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MANAGEMENT BRIEF

Evaluation of Visible Implant Elastomer Tags in Wild Coastal Cutthroat Trout in the Marine Environment

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Abstract

We evaluated the detectability of visible implant elastomer (VIE) tags in Coastal Cutthroat Trout *Oncorynchus clarkii clarkii* in the marine environment by comparing visually identified recaptures from VIE tags with known recaptures that were identified through genotype matching. A total of 89 individual Coastal Cutthroat Trout were marked in the lower jaw with colored VIE tags, sampled for genetics, and recaptured across 12 months in 2015. The rate of correspondence between the VIE tags and genetic matches was 92% (82/89) of the recaptured Coastal Cutthroat Trout in the nearshore marine environment. We found that red- and blue-colored VIE tags were detected at a higher rate (100%) than were yellow- and orange-colored tags (87.3% and 90.6%, respectively). In contrast, tag type (single or double), tag location (left or right), fish length (FL, mm), and time (days) since tagging had no effect on tag detectability during the study period. All of the tag colors were recovered for the maximum life of the study (up to 342 days). In all of the cases of nondetections (5/89), the tags were not identified upon initial recapture or subsequent capture events, suggesting that they were lost or not visible immediately upon insertion in the field—as opposed to being unidentified due to the degradation of tag detectability over time. The results of this study suggest that VIE tags have the potential to be detectable in juvenile and adult Coastal Cutthroat Trout for at least 12 months after insertion, with blue and red performing the best. Additional monitoring extending beyond 12 months after tagging would be necessary to identify the maximum life of VIE tags.

The marking or tagging of fish is an important tool in fisheries research and management, and this practice has aided in acquiring information on growth, survival, abundance, and movement across various life stages. Depending on the study objectives, researchers must consider a range of factors that are associated with tagging fish, such as its effects on subject survival, growth, and behavior, as well as practical constraints such as mark detectability, application efficiency, and cost (McFarlane et al. 1990; Nielsen and Johnson 1983). Historically, external tags (e.g., anchors, disks, etc.) have been the most widely used, as they offer the advantage of detection without dissection and can be enumerated easily without specialized equipment (Nielsen and Johnson 1983). However, the relatively

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invasive application procedure has been associated with increased mortality (Carline and Brynildson 1972; McAllister et al. 1992) and reduced growth (Warner 1971). Internal tags leave little to no material exposed to the natural environment and are associated with reduced stress relative to external tags (Hale and Gray 1998; Nielsen and Johnson 1983). However, the most common internal tags, such as coded wire and passive integrated transponder (PIT) tags rely on specialized equipment and/or removal for identification. For studies operating on a small budget where limited to no mortality is a desired outcome, a tagging method is needed that causes minimal harm and can be visually detected.

A visible implant elastomer (VIE) is a colored internal tag, applied subcutaneously, that can be externally detected by the naked eye (Northwest Marine Technology 2020). Visible implant elastomer tags offer many of the advantages of external and internal identification methods but at a relatively low cost, with greater application speed, and with little to no negative biological effects (Bailey et al. 1998; Fitzgerald et al. 2004). Previous studies evaluating VIEs in *Salmo* and *Oncorhynchus* spp. have validated the rates for tag retention (>95%) and detection (>90%) (Blankenship and Tipping 1993; Bonneau et al. 1995; Fitzgerald et al. 2004; Hale and Gray 1998). However, these and other tag studies have occurred in closed or controlled marine environments with hatchery-reared fish or spanned a duration of no more than several months. Furthermore, no study of this kind has been conducted using Coastal Cutthroat Trout *Oncorhynchus clarkii clarkii* as the study species.

Coastal Cutthroat Trout occupy a diverse range of habitats throughout their life including freshwater, estuarine, and marine environments but maintain a relatively small home range, making them an ideal candidate for mark–recapture-based tagging studies (Losee et al. 2017; Moore et al. 2010). The objective of our study was to evaluate the retention and detectability of VIEs on wild Coastal Cutthroat Trout that were released and recovered in south Puget Sound over 12 months.

METHODS

Sample collection.— Coastal Cutthroat Trout were marked and recaptured at a northwest-facing beach on the southeast shore of Eld Inlet in Thurston County, Washington (47.08°, −122.98°; Figure 1), during daylight hours. The sampling events occurred monthly from January through December 2015, with two events in March, for a total of 13 sampling events (Table 1). The fish were collected in the nearshore with a straight beach seine that was 36 m in length and constructed of uniform 3.2-mm mesh, with asymmetrical tapering of 3.7 to 1.6 m in wing depth. Beach seines allow for rapid sampling, where fish are obtained live and with minimal trauma (Zale et al. 2013).

Fish tagging.— After being anesthetized in a solution of tricaine methane sulfonate (MS-222) at a concentration of approximately 100 mg/L, the Coastal Cutthroat Trout were marked by using VIE tags (Northwest Marine Technology 2020). The two-part elastomer material was mixed and applied using a 29-gauge hypodermic needle. The needle that is inserted into the fish creates a 3–5-mm track in the tissue that is then filled with elastomer. All of the fish were tagged in the transparent tissue of the lower anterior jaw. This tagging location is novel for Coastal Cutthroat Trout and was chosen because the tissue color at this location (white) contrasts well with the VIE color palette and is consistent across age and sex for this species (Figure 2). At each sampling event, a unique batch–tag combination was applied to all of the fish and distinguished by color (yellow, orange, red, or blue), location (right or left; Figure 2; Table 1) and type (double or single). For example, the batch–tag combination that was applied during the January sample event was single yellow left (SYL). "Double-tagged" fish received two tags, less than 10 mm apart running parallel to one another (Figure 2B). Every fish that was captured was tagged at every event regardless of preexisting tags, and thereby they could show a pattern of 11 potential batch–tag combinations given that two sampling events occurred in March and no Coastal Cutthroat Trout were caught in June. For each fish, the presence and description (type, color, and location) of previous tags and length (cm) were recorded.

For the genetic component of this study, caudal fin clips were collected from each fish. All of the fish were transferred to a nonmedicated holding tank for a recovery period of greater than 10 minutes before release. Recaptures of the same fish were identified by genetic analysis; samples with matching genotypes were assumed to be from the same individual. This allowed for the evaluation of tag retention of known tagged fish through the life of the study. The genetic samples were processed at the Washington Department of Fish and Wildlife Molecular Genetics Lab consistent with the methods that are described in (Losee et al. 2017). Genotyping errors may cause mismatches in repeated samples from the same individual. To account for genotyping errors, matching genotypes were identified by using the maximum-likelihood algorithms in COLONY v2.0.6.1 (Wang 2016).

Statistical analysis.— Because this study focused on fish that were not in captivity, we could only assess tag retention on fish that were recaptured in subsequent sampling events. Each genetically identified recapture provided the opportunity to verify any elastomer tags that were associated with previous sampling events. Therefore, if a unique fish was captured and tagged four times, we would

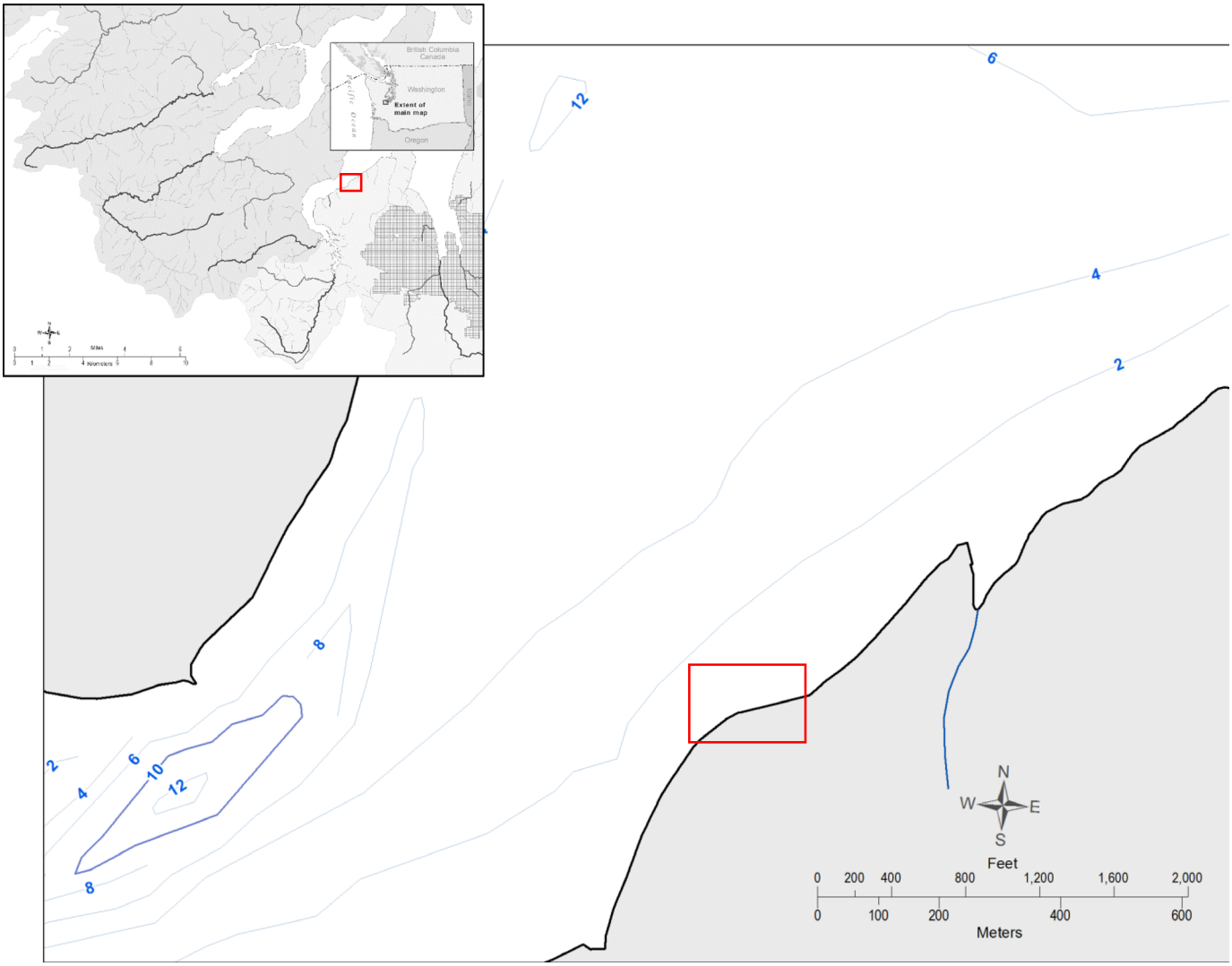

FIGURE 1. Location of monthly sampling of Coastal Cutthroat Trout at Evergreen Beach in Eld Inlet, Thurston County, Washington.

genetically verify every tag at all four events. We defined recaptures as fish that were sampled with matching genotypes (i.e., the same individual) across multiple sampling events. Recapture rate (%), defined as "detectability," was calculated as the proportion of the genetically identified recaptures that was also visually identified via VIE tags.

We compared the detectability at initial recapture with several variables that have been shown to affect tag visibility and retention: color (red, blue, yellow, and orange), location (left versus right side), type (single versus double), and time since tagging (in 50-day bins; Fitzgerald et al. 2004; Hale and Gray 1998). An *F*-test for equality of variance was conducted to determine the need for transformations. A factorial ANOVA was used to test for any effects of color, type (single versus double), and days since initial tagging on the rate of detection at initial recapture, using R statistical software (R Development Core Team 2018). We were also interested in whether our team of all right-handed taggers was more successful by tagging on one side of the fish or the other. To test for differences in the proportion of detected versus undetected tags between tags that were inserted on the left versus the right side of jaw (location), we used a chi-square test.

RESULTS

Thirteen sampling events occurred over 342 days from January 2015 to December 2015. A total of 385 fish were captured, tagged, and genetically sampled over the course of our study (Table 1). The mean catch per sampling event was 32.0 ± 23.2 fish (mean $\pm$ SD) and ranged from a minimum of zero fish captured in June to 89 fish captured in February. The fork length of the tagged fish ranged from 129 to 416 mm (297 ± 68.9; Figure 3).

TABLE 1. Summary of elastomer tags implanted in Coastal Cutthroat Trout in 2015 in Eld Inlet, Washington. The table shows the number of VIE tags that were implanted, the total number recaptured, and the detection rate (%) of the recaptured tags.

Date	Type	Color	Side	Tagged (*n*)	Recaptured (*n*)	Detection rate (%)
Jan 15	Single	Yellow	Left	28	12	91.7
Feb 26	Single	Orange	Left	89	24	100.0
Mar 24	Single	Red	Right	52	20	100.0
Mar 26	Single	Blue	Right	25	12	100.0
Apr 22	Double	Orange	Right	21	5	80.0
May 20	Double	Blue	Left	49	5	100.0
Jul 21	Single	Orange	Right	12	2	0.0
Aug 17	Single	Yellow	Right	30	2	50.0
Sep 16	Double	Red	Right	7	2	100.0
Oct 14	Double	Yellow	Left	49	4	100.0
Nov 23	Back	Orange	Right	21	1	100.0
Dec 23	Back	Red	Left	2		
				385	89	95.5

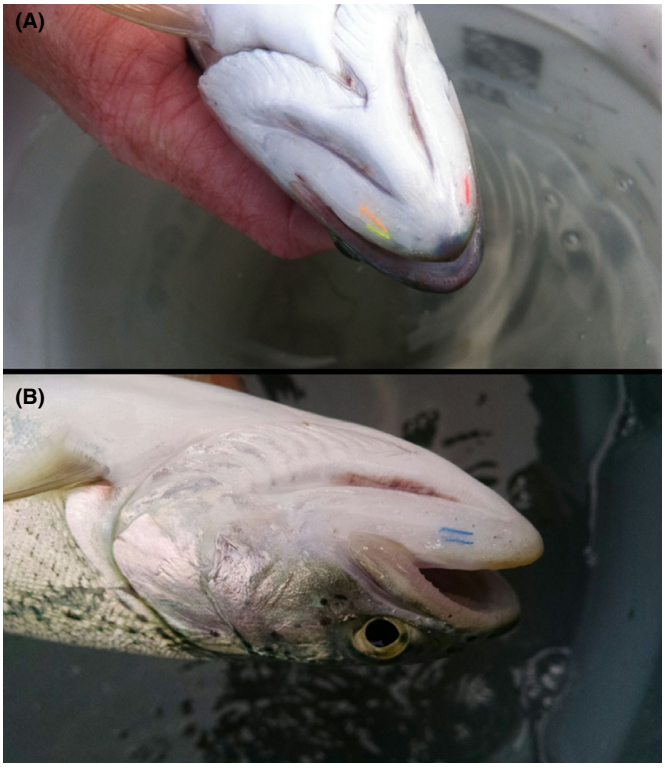

FIGURE 2. Coastal Cutthroat Trout captured and tagged **(A)** on three subsequent sampling events in 2015 in Eld Inlet, Washington, during January (yellow), February (orange), and March (red), and **(B)** in May (double blue) with VIE tags.

Of the 385 Coastal Cutthroat Trout that were captured and tagged throughout the duration of the study, 58 were recaptured. The recaptured individuals included fish from each tagging event and fish that had been captured up to four times after initial tagging ($n = 3$). In total, these 58 recaptured individuals were encountered 147 times over the course of our study. All of the fish were tagged at each sampling event, regardless of previous capture. Pooling all of the tags that were encountered in at least two sampling events resulted in 89 unique VIE tags (Table 1). Of those unique tags, 92.1% ($n = 82/89$) were visually identified at every genetically identified encounter and all of the colors that were used showed the potential to be visually identified longer than 200 d after initial capture. The VIE tags were visually identified across the study period ranging from 2 d after insertion to 342 d (Table 1). All instances of VIE tags that went undetected in one sampling event occurred on the initial recapture event, and these tags were not detected in subsequent sampling events (e.g., tag #79; Figure 4). The month of tagging for those tags that ultimately went undetected occurred across four sampling events (January, April, July, and August).

The data that were used in the multifactor ANOVA exhibited equal variance; therefore, no transformations were used. The detectability of the VIE tags at initial capture was associated with tag color (Table 2; multifactor ANOVA, $P < 0.05$). Specifically, red and blue tags were identified 100% of the time, whereas yellow and orange tags went undetected 22.2% and 9.4% of the time at initial recapture and thereafter (Figure 5). In contrast, tag type (double versus single), days since tagging (Table 2; $P > 0.05$), fish length (Figure 3), and location of tag (left versus right side of jaw) were not significantly related to detectability ($\chi^2 = 0.093$, $df = 1$, $P > 0.05$).

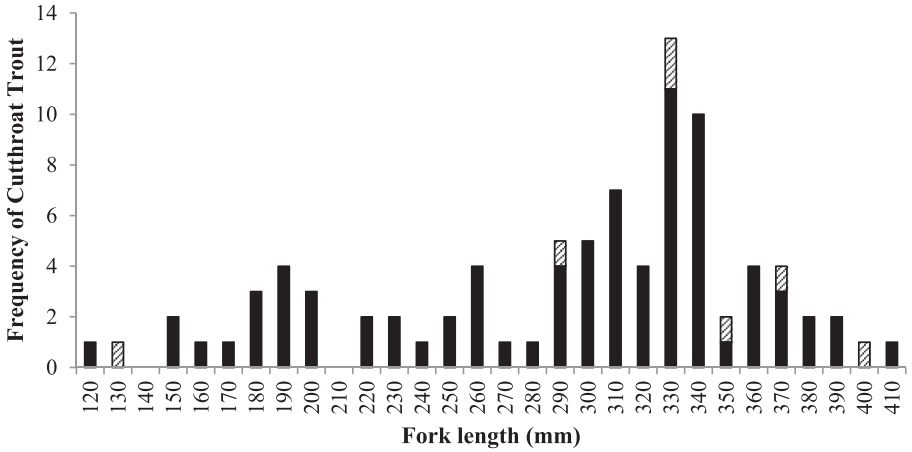

FIGURE 3. Length frequency distribution (fork length, mm) of recaptured Coastal Cutthroat Trout identified through genetic analysis in 2015 in Eld Inlet, Washington. The stacked bars distinguish the counts for fish whose VIE tag was visually detected (black) versus not visually detected (gray).

DISCUSSION

Coastal Cutthroat Trout are the least studied of the anadromous salmonids in the genus *Oncorhynchus*; thus, the tools that are used to investigate the biology and life history of this species have not been fully explored. The current study demonstrated that VIE tagging is a reliable and easy technique to use for marking juvenile and adult Coastal Cutthroat Trout for later identification in the wild. With a detection rate of greater than 95% across the 12-month life of the study, the results from this work support previous conclusions that VIE tagging serves as an effective tagging method for projects with limited resources (i.e., time, funding, and staff) that are implemented to investigate the movement of marine fish species with a small home range (Curtis 2006; Sandford et al. 2020; Uglem et al. 1996). Furthermore, the ventral side of the jaw represents a novel and satisfactory tagging location for Coastal Cutthroat Trout, especially given their light-colored ventral surface.

Time was not an important predictor of detectability in our study, but it is highly likely that the detectability of VIE tags in anadromous Coastal Cutthroat Trout would decrease if it was evaluated beyond 12 months. In numerous lab studies >90% tag retention has been demonstrated in freshwater environments for periods of less than 1 month (McMahon et al. 1996; Turek et al. 2014). Beyond this period, estimates of tag retention are variable but have been shown to remain high (>50%; Hughes et al. 2000; Treasurer 1996). While there are few estimates for salmonids that are monitored in the wild or in the marine environment, Bryan and Ney (1994) reported a nearly 100% tag retention rate for wild Brook Trout *Salvelinus fontinalis* measuring greater than 200 mm in length over a 12-month period. This is consistent with the high retention rates (>90%) that were observed by Fitzgerald et al. (2004) during the first 12 months of a study that was focused on pen-reared Atlantic Salmon *Salmo salar* in the marine environment across a broad size range (165–885 mm). Researchers have demonstrated a sharp decline in the detectability of VIE tags after 17 months when they are placed on the lower jaw of Atlantic Salmon. While studies focused on Coastal Cutthroat Trout are limited, two studies (McMahon et al. 1996; Shepard et al. 1996) demonstrated high retention rates for Westslope Cutthroat Trout *O. clarki lewisi* measuring >200 mm in length in freshwater, particularly during the initial 60 d after tagging, with a sharp decline during subsequent days. However, both McMahon et al. (1996) and Shepard et al. (1996) cited challenges that are associated with tagging small Westslope Cutthroat Trout, resulting in significantly lower retention. By focusing our work on wild trout in the marine environment and including fish across the length distribution for this species, we were able to build on the work of others and improve our understanding of VIE tag retention for anadromous trout at multiple life stages (smolt to adult). Given the rapid growth and diverse movement patterns of Coastal Cutthroat Trout between freshwater, estuarine, and marine environments, an important next step would be to evaluate tag life across an extended period for this species.

In all of the cases of nondetections ($n = 5/89$), the tags were not identified upon initial recapture and were not identified upon any of the subsequent capture events. This result highlights the benefit of capturing tagged fish multiple times and suggests that these tags were immediately lost or masked upon insertion in the field, as opposed to being unidentified due to the degradation of tag detection over time. Because these undetected tags were comprised of only orange- and yellow-colored tags that failed across multiple tagging events, it is likely that tag color rather

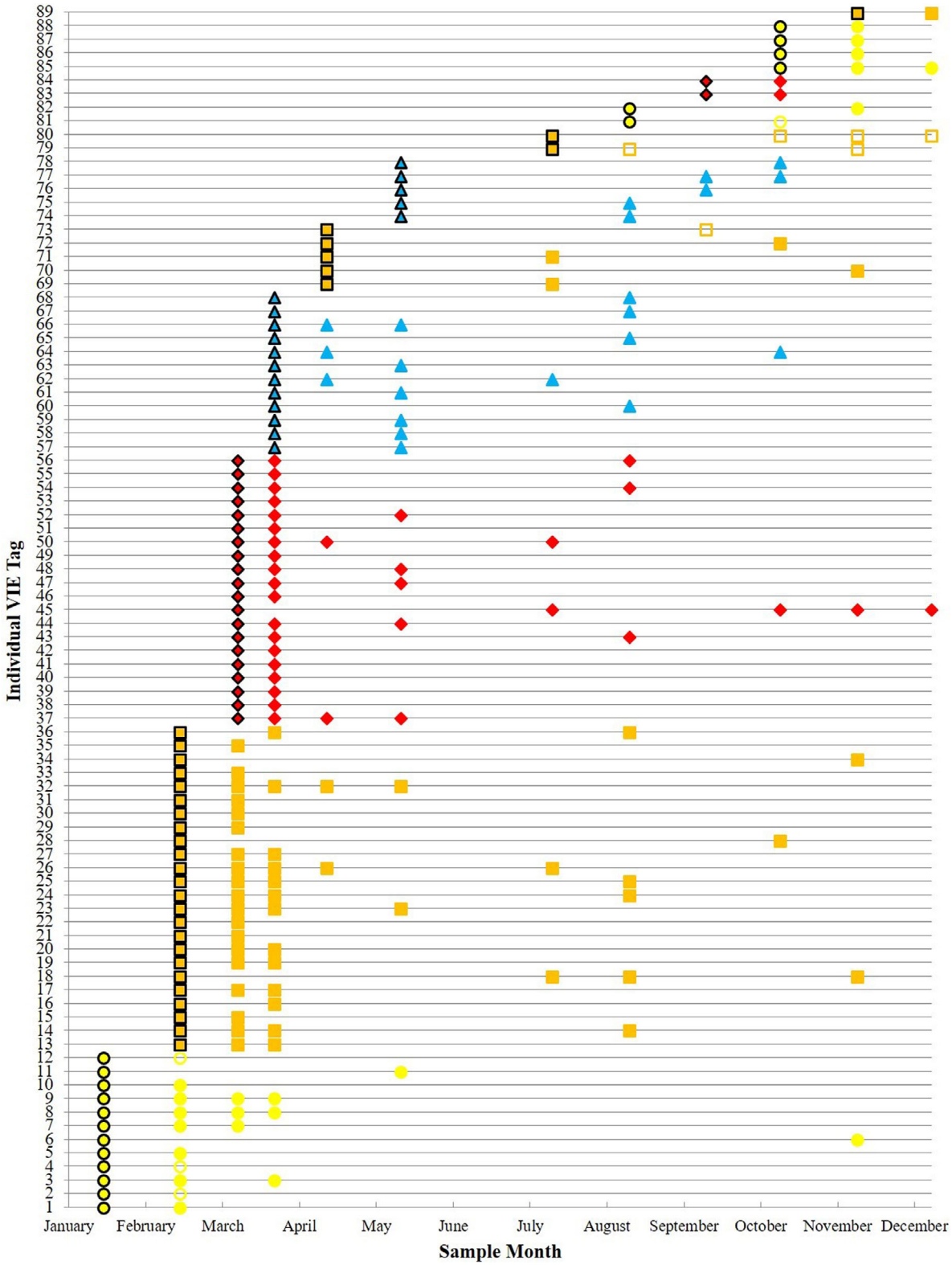

FIGURE 4. Tagged Coastal Cutthroat Trout across sample months in Eld Inlet, Washington. Each horizontal line represents an individual VIE tag ($n = 89$). The colors in the figure correspond to the color of the elastomer tag that was implanted (i.e., yellow, orange, red, or blue). The initial tag application event is denoted by the circles that are outlined in black. The tags that were visually detected are denoted by filled circles, and the tags that were not visually detected are denoted by open circles.

TABLE 2. Multifactor analysis of variance for main effects—color (yellow, orange, blue, and red), type (single versus double), and days since tagging (50-d bins)—on detectability of VIE tagging of Coastal Cutthroat Trout in the marine waters of south Puget Sound, Washington. The abbreviations are defined as follows: SS = sum of squares; MS = mean square.

Response	Explanatory	df	SS	MS	*F*-ratio	*P*-value
Detectability	Color	3	0.62	0.21	2.96	<0.05
	Type	1	0.01	0.01	0.14	0.71
	Days	3	0.01	0.01	0.17	0.68
	Color × type	3	0.31	0.10	1.47	0.23
	Color × days	3	0.10	0.30	0.39	0.76
	Residuals	77	5.41	0.07		

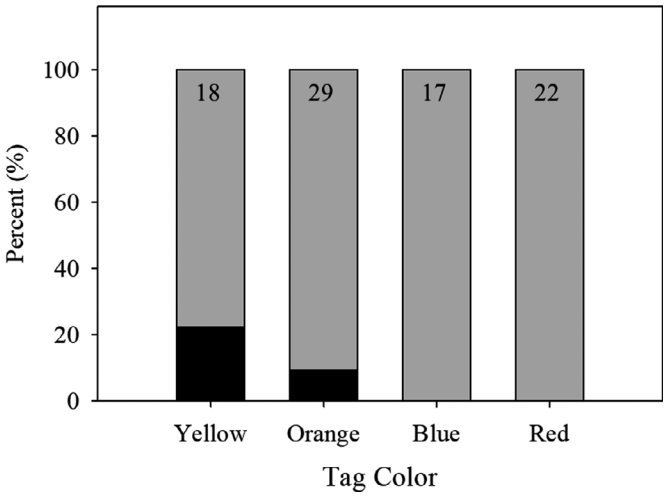

FIGURE 5. Proportion of VIE tags that were detected (open) and undetected (hatched) by color in Coastal Cutthroat Trout in 2015 in Eld Inlet, Washington.

than tagging error was an important factor. The manufacturer of the VIE tags that were used in this study (Northwest Marine Technology) suggests using UV light to increase the detectability of some colors of VIE tags (Northwest Marine Technology 2020), and Bailey et al. (1998) and Fitzgerald et al. (2004) determined that UV light improved detectability significantly for tags that were implanted deep in the tissue or fish that were sampled more than 27 months after tagging. We did not use UV light, but it is possible that doing so would have improved the detectability of all of the tags including those that went undetected upon initial recapture.

The current study targeted wild Coastal Cutthroat Trout that were captured in their natural environment and was therefore limited to evaluating tag detectability only of those fish that were recaptured. The fate of the fish that were tagged and not recaptured (76.9%) is unknown, but it is likely that some proportion perished during the life of the study. While this study design did not permit an estimate of mortality associated with VIE tags, previous work comparing the survival of VIE-tagged and nontagged juvenile Coho Salmon *O. kisutch* suggests that the short-term or long-term effect of VIE tags on survival is insignificant (Bailey et al. 1998). Furthermore, Bryan and Ney (1994) demonstrated that rates of recapture of Brook Trout that were tagged with VIE tags were consistent with independently reported rates of survival, suggesting that little to no additional mortality was incurred due to tagging. In the current study, a few individuals were recaptured and tagged up to five times ($n = 3$), with no visible sign of infection or injury due to tagging (Figure 2). Therefore, tag-related mortality is likely low.

By marking and recapturing wild anadromous Coastal Cutthroat Trout in the marine environment, we demonstrated that VIE tags serve as an effective tool for marking and identifying previously captured Coastal Cutthroat Trout within a 1-year time frame, with red- and blue-colored tags performing the best for this species. Because these tags are easily identifiable to the naked eye when they are placed in the lower jaw, they may also function well as a tool for angler reporting of tagged fish. Anadromous Coastal Cutthroat Trout have received little attention from the scientific community relative to other anadromous salmonids in the genus *Oncorhynchus*. Managers and researchers that are tasked with insuring the long-term persistence of this unique species should explore additional safe, cost-effective tools that support the continued scientific investigation of the understudied anadromous form of Coastal Cutthroat Trout.

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REFERENCES

Bailey, R. E., J. R. Irvine, F. C. Dalziel, and T. C. Nelson. 1998. Evaluations of visible implant fluorescent tags for marking Coho Salmon smolts. North American Journal of Fisheries Management 18:191–196.

Blankenship, H. L., and J. M. Tipping. 1993. Evaluation of visible implant and sequentially coded wire tags in sea-run Cutthroat Trout. North American Journal of Fisheries Management 13:391–394.

Bonneau, J. L., R. F. Thurow, and D. L. Scarnecchia. 1995. Capture, marking, and enumeration of juvenile Bull Trout and Cutthroat Trout in small, low-conductivity streams. North American Journal of Fisheries Management 15:563–568.

Bryan, R. D., and J. J. Ney. 1994. Visible implant tag retention by and effects on condition of a stream population of Brook Trout. North American Journal of Fisheries Management 14:216–219.

Carline, R. F., and O. M. Brynildson. 1972. Effects of the Floy anchor tag on the growth and survival of Brook Trout (*Salvelinus fontinalis*). Journal of Fisheries Research Board of Canada 29:458–460.

Curtis, J. M. R. 2006. Visible implant elastomer color determination, tag visibility, and tag loss: potential sources of error for mark–recapture studies. North American Journal of Fisheries Management 26:327–337.

Fitzgerald, J. L., T. F. Sheehan, and J. F. Kocik. 2004. Visibility of visual implant elastomer tags in Atlantic Salmon reared for two years in marine net-pens. North American Journal of Fisheries Management 24:222–227.

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.

Hughes, T. C., D. C. Josephson, C. C. Krueger, and P. J. Sullivan. 2000. Comparison of large and small visible implant tags: retention and readability in hatchery Brook Trout. North American Journal of Aquaculture 62:273–278.

Losee, J. P., T. R. Seamons, and J. Jauquet. 2017. Migration patterns of anadromous Cutthroat Trout in south Puget Sound: a fisheries management perspective. Fisheries Research 187:218–225.

McAllister, K. W., P. E. McAllister, R. C. Simon, and J. K. Werner. 1992. Performance of nine external tags on hatchery-reared Rainbow Trout. Transaction of the American Fisheries Society 121:192–198.

McFarlane, G. A., R. S. Wydoski, and E. D. Prince, editors. 1990. Historical review of the development of external tags and marks. American Fisheries Society, Symposium 7, Bethesda, Maryland.

McMahon, T. E., S. R. Dalbey, S. C. Ireland, J. P. Magee, and P. A. Byorth. 1996. Field evaluation of visible implant tag retention by Brook Trout, Cutthroat Trout, Rainbow Trout, and Arctic Grayling. North American Journal of Fisheries Management 16:921–925.

Moore, M. E., F. A. Goetz, D. M. Van doornik, E. P. Tezak, T. P. Quinn, J. J. Reyes-Tomassini, and B. S. Berejikian. 2010. Early marine migration patterns of wild Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*), steelhead trout (*Oncorhynchus mykiss*), and their hybrids. PLoS (Public Library of Science) ONE [online serial] 5: e12881.

Nielsen, L. A., and D. L. Johnson, editors. 1983. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Northwest Marine Technology. 2020. Visible implant elastomer tags project manual. Northest Marine Technology, Anacortes, Washington.

R Development Core Team. 2018. R: a language and environment for statistical computing, version 3.6.0. R Foundation for Statistical Computing, Vienna.

Sandford, M., C. Gonzalo, and T.-C. Hung. 2020. A review of fish identification methods applied on small fish. Reviews in Aquaculture 12:542–554.

Shepard, B. B., J. Robison-Cox, S. C. Ireland, and R. G. White. 1996. Factors influencing retention of visible implant tags by Westslope Cutthroat Trout inhabiting headwater streams of Montana. North American Journal of Fisheries Management 16:913–920.

Treasurer, J. W. 1996. Retention of visible implant tags in farmed Atlantic Salmon, *Salmo salar* L. Aquaculture Research 27:293–295.

Turek, K. C., M. A. Pegg, and K. L. Pope. 2014. Short-term evaluation of visible implant alpha tags in juveniles of three fish species under laboratory conditions. Journal of Fish Biology 84:971–981.

Uglem, I., H. Nœss, E. Farestveit, and K. E. Jørstad. 1996. Tagging of juvenile lobsters (*Homarus gammarus* (L.)) with visible implant fluorescent elastomer tags. Aquacultural Engineering 15:499–501.

Wang, J. 2016. Individual identification from genetic marker data: developments and accuracy comparisons of methods. Molecular Ecology Resources 16:163–175.

Warner, K. 1971. Effects of jaw tagging on growth and scale characterization of landlocked Atlantic Salmon, *Salmo salar*. Journal of the Fisheries Research Board of Canada 28:537–542.

Zale, A. V., D. L. Parrish, and T. M. Sutton. 2013. Fisheries techniques, 3rd edition. American Fisheries Society, Bethesda, Maryland.