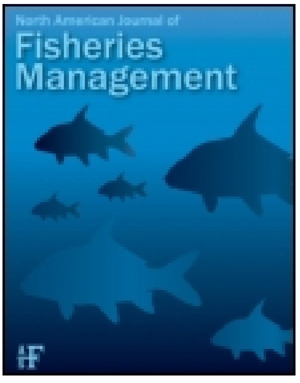

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Passive Integrated Transponder Tag Retention Rates in Headwater Populations of Coastal Cutthroat Trout

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[Management Brief]

Passive Integrated Transponder Tag Retention Rates in Headwater Populations of Coastal Cutthroat Trout

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Abstract.—Passive integrated transponder (PIT) tags have desirable qualities (e.g., unique identification, indefinite tag life, and capacity for remote detection) that make them useful for evaluating survival, growth, and movement of fish, but low tag retention rates can confound data interpretation. Although the effects of PIT tags on short-term growth and survival have been minimal and tag retention rates in laboratory and field studies using only juvenile individuals have been high, tag retention rates for fish at different ontological stages (including reproductively active males and females) remain unknown. We evaluated tag retention rates in wild populations of coastal cutthroat trout *Oncorhynchus clarkii clarkii* in three catchments of western Oregon using a double-marking approach (i.e., the adipose fin was removed from all fish that were PIT-tagged). Tags were inserted into the body cavities of fish 100 mm or more in length (fork length; range = 100–250 mm). In the study catchments, this size range includes both juvenile and mature fish. Tag retention rates were approximately 25% lower than those reported by previous studies of juvenile salmonids alone. A number of PIT tags were recovered in redds, indicating that mature individuals eject tags during spawning. Although some coastal cutthroat trout retained PIT tags for up to 4 years, others expelled them repeatedly and were implanted with a minimum of three different PIT tags during the same period. These data are concordant with those of other studies in which PIT tags had been inserted into the body cavity of salmonids and the population of tagged fish comprised both juvenile and mature individuals. Therefore, for multiple-year studies, it may be prudent to double-mark fish when PIT tags are to be inserted in the body cavity.

Passive integrated transponder (PIT) tags have desirable qualities (e.g., individually unique identification, tag life equal to that of the tagged individual, and capacity for remote detection) that make them useful for evaluating survival, growth, and movement of fish (Peterson et al. 1994; Zydlewski et al. 2003; Gresswell and Hendricks 2007). Because tag retention rates and the effects of tagging can confound data interpretation, these factors have been studied extensively in juvenile trout (Dare 2003). In general, the effects of PIT tags on growth and survival have been minimal (Gries and Letcher 2002; Dare 2003; Bateman and Gresswell 2006), and in studies using juvenile salmonids, tag retention rates are high. For example, Prentice et al. (1990) reported retention rates ranging from 98% to 100% for juvenile Chinook salmon *Oncorhynchus tshawytscha*, sockeye salmon *O. nerka*, and steelhead *O. mykiss*. Retention rates in juvenile Atlantic salmon *Salmo salar* have equaled or exceeded 99% (Zydlewski et al. 2001; Gries and Letcher 2002). Similar results have been reported by Ombredane et al. (1998) for juvenile brown trout *S. trutta* (retention rate, 97%), and Zydlewski et al. (2003) for steelhead (retention rates for two groups = 89% and 98%). Retention rates (97%) documented by Bateman and Gresswell (2006) were comparable for this species.

As the desirable qualities of PIT tag technology have become more apparent, researchers have begun to monitor individuals throughout the life cycle (Zydlewski et al. 2006). For extended studies, however, it is critical to assess tag retention rates for fish at different ontological stages because it has been documented that females of some fish species lose tags during spawning (Prentice et al. 1990). Differences in tag retention rates between immature and mature, or between male and female fish, could create biased estimates of survival, growth, and movement. In this study, we evaluated tag retention rates in wild populations of coastal cutthroat trout *O. clarkii clarkii* and the effect of tag loss on

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estimates of trout survival in three catchments of western Oregon using a double-marking approach (i.e., the adipose fin was removed from all fish that were PIT-tagged). We focus specifically on PIT tags inserted into the body cavity of trout greater than or equal to 100- mm fork length.

Methods

Study catchments were located in the Umpqua River watershed in western Oregon, and drainage areas were 858, 1,083, and 2,202 ha for North Fork Hinkle Creek, South Fork Hinkle Creek, and Camp Creek, respectively. Fish species occurring in Hinkle Creek include reticulate sculpin *Cottus perplexus*, steelhead, and coastal cutthroat trout (anadromous and potamodromous life history types). The coastal cutthroat trout is the only salmonid present in Camp Creek. Trout can move freely throughout both forks of Hinkle Creek and into the Umpqua River, but the study area in Camp Creek is located above a 4-m-high waterfall approximately 13 km upstream from the confluence of Camp and Mill creeks.

Bedrock geology of Hinkle Creek is primarily basalt and andesite (Meacham and Steiner 2002). Camp Creek is characterized by steep canyons of sedimentary rock (Bateman Formation) and a bedrock-dominated stream channel. Precipitation in the area is primarily rainfall, averaging 100–160 cm annually (BLM 1995). Overstory forest vegetation is predominately Douglas-fir *Pseudotsuga menziesii*, but western red cedar *Thuja plicata* is common and western hemlock *Tsuga heterophylla* is locally abundant in some locations.

A double-marking technique was used to evaluate PIT tag retention rates. Removal of the adipose fin provided a permanent mark for each individual fish. Fin clipping and PIT tagging occurred simultaneously in the North and South forks of Hinkle Creek during 2003–2005 and in Camp Creek during 2003–2004.

Cutthroat trout were collected annually during summer low-flow conditions using single-pass electrofishing (Bateman et al. 2005). All pool and cascade habitat types in the fish-bearing portion of the stream network were sampled. Trout were anesthetized in clove oil prior to measuring length (nearest mm fork length) and weight (nearest 0.1 g). The adipose fin was removed from all cutthroat trout greater than of equal to 100-mm fork length and a 23.00-mm × 3.85-mm glass encapsulated, half-duplex PIT tag (Texas Instruments, Dallas, Texas) was surgically implanted in the body cavity (Gries and Letcher 2002). Individual PIT tag numbers were recorded using an Allflex Model RS601–3 handheld scanner (Allflex USA, Dallas, Texas). Upon recovery from the anesthetic, trout were released into the habitat unit of capture. Water temperatures generally ranged from 11–17°C during tagging activities, except in Camp Creek during 2003 when temperatures ranged from 4°C to 9°C.

During subsequent electrofishing events, trout 100-mm fork length or longer having all fins present were fin-clipped and implanted with a PIT tag. Cutthroat trout without an adipose fin and with a PIT tag were enumerated and released. A new tag was implanted into individuals without an adipose fin that did not have a PIT tag, and each of these trout received a retagging mark so that it could be identified in the future. If only the adipose fin was missing, the right pelvic fin was removed; if the adipose and right pelvic were both missing, the left pelvic fin was removed. The proportion of trout retaining tags was estimated annually as

$$R = r_c/(r_c + r_t),$$

where R is tag retention, r_c is the number of recaptured fish, and r_t is the number of retagged fish. Annual retention rates for specific tagging-groups are discernable only for the 2003-group. For subsequent tagging-groups, yearly retention rates become confounded due to the inability to distinguish the initial tagging date for retagged trout.

Because sampling did not occur on exactly the same dates each year, only trout that had been at large for a minimum of 274 d were included in the retention analysis. This time interval insured that retention estimates were based on individuals that had persisted through the spring spawning season.

During December, March, and June of each year, PIT-tagged trout were remotely relocated using portable antennas (Zydlewski et al. 2001). The entire wetted area of the trout-bearing portion of the stream network in each catchment was scanned during each census event. If a tag was located, data on time, location, and habitat type were recorded. In addition, an index of tag status was used to differentiate between detection of live trout and false positives (i.e., tag was no longer in a live trout). Index categories were shed tag (tag located in habitat that would not shelter trout [i.e., dry channel or shallow water with very fine substrate]), possible shed tag (tag located in habitat unlikely to shelter trout), possible live trout (tag located in habitat likely to shelter trout), and live trout (tag location changing). All tags located in redds were tallied.

To illustrate the potential effect of tag loss on annual apparent survival, seasonal apparent survival estimates for the North and South forks of Hinkle Creek were estimated annually (Berger 2007). Apparent survival was corrected by dividing by the true annual tag retention rate. Logistic regressions were used to model

TABLE 1.—Total number of cutthroat trout implanted with PIT tags by catchment and year and corresponding numbers of recaptured and retagged individuals and estimated retention rates.

Catchment	Year and statistic[a]	Recaptured[b]	Retagged	Retention rate
North Fork Hinkle Creek	2004	32	8	0.80
	2005	33	11	0.75
	2006	37	23	0.62
	Mean (CV)			0.72 (13)
South Fork Hinkle Creek	2004	59	22	0.73
	2005	61	30	0.67
	2006	92	24	0.79
	Mean (CV)			0.76 (8)
Camp Creek	2004	195	87	0.69
	2005	216	54	0.80
	Mean (CV)			0.75 (10)
Catchments combined	Mean (CV)	725	259	0.74 (9)

[a] CV = coefficient of variation (100 × SD/mean).
[b] Includes fish that were tagged in all previous years.

the relationship between (1) tag retention rate and fork length, by stream, using recaptured and retagged (tag loss had occurred) fish from 2003 (response variable) and (2) initial length of fish at tagging and duration of tag retention for fish whose tag was located in a redd (predictor variables). The latter group of fish was divided into two categories: tags recovered within 1 year of initial tagging (i.e., one spawning season), and tags recovered greater than 1 year after initial tagging (i.e., more than one spawning season). Due to small sample size, data were combined among sites and years. Model fit was assessed using a maximum likelihood R^2 as a comparative measure (Hintz 2007). All statistical analyses were performed using NCSS and GESS 2007 (Hintz 2007).

Results and Discussion

Tag retention rates observed in this study (Table 1) were approximately 25% lower than estimates commonly reported for juvenile salmonids (Peterson et al. 1994; Ombredane et al. 1998; Gries and Letcher 2002; Zydlewski et al. 2003). Moreover, the range of retention rates observed in this study (0.62–0.80) did not overlap with values from studies with only juvenile salmonids (0.89–1.00). Apparently, tag loss is higher in tagging-groups with a mixture of juvenile and mature wild trout than it is in groups comprising only juveniles. Furthermore, in long-term studies, tagged fish may mature sometime following tag insertion. For example, our results are similar to a double-marking study of adult Arctic grayling *Thymallus arcticus* where PIT tags were injected into the body cavity and annual PIT tag retention rate during a 5-year period was 0.83 (range = 0.74–1.00; Buzby and Deegan 1999).

Retention rates can be affected by differences among tagging crews. Dare (2003) reported that 85% of shed tags came from salmon that were tagged at two tagging stations where personnel turnover rates were high. The remaining station, where personnel remained unchanged throughout the study, accounted for only 16% of shed tags. Despite these differences, however, the overall retention rate was 99.996% (Dare 2003). These findings suggest that, in general, the effect of crew quality on PIT tag retention rate was small relative to the retention rate observed in our study. The fact that field crew turnover rates were low further supports this assumption.

In some headwater populations of cutthroat trout, length has been shown to be a better predictor of sexual maturity than age, especially for females. For example, Downs et al. (1997) found that male westslope cutthroat trout *O. c. lewisi* matured across a wider range of lengths than females. In the current study, 54 PIT tags were found in redds (14, 11, and 29 from North Fork Hinkle, South Fork Hinkle, Camp Creek, respectively). Of the tags located in redds, 41 (76%) were found during the first spawning season following tagging, 12 came from fish during the second spawning season after tagging, and one from a fish during the third posttagging spawning season. Length was a statistically significant predictor of tag retention time for fish whose tags were located in redds ($P = 0.02$). Fish that were 122-mm fork length (≤25th percentile) or shorter at initial tagging were eight times more likely to retain tags through the first spawning season posttagging than fish that were at least 162-mm fork length (≥75th percentile) at initial tagging. Length at tagging explained only a small ($R^2 = 0.18$) proportion of the variation in tag retention time. Presumably, fish length at initial spawning varies substantially in these catchments.

Although the relationship between fish length (recaptured and retagged cutthroat trout tagged in

TABLE 2.—Corrected and uncorrected apparent annual survival estimates for coastal cutthroat trout in main-stem segments of North Fork Hinkle Creek and South Fork Hinkle Creek (2003–2005).

		Apparent annual survival		
Catchment	Year	Uncorrected	Corrected[a]	Difference (%)
North Fork Hinkle Creek	2003	0.39	0.47	19
	2004	0.24	0.31	30
	2005	0.20	0.33	61
South Fork Hinkle Creek	2003	0.39	0.53	35
	2004	0.31	0.46	49
	2005	0.28	0.35	27

[a] Uncorrected rates divided by the true annual tag retention rates.

2003 and recaptured in 2004 only) and tag retention was not statistically significant for the North and South forks of Hinkle Creek ($P > 0.05$), sample sizes were small and variance was high. When data were pooled among catchments, a statistically significant relationship was observed between length and tag retention ($P < 0.01$). Fish with lengths equal to, or below the 25th percentile (140 mm) at recapture were at least 1.4 times more likely to have retained their tags than fish with lengths at or above the 75th percentile (174 mm). The poor fit of the logistic regression model ($R^2 = 0.05$) is probably the result of some unknown portion of mature fish retaining their tag during spawning and because all tag loss may not be associated with spawning. Collectively, results from the comparison of recaptured with retagged fish and data from tags found in redds suggest that larger trout are more likely to shed tags than smaller trout.

The number of PIT tags in redds varied among years and catchments, ranging from a low of 0 in North Fork Hinkle Creek in 2006 to a high of 20 in Camp Creek during 2005. It is apparent, however, that estimates were influenced by sampling dates. For example, the March and June census events were based on calendar dates, not on environmental variables such as water temperature and discharge. Because the ability to identify redds is related to the peak of spawning and to the frequency, magnitude, and timing of spates, the total number of tags expelled during spawning is probably underestimated.

Although few studies have focused on PIT tag retention rates in reproductively active fish, tag loss appears to vary among species, and possibly between genders. Harvey and Campbell (1989) reported 100% retention of PIT tags that were implanted in 22 largemouth bass *Micropterus salmoides* (6 males and 16 females) that subsequently spawned. In a group of 21 male and 60 female Atlantic salmon, Prentice et al. (1990) reported retention rates of 100, 83, and 100% for males, spawning females, and nonspawning females, respectively. Because salmon in their study were hand stripped, it is difficult to extrapolate these results to naturally spawning salmonids; however, it does document that tags can be lost from the body cavity via the vent during egg release. In one sample from the current study (North and South forks of Hinkle Creek, April 2007), four cutthroat trout that lost tags were positively identified as males, suggesting that both sexes can lose tags.

The effects of unidentified tag loss on apparent survival estimates can be important (Pollock et al. 1990). Tag loss imposes a negative bias on survival estimates due to a reduction in marked individuals available for recapture. We observed considerable variation in annual apparent survival among catchment and years, and differences between corrected and uncorrected apparent survival ranged from 19% to 61% (Table 2). These data suggest that comparisons of annual apparent survival among years within an individual catchment or among catchments could be highly biased without correction for variation in tag retention rate. Frequently, managers use tags or marking techniques to monitor fish stocks and estimate vital population-level parameters. However, without adjusting for tag loss (or accounting for tag loss by explicitly incorporating it into the population model itself; Nichols and Hines 1993), the potential to underestimate survival increases.

The current study suggests that PIT tag loss for tagging-groups composed of both juvenile and adult trout is greater than it is for juvenile trout alone. It is still unclear, however, whether there is a strong gender bias associated with tag loss. Because movement, growth, and survival in salmonids often differ between males and females, tag retention rates also may be related to gender. Although individual coastal cutthroat trout retained PIT tags for up to 4 years after tagging, some individuals were implanted with a minimum of three different PIT tags over the same period.

We documented PIT tag retention rates that are lower than those previously reported and have shown that some portion of tag loss is associated with spawning. Undoubtedly, there are other causes of tag loss in wild populations. For example, Swanberg (1997) documented a case where radio tags were expelled through the body wall of bull trout *Salvelinus confluentus*; to our knowledge, this phenomena has not been documented with PIT tags. Collectively, these results suggest that regardless of cause, in cases where retention rates can influence the results of a study (e.g., estimation of survival and abundance), it may be prudent to consider double-marking when PIT tags are to be inserted in the body cavity of trout and to monitor retention rates at the appropriate temporal scale.

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References

Bateman, D. S., and R. E. Gresswell. 2006. Survival and growth of age-0 steelhead after surgical implantation of 23-mm passive integrated transponders. North American Journal of Fisheries Management 26:545–550.

Bateman, D. S., R. E. Gresswell, and C. E. Torgersen. 2005. Evaluating single-pass catch as a tool for identifying spatial pattern in fish distribution. Journal of Freshwater Ecology 20:335–346.

Berger, A. M. 2007. Patterns of coastal cutthroat trout survival in two headwater stream networks. Master's thesis. Oregon State University, Corvallis.

BLM (Bureau of Land Management). 1995. Mill Creek watershed analysis. BLM, Coos Bay, Oregon.

Buzby, K., and L. Deegan. 1999. Retention of anchor and passive integrated transponder tags by arctic grayling. North American Journal of Fisheries Management 19:1147–1150.

Dare, M. R. 2003. Mortality and long-term retention of passive integrated transponder tags by spring Chinook salmon. North American Journal of Fisheries Management 23:1015–1019.

Downs, C. C., R. G. White, and B. B. Shepard. 1997. Age at sexual maturity, sex ratio, fecundity, and longevity of isolated headwater populations of westslope cutthroat trout. North American Journal of Fisheries Management 17:85–92.

Gresswell, R. E., and S. R. Hendricks. 2007. Population-scale movement of coastal cutthroat trout in a naturally isolated stream network. Transactions of the American Fisheries Society 136:238–253.

Gries, G., and B. Letcher. 2002. Tag retention and survival of age-0 Atlantic salmon following surgical implantation with passive integrated transponder tags. North American Journal of Fisheries Management 22:219–222.

Harvey, W. D., and D. L. Campbell. 1989. Retention of passive integrated transponder tags in largemouth bass brood fish. Progressive Fish-Culturist 51:164–166.

Hintz, J. 2007. NCSS 2007. NCSS, Kaysville, Utah.

Meacham, J. E., and E. B. Steiner. 2002. Atlas of Oregon (CD-ROM). University of Oregon Press, Eugene.

Nichols, J. D., and J. E. Hines. 1993. Survival rate estimation in the presence of tag loss using joint analysis of capture–recapture and resighting data. Pages 229–243 *in* J. D. Lebreton and P. M. North, editors. Marked individuals in the study of bird populations. Birkhäuser Verlag, Basel, Switzerland.

Ombredane, D., J. Bagliniere, and F. Marchand. 1998. The effects of passive integrated transponder tags on survival and growth of juvenile brown trout (*Salmo trutta* L.) and their use for studying movement in a small river. Hydrobiologia 371:99–106.

Peterson, P., E. Prentice, and T. Quinn. 1994. Comparison of sequential coded wire and passive integrated transponder tags for assessing overwinter growth and survival of juvenile coho salmon. North American Journal of Fisheries Management 14:870–873.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference or capture–recapture experiments. Wildlife Monographs 107.

Prentice, E., T. Flagg, and C. McCutcheon. 1990. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. Pages 317–322 *in* N. Parker, A. Giorgi, R. Heidinger, D. Jester, E. Prince, and G. Winans, editors. Fish-marking techniques. American Fisheries Society, Symposium 7, Bethesda, Maryland.

Swanberg, T. R. 1997. Movements of and habitat use by fluvial bull trout in the Blackfoot River, Montana. Transactions of the American Fisheries Society 126:735–746.

Zydlewski, G., A. Haro, G. Whalen, and D. McCormick. 2001. Performance of stationary and portable passive transponder detection systems for monitoring of fish movements. Journal of Fish Biology 58:1471–1475.

Zydlewski, G., G. Horton, T. Dubreuil, B. Letcher, S. Casey, and J. Zydlewski. 2006. Remote monitoring of fish in small streams: a unified approach using PIT tags. Fisheries 31:492–502.

Zydlewski, G., C. Winter, E. McClanahan, J. Johnson, and J. Zydlewski. 2003. Evaluation of fish movements, migration patterns, and population abundance with stream width PIT tag interrogation systems. Bonneville Power Administration, Report 00005464, Portland, Oregon.