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Brian C. Peterson
University of Nebraska-Kearney, petersonbc@unk.edu

Byron W. Sellers
USGS Grand Island Field Office, bsellers@usgs.gov

Nicolas J. Fryda
Nebraska Game and Parks Commission, Kearney, nic.fryda@nebraska.gov

Keith D. Koupal
Nebraska Game and Parks Commission, Kearney, keith.koupal@nebraska.gov

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Assessment of Water Quality and Response Rate of Zooplankton in a Nebraska “Barrow Pit” After Rotenone Application

Brian C. Peterson[1], Byron W. Sellers[2], Nicolas J. Fryda[3], and Keith D. Koupal[3]

[1]Department of Biology, University of Nebraska-Kearney, 2401 11th Ave, Kearney, Nebraska 68849

[2]USGS Grand Island Field Office, 2608 Sothman Drive, Grand Island, Nebraska 68801

[3]Nebraska Game and Parks Commission, 1617 First Avenue, Kearney, Nebraska 68847

Correspondence: Brian C. Peterson, petersonbc@unk.edu, (308) 865-1589, fax (308) 865-8045

Understanding the extent and depth of rotenone impacts on all trophic levels is essential to effective aquatic management. We examined changes in water quality tenets and zooplankton communities following the establishment of 3 ppm rotenone concentration in a Nebraska barrow pit. Dissolved oxygen initially decreased 57% and subsequently increased 298% the week following rotenone application. Turbidity decreased from 25.8 FAU ± 0.80 pre-treatment to 6.6 FAU ± 0.98 one year later. Total zooplankton (0.17/L ± 0.03) were limited prior to rotenone application and absent for the following 3 weeks. One year later the total number of zooplankton increased 1024%, and during the same timeframe both pseudo-control barrow pits remained similar or decreased in total zooplankton present. Rotifers were the first taxon to recover. Copepods and their nauplii were absent for 2 months and recovered to levels greater than pseudo-controls three months after the rotenone treatment. Cladocerans were the slowest to re-establish as they were absent for 3 months and did not match those recorded in pseudo-controls until 7 months later. This research can assist aquatic managers in understanding how water quality and zooplankton communities will change following the application of rotenone in a Nebraska barrow pit.

Introduction

Indigenous populations of Southeast Asia and South America have used natural toxic properties of several tropical plants for centuries (M’Gonigle and Smith 1938, Ball 1948). Rotenone has been developed as a commercially prepared product from derris plant roots and has become one of the best studied natural toxic compounds (Ling 2002). Derris toxins affect cellular respiration by blocking mitochondrial electron transport (Singer and Ramsay 1994).

Many uses have been developed for rotenone. Chemical renovations with rotenone have been employed to manage sport fisheries, quantify fish populations, eliminate competing species in aquaculture ponds, eradicate exotic species, clean watersheds prior to impoundment, eradicate diseases and selectively control pest species (Ling 2002). Rotenone has been used for fisheries management for over 100 years (Solman 1950, Kiser *et al.* 1963) and in at least 30 countries (Lennon *et al.* 1970). The Nebraska Game and Parks Commission uses rotenone to eliminate “rough fish” such as common carp (*Cyprinus carpio* (Linnaeus)) and gizzard shad (*Dorosoma cepedianum* (Lesueur)).

While rotenone is an effective piscicide, Sanders and Cope (1968) suggests that non-target invertebrate organisms may have even lower tolerance. Zooplankton appear to be highly sensitive with near total loss of the community following rotenone applications (Anderson 1970). Impact on insect communities varies depending on the sensitivity of the species (Chandler 1982), while phytoplankton abundance and species composition are almost unaffected (Anderson 1970). Other literature suggests that reduction in fish communities results in moderate numbers of damselfly and caddisfly larvae the year following treatment (Claffey and Ruck 1967) and corresponding increases in calanoida copepod and cladocerans (Ling 2002). The variability in observed responses of community components undoubtedly stems from a difference in level of tolerance for each species, the time of year rotenone was applied, and the variability in toxicity of rotenone depending on existing water quality parameters.

To date, assessments of zooplankton communities following rotenone applications have been performed on natural lakes (Anderson 1970, Prejs *et al.* 1997), ponds (Brown and Ball 1942, Beal and Anderson 1993), and reservoir coves (Neves 1975). We are not aware of any studies performed in barrow pits or with the removal of gizzard shad as the dominant fish species. Our objectives for this study were to 1) monitor changes in various water quality parameters due to rotenone application in a barrow pit; 2) document the impact of rotenone application on the zooplankton community in a barrow pit; 3) assess recolonization rates for various zooplankton including successional patterns following a rotenone application in a barrow pit. Developing a greater understanding of these objectives will allow us to realize the impact of rotenone applications in these systems on abiotic and biotic communities.

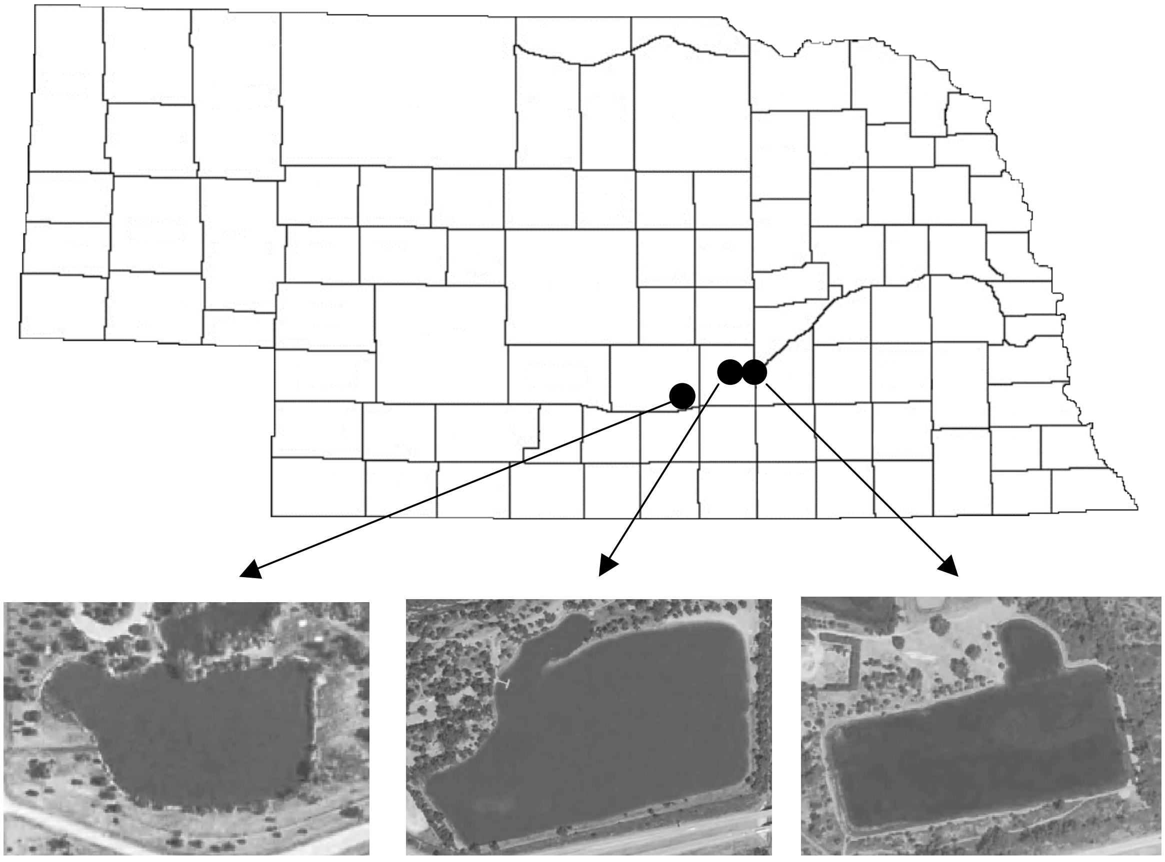
Study Sites

Experimental and control sites for this study were all considered to be "barrow pits". For the purpose of our study, we define "barrow pits" as man-made impoundments that were created when soil was removed for construction purposes. These impoundments have water levels maintained by groundwater and lack a natural drainage. The experimental site for this project was Mormon Island Middle (MIM), a 7.7 ha barrow pit located in Hall County, Nebraska (Figure 1). The maximum depth of MIM is 3.7 m. The fish community was inundated with gizzard shad and common carp. Mormon Island West (MIW) and Windmill #1 (WM1) were selected as pseudo-controls to monitor abiotic and biotic changes in a geographically proximate and similar sized barrow pit during this evaluation (Figure 1). MIW is located approximately 0.3 km due west of MIM and covers 17.0 ha with a maximum depth of 7.3 m. WM1 is located in Buffalo County, Nebraska approximately 48 km west of MIM and covers 9.3 ha with a maximum depth of 8.2 m. Both pseudo-control barrow pits have gizzard shad and common carp within the fish community but were not considered inundated by the Nebraska Game and Parks Commission at the time of the project.

METHODS

MIM was treated with 3 ppm of 5% liquid rotenone on 23 August 2005. Sampling to monitor abiotic and biotic characteristics of MIM was initiated one week prior to the rotenone application. Post-treatment samples on MIM were collected after 2 hours, 1 day, 2 days, 3 days and weekly through September. Additional post-treatment monitoring on MIM was conducted monthly in October and November 2005, and February-November 2006. Sampling on pseudo-control barrow pits was conducted on a similar schedule to those used on MIM, except only one sample was collected during the week of the rotenone application (3 days post-treatment). Five geographically dispersed locations were standardized on each study site and used for each sampling period.

Temperature and dissolved oxygen were sampled with a YSI-95 meter for each meter of the water column. Digital readings were recorded on site. Results were pooled for each sampling date at 1 m of



Windmill #1 (WM1)

Mormon Island West (MIW)

Mormon Island Middle (MIM)

Figure 1. Geographical Locations and Aerial Photographs of Experimental and Pseudo-Control Barrow Pits Within Central-Nebraska.

depth to establish mean readings and variability of these parameters. Temperature and dissolved oxygen readings from other depths were not used for assessment as the variable presence of thermoclines in pseudo-controls altered readings and surface water readings were influenced by the time of day readings were taken. Water clarity was measured using a Secchi disk at each location. Integrated water samples were taken with a Van Dorn bottle sampler from each meter of depth starting at the surface. All water samples were pooled in a bucket and stirred to assume homogeneity. Subsamples were drawn from the integrated water samples and analyzed by a Turner Designs *Aqua*fluor$^{(\text{TM})}$ Handheld Fluorometer and Turbidimeter.

Assessment of the zooplankton community consisted of vertically towing an 80-µm plankton net (0.5 m^2 opening) from the substrate to the surface at each station. Samples were preserved in a 4% formalin sucrose solution to prevent osmotic distortion (Haney and Hall 1973). All samples were taken back to the University of Nebraska at Kearney Biology Department for identification and enumeration to the lowest possible taxa under 20-25X magnification with a Leica Stereomicroscope as outlined by Peterson *et al.* (2005). Each sample was diluted to a known working volume (100-1000 ml), from which four 1 ml subsamples were drawn with a Hensen-Stempel pipette. Each 1 ml subsample was placed within the channel of a Ward Counting Wheel, zooplankton were counted individually, and mean number per liter towed was calculated for each identified lowest taxon.

Readings for each abiotic component were summed and divided by the number of collected readings to determine a mean reading on each water body for each sample date. Density of zooplankton taxa groups was established by summing results from 4 subsamples per sample and considering depth of sample, working volume of diluted sample, and diameter of plankton net to determine a sample mean. All sample means were summed by sample date and water body and divided by the number of collected sites to provide an estimated density of each zooplankton taxa group. Results were entered into Excel for determination of means and corresponding estimate of error, which is reported as ±1 standard error.

Results

The rotenone application at MIM in August 2005 appears to have influenced water quality. Dissolved oxygen readings decreased 57% after rotenone treatment and subsequently rose 298% over the next week. Dissolved oxygen readings returned to higher levels than pseudo-control waters (MIM 11.77±0.05; MIW 9.82±0.18; WM1 8.67±0.28) approximately 2 months after rotenone application and were similar to pre-treatment readings the following August (Table 1).

Water clarity improved after rotenone treatment. Prior to treatment MIM displayed greater turbidity and lower Secchi disk readings than pseudo-control waters (Table 1). Continuous improvements in readings were recorded for turbidity and Secchi depths from the time of rotenone application until the next spring (Table 2). Water clarity measurements in

Table 1. Mean Water Quality Parameters and Zooplankton Collected (± SE) For Experimental and Pseudo-Control Barrow Pits Pre- and Post- (1 year) Rotenone Application.

	MIM		**MIW**		**WM1**	
	Mean ± 1 *S.E.*		Mean ± 1 *S.E.*		Mean ± 1 *S.E.*	
Water Quality Parameter	**Aug-2005**	**Aug-2006**	**Aug-2005**	**Aug-2006**	**Aug-2005**	**Aug-2006**
Dissolved Oxygen	6.7 ± 0.14	7.4 ± 0.16	7.5 ± 0.16	6.7 ± 0.41	10.1 ± 0.15	10.4 ± 0.08
Secchi (cm)	69.1 ± 3.72	229.2 ± 23.29	92.5 ± 3.98	83.4 ± 3.47	114.8 ± 2.83	139 ± 5.17
Turbidity (FAU)	25.8 ± 0.80	6.6 ± 0.98	15.4 ± 0.87	16.6 ± 1.03	12.6 ± 1.17	11.2 ± 1.74
Chlorophyll *a* (µg/L)	101.2 ± 11.51	16.8 ± 3.30	51.1 ± 3.83	118.1 ± 15.46	66.6 ± 3.53	123.5 ± 36.26
Temperature (°C)	24.8 ± 0.02	25.8 ± 0.04	24.7 ± 0.08	25.5 ± 0.11	25.4 ± 0.19	26.2 ± 0.26
Zooplankton/L^{-1}						
Rotifers	0.06 ± 0.01	0.00 ± 0.00	0.04 ± 0.04	0.00 ± 0.00	0.17 ± 0.09	0.00 ± 0.00
Copepods[a]	0.01 ± 0.00	0.73 ± 0.24	1.12 ± 0.17	1.24 ± 0.16	0.05 ± 0.01	0.57 ± 0.19
Nauplii	0.11 ± 0.02	0.71 ± 0.33	1.38 ± 0.23	1.54 ± 0.66	0.18 ± 0.04	0.19 ± 0.04
Cladocerans[b]	0.00 ± 0.00	1.04 ± 0.09	1.63 ± 0.24	0.08 ± 0.04	0.08 ± 0.04	0.02 ± 0.01
Total Zooplankton	0.17 ± 0.03	2.49 ± 0.54	4.17± 0.65	2.85 ± 0.55	0.48 ± 0.13	0.78 ± 0.06

[a] Copepods consisted of mature and copepodid, calanoid and cyclopoid species.

[b] Cladocerans consisted of *Alona, Bosmina, Daphnia*, and *Diaphanosoma* species.

Table 2. Mean Water Quality Parameter Readings (± *SE*) Recorded From Mormon Island Middle.

Sampling Date	Dissolved Oxygen	Secchi (cm)[1]	Turbidity (FAU)	Chlorophyll *a* (µg/L)	Temperature (°C)
8/16/2005	6.7 ± 0.14	69.1 ± 3.72	25.8 ± 0.80	101.2 ± 11.51	24.8 ± 0.02
8/23/2005	5.1 ± 0.14	77.2 ± 7.46	14.6 ± 1.69	196.7 ± 11.46	24.7 ± 0.04
8/24/2005	3.6 ± 0.21	102.4 ± 1.63	12.6 ± 3.38	107.8 ± 4.78	23.7 ± 0.02
8/25/2005	3.1 ± 0.09	108.4 ± 3.74	11.2 ± 0.66	76.7 ± 2.90	23.9 ± 0.01
8/26/2005	2.9 ± 0.11	83.8 ± 3.85	17.8 ± 2.78	76.5 ± 4.71	24.0 ± 0.05
8/31/2005	11.6 ± 0.42	74.2 ± 1.68	19.8 ± 1.16	733.7 ± 34.85	25.4 ± 0.02
9/7/2005	11.3 ± 0.22	78.7 ± 2.66	14.6 ± 1.03	385.7 ± 32.08	24.9 ± 0.05
9/14/2005	4.6 ± 0.10	79.8 ± 1.29	17.2 ± 0.97	114.3 ± 4.74	23.6 ± 0.07
9/20/2005	6.7 ± 0.13	87.3 ± 1.29	10.2 ± 2.31	107.8 ± 14.36	22.5 ± 0.07
10/19/2005	11.8 ± 0.05	115.3 ± 2.21	13.2 ± 4.26	217.8 ± 27.56	15.8 ± 0.02
11/17/2005	13.3 ± 0.11	171.7 ± 2.06	5.8 ± 1.80	131.8 ± 13.11	5.1 ± 0.07
2/9/2006	15.7 ± 0.08	≥300 ± 0.00*	4.4 ± 1.50	46.8 ± 4.28	2.8 ± 0.06
3/9/2006	12.1 ± 0.03	≥300 ± 0.00*	0.2 ± 0.20	22.6 ± 3.27	7.5 ± 0.04
4/12/2006	10.2 ± 0.23	≥300 ± 0.00*	2.8 ± 0.86	14.6 ± 1.41	14.3 ± 0.04
5/11/2006	11.4 ± 0.01	≥300 ± 0.00*	6.6 ± 0.93	14.7 ± 1.13	15.8 ± 0.03
6/14/2006	8.4 ± 0.15	246.0 ± 36.96	5.8 ± 1.56	11.7 ± 5.35	25.0 ± 0.05
7/12/2006	10.0 ± 0.31	252.0 ± 30.72	4.8 ± 0.97	N/A	27.3 ± 0.09
8/17/2006	7.4 ± 0.16	229.2 ± 23.29	6.6 ± 0.98	16.8 ± 3.30	25.8 ± 0.04
9/13/2006	10.1 ± 0.14	223.4 ± 28.99	1.2 ± 0.58	30.4 ± 6.45	20.9 ± 0.28
10/17/2006	11.3 ± 0.11	246.0 ± 21.82	0.0 ± 0.00	25.5 ± 3.06	12.5 ± 0.04
11/8/2006	15.3 ± 0.12	252.0 ± 29.56	0.6 ± 0.40	6.9 ± 2.29	9.0 ± 0.08

[1] Secchi depth achieved barrow pit maximum depth in all samples with a mean of ≥300 cm.

MIM went from the worst recorded in our pre-treatment waters to the best recorded one year following treatment (Table 1). Available chlorophyll *a* increased 859% in the days following rotenone treatment and returned to similar levels of pseudo-control waters in approximately 3 weeks (MIM 114.36 µg/L ±4.74; MIW 102.45 µg/L ±2.36; WM1 96.09 µg/L ±21.78). Available chlorophyll *a* in MIM was lower than pre-treatment and pseudo-control readings 1 year after the rotenone application (Table 1).

Temperature readings remained similar to pseudo-control waters throughout the evaluation (Table 1). Temperature was unaffected by rotenone treatment, and no statistical difference was seen between barrow pits.

The abundance of total zooplankton in MIM was limited (0.17/L ± 0.03) prior to the rotenone treatment. Zooplankton were completely absent from the water column for three weeks following the rotenone treatment until 20 September 2005 when rotifers established (Figure 2). Copepods were absent for 2 months and recovered to levels greater than pseudo-controls 3 months after the rotenone treatment (MIM 5.30/L ±1.12; MIW 2.88/L ±0.61; WM1 1.17/L ±0.30); nauplii of these copepods followed a similar recovery timeframe. Cladocerans took the longest time to re-establish from the rotenone application as minimal numbers were available 2-3 months later (Figure 2), but levels did not match those recorded in pseudo-controls until March 2006 (MIM 0.78/L ±0.09; MIW 1.14/L±0.33; WM1 0.14/L±0.03). The total number of zooplankton available during August increased 1024% one year after the rotenone application (Table 1). Total zooplankton abundance in pseudo-control waters was similar or decreased during this same timeframe (Table 1). The change in zooplankton abundance can mostly be attributed to an increase in cladocerans with only minor increases in copepods and their nauplii.

Discussion

After rotenone treatment the improvements in water clarity and a decrease in chlorophyll *a* were similar to water quality changes observed in small lakes. Groundwater seepage and sandy substrate did not impact the response of these lakes to a rotenone event. Prejs *et al.* (1997) reported a 40% improvement in water quality, which was sustained for 3 years following a rotenone application in a small eutrophic lake. Ling (2002) stated that "rotenone has been shown to effectively improve water quality in small eutrophic lakes by exterminating planktivorous fishes and bottom-scavenging fishes that re-suspend bottom sediments and nutrients." However, a significant decrease in turbidity and chlorophyll *a* were observed in ponds treated with rotenone that lacked fish (Dawson *et al.* 1991). The fish community in MIM is thought to have been completely removed as

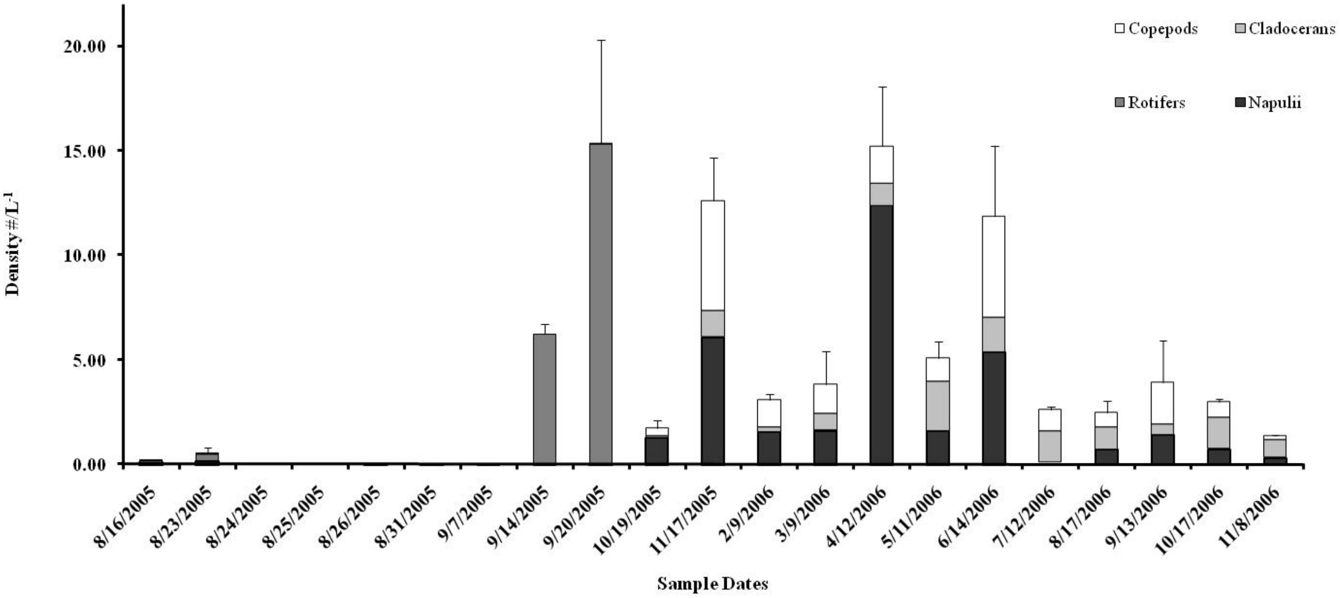


Figure 2. Zooplankton Densities and Taxa Compositions From Mormon Island Middle.

evidenced by only stocked fish being captured in a standardized survey the year following rotenone treatment. Sanni and Waervagen (1990) believed the decrease in chlorophyll *a* concentrations they observed were both an effect of decreased total phosphate concentrations and a direct effect of increased grazing by zooplankton.

Zooplankton were absent from MIM for 3 weeks following the rotenone application and all taxa groups met or exceeded pre-treatment levels within 2 months. However, the timing of the rotenone application coincided with a natural depression in zooplankton abundance and a better assessment is the comparison to zooplankton abundance in pseudo-control barrow pits. Total zooplankton abundance for all taxa groups met or exceeded levels in pseudo-controls 3 months following rotenone application. However, the recovery of cladocerans did not occur for 7 months during our observations. The rate of recovery observed in MIM was longer than the 5 weeks reported by Brown and Ball (1942), equal to the 6-8 months by Beal and Anderson (1993), but shorter than 1-2 years, and 3 years observed by Serns (1979) and Anderson (1970), respectively. The rapid rate of recovery in MIM was most likely a result of the rotenone being applied in August when zooplankton abundance is typically low and because the inundated gizzard shad population likely suppressed zooplankton abundance (Stein *et al.* 1995).

The sequence of recovery for taxa groups in MIM was slightly different than reported in other studies. Rotifers appeared first followed by copepods and their nauplii and then cladocerans. Beal and Anderson (1993) found copepods within one month followed by rotifers and cladocerans, which took 8 months to reach pre-treatment levels. Copepods and cladocerans were assessed among the most rotenone-susceptible invertebrate groups, and cladocerans usually take the longest time to recover from a rotenone application (Ling 2002).

The results from this study need to be weighed with caution. Ideally the pre-treatment assessment on experimental and pseudo-control ponds would have occurred for an entire year prior to renovation. Unfortunately, the project was developed in the months and weeks prior to the rotenone application and that information is unavailable. Despite the recognized lack of pre-treatment assessment we believe the information collected, accurately depicts the biological interactions associated with this rotenone application and that there is value to aquatic managers in this information. Aquatic managers employing rotenone treatments should understand that the impacts of rotenone application extend beyond targeted aquatic species. Additionally, aquatic managers can anticipate an improvement in water clarity following a rotenone application, which may impact the species they select for re-introduction. Some species such as white crappie (*Pomoxis annularis* Rafinesque) are known to be more successful in turbid waters when compared to the closely related species of black crappie (*Pomoxis nigromaculatus* (Lesueur)) (Goodson 1966).

The timing of rotenone application can also affect the recovery period. Kiser *et al.* (1963) found that in natural lakes rotenone applications used in the spring or early summer had a more severe and lingering effect than rotenone applied in the autumn months.

The results from this assessment would concur that rotenone applications in barrow pits during the late summer have a limited impact on zooplankton communities. The resulting change in fish community assemblage may have a greater impact on long-term changes in zooplankton diversity abundance. Finally, aquatic managers may find usefulness in understanding the recovery time of zooplankton communities in their efforts to re-stock and ensure that an adequate food supply is available for these fish during their early life stages. This assessment provides information surrounding a single rotenone application in a barrow pit. We recommend that additional research be employed to develop a greater understanding on impacts to other trophic levels specifically phytoplankton and aquatic micro-invertebrates. Variable timing for rotenone application should be investigated.

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