ZOOPLANKTON MONITORING REPORT

WDFW FISH MANAGEMENT PERMIT
NPDES PERMIT No. WA0041009

For the years 2010-2011 through 2011-2012

MAY 2012

Prepared for:
Department of Ecology
Water Quality Program

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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 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 2010-2011 through 2011-2012.

Table 1. Locations and dates for zooplankton samples taken to comply with NPDES Permit No. WA0041009 from 2010-11 through 2011-12.

LAKES TREATED	TREATMENT DATE	PRE-TREATMENT	SIX MONTHS	ONE YEAR
2010-11				
BEDA LAKE	9/15/2010	9/15/10	4/04/11	10/12/11
DUNE LAKE	9/15/2010	9/15/10	3/30/11	10/28/11
HARRIS LAKE	9/15/2010	9/15/10	4/04/11	10/28/11
SEDGE/TERN LAKES	9/15/2010	9/15/10	4/04/11	10/28/11
WINDMILL LAKE	10/03/2010	10/03/10	5/11/11	10/13/11
NORTH WINDMILL LAKE	10/05/2010	10/05/10	5/11/11	10/13/11
N.-N. WINDMILL LAKE	10/05/2010	10/05/10	5/11/11	10/13/11
CANAL LAKE	10/03/2010	10/03/10	5/11/11	10/13/11
PIT LAKE	10/03/2010	10/03/10	5/11/11	10/13/11
HEART LAKE	10/03/2010	10/03/10	5/11/11	10/13/11
LYLE LAKE	10/13/2010	10/13/10	5/10/11	10/28/11
NORTH TEAL LAKE	10/12/2010	10/12/10	5/11/11	10/12/11
SOUTH TEAL LAKE	10/12/2010	10/12/10	5/11/11	10/12/11
HERMAN LAKE	10/12/2010	10/12/10	5/11/11	10/12/11
JUNE LAKE	10/05/2010	10/05/10	5/11/11	10/13/11
LOWER CALICHE LAKE	10/25/2010	10/25/10	5/10/11	10/28/11
UPPER CALICHE LAKE	10/25/2010	10/25/10	5/10/11	10/12/11
MARTHA LAKE	10/25/2010	10/25/10	5/10/11	10/12/11
WEST CALICHE	10/25/2010	10/25/10	5/10/11	10/28/11
2011-12				
KINGS LAKE	9/27/2011	9/23/2011	**NOT ANALYZED**	**TO BE COLLECTED**
ALTA LAKE	10/04/2011	10/02/2011	**NOT ANALYZED**	**TO BE COLLECTED**
FISH LAKE	10/25/2011	10/24/2011	**NOT ANALYZED**	**TO BE COLLECTED**
SCHALLOW POND	10/26/2011	10/24/2011	**NOT ANALYZED**	**TO BE COLLECTED**

Disposition of Samples

Since 2006, the Washington Department of Fish and Wildlife's, Large Lakes Research Team (LLRT) has been conducting the analysis of all samples taken in the lake rehabilitation program. Methods, analysis and the LLRT's report to the lake rehabilitation program are included in this document as Attachment 1.

Results of Analyses

The response of zooplankton to the effects of the rotenone treatments was variable in each of the lakes sampled. In general, the ratio of cladocerans to copepods tended to decline substantially after six months post-treatment, then was found to have returned 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 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. Locations and dates for zooplankton samples taken to comply with NPDES Permit No. WA0041009 from 2010-11 and 2011-12. Cladoceran to copepod ratios, and average lengths in millimeters.

2009-10 Lakes Treated	DATE	Ratio of Cladocerans:Copepods	Cladocerans Avg. Length (mm)	Copepods Avg. Length (mm)
BEDA LAKE				
Pre-Treatment	9/15/2010	1:1.50	0.15	0.68
Six Month Post-Treatment	4/04/2011	1:8.74	0.46	0.70
One Year Post-Treatment	10/12/2011	1.22:1	0.53	0.73
DUNE LAKE				
Pre-Treatment	9/15/2010	1:1.36	0.24	1.14
Six Month Post-Treatment	3/30/2011	1:15.57	0..40	1.2
One Year Post-Treatment	10/28/2011	1:18.36	0.37	0.91
HARRIS LAKE				
Pre-Treatment	9/15/2010	1:19.45	0.27	1.10
Six Month Post-Treatment	4/04/2011	1.07:1	0.42	0.80
One Year Post-Treatment	10/28/2011	1.33:1.07	0.38	0.47
SEDGE/TERN LAKE				
Pre-Treatment	9/15/2010	4.72:1	0..20	0.87
Six Month Post-Treatment	4/04/2011	1:2.00	0.50	0.84
One Year Post-Treatment	10/28/2011	8.42:1	0.71	1.1
WINDMILL LAKE				
Pre-Treatment	10/03/2010	4.21:1	1.10	1.10
Six Month Post-Treatment	5/11/2011	1:37.47	0.86	0.81
One Year Post-Treatment	10/13/2011	3.11:1	0.78	0.80
NORTH WINDMILL LAKE				
Pre-Treatment	10/05/2010	7.26:1	0.38	0.76
Six Month Post-Treatment	5/11/2011	2.03:1	1.29	0.68
One Year Post-Treatment	10/13/2011	1.73:1	0.98	1.14
NORTH-NORTH WINDMILL LAKE				
Pre-Treatment	10/05/2010	1:8.60	0.41	0.84
Six Month Post-Treatment	5/11/2011	3.83:1	1.71	0.72
One Year Post-Treatment	10/13/2011	6.46:1	1.13	1.27

Table 2. (cont.) Locations and dates for zooplankton samples taken to comply with NPDES Permit No. WA0041009 from 2010-11 and 2011-12. Cladoceran to copepod ratios, and average lengths in millimeters.

2010-11 Lakes Treated	DATE	Ratio of Cladocerans:Copepods	Cladocerans Avg. Length (mm)	Copepods Avg. Length (mm)
CANAL LAKE				
Pre-Treatment	10/03/2010	1.94:1	1.0	0.96
Six Month Post-Treatment	5/11/2011	1.37:1.07	1.38	0.86
One Year Post-Treatment	10/13/2011	1:1.77	1.05	1.07
PIT LAKE				
Pre-Treatment	10/03/2010	1:1.03	1.10	1.23
Six Month Post-Treatment	5/11/2011	2.02:1	1.02	0.93
One Year Post-Treatment	10/13/2011	1:2.82	1.48	0.85
HEART LAKE				
Pre-Treatment	10/03/2010	1:1.01	0.90	1.02
Six Month Post-Treatment	5/11/2011	1:18.44	0.64	1.04
One Year Post-Treatment	10/13/2011	9.33:1	1.10	0.86
LYLE LAKE				
Pre-Treatment	10/13/2010	5.46:1	0.46	1.03
Six Month Post-Treatment	5/10/2011	5.56:1	0.50	0.74
One Year Post-Treatment	10/28/2011	2.95:1	0.39	0.58
NORTH TEAL LAKE				
Pre-Treatment	10/12/2010	6.53:1	1.64	0.99
Six Month Post-Treatment	5/11/2011	1.22:1.14	1.32	0.81
One Year Post-Treatment	10/12/2011	2.09:1	1.04	0.96
SOUTH TEAL LAKE				
Pre-Treatment	10/12/2010	1.35:1	0.75	0.82
Six Month Post-Treatment	5/11/2011	1.32:1.29	1.20	0.82
One Year Post-Treatment	10/12/2011	10.77:1	0.34	0.42
HERMAN LAKE				
Pre-Treatment	10/12/2010	1.04:1	0.59	0.95
Six Month Post-Treatment	5/11/2011	1:6.78	0.41	0.68
One Year Post-Treatment	10/12/2011	1:1.48	0.57	0.78
JUNE LAKE				
Pre-Treatment	10/05/2010	1.58:1	0.93	0.96
Six Month Post-Treatment	5/11/2011	1:5.59	1.23	1.11
One Year Post-Treatment	10/13/2011	1.80:1	1.35	0.80
LOWER CALICHE LAKE				
Pre-Treatment	10/25/2010	4.13:1	0.18	0.76
Six Month Post-Treatment	5/10/2011	1:22.04	0.93	0.88
One Year Post-Treatment	10/28/2011	1:4.39	1.27	0.89

Table 2. (cont.) Locations and dates for zooplankton samples taken to comply with NPDES Permit No. WA0041009 from 2010-11 and 2011-12. Cladoceran to copepod ratios, and average lengths in millimeters.

2010-11 Lakes Treated	DATE	Ratio of Cladocerans:Copepods	Cladocerans Avg. Length (mm)	Copepods Avg. Length (mm)
UPPER CALICHE LAKE				
Pre-Treatment	10/25/2010	1:13.6	0.53	0.98
Six Month Post-Treatment	5/10/2011	1:22.71	0.78	0.98
One Year Post-Treatment	10/12/2011	4.05:1	1.21	0.81
MARTHA LAKE				
Pre-Treatment	10/25/2010	2.12:1	0.61	0.75
Six Month Post-Treatment	5/10/2011	8.12:1	0.73	0.74
One Year Post-Treatment	10/12/2011	2.44:1	0.90	0.80
WEST CALICHE LAKE				
Pre-Treatment	10/25/2010	26.23:1	0.47	0.61
Six Month Post-Treatment	5/10/2011	1.67:4.09	0.53	0.70
One Year Post-Treatment	10/28/2011	1:4.13	1.04	0.96
KINGS LAKE				
Pre-Treatment	9/23/2011	1.72:1	1.40	0.17
Six Month Post-Treatment	NOT ANALYZED			
One Year Post-Treatment	TO BE COLLECTED			
ALTA LAKE				
Pre-Treatment	10/02/2011	1:8.04	1.16	0.14
Six Month Post-Treatment	NOT ANALYZED			
One Year Post-Treatment	TO BE COLLECTED			
FISH LAKE				
Pre-Treatment	10/24/2011	8.08:1	0.75	0.07
Six Month Post-Treatment	NOT ANALYZED			
One Year Post-Treatment	TO BE COLLECTED			
SCHALLOW POND				
Pre-Treatment	10/24/2011	7.12:1	0.72	0.06
Six Month Post-Treatment	NOT ANALYZED			
One Year Post-Treatment	TO BE COLLECTED			

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.

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Attachment 1.

Zooplankton Identification and Analysis

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May 25, 2012

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Introduction

In 2011, the Fish Management Division of the Washington Department of Fish and Wildlife (WDFW) solicited the WDFW Large Lakes Research Team to conduct analyses on zooplankton samples collected during lake rehabilitations from 2010 to 2011. Samples were collected from 18 lakes with multiple samples from each lake, equating to 114 samples.

Methods and Results for Zooplankton Analyses

Preserved zooplankton samples were identified and enumerated (Washington Department of Ecology 2002). For zooplankton samples with less than 500 individuals, the entire sample was enumerated, 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.

Relative abundance and mean length (mm) were determined for cladocerans and copepods for each zooplankton sample and sub-sample. Relative abundance was estimated using a Leica 0.8-3.5 x-dissecting microscope. Lengths for copepods and cladocerans (up to 20 individuals of each type) were measured to the nearest 0.02 mm using an ocular micrometer (Table 1). The results were reported as a ratio of total cladocerans: total copepods (Table 2).

Table 1. Average zooplankton length (nearest 0.02 mm) ± 2 SE.

Lake	Date	Cladoceran Average TL	SE	Copepod Average TL	SE
Caliche	04/10/2011	0.786	0.083	0.750	0.078
L Caliche	05/10/2011	1.018	0.123	0.899	0.094
L Caliche	05/10/2011	0.848	0.162	0.865	0.090
W Caliche	05/10/2011	0.828	0.159	0.780	0.082
W Caliche	05/10/2011	0.755	0.099	0.709	0.173
W Caliche	05/10/2011	0.675	0.109	0.767	0.166
U Caliche	05/10/2011	-	-	1.123	0.148
Caliche	05/10/2011	0.760	0.082	0.756	0.095
U Caliche	05/10/2011	1.043	0.145	0.838	0.109
NN Windmill	05/11/2011	2.118	0.107	0.744	0.040
NN Windmill	05/11/2011	1.386	0.219	0.674	0.044
NW Windmill	05/11/2011	1.614	0.153	0.734	0.072
N Windmill	05/11/2011	1.435	0.181	0.700	0.059
N Windmill	05/11/2011	1.320	0.191	0.744	0.043
N Windmill	05/11/2011	1.112	0.096	0.601	0.061
Canal	05/11/2011	0.970	0.174	0.783	0.092
Canal	05/11/2011	1.431	0.191	0.969	0.089
Canal	05/11/2011	1.748	0.191	0.819	0.117
Pit	05/11/2011	0.861	0.101	0.933	0.059
Pit	05/11/2011	1.113	0.135	0.765	0.080
Pit	05/11/2011	1.078	0.118	1.076	0.072
Windmill	05/11/2011	0.653	0.129	0.880	0.073
Windmill	05/11/2011	1.137	0.207	0.941	0.116
Windmill	05/11/2011	0.783	0.178	0.604	0.068
S Teal	05/11/2011	1.233	0.239	0.953	0.067
S Teal	05/11/2011	1.172	0.226	0.703	0.107
S Teal	05/11/2011	1.196	0.258	0.806	0.061
N Teal	05/11/2011	1.270	0.216	0.676	0.095
N Teal	05/11/2011	1.328	0.241	0.844	0.078
N Teal	05/11/2011	1.356	0.135	0.909	0.062
Lyle	05/10/2011	0.513	0.135	0.705	0.097
Lyle	05/10/2011	0.486	0.083	0.706	0.061
Lyle	05/10/2011	0.489	0.115	0.794	0.070
Herman	05/11/2011	0.442	0.066	0.788	0.062
Herman	05/11/2011	0.348	0.028	0.574	0.059
Herman	05/11/2011	0.434	0.049	0.674	0.088
Martha	05/10/2011	0.553	0.081	0.885	0.162
Martha	05/10/2011	0.740	0.062	0.853	0.101
Martha	05/10/2011	0.647	0.107	0.855	0.096
June Lake	05/11/2011	1.259	0.173	0.978	0.113
June Lake	05/11/2011	1.050	0.202	1.066	0.096
June Lake	05/11/2011	1.366	0.184	1.271	0.098
Heart	05/11/2011	0.697	0.086	1.128	0.096
Heart	05/11/2011	0.667	0.112	1.156	0.112
Heart	05/11/2011	0.570	0.083	0.845	0.071
W Caliche	10/28/2011	0.395	0.118	0.364	0.228

W Caliche	10/28/2011	0.521	0.198	0.964	0.088
W Caliche	10/28/2011	0.460	0.097	0.826	0.208
Herman	10/12/2011	0.453	0.058	0.785	0.099
Herman	10/12/2011	0.655	0.124	0.715	0.085
Herman	10/12/2011	0.596	0.103	0.840	0.119
Pit	10/13/2011	1.433	0.221	0.843	0.080
Pit	10/13/2011	1.504	0.178	0.788	0.153
Pit	10/13/2011	1.489	0.202	0.906	0.160
June Lake	10/13/2011	1.326	0.172	0.795	0.073
June Lake	10/13/2011	1.276	0.164	0.833	0.056
June Lake	10/13/2011	1.438	0.179	0.784	0.088
Martha	10/12/2011	0.824	0.101	0.599	0.084
Martha	10/12/2011	0.707	0.071	0.760	0.093
Martha	10/12/2011	0.706	0.086	0.483	0.118
Lyle	10/28/2011	0.377	0.028	0.430	0.087
Lyle	10/28/2011	0.423	0.056	0.739	0.127
Lyle	10/28/2011	0.360	0.024	0.568	0.126
N Windmill	10/13/2011	1.055	0.105	0.985	0.099
N Windmill	10/13/2011	0.923	0.103	1.400	0.156
N Windmill	10/13/2011	0.973	0.126	1.024	0.212
Windmill	10/13/2011	0.680	0.059	0.725	0.055
Windmill	10/13/2011	0.977	0.105	0.856	0.084
Windmill	10/13/2011	0.667	0.071	0.808	0.039
Dune Lake	10/28/2011	0.345	0.038	0.706	0.090
Dune Lake	10/28/2011	0.343	0.046	1.025	0.082
Dune Lake	10/28/2011	0.409	0.060	0.986	0.091
L Caliche	10/28/2011	1.295	0.149	1.044	0.152
L Caliche	10/28/2011	1.163	0.166	0.688	0.100
L Caliche	10/28/2011	1.364	0.185	0.951	0.126
Canal	10/13/2011	1.086	0.192	0.891	0.128
Canal	10/13/2011	1.075	0.156	1.110	0.243
Canal	10/13/2011	0.986	0.201	1.194	0.244
U Caliche	10/12/2011	1.148	0.150	0.790	0.268
U Caliche	10/12/2011	1.189	0.145	0.804	0.061
U Caliche	10/12/2011	1.306	0.105	0.825	0.098
Sedge Tern Lake	10/28/2011	0.729	0.129	1.169	0.055
Sedge Tern Lake	10/28/2011	0.649	0.155	0.905	0.105
Sedge Tern Lake	10/28/2011	0.759	0.120	1.084	0.094
Beda Lake	10/12/2011	0.335	0.085	0.774	0.098
Beda Lake	10/12/2011	0.286	0.013	1.108	0.036
Beda Lake	10/12/2011	0.976	0.116	0.319	0.027
Heart Lake	10/13/2011	1.086	0.177	0.796	0.179
Heart Lake	10/13/2011	1.222	0.166	0.999	0.131
Heart Lake	10/13/2011	1.000	0.166	0.789	0.088
Harris Lake	10/28/2011	0.305	0.026	0.464	0.095
Harris Lake	10/28/2011	0.389	0.053	0.554	0.077
Harris Lake	10/28/2011	0.435	0.072	0.381	0.038
N Teal	10/12/2011	1.111	0.216	1.060	0.152
N Teal	10/12/2011	1.050	0.207	0.958	0.100
N Teal	10/12/2011	0.957	0.183	0.874	0.106

S Teal	10/12/2011	0.335	0.025	0.384	0.025
S Teal	10/12/2011	0.359	0.031	0.440	0.060
S Teal	10/12/2011	0.325	0.029	0.420	0.074
NN Windmill	10/13/2011	1.070	0.111	1.131	0.207
NN Windmill	10/13/2011	1.076	0.087	1.375	0.230
NN Windmill	10/13/2011	1.256	0.110	1.289	0.252
Alta Lake	10/02/2011	1.199	0.118	0.954	0.138
Alta Lake	10/02/2011	1.204	0.125	0.909	0.173
Alta Lake	10/02/2011	1.068	0.166	0.910	0.102
Fish Lake	10/24/2011	0.764	0.078	0.679	0.192
Fish Lake	10/24/2011	0.725	0.066	0.609	0.166
Fish Lake	10/24/2011	0.750	0.064	0.248	0.116
Schallow Lake	10/24/2011	0.748	0.063	0.738	0.227
Schallow Lake	10/24/2011	0.705	0.070	1.015	0.261
Schallow Lake	10/24/2011	0.712	0.054	0.666	0.213
Kings Lake	09/23/2011	1.606	0.148	0.708	0.031
Kings Lake	09/23/2011	1.233	0.171	0.768	0.104
Kings Lake	09/23/2011	1.357	0.200	0.751	0.064

Table 2. Zooplankton total enumeration and ratio.

		Total Count Ratio		Ratio	
Lake	**Date**	**Cladocerans**	**Copepods**	**Cladocerans**	**Copepods**
Caliche	04/10/2011	640	12560	1.00	19.63
L Caliche	05/10/2011	165	5265	1.00	31.91
L Caliche	05/10/2011	1240	15080	1.00	12.16
W Caliche	05/10/2011	254	74	3.43	1.00
W Caliche	05/10/2011	184	14	13.14	1.00
W Caliche	05/10/2011	45	15	3.00	1.00
U Caliche	05/10/2011	10	440	1.00	44.00
Caliche	05/10/2011	210	846	1.00	4.03
U Caliche	05/10/2011	120	170	1.00	1.42
NN Windmill	05/11/2011	8800	2800	3.14	1.00
NN Windmill	05/11/2011	10360	2320	4.47	1.00
NW Windmill	05/11/2011	6060	1560	3.88	1.00
N Windmill	05/11/2011	26880	12880	2.09	1.00
N Windmill	05/11/2011	15480	8760	1.77	1.00
N Windmill	05/11/2011	11060	4970	2.23	1.00
Canal	05/11/2011	19700	16600	1.19	1.00
Canal	05/11/2011	15200	18200	1.00	1.20
Canal	05/11/2011	20160	10480	1.92	1.00
Pit	05/11/2011	1800	780	2.31	1.00
Pit	05/11/2011	990	735	1.35	1.00
Pit	05/11/2011	3900	1625	2.40	1.00
Windmill	05/11/2011	660	29850	1.00	45.23
Windmill	05/11/2011	540	21900	1.00	40.56
Windmill	05/11/2011	440	11720	1.00	26.64
S Teal	05/11/2011	6120	6920	1.00	1.13
S Teal	05/11/2011	6965	3535	1.97	1.00
S Teal	05/11/2011	8040	13960	1.00	1.74
N Teal	05/11/2011	15150	9600	1.58	1.00
N Teal	05/11/2011	9950	9200	1.08	1.00
N Teal	05/11/2011	10400	14800	1.00	1.42
Lyle	05/10/2011	438	73	6.00	1.00
Lyle	05/10/2011	288	67	4.30	1.00
Lyle	05/10/2011	312	49	6.37	1.00
Herman	05/11/2011	1680	16280	1.00	9.69
Herman	05/11/2011	2025	14490	1.00	7.16
Herman	05/11/2011	2370	8250	1.00	3.48
Martha	05/10/2011	2080	40	52.00	1.00
Martha	05/10/2011	2757	59	46.73	1.00
Martha	05/10/2011	792	42	18.86	1.00
June Lake	05/11/2011	1890	15930	1.00	8.43
June Lake	05/11/2011	2340	11480	1.00	4.91
June Lake	05/11/2011	3395	11690	1.00	3.44
Heart	05/11/2011	35	860	1.00	24.57
Heart	05/11/2011	49	974	1.00	19.88
Heart	05/11/2011	69	751	1.00	10.88
W Caliche	10/28/2011	5	8	1.00	1.6
W Caliche	10/28/2011	6	58	1.00	9.67
W Caliche	10/28/2011	17	19	1.00	1.12
Herman	10/12/2011	7200	11800	1.00	1.64
Herman	10/12/2011	4400	7900	1.00	1.80

Herman	10/12/2011	7200	7200	1.00	1.00
Pit	10/13/2011	1290	1290	1.00	1.00
Pit	10/13/2011	810	3000	1.00	3.70
Pit	10/13/2011	720	2700	1.00	3.75
June Lake	10/13/2011	1260	900	1.40	1.00
June Lake	10/13/2011	1560	1140	1.37	1.00
June Lake	10/13/2011	2750	1050	2.62	1.00
Martha	10/12/2011	493	123	4.01	1.00
Martha	10/12/2011	780	520	1.50	1.00
Martha	10/12/2011	450	250	1.80	1.00
Lyle	10/28/2011	1620	660	2.45	1.00
Lyle	10/28/2011	1605	435	3.69	1.00
Lyle	10/28/2011	1710	630	2.71	1.00
N Windmill	10/13/2011	7400	4100	1.80	1.00
N Windmill	10/13/2011	6100	3950	1.54	1.00
N Windmill	10/13/2011	5900	3200	1.84	1.00
Windmill	10/13/2011	22100	8400	2.63	1.00
Windmill	10/13/2011	32130	8330	3.86	1.00
Windmill	10/13/2011	21360	7520	2.84	1.00
Dune Lake	10/28/2011	76	826	1.00	10.87
Dune Lake	10/28/2011	39	1245	1.00	31.92
Dune Lake	10/28/2011	107	1314	1.00	12.28
L Caliche	10/28/2011	600	3275	1.00	5.46
L Caliche	10/28/2011	575	2950	1.00	5.13
L Caliche	10/28/2011	1680	4340	1.00	2.58
Canal	10/13/2011	7920	10080	1.00	1.27
Canal	10/13/2011	6390	17370	1.00	2.72
Canal	10/13/2011	6650	8800	1.00	1.32
U Caliche	10/12/2011	4080	840	4.86	1.00
U Caliche	10/12/2011	4500	1260	3.57	1.00
U Caliche	10/12/2011	4850	1300	3.73	1.00
Sedge Tern Lake	10/28/2011	39065	4615	8.46	1.00
Sedge Tern Lake	10/28/2011	54200	5200	10.42	1.00
Sedge Tern Lake	10/28/2011	36000	5640	6.38	1.00
Beda Lake	10/12/2011	16400	12400	1.32	1.00
Beda Lake	10/12/2011	20640	16800	1.23	1.00
Beda Lake	10/12/2011	15360	13860	1.11	1.00
Heart Lake	10/13/2011	10400	1150	9.04	1.00
Heart Lake	10/13/2011	10440	870	12.00	1.00
Heart Lake	10/13/2011	10400	1500	6.93	1.00
Harris Lake	10/28/2011	1650	2010	1.00	1.22
Harris Lake	10/28/2011	2300	1825	1.26	1.00
Harris Lake	10/28/2011	2790	1620	1.72	1.00
N Teal	10/12/2011	5600	2590	2.16	1.00
N Teal	10/12/2011	6700	3200	2.09	1.00
N Teal	10/12/2011	4800	2400	2.00	1.00
S Teal	10/12/2011	37900	5100	7.43	1.00
S Teal	10/12/2011	28400	1380	20.58	1.00
S Teal	10/12/2011	19410	4500	4.31	1.00
NN Windmill	10/13/2011	7880	1120	7.04	1.00
NN Windmill	10/13/2011	10650	1450	7.34	1.00
NN Windmill	10/13/2011	5500	1100	5.00	1.00
Alta Lake	10/02/2011	255	1025	1.00	4.02
Alta Lake	10/02/2011	205	1510	1.00	7.37

Alta Lake	10/02/2011	135	1720	1.00	12.74
Fish Lake	10/24/2011	1183	168	7.04	1.00
Fish Lake	10/24/2011	973	168	5.79	1.00
Fish Lake	10/24/2011	798	70	11.40	1.00
Schallow Lake	10/24/2011	756	161	4.70	1.00
Schallow Lake	10/24/2011	955	105	9.10	1.00
Schallow Lake	10/24/2011	945	125	7.56	1.00
Kings Lake	09/23/2011	2850	1800	1.58	1.00
Kings Lake	09/23/2011	8610	5070	1.70	1.00
Kings Lake	09/23/2011	7320	3870	1.89	1.00

Recommendations

Field Sampling:

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. To reduce the error of overestimating zooplankton abundance, 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. 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

Preservation:

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.

Analysis:

The zooplankton sampling protocol (Washington Department of Ecology 2002) requires a cladoceran/copepod ratio for each sample. Although this is the prescribed methodology, we feel an additional descriptive approach may be warranted. The identification of zooplankton to family would provide more information and be useful to temporally and spatially compare samples within and among systems. Furthermore, the descriptive approach may be useful to detect invasive species such as the zebra mussel (*Dreissena polymorpha*) larvae or veliger, which range in size from 97-228 µm depending on the ontogenetic stage (USACE 2007). However, it should be noted that the sampling efforts associated with the rehabilitation requirements could only supplement, not replace the existing efforts dedicated to detecting invasive species such as zebra mussels.

Conclusions:

We recommend that all future samples be analyzed shortly after they are collected to reduce the likelihood of damage to zooplankton carapaces. The methods that we recommended will reduce the volume of alcohol required while maintaining the integrity of zooplankton structures used for analysis. We have constructed all of the necessary equipment needed to follow our methodologies and will gladly supply WDFW staff with these material when needed. Thank you for using the Large Lakes Research Team to perform your mandated tasks and we look forward to becoming more involved in future Lake Rehabilitation Program efforts.

References:

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