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Great Plains Research, Volume 26, Number 1, Spring 2016, pp. 51-55
(Article)

Published by University of Nebraska Press

DOI: <https://doi.org/10.1353/gpr.2016.0014>

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Westslope Cutthroat Trout Mortality Following Detoxification of Rotenone with Potassium Permanganate

Maria L. Chaney and Casey W. Schoenebeck

ABSTRACT—The westslope cutthroat trout, *Oncorhynchus clarkii lewisi*, has experienced substantial declines across its historic range. Natural resource managers have actively worked to restore populations using piscicide treatments to remove competing non-native trout prior to repatriation of the species. Rotenone is commonly employed as a piscicide treatment in streams, followed by the application of potassium permanganate to detoxify rotenone so as not to adversely affect native trout that may inhabit downstream areas. However, at certain concentrations potassium permanganate can also cause trout mortality. We placed five westslope cutthroat trout in each of four live carriers within a potassium permanganate detoxification zone to determine if and when *in situ* levels of potassium permanganate resulted in trout mortality. After application of potassium permanganate, we monitored its concentration and trout mortality in the carriers every hour for five hours. Westslope cutthroat trout mortality was 100% after five hours of exposure, with a mean potassium permanganate concentration of 2.96 ± 0.19 (SE) mg/L over the duration of the experiment. Our results suggest that for treatment times of five hours, residual potassium permanganate concentrations should be below 2.96 mg/L for westslope cutthroat trout to survive downstream of rotenone treatments in a detoxification zone.

Key Words: mortality, potassium permanganate, restoration, rotenone, westslope cutthroat trout

Introduction

The westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) has experienced substantial declines across its historic range (Fig. 1) and has been listed as a species of concern by Montana Fish, Wildlife, and Parks, vulnerable by Idaho Department of Fish and Game, and sensitive by the US Forest Service and Bureau of Land Management (Shepard et al. 1997; Verschuren and Marnell 1997). Westslope cutthroat trout populations have declined due to overangling, habitat loss, hybridization, and competition from non-native fishes (Downs et al. 1997; Shepard et al. 1997; Verschuren and Marnell 1997; Shepard et al. 2005). In 1997 the species occupied less than 5% of its original habitat in Montana's upper Missouri River drainage (Shepard et al. 1997).

Conservation efforts have focused on piscicide treat-

ments such as rotenone to eradicate non-native trout, including brook trout *Salvelinus fontinalis* and rainbow trout *Oncorhynchus mykiss*, above natural or artificial stream barriers that isolate reintroduced westslope cutthroat trout from reinvasions and hybridization with non-native trout (Finlayson et al. 2010b). Potassium permanganate, KMnO_4 , is traditionally used to detoxify rotenone downstream of the restoration site to minimize mortality of native trout below treatment areas (Guenther 2011).

However, potassium permanganate is a strong oxidizing substance that can increase cortisol levels and damage surface organs of fish, such as the gills, and result in mortality (Darwish et al. 2002; Griffin et al. 2002; Hoseini and Tarkhani 2012). Potassium permanganate is usually administered in powder form at a recommended residual (i.e., the portion of the applied chemical not reacting with rotenone) concentration of 1 mg/L and takes between 15 and 30 minutes of contact time within a stream to detoxify rotenone (Guenther 2011). Fish mortality could occur within the detoxification zone while

Manuscript received for review, 12/15/14;

accepted for publication, 5/21/15.

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Figure 1. Historic range of westslope cutthroat trout. Source: Montana Fish, Wildlife, and Parks (2014).

Figure 2. Map of Crawford Creek, Montana, showing locations of rotenone treatment reach, fish barrier, potassium permanganate detoxification zone, and the control.

rotenone and potassium permanganate are mixing and after, if residual concentrations of potassium permanganate are too high. Although 4 mg/L of potassium permanganate was the highest residual concentration recommended for safe use in aquaculture (Hoseini and Tarkhani 2012), we could not find research documenting concentrations of potassium permanganate that cause mortality in wild trout. This is of concern, as residual potassium permanganate may cause mortality of native trout downstream of the application site. Knowledge of lethal potassium permanganate concentrations will allow for more precise treatments that minimize adverse downstream effects. Therefore, our objective was to determine what *in situ* concentrations of residual potassium permanganate at hourly intervals are lethal to westslope cutthroat trout.

Methods

We captured 25 westslope cutthroat trout ranging from 100 to 190 mm in length by electrofishing a reach of Crawford Creek (Fig. 2), near Neihart, Montana (latitude 47.00082, longitude 110.77176). Crawford Creek is a first-order stream (flow was 2 cfs [cubic feet per second] and average channel width was 1 meter) that contained brook trout, westslope cutthroat trout, and rainbow trout crossed with westslope cutthroat trout hybrids. We used the same stream reach for our experiment. We placed five trout in each of four live carriers (36 × 33 × 33 cm dimensions) spaced 50 m apart downstream within a potassium permanganate detoxification zone (4 sites, $n = 20$) and five trout in a live carrier (the control) outside the treatment area (1 site, $n = 5$).

TABLE 1. Concentration of potassium permanganate (KmNo_4 , mg/L), number of trout mortalities, and proportion of total mortality in Crawford Creek, Montana.

	Hour 1		Hour 2		Hour 3		Hour 4		Hour 5	
	KmNo ₄	Mortalities	KmNo ₄	Mortalities	KmNo ₄	Mortalities	KmNo ₄	Mortalities	KmNo ₄	Mortalities
Site 1 ^a	4.1	0	2.8	1	2.6	4	2.2	—	2.9	—
Site 2 ^a	4.2	0	3.2	0	2.6	0	2.3	2	2.4	3
Site 3 ^a	4.4	0	3.2	0	2.9	0	2.4	2	2.2	3
Site 4 ^a	3.7	0	4.8	0	2.2	0	2.1	0	2.0	5
Control ^b	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0
Proportion of total mortality		0.00		0.05		0.25		0.45		1.00

^{a,b}Significant differences among carriers are denoted by different letters.

We applied rotenone to a 2.4 km reach of Crawford Creek above an artificial barrier using four drip stations at the recommended concentration for flowing water of 0.5–1.0 ppm (Fig. 2). At the same time, we applied potassium permanganate directly below the artificial barrier with a dry solids volumetric feeder set at 35 rpm. We waited four hours after the start of the treatments before placing trout in the carriers to ensure rotenone had traveled downstream and was mixing with potassium permanganate. Using a colorimeter (Finlayson et al. 2010a), we recorded the concentration of residual potassium permanganate hourly for five hours in each carrier in the detoxification zone and in the control carrier and documented any corresponding fish mortalities.

We evaluated potential differences in concentrations of potassium permanganate among carriers using a single factor ANOVA with significance defined as $\alpha = 0.05$ with a Tukey's post-hoc test. In addition, we compared the mean concentration of potassium permanganate that resulted in westslope cutthroat trout mortality to the accepted safe concentration of 4 mg/L (the highest recommended value to be used in aquaculture [Hoseini and Tarkhani 2012]) using a one-tailed t -test ($p < 0.05$, Graphpad statistical software version 3.10). All methods for the use of potassium permanganate to detoxify rotenone were administered by Montana Fish, Wildlife, and Parks consistent with the guidelines from the Rotenone Standard Operating Procedures Manual (Finlayson et al. 2010a) and approved by the University of Nebraska Institutional Animal Care and Use Committee (#21113).

Results

The proportion of total mortality increased from 0.05 to 1.00 from hour 2 to hour 5 for fish in the treatment carriers, while fish in the control carrier experienced no mortality (Table 1). The concentration of potassium permanganate did not vary significantly among treatment carriers, averaging 2.96 ± 0.19 (SE) mg/L throughout the experiment, but potassium permanganate concentrations were significantly greater at the four treatment sites than at the control site ($F = 12.82$, $df = 4, 20$, $P < 0.001$, control = 0 mg/L). The average residual concentration of potassium permanganate causing mortality of westslope cutthroat trout was significantly lower (2.96 ± 0.19 (SE) mg/L, $t = 30.98$, $df = 19$, $P < 0.001$) than the maximum residual concentration of 4 mg/L recommended for aquaculture applications (Hoseini and Tarkhani 2012).

Discussion

Our results suggest that an average residual concentrations of potassium permanganate of about 3.0 mg/L over a duration of 5 hours will result in substantial westslope cutthroat trout mortality. However, even a shorter exposure to a similar average concentration (e.g., 3.1 mg/L) of potassium permanganate (see Site 1, Hour 3, in Table 1) can also result in substantial westslope cutthroat trout mortality.

If rotenone and potassium permanganate concentrations are applied as recommended, residual con-

centrations of potassium permanganate within the detoxification zone may still be above the recommended residual concentration of 1 mg/L (as we found). During our study we estimated rotenone concentrations to be fairly stable and within recommended concentrations above the barrier (range of 0.5–0.9 ppm). Concentration of residual potassium permanganate that we found below the barrier in the detoxification zone suggests that rotenone was adequately detoxified, and the residual potassium permanganate was likely the cause of trout mortality. Therefore, we suggest that westslope cutthroat trout be removed from the detoxification zone and held outside the treatment area if potassium permanganate cannot be maintained at concentrations of 1.0 mg/L.

We suggest further research examine the potentially lethal residual concentrations of potassium permanganate below 3.0 mg/L at varying treatment durations and with smaller fish (<100 mm). Longer durations of exposure to lower levels of potassium permanganate may also be lethal (Reardon and Harrell 1994). In addition, smaller fish are more susceptible than larger fish to mortality by potassium permanganate (Taylor and Glenn 2008), so lengths of westslope cutthroat trout less than 100 mm should be considered in future experiments.

Piscicide treatments of non-native trout upstream of fish barriers are necessary before native trout repatriation. If possible, natural resource managers should minimize residual potassium permanganate levels during renovations by closely monitoring concentrations and subsequently adjusting applications to limit the mortality of any westslope cutthroat trout that may be in the detoxification zone. An alternative would be to capture and hold these trout for later restocking.

Acknowledgments

We would like to thank Dave Moser and Dan Fraiser for helpful discussion and technical assistance during the project. This manuscript was improved by the comments of two anonymous reviewers and editor Gary Willson.

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