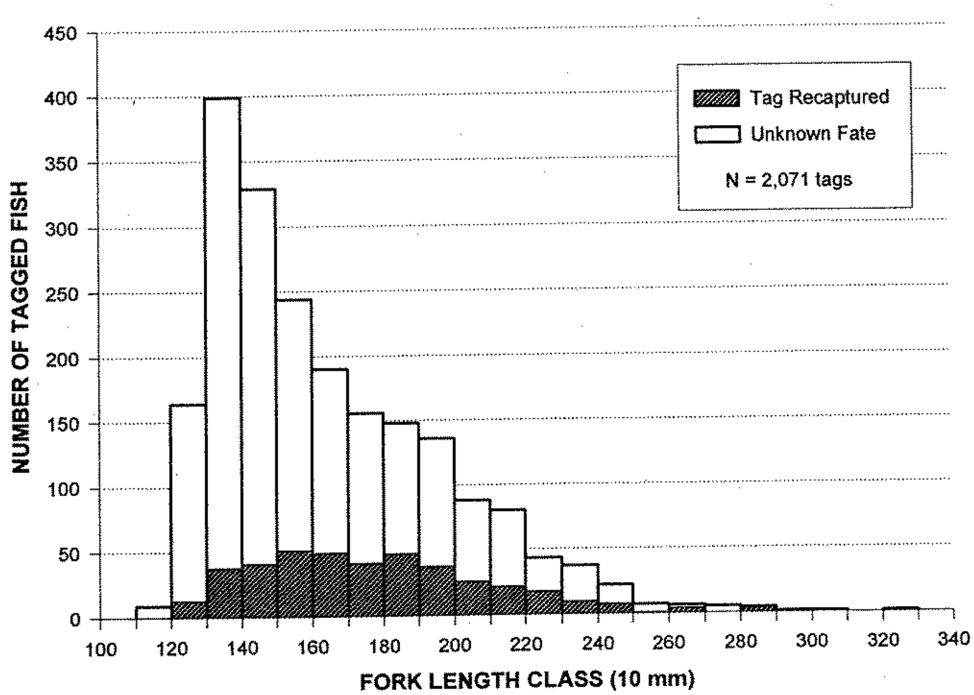

FIGURE 2.—Size distribution of westslope cutthroat trout tagged with visible implant tags in 1993 and of those recaptured with tags during 1993 and 1994.

tags were injected into the clear postorbital adipose tissue with a Northwest Marine Technology tagging syringe. A few fish were tagged behind the right eye when tag insertion was poor behind the left eye. Each person who tagged fish had extensive experience applying VI tags (at least 1,000 tags) prior to this study. Adipose fins were excised from all tagged fish to assess tag retention. Prior to excision, no westslope cutthroat trout were missing their adipose fin in any of our sampled streams.

We rated tagging quality in three classes: (1) good—tag was properly inserted without tearing any adipose tissue and easily read; (2) fair—some adipose tissue was torn or the tag was inserted too deeply for easy reading; and (3) poor—a large rip was made in adipose tissue or the tag was inserted so deeply that it was extremely difficult to read or could not be read. Of the 2,071 tags implanted, 1,421 (69%) were classified as good insertions, 494 (24%) as fair, and 34 (1%) as poor; 122 (6%) were not classified. Tagged fish were allowed to fully recover from anesthetic in a bucket before they were released into calm water in the streams.

Recoveries of tagged fish were made from 1 to 406 d after tagging. We followed the protocol of Geoghegan et al. (1990) for quality control and assurance of tag data with the following modifications. When a fish with a clipped adipose fin was recaptured, an attempt was made to find and read the VI tag by inspecting the postorbital tissue behind each eye. If no VI tag was observed after inspection by two crew members, it was recorded as lost. Fish that had lost their original VI tag were retagged if possible. We were unable to retag eight adipose-clipped fish in 1993 and 35 in 1994.

When a fish was recaptured, its tag code was recorded when possible. If a tag was difficult to read, a second person read the tag in an attempt to reduce observer error. Tags were classified as unreadable, difficult to read (there was a question on one or more of the letters or numbers), or readable. All retained tags were considered as tag recoveries, regardless of readability. Tag retention at recapture was estimated within the year of tagging and the year following tagging by dividing the number of recaptured westslope cutthroat trout with tags by the number recaptured with adipose fin clips.

McMahon et al. (1996) and Bergman (personal communication) indicated that different stocks inhabiting different environments might retain VI tags differentially. To assess potential effects of different stream environments on tag retention by means of easily measured variables, wetted stream widths and reach gradients were estimated. Wetted stream widths were measured and averaged to the nearest 0.1 m for each reach. Reach gradients were estimated to the nearest 1% from 1:24,000 U.S. Geological Survey contour maps. Reaches were subdivided according to the distribution of westslope cutthroat trout and changes in channel gradient (Table 1).

Tag retention was coded as 0 (tag missing) or 1 (tag present) so that logistic regressions (Hosmer and Lemeshow 1989) could be used to model the probability of tag retention. We used weighted logistic regression whereby a weighting variable was assigned to each tagged fish based on our estimated probability that the fish subsequently would be recaptured. A weighting of 1 was assigned to each fish subsequently recaptured with a tag.

Because fin clips did not uniquely identify each fish, length at tagging was unknown for recaptured fish that had lost their tags. To estimate their length at tagging, we calculated the mean daily growth of tag-retaining fish in each drainage, assuming a growth season of May 15 to September 30. We then applied these rates to fish that had lost tags, back-calculating 95% prediction intervals for length at tagging according to the time each tag-losing fish had been at large in drainage.

Regression weightings were assigned to all tagged fish by assessing their probability of recapture. We attempted to match recaptured fish known to have lost tags with fish that were tagged but not recaptured. For this matching we assumed fish did not move more than 200 m between tagging and first recapture, which was true for more than 95% of the fish recaptured with tags.

For example, if a fish was recaptured without a tag, we could estimate its length at tagging—say, 165–185 mm (95% prediction interval)—using the growth regression. All fish n of "unknown fate" (those recaptured without a tag plus those not recaptured) that had been tagged within 200 m of the recapture location and that had a recorded length at tagging within 165–185 mm were assigned weightings of $1/n$. If three fish fit the criterion, each was given a weighting of 0.33. We followed this procedure for each adipose-marked fish recaptured without a tag, and weightings accumulated to a maximum of 1.0 for each fish tagged.

For weighted logistic regression we had a sample size of 770 fish (see Table 1 for sample size by reach). We were unable to weigh 58 fish, so the sample size was 712 for models testing the effects of fish condition (359 fish recaptured with tags and 353 potentially recaptured without them). The ef-

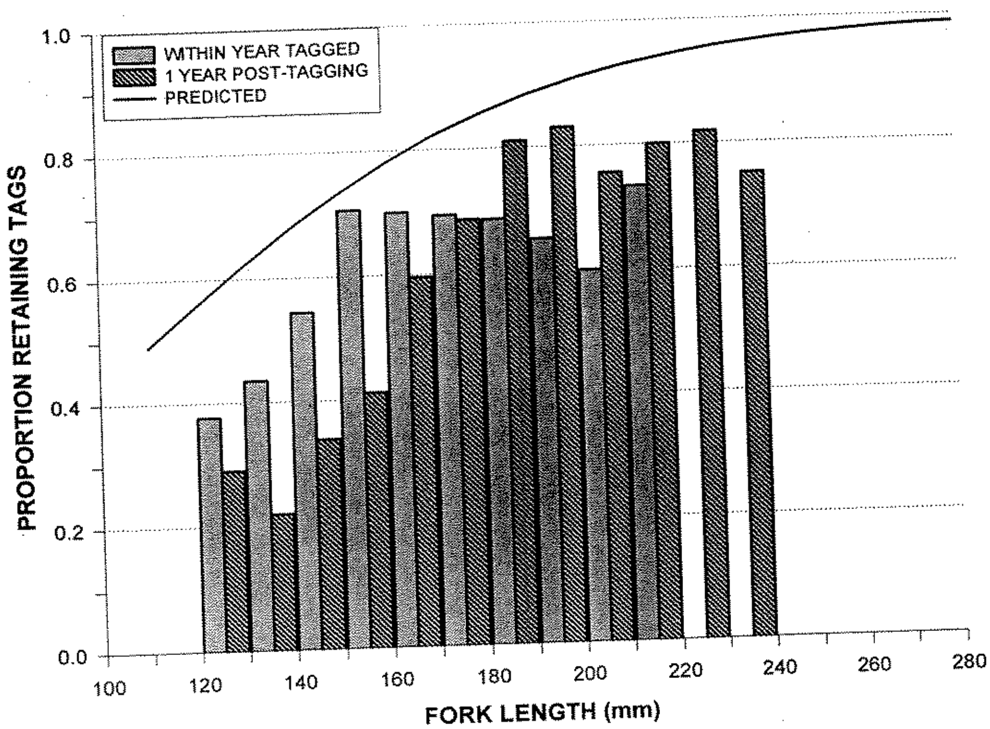

FIGURE 3.—Proportional size distributions at recapture of westslope cutthroat trout that retained visible implant tags within the year of tagging (shaded bars) and 1 year after tagging (crosshatched bars), and the predicted retention of visible implant tags based on length at tagging (solid line).

fective degrees of freedom were 501. We did not rate tag insertion quality for 59 fish, so models testing the effects of tag insertion quality had a sample size of 711 with 500 effective degrees of freedom. Explanatory variables explored were fork length at tagging (FL), condition factor (C), tag rating (R), reach gradient (G), wetted width (W), and drainage (locality) as a class variable (LOC). Variables were added to the model one at a time and tested to determine if they added significantly to the model by comparing the two models under a chi-square distribution with the appropriate degrees of freedom (Hosmer and Lemeshow 1989).

We tested for differences in length–weight relationships (a) between recaptured fish that had lost tags and those that retained them, and (b) between fish that had been tagged and those that had not been; in both cases we compared $\log_{10}$(length)–$\log_{10}$(weight) regressions (Anderson and Gutreuter 1983). If regression slopes did not differ significantly, we tested for differences in elevations (intercepts) according to methods described by Zar (1974). We also tested for influences of tagging on fish condition by comparing condition factors between previously tagged and untagged cutthroat trout at least 110 mm long. For this we used analysis of covariance (ANCOVA) after accounting for effects of tributary drainage (13 drainages tested) and year of capture (year of tagging or year after tagging) on 4,960 observations. Statistical tests were made via the SAS Windows program (version 6.03; SAS Institute 1994) and Splus (version 3.1; Statistical Sciences 1993) with significance levels set to 0.05.

Results

We recaptured 348 previously tagged (clipped adipose fin) westslope cutthroat trout during the year they were marked. Of these, 201 (58%) had retained their tag. Of 616 previously tagged westslope cutthroat trout recaptured the year after tagging, 355 (58%) had retained their tag. We observed a sigmoidal relationship between tag retention and fish length at time of recapture (Figure 3).

Weighted logistic regression analyses indicated that fish length had the most significant influence on tag retention ($N = 712$; deviance improvement was 42.5 over the intercept-only model; $P < 0.001$). Fish condition did not significantly improve the deviance performance of the length mod-

TABLE 2.—Results of weighted logistic regression analyses to assess the probability of westslope cutthroat trout retaining visible implant tags, showing the improvement in model deviance provided by explanatory variables. Explanatory variables are fork length at tagging (FL), tag insertion quality rating (R), wetted stream width (W), stream channel gradient as a percentage (G), and drainage (LOC). Standard errors of coefficients are shown in parentheses. Only tagging data for which tag insertions were rated were used in the model.

Covariate(s)	df	Deviance	Deviance improvement	P	Coefficients (SE)
Intercept	499	598.5			
FL	498	551.1	47.4	<0.001	− 2.888(0.612) + 0.025(0.004)·FL
FL + R	496	544.0	7.1	0.029	0.026(0.004)·FL − 2.894(0.615), when tag rating "good" − 3.406(0.676), when tag rating "fair" − 5.212(1.494), when tag rating "poor"
FL + R + W	495	512.8	31.2	<0.001	0.029(0.004)·FL − 1.873(0.659), when tag rating "good" − 2.348(0.722), when tag rating "fair" − 4.056(1.403), when tag rating "poor" − 0.753(0.138)·W
FL + R + W + G	494	496.4	16.4	<0.001	0.027(0.004)·FL + 0.611(0.908), when tag rating "good" + 0.181(0.963), when tag rating "fair" − 1.706(1.512), when tag rating "poor" − 1.069(0.163)·W − 0.291(0.074)·G
FL + R + LOC	483	482.5	13.9	0.382	

el (N = 712; deviance improvement was only 0.2 over the intercept-and-length model; P = 0.69), so we added the 58 fish that could not be weighed back into the sample. We then tested effects of tagging quality (R), so we removed the 59 fish for which tagging quality had not been rated from the sample. Fish length was still the most significant variable influencing tag retention ($P < 0.001$; Table 2). Tag rating, wetted stream width, and reach gradient significantly improved the model. Tag retention improved as fish length increased, as tag insertions improved, and as streams became narrower and of lower gradient. The model that incorporated tributary drainage as a class variable was not significantly better than the model with reach estimates of wetted width and channel gradient, suggesting that drainage effects were not as important as reach effects. There was not a significant difference ($P > 0.10$) in slopes or intercepts of $\log_{10}$(length)–$\log_{10}$(weight) regressions between recaptured fish that had retained tags and those that had lost them.

After differences between drainages and year were accounted for (analysis of variance; $P < 0.01$), fish condition was not significantly different (ANCOVA; $P > 0.95$) between previously tagged and untagged westslope cutthroat trout. There was also no significant difference in slopes ($P > 0.50$) or intercepts ($P > 0.05$) of $\log_{10}$(length)–$\log_{10}$(weight) regressions between previously tagged and never-tagged fish (≥110 mm) across all drainages. However, when length–weight data from the 11 drainages with adequate sample sizes were run individually, significant ($P < 0.05$) differences between tagged and untagged fish were found for regression slopes in one drainage and for intercepts in three other drainages.

Ninety-five percent (526 of 556) of all tags were easily readable at recapture, 96% (193 of 201) within the year of tagging and 94% (333 of 355) a year later. Only one (<1%) recaptured fish had a tag that was unreadable in the year it was implanted; three tags (1%) were unreadable one winter after tagging. Tags were unreadable either because they had been inserted too deeply into opaque tissue or because adipose tissue had clouded over the tags. We subsequently found that unreadable tags could be read if they could be extracted with a syringe.

Discussion

The proportions of recovered westslope cutthroat trout retaining VI tags within the year of tagging (58%; N = 348) and the year after tagging (58%; N = 616) were consistent, but our estimated retention rates were lower than in most previous studies of VI tag retention. These results can be partially explained by the small lengths at which we tagged the majority of our fish (1,145, or 55%, were smaller than 150 mm FL). Using logistic regression, we predicted tag retention (P_r) based on fork length at tagging (not at recapture) and on good quality tag insertions as

$$P_r = e^{-2.894+0.026FL}/1 + e^{-2.894+0.026FL}$$

(Figure 3).

Our predicted retention rates were consistent with observed retention rates of 94% for 200–307-mm FL, hatchery-raised, sea-run cutthroat trout *O. clarki* released into the Cowlitz River, Washington (Blankenship and Tipping 1993) and 82% for rainbow trout 140–240 mm TL (Mourning et al. 1994), but slightly higher than the 50% retention observed for brook trout 130–160 mm TL and slightly lower than the 100% retention observed for brook trout 200 mm and longer in the wild (Bryan and Ney 1994). Our predicted and observed tag retention rates indicate that the manufacturer's recommended minimum tagging length of 150 mm TL would result in at least a 73% retention rate for fish this length and longer. For retention rates over 90%, the minimum size at tagging for westslope cutthroat trout would have to increase to about 195 mm.

Quality of tag insertion (tag rating) was significantly related to retention, as we had expected. This result emphasizes the need to have experienced personnel do the tagging.

Tag retention varied by drainage, but most drainage variation appeared to be explained by estimates of wetted width and channel gradient made in each reach. These variables are relatively easy to estimate. We are uncertain of the mechanism by which these two variables affect tag retention. We speculate that because higher channel gradients indicate faster water velocities, tag retention is related to water velocity. Niva (1995) reported that VI tag retention was related to immediate post-tagging handling; tag loss was greater when fish were dropped into the water than when they were gently placed into it. Release of VI tagged fish into high or highly variable velocities might cause similar tag loss. Differences in tag retention rates may also be related to differences between species or environments (McMahon et al. 1996; Bergman, personal communication). We recommend further research to determine if, and why, different environments, or different fish stocks, lead to different tag retention rates.

We expected fish in better condition to retain tags at higher rates because we initially believed that adipose tissue at tag insertion sites was a form of fatty, or excess, tissue. However, fish condition did not significantly improve deviance performance in the logistic regression model nor did $\log_{10}$(length)–$\log_{10}$(weight) regression slopes or elevations differ significantly between recaptured fish that had retained or lost tags. Our inability to find a significant relationship between fish condition and tag retention led us to question our original assumption that postorbital adipose tissue is fatty, or excess, tissue. We have subsequently discovered that the clear tissue at postorbital tag insertion sites is primarily a stroma (matrix) of extremely fine microfibrils of collagen, a form of connective tissue, which contains a few fibrocytes (which form and maintain the collagen), blood vessels, and sinuses (J. Morrison, U.S. Fish and Wildlife Service, personal communication).

We found no significant difference ($P > 0.95$; ANCOVA) in fish condition between previously tagged and untagged westslope cutthroat trout in our study. This finding is consistent with findings of Bryan and Ney (1994), who found no significant differences ($P > 0.2$) between condition factors of VI-tagged and untagged brook trout in the wild. We also found no significant differences in length–weight regression slopes ($P > 0.50$) and elevations ($P > 0.05$) between previously tagged and untagged fish. However, we did observe significant differences ($P < 0.05$) in either slopes or elevations for 4 of 11 drainages tested. We are uncertain if these differences were caused by effects from tagging or factors associated with electrofishing and handling. Because we do not have good evidence that VI tags affect condition of tagged fish, we suggest that growth (and inferentially survival) may not be affected by VI tags. We recommend that studies be conducted to further test potential effects of VI tags on growth and survival of tagged fish.

We used adipose fin clips as secondary marks, so our efforts to find VI tags on recaptured fin-clipped trout were probably more thorough than if no secondary mark had been used. Coombs et al. (1990) found little (0.2%) adipose fin regeneration on clipped Atlantic salmon and little effect of fin removal on growth or survival 3 months after excision. We believe that adipose clips allowed us to identify all recaptured tagged fish and did not affect their growth or survival. Use of this secondary mark might have led to a slight positive bias in our assessment of tag retention.

We conclude that VI tags provide a valuable means to individually mark small fish that typically make up headwater populations; however, investigators must recognize that a relatively high rate of tag loss (>25%) may occur from fish under 150 mm because tag retention is strongly and positively related to fish length. In spite of the relatively low tag retention rates for these smaller fish, we obtained valuable information on movements for fish that retained their tags. Tag insertion quality positively influenced tag retention and should be considered and documented in any tagging study.

For use of VI tags, we recommend the following: (1) personnel inserting the tags must be experienced (Niva 1995) and records should be kept of tag insertion quality; (2) tagging and tag recovery protocols must be established and followed (Geoghegan et al. 1990); (3) if it is necessary to use different tag colors, the colors should differ markedly so they can be recognized accurately in the field (Niva 1995); and (4) tag retention should be evaluated (McFarlane et al. 1990; Vreeland 1990; Nielsen 1992). We developed a predictive equation to estimate tag retention by length at tagging for westslope cutthroat trout 100–300 mm long (FL) and suggest that future investigators could adopt this protocol to evaluate tag retention.

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