ZOOPLANKTON MONITORING REPORT

WDFW FISH MANAGEMENT PERMIT
NPDES PERMIT No. WA0041009

For the years 2011-2012 through 2012-2013

August 2013

Prepared for:
Department of Ecology
Water Quality Program

By: William Baker
Washington Department of Fish and Wildlife
District 1 Fish Biologist
Colville, Washington

Table of Contents

List of Tables

Introduction

With their gill-like tracheae, aquatic invertebrates are theoretically as susceptible to the toxic effects of rotenone as fish or amphibian larvae (Bradbury 1986). After laboratory based tests, Chandler and Marking (1982) concluded that, apart from an ostracod (*Cypridopsis sp*.), aquatic invertebrates are generally more tolerant of rotenone than most fishes and amphibian larval stages. In their study the most resistant organisms exposed were a snail (*Helisoma sp.*) and the Asiatic clam (*Corbicula manilensis*) for which the LC_{50} 96h concentrations were 50 times greater than those Marking and Bills (1976) reported for the Black bullhead (*Ictalurus melas*), one of their most resistant fishes. Sanders and Cope (1968) also conducted lab tests examining the effect of rotenone to the nymph or naiad stage of a stonefly (*Pteronarcys californica*). They found that the LC_{50} 24h was 2,900 µg/L and the LC_{50} 96h was 380 µg/L. These values are greater by an order of magnitude to those found by Marking and Bills (1976) for the black bullhead (*Ictalurus melas*), indicating that some aquatic invertebrates are much less sensitive to rotenone than fish. Larger, later instar naiads were less susceptible to given concentrations of toxin than were smaller, earlier instars of the same species (Sanders and Cope, 1968).

The immediate effect of rotenone on zooplankton communities can be catastrophic (Bradbury 1986), and we expect that at least 50% of the cladocerans and copepods present would die from exposure to rotenone concentrations (0.5 to 4.0 ppm) commonly used in fisheries management projects. There is general agreement that the planktonic crustaceans, especially cladocerans, are the group most affected, and rotifers are deemed more resistant to rotenone. Bradbury (1986) estimated that zooplankton would be reduced to non-measurable levels for a period from two to twelve weeks. Once plankters reappear, the community begins to rebuild, eventually returning to pre-treatment levels and diversity.

The Washington Department of Fish and Wildlife (WDFW) obtained National Pollutant Discharge Elimination System (NPDES)/Waste Discharge Individual Permit No. WA0041009 in July, 2002 to apply rotenone, an aquatic pesticide used to manage fish populations in lakes and streams in the State of Washington. The safe and effective treatment of populations of undesirable fish species improves aquatic and riparian fish and wildlife habitats, establishes conditions favorable for the growth of desirable game fish species, and promotes the social and economic benefits of a healthy recreational fishery in the lakes that have been treated.

Special condition S.2 of the NPDES requires sampling of zooplankton in treated lakes according to the protocols set forth in "Water Quality Assessments of Selected Lakes within Washington State 1998", Department of Ecology, December 2000, Publication No. 00-03-039, (NPDES Appendix B). Sampling frequency was set at pre-treatment, six months post-treatment, and one year post-treatment. Samples were to be analyzed for relative abundance of cladocerans and copepods, and their mean length, and tabulated as the ratio of total cladocerans : total copepods.

Sampling Results

Table 1 represents the lakes treated with rotenone during the years 2011-2012 through 2012-2013.

Table 1. Locations and dates for zooplankton samples taken to comply with NPDES Permit No. WA0041009 from 2011-12 through 2012-13.

LAKES TREATED	TREATMENT DATE	PRE-TREATMENT	SIX MONTHS	ONE YEAR
2011-12				
KINGS LAKE	9/27/2011	9/23/2011	04/25/2012	09/25/2012
ALTA LAKE	10/04/2011	10/02/2011	04/19/2012	10/26/2012
FISH LAKE	10/25/2011	10/24/2011	04/06/2012	10/02/2012
SCHALLOW POND	10/26/2011	10/24/2011	04/06/2012	10/02/2012
2012-13				
FISH LAKE (SPOKANE CO.)	10/22/2012	10/21/2012	NOT ANALYZED	TO BE COLLECTED
BURKE LAKE	10/24/2012	10/23/2012	NOT ANALYZED	TO BE COLLECTED
LITTLE BEAVER LAKE	10/29/2012	10/27/2012	NOT ANALYZED	TO BE COLLECTED

Disposition of Samples

Since 2006, WDFW’s Large Lakes Research Team (LLRT) has been conducting the analysis of all zooplankton samples taken in the lake rehabilitation program. The LLRT’s report to the lake rehabilitation program, which includes methods and analysis of results, is included in this document as Attachment 1.

Results of Analyses

The response of zooplankton to rotenone treatment was variable in each of the lakes sampled. In general, the ratio of cladocerans to copepods tended to decline substantially at six months post-treatment, returning to near pre-treatment levels at one year post-treatment. The average length of cladocerans showed an inconsistent response at six months post-treatment, and generally was near, or slightly larger, at one year post-treatment. Copepod average lengths also showed inconsistent response at six months post-treatment and tended to increase in size or remain the same at one year post-treatment (Table 2).

Table 2. Ratio of cladocerans: copepods and average length of cladocerans and copepods in zooplankton samples collected pre-treatment, six months post-treatment, and one year post-treatment from waters treated with rotenone in 2011-12**.**

Lake and Sample	Date	Ratio of Cladocerans:Copepods	Cladoceran Avg. Length (mm)	Copepod Avg. Length (mm)
Kings Lake (Pend Oreille Co.)				
Pre-Treatment	09/23/2011	1.72:1	1.399	0.742
Six Month Post-Treatment	04/25/2012	1:8.38	0.888	0.990
One Year Post-Treatment	09/25/2012	1.14:1	1.287	0.749
Alta Lake (Okanogan Co.)				
Pre-Treatment	10/02/2011	1:8.04	1.157	0.924
Six Month Post-Treatment	04/19/2012	1:491.00	*	0.871
One Year Post-Treatment	10/26/2012	1:4.87	0.992	0.912
Fish Lake (Okanogan Co.)				
Pre-Treatment	10/24/2011	8.08:1	0.746	0.512
Six Month Post-Treatment	04/06/2012	1:12.00	0.825	0.564
One Year Post-Treatment	10/02/2012	10.44:1	0.757	1.095
Schallow Pond (Okanogan Co.)				
Pre-Treatment	10/24/2011	7.12:1	0.722	0.806
Six Month Post-Treatment	04/06/2012	1:3.00	*	0.717
One Year Post-Treatment	10/02/2012	11.26:1	0.742	0.903

*Indicates value cannot be reported due to sample degradation.

Discussion

Changes in the abundance and/or structure of the plankton community by the use of chemicals like rotenone can have marked effects on subsequent fish populations that depend on plankton either directly or indirectly for nutrition. Hoffman and Olive (1961) conducted an experiment to document the effect of rotenone on the zooplankton community in a Colorado reservoir from 1954-1955. They observed a complete kill of protozoans and Entomostracans and a major reduction in the Rotifer population following the treatment. Their finding agreed with previous research (Hooper, 1948; Brown and Ball, 1943; Hamilton, 1941) and more recent findings have demonstrated that rotenone is indeed variably toxic to zooplankton communities (Melaas et al., 2001; Beal and Anderson, 1993; Neves, 1975; Anderson, 1970; Kiser et al, 1963), especially in acidic conditions (Kiser et al. 1963).

Unlike many benthic invertebrates, which may escape the immediate effects of rotenone by burrowing into sediment, zooplanktons are exposed to rotenone for the full duration of its activity in the water column. However, populations may recover from resistant life-stages and or eggs (Kiser et al. 1963). A full recovery of the zooplankton community may take longer, however. Beal and Anderson (1993) demonstrated that some populations may take up to 8 months to recover following rotenone treatment, while Anderson (1970) noted a 3-year recovery period in two mountain lakes.

Therefore, when rotenone is used in a fisheries management program where future restocking and growth of game fish depends on naturally produced food items, consideration must be given for an adequate amount of time for the zooplankton communities to re-establish themselves, before fish are re-introduced into the lake.

Field studies examining the effect of rotenone on aquatic macroinvertebrate communities have provided varied results. Whereas some workers noticed dramatic, long-term effects (Mangum and Madrigal 1999; Binns 1967), others observed rotenone has a negligible effect on most aquatic macroinvertebrates (Demong, 2001; Melaas, 2001). Most researchers would agree, however, that the effects of rotenone are less pronounced and more variable to macroinvertebrates than the effects of the chemical on zooplankton. Similar to the range of sensitivities demonstrated by various fish species to rotenone, different species of aquatic macroinvertebrates exhibit a range of tolerances (Mangum and Madrigal, 1999; Chandler and Marking, 1982; Engstrom-Heg et al., 1978) likely based on their oxygen requirements.

The results of monitoring the zooplankton in lakes treated with rotenone under Permit No. WA0041009 reveals a similar variability. The short-term effects appear to be temporary, with most taxa or groups of taxa recovering to pre-treatment levels, or re-establishing populations and relative abundances of cladocerans and copepods that reflect a modified predatory assemblage.

It is expected that rotenone will reduce overall populations of zooplankton immediately subsequent to treatment of the lake, but that zooplankton communities will fully recover in almost all cases (Bradbury 1986). Following an autumn treatment, zooplankton recovery will be slow due to low water temperatures through the winter months. As the water warms and primary production results in growth of phytoplankton, the remaining zooplankton populations respond positively and proportionally.

The zooplankton populations at the time of treatment were influenced by the predatory effects of populations of fish deemed undesirable for the game fish management plan of the individual lake. It is expected that, subsequent to rotenone treatment and the re-stocking of desirable game fish, the zooplankton populations will re-establish themselves at levels somewhat different to the pre-treatment state. A variety of temporary shifts in zooplankton community structure occur during the post-treatment period, with the most common shift being toward larger-sized cladocerans while fish are absent (Bradbury 1986). When fish are reintroduced, the zooplankton community returns to a structure, level of abundance, and diversity more closely resembling that observed pre-treatment.

Literature Cited

Anderson, R.S. 1970. Effects of rotenone on zooplankton communities and a study of their recovery patterns in two mountain lakes in Alberta. J. Fish Res. Bd. Can. 27: 1335-1356.

Beal, D. L. and R.V. Anderson. 1993. Response of zooplankton to rotenone in a small pond. Bulletin of Environmental Contamination and Toxicology. Vol. 51: 551-556.

Binns, N.A. 1967. Effects of rotenone treatment on the fauna of the Green River, Wyoming. Fisheries Research Bulletin 1. Wyoming Fish and Game Commission, Cheyenne. 114pp.

Bradbury, A. 1986. Rotenone and trout stocking. Washington Department of Game,
Fisheries Management Division. Fish. Manage. Rep. 86-2. 181 pp.

Brown, C. J. D., and R. C. Ball. 1943. An experiment in the use of derris root (rotenone) on the fish and fish-food organisms of Third Sister Lake. *Transactions of the American Fisheries Society*. 72: 267-284.

Chandler, J.H. Jr., and L.L. Marking. 1982. Toxicity of rotenone to selected aquatic invertebrates and frog larvae. Progressive Fish Culturist. 44(2): 78-80.

Demong, L. 2001. The use of rotenone to restore native brook trout in the Adirondack Mountains of New York - an overview. pp. 29-35 *in* R.L. Cailteux, L. DeMong, B.J. Finlayson, W. Horton, W. McClay, R.A. Schnick, and C. Thompson, eds. Rotenone in fisheries: are the rewards worth the risks? American Fisheries Society. Trends in Fisheries Science and Management 1, Bethesda, Maryland.

Engstrom-Heg, R., R.T. Colesante and E. Silco. 1978. Rotenone tolerances of stream-bottom insects. *New York Fish and Game Journal.* 25(1): 31-41.

Hamilton, H.L. 1941. The biological action of rotenone on freshwater animals. *Proceedings from Iowa Academy of Sciences*. 48: 467-479.

Hoffman, D.A., and J.R. Olive. 1961. The effects of rotenone and toxaphene upon plankton of two Colorado reservoirs. Journal of Limnology and Oceanography. 6: 219-222.

Hooper, F. F. 1948. The effect of derris root (rotenone) upon plankton and bottom fauna organisms of a small Minnesota lake. *Proceedings from Minnesota Academy of Sciences*. 16: 29-32.

Kiser R.W., J.R. Donaldson, and P.R. Olson. 1963. The effect of rotenone on zooplankton populations in freshwater lakes. *Transactions of the American Fisheries Society*. 92:17–24.

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(1): 125-134.

Marking, L.L., and T.D. Bills. 1976. Toxicity of rotenone to fish in standardized laboratory
tests*. U.S. Fish and Wildlife Service Investigations in Fish Control.* 72: 1-11.

Melaas, C.L., K.D. Zimmer, M.G. Butler and M.A. Hanson. 2001. Effects of rotenone on aquatic invertebrate communities in prairie wetlands. *Hydrobiologia*. Vol. 459: 177-186.

Neves, R.J. 1975. Zooplankton recolonization of a lake cove treated with rotenone*. Transactions of the American Fisheries Society*. 104(2): 390–393.

Sanders, H.O., and O.B. Cope. 1968. The relative toxicities of several pesticides to naiads of three species of stoneflies. *Journal of Limnology and Oceanography*. 13(1):112-117.

Attachment 1.

Zooplankton Identification and Analysis

Washington Department of Fish and Wildlife

August 1, 2013

Prepared for:

Fish Management Division

By:

The Large Lakes Research Team

Introduction

During the 2012 lake rehabilitation season the WDFW sampled zooplankton from 7 lakes and collected 36 samples. Collected samples were given to the Large Lakes research team to for identification and enumeration as per the Washington Department of Ecology's requirements (2002).

Methods and Results

Collected zooplankton samples were delivered to the LLRT lab shortly after collections. Entire samples were enumerated for those that had less than 500 individuals. Whereas, samples with more than 500 individuals of any one species were sub-sampled. Prior to sub-sampling, the sample was reduced into a graduated beaker using an open-ended nytex mesh cup and water. Using a Hensen-Stempel pipette, 10 mL were removed from the stirred sample to assure a homogenous distribution of zooplankton throughout. The process of sub-sampling was repeated if the initial sub-sample contained more than 500 individuals. Based on the total number of individuals in the sub-sample, the entire sample was estimated.

Zooplankton was identified using a Leica 0.8-3.5 x-dissecting microscope. Relative abundance was determined for cladocerans and copepods for each zooplankton sample and sub-sample. The results were reported as a ratio of total cladocerans: total copepods (Table 1). In addition mean lengths and 95% confidence intervals (C.I.) of cladocerans and copepods were calculated (Table 2).

Table 1. Zooplankton total enumeration and ratio.

		Total Count Ratio		Ratio	
Lake	**Date**	**Cladocerans**	**Copepods**	**Cladocerans**	**Copepods**
Little Beaver	10/27/2012	1989	19	104.68	1
Little Beaver	10/27/2012	372	39	9.54	1
Little Beaver	10/27/2012	331	11	30.09	1
Little Beaver	10/22/2012	153	18	8.50	1
Schallow Pond	10/2/2012	130	15	8.67	1
Schallow Pond	10/2/2012	166	10	16.60	1
Fish Lake	10/2/2012	221	20	11.05	1
Fish Lake	10/2/2012	143	12	11.92	1
Fish Lake	10/2/2012	309	37	8.35	1
Alta Lake	10/26/2012	69	446	1	6.46
Alta Lake	10/26/2012	75	293	1	3.91
Alta Lake	10/26/2012	74	313	1	4.23
Schallow Pond	4/6/2012	0	0	Na	Na
Schallow Pond	4/6/2012	0	0	Na	Na
Schallow Pond	4/6/2012	1	3	1	3.00
Fish Lake	4/6/2012	2	12	1	6.00
Fish Lake	4/6/2012	1	18	1	18.00
Fish Lake	4/6/2012	0	11	Na	
Alta Lake	4/19/2012	1	491	1	491.00
Alta Lake	4/19/2012	0	214	Na	Na
Alta Lake	4/19/2012	0	241	Na	Na
Kings Lake	4/25/2012	51	272	1	5.33
Fish Lake	10/21/2012	365	173	2.11	1
Fish Lake	10/21/2012	299	158	1.89	1
Fish Lake	10/21/2012	266	196	1.36	1
Kings Lake	9/25/2012	124	117	1.06	1
Kings Lake	9/25/2012	102	99	1.03	1
Kings Lake	9/25/2012	122	92	1.33	1
Kings Lake	4/25/2012	23	256	1	11.13
Kings Lake	4/25/2012	32	278	1	8.69
Burke Lake	10/23/2012	434	121	3.59	0.28
Burke Lake	10/23/2012	479	132	3.63	1
Burke Lake	10/23/2012	575	148	3.89	1
Fish Lake (Spokane)	4/19/2013	75	8633	1	115.11
Fish Lake (Spokane)	4/19/2013	105	8405	1	80.05
Fish Lake (Spokane)	4/19/2013	9	514	1	57.11

Table 2. Mean length (mm) and 95% confidence intervals of cladocerans and copepods.

Body of Water	Date	Cladocerans		Copepods	
		Mean Length (mm)	95% C.I.	Mean Length (mm)	95% C.I.
Little Beaver	10/27/12	2.737	4.982	0.585	0.078
Little Beaver	10/27/12	0.328	0.032	0.570	0.094
Little Beaver	10/27/12	0.369	0.049	*	*
Schallow Pond	10/22/12	0.730	0.100	1.060	0.269
Schallow Pond	10/2/12	0.763	0.047	0.928	0.306
Schallow Pond	10/2/12	0.733	0.065	0.720	0.243
Fish Lake	10/2/12	0.761	0.082	1.070	0.246
Fish Lake	10/2/12	0.723	0.077	1.086	0.451
Fish Lake	10/2/12	0.788	0.085	1.130	0.223
Alta Lake	10/26/12	0.839	0.172	0.948	0.056
Alta Lake	10/26/12	0.953	0.207	0.929	0.055
Alta Lake	10/26/12	1.184	0.227	0.860	0.044
Schallow Pond	4/6/12	*	*	*	*
Schallow Pond	4/6/12	*	*	*	*
Schallow Pond	4/6/12	*	*	0.717	0.597
Fish Lake	4/6/12	0.825	3.494	0.571	0.062
Fish Lake	4/6/12	*	*	0.531	0.057
Fish Lake	4/6/12	*	*	0.591	0.104
Alta Lake	4/19/12	*	*	0.865	0.173
Alta Lake	4/19/12	*	*	0.871	0.142
Alta Lake	4/19/12	*	*	0.876	0.100
Kings Lake	4/25/12	1.200	0.219	0.846	0.099
Fish Lake	10/21/12	0.783	0.153	0.928	0.077
Fish Lake	10/21/12	0.763	0.116	0.888	0.083
Fish Lake	10/21/12	0.734	0.105	0.863	0.077
Kings Lake	9/25/12	1.260	0.192	0.726	0.084
Kings Lake	9/25/12	1.283	0.171	0.774	0.047
Kings Lake	9/25/12	1.319	0.200	0.748	0.062
Kings Lake	4/25/12	0.880	0.150	0.950	0.090
Kings Lake	4/25/12	0.896	0.147	1.029	0.073
Burke Lake	10/23/12	0.959	0.220	1.070	0.099
Burke Lake	10/23/12	0.881	0.178	1.043	0.098
Burke Lake	10/23/12	0.841	0.202	1.040	0.101
Fish Lake (Spokane)	4/19/13	0.725	0.091	1.293	0.038
Fish Lake (Spokane)	4/19/13	0.632	0.043	1.189	0.094
Fish Lake (Spokane)	4/19/13	0.574	0.060	1.056	0.106

*Indicates no measureable zooplankton

Field Collection Standard Operating Procedures

Zooplankton samples can be readily collected with a 150 micron mesh Wisconsin type zooplankton net. Each sample should be taken from an anchored site, from the bottom of the lake straight up to the lake surface, rather than at an angle. If a sample contains benthic debris, the sample should be emptied and taken again. Depth should be recorded to calculate the volume of water sampled. Zooplankton density can then be computed from the known volume in the sample and expanded to number/liter, which is useful when comparing data among water bodies In addition, each sample should contain a label tag written in pencil on waterproof paper (e.g. "Rite in the Rain"®) for site identification. Some of the sample bottles were labeled in permanent ink, which dissolves in ethanol. Consequently, some of the sample bottles lacked pertinent information regarding area of collection and depth. The following information should be recorded on a label tag:

- Lake Name
- Location of Sample (description or coordinates)
- Date
- Time
- Depth
- Water Temperature

We recommend that the following preservation techniques, similar to those developed by Black and Dodson (2003), be used when collecting zooplankton samples. Immediately following a tow, each sample should be flushed into an open-ended nytex mesh cup designed to capture all zooplankton within the sample while allowing the water to pass through. Once the majority of water has drained from the sample, the nytex cup should be placed in a tray of 95% ethanol for approximately 10 seconds in order to fix the zooplankton. Once the sample is fixed it should be irrigated from the cup with 70% ethanol into a Whirl-Pak® or 125 mL plastic bottle. Samples should be stored in 70% ethanol until lab analysis. To prevent samples from drying, an adequate volume of ethanol should be used to fill the storage vessel. Other types of alcohol such as isopropyl should not be used as they can destroy cladoceran carapaces. During our zooplankton analysis, some cladocerans could not be measured because of carapace deterioration.

References:

Black, A. R. and S. I. Dodson. 2003. Ethanol: a better preservation technique for *Daphnia*. Limnology and Oceanography: Methods 1:45-50.

United States Army Corp. of Engineers. 2007. http://el.erdc.usace.army.mil/zebra/zmis/zmishelp4/dreissena_polymorpha_zebra_mussel_larva.htm

Washington Department of Ecology. 2002. Fishery Resource Management. National Pollutant Discharge Elimination System, Water Discharge Individual Permit No. WA0041009. Pages 28-29.