Minimizing Effects of Piscicides on Macroinvertebrates

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ABSTRACT— Great Basin National Park minimized effects of piscicides through surveys for fishless areas and monitoring macroinvertebrate response to rotenone and antimycin. Fish distribution surveys found 5 km of Strawberry Creek and 3.9 km of Snake Creek would not require treatment. Rotenone was dispensed for two days into Strawberry Creek at 5 mg/l for one hour and 2 mg/l for seven hours each day. Antimycin was dispensed into Snake Creek averaging 8 μl/l for eight hours. Under rotenone, macroinvertebrate abundance declined 85% (1,762/m^2 to 263/m^2) at one-month post-treatment. Taxa numbers were reduced 95% at one-week post-treatment but increased to 68% of pre-treatment levels by one-month. Ephemeroptera, Plecoptera and Trichoptera (EPT) group abundance declined 99% (833/m^2 to 10/m^2) with only four taxa present. Abundance and taxa numbers has not exceeded pre-treatment levels after three years. Five taxa had not returned after one year and two taxa are still absent after three years. Under antimycin, total abundance declined 61% (1,642/m^2 to 635/m^2) while EPT abundance declined 54% (766/m^2 to 353/m^2) one-month post-treatment. Taxa numbers declined less than 30%. All but one taxon has returned after one-year. Macroinvertebrates were least impacted by antimycin and focusing treatments to provide refugium in fishless headwater areas.

INTRODUCTION

While piscicides are especially intended to eradicate fish, they are also toxic to other aquatic biota, such as aquatic macroinvertebrates and amphibians. The impact on aquatic macroinvertebrates is a concern because of their abundant populations, their role in aquatic ecosystem processes and their importance as a food source for fish. Reductions in abundance and taxa numbers or diversity with limited recovery could lead to an altered ecosystem and inadequate forage for translocated fish. Recently this concern has become a primary issue during fish restoration planning. However, knowledge is limited about impacts from piscicide treatments using rotenone or antimycin in intermountain streams, particularly for antimycin.

The Organic Act of 1916 mandates the National Park Service to protect all native species. To restore the native Bonneville cutthroat trout (*Oncorhynchus clarki utah*) in Great Basin National Park, piscicide use was chosen as a preferred method to achieve nonnative fish removal. To address the issue of piscicide effects on other native wildlife it was proposed to minimize the treated area through fish distribution surveys (Whelan 2002). In other words, refuges would be maintained from which macroinvertebrates could disperse to treated areas. Because of the limited information on the short-term response and recovery of macroinvertebrates from piscicide treatments, treatments using rotenone and antimycin on separate streams were completed and macroinvertebrate abundance and taxa numbers monitored (Williams et al 1999). The Ephemeroptera, Plecoptera and Trichoptera (EPT) group was especially monitored due to their sensitivity to pollutants. The objective was to determine baseline abundance and taxa composition, assess macroinvertebrate response to rotenone and antimycin, and track recovery in streams where the treated area was minimized.

METHODS

Study Area. Great Basin National Park is located in east central Nevada along the border with Utah (Figure 1). It is part of the Great Basin ecosystem province. Elevations range from 1,585 m in the basin to over 3,982 m at the summit of Wheeler Peak. Strawberry Creek is located in the northernmost area of the park while Snake Creek is found in the center of the park (Figure 1). Water flows vary between 0.09 and 0.01 cms. Vegetation communities include Engelmann spruce (*Picea engelmannii*) forest in the headwaters transitioning to mixed conifer, aspen (*Populus tremuloides*), river birch (*Betula occidentalis*) and pinyon (*Pinus monophylla*) and juniper (*Juniperus osteosperma*) forests as elevations decrease.

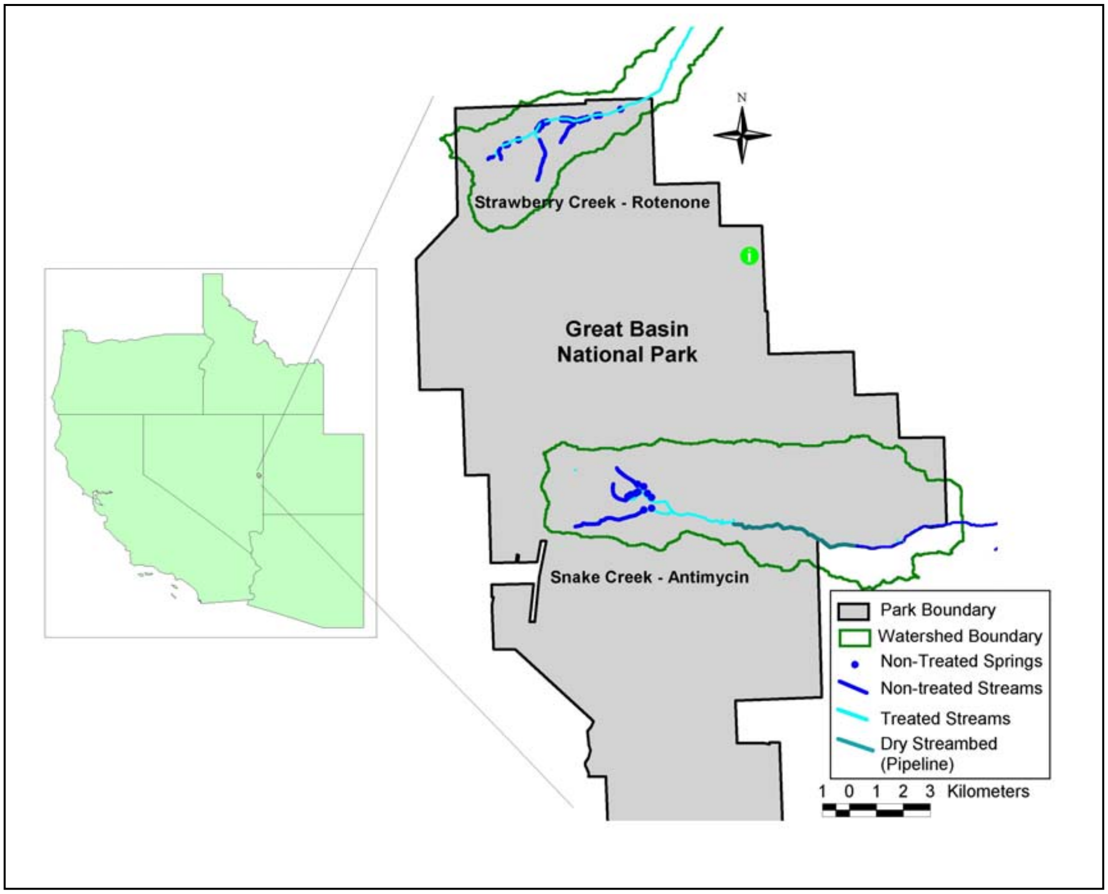

Figure 1. Location of Great Basin National Park, Strawberry Creek and Snake Creek, and the distribution of treated and non-treated stream and spring areas.

Fish Distribution. The uppermost limit of fish distribution was determined by spot electrofishing. Electrofishing continued upstream until no fish were detected for 500 meters or the end of potential fish habitat was reached.

Macroinvertebrate Sampling. Macroinvertebrates were sampled using quantitative and qualitative methods described by Hawkins et al. (2001). Quantitative sampling consisted of a series of four fixed area sweeps using a 500 micron mesh kick net taken from four different riffle areas per sample site. The surface area was agitated and brushed to dislodge specimens within a 30.5 cm square. Macroinvertebrates and material were sorted and placed in 95% ethanol. Qualitative sampling focused on multiple habitats in proportion to their occurrence. A kick net was used to sweep each habitat as surface areas were agitated. Collections were placed in a pan and all visible specimens were handpicked over a one-person hour time constraint. Specimens were place in a 50 ml jar with 95% ethanol. The National Aquatic Monitoring Center identified and quantified all specimens.

Quantitative and qualitative macroinvertebrate sampling in Strawberry Creek occurred approximately one-year and one-day prior to treatment with rotenone. Post-treatment sampling occurred at one month, 9-months, 10-months, 11-months, one-year, two-years and three-years. In addition, qualitative samples were collected at one-day and one-week post-treatment because only live specimens are handpicked and determination of mortality from the treatment could be ascertained.

Quantitative and qualitative macroinvertebrate sampling in Snake Creek occurred two-years, one-year and one-day prior to treatment with antimycin. Post-treatment sampling occurred at one-week, one-month, 9-months and one-year.

Rotenone Application. 125 l (33 gallons) of 5% rotenone and 10.9 kg (24 lbs.) of 8.5% rotenone dry powdered toxicant was used on 11.9 km of Strawberry Creek September 12 and 13, 2000. Application over the two days was 5 mg/l the first hour and 2 mg/l for seven hours each day. The rotenone dry powder was mixed with sand and gelatin with handfuls deposited in rivulets that fed the main channel from seeps and springs. Larger rivulets, where sand eroded away quickly, were treated with backpack sprayers.

Antimycin Application. Four liters (1.1 gallons) of Fintrol was dispensed into Snake Creek from drip stations August 5-10, 2002. Concentrations of antimycin averaged 8 μ/l. Concentration within various headwater reaches often exceeded 25 μ/l to compensate for spring and seep inflows between drip stations. Back eddies of the stream and adjacent springs and seeps were treated with 250 ml of Fintrol using a backpack sprayer. Areas sprayed corresponded to the treated reach for that day.

Data Analysis. Total and Ephemeroptera, Plecoptera and Trichoptera (EPT) group abundance was based on the number of all individuals of each taxa identified from quantitative samples. Abundance was then averaged from all samples within respective treated areas. Overall and EPT group taxa numbers were based on the number of taxa identified from a composite of quantitative and qualitative samples. The average of taxa numbers was obtained from samples within respective treated areas. Macroinvertebrates were considered resistant if they appeared one-month post-treatment or earlier and they were considered recovered when they first appeared in post-treatment samples. Some resistant and missing taxa were excluded from analysis based on their low occurrences. Taxa of low occurrence, less than 0.5% of the overall sample, are of concern because their lack of subsequent detections may be due to sampling error rather than any treatment effect (Whelan 2002). We excluded those taxa that averaged less than one individual from pre-treatment samples in each stream, leaving taxa that were consistently detected at or between sampling sites.

RESULTS

Strawberry Creek - Rotenone

Fish Distribution. Fish were restricted to 11.9 km of stream from a total 16.9 km surveyed (Figure 1). All fish were restricted to the main channel and approximately 250 m of the Blue Canyon tributary and 100 m of an unnamed tributary. Some 61 springs and seeps were located adjacent to Strawberry Creek in which 13 were found to shelter fish. Maximum distances between treated and non-treated waters were 1.3 km. Fish densities were estimated at over 560 fish/km.

Short-term Response. Total macroinvertebrate abundance averaged 1,762.25 specimens/m^2 in pre-treatment samples while the EPT group abundance average was 833 specimens/m^2 (Figure 2). Total abundance declined to an average 263 specimens/m^2 (-85% of pre-treatment average). EPT group abundance declined to an average 10 specimens/m^2 (-99% of pre-treatment average).

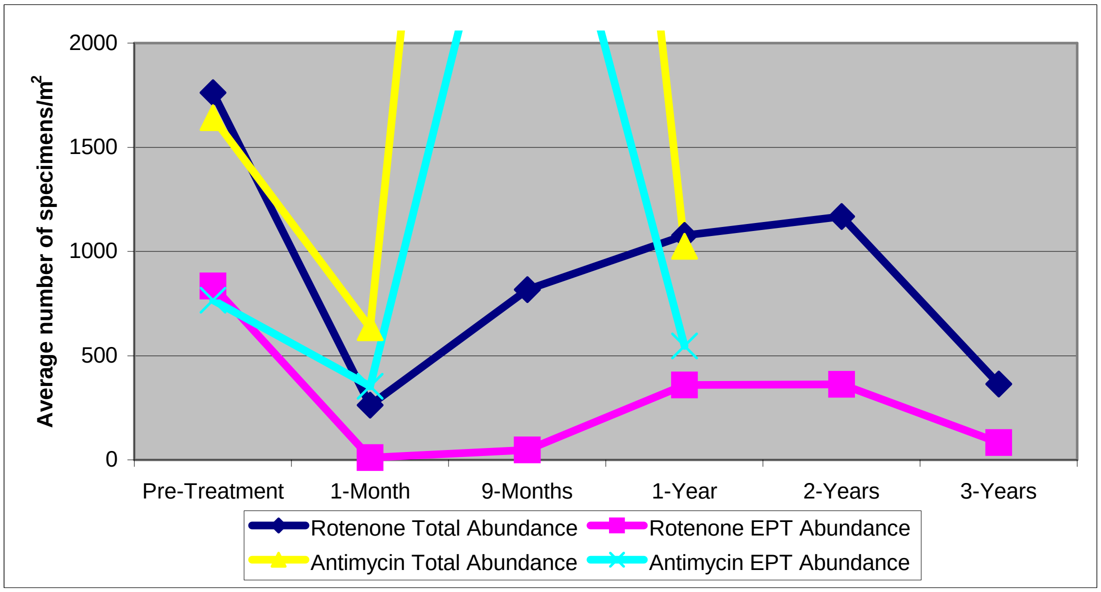

Figure 2. Total and Ephemeroptera, Plecoptera and Trichoptera (EPT) group abundances prior to treatments with rotenone and antimycin and up to three years post-treatment.

Overall taxa numbers averaged 46.75 taxa and EPT group taxa numbers averaged 26 taxa (Figure 3). Qualitative samples collected at one-day and one-week post–treatment indicated that overall taxa numbers declined to an average of 3.75 and 2.25 taxa, respectively. Average EPT group taxa numbers declined to 0.25 taxa at one-day post-treatment and 0 taxa by one-week. By one-month post-treatment overall taxa numbers increased to an average 14.75 taxa (-69%) while the average EPT group taxa numbers increased to 3.75 taxa (-86%).

Taxa most resistant to rotenone were from the Coleoptera, Diptera and Amphipoda orders. Specimens from these orders were collected at all three time periods: one-day, one-week and one-month post-treatment.

Long-term Response. Total abundance recovered to an average of 1,167 specimens/m^2 (-34% of pre-treatment average) after two years. EPT group abundance recovery was slower being only 362.5 specimens/m^2 (-57% of pre-treatment average) after two years (Figure 2). Only one sample site had total abundance that exceeded pre-treatment levels over three years. EPT group abundance never exceeded pre-treatment levels over three years.

Overall taxa numbers recovered to an average of 42 taxa (-9%of pre-treatment average) by the second year while EPT group taxa numbers recovered to an average of 20 taxa (-23% of pre-treatment average) (Figure 3). Taxa numbers have not returned to pre-treatment levels after three years.

There was a steep decline in total and EPT group abundance at three-years post-treatment (Figure 2). The likely cause was a worsening drought that has significantly reduced water flows. Taxa numbers remained unchanged three-years post-treatment (Figure 3).

Pre-treatment samples consisted of 51 taxa that averaged one or more individuals from four sampling sites, five taxa were missing one-year post-treatment and two taxa were still absent after three-years (Table 1). Four of the five taxa occurred in samples from non-treated areas since the treatment but averaged less than one individual (Darby et al. unpublished data). The remaining taxon, *Antocha spp*. a cranefly, had never been collected from non-treated sample sites but was common in pre-treatment samples at the lowest elevation site treated.

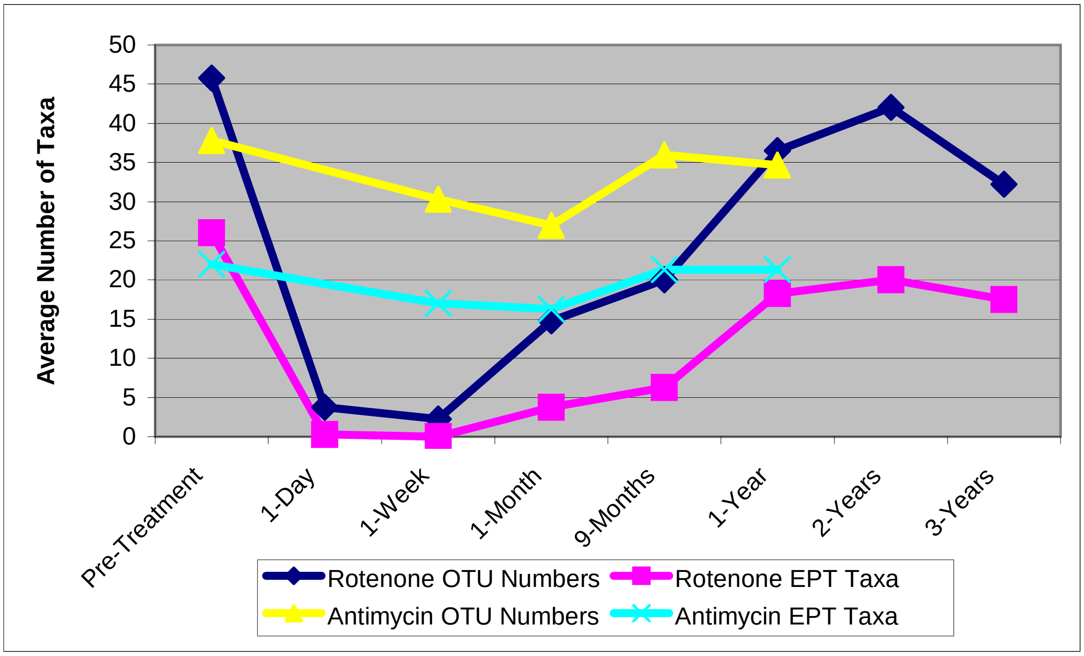

Figure 2. Overall Taxa (OTU) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) group taxa numbers prior to treatments with rotenone and antimycin and up to three-years post-treatment.

Snake Creek – Antimycin

Fish Distribution. Fish were restricted to 6.8 km of stream from a total 10.6 km surveyed (Figure 1). All fish were restricted to the main channel and three tributaries. Some 15 springs and seeps were located adjacent to Snake Creek in which all sheltered fish where rivulets joined the main channels. Maximum distances between treated and non-treated waters were 3.2 km. Fish densities were estimated at over 932 fish/km.

Table 1. Taxa still missing from treated areas of Strawberry and Snake Creeks.

	Strawberry Creek - Rotenone				**Snake Creek - Antimycin**	
	Order	Family	Genus	Species	Order	Family
One Year Post-treatment	Plecoptera	Nemouridae			Trichoptera	Philopotamidae
	Trichoptera	Glossosomatidae				
	Trichoptera	Philopotamidae	*Dolophilodes*			
Three Years Post-treatment	Diptera	Tipulidae	*Antocha*		**N/A**	
	Ephemeroptera	Baetidae	*Baetis*	*bicaudata*		

Short-term Response. Total macroinvertebrate abundance averaged 1,642 specimens/m^2 in pre-treatment samples while the EPT group abundance averaged 766 specimens/m^2 (Figure 2). Quantitative samples collected at one-week post-treatment showed total abundance actually increased from pre-treatment levels to 1,680 specimens/m^2 but EPT group abundance declined 13% to 670 specimens/m^2. By one-month post-treatment total abundance declined to 634.5 specimens/m^2 (-61% of pre-treatment average) while EPT group abundance declined to an average 353 specimens/m^2 (-54% of pre-treatment average) (Figure 2).

Overall taxa numbers averaged 38 taxa and EPT group taxa numbers averaged 22 taxa in pre-treatment samples (Figure 3). Qualitative and quantitative samples collected at one-week post–treatment indicated that overall taxa numbers declined to an average of 30.33 taxa (-20% of pre-treatment average) and EPT group taxa numbers declined to an average of 17 taxa (-23% of pre-treatment average). By one-month post-treatment taxa numbers declined further to 27 taxa (-29%) and 16.33 taxa (-26%) for overall taxa and EPT group taxa numbers, respectively (Figure 3).

Long-term Response. By 9-months post-treatment, total abundance increased 379% from pre-treatment levels to 7,874 specimens/m^2 (Figure 2). Over 62% of the increase occurred at sample site two but total abundance exceeded pre-treatment levels at two of three sites. EPT group abundance increased 342% to 3,384 specimens/m^2 with all three sample sites exceeding abundance from the pre-treatment average (Figure 2). Abundance declined to just below pre-treatment levels by one-year post-treatment.

Overall taxa numbers recovered within 5% of pre-treatment levels after 9-months with 36 taxa. EPT group taxa numbers were 3% of pre-treatment average at 21.3 taxa (Figure 3). The number of taxa remained almost unchanged by one-year post-treatment.

From 61 taxa that averaged one or more individuals from pre-treatment samples, one taxon had not reoccurred by one-year post-treatment (Table 1). This taxon occurred in samples from non-treated areas since the treatment but averaged less than one individual from samples in non-treated areas (Darby et al. unpublished data).

Discussion

Results presented here are similar to what other monitoring efforts have noted. Several studies have assessed the impact of rotenone on the short-term response of macroinvertebrate assemblages to short-term rotenone application in streams (Binns 1967, Cook and Moore 1969, Engstrom-Heg et al. 1978, Mangum and Madrigal 1999, and Whelan 2002). Only Mangum and Madrigal (1999) studied the long-term effects of rotenone application on invertebrate assemblages. Even fewer studies have assessed the impact of antimycin on macroinvertebrate assemblages in streams (Degan 1973, Jacobi and Degan 1977, Minckley and Mihalick 1981, Walker 2003).

Reductions in total macroinvertebrate and EPT group abundance was high for both the Strawberry Creek rotenone and Snake Creek antimycin treatments (Figure 2). Other monitoring efforts have also noted the rapid eradication of many if not all members of macroinvertebrates from typical rotenone stream treatments (Binns 1967, Cook and Moore 1969, Engstrom-Heg et al. 1978, Mangum and Madrigal 1999, and Whelan 2002). Our samples reflected this with 85% declines in total abundance and 99% declines in EPT group abundance. The Snake Creek antimycin treatment impacted total abundance less but still averaged over 61%. Minckley and Mihalick (1981) noted the "decimation" of macroinvertebrates from a antimycin treatment in Arizona, and Walker (2003) measured macroinvertebrate abundance declines of up to 64% from an antimycin treatment on Sam's Creek, Tennessee. Antimycin appears to minimize the decline in macroinvertebrate abundance compared to rotenone.

Marked differences on the impacts of rotenone and antimycin to the number of taxa were noted. The Strawberry Creek rotenone treatment resulted in a decline of 95% of overall taxa numbers and 100% for EPT group taxa numbers (Figure 3). Again, other monitoring efforts of rotenone treatments have noted the rapid eradication of many of the macroinvertebrates including the complete eradication of the EPT group (Binns 1967, Cook and Moore 1969, Engstrom-Heg et al. 1978, Mangum and Madrigal 1999, and Whelan 2002). The Snake Creek antimycin treatment resulted in declines of only 29% of overall taxa numbers and 26% for EPT group taxa numbers. Walker (2003) also noted declines of overall taxa and EPT group taxa numbers of less than 30%. Jacobi and Degan (1977) found a high retention of taxa diversity from an antimycin treatment in Wisconsin.

The ability to retain high taxa diversity after a piscicide treatment could have major influences on recovery rates of macroinvertebrates. The ability of taxa to recolonize treated areas is likely a function of their overall population sizes and distribution within the basin, upstream and local habitat conditions, and the dispersal abilities of individual taxon. With a high reduction in taxa numbers, recovery would depend more on the dispersal capabilities of macroinvertebrates, thus, recovery could be expected to be slower and there would be a greater potential to alter the original pre-treatment taxa composition (Mangum and Madrigal 1999). Where a treatment retained the majority of pre-treatment taxa composition, the still diverse macroinvertebrate community could rely primarily on their reproductive potential for recovery. This would happen in habitats that would be devoid of their primary predator fish and could be expected to be a quicker recovery.

Non-treated refuges appear to aid in recovery of most but not all macroinvertebrates to treated areas. Five taxa were still missing after one-year and two taxa are still absent after three-years from the Strawberry Creek rotenone treatment (Table 1). Though 48 springs and seeps located throughout the watershed were not treated, different habitat conditions may not have supported many of the taxa found in the stream. The majority of the non-treated stream areas on Strawberry Creek (Figure 1) were located in the headwaters, which greatly increases dispersal distances between non-treated and downstream treated areas. In addition, some taxa show an elevation restriction (Darby et al. unpublished data). *Antocha spp*. was collected only at lower elevation sites and was never collected at high elevation non-treated sites before or after the treatment. Lack of low elevation non-treated streams may be hampering recovery of this taxon. *Baetis bicaudata* were collected at non-treated sites since the Strawberry Creek rotenone treatment but never exceeded four individuals, so numbers were low. The single taxon from the Trichoptera family Philopotamidae missing after the Snake Creek antimycin treatment has also been collected in non-treated area samples but has never exceeded three individuals. Low occurrence of *Baetis bicaudata* and Philopotamidae at non-treated sites could delay recovery in treated areas due to few dispersers.

Worsening drought conditions are another factor that could be affecting recovery. Stream flows have declined desiccating headwater reaches and reducing the area of habitat available, especially in Strawberry Creek. Stream flows in Strawberry Creek at the time of the rotenone treatment were 0.04 cms (1.5 cfs) in 2000 and 0.02 cms (0.6 cfs) in 2003.

Results here suggest that providing non-treated areas and the use of antimycin would best minimize impacts to the macroinvertebrate assemblages. Furthermore, certain management objectives may dictate which piscicide would be most appropriate for use. In systems where macroinvertebrate taxa composition and abundance is already compromised, antimycin would be a more logical choice due to lesser impacts on taxa numbers and abundance. Where native fish are removed prior to treatment and replacement is desired as soon as possible, antimycin is a logical choice due to rapid recovery of macroinvertebrate abundance. We hope the information provided here will allow fisheries and land managers to make more informed decisions related to piscicide treatments.

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REFERENCES

Binns, N.L. 1967. Effects of rotenone treatment on the fauna of the Green River, Wyoming. Fisheries Research Bulletin 1, Wyoming Fish and Game Commission.

Cook, S.F. Jr. and R.L. Moore. 1969. The effects of a rotenone treatment on the insect fauna of a California Stream. Transactions American Fisheries Society 3:539-544.

Degan, D.J. 1973. Observations on aquatic macroinvertebrates in a trout stream before, during and after treatment with Antimycin. M.S. thesis, University of Wisconsin, Stevens Point.

Engstrom-Heg, R., R.. Colesante, and E. Silco. 1978. Rotenone tolerances of stream bottom insects. New York Fish and Game Journal 25:31-41.

Hawkins, C., J. Ostermiller, M. Vinson and R. J. Stevenson. 2001. Stream algae, invertebrate and environmental sampling associated with biological water quality assessments: Field protocols. Department of Fisheries and Wildlife, Utah State University, Logan, Utah. 23 p.

Jacobi, G.Z. and D.J. Degan. 1977. Aquatic macroinvertebrates in a small Wisconsin stream before, during, and two years after treatment with the fish toxicant antimycin. Investigations in Fish Control No. 81. U.S. Department of Interior, Fish and Wildlife Service, Washington, D.C.

Mangum, F. A. and J.L. Madrigal 1999. Rotenone effects on aquatic macroinvertebrates of the Strawberry River, Utah: a five year summary. Journal of Freshwater Ecology 14:125-135.

Minckley, W.L. and P. Mihalick. 1981. Effects of chemical treatment for fish eradication on stream-dwelling invertebrates. Journal of the Arizona-Nevada Academy of Science 16:79-82.

Walker, C.A. 2003. Effects of Antimycin Treatment on Benthic Macroinvertebrates in Sams Creek and Starkey Creek, Great Smoky Mountains National Park, Blount/Sevier counties, Tennessee. M.S. thesis, University of Tennessee, Knoxville.

Whelan, J.E. 2002. Aquatic macroinvertebrate monitoring results of the 1995 and 1996 rotenone treatments of Manning Creek, Utah. Utah Division of Wildlife Resources Publication Number 02-04.

Williams, T.B., A.H. Pfaff, K. Pfaff, J. Jasper, and W. Cole. 1999. Great Basin National Park Bonneville cutthroat trout reintroduction and recreational fisheries management plan. U.S. Dept. of Interior, National Park Service. 65 p.