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MANAGEMENT BRIEF

Relying on Fin Erosion to Identify Hatchery-Reared Brown Trout in a Tennessee River

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Abstract
Hatchery-induced fin erosion can be used to identify recently stocked catchable-size brown trout *Salmo trutta* during annual surveys to qualitatively estimate contributions to a fishery. However, little is known about the longevity of this mark and its effectiveness as a short-term (≤1 year) mass-marking technique. We evaluated hatchery-induced pectoral fin erosion as a mass-marking technique for short-term stocking evaluations by stocking microtagged brown trout in a tailwater and repeatedly sampling those fish to observe and measure their pectoral fins. At Dale Hollow National Fish Hatchery, 99.1% (228 of 230) of microtagged brown trout in outdoor concrete raceways had eroded pectoral fins 1 d prior to stocking. Between 34 and 68 microtagged and 26–35 wild brown trout were collected during eight subsequent electrofishing samples. In a blind test based on visual examination of pectoral fins at up to 322 d poststocking, one observer correctly identified 91.7% to 100.0% (mean of 96.9%) of microtagged brown trout prior to checking for microtags. In the laboratory, pectoral fin length and width measurements were recorded to statistically compare the fin measurements of wild and microtagged hatchery brown trout. With only one exception, all pectoral fin measurements on each date averaged significantly larger for wild trout than for microtagged brown trout. Based on the number of pectoral fin measurements falling below 95% prediction intervals, 93.7% (148 of 158) of microtagged trout were correctly identified as hatchery fish based on regression models up to 160 d poststocking. Only 72.2% (70 of 97) of microtagged trout were identified correctly after 160 d based on pectoral fin measurements and the regression models. We concluded that visual examination of pectoral fin erosion was a very effective way to identify stocked brown trout for up to 322 d poststocking.

Many hatchery-reared catchable-size (i.e., >200 mm total length [TL]) trout have parts of one or both pectoral fins missing due to the degenerative disease known as fin rot (e.g., fin erosion; Heimer et. al 1985). Fin erosion in hatchery environments begins with damage to the epidermis and has been correlated with fish density, water temperature, raceway substrate and design, feed rate, alkalinity, and ammonia levels (Bosakowski and Wagner 1994a; Winfree et al. 1998; Arndt et al. 2001). Fin erosion has concerned hatchery managers for many years because it provides a site for bacterial infection (Schneider and Nicholson 1980) and can reduce survival and increase production costs. Therefore, much attention has been focused on improving hatchery raceway conditions in large-scale culture operations in an effort to increase trout aesthetics and reduce microbial infection and hemorrhage of released trout (Bosakowski and Wagner 1995; Arndt et al. 2002; Latremouille 2003). Unfortunately, modifications to large-scale production facilities that might improve fin condition are often not practical (Arndt et al. 2001). Until substantial improvements at many state and federal hatcheries are addressed, many catchable-size trout stocked into rivers and streams across the USA are inadvertently marked by excessive fin erosion.

Fisheries managers often capitalize on this as a way to identify recently stocked catchable-size trout during annual surveys. This approach provides fisheries managers with cursory data on stocking contribution and cohort survival and is an attractive alternative to marking large quantities of fish using traditional marking methods. However, the practice of using hatchery-induced fin erosion as a mark for fisheries assessments (i.e., quantitative or qualitative) has not been adequately described in the literature (e.g., detectability and longevity of mark). The primary assumption of any tag or mark is that fish retain their

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mark and the mark can be recognized (Guy et al. 1996). A study that evaluated partial fin clips found that fins regenerated to their original length in about a year, but were still characteristically deformed (Stuart 1958). The inability to detect an eroded fin due to partial or complete regeneration would seriously compromise fisheries evaluations, especially those that are attempting to evaluate the success of stocking programs. In other evaluations, it may be important that the mark does not affect fish behavior (e.g., survival or growth). Although hatchery-induced fin erosion may be aesthetically displeasing to anglers and provide a site for bacterial infection, evidence that fin erosion directly influences trout performance in the wild is lacking. Heimer et al. (1985) investigated the effect of hatchery-induced pectoral fin erosion on rainbow trout *Oncorhynchus mykiss* performance in the wild and observed no difference in the growth, survival, or movement of stocked trout with or without pectoral fins. It is important to estimate rates of fin regeneration by eroded fins and detectability prior to any evaluation using fin erosion as a primary fish mark. No studies have evaluated how long it takes for an eroded fin to regenerate. Therefore, the objective of this study was to determine the effectiveness of using hatchery-induced pectoral fin erosion to identify stocked brown trout *Salmo trutta* during a short-term (≤1 year) stocking evaluation in a Tennessee river.

METHODS

All brown trout used in this study were hatched and reared at the Dale Hollow National Fish Hatchery, a large federal hatchery that produces about 1.3 million salmonids annually. Fry and fingerling brown trout were kept in indoor concrete raceways until they averaged 1,100–1,320 fish/kg (40–50 mm total length [TL]). Fish then were transferred to two outdoor concrete raceways (30 × 2.4 m, water depth = 0.5 m) with low (2 cm/s) water velocity and fed a dry pellet diet 3–5 times daily. The hatchery is supplied by water pulled from the hypolimnion of Dale Hollow Lake where the water temperature fluctuates annually between 4°C and 16°C. Water passes through packed columns before entering the raceways, which ensures oxygen saturation. It takes on average 16 months to rear a brown trout to stocking size (≥229 mm TL). On 14–15 November 2002, uncoded wire microtags (1.5 mm long) were injected into the nape of 23,655 brown trout using Mark IV Automatic Tag Injectors (Northwest Marine Technology, Inc., Olympia, Washington). A subsample of 187 brown trout was examined for tag retention 98 d after tagging. On 21 April 2003, less than 2 d before stocking, 230 brown trout were indiscriminantly selected and TLs, weights (g), and pectoral fin erosion scores (marked or unmarked; one observer) were recorded. Both pectoral fins were observed and a fish was scored as "marked" if either fin exhibited one or more of the following traits: curled or frayed posterior pectoral fin rays, shortened pectoral fin rays, or complete fin removal at the point of attachment with the pectoral girdle. Fish were scored as "unmarked" if neither pectoral fin exhibited those traits.

On 22–23 April 2003, we stocked 18,054 microtagged brown trout into the South Fork of the Holston River in east Tennessee; the remaining microtagged fish were stocked into other rivers. Dissolved oxygen concentrations, water temperatures, and habitat in this tailwater below South Holston Dam are conducive for trout survival and reproduction (Bettoli et al. 1999; Banks and Bettoli 2000). In the late 1990s about 15–55% of the brown trout population (160–250 mm TL) in the tailwater was presumed to be wild (Bettoli et al. 1999). Through the late 1990s the Tennessee Wildlife Resource Agency annually stocked catchable or fingerling brown trout, or both, into the tailwater.

Brown trout were sampled on eight occasions between May 2003 and March 2004 using a 4.9-m tunnel-hull johnboat powered by a jet-drive outboard motor and equipped with a Smith-Root Model GPP 2.5 DC electrofishing system. Captured brown trout were placed in an aerated live well and anaesthetized using carbon dioxide before their TLs and weights were recorded. Prior to checking for microtags, both pectoral fins were observed, and fish were scored as marked or unmarked using the criteria previously mentioned. A fish was known to be stocked if a microtag was subsequently detected via a Northwest Marine Technology detection wand. The number of fish visually scored as having marked pectoral fins but no microtag was also recorded.

During each sampling event a random subsample of both microtagged and presumed wild brown trout of similar sizes were sacrificed with MS-222 (tricaine methanesulfonate) overdoses and put on ice. The observed lengths of microtagged brown trout dictated the sizes of wild fish retained. In the laboratory, TLs and weights were recorded from all sacrificed brown trout. Both pectoral fins were removed from the point of attachment with the girdle and the maximum length and width (mm) of each pectoral fin were recorded. One investigator made all fin measurements to reduce experimental error. To compare regeneration and extent of fin wear, pectoral fin length measurements for hatchery and wild fish were divided by TL and then multiplied by 100 to obtain relative fin lengths (Kindschi 1987; Bosakowski and Wagner 1994b). Mean relative fin length (right and left), pectoral fin length and width (right and left), and TL were compared between hatchery and wild brown trout for each sampling event via *t*-tests ($\alpha = 0.05$). Approximate *t*-tests and Satterthwaite's approximation for degrees of freedom (SAS 2001) were used if the folded form of the *F*-statistic indicated heterogeneous variances ($P < 0.05$). In instances where mean TLs of tagged and wild brown trout in a sample were dissimilar ($P < 0.05$), fin measurements (pectoral fin length or width) were not compared.

Simple linear regression models were developed to relate pectoral fin lengths and widths of wild brown trout (right and left; dependent variables) to TL (independent variable); 95% prediction intervals were calculated for each pectoral fin length and width measurement (Bosakowski and Wagner 1994b). We considered any observation with a studentized residual that exceeded ± 3 to be a recording error and deleted it. Scatterplots

TABLE 1. Number, mean total length, and right (R) and left (L) fin characteristics at 8–322 d poststocking of hatchery (H) and wild (W) brown trout collected from the South Fork of the Holston River between 8 and 322 d poststocking. Different letters denote significant differences between hatchery and wild fish ($P < 0.05$) for that given metric and sample day. Fin measurements of the two groups were not compared for fish collected 104 d poststocking because mean lengths differed significantly.

	Days poststocking							
Origin	8	41	71	104	160	223	259	322
Number of trout subsampled								
H	32	30	30	30	36	33	34	30
W	27	28	29	31	26	27	35	30
Mean total length (mm)								
H	190 z	192 z	207 z	218 z	253 z	265 z	269 z	290 z
W	184 z	201 z	205 z	232 y	257 z	275 z	261 z	292 z
Mean pectoral fin length (R)								
H	19.6 z	20.0 z	24.0 z	20.7	27.8 z	32.6 z	34.4 z	35.4 z
W	26.8 y	28.3 y	28.9 y	31.5	35.8 y	40.8 y	37.7 y	41.8 y
Mean pectoral fin length (L)								
H	18.3 z	16.1 z	19.8 z	16.7	24.4 z	30.7 z	29.3 z	31.6 z
W	26.9 y	28.1 y	29.0 y	31.4	35.8 y	40.9 y	37.4 y	41.7 y
Mean pectoral fin width (R)								
H	18.0 z	18.3 z	18.3 z	20.0	23.7 z	26.5 z	26.1 z	28.0 z
W	21.4 y	23.1 y	22.3 y	24.0	26.7 y	31.3 y	28.5 z	31.2 y
Mean pectoral fin width (L)								
H	16.4 z	16.3 z	15.9 z	18.4	20.2 z	23.5 z	22.5 z	24.4 z
W	21.4 y	23.2 y	22.0 y	24.2	26.5 y	31.4 y	28.1 y	31.4 y
Mean relative fin length (R)								
H	10.3 z	10.4 z	11.6 z	9.4 z	11.0 z	12.3 z	12.8 z	12.2 z
W	14.6 y	14.1 y	14.1 y	13.6 y	13.9 y	14.9 y	14.4 y	14.3 y
Mean relative fin length (L)								
H	9.6 z	8.4 z	9.5 z	7.8 z	9.7 z	11.5 z	10.9 z	11.0 z
W	14.7 y	14.0 y	14.1 y	13.5 y	14.0 y	14.9 y	14.3 y	14.3 y

of pectoral fin lengths and widths versus TL for all microtagged brown trout were overlaid on the regression curves of wild brown trout for each pectoral fin measurement. Brown trout were classified as marked if at least one pectoral fin measurement fell outside (below) the 95% prediction interval for that measurement. Deviations of hatchery fish fin lengths and widths versus TL from 95% prediction intervals for wild fish were quantified to: (1) evaluate the longevity of the mark using quantitative methods, (2) compare the degree of fin erosion between left and right pectoral fins, and (3) validate our visual observations of pectoral fin scores. We used the chi-square test of independence ($\alpha = 0.05$) to evaluate the difference in pectoral fin measurements (left, right, length, and width) that fell within or outside the 95% prediction interval over 322 d. Chi-square tests were also used to test for differences between fish scored as marked or unmarked via visual pectoral fin observation and pectoral fin measurements.

RESULTS

Nearly all of the brown trout (96.3%; 180 of 187) retained their microtags after 98 d in the hatchery. Erosion of at least one pectoral fin was evident in 228 of 230 (99.1%) brown trout (mean TL = 182 mm) subsampled the day before fish were stocked. During each tailwater sampling event, 34–68 microtagged brown trout (total, 442; subsample, 255) were collected, spanning 8 to 322 d poststocking (Table 1). Based on visual examination of pectoral fins, one observer correctly identified 91.7–100.0% (mean of 96.9%, SE = 0.80) of microtagged brown trout covering up to 322 d poststocking (Figure 1).

On each sampling event, 30–36 microtagged and 26–35 wild brown trout (i.e., the subsample target was $30\pm$) were sacrificed for pectoral fin measurements (Table 1). The mean TLs of microtagged and wild brown trout 104 d poststocking differed ($t = -2.78$, df = 49, $P < 0.01$); therefore, pectoral fin length and width measurements on that date were not compared. Mean TLs of microtagged and wild brown trout were similar ($t < \pm 1.55$, df > 38, $P > 0.12$) all other dates. With only one exception, pectoral fin measurements were larger on average for wild brown trout than microtagged brown trout ($t \geq -2.20$, pooled df ≥ 31.3, $P \leq 0.03$). Mean widths of the right pectoral fin at 259 d poststocking did not differ ($t < -1.78$, pooled df = 67, $P = 0.08$; Table 1).

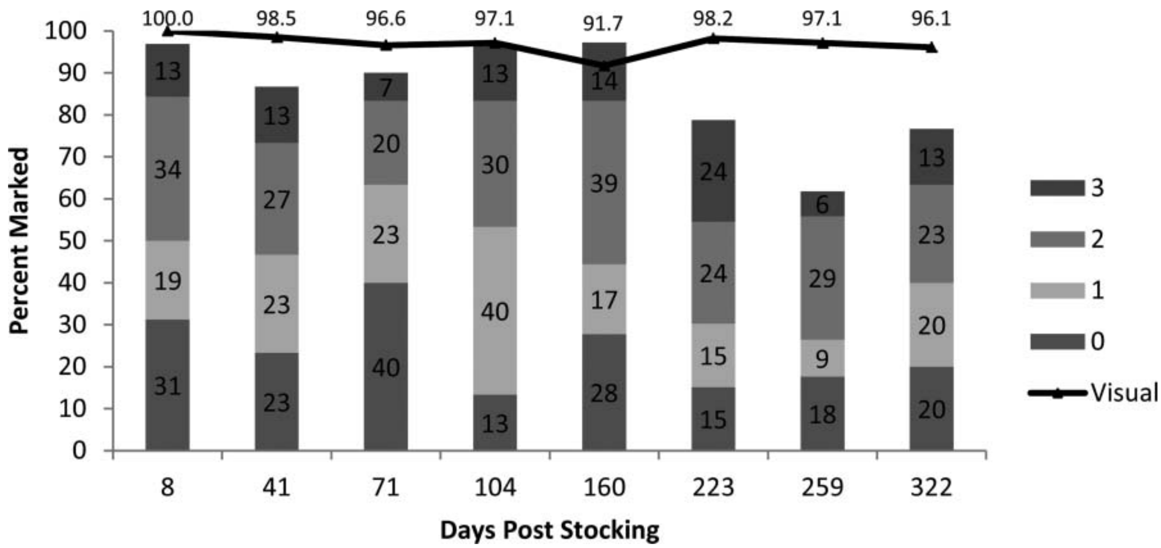

FIGURE 1. Percent of recaptured microtagged brown trout scored as marked using visual observation of the pectoral fins (line) versus percent scored as marked because at least one measured fin characteristic (right pectoral fin length or width, left pectoral fin length or width) fell below the 95% prediction interval obtained from a sample of similar-sized wild brown trout at 8–322 d poststocking. Trout were scored as unmarked if all four pectoral fin measurements were within the 95% prediction interval. Legend scores (0–3) refer to number of fins of recaptured fish that were characteristic of wild fish.

Not surprisingly, pectoral fin lengths and widths varied directly with the TL of wild brown trout ($P = < 0.0001$; Table 2; Figure 2). Fin or total length measurements of four wild brown trout were identified as outliers in at least one of the four regression equations; therefore, all data from those fish were removed from all regression modeling. Overall, most (85.4%) microtagged brown trout over the entire 322-d study were identified correctly because at least one of their pectoral fin measurements fell below 95% prediction intervals of wild brown trout; 72.5% had at least two measurements below the 95% prediction intervals (Figure 2). Most (93.7%) of the 158 microtagged brown trout examined at up to 160 d poststocking would have been correctly identified as hatchery fish because their pectoral fin measurements fell below 95% prediction intervals (Figure 1). However, beyond 160 d poststocking, only 72.2% (70 of 97) would have been correctly identified as hatchery fish based on their pectoral fin measurements.

Visual examination of the pectoral fins was the most effective way to identify stocked brown trout over the entire 322-d study ($\chi^2 = 31.68$, df = 1, $P < 0.0001$). However, at up to 160 d poststocking, pectoral fin measurements and the 95% prediction interval were as effective as visual examination of the pectoral fin (Figure 1; $\chi^2 = 2.27$, df = 1, $P = 0.13$). Past 160 d, 97.1% (136 of 140) of hatchery brown trout were correctly identified using visual examination of the pectoral fins, whereas only 72.2% (70 of 97) of hatchery brown trout were identified using fin measurements and the 95% prediction interval (Figure 1). All fin measurements for 37 fish fell within 95% prediction intervals, and they were classified as wild fish based on the regression models. However, visual examination of the pectoral fins of 83.7% (31 of those 37 fish) revealed abnormal fins, and those fish were subsequently scored as hatchery fish. Over the 322-d study, 85.7% (6 of 7) of the microtagged brown trout that were visually identified as wild trout had all fin measurements within the 95% prediction interval. Fourteen brown trout were visually identified as hatchery fish but lacked a microtag.

Left pectoral fin length was the best single pectoral fin measurement that correctly identified hatchery brown trout (i.e., 74.9% correctly identified over the entire study using that fin measurement; $\chi^2 \geq 12.27$, df = 1, $P \leq 0.0005$). Other pectoral fin measurements did not perform as well in identifying stocked brown trout over the entire study (37.6–60.4% correctly identified). There were no significant differences in the ability to correctly identify hatchery brown trout using the right pectoral fin length or left pectoral fin width measurements ($\chi^2 = 3.19$, df = 1, $P = 0.07$). The right pectoral fin width measurement was the worst fin measurement to identify hatchery brown trout ($\chi^2 \geq 11.44$, df = 1, $P \leq 0.0007$).

TABLE 2. Linear regression statistics relating pectoral fin measurements of 229 wild brown trout to total length (147–353 mm).

Pectoral fin	Measurement	Slope	y-intercept	r^2	P
Right	Length	0.14	0.15	0.90	<0.0001
	Width	0.10	2.14	0.81	<0.0001
Left	Length	0.14	0.02	0.90	<0.0001
	Width	0.10	1.92	0.82	<0.0001

DISCUSSION

Visual examination of pectoral fins was a quicker, more accurate technique to distinguish hatchery from wild brown trout than were regression models relating pectoral fin lengths and

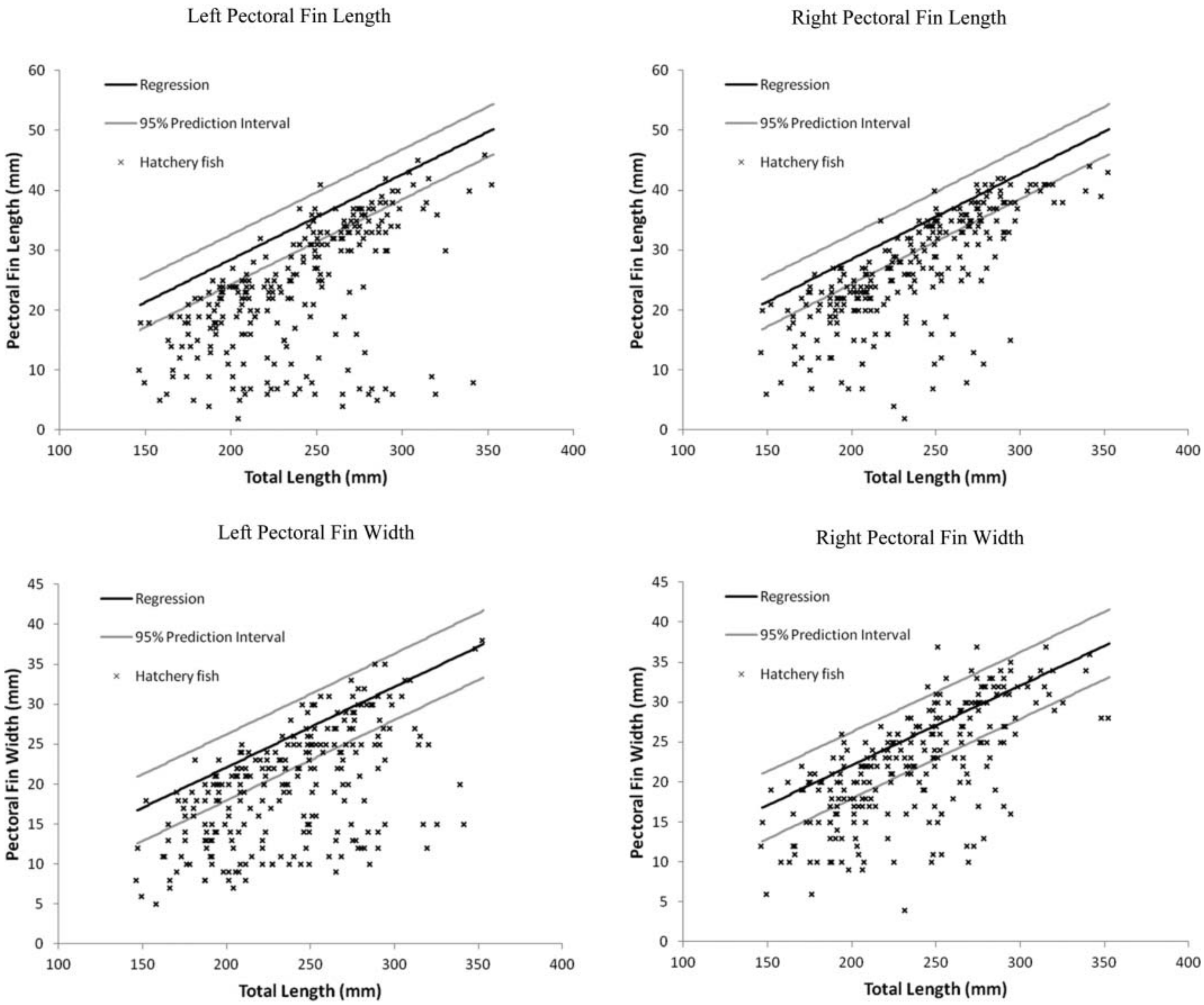

FIGURE 2. Scatterplot of right and left pectoral fin length and width measurements versus total length for 255 microtagged brown trout recaptured at up to 322 d poststocking in the South Fork of the Holston River, Tennessee. The linear regression models (with 95% prediction intervals) relate pectoral fin measurements to total length of 229 wild brown trout in the same river.

widths to fish TL. Our results support the practice of relying on the visual characteristics of pectoral fins to identify stocked brown trout from Dale Hollow National Fish Hatchery in short-term studies (<322 d). However, the degree of fin erosion depends on specific raceway conditions, rearing densities, water quality, and the duration of the grow-out phase, all of which are hatchery-specific. Thus, detectability of the inadvertent fin erosion "mark" may vary among hatcheries, and the fins of a subsample of brown trout should be scored prior to any stocking evaluation that will use fin erosion as a short-term (≤1 year) mark. Managers who want to evaluate fin damage should consider methods to rank fin erosion similar to the procedure used by Person-Le Ruyet et al. (2007). We did not rank the degree of fin erosion because we were only interested in whether or not the mark (i.e., fin erosion) was detectable and assessing the degree of fin damage was outside of scope of this project. However, our measurements of pectoral fin length, expressed as relative fin length, provide managers with a baseline indicator of whether or not visual observation may be an effective short-term mark for brown trout stocked at 190–292 mm TL. For example, in hatcheries where the degree of fin erosion is unknown, pectoral fin length measurements could easily be obtained from a sample of fish and converted to represent relative fin length. If mean relative fin length measurements were between 7.8 and 12.8 (range of mean relative fin length measurements we observed for hatchery fish at 8–322 d poststocking), fin erosion may be an effective short-term mark for brown trout stocked from their hatchery. Fish with relative fin length measurements ≤12.8 would be easily identified as hatchery fish because all sizes (184–292 mm TL) of wild brown in our study had mean relative fin length measurements that exceeded 13.5. Because we observed significant differences in pectoral fin length and width for hatchery brown trout throughout the study, we suggest both left and right pectoral fin length be recorded prior to stocking. Note that the relative fin lengths we reported for hatchery and wild brown trout, as well as regression models and 95% prediction intervals, were probably very accurate because all fin measurements were made in the laboratory.

Fin regeneration concerns researchers because individuals that regenerate removed fins will confound stocking evaluations and age validation research. Regeneration of fins afflicted with fin rot has not been adequately described in the literature. Studies that evaluated regeneration of clipped fins (including adipose fins) concluded that fins usually do not regenerate when they are removed at the point of attachment to the bone (Stuart 1958; Eipper and Forney 1965) or if fully clipped (adipose fins; Thompson and Blankenship 1997). We did not record the severity of fin erosion prior to stocking; thus, we cannot estimate the number of trout that might have been marked permanently via complete removal of the fin. However, even after 322 d poststocking, visual examination of the pectoral fin to identify hatchery fish was still possible for 96.1% of hatchery fish, which suggested that substantial fin regeneration had not occurred. Our regression models were more sensitive to fin regeneration, and regeneration became problematic after 160 d poststocking, which suggested that most of our brown trout had fin erosion similar to a partial fin clip. Stuart (1958) reported that brown trout are able to regenerate partial pectoral fin clips to nearly their original length within a year, but those same fins were characteristically deformed throughout their life. Churchill (1963) also found that even when fish regenerated clipped fins, they were easily recognized in subsequent samples due to fin deformities during the regeneration process. Those findings may explain why we incorrectly identified many hatchery brown trout based on fin measurements, but correctly identified most of those fish via visual observation, even at 322 d poststocking.

We were able to correctly identify 96.9% of hatchery trout based on visual examination over the 322-d study and identification rates were always above 91%. Fourteen brown trout were classified as hatchery brown trout but lacked a microtag. Since microtag retention was not 100%, we expected to encounter some hatchery fish that did not have a microtag. These fish were not included in the analysis as being marked but verified the potential for using fin erosion as a secondary mark. In our study, 96.3% of brown trout retained their microtag in the hatchery after 98 d. Our estimate of tag retention based off the recaptures of untagged fish that had evidence of fin erosion was nearly identical to the initial 96.9% tag retention rate (442 of 456). Visual examination of pectoral fins was much better than using regression models and prediction intervals (85.4% success rate) and was faster and less expensive. A combination of visual examination and pectoral fin measurements could be used to determine origins of sampled fish; however, using visual observation of the pectoral fin alone resulted in high identification rates suitable for many fisheries evaluations. The additional time and effort to remove and measure pectoral fins and the low detectability after 160 d restricted pragmatic use of regression models and prediction intervals to identify stocked brown trout. We conclude that visual examination of pectoral fin erosion is an effective way to assess short-term stocking contributions of brown trout reared at the Dale Hollow National Fish Hatchery and stocked into Tennessee rivers.

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