

ABSTRACT

LYNCH, CLAYTON L. Assessing the Acute and Chronic Toxicity of Manganese to Freshwater Mussels (Under the direction of Dr. W. Gregory Cope).

Freshwater mussels, vital components of aquatic ecosystems, are experiencing severe declines attributed to habitat alteration, pollution, and other anthropogenic factors. Among pollutants, manganese (Mn) has emerged as a potential contributor to recent enigmatic mussel die-offs. This study investigates the acute and chronic toxicity of manganese to freshwater mussels, focusing on the glochidia (larvae) and juvenile life stages. Nine mussel species were evaluated using controlled laboratory exposures to two common manganese compounds, $MnCl_2$ and $MnSO_4$. Acute toxicity tests revealed species- and life stage-specific sensitivities, with glochidia being more vulnerable than juveniles. The median effective concentration (EC50) ranged from 16.8 mg/L to 125 mg/L for glochidia and 18.9 mg/L to 144 mg/L for juveniles. Chronic exposure studies showed sublethal effects, including altered ion balance in mussel tissues, suggesting manganese disrupts essential physiological processes.

Environmental relevance was assessed by comparing toxicity thresholds to manganese concentrations in U.S. surface waters from 2000 to 2023. Results indicated that while average Mn levels are generally below toxicity thresholds, localized maximum concentrations often exceed them, posing risks to mussel populations, particularly in biodiversity hotspots. These findings highlight the need for updated water quality criteria to address manganese pollution and protect freshwater mussels. The study underscores the importance of mitigating manganese exposure to preserve these ecologically critical and highly imperiled organisms.

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Assessing the Acute and Chronic Toxicity of
Manganese to Freshwater Mussels

by
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BIOGRAPHY

I was born on September 21, 1994, in northeastern North Carolina, and I spent most of my childhood outdoors, fishing and exploring nature whenever I could. I have always had a deep connection to the natural world, especially aquatic ecosystems, and my heritage as a member of the Haliwa-Saponi tribe played a big role in shaping that connection. My educational journey was not traditional. After high school, I took a year off to work before enrolling at Nash Community College. That was where I started my path toward higher education. I later transferred to North Carolina State University (NCSU) to complete my undergraduate studies. It was at NCSU that I truly found my passion for conservation. Working with Dr. Cope and the aquatic ecology unit, I was inspired by their dedication and love for nature, which deepened my own commitment to conservation. After graduating, I worked with the North Carolina Wildlife Resources Commission (NCWRC) on their Aquatic Wildlife Diversity team. I spent that season snorkeling for mussels, conducting population research, and contributing to conservation efforts.

Later, I had the incredible opportunity to work with the late Dr. Kwak, where I assisted his graduate students in Puerto Rico on research projects, including American eel migration and native fish habitat use. Eventually, I was offered a Master's position in Dr. Cope's Lab at NCSU, which brought me full circle to where my passion for aquatic ecology and conservation had first begun.

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INTRODUCTION

The precipitous and widespread decline of native freshwater mussels in North America is well recognized and documented across the continent, yet the severity and importance of enigmatic declines are underappreciated by many in the conservation community (Haag 2019). Freshwater mussels in the family Unionidae are experiencing high imperilment due to habitat alteration and destruction, pollution and poor water quality, and the introduction of aquatic invasive species (Strayer et al. 2004; Cope et al. 2008; Downing et al. 2010). The Southeastern, Mid-Atlantic, and Midwestern regions of the United States contain the greatest biodiversity of native freshwater mussels in the world (Haag 2012). These areas of high diversity are at great risk of collapse from the continued stresses of human-mediated changes to the landscape through urban and rural development, mining activities, climate change, nutrient influx, and their associated impacts to water and sediment quality. Dissolved metals and pollutants from these activities are a major threat to the survival and persistence of unionid mussels. Freshwater mussels are known to be more susceptible to trace metal exposure and ionic changes than many other aquatic organisms due to their behavior of burrowing in fine grained sediments and suspension- and deposit-feeding strategies, with their glochidia (larvae) being even more sensitive (Bringolf et al. 2022, Wang et al. 2010, Shoults-Wilson 2008). The sensitivity of glochidia to dissolved solids and ionic changes creates a bottleneck for freshwater mussel population survival and reproductive dispersal (McIver et al. 2023). Field studies and laboratory toxicity testing in areas of declining mussel richness and density have been related to rising concentrations of dissolved solids from coal mining operations (Ciparis et al. 2015), showing that high levels of certain trace elements can negatively affect populations. The U.S. Fish and Wildlife Service and many state fish and wildlife management agencies have responded

to an increased frequency of mussel die-offs, enigmatic declines, and problems with decreased mussel growth and survival (Waller and Cope 2019).

There are currently no U.S. Environmental Protection Agency (US EPA) promulgated aquatic life criteria for Mn concentrations in aquatic environments. The current data regarding average Mn concentrations in aquatic environments summarized by the US EPA is outdated (circa late 1980s). Investigations into several observed die-offs and declines of native freshwater mussels have yet to identify a definitive biological infectious agent, contaminant, or water quality condition to explain the cause (Waller and Cope 2019). Although a definitive cause has not been identified, an unexplained relationship has been identified between relatively high measured manganese (Mn) concentrations and several of these mussel declines and die-off events. For example, from 2016-2018, there was an unexplained die-off of mussels in a zone of mussel stability in the lower Virginia and upper Tennessee sections of the Clinch River. Investigations into the event revealed that concentrations of Mn in resident adult mussels were strongly related to Mn concentrations in surface water, pore water, particulate and bed sediment, as well as to the growth and survival of juvenile mussels in the river and in laboratory tests (Cope and Jones 2016; Archambault et al. 2017; Rogers et al. 2018). The mussels from this die off showed evidence of high levels of oxidative stress and organ impairment after examination of kidney cells (Henley et al. 2019). Similarly, investigations into a die-off and decline of the federally endangered Appalachian Elktoe mussel (*Alasmidonta raveneliana*) that occurred from 2004-2009 in the Little Tennessee River of North Carolina revealed elevated Mn in the mussel tissues and gill pathology of affected mussels, mussels also exhibited stress response of sloughing mucus membranes (Chris Eads, personal communication, NCSU). Similar

observations with Mn have been made in mussel declines in Tennessee and Kentucky and may be indicative of a larger-scale issue pertinent to other systems and regions (Haag et al. 2019).

Manganese is the 12th most common element in the Earth's crust, yet it is not commonly studied in freshwater ecosystems relative to other transition metals such as zinc, copper, cadmium, and mercury (Dittman and Buchwalter 2010). Manganese is ubiquitously distributed throughout surface soils, with known geographic areas of higher concentrations (Figure 1), aquatic sediments, ground waters, and surface waters. Manganese is an essential trace metal in many organisms, serving as an important constituent in several key enzymes and cofactors (Harford et al. 2015). Manganese is released to the environment from industrial emissions, fossil fuel combustion, and erosion of manganese-containing soils. The concentrations of Mn in fresh waters vary widely but are commonly elevated near discharges from mining, smelting, and other industrial activities (ATSDR 2012). When present in high concentrations in water, Mn accumulates in organisms in the aquatic food web causing internal dysregulation and toxicity (Altenhofen et al. 2017). The mechanism of Mn toxicity in aquatic species is not well understood, and no published data exists on the biochemical or physiological effects of Mn on native freshwater mussels. Research has shown that high Mn concentrations in the water column and particulate sediment can negatively impact the survival and biomass of juvenile unionid mussels (Archambault et al. 2017). Several studies of marine bivalves have shown that Mn disrupts nervous system transmission in the gill and in associated signaling pathways important to survival and reproduction (Martin et al. 2008; Fraser et al. 2018). Although the toxicity of Mn to unionid mussels has not been widely investigated, several studies with marine and neotropical freshwater mussels have indicated acute lethality to larvae at 30 mg Mn/L (Morgan et al., 1986). With this information, it is plausible to hypothesize that Mn may have similar adverse effects and

lethality on unionid mussels and may be a factor in the recent observed die-offs and declines in the Clinch River (Cope and Jones 2016) or elsewhere. Therefore, the aim of this research was to examine the toxicity of two common forms of Mn ($MnCl_2$ and $MnSO_4$) to mussels in controlled laboratory tests (ASTM International 2022) with captively propagated larval and juvenile mussels.

MATERIALS AND METHODS

Test Organisms

In total, we tested the glochidia and juvenile life stages of 9 mussel species representing two tribes (Lampsilini, Anodontini) in the family Unionidae. The tribe Lampsilini test species included *Lampsillis abrubta*, *Ortmanniana pectorosa* (formerly known as *Actinonaias pectorosa*), *Lampsilis cardium*, *Epioblasma triquetra*, *Sagittunio nasutus*, *Obovaria subrotunda*, *Venustaconcha troostensis*, and *Ptychobranthus subtentus*, and the tribe Anodontini test species included *Utterbackia imbecillis*. All glochidia and juveniles were obtained and propagated by the Kentucky Center for Mollusk Conservation (Frankfort, Kentucky) using standard host fish propagation (Barnhart et al. 2008). All of the test species are native to the southeastern and central U.S., are distributed in the Atlantic Slope and Interior basins, and represent a range of conservation statuses, from secure to federally endangered. Test organisms were shipped to the Aquatic Toxicology Laboratory at NC State University via overnight courier. Upon arrival, glochidia and juvenile viability was assessed, length was recorded, and mussels were acclimated to the test water (ASTM soft water) and test temperature of 25°C, by adjusting their arrival temperature by 2.5°C/d, with a standard 24-h acclimation period once the target temperature was attained. Each of the tests were conducted according to the ASTM standard guide for conducting laboratory toxicity tests with freshwater mussels (ASTM, 2022).

Acute Glochidia Toxicity Testing

To determine the sensitivity of glochidia to Mn, we exposed mussels from each species to six concentrations of Mn. Manganese concentrations were prepared from two common forms of Mn, manganese sulfate (MnSO_4) and manganese chloride (MnCl_2), both purchased from Fisher Scientific. In total, eighteen separate tests were conducted. Each test consisted of a control and six treatment concentrations: 5 mg/L, 10 mg/L, 20 mg/L, 40 mg/L, 80 mg/L, and 160 mg/L. The treatment concentrations were chosen based on Mn concentrations measured in environmental samples (Archambault et al. 2017). Mussels were tested at a temperature of 25 °C with a 12:12 hour light: dark photoperiod. Each treatment concentration and the control consisted of three replicate exposures with approximately 250 glochidia per replicate in 250-mL evaporating dishes. Tests were 48-hour non-aerated static tests, in which viability was assessed at hour 24 and hour 48 using a subset of 50 impartially selected glochidia per replicate. Tests were conducted for 48 hours to simulate effects on glochidia that may have remained in the water column more than 24 hours after release from the female. Water quality conditions were measured at the beginning of each test, at hour 24 before the viability assessment, and at hour 48. Initial viability was calculated by counting the number of closed glochidia after adding a saturated salt (NaCl) solution subtracted by the number of closed glochidia before adding the saturated salt solution divided by the number of open and closed glochidia after adding the saturated salt solution (ASTM, 2022). The median effective concentration (EC_{50}) of MnCl_2 or MnSO_4 was calculated for each of the eighteen tests.

Acute Juvenile Toxicity Testing

To determine the sensitivity of juvenile mussels to Mn, we exposed five mussel species to six concentrations of Mn. The lengths of the juvenile mussels were recorded before the tests

began. Average length for each species was as follows: *O. pectorosa* (0.856 mm), *L. abrupta* (0.892 mm), *L. cardium* (0.885 mm), *U. imbecillis* (0.742 mm), and *V. troostensis* (1.324 mm). Similar to tests with glochidia, manganese test concentrations were prepared from manganese sulfate (MnSO₄) and manganese chloride (MnCl₂). In total, ten separate tests were conducted; each test consisted of a control and six treatment concentrations: 5 mg/L, 10 mg/L, 20 mg/L, 40 mg/L, 80 mg/L, and 160 mg/L. Mussels were tested at a temperature of 25 °C with a 12:12 hour light: dark photoperiod. Each treatment concentration and the control consisted of three replicate exposures with 10 mussels per replicate in 250-mL evaporating dishes. Tests were 96-hour non-aerated static-renewal tests, where a 90% water and toxicant renewal was conducted at hour 48. Water quality conditions were measured at the beginning of each test, at hour 48 before the water renewal, and at hour 96. Mussel viability was assessed at hour 48 and hour 96. Mussel viability was determined by observing foot movement, active siphoning, or a heartbeat within 5 minutes of observation, and examining the integrity of tissues within the shell (ASTM, 2022).

Chronic Juvenile Toxicity Testing

We conducted a chronic Mn toxicity test with *Lampsilis cardium* and MnCl₂. The experiment was a 28-d aerated static-renewal exposure consisting of five Mn treatment concentrations 2.5 mg/L, 5 mg/L, 10 mg/L, 30 mg/L, 60 mg/L and a control, with three replicate aquaria per treatment. Each aquarium contained six juvenile *Lampsilis cardium* individuals and 3L of test solution, consisting of ASTM soft water and an appropriate spike of MnCl₂ stock solution to achieve the target treatment concentrations. A 100% solution renewal was conducted daily to keep Mn concentrations stable and near target as mussels filtered the water. Aquaria

were wiped clean of accumulated biofilm at the end of each week to reduce the possibility of Mn adsorbing to organic matter. Prior to starting the tests, mussels were distributed into aerated aquaria containing fresh ASTM soft water for acclimation to the test holding conditions at least 12 h prior to Mn exposures. During the test, mussels were fed daily, immediately following renewal of the test solutions. The mussels were fed a mixture of 2 mL Instant Algae® Shellfish Diet and 1 mL Nannochloropsis (Nanno 3600) concentrate diluted in 1 L of reconstituted water (Reed Mariculture, Campbell, California, USA). Approximately 44 mL of food mixture was added to each replicate to ensure mussels had access to adequate amounts of food. Water quality conditions (i.e., alkalinity, hardness, conductivity, pH, ammonia, and dissolved oxygen) were monitored daily with each renewal and all metrics were within acceptable ranges throughout the experiment.

Mussels were sampled from each treatment (two mussels per replicate) at the 7-day, 14-day, and 28-day time points and processed by severing the anterior and posterior adductor muscles with a small stainless-steel scalpel. The mussel's body tissue was removed from its shell and placed into a 60 mL conical tube and immediately stored frozen at -20°C for ion chemistry analyses. Length and total wet weight were measured for each mussel before sampling. After sampling, the mussel's tissue and shell were weighed separately. Length was measured to the nearest millimeter using a digital caliper and weight was measured to the nearest gram using a digital balance. The *L. cardium* used in this test had an average shell length of 19.62 mm, an average tissue + shell weight of 1.17 g, an average tissue weight of 0.423 g, and an average shell weight of 0.608 g.

Quality Assurance

All tests were conducted according to the ASTM International Standard Guide for Conducting Laboratory Toxicity Tests with Freshwater Mussels (ASTM, 2022). All glochidia tests had >90% control viability at the end of hour 24 and again at the end of hour 48. Likewise, all juvenile tests had >90% control viability at test termination (hour 96). Water quality conditions of temperature, conductivity, salinity, and dissolved oxygen were measured with a calibrated meter (YSI model 566 MPS multi-probe, Yellow Springs Instrument Co., Yellow 12 Springs, Ohio) from a composite water sample at each treatment concentration. pH was also measured from a composite water sample at each treatment concentration with a calibrated meter (Beckman Coulter model PHI410, Beckman Coulter, Inc., Brea, California). Alkalinity and hardness were measured using standard titrimetric procedures (APHA, 2005). Average water quality (and ranges) among all acute glochidia and juvenile tests were: temperature 21.7 °C (20.6-22.2 °C); conductivity 407.95 $\mu\text{S}/\text{cm}$ (281.0-749.5); dissolved oxygen 8.39 mg/L (7.04-8.33); pH 7.64 (7.44-7.81); alkalinity 40 mg/L CaCO_3 (26-70); hardness 48 mg/L CaCO_3 (36-64). The water quality conditions of each acute glochidia and juvenile test are given in Table 1. The water test temperature was maintained at 25 °C within each test incubator; however, water temperature of some samples collected for water quality measurements likely cooled to near ambient room temperature (~ 21 °C) during the viability assessments and before measurement; hence the difference between incubator set temperature and average measured temperature. Toxicant exposure concentrations of Mn were verified on samples of test water from each treatment and test by RTI International (Research Triangle Park, NC) with a Thermo iCAP7600 ICP-OES equipped with an autosampler enclosed in a HEPA filtered exhaust box for sodium (Na^+), sulfur (S^{2-}), calcium (Ca^{++}), magnesium (Mg^{++}), strontium (Sr^{++}), and potassium

(K⁺). After receiving the water chemistry results, each Mn treatment concentration for acute tests (5 mg/L, 10 mg/L, 20 mg/L, 40 mg/L, 80 mg/L, 160 mg/L) and chronic tests (2.5 mg/L, 5 mg/L, 10 mg/L, 30 mg/L, 60 mg/L) were confirmed and a percent recovery was calculated. Briefly, the average percent recovery (and range) of each acute Mn treatment as calculated (all were in acceptable limits) were as follows: 5 mg/L, 97.8% (80.2%-124.9%); 10 mg/L, 97.8% (80.1%-124.6%); 20 mg/L, 93.6% (80.9%- 120%); 40 mg/L, 92.5% (80.01%-114.4%); 80 mg/L, 92.2% (80.3%-100.9%); 160 mg/L, 92.2% (80.1%-100.1%). All EC50 data are presented based on measured Mn concentrations rather than target concentrations even though there was agreement between the two in analytical recoveries. The average percent recovery of each chronic Mn treatment as calculated were as follows: 2.5 mg/L, 78.4%; 5 mg/L, 41.7%; 10 mg/L, 84%; 30 mg/L, 107.7%; 60 mg/L, 110.4%. All analyses for chronic treatments were performed using the measured concentrations rather than target concentrations because the two lowest treatment concentrations had unexplained low percent recovery, 78.4% and 41.7%, respectively, whereas the other treatments were all in an acceptable (80-120%) range.

Statistical Analysis

The median effective concentration, or EC50, was the concentration of the toxicant producing an adverse effect to 50% of the test population in the specified time. EC50s were estimated with the trimmed spearman-karber test using the Comprehensive Environmental Toxicity Information Software package (CETIS) (v1.9.7.10, Tidepool Scientific, LLC, McKinleyville, California). Confidence intervals of 95% were calculated for each EC50, and EC50s with non-overlapping confidence intervals were considered statistically different (Bringolf et al., 2007; Archambault et al., 2013; Popp et al., 2018).

Mussel tissue ion chemistry results from the chronic toxicity test were analyzed by performing statistical analyses in R (R v4.4.1, R Core Team 2024). To assess the potential effects of Mn treatment concentrations and time on mussel tissue ion concentrations, we used a Linear Regression Model using the ‘stats’ package in program R (Chambers, 1992). We performed a Type III ANOVA to evaluate the main effects of treatment and time, using a significance level (α) of 0.05 to determine statistically significant differences. Estimated marginal means were used to predict mean values and 95% confidence intervals for each time/concentration for a given treatment. Tukey pairwise comparisons of the estimated marginal means were evaluated using the compact letter display `cld()` function from the ‘multcomp’ package in R (Piepho, 2004).

Measured Environmental Manganese Concentrations

To gauge environmental relevance, we compared our mussel toxicity EC50 values to measured environmental concentration data for surface waters in the US. The data were obtained from the National Water Quality Monitoring Council through their water quality data lookup website (<https://www.waterqualitydata.us/>). For this analysis, the data queried were filtered to include only total recoverable Mn from surface waters from the year 2000 to 2023. The concentrations were then averaged and the minimum and maximum values recorded.

RESULTS

Acute Glochidia Toxicity Tests

Manganese toxicity tests conducted with the two forms of Mn on glochidia of nine species of mussels (*E. triquetra*, *P. subtentus*, *U. imbecillis*, *O. subrotunda*, *L. abrupta*, *S. nasutus*, *L. cardium*, *O. pectorosa*, and *V. troostensis*) showed a range of 24 h EC50s from 18 mg/L to 125 mg/L for MnSO₄ and a range of 16.8 mg/L to 116 mg/L for MnCl₂ (Table 2). The mean EC50 for MnSO₄ was 52 mg/L and the mean EC50 for MnCl₂ was 52.6 mg/L. During the MnSO₄ tests *O. pectorosa* and *V. troostensis* exhibited no mortality at the highest test concentration. The glochidia of *E. triquetra* were the most sensitive species to both forms of Mn with EC50s of 16.8 mg/L for MnCl₂ and 18.1 mg/L for MnSO₄. *L. cardium* glochidia were the least sensitive of the species that exhibited mortality to MnSO₄ with an EC50 of 125 mg/L, whereas *V. troostensis* was the least sensitive species to MnCl₂ with an EC50 of 116 mg/L. (Figure 2)

Acute Juvenile Toxicity Tests

Manganese toxicity tests conducted with the two forms of Mn on juveniles of five mussel species (*U. imbecillis*, *L. cardium*, *L. abrupta*, *O. pectorosa*, and *V. troostensis*) showed a range of EC50s from 18.9 mg/L to 144 mg/L for MnSO₄ and a range of 22.8 mg/L to 160 mg/L for MnCl₂ at the 96 h time point (Table 2). Like the results for glochidia, *V. troostensis* showed no mortality to either form of Mn during the tests (Table 2). Because *V. troostensis* exhibited no mortality at the 96 h time point, we extended the test until mortality occurred, which was at the 192 h time point with an EC50 of 136 mg/L for MnSO₄ and 86.2 mg/L for MnCl₂. *U. imbecillis* juveniles were the most sensitive species to both forms of Mn, with an EC50 of 18.9 mg/L for MnSO₄ and 22.8 mg/L for MnCl₂ (Figure 2)

Chronic Juvenile Toxicity Tests

Chronic Mn toxicity tests with MnCl_2 and *Lampsilis cardium* juveniles showed no mortality at any of the test concentrations. However, visual observations of the mussels during the tests showed that the individuals in the higher concentrations (30 mg/L, 60 mg/L) experienced potential signs of toxicity, including the sloughing of excess mucus and lethargy in the form of reduced foot reflexes. Observations also showed signs of reduced feeding behavior in the higher treatment concentrations.

The tissue ion chemistry analysis data showed that treatment concentration significantly affected the concentrations of calcium ($p < 0.05$), manganese ($p < 0.001$), and strontium ($p < 0.05$), indicating that Mn exposure influenced changes in these elements. An evaluation of Mn treatment over time (0, 7, 14, 28 d) showed that time significantly influenced magnesium ($p < 0.01$), phosphorus ($p < 0.01$), potassium ($p < 0.001$), and strontium ($p < 0.001$), suggesting these elements change in concentration due to the amount of time spent in contact with Mn. Notably, sodium showed no significant changes due to either Mn treatment or time, whereas calcium and manganese concentrations showed no significant variation over time.

The results for the Tukey pairwise analysis that focused on the significant changes in ion concentrations (calcium, magnesium, manganese, phosphorus, potassium, sodium, strontium, and sulfur) over the four time points (0, 7, 14, and 28 days) showed that magnesium had the most notable decrease, with concentrations significantly dropping from day 0 to day 28 (Figure 3). Potassium also exhibited clear differences, with significant variation between time points 7, 14, and 28 days showing a decrease in concentrations. Phosphorus and strontium demonstrated significant changes, particularly between time points 7 and 28 days, whereas sulfur displayed distinct differences between time points 7 and 14 days, with time points 14 and 28 days showing similar responses. In contrast, manganese and sodium levels remained stable, with no significant

changes over time. The 7-day time point exhibited significant differences among concentrations from time points 14 and 28 in magnesium, phosphorus, potassium, and sulfur, but the 7-day time point was not significantly different from day 0. This suggests that Mn exposure over time lowers the tissue concentrations of these ions.

The other Tukey pairwise analysis examined changes in ion concentrations (calcium, magnesium, manganese, phosphorus, potassium, sodium, strontium, and sulfur) among treatment groups (0 mg/L, 2.5 mg/L, 5 mg/L, 10 mg/L, 30 mg/L, and 60 mg/L). These results showed that phosphorus, magnesium, potassium, sodium, and sulfur did not show any significant differences between treatments ($p > 0.05$). However, there were significant differences in calcium, manganese, and strontium levels ($p < 0.05$) between certain treatment groups (Figure 4). For calcium, there was some variation between groups, with a slight decrease in tissue calcium levels as manganese concentrations increased. The control treatment with 0 mg/L of Mn (Tukey grouping B) was significantly different from the treatments with 8.4 mg/L and 32.3 mg/L of Mn (Tukey grouping A). This suggests that manganese may affect calcium metabolism in the mussels. Manganese concentrations showed expected variation, increasing in the mussel tissue as manganese exposure concentrations in the water increased. This indicates that the mussels were accumulating manganese from their environment. Strontium levels also showed differences among treatments, particularly the 1.96 mg/L and 66.2 mg/L treatments. However, the control with 0 mg/L of Mn did not show significant differences from the other treatment groups, suggesting that changes in strontium levels were not directly related to manganese treatments.

Comparisons to Measured Environmental Concentrations of Manganese

Surface water concentrations of manganese were obtained from 23 states for the period from 2000 to 2023. Manganese concentrations varied substantially among the different states,

with some areas exhibiting notably higher concentrations than others (Table 3). Among all states, Georgia recorded the highest average concentration at 0.429 mg/L, with a maximum measured concentration of 470 mg/L. This indicates a significant presence of the Mn in certain water bodies, possibly driven by localized factors such as industrial runoff, agricultural or mining practices, or natural conditions. Alabama reported the second-highest maximum concentration, reaching 267 mg/L, though its average concentration was relatively moderate at 0.186 mg/L, based on 8,295 samples. Again, this relatively high maximum concentration in Alabama suggests isolated areas of high contamination, potentially linked to specific events or locations. Arkansas also exhibited relatively high concentrations with an average of 0.318 mg/L and a maximum concentration of 81.6 mg/L from 19,611 samples. The sample count suggests widespread monitoring efforts in the state, capturing both low and high concentration sites. In contrast, Florida displayed the lowest average concentration of 0.044 mg/L across a large dataset of 79,087 samples, with a maximum value of 14.0 mg/L. Delaware similarly had a lower average concentration of 0.076 mg/L, with a maximum of 11.0 mg/L.

The average Mn concentration of all 23 states was well below the mean of measured EC50s for both the glochidia and juveniles. Although 39% of the 23 states' maximum measured concentrations exceeded the mean EC50 of 52 mg/L, measured for glochidia. 65% of the state's maximum measured concentrations exceeded the lowest EC50, and 17% of states maximum measured concentrations exceeded the highest recorded EC50 for glochidia. The juvenile mean EC50 of 90 mg/L was exceeded by 22% of the 23 state's maximum measured surface water concentrations. The lowest juvenile EC50 was exceeded by 65% state's maximum measured surface water concentrations and the highest EC50 was exceeded by 17% state's maximum measured surface water concentrations.

DISCUSSION

Our findings showed that elevated concentrations of manganese were acutely toxic to both glochidia and juvenile life stages of freshwater mussels. Additionally, we found differences in sensitivity among species, as well as life stage. Regardless of mussel species, we found glochidia to be more sensitive than juveniles. This suggests that excessive concentrations of dissolved manganese in surface waters may have an adverse effect on sustainability of future mussel populations. These findings are consistent with previous research on freshwater mussel sensitivity to environmental contaminants describing glochidia as the most sensitive life stage (Cope et al 2008). This acute toxicity could help explain why areas with elevated surface water concentrations of manganese have been negatively related to mussel population metrics such as recruitment and the number of imperiled species (Johnson et al. 2014, Archambault et al 2017). Interestingly, *V. troostensis*, a federally threatened species, showed a remarkable lack of sensitivity to Mn throughout our toxicity tests; this species has a distribution range that overlaps with relatively high levels of Mn in water and sediment due to the geology of the rivers in Kentucky and Tennessee, specifically the Cumberland River drainage, that the mussels inhabit (Figure 1). Our results also support field observations from the Clinch River in southwestern Virginia, in which *O. pectorosa*, a relatively Mn resistant species according to the acute tests, was the only species present after a die-off event (Cope et. al 2021; Zipper et al. 2014). The die-off event in the Clinch River occurred in an area that stretched approximately 68-kilometers from St. Paul, Virginia to Clinchport, Virginia, and was defined as a “zone of decline”. This area is characterized by dramatic declines in mussel populations, with notable losses in density and species richness (Zipper et al 2014). Historically, the Clinch River supported around 50 species of freshwater mussels. However, due to environmental challenges, the current mussel

populations have diminished. Among the remaining species, the pheasant shell (*Ortmanniana pectorosa*) is notably prevalent (Zipper et al 2014, Jones et al 2018).

Obovaria subrotunda, a relatively common species, and *P. subtentus*, an imperiled species, had the most sensitive glochidia (Table 2). *U. imbecillis* juveniles were the most sensitive in our toxicity tests, this species is common throughout its range. These findings illustrate an alternative hypothesis that is counter to conventional assumptions that imperiled species tend to be the most sensitive to certain toxicants. Although the mechanism for manganese toxicity is still unknown in mussels of the family Unionidae, we hypothesize that freshwater mussels may suffer a similar fate as blue mussels (*Mytilus edulis*), a marine species. Studies have shown that chronic exposure to environmentally relevant levels of manganese in blue mussels can alter their serotonin system (Fraser et al. 2018). The serotonin system regulates several important physiological processes in bivalves such as sexual differentiation, gamete production, and spawning behavior (Gibbons & Castagna 1984, Gies 1986, Ram et al 1999). It is possible that exposure to manganese could suppress spawning and lead to an aging population structure with little to no recruitment. There is also evidence that manganese may suppress metabolic rates in the gills of freshwater bivalves (de Oliveira et al 2019). Manganese may be suppressing the metabolism of mitochondrial oxygen in freshwater mussels leading to reduced fitness and possible lethal endpoints, especially in the sensitive glochidial stage. Another study found that Mn and Zn may exhibit genotoxic effects on freshwater mussels when bioaccumulated into soft tissues (Khan et al 2018). Their study showed DNA damage in the hemocytes of individuals collected from contaminated water sources. It may be possible that Mn is exhibiting genotoxic effects and causing reduced fitness in the young of affected individuals, leading to reduced fitness of progeny.

The chronic toxicity test conducted as part of this study provided us with strong insight into the adverse effects of Mn on freshwater mussel tissue ion concentrations and regulation. For example, our results revealed that Mn treatment had a statistically significant effect on calcium levels ($p = <0.05$), indicating that different Mn concentrations lead to measurable differences in intracellular calcium concentration in the tissues. This suggests that Mn may be interacting with calcium in mussel tissues when present at high levels. Calcium ions are central to cell signaling processes such as muscle contraction and neurotransmission (Katz 2016). The observed relationship between Mn and calcium is important because calcium and manganese ions often interact by competing for binding sites in enzymes, proteins, and structural matrices, leading to altered biochemical processes. It has been shown that manganese can compete with calcium in nerve terminals, affecting neurotransmitter release and that manganese can interfere with calcium-dependent enzymes involved in synaptic vesicle release, in non-human primates and rodents when present at environmentally high levels (Ijomone et al 2019). Hessen & Alstad (1994) found that *Daphnia*'s calcium-dependent enzymes are affected by manganese exposure causing metabolic adjustments to counteract competitive inhibition by manganese. A study on *Crassostrea virginica*, the Eastern Oyster, found that manganese interferes with dopamine signaling in the gill cilia, this interference causes gill cilia to not properly modulate their beating rates in response to environmental stimuli, affecting the oyster's ability to filter-feed and breathe efficiently (Nelson et al 2018). It is possible that Mn can affect freshwater mussels in a similar way as their marine cousins, causing their gill cilia to not respond to environmental stimuli leading to reduced feeding rates and loss of fitness. Manganese is a cofactor for manganese-dependent superoxide dismutase (Mn-SOD), which helps mitigate oxidative stress, while calcium is involved in pathways regulating apoptosis through reactive oxygen species (ROS)

production in oysters. In cases where manganese levels are high, it may interfere with calcium's roles in oxidative stress management, either by displacing calcium from its binding sites or altering the activity of calcium-regulated proteins (Balbi et al 2021). Manganese may inhibit the mussel's ability to detoxify these ROS products leading to oxidative stress and the impairment of physiological processes such as reproduction, growth, and immune response. As with the Eastern Oyster, additional research with unionids is warranted to address these potential responses.

Our review of dissolved Mn in surface water from the over the past 20 years across the eastern US shows variability in both average and maximum concentrations across states and underscores the heterogeneity of Mn in waters across the United States. Although the averages of each state were less than our calculated acute median effective concentrations (EC50s) for glochidia and juveniles in our study, many areas of each state had maximum measured concentrations that exceeded the EC50 threshold. There is currently no US EPA aquatic life criteria for manganese, meaning that unless surface waters pose a threat to human drinking water then there is no regulation on allowable Mn concentrations to protect aquatic life. States like Georgia and Alabama with exceptionally high maximum measured concentrations in surface water highlight the potential for localized pollution sources or extreme environmental conditions. The extreme maximum concentrations observed in Georgia (470 mg/L), Tennessee (910 mg/L), and Kentucky (1120 mg/L) are particularly problematic for mussel populations. These values are much greater than our highest recorded EC50 for glochidia (116 mg/L) and juveniles (144 mg/L). These areas of extreme concentrations also overlap with areas of high mussel richness (Grabarkiewicz & Wayne, 2008). Kentucky and Tennessee have naturally high levels of Mn in the surface soils, so runoff from mining activities and other geologic disturbances could deposit extremely high levels of manganese into nearby surface waters. Elevated Mn concentrations

could result in direct toxicity, impaired physiological functions, or even mortality in sensitive mussel species. Given that mussels often serve as sensitive early warning sentinels of ecosystem health, such high Mn levels suggest that not only are mussel populations at risk, but it could foreshadow future impacts to the entire aquatic ecosystem. The substantial variability in Mn concentrations among states, with some regions like Florida and Delaware having lower average concentrations (0.044 mg/L and 0.076 mg/L, respectively), highlights the need for regional or water body-specific studies in the future. In states with relatively lower Mn concentrations, such as Florida, mussel populations may be less immediately at risk but still vulnerable to localized pollution events or changes in land use. On the other hand, in states like Tennessee and Kentucky, where high maximum concentrations indicate significant pollution sources, targeted evaluations of hazard and risk assessments are crucial. These efforts could include enhanced monitoring, habitat restoration, and mitigation of pollution sources to protect existing mussel populations.

In conclusion, based on a series of acute toxicity tests and state-reported water quality data, we found that Mn is toxic to freshwater mussels at environmentally relevant concentrations. Water-only toxicity tests evaluate the lethal effect of Mn in overlying water, however, they do not account for the potentially significant exposure through the sediment (Archambault et al 2017). Mussels are relatively sessile organisms inhabiting benthic environments. As mussels burrow in the sediment, they are consistently exposed to toxic levels of manganese, especially in areas with high levels of mining activity (Li et al 2019). This life-long chronic exposure may lead to disruptions in the production of gametes and spawning behavior, which in turn may be causing populations to decline through age out attrition. From this study, we may also conclude

that Mn is acutely toxic to glochidia and juveniles of *Lampsillis abrubta*, *Ortmanniana pectorosa*, *Lampsilis cardium*, *Epioblasma triquetra*, *Utterbackia imbecillis*, *Obovaria subrotunda*, *Venustaconcha troostensis*, *Ptychobranthus subtentus*, and *Sagittunio nasutus* in the family Unionidae and that sensitivity to Mn varies among species. The presumed additive effects of manganese exposure through the water column and sediment constitutes even greater concern for the continued health of the freshwater mussels and warrants additional research. Many freshwater mussel species are already endangered or threatened, and our findings raise further concerns about their future. States with high Mn surface water concentrations are often home to diverse mussel communities, including several species listed under the Endangered Species Act. For example, Tennessee and Kentucky are both biodiversity hotspots for freshwater mussels (Haag 2019; Strayer et al 2004), making the extreme Mn levels even more concerning. Efforts to preserve these species may require a Mn water quality criterion at the national level and adoptions of a Mn standard at the state level, as well as habitat protection and restoration projects aimed at reducing the impact of Mn on critical mussel habitats. The information obtained from our study may be used to aid in the development of a Mn water quality criterion and the conservation of freshwater mussels by identifying at-risk areas in streams where mussels reside and helping to pinpoint potential causal mechanisms for die-offs. Studies like this one are crucial for understanding how pollutants and environmental stressors affect mussel populations. By identifying specific contaminants or conditions that harm mussels, these studies contribute to broader conservation efforts aimed at mitigating habitat degradation, improving water management, and addressing the complex factors driving their decline.

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Figures

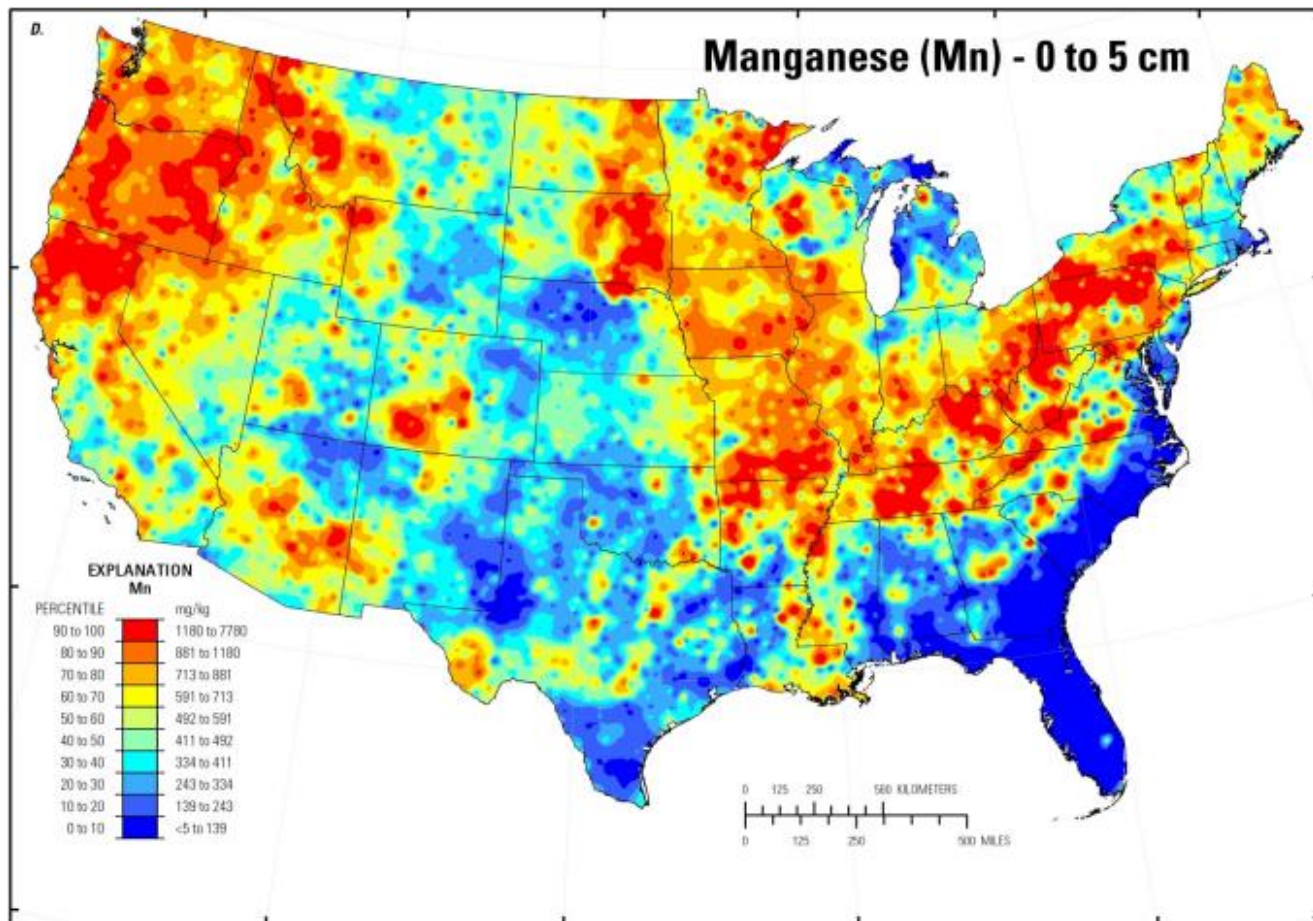


Figure 1. Heat map showing the varying concentrations of Manganese in soils across the USA. Obtained from the U.S. Geological Survey at https://pubs.usgs.gov/sir/2017/5118/sir20175118_element.php?el=25.

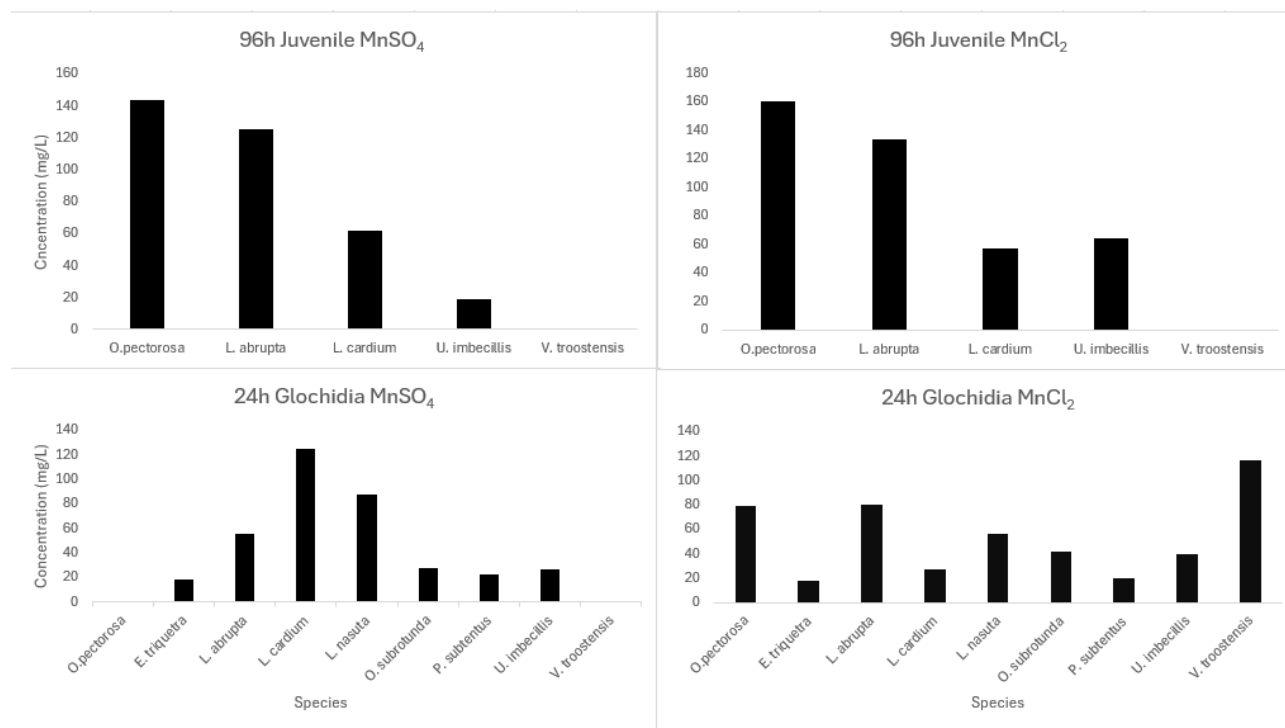


Figure 2. Comparison of the median effective concentrations (EC50s) from the acute toxicity tests with juveniles and glochidia of freshwater mussels exposed to two forms of manganese; manganese sulfate (MnSO₄) and manganese chloride (MnCl₂).

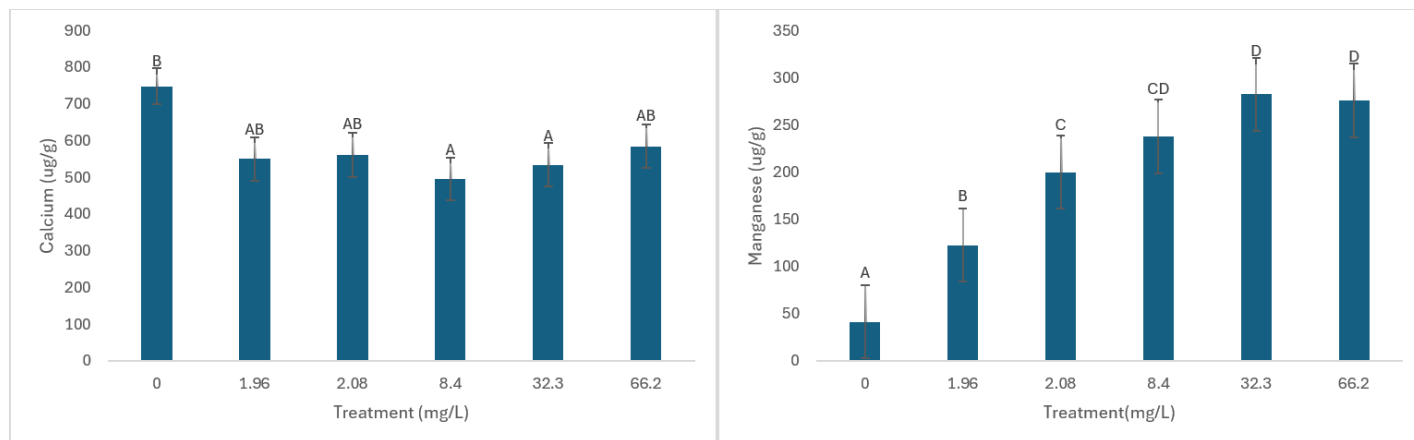


Figure 3. Mean mussel tissue concentrations ($\mu\text{g/g}$) of calcium and manganese after a 28-day exposure to five measured manganese chloride concentrations and a water-only control. Bars accompanied by the same letters are not significantly different ($\alpha = 0.05$) from one another based on a Tukey pairwise comparison.

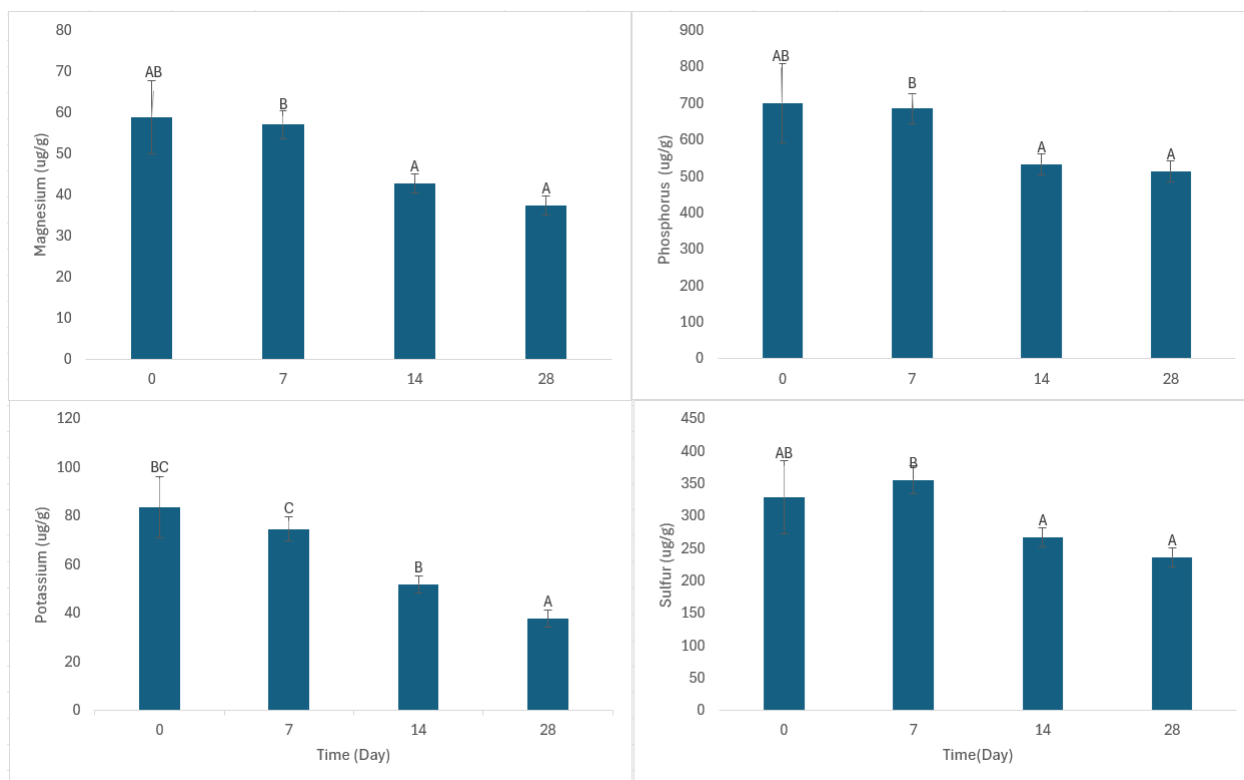


Figure 4. Tukey pairwise comparisons of exposure time (0, 7, 14, 28 days) and mussel tissue concentrations ($\mu\text{g/g}$ of magnesium, phosphorus, potassium, sulfur during a 28-day exposure to manganese chloride. Bars accompanied by the same letters are not significantly different ($\alpha = 0.05$) from one another.

Tables

Table 1. Average water quality parameters measured during the 48-hour acute toxicity tests with glochidia (G) and 96-hour acute toxicity tests with juveniles (J) of nine species of freshwater mussels.

| Species | Life Stage | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------------|------------|------------|----------------------|----------------|--------|----------|------|-------------------|-----------------|
| <i>L. nasuta</i> | G | 20.56 | 749.5 | 0.11 | 78.25 | 7.035 | 7.44 | 26 | 36 |
| <i>L. cardium</i> | G | 21.125 | 374 | 0.13 | 88.75 | 7.885 | 7.47 | 28 | 40 |
| <i>L. abrupta</i> | G | 21.76 | 373.5 | 0.135 | 96.8 | 8.5 | 7.48 | 30 | 42 |
| <i>V. troostensis</i> | G | 21.57 | 404 | 0.18 | 99 | 8.72 | 7.58 | 34 | 44 |
| <i>P. subtentus</i> | G | 21.735 | 386 | 0.185 | 99.15 | 8.7 | 7.60 | 34 | 44 |
| <i>L. cardium</i> | J | 21.78 | 451 | 0.185 | 95.6 | 8.38 | 7.61 | 38 | 44 |
| <i>P. subtentus</i> | G | 21.87 | 281.5 | 0.185 | 98.9 | 8.66 | 7.61 | 38 | 46 |
| <i>O. pectorosa</i> | G | 21.99 | 281 | 0.195 | 97.8 | 8.545 | 7.62 | 38 | 46 |
| <i>U. imbecillis</i> | G | 21.99 | 430 | 0.195 | 97.9 | 8.55 | 7.62 | 39 | 46 |
| <i>O. pectorosa</i> | J | 21.78 | 408.5 | 0.195 | 96.8 | 8.49 | 7.69 | 40 | 48 |
| <i>O. subrotunda</i> | G | 21.785 | 383.5 | 0.195 | 96.6 | 8.475 | 7.71 | 42 | 50 |
| <i>E. triquetra</i> | G | 21.68 | 386.5 | 0.2 | 94.9 | 8.35 | 7.76 | 44 | 52 |
| <i>U. imbecillis</i> | J | 21.675 | 403 | 0.205 | 100.1 | 8.78 | 7.81 | 50 | 56 |
| <i>L. abrupta</i> | J | 21.77 | 404 | 0.22 | 98.05 | 8.6 | 7.81 | 56 | 62 |
| <i>V. troostensis</i> | J | 22.18 | 403.5 | 0.3 | 95.65 | 8.325 | 7.81 | 70 | 64 |

Table 2. Median effective concentrations (EC50s in mg/L) of manganese (with 95% confidence intervals) in acute tests with glochidia and juvenile of nine mussel species belonging to the family Unionidae.

| Life Stage | Species | Time (hr) | MnCl ₂ (mg/L) EC50 | MnSO ₄ (mg/L) EC50 |
|-----------------------|-----------------------|-------------------------|----------------------------------|----------------------------------|
| Glochidia | <i>O. pectorosa</i> | 24 | 79.03 (68.41, 91.31) | (NC) |
| | | 48 | 50.40 (45.88, 55.38) | 56.36 (48.10, 66.05) |
| | <i>E. triquetra</i> | 24 | 16.80 (15.47, 18.25) | 18.06 (16.41, 19.87) |
| | | 48 | 19.01 (17.67, 20.45) | 16.86 (15.09, 18.83) |
| | <i>L. abrupta</i> | 24 | 79.73 (73.32, 86.71) | 55.21 (48.04, 63.45) |
| | | 48 | 51.57 (48.66, 54.66) | 48.97 (45.29, 52.94) |
| | <i>L. cardium</i> | 24 | 26.99 (24.99, 29.16) | 125.20 (110.90, 141.30) |
| | | 48 | 25.45 (22.98, 28.17) | 57.12 (52.17, 61.91) |
| | <i>L. nasuta</i> | 24 | 56.15 (53.58, 58.84) | 87.81 (81.14, 95.02) |
| | | 48 | 40.61 (37.52, 43.94) | 54.16 (49.83, 58.87) |
| | <i>O. subrotunda</i> | 24 | 41.04* (37.93, 44.40) | 27.29 (24.13, 30.85) |
| | | 48 | 20.00* (18.89, 21.18) | 12.50* (11.56, 13.51) |
| | <i>P. subtentus</i> | 24 | 19.32 (17.95, 20.79) | 22.89 (21.07, 24.86) |
| | | 48 | 13.05 (12.27, 13.88) | 16.10 (13.90, 18.65) |
| | <i>U. imbecillis</i> | 24 | 38.62 (35.15, 42.42) | 26.78 (23.89, 30.03) |
| 48 | | 26.98 (24.38, 29.86) | 27.80 (25.84, 29.91) | |
| <i>V. troostensis</i> | 24 | 115.60 (108.70, 123.00) | NC | |
| | 48 | 106.30 (102.60, 110.10) | 139.40 (129.90, 149.70) | |
| Juvenile | <i>O. pectorosa</i> | 48 | (NC) | (NC) |
| | | 96 | 160.00 (NC) | 143.70 (53.21, 387.9) |
| | <i>L. abrupta</i> | 48 | (NC) | (NC) |
| | | 96 | 133.00 (110.60, 160.00) | 125.50 (112.00, 140.70) |
| | <i>L. cardium</i> | 48 | 55.89 (46.91, 66.58) | 57.77 (36.08, 92.49) |
| | | 96 | 56.61 (47.73, 67.16) | 61.89 (49.02, 78.13) |
| | <i>U. imbecillis</i> | 48 | 64.15 (50.28, 81.84) | 60.91 (50.58, 73.35) |
| | | 96 | 22.76 (19.28, 26.88) | 18.86 (14.98, 23.75) |
| | <i>V. troostensis</i> | 48 | (NC) | (NC) |
| | | 96 | (NC) | (NC) |
| 144 | | (NC) | (NC) | |
| 192 | | 86.17 (65.24, 113.80) | 136.30 (108.80, 170.90) | |

Table 3. Average total recoverable manganese concentration, with minimum (Min) and maximum (Max), and the number (N) of samples analyzed by each state in the United States. Data compiled from the National Water Quality Council website (<https://www.waterqualitydata.us/>) from the year 2000 to 2023.

| State | Average(mg/L) | Min(mg/L) | Max (mg/L) | N |
|----------------|----------------------|------------------|-------------------|----------|
| Alabama | 0.186 | 0.00084 | 267.000 | 8295 |
| Arkansas | 0.318 | 0.001 | 81.600 | 19611 |
| Delaware | 0.076 | 0 | 11.000 | 547 |
| Florida | 0.044 | 0 | 14.000 | 79087 |
| Georgia | 0.429 | 0.0019 | 470.000 | 4681 |
| Illinois | 0.223 | 0 | 40.000 | 42015 |
| Indiana | 0.097 | 0 | 41.300 | 15152 |
| Iowa | 0.137 | 0.0053 | 1.620 | 396 |
| Kentucky | 0.598 | 0 | 1120.000 | 24408 |
| Louisiana | 0.676 | 0.0022 | 10.200 | 962 |
| Maryland | 0.095 | 0.0031 | 4.600 | 2171 |
| Michigan | 0.063 | 0 | 19.000 | 1837 |
| Minnesota | 0.215 | 0.000178 | 16.300 | 2339 |
| Mississippi | 0.138 | 0.00917 | 3.260 | 1887 |
| Missouri | 0.367 | 0.00001 | 47.300 | 975 |
| New Jersey | 0.095 | 0.000016 | 58.500 | 5436 |
| North Carolina | 0.249 | 0 | 23.400 | 14786 |
| Ohio | 0.239 | 0 | 55.400 | 53282 |
| Pennsylvania | 0.217 | 0 | 81.000 | 65557 |
| South Carolina | 0.093 | 0 | 16.000 | 31739 |
| Tennessee | 0.768 | 0 | 910.000 | 27969 |
| Virginia | 0.301 | 0 | 29.800 | 1616 |
| West Virginia | 0.333 | 0 | 61.300 | 8870 |
| Wisconsin | 0.119 | 0 | 10.250 | 2270 |

APPENDICES

APPENDICES

Appendix A

Table 1. Water Chemistry data for *L. nasuta* glochidia acute toxicity tests.

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 19.99 | 223 | 0.11 | 68.1 | 6.18 | 7.91 | 32 | 64 |
| 0 | MnCl ₂ | 5 | 20.05 | 216 | 0.1 | 65.6 | 5.95 | 7.89 | | |
| 0 | MnCl ₂ | 10 | 19.96 | 235 | 0.11 | 63 | 5.73 | 7.83 | | |
| 0 | MnCl ₂ | 20 | 19.91 | 272 | 0.13 | 64 | 5.82 | 7.72 | | |
| 0 | MnCl ₂ | 40 | 19.88 | 345 | 0.17 | 61.1 | 5.57 | 7.63 | | |
| 0 | MnCl ₂ | 80 | 19.85 | 493 | 0.24 | 60.3 | 5.49 | 7.53 | | |
| 0 | MnCl ₂ | 160 | 19.94 | 780 | 0.38 | 59.4 | 5.4 | 7.49 | 32 | |
| 0 | MnSO ₄ | 0 | 20.68 | 209 | 0.1 | 58.3 | 5.23 | 7.67 | 36 | 66 |
| 0 | MnSO ₄ | 5 | 20.67 | 216 | 0.1 | 58.4 | 5.24 | 7.63 | | |
| 0 | MnSO ₄ | 10 | 20.7 | 229 | 0.11 | 58.1 | 5.21 | 7.58 | | |
| 0 | MnSO ₄ | 20 | 20.73 | 263 | 0.13 | 57.7 | 5.17 | 7.53 | | |
| 0 | MnSO ₄ | 40 | 20.7 | 327 | 0.16 | 57 | 5.1 | 7.51 | | |
| 0 | MnSO ₄ | 80 | 20.71 | 441 | 0.21 | 56.8 | 5.08 | 7.53 | | |
| 0 | MnSO ₄ | 160 | 20.81 | 655 | 0.32 | 56.3 | 5.03 | 7.46 | 38 | |
| 24 | MnCl ₂ | 0 | 20.07 | 303 | 0.14 | 95.9 | 8.6 | 8.08 | 44 | 72 |
| 24 | MnCl ₂ | 5 | 20.9 | 218 | 0.1 | 96.3 | 8.6 | 7.96 | | |
| 24 | MnCl ₂ | 10 | 20.88 | 235 | 0.11 | 95.3 | 8.51 | 7.92 | | |
| 24 | MnCl ₂ | 20 | 20.78 | 274 | 0.13 | 93.4 | 8.36 | 7.82 | | |
| 24 | MnCl ₂ | 40 | 20.74 | 347 | 0.17 | 89.5 | 8.02 | 7.72 | | |
| 24 | MnCl ₂ | 80 | 20.66 | 495 | 0.24 | 89.2 | 7.99 | 7.65 | | |
| 24 | MnCl ₂ | 160 | 20.76 | 781 | 0.38 | 87.8 | 7.85 | 7.61 | | |
| 24 | MnSO ₄ | 0 | 21.19 | 207 | 0.1 | 86.8 | 7.71 | 7.69 | 54 | 66 |
| 24 | MnSO ₄ | 5 | 21.01 | 221 | 0.1 | 86.6 | 7.71 | 7.63 | | |
| 24 | MnSO ₄ | 10 | 20.99 | 234 | 0.11 | 86.4 | 7.7 | 7.59 | | |
| 24 | MnSO ₄ | 20 | 21.07 | 266 | 0.13 | 86.3 | 7.68 | 7.54 | | |
| 24 | MnSO ₄ | 40 | 21.05 | 329 | 0.16 | 87.2 | 7.76 | 7.48 | | |
| 24 | MnSO ₄ | 80 | 21.02 | 443 | 0.21 | 86 | 7.66 | 7.52 | | |
| 24 | MnSO ₄ | 160 | 21.08 | 656 | 0.32 | 87.1 | 7.74 | 7.52 | | |
| 48 | MnCl ₂ | 0 | 21.08 | 355 | NA | 90.3 | 8.01 | 7.9 | 44 | 74 |
| 48 | MnCl ₂ | 5 | 20.99 | 223 | NA | 99.3 | 8.86 | 7.9 | 44 | 70 |
| 48 | MnCl ₂ | 10 | 20.89 | 238 | NA | 95.5 | 8.52 | NA | | |
| 48 | MnCl ₂ | 20 | 21.02 | 274 | NA | 92.9 | 8.26 | 7.74 | | |
| 48 | MnCl ₂ | 40 | 20.99 | 348 | NA | 90.4 | 8.04 | 7.65 | | |
| 48 | MnCl ₂ | 80 | 20.97 | 498 | NA | 89.5 | 7.95 | 7.65 | | |
| 48 | MnCl ₂ | 160 | 21.11 | 785 | NA | 89.1 | 7.9 | 7.63 | 44 | |

Table 1 continued

| | | | | | | | | | | |
|----|-------------------|-----|-------|------|----|------|------|------|----|----|
| 48 | MnSO ₄ | 0 | 20.87 | 204 | NA | 88.1 | 7.85 | 8.19 | 46 | 62 |
| 48 | MnSO ₄ | 5 | 20.88 | 219 | NA | 88.4 | 7.89 | 8.07 | 48 | 70 |
| 48 | MnSO ₄ | 10 | 20.88 | 236 | NA | 88.3 | 7.88 | 7.99 | | |
| 48 | MnSO ₄ | 20 | 20.91 | 266 | NA | 89.9 | 7.81 | 7.9 | | |
| 48 | MnSO ₄ | 40 | 20.9 | 330 | NA | 88.3 | 7.86 | 7.81 | | |
| 48 | MnSO ₄ | 80 | 21.93 | 444 | NA | 88.1 | 7.84 | 7.75 | | |
| 48 | MnSO ₄ | 160 | 21.13 | 1276 | NA | 88.4 | 7.89 | 7.7 | 46 | |

Table 2. Water Chemistry data for *L. cardium* glochidia acute toxicity tests.

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 20.17 | 138 | NA | 87.8 | 7.95 | 7.81 | 28 | 42 |
| 0 | MnCl ₂ | 5 | 20.06 | 154 | NA | 88.8 | 8.09 | 7.7 | | |
| 0 | MnCl ₂ | 10 | 20.01 | 175 | NA | 88.4 | 8.03 | 7.61 | | |
| 0 | MnCl ₂ | 20 | 19.96 | 216 | NA | 88.2 | 8.03 | 7.51 | | |
| 0 | MnCl ₂ | 40 | 19.95 | 292 | NA | 88.4 | 8.03 | 7.4 | | |
| 0 | MnCl ₂ | 80 | 19.98 | 446 | NA | 88.2 | 8.02 | 7.36 | | |
| 0 | MnCl ₂ | 160 | 19.99 | 747 | NA | 87.7 | 7.92 | 7.33 | | |
| 0 | MnSO ₄ | 0 | 20.45 | 146 | NA | 86.9 | 7.82 | 7.45 | 28 | 42 |
| 0 | MnSO ₄ | 5 | 20.19 | 154 | NA | 88.4 | 8 | 7.36 | | |
| 0 | MnSO ₄ | 10 | 20.22 | 171 | NA | 88.2 | 7.99 | 7.29 | | |
| 0 | MnSO ₄ | 20 | 20.15 | 214 | NA | 88.4 | 8.01 | 7.31 | | |
| 0 | MnSO ₄ | 40 | 20.21 | 278 | NA | 87.6 | 7.95 | 7.32 | | |
| 0 | MnSO ₄ | 80 | 20.29 | 388 | NA | 88.1 | 7.95 | 7.31 | | |
| 0 | MnSO ₄ | 160 | 20.42 | 608 | NA | 88.1 | 7.96 | 7.28 | | |
| 24 | MnCl ₂ | 0 | 21.69 | 139 | 0.06 | 90.3 | 7.94 | 7.74 | 26 | 40 |
| 24 | MnCl ₂ | 5 | 21.45 | 156 | 0.07 | 90.2 | 7.96 | 7.7 | | |
| 24 | MnCl ₂ | 10 | 21.56 | 175 | 0.08 | 89.2 | 7.87 | 7.62 | | |
| 24 | MnCl ₂ | 20 | 21.53 | 214 | 0.1 | 89.9 | 7.97 | 7.53 | | |
| 24 | MnCl ₂ | 40 | 21.57 | 290 | 0.14 | 89.2 | 7.86 | 7.43 | | |
| 24 | MnCl ₂ | 80 | 21.52 | 446 | 0.21 | 89.3 | 7.87 | 7.39 | | |
| 24 | MnCl ₂ | 160 | 21.61 | 745 | 0.36 | 89.2 | 7.85 | 7.32 | | |
| 24 | MnSO ₄ | 0 | 22.2 | 144 | 0.07 | 98.5 | 8.57 | 7.45 | 26 | 40 |
| 24 | MnSO ₄ | 5 | 21.91 | 156 | 0.07 | 97.2 | 8.5 | 7.38 | | |
| 24 | MnSO ₄ | 10 | 21.91 | 174 | 0.08 | 95.7 | 8.37 | 7.32 | | |
| 24 | MnSO ₄ | 20 | 21.89 | 215 | 0.1 | 94.5 | 8.28 | 7.25 | | |
| 24 | MnSO ₄ | 40 | 21.91 | 279 | 0.13 | 94.4 | 8.27 | 7.33 | | |
| 24 | MnSO ₄ | 80 | 21.94 | 389 | 0.19 | 93 | 8.14 | 7.3 | | |
| 24 | MnSO ₄ | 160 | 21.85 | 609 | 0.3 | 91.9 | 8.04 | 7.29 | | |
| 48 | MnCl ₂ | 0 | 22.37 | 142 | 0.07 | 94 | 8.17 | 7.8 | 30 | 32 |
| 48 | MnCl ₂ | 5 | 22.07 | 158 | 0.07 | 93.7 | 8.18 | 7.78 | | |
| 48 | MnCl ₂ | 10 | 22.02 | 176 | 0.08 | 93.6 | 8.19 | 7.7 | | |
| 48 | MnCl ₂ | 20 | 22.08 | 215 | 0.1 | 92.5 | 8.07 | 7.59 | | |
| 48 | MnCl ₂ | 40 | 22.11 | 291 | 0.14 | 92.2 | 8.04 | 7.48 | | |
| 48 | MnCl ₂ | 80 | 22.09 | 446 | 0.21 | 92.4 | 8.06 | 7.42 | | |
| 48 | MnCl ₂ | 160 | 22.06 | 744 | 0.36 | 92 | 8.02 | 7.38 | | |
| 48 | MnSO ₄ | 0 | 22.15 | 156 | 0.07 | 91.4 | 7.96 | 7.43 | 28 | 46 |
| 48 | MnSO ₄ | 5 | 22.1 | 158 | 0.07 | 91.5 | 7.98 | 7.36 | | |
| 48 | MnSO ₄ | 10 | 22.09 | 177 | 0.08 | 90.6 | 7.9 | 7.28 | | |
| 48 | MnSO ₄ | 20 | 22.04 | 216 | 0.1 | 89.5 | 7.82 | 7.36 | | |
| 48 | MnSO ₄ | 40 | 22.12 | 278 | 0.13 | 91 | 7.89 | 7.35 | | |

Table 2 continued

| | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|
| 48 | MnSO ₄ | 80 | 22.1 | 389 | 0.19 | 89.8 | 7.83 | 7.34 |
| 48 | MnSO ₄ | 160 | 22.08 | 610 | 0.3 | 89.7 | 7.82 | 7.34 |

Table 3. Water Chemistry data for *L. abrupta* glochidia acute toxicity tests.

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 21.59 | 137 | 0.06 | 97.7 | 8.61 | 7.94 | 26 | 36 |
| 0 | MnCl ₂ | 5 | 21.13 | 152 | 0.07 | 97.2 | 8.65 | 7.73 | | |
| 0 | MnCl ₂ | 10 | 21.13 | 171 | 0.08 | 95.5 | 8.5 | 7.61 | | |
| 0 | MnCl ₂ | 20 | 21.15 | 208 | 0.1 | 94.7 | 8.42 | 7.5 | | |
| 0 | MnCl ₂ | 40 | 21.15 | 282 | 0.13 | 94.1 | 8.37 | 7.44 | | |
| 0 | MnCl ₂ | 80 | 21.09 | 438 | 0.21 | 92.9 | 8.26 | 7.38 | | |
| 0 | MnCl ₂ | 160 | 21.07 | 748 | 0.37 | 92.3 | 8.21 | 7.33 | | |
| 0 | MnSO ₄ | 0 | 21.28 | 150 | 0.07 | 91.5 | 8.11 | 7.94 | 28 | 46 |
| 0 | MnSO ₄ | 5 | 21.26 | 150 | 0.07 | 90.8 | 8.05 | 7.82 | | |
| 0 | MnSO ₄ | 10 | 21.18 | 167 | 0.08 | 90.4 | 8.03 | 7.71 | | |
| 0 | MnSO ₄ | 20 | 21.19 | 201 | 0.09 | 90.4 | 8.03 | 7.61 | | |
| 0 | MnSO ₄ | 40 | 21.13 | 269 | 0.13 | 90 | 8 | 7.53 | | |
| 0 | MnSO ₄ | 80 | 21.19 | 390 | 0.19 | 89.9 | 7.97 | 7.46 | | |
| 0 | MnSO ₄ | 160 | 21.16 | 609 | 0.3 | 89.3 | 7.93 | 7.42 | | |
| 24 | MnCl ₂ | 0 | 21.68 | 138 | 0.06 | 97.2 | 8.55 | 7.2 | 32 | 42 |
| 24 | MnCl ₂ | 5 | 21.3 | 152 | 0.07 | 97.1 | 8.6 | 7.27 | | |
| 24 | MnCl ₂ | 10 | 21.18 | 171 | 0.08 | 96.4 | 8.56 | 7.3 | | |
| 24 | MnCl ₂ | 20 | 21.16 | 209 | 0.1 | 95.9 | 8.52 | 7.3 | | |
| 24 | MnCl ₂ | 40 | 21.13 | 283 | 0.13 | 95.4 | 8.48 | 7.3 | | |
| 24 | MnCl ₂ | 80 | 21.15 | 440 | 0.21 | 95.1 | 8.45 | 7.22 | | |
| 24 | MnCl ₂ | 160 | 21.26 | 750 | 0.37 | 94.4 | 8.36 | 7.25 | | |
| 24 | MnSO ₄ | 0 | 21.35 | 147 | 0.07 | 93.4 | 8.27 | 7.84 | 28 | 44 |
| 24 | MnSO ₄ | 5 | 21.36 | 150 | 0.07 | 92.9 | 8.22 | 7.72 | | |
| 24 | MnSO ₄ | 10 | 21.37 | 177 | 0.08 | 91.7 | 8.11 | 7.63 | | |
| 24 | MnSO ₄ | 20 | 21.33 | 202 | 0.1 | 91.1 | 8.07 | 7.56 | | |
| 24 | MnSO ₄ | 40 | 21.35 | 270 | 0.13 | 90.6 | 8.02 | 7.46 | | |
| 24 | MnSO ₄ | 80 | 21.33 | 390 | 0.19 | 90.3 | 7.99 | 7.43 | | |
| 24 | MnSO ₄ | 160 | 21.5 | 608 | 0.3 | 89.5 | 7.89 | 7.4 | | |
| 48 | MnCl ₂ | 0 | 22.2 | 146 | 0.07 | 95.6 | 8.32 | 7.78 | 26 | 46 |
| 48 | MnCl ₂ | 5 | 22.15 | 153 | 0.07 | 95.8 | 8.35 | 7.66 | | |
| 48 | MnCl ₂ | 10 | 22.08 | 172 | 0.08 | 95.6 | 8.35 | 7.57 | | |
| 48 | MnCl ₂ | 20 | 22.11 | 210 | 0.1 | 95.6 | 8.34 | 7.47 | | |
| 48 | MnCl ₂ | 40 | 22.17 | 284 | 0.13 | 94.9 | 8.27 | 7.43 | | |
| 48 | MnCl ₂ | 80 | 22.15 | 441 | 0.21 | 94.1 | 8.19 | 7.38 | | |
| 48 | MnCl ₂ | 160 | 22.03 | 752 | 0.37 | 93.9 | 8.19 | 7.34 | | |
| 48 | MnSO ₄ | 0 | 22.03 | 135 | 0.06 | 97.58 | 8.53 | 7.36 | 28 | 36 |
| 48 | MnSO ₄ | 5 | 21.83 | 153 | 0.07 | 97.4 | 8.54 | 7.31 | | |
| 48 | MnSO ₄ | 10 | 21.87 | 168 | 0.08 | 97.4 | 8.54 | 7.25 | | |
| 48 | MnSO ₄ | 20 | 21.93 | 202 | 0.09 | 97.1 | 8.5 | 7.19 | | |

Table 3 continued

| | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|
| 48 | MnSO ₄ | 40 | 21.94 | 270 | 0.13 | 97.4 | 8.52 | 7.26 |
| 48 | MnSO ₄ | 80 | 21.91 | 391 | 0.19 | 96.2 | 8.42 | 7.27 |
| 48 | MnSO ₄ | 160 | 21.93 | 610 | 0.3 | 95.9 | 8.39 | 7.27 |

Table 4. Water Chemistry data for *V. troostensis* glochidia acute toxicity tests.

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 21.56 | 177 | 0.08 | 100.5 | 8.86 | 7.59 | 38 | 56 |
| 0 | MnCl ₂ | 5 | 21.43 | 186 | 0.09 | 99.8 | 8.82 | 7.5 | | |
| 0 | MnCl ₂ | 10 | 21.39 | 204 | 0.1 | 99.7 | 8.82 | 7.42 | | |
| 0 | MnCl ₂ | 20 | 21.38 | 240 | 0.11 | 99.2 | 8.77 | 7.42 | | |
| 0 | MnCl ₂ | 40 | 21.42 | 318 | 0.15 | 98.9 | 8.74 | 7.39 | | |
| 0 | MnCl ₂ | 80 | 21.47 | 464 | 0.22 | 98.7 | 8.7 | 7.35 | | |
| 0 | MnCl ₂ | 160 | 21.57 | 763 | 0.37 | 98.3 | 8.65 | 7.3 | | |
| 0 | MnSO ₄ | 0 | 21.52 | 166 | 0.08 | 101.5 | 8.95 | 7.85 | 38 | 48 |
| 0 | MnSO ₄ | 5 | 21.28 | 183 | 0.09 | 101.1 | 8.96 | 7.81 | | |
| 0 | MnSO ₄ | 10 | 21.33 | 200 | 0.09 | 100.6 | 8.91 | 7.74 | | |
| 0 | MnSO ₄ | 20 | 21.27 | 232 | 0.11 | 100.3 | 8.89 | 7.64 | | |
| 0 | MnSO ₄ | 40 | 21.22 | 296 | 0.14 | 100 | 8.87 | 7.54 | | |
| 0 | MnSO ₄ | 80 | 21.25 | 414 | 0.2 | 100.1 | 8.87 | 7.46 | | |
| 0 | MnSO ₄ | 160 | 21.41 | 629 | 0.31 | 100 | 8.83 | 7.43 | | |
| 24 | MnCl ₂ | 0 | 21.92 | 168 | 0.08 | 99.8 | 8.74 | 7.83 | 42 | 56 |
| 24 | MnCl ₂ | 5 | 21.59 | 185 | 0.09 | 99 | 8.72 | 7.73 | | |
| 24 | MnCl ₂ | 10 | 21.59 | 206 | 0.1 | 99 | 8.72 | 7.66 | | |
| 24 | MnCl ₂ | 20 | 21.5 | 244 | 0.12 | 99.1 | 8.74 | 7.58 | | |
| 24 | MnCl ₂ | 40 | 21.36 | 321 | 0.15 | 98.8 | 8.74 | 7.52 | | |
| 24 | MnCl ₂ | 80 | 21.48 | 469 | 0.23 | 98.7 | 8.71 | 7.48 | | |
| 24 | MnCl ₂ | 160 | 21.56 | 769 | 0.38 | 98.6 | 8.68 | 7.44 | | |
| 24 | MnSO ₄ | 0 | 21.91 | 167 | 0.08 | 98.6 | 8.63 | 7.4 | 44 | 60 |
| 24 | MnSO ₄ | 5 | 21.83 | 184 | 0.09 | 98.4 | 8.63 | 7.35 | | |
| 24 | MnSO ₄ | 10 | 21.77 | 201 | 0.09 | 98 | 8.6 | 7.31 | | |
| 24 | MnSO ₄ | 20 | 21.72 | 234 | 0.11 | 98.8 | 8.68 | 7.35 | | |
| 24 | MnSO ₄ | 40 | 21.66 | 298 | 0.14 | 97.3 | 8.55 | 7.37 | | |
| 24 | MnSO ₄ | 80 | 21.61 | 416 | 0.2 | 97.2 | 8.55 | 7.38 | | |
| 24 | MnSO ₄ | 160 | 21.67 | 632 | 0.31 | 97.3 | 8.54 | 7.38 | | |
| 48 | MnCl ₂ | 0 | 21.71 | 175 | 0.08 | 96.8 | 8.51 | 7.84 | 40 | 56 |
| 48 | MnCl ₂ | 5 | NA | NA | NA | NA | NA | 7.8 | | |
| 48 | MnCl ₂ | 10 | 21.67 | 207 | 0.1 | 97.2 | 8.55 | 7.71 | | |
| 48 | MnCl ₂ | 20 | 21.64 | 245 | 0.12 | 97.5 | 8.58 | 7.61 | | |
| 48 | MnCl ₂ | 40 | 21.68 | 321 | 0.15 | 97.4 | 8.56 | 7.54 | | |
| 48 | MnCl ₂ | 80 | 21.65 | 472 | 0.23 | 96.6 | 8.47 | 7.47 | | |
| 48 | MnCl ₂ | 160 | 21.69 | 776 | 0.38 | 97.3 | 8.54 | 7.41 | | |
| 48 | MnSO ₄ | 0 | 22.19 | 174 | 0.08 | 98.4 | 8.57 | 7.4 | 38 | 50 |
| 48 | MnSO ₄ | 5 | 21.64 | 184 | 0.09 | 99 | 8.71 | 7.42 | | |
| 48 | MnSO ₄ | 10 | 21.48 | 200 | 0.09 | 98.2 | 8.67 | 7.39 | | |
| 48 | MnSO ₄ | 20 | 21.5 | 234 | 0.11 | 98.4 | 8.68 | 7.41 | | |
| 48 | MnSO ₄ | 40 | 21.48 | 298 | 0.14 | 97.9 | 8.64 | 7.39 | | |

Table 4 continued

| | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|
| 48 | MnSO ₄ | 80 | 21.48 | 415 | 0.2 | 97.3 | 8.59 | 7.37 |
| 48 | MnSO ₄ | 160 | 21.58 | 631 | 0.31 | 97.5 | 8.58 | 7.36 |

Table 5. Water Chemistry data for *P. subtentus* glochidia acute toxicity tests.

| Time Point (hr) | Toxicant | Conc. | | Conductivity ($\mu\text{S}/\text{cm}$) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|--------------|---------------------------------|---|-------------------|-----------|--------------|------|----------------------|--------------------|
| | | Mn (mg/L) | Temp. ($^{\circ}\text{C}$) | | | | | | | |
| 0 | MnCl ₂ | 0 | 21.98 | 156 | 0.07 | 98.4 | 8.6 | 8 | 34 | 46 |
| 0 | MnCl ₂ | 5 | 21.87 | 160 | 0.07 | 98.1 | 8.6 | 7.97 | | |
| 0 | MnCl ₂ | 10 | 21.78 | 169 | 308 | 97.9 | 8.59 | 7.9 | | |
| 0 | MnCl ₂ | 20 | 21.71 | 188 | 0.09 | 98.1 | 8.62 | 7.81 | | |
| 0 | MnCl ₂ | 40 | 21.5 | 225 | 0.11 | 98.2 | 8.66 | 7.72 | | |
| 0 | MnCl ₂ | 80 | 21.6 | 306 | 0.15 | 98.3 | 8.66 | 7.7 | | |
| 0 | MnCl ₂ | 160 | 21.59 | 458 | 0.22 | 98.1 | 8.64 | 7.66 | | |
| 0 | MnSO ₄ | 0 | 22.25 | 149 | 0.07 | 98.1 | 8.54 | 8.04 | | |
| 0 | MnSO ₄ | 5 | 21.84 | 158 | 0.07 | 98.4 | 8.63 | 7.93 | | |
| 0 | MnSO ₄ | 10 | 21.77 | 167 | 0.08 | 98.2 | 8.62 | 7.83 | | |
| 0 | MnSO ₄ | 20 | 21.84 | 190 | 0.09 | 97.5 | 8.55 | 7.72 | | |
| 0 | MnSO ₄ | 40 | 21.85 | 153 | 0.07 | 98.3 | 8.62 | 7.86 | 52 | 44 |
| 0 | MnSO ₄ | 80 | 21.82 | 284 | 0.13 | 97.4 | 8.54 | 7.53 | | |
| 0 | MnSO ₄ | 160 | 21.94 | 401 | 0.19 | 98.3 | 8.6 | 7.49 | | |
| 24 | MnCl ₂ | 0 | 21.75 | 163 | 0.08 | 97.7 | 8.59 | 7.91 | 38 | 44 |
| 24 | MnCl ₂ | 5 | 21.65 | 161 | 0.08 | 98.3 | 8.65 | 7.84 | | |
| 24 | MnCl ₂ | 10 | 21.58 | 170 | 0.08 | 98.3 | 8.66 | 7.78 | | |
| 24 | MnCl ₂ | 20 | 21.61 | 189 | 0.09 | 97.8 | 8.61 | 7.69 | | |
| 24 | MnCl ₂ | 40 | 21.6 | 227 | 0.11 | 97.8 | 8.61 | 7.59 | | |
| 24 | MnCl ₂ | 80 | 21.6 | 308 | 0.15 | 97.8 | 8.61 | 7.53 | | |
| 24 | MnCl ₂ | 160 | 21.64 | 460 | 0.22 | 98.1 | 8.62 | 7.47 | | |
| 24 | MnSO ₄ | 0 | 21.88 | 614 | 0.3 | 98.7 | 8.64 | 7.42 | | |
| 24 | MnSO ₄ | 5 | 21.69 | 170 | 0.08 | 98.5 | 8.66 | 7.54 | | |
| 24 | MnSO ₄ | 10 | 21.64 | 169 | 0.08 | 98.2 | 8.65 | 7.49 | | |
| 24 | MnSO ₄ | 20 | 21.65 | 193 | 0.09 | 98.2 | 8.64 | 7.41 | | |
| 24 | MnSO ₄ | 40 | 21.69 | 155 | 0.07 | 98 | 8.62 | 7.58 | 52 | 44 |
| 24 | MnSO ₄ | 80 | 21.66 | 288 | 0.14 | 98.8 | 8.69 | 7.42 | | |
| 24 | MnSO ₄ | 160 | 21.68 | 406 | 0.19 | 98.6 | 8.67 | 7.42 | | |
| 48 | MnCl ₂ | 0 | 21.82 | 160 | 0.07 | 99.8 | 8.75 | 7.81 | 44 | 46 |
| 48 | MnCl ₂ | 5 | 21.7 | 162 | 0.08 | 99.7 | 8.77 | 7.84 | | |
| 48 | MnCl ₂ | 10 | 21.7 | 171 | 0.08 | 99.9 | 8.78 | 7.78 | | |
| 48 | MnCl ₂ | 20 | 21.68 | 190 | 0.09 | 99.5 | 8.76 | 7.7 | | |
| 48 | MnCl ₂ | 40 | 21.72 | 228 | 0.11 | 99.6 | 8.75 | 7.6 | | |
| 48 | MnCl ₂ | 80 | 21.75 | 309 | 0.15 | 99.7 | 8.76 | 7.53 | | |
| 48 | MnCl ₂ | 160 | 21.74 | 461 | 0.22 | 99.4 | 8.73 | 7.48 | | |
| 48 | MnSO ₄ | 0 | 21.82 | 185 | 0.09 | 99.6 | 8.73 | 7.52 | | |
| 48 | MnSO ₄ | 5 | 21.73 | 161 | 0.08 | 99.7 | 8.76 | 7.52 | | |
| 48 | MnSO ₄ | 10 | 21.73 | 172 | 0.08 | 99.8 | 8.77 | 7.46 | | |
| 48 | MnSO ₄ | 20 | 21.7 | 194 | 0.09 | 99.3 | 8.74 | 7.39 | | |
| 48 | MnSO ₄ | 40 | 21.7 | 156 | 0.07 | 99.4 | 8.74 | 7.65 | 60 | 46 |
| 48 | MnSO ₄ | 80 | 21.67 | 289 | 0.14 | 99.7 | 8.77 | 7.3 | | |

Table 6. Water Chemistry data for *O. pectorosa* glochidia acute toxicity tests.

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 21.85 | 155 | 0.07 | 97.6 | 8.55 | 8.02 | 38 | 46 |
| 0 | MnCl ₂ | 5 | 21.6 | 159 | 0.07 | 97.9 | 8.62 | 7.97 | | |
| 0 | MnCl ₂ | 10 | 21.57 | 169 | 0.08 | 97.7 | 8.61 | 7.9 | | |
| 0 | MnCl ₂ | 20 | 21.61 | 187 | 0.09 | 96.6 | 8.51 | 7.81 | | |
| 0 | MnCl ₂ | 40 | 21.48 | 226 | 0.11 | 97.3 | 8.59 | 7.71 | | |
| 0 | MnCl ₂ | 80 | 21.49 | 305 | 0.15 | 97.4 | 8.6 | 7.66 | | |
| 0 | MnCl ₂ | 160 | 21.72 | 455 | 0.22 | 96.8 | 8.5 | 7.62 | | |
| 0 | MnSO ₄ | 0 | 21.74 | 153 | 0.07 | 98 | 8.6 | 7.93 | 26 | 20 |
| 0 | MnSO ₄ | 5 | 21.65 | 158 | 0.07 | 98 | 8.62 | 7.91 | | |
| 0 | MnSO ₄ | 10 | 21.71 | 166 | 0.08 | 98.1 | 8.63 | 7.84 | | |
| 0 | MnSO ₄ | 20 | 21.77 | 183 | 0.09 | 98.3 | 8.63 | 7.77 | | |
| 0 | MnSO ₄ | 40 | 21.78 | 206 | 0.1 | 98.2 | 8.62 | 7.72 | | |
| 0 | MnSO ₄ | 80 | 21.76 | 281 | 0.13 | 97.6 | 8.57 | 7.6 | | |
| 0 | MnSO ₄ | 160 | 22.01 | 402 | 0.19 | 97.5 | 8.51 | 7.53 | | |
| 24 | MnCl ₂ | 0 | 22.2 | 157 | 0.07 | 97.2 | 8.46 | 7.9 | 46 | 50 |
| 24 | MnCl ₂ | 5 | 22.3 | 161 | 0.08 | 97 | 8.43 | 7.95 | | |
| 24 | MnCl ₂ | 10 | 22.29 | 171 | 0.08 | 97.1 | 8.44 | 7.9 | | |
| 24 | MnCl ₂ | 20 | 22.2 | 191 | 0.09 | 97.9 | 8.53 | 7.81 | | |
| 24 | MnCl ₂ | 40 | 22.22 | 227 | 0.11 | 96.8 | 8.43 | 7.7 | | |
| 24 | MnCl ₂ | 80 | 22.21 | 307 | 0.15 | 96.1 | 8.36 | 7.61 | | |
| 24 | MnCl ₂ | 160 | 22.17 | 464 | 0.22 | 96.6 | 8.41 | 7.57 | | |
| 24 | MnSO ₄ | 0 | 22.5 | 149 | 0.07 | 98.2 | 8.51 | 7.99 | 40 | 44 |
| 24 | MnSO ₄ | 5 | 22.42 | 158 | 0.07 | 98.2 | 8.51 | 7.92 | | |
| 24 | MnSO ₄ | 10 | 22.53 | 168 | 0.08 | 97.4 | 8.43 | 7.86 | | |
| 24 | MnSO ₄ | 20 | 22.5 | 184 | 0.09 | 97.7 | 8.45 | 7.78 | | |
| 24 | MnSO ₄ | 40 | 22.43 | 207 | 0.1 | 97.5 | 8.45 | 7.7 | | |
| 24 | MnSO ₄ | 80 | 22.31 | 283 | 0.13 | 97.6 | 8.48 | 7.58 | | |
| 24 | MnSO ₄ | 160 | 22.19 | 405 | 0.19 | 97.6 | 8.5 | 7.55 | | |
| 48 | MnCl ₂ | 0 | 22.39 | 150 | 0.07 | 97.5 | 8.46 | 7.96 | 66 | 44 |
| 48 | MnCl ₂ | 5 | 22.32 | 161 | 0.08 | 97.3 | 8.45 | 7.93 | | |
| 48 | MnCl ₂ | 10 | 22.26 | 171 | 0.08 | 98.2 | 8.54 | 7.87 | | |
| 48 | MnCl ₂ | 20 | 22.24 | 192 | 0.09 | 98.1 | 8.54 | 7.78 | | |
| 48 | MnCl ₂ | 40 | 22.19 | 228 | 0.11 | 98.1 | 8.55 | 7.68 | | |
| 48 | MnCl ₂ | 80 | 22.33 | 309 | 0.15 | 96.7 | 8.4 | 7.6 | | |
| 48 | MnCl ₂ | 160 | 22.24 | 466 | 0.22 | 97.6 | 8.48 | 7.55 | | |
| 48 | MnSO ₄ | 0 | 22.04 | 157 | 0.07 | 97.6 | 8.53 | 7.99 | 34 | 48 |
| 48 | MnSO ₄ | 5 | 22.02 | 163 | 0.08 | 98.3 | 8.59 | 7.98 | | |
| 48 | MnSO ₄ | 10 | 21.91 | 183 | 0.09 | 98 | 8.58 | 7.93 | | |
| 48 | MnSO ₄ | 20 | 22.11 | 185 | 0.09 | 97.5 | 8.5 | 7.85 | | |
| 48 | MnSO ₄ | 40 | 22.14 | 208 | 0.1 | 96.8 | 8.43 | 7.78 | | |

Table 6 continued.

| | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|
| 48 | MnSO ₄ | 80 | 22.12 | 285 | 0.14 | 97.9 | 8.54 | 7.65 |
| 48 | MnSO ₄ | 160 | 22.13 | 407 | 0.19 | 98 | 8.54 | 7.6 |

Table 7. Water Chemistry data for *U. imbecillis* glochidia acute toxicity tests.

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------------|---------------|-------------------------|-------------------|-----------|--------------|------|----------------------|--------------------|
| 0 | MnCl ₂ | 0 | 22.17 | 216 | 0.1 | 98.4 | 8.57 | 7.91 | 56 | 62 |
| 0 | MnCl ₂ | 5 | 22.26 | 224 | 0.11 | 98.7 | 8.59 | 7.89 | | |
| 0 | MnCl ₂ | 10 | 22.19 | 244 | 0.12 | 98.5 | 8.58 | 7.83 | | |
| 0 | MnCl ₂ | 20 | 22.13 | 280 | 0.13 | 97.8 | 8.52 | 7.74 | | |
| 0 | MnCl ₂ | 40 | 22.12 | 351 | 0.17 | 97 | 8.46 | 7.65 | | |
| 0 | MnCl ₂ | 80 | 22.18 | 509 | 0.25 | 96.8 | 8.42 | 7.66 | | |
| 0 | MnCl ₂ | 160 | 22.16 | 798 | 0.39 | 97.4 | 8.46 | 7.49 | | |
| 0 | MnSO ₄ | 0 | 22.12 | 169 | 0.08 | 98.8 | 8.62 | 7.56 | 38 | 58 |
| 0 | MnSO ₄ | 5 | 21.98 | 215 | 0.1 | 99 | 8.66 | 7.55 | | |
| 0 | MnSO ₄ | 10 | 22.08 | 206 | 0.1 | 98.8 | 8.62 | 7.56 | | |
| 0 | MnSO ₄ | 20 | 22.06 | 239 | 0.11 | 98.5 | 8.59 | 7.49 | | |
| 0 | MnSO ₄ | 40 | 22.14 | 301 | 0.14 | 98.8 | 8.61 | 7.48 | | |
| 0 | MnSO ₄ | 80 | 22.14 | 425 | 0.2 | 99 | 8.63 | 7.47 | | |
| 0 | MnSO ₄ | 160 | 22.16 | 638 | 0.31 | 98.6 | 8.58 | 7.39 | | |
| 24 | MnCl ₂ | 0 | 22.07 | 204 | 0.1 | 98.8 | 8.62 | 8.01 | 46 | 68 |
| 24 | MnCl ₂ | 5 | 22.01 | 223 | 0.11 | 98.6 | 8.62 | 7.92 | | |
| 24 | MnCl ₂ | 10 | 21.97 | 243 | 0.12 | 98.6 | 8.62 | 7.84 | | |
| 24 | MnCl ₂ | 20 | 22.05 | 280 | 0.13 | 98.3 | 8.58 | 7.76 | | |
| 24 | MnCl ₂ | 40 | 22.05 | 351 | 0.17 | 98.5 | 8.6 | 7.68 | | |
| 24 | MnCl ₂ | 80 | 22.04 | 513 | 0.25 | 97.6 | 8.52 | 7.61 | | |
| 24 | MnCl ₂ | 160 | 22.03 | 804 | 0.39 | 98.1 | 8.56 | 7.54 | | |
| 24 | MnSO ₄ | 0 | 22.33 | 174 | 0.08 | 97.7 | 8.48 | 7.69 | 38 | 50 |
| 24 | MnSO ₄ | 5 | 22.24 | 191 | 0.09 | 97 | 8.44 | 7.6 | | |
| 24 | MnSO ₄ | 10 | 22.14 | 206 | 0.1 | 98 | 8.54 | 7.54 | | |
| 24 | MnSO ₄ | 20 | 22.2 | 240 | 0.11 | 97.1 | 8.46 | 7.53 | | |
| 24 | MnSO ₄ | 40 | 22.22 | 302 | 0.14 | 97.5 | 8.48 | 7.51 | | |
| 24 | MnSO ₄ | 80 | 22.16 | 426 | 0.2 | 97.3 | 8.47 | 7.51 | | |
| 24 | MnSO ₄ | 160 | 22.15 | 641 | 0.31 | 97 | 8.44 | 7.49 | | |
| 48 | MnCl ₂ | 0 | 21.98 | 204 | 0.1 | 97.4 | 8.52 | 8.06 | 50 | 62 |
| 48 | MnCl ₂ | 5 | 21.91 | 224 | 0.11 | 97.7 | 8.55 | 8.01 | | |
| 48 | MnCl ₂ | 10 | 21.92 | 245 | 0.12 | 97.4 | 8.53 | 7.94 | | |
| 48 | MnCl ₂ | 20 | 21.98 | 282 | 0.13 | 97.8 | 8.55 | 7.85 | | |
| 48 | MnCl ₂ | 40 | 21.97 | 353 | 0.17 | 97.4 | 8.51 | 7.81 | | |
| 48 | MnCl ₂ | 80 | 21.96 | 516 | 0.25 | 97.3 | 8.5 | 7.75 | | |
| 48 | MnCl ₂ | 160 | 21.87 | 808 | 0.4 | 96.6 | 8.45 | 7.72 | | |
| 48 | MnSO ₄ | 0 | 21.9 | 172 | 0.08 | 97.5 | 8.53 | 7.94 | 40 | 48 |
| 48 | MnSO ₄ | 5 | 21.65 | 193 | 0.09 | 98 | 8.63 | 7.87 | | |
| 48 | MnSO ₄ | 10 | 21.73 | 208 | 0.1 | 96.8 | 8.5 | 7.8 | | |
| 48 | MnSO ₄ | 20 | 21.71 | 243 | 0.12 | 97.3 | 8.55 | 7.73 | | |
| 48 | MnSO ₄ | 40 | 21.78 | 303 | 0.14 | 97.2 | 8.53 | 7.67 | | |

Table 7 continued

| | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|
| 48 | MnSO ₄ | 80 | 21.72 | 431 | 0.21 | 96.5 | 8.48 | 7.63 |
| 48 | MnSO ₄ | 160 | 21.81 | 644 | 0.31 | 97.4 | 8.53 | 7.6 |

Table 8. Water Chemistry data for *O. subrotunda* glochidia acute toxicity tests.

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------------|---------------|-------------------------|-------------------|-------------|--------------|-------------|----------------------|--------------------|
| 0 | MnCl ₂ | 0 | 21.66 | 144 | 0.07 | 97 | 8.53 | 7.84 | 42 | 44 |
| 0 | MnCl ₂ | 5 | 21.55 | 163 | 0.08 | 97.3 | 8.58 | 7.79 | | |
| 0 | MnCl ₂ | 10 | 21.5 | 196 | 0.09 | 96.8 | 8.54 | 7.67 | | |
| 0 | MnCl ₂ | 20 | 21.65 | 222 | 0.1 | 96.3 | 8.47 | 7.59 | | |
| 0 | MnCl ₂ | 40 | 21.77 | 297 | 0.14 | 96.6 | 8.48 | NA | | |
| 0 | MnCl ₂ | 80 | 21.86 | 459 | 0.22 | 96.2 | 8.42 | 7.35 | | |
| 0 | MnCl ₂ | 160 | 22.07 | 754 | 0.37 | 96 | 8.36 | 7.29 | | |
| 0 | MnSO ₄ | 0 | 21.71 | 166 | 0.08 | 96.5 | 8.48 | 7.75 | 30 | 58 |
| 0 | MnSO ₄ | 5 | 21.76 | 178 | 0.08 | 96.7 | 8.49 | 7.73 | | |
| 0 | MnSO ₄ | 10 | 21.87 | 209 | 0.1 | 96.8 | 8.48 | 7.65 | | |
| 0 | MnSO ₄ | 20 | 21.87 | 271 | 0.13 | 96.7 | 8.47 | 7.54 | | |
| 0 | MnSO ₄ | 40 | 21.87 | 151 | 0.07 | 96.9 | 8.49 | 7.8 | | |
| 0 | MnSO ₄ | 80 | 21.88 | 406 | 0.19 | 96.6 | 8.46 | 7.41 | | |
| 0 | MnSO ₄ | 160 | 22.02 | 620 | 0.3 | 96 | 8.38 | 7.36 | | |
| 24 | MnCl ₂ | 0 | 21.91 | 158 | 0.07 | 97.1 | 8.5 | 7.94 | 40 | 48 |
| 24 | MnCl ₂ | 5 | 21.84 | 164 | 0.08 | 97.2 | 8.52 | 7.88 | | |
| 24 | MnCl ₂ | 10 | 21.8 | 196 | 0.09 | 97.6 | 8.56 | 7.75 | | |
| 24 | MnCl ₂ | 20 | 21.8 | 222 | 0.11 | 97.7 | 8.57 | 7.68 | | |
| 24 | MnCl ₂ | 40 | 21.79 | 297 | 0.14 | 97.5 | 8.56 | 7.56 | | |
| 24 | MnCl ₂ | 80 | 21.83 | 458 | 0.22 | 97.3 | 8.53 | 7.48 | | |
| 24 | MnCl ₂ | 160 | 21.82 | 753 | 0.37 | 97.4 | 8.53 | 7.41 | | |
| 24 | MnSO ₄ | 0 | 21.93 | 172 | 0.08 | 95.9 | 8.4 | 7.91 | 36 | 54 |
| 24 | MnSO ₄ | 5 | 21.98 | 179 | 0.08 | 97 | 8.48 | 7.81 | | |
| 24 | MnSO ₄ | 10 | 21.91 | 209 | 0.1 | 97.3 | 8.52 | 7.71 | | |
| 24 | MnSO ₄ | 20 | 21.85 | 272 | 0.13 | 97.5 | 8.55 | 7.61 | | |
| 24 | MnSO ₄ | 40 | 21.92 | 154 | 0.07 | 96.5 | 8.45 | 7.87 | | |
| 24 | MnSO ₄ | 80 | 21.95 | 408 | 0.2 | 96.6 | 8.45 | 7.47 | | |
| 24 | MnSO ₄ | 160 | 21.98 | 619 | 0.3 | 97.3 | 8.49 | 7.42 | | |
| 48 | MnCl ₂ | 0 | 21.69 | 159 | 0.07 | 95.2 | 8.37 | 7.53 | 42 | 46 |
| 48 | MnCl ₂ | 5 | 21.57 | 165 | 0.08 | 95.2 | 8.39 | 7.45 | | |
| 48 | MnCl ₂ | 10 | 21.67 | 197 | 0.09 | 96.3 | 8.47 | 7.33 | | |
| 48 | MnCl ₂ | 20 | 21.65 | 224 | 0.11 | 95.7 | 8.42 | 7.34 | | |
| 48 | MnCl ₂ | 40 | 21.75 | 299 | 0.14 | 95.9 | 8.42 | 7.31 | | |
| 48 | MnCl ₂ | 80 | 21.91 | 461 | 0.22 | 95 | 8.32 | 7.28 | | |
| 48 | MnCl ₂ | 160 | 21.98 | 758 | 0.37 | 95.9 | 8.38 | 7.23 | | |
| 48 | MnSO ₄ | 0 | 21.88 | 173 | 0.08 | 95.8 | 8.4 | 7.81 | 36 | 50 |
| 48 | MnSO ₄ | 5 | 21.79 | 180 | 0.08 | 96.1 | 8.43 | 7.7 | | |
| 48 | MnSO ₄ | 10 | 21.81 | 210 | 0.1 | 96.4 | 8.46 | 7.61 | | |
| 48 | MnSO ₄ | 20 | 21.83 | 274 | 0.13 | 96.4 | 8.45 | 7.51 | | |
| 48 | MnSO ₄ | 40 | 21.93 | 153 | 0.07 | 95.9 | 8.4 | 7.83 | | |

Table 8 continued.

| | | | | | | | | |
|----|-------------------|-----|-------|-----|-----|------|------|------|
| 48 | MnSO ₄ | 80 | 21.9 | 412 | 0.2 | 95.2 | 8.33 | 7.43 |
| 48 | MnSO ₄ | 160 | 21.91 | 623 | 0.3 | 96.2 | 8.42 | 7.39 |

Table 9. Water Chemistry data for *E. triquetra* glochidia acute toxicity tests

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 21.7 | 154 | 0.07 | 95.9 | 8.44 | 7.75 | 50 | 44 |
| 0 | MnCl ₂ | 5 | 21.57 | 164 | 0.08 | 95.9 | 8.45 | 7.69 | | |
| 0 | MnCl ₂ | 10 | 21.56 | 184 | 0.09 | 95.9 | 8.46 | 7.61 | | |
| 0 | MnCl ₂ | 20 | 21.53 | 221 | 0.1 | 96 | 8.46 | 7.51 | | |
| 0 | MnCl ₂ | 40 | 21.59 | 297 | 0.14 | 95.9 | 8.44 | 7.43 | | |
| 0 | MnCl ₂ | 80 | 21.52 | 455 | 0.22 | 96.6 | 8.52 | 7.35 | | |
| 0 | MnCl ₂ | 160 | 21.59 | 744 | 0.36 | 96.1 | 8.45 | 7.29 | | |
| 0 | MnSO ₄ | 0 | 21.59 | 162 | 0.08 | 95.8 | 8.44 | 7.49 | 44 | 44 |
| 0 | MnSO ₄ | 5 | 21.53 | 166 | 0.08 | 96 | 8.47 | 7.39 | | |
| 0 | MnSO ₄ | 10 | 21.53 | 180 | 0.08 | 95.6 | 8.43 | 7.32 | | |
| 0 | MnSO ₄ | 20 | 21.49 | 209 | 0.1 | 95.2 | 8.4 | 7.29 | | |
| 0 | MnSO ₄ | 40 | 21.53 | 276 | 0.13 | 95.8 | 8.46 | 7.27 | | |
| 0 | MnSO ₄ | 80 | 21.57 | 394 | 0.19 | 95.6 | 8.42 | 7.32 | | |
| 0 | MnSO ₄ | 160 | 21.58 | 614 | 0.3 | 95.6 | 8.41 | 7.25 | | |
| 24 | MnCl ₂ | 0 | 22.06 | 147 | 0.07 | 94.3 | 8.23 | 7.9 | 32 | 40 |
| 24 | MnCl ₂ | 5 | 21.91 | 166 | 0.08 | 95 | 8.32 | 7.78 | | |
| 24 | MnCl ₂ | 10 | 21.92 | 185 | 0.09 | 95 | 8.32 | 7.69 | | |
| 24 | MnCl ₂ | 20 | 21.92 | 223 | 0.11 | 94.3 | 8.26 | 7.59 | | |
| 24 | MnCl ₂ | 40 | 21.9 | 299 | 0.14 | 95.1 | 8.33 | 7.5 | | |
| 24 | MnCl ₂ | 80 | 21.9 | 457 | 0.22 | 94.7 | 8.28 | 7.41 | | |
| 24 | MnCl ₂ | 160 | 21.89 | 747 | 0.36 | 95.3 | 8.33 | 7.34 | | |
| 24 | MnSO ₄ | 0 | 22.01 | 156 | 0.07 | 94.6 | 8.26 | 7.58 | 44 | 42 |
| 24 | MnSO ₄ | 5 | 21.98 | 168 | 0.08 | 95.5 | 8.35 | 7.46 | | |
| 24 | MnSO ₄ | 10 | 21.94 | 180 | 0.08 | 95.7 | 8.38 | 7.42 | | |
| 24 | MnSO ₄ | 20 | 21.81 | 211 | 0.1 | 95.1 | 8.35 | 7.37 | | |
| 24 | MnSO ₄ | 40 | 21.86 | 277 | 0.13 | 95.7 | 8.38 | 7.36 | | |
| 24 | MnSO ₄ | 80 | 21.91 | 395 | 0.19 | 95.6 | 8.37 | 7.36 | | |
| 24 | MnSO ₄ | 160 | 21.87 | 616 | 0.3 | 95.8 | 8.39 | 7.34 | | |
| 48 | MnCl ₂ | 0 | 22.11 | 145 | 0.07 | 93.8 | 8.18 | 7.97 | 34 | 40 |
| 48 | MnCl ₂ | 5 | 21.93 | 166 | 0.08 | 94.3 | 8.25 | 7.84 | | |
| 48 | MnCl ₂ | 10 | 21.93 | 186 | 0.09 | 94.3 | 8.25 | 7.74 | | |
| 48 | MnCl ₂ | 20 | 21.91 | 224 | 0.11 | 93.8 | 8.21 | 7.63 | | |
| 48 | MnCl ₂ | 40 | 21.87 | 301 | 0.14 | 94.4 | 8.27 | 7.51 | | |
| 48 | MnCl ₂ | 80 | 21.85 | 459 | 0.22 | 93.9 | 8.22 | 7.43 | | |
| 48 | MnCl ₂ | 160 | 21.87 | 747 | 0.37 | 92.4 | 8.09 | 7.38 | | |
| 48 | MnSO ₄ | 0 | 21.97 | 153 | 0.07 | 93.3 | 8.16 | 7.97 | 40 | 46 |
| 48 | MnSO ₄ | 5 | 21.93 | 169 | 0.08 | 93 | 8.14 | 7.89 | | |
| 48 | MnSO ₄ | 10 | 21.77 | 179 | 0.08 | 95 | 8.34 | 7.81 | | |
| 48 | MnSO ₄ | 20 | 21.9 | 212 | 0.1 | 92.8 | 8.12 | 7.72 | | |
| 48 | MnSO ₄ | 40 | 21.73 | 278 | 0.13 | 93.2 | 8.19 | 7.61 | | |

Table 9 continued

| | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|
| 48 | MnSO ₄ | 80 | 21.72 | 397 | 0.19 | 93.2 | 8.19 | 7.52 |
| 48 | MnSO ₄ | 160 | 21.66 | 619 | 0.3 | 93.9 | 8.26 | 7.46 |

Table 10. Water Chemistry data for *L. cardium* juvenile acute toxicity tests

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 21.86 | 272 | 0.13 | 96 | 8.41 | 7.44 | | |
| 0 | MnCl ₂ | 5 | 21.78 | 191 | 0.09 | 96.5 | 8.47 | 7.42 | | |
| 0 | MnCl ₂ | 10 | 21.77 | 170 | 0.08 | 96.7 | 8.49 | 7.58 | 22 | 40 |
| 0 | MnCl ₂ | 20 | 21.77 | 224 | 0.11 | 96.7 | 8.49 | 7.44 | | |
| 0 | MnCl ₂ | 40 | 21.71 | 303 | 0.14 | 96.8 | 8.51 | 7.38 | | |
| 0 | MnCl ₂ | 80 | 21.69 | 458 | 0.22 | 97.2 | 8.54 | 7.33 | | |
| 0 | MnCl ₂ | 160 | 21.68 | 763 | 0.37 | 98 | 8.61 | 7.32 | | |
| 0 | MnSO ₄ | 0 | 21.61 | 161 | 0.08 | 98.1 | 8.64 | 7.82 | 36 | 46 |
| 0 | MnSO ₄ | 5 | 21.45 | 169 | 0.08 | 99.2 | 8.76 | 7.72 | | |
| 0 | MnSO ₄ | 10 | 21.41 | 183 | 0.09 | 97.6 | 8.63 | 7.65 | | |
| 0 | MnSO ₄ | 20 | 21.36 | 222 | 0.1 | 96.7 | 8.51 | 7.55 | | |
| 0 | MnSO ₄ | 40 | 21.47 | 284 | 0.13 | 97.3 | 8.59 | 7.47 | | |
| 0 | MnSO ₄ | 80 | 21.61 | 415 | 0.2 | 97.8 | 8.61 | 7.47 | | |
| 0 | MnSO ₄ | 160 | 21.58 | 623 | 0.3 | 97.5 | 8.57 | 7.39 | | |
| 48 | MnCl ₂ | 0 | 21.48 | 162 | 0.08 | 97 | 8.56 | 7.9 | 30 | 48 |
| 48 | MnCl ₂ | 5 | 21.35 | 169 | 0.08 | 97.2 | 8.6 | 7.9 | | |
| 48 | MnCl ₂ | 10 | 21.34 | 189 | 0.09 | 98 | 8.68 | 7.78 | | |
| 48 | MnCl ₂ | 20 | 21.27 | 230 | 0.11 | 97.4 | 8.63 | 7.66 | | |
| 48 | MnCl ₂ | 40 | 21.28 | 307 | 0.15 | 96.3 | 8.53 | 7.55 | | |
| 48 | MnCl ₂ | 80 | 21.39 | 462 | 0.22 | 96.5 | 8.53 | 7.49 | | |
| 48 | MnCl ₂ | 160 | 21.4 | 768 | 0.38 | 96.6 | 8.52 | 7.45 | | |
| 48 | MnSO ₄ | 0 | 21.78 | 169 | 0.08 | 97.3 | 8.55 | 7.55 | 32 | 40 |
| 48 | MnSO ₄ | 5 | 21.59 | 171 | 0.08 | 97.2 | 8.56 | 7.47 | | |
| 48 | MnSO ₄ | 10 | 21.46 | 185 | 0.09 | 98.3 | 8.68 | 7.41 | | |
| 48 | MnSO ₄ | 20 | 21.52 | 224 | 0.11 | 98.5 | 8.68 | 7.33 | | |
| 48 | MnSO ₄ | 40 | 21.41 | 288 | 0.14 | 97.3 | 8.6 | 7.44 | | |
| 48 | MnSO ₄ | 80 | 21.4 | 419 | 0.2 | 96.7 | 8.55 | 7.41 | | |
| 48 | MnSO ₄ | 160 | 21.49 | 629 | 0.31 | 97 | 8.55 | 7.41 | | |
| 48 | MnCl ₂ | 0 | 21.48 | 164 | 0.08 | 98.8 | 8.73 | 7.89 | 34 | 50 |
| 48 | MnCl ₂ | 5 | 21.49 | 175 | 0.08 | 97.5 | 8.61 | 7.94 | | |
| 48 | MnCl ₂ | 10 | 21.39 | 192 | 0.09 | 97.7 | 8.61 | 7.87 | | |
| 48 | MnCl ₂ | 20 | 21.42 | 212 | 0.11 | 98.7 | 8.73 | 7.75 | | |
| 48 | MnCl ₂ | 40 | 21.39 | 310 | 0.15 | 98.2 | 8.69 | 7.63 | | |
| 48 | MnCl ₂ | 80 | 21.44 | 160 | 0.22 | 98.5 | 8.69 | 7.52 | | |
| 48 | MnCl ₂ | 160 | 21.44 | 771 | 0.38 | 99.7 | 8.8 | 7.44 | | |
| 48 | MnSO ₄ | 0 | 21.64 | 167 | 0.08 | 102.2 | 9 | 8.04 | | |
| 48 | MnSO ₄ | 5 | 21.45 | 170 | 0.08 | 100.5 | 8.88 | 7.92 | | |
| 48 | MnSO ₄ | 10 | 21.4 | 187 | 0.09 | 100.2 | 8.86 | 7.83 | | |
| 48 | MnSO ₄ | 20 | 21.39 | 220 | 0.1 | 99.4 | 8.79 | 7.73 | | |
| 48 | MnSO ₄ | 40 | 21.37 | 281 | 0.13 | 99.4 | 8.79 | 7.62 | | |

Table 10 continued

| | | | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|----|----|
| 48 | MnSO ₄ | 80 | 21.44 | 409 | 0.2 | 98.9 | 8.73 | 7.54 | | |
| 48 | MnSO ₄ | 160 | 21.4 | 626 | 0.3 | 99.2 | 8.76 | 7.45 | | |
| 96 | MnCl ₂ | 0 | 21.65 | 174 | 0.08 | 95.5 | 8.37 | 7.99 | 34 | 54 |
| 96 | MnCl ₂ | 5 | 21.58 | 175 | 0.08 | 95.9 | 8.45 | 7.86 | | |
| 96 | MnCl ₂ | 10 | 21.6 | 193 | 0.09 | 96.4 | 8.48 | 7.77 | | |
| 96 | MnCl ₂ | 20 | 21.61 | 242 | 0.11 | 96.3 | 8.49 | 7.67 | | |
| 96 | MnCl ₂ | 40 | 21.59 | 312 | 0.15 | 96.1 | 8.46 | 7.61 | | |
| 96 | MnCl ₂ | 80 | 21.59 | 464 | 0.22 | 96.2 | 8.46 | 7.57 | | |
| 96 | MnCl ₂ | 160 | 21.6 | 773 | 0.38 | 95.5 | 8.39 | 7.53 | | |
| 96 | MnSO ₄ | 0 | 21.81 | 665 | 0.32 | 97.7 | 8.55 | 7.43 | | |
| 96 | MnSO ₄ | 5 | 21.83 | 189 | 0.09 | 95.3 | 8.36 | 7.58 | 34 | 52 |
| 96 | MnSO ₄ | 10 | 21.76 | 232 | 0.11 | 96.7 | 8.48 | 7.49 | | |
| 96 | MnSO ₄ | 20 | 21.78 | 283 | 0.13 | 95.4 | 8.37 | 7.51 | | |
| 96 | MnSO ₄ | 40 | 21.73 | 191 | 0.09 | 95.7 | 8.41 | 7.68 | | |
| 96 | MnSO ₄ | 80 | 21.72 | 410 | 0.2 | 94.7 | 8.3 | 7.51 | | |
| 96 | MnSO ₄ | 160 | 21.7 | 630 | 0.31 | 95.2 | 8.35 | 7.44 | | |

Table 11. Water Chemistry data for *O. pectorosa* juvenile acute toxicity tests

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------------|---------------|-------------------------|-------------------|-----------|--------------|------|----------------------|--------------------|
| 0 | MnCl ₂ | 0 | 21.94 | 182 | 0.09 | 94.1 | 8.23 | 7.45 | 70 | 48 |
| 0 | MnCl ₂ | 5 | 21.76 | 191 | 0.09 | 96.4 | 8.47 | 7.39 | | |
| 0 | MnCl ₂ | 10 | 21.72 | 210 | 0.1 | 96.3 | 8.47 | 7.33 | | |
| 0 | MnCl ₂ | 20 | 21.64 | 249 | 0.12 | 96.2 | 8.47 | 7.26 | | |
| 0 | MnCl ₂ | 40 | 21.62 | 327 | 0.16 | 96.1 | 8.46 | 7.52 | | |
| 0 | MnCl ₂ | 80 | 21.58 | 476 | 0.23 | 96.1 | 8.46 | 7.38 | | |
| 0 | MnCl ₂ | 160 | 21.63 | 775 | 0.38 | 95.9 | 8.43 | 7.34 | | |
| 0 | MnSO ₄ | 0 | 21.66 | 186 | 0.09 | 96.5 | 8.49 | 7.93 | 28 | 56 |
| 0 | MnSO ₄ | 5 | 21.62 | 191 | 0.09 | 97.1 | 8.55 | 7.86 | | |
| 0 | MnSO ₄ | 10 | 21.55 | 206 | 0.1 | 96.5 | 8.51 | 7.78 | | |
| 0 | MnSO ₄ | 20 | 21.64 | 239 | 0.11 | 96.6 | 8.5 | 7.69 | | |
| 0 | MnSO ₄ | 40 | 21.59 | 301 | 0.14 | 96.4 | 8.49 | 7.59 | | |
| 0 | MnSO ₄ | 80 | 21.67 | 421 | 0.2 | 96.5 | 8.49 | 7.52 | | |
| 0 | MnSO ₄ | 160 | 21.63 | 636 | 0.31 | 96.6 | 8.49 | 7.47 | | |
| 48 | MnCl ₂ | 0 | 21.58 | 180 | 0.08 | 97.8 | 8.62 | 7.95 | 56 | 50 |
| 48 | MnCl ₂ | 5 | 21.63 | 192 | 0.09 | 98.9 | 8.7 | 7.91 | | |
| 48 | MnCl ₂ | 10 | 21.61 | 212 | 0.1 | 98.1 | 8.64 | 7.84 | | |
| 48 | MnCl ₂ | 20 | 21.61 | 251 | 0.12 | 98.2 | 8.65 | 7.74 | | |
| 48 | MnCl ₂ | 40 | 21.66 | 327 | 0.16 | 98.6 | 8.67 | 7.66 | | |
| 48 | MnCl ₂ | 80 | 21.69 | 481 | 0.23 | 98.5 | 8.65 | 7.59 | | |
| 48 | MnCl ₂ | 160 | 21.72 | 799 | 0.39 | 98.8 | 8.66 | 7.55 | | |
| 48 | MnSO ₄ | 0 | 21.73 | 179 | 0.08 | 99.8 | 8.77 | 8.15 | 36 | 54 |
| 48 | MnSO ₄ | 5 | 21.48 | 194 | 0.09 | 99.2 | 8.76 | 8.08 | | |
| 48 | MnSO ₄ | 10 | 21.48 | 210 | 0.1 | 99.7 | 8.8 | 7.99 | | |
| 48 | MnSO ₄ | 20 | 21.48 | 245 | 0.12 | 99.6 | 8.79 | 7.88 | | |
| 48 | MnSO ₄ | 40 | 21.53 | 305 | 0.15 | 99.7 | 8.79 | 7.77 | | |
| 48 | MnSO ₄ | 80 | 21.59 | 423 | 0.2 | 99.4 | 8.76 | 7.67 | | |
| 48 | MnSO ₄ | 160 | 21.7 | 652 | 0.32 | 98.8 | 8.68 | 7.59 | | |
| 48 | MnCl ₂ | 0 | 21.99 | 183 | 0.09 | 99.7 | 8.7 | 7.36 | | |
| 48 | MnCl ₂ | 5 | 21.84 | 214 | 0.1 | 99.4 | 8.72 | 7.48 | 42 | 58 |
| 48 | MnCl ₂ | 10 | 21.99 | 204 | 0.1 | 99.1 | 8.66 | 7.42 | | |
| 48 | MnCl ₂ | 20 | 21.83 | 248 | 0.12 | 99.4 | 8.71 | 7.35 | | |
| 48 | MnCl ₂ | 40 | 21.84 | 325 | 0.15 | 99.3 | 8.7 | 7.36 | | |
| 48 | MnCl ₂ | 80 | 21.83 | 485 | 0.23 | 99.4 | 8.7 | 7.35 | | |
| 48 | MnCl ₂ | 160 | 21.82 | 787 | 0.39 | 99.4 | 8.71 | 7.34 | | |
| 48 | MnSO ₄ | 0 | 21.53 | 174 | 0.08 | 99.2 | 8.75 | 7.91 | 74 | 56 |
| 48 | MnSO ₄ | 5 | 21.56 | 182 | 0.09 | 98.9 | 8.72 | 7.93 | | |
| 48 | MnSO ₄ | 10 | 21.59 | 200 | 0.09 | 99.4 | 8.76 | 7.84 | | |
| 48 | MnSO ₄ | 20 | 21.57 | 233 | 0.11 | 99.3 | 8.75 | 7.75 | | |

Table 11 continued

| | | | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|----|----|
| 48 | MnSO ₄ | 40 | 21.64 | 297 | 0.14 | 99.1 | 8.72 | 7.64 | | |
| 48 | MnSO ₄ | 80 | 21.63 | 417 | 0.2 | 99.3 | 8.74 | 7.54 | | |
| 48 | MnSO ₄ | 160 | 21.62 | 635 | 0.31 | 99.5 | 8.75 | 7.48 | | |
| 96 | MnCl ₂ | 0 | 22.17 | 357 | 0.19 | 98 | 8.53 | 7.81 | 48 | 70 |
| 96 | MnCl ₂ | 5 | 22.07 | 207 | 0.1 | 98.5 | 8.6 | 7.82 | | |
| 96 | MnCl ₂ | 10 | 21.9 | 213 | 0.1 | 98.2 | 8.61 | 7.73 | | |
| 96 | MnCl ₂ | 20 | 21.91 | 253 | 0.12 | 99 | 8.65 | 7.63 | | |
| 96 | MnCl ₂ | 40 | 21.81 | 332 | 0.16 | 97.5 | 8.55 | 7.52 | | |
| 96 | MnCl ₂ | 80 | 21.85 | 498 | 0.24 | 98.7 | 8.65 | 7.47 | | |
| 96 | MnCl ₂ | 160 | 21.81 | 797 | 0.39 | 98.7 | 8.65 | 7.47 | | |
| 96 | MnSO ₄ | 0 | 21.58 | 182 | 0.09 | 98.3 | 8.66 | 7.53 | 42 | 50 |
| 96 | MnSO ₄ | 5 | 21.61 | 185 | 0.09 | 98.5 | 8.67 | 7.46 | | |
| 96 | MnSO ₄ | 10 | 21.63 | 202 | 0.1 | 98.7 | 8.7 | 7.39 | | |
| 96 | MnSO ₄ | 20 | 21.6 | 235 | 0.11 | 99 | 8.72 | 7.33 | | |
| 96 | MnSO ₄ | 40 | 21.7 | 301 | 0.14 | 98.1 | 8.62 | 7.39 | | |
| 96 | MnSO ₄ | 80 | 21.66 | 421 | 0.2 | 98.6 | 8.67 | 7.42 | | |
| 96 | MnSO ₄ | 160 | 21.65 | 642 | 0.31 | 98.5 | 8.69 | 7.43 | | |

Table 12. Water Chemistry data for *U. imbecillis* juvenile acute toxicity tests

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 21.54 | 171 | 0.08 | 97.8 | 8.62 | 8.11 | 44 | 44 |
| 0 | MnCl ₂ | 5 | 21.57 | 190 | 0.09 | 97.8 | 8.62 | 8 | | |
| 0 | MnCl ₂ | 10 | 21.57 | 209 | 0.1 | 97.5 | 8.6 | 7.92 | | |
| 0 | MnCl ₂ | 20 | 21.66 | 248 | 0.12 | 97.9 | 8.61 | 7.8 | | |
| 0 | MnCl ₂ | 40 | 21.75 | 317 | 0.15 | 97.9 | 8.6 | 7.74 | | |
| 0 | MnCl ₂ | 80 | 21.77 | 472 | 0.23 | 97.6 | 8.56 | 7.66 | | |
| 0 | MnCl ₂ | 160 | 21.82 | 773 | 0.38 | 97.8 | 8.56 | 7.64 | | |
| 0 | MnSO ₄ | 0 | 12.78 | 169 | 0.08 | 97.2 | 8.53 | 7.94 | 50 | 48 |
| 0 | MnSO ₄ | 5 | 21.7 | 187 | 0.09 | 97.7 | 8.59 | 7.9 | | |
| 0 | MnSO ₄ | 10 | 21.7 | 204 | 0.1 | 97.8 | 8.6 | 7.83 | | |
| 0 | MnSO ₄ | 20 | 21.75 | 238 | 0.11 | 97.7 | 8.58 | 7.74 | | |
| 0 | MnSO ₄ | 40 | 21.75 | 303 | 0.14 | 97.8 | 8.59 | 7.64 | | |
| 0 | MnSO ₄ | 80 | 21.82 | 418 | 0.2 | 97.8 | 8.58 | 7.64 | | |
| 0 | MnSO ₄ | 160 | 21.83 | 639 | 0.31 | 97.7 | 8.56 | 7.54 | | |
| 48 | MnCl ₂ | 0 | 21.66 | 170 | 0.08 | 99.1 | 8.72 | 8.01 | 46 | 84 |
| 48 | MnCl ₂ | 5 | 21.57 | 193 | 0.09 | 98.9 | 8.72 | 7.95 | | |
| 48 | MnCl ₂ | 10 | 21.54 | 210 | 0.1 | 98.5 | 8.69 | 7.89 | | |
| 48 | MnCl ₂ | 20 | 21.42 | 249 | 0.12 | 98.8 | 8.73 | 7.79 | | |
| 48 | MnCl ₂ | 40 | 21.53 | 320 | 0.15 | 98.3 | 8.66 | 7.71 | | |
| 48 | MnCl ₂ | 80 | 21.59 | 475 | 0.23 | 98.5 | 8.68 | 7.62 | | |
| 48 | MnCl ₂ | 160 | 21.52 | 780 | 0.38 | 98.3 | 8.66 | 7.55 | | |
| 48 | MnSO ₄ | 0 | 21.71 | 170 | 0.08 | 98.2 | 8.63 | 8.01 | 42 | 50 |
| 48 | MnSO ₄ | 5 | 21.6 | 189 | 0.09 | 96.8 | 8.53 | 7.97 | | |
| 48 | MnSO ₄ | 10 | 21.56 | 206 | 0.1 | 97.4 | 8.59 | 7.9 | | |
| 48 | MnSO ₄ | 20 | 21.53 | 240 | 0.11 | 98 | 8.64 | 7.81 | | |
| 48 | MnSO ₄ | 40 | 21.61 | 305 | 0.15 | 98.1 | 8.63 | 7.72 | | |
| 48 | MnSO ₄ | 80 | 21.63 | 421 | 0.2 | 97.4 | 8.57 | 7.65 | | |
| 48 | MnSO ₄ | 160 | 21.73 | 646 | 0.31 | 97.8 | 8.58 | 7.58 | | |
| 48 | MnCl ₂ | 0 | 21.68 | 168 | 0.08 | 97.8 | 8.6 | 8.08 | 44 | 50 |
| 48 | MnCl ₂ | 5 | 21.86 | 186 | 0.09 | 97.3 | 8.53 | 8.01 | | |
| 48 | MnCl ₂ | 10 | 21.71 | 207 | 0.1 | 97.8 | 8.6 | 7.93 | | |
| 48 | MnCl ₂ | 20 | 21.73 | 246 | 0.12 | 97.6 | 8.57 | 7.83 | | |
| 48 | MnCl ₂ | 40 | 21.69 | 323 | 0.15 | 96.6 | 8.49 | 7.72 | | |
| 48 | MnCl ₂ | 80 | 21.74 | 475 | 0.23 | 97.1 | 8.52 | 7.61 | | |
| 48 | MnCl ₂ | 160 | 21.78 | 775 | 0.38 | 97 | 8.5 | 7.51 | | |
| 48 | MnSO ₄ | 0 | 21.8 | 168 | 0.08 | 98.3 | 8.63 | 8.14 | 44 | 50 |
| 48 | MnSO ₄ | 5 | 21.94 | 183 | 0.09 | 97.7 | 8.55 | 8.06 | | |
| 48 | MnSO ₄ | 10 | 21.81 | 204 | 0.1 | 97.7 | 8.57 | 7.96 | | |
| 48 | MnSO ₄ | 20 | 21.84 | 235 | 0.11 | 97.7 | 8.56 | 7.87 | | |
| 48 | MnSO ₄ | 40 | 21.8 | 298 | 0.14 | 96.7 | 8.49 | 7.75 | | |

Table 12 continued

| | | | | | | | | | | |
|----|-------------------|-----|-------|-----|------|-------|------|------|----|----|
| 48 | MnSO ₄ | 80 | 21.71 | 416 | 0.2 | 96.3 | 8.46 | 7.66 | | |
| 48 | MnSO ₄ | 160 | 21.76 | 632 | 0.31 | 97.3 | 8.53 | 7.57 | | |
| 96 | MnCl ₂ | 0 | 21.72 | 177 | 0.08 | 96.8 | 8.51 | 8.04 | 52 | 44 |
| 96 | MnCl ₂ | 5 | 21.64 | 190 | 0.09 | 96.7 | 8.5 | 7.99 | | |
| 96 | MnCl ₂ | 10 | 21.65 | 210 | 0.1 | 96.5 | 8.49 | 7.89 | | |
| 96 | MnCl ₂ | 20 | 21.67 | 248 | 0.12 | 97.1 | 8.54 | 7.76 | | |
| 96 | MnCl ₂ | 40 | 21.71 | 326 | 0.16 | 96.9 | 8.52 | 7.65 | | |
| 96 | MnCl ₂ | 80 | 21.73 | 479 | 0.23 | 96.1 | 8.43 | 7.55 | | |
| 96 | MnCl ₂ | 160 | 21.73 | 777 | 0.38 | 96.8 | 8.49 | 7.47 | | |
| 96 | MnSO ₄ | 0 | 21.73 | 183 | 0.09 | 96.4 | 8.47 | 7.92 | 50 | 56 |
| 96 | MnSO ₄ | 5 | 21.71 | 187 | 0.09 | 96.5 | 8.48 | 7.89 | | |
| 96 | MnSO ₄ | 10 | 21.68 | 206 | 0.1 | 96.3 | 8.47 | 7.83 | | |
| 96 | MnSO ₄ | 20 | 21.8 | 236 | 0.11 | 96 | 8.42 | 7.75 | | |
| 96 | MnSO ₄ | 40 | 21.79 | 300 | 0.14 | 96 | 8.42 | 7.66 | | |
| 96 | MnSO ₄ | 80 | 21.78 | 418 | 0.2 | 96.4 | 8.46 | 7.58 | | |
| 96 | MnSO ₄ | 160 | 21.81 | 635 | 0.31 | 102.3 | 8.94 | 7.51 | | |

Table 13. Water Chemistry data for *L. abrupta* juvenile acute toxicity tests

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 21.82 | 169 | 0.08 | 97.5 | 8.56 | 7.9 | 40 | 46 |
| 0 | MnCl ₂ | 5 | 21.79 | 190 | 0.09 | 97.8 | 8.58 | 7.82 | | |
| 0 | MnCl ₂ | 10 | 21.8 | 209 | 0.1 | 97.7 | 8.57 | 7.74 | | |
| 0 | MnCl ₂ | 20 | 21.81 | 246 | 0.12 | 97.3 | 8.53 | 7.64 | | |
| 0 | MnCl ₂ | 40 | 21.82 | 322 | 0.15 | 96.8 | 8.49 | 7.53 | | |
| 0 | MnCl ₂ | 80 | 21.81 | 479 | 0.23 | 97.4 | 8.54 | 7.45 | | |
| 0 | MnCl ₂ | 160 | 21.95 | 778 | 0.38 | 96.8 | 8.46 | 7.36 | | |
| 0 | MnSO ₄ | 0 | 21.79 | 179 | 0.08 | 97.2 | 8.53 | 7.68 | 52 | 50 |
| 0 | MnSO ₄ | 5 | 21.65 | 189 | 0.09 | 97.3 | 8.57 | 7.6 | | |
| 0 | MnSO ₄ | 10 | 21.66 | 208 | 0.1 | 97.5 | 8.58 | 7.54 | | |
| 0 | MnSO ₄ | 20 | 21.67 | 239 | 0.11 | 96.8 | 8.51 | 7.48 | | |
| 0 | MnSO ₄ | 40 | 21.81 | 304 | 0.14 | 97.6 | 8.56 | 7.43 | | |
| 0 | MnSO ₄ | 80 | 21.87 | 422 | 0.2 | 97.4 | 8.53 | 7.37 | | |
| 0 | MnSO ₄ | 160 | 21.95 | 642 | 0.31 | 97.2 | 8.49 | 7.32 | | |
| 48 | MnCl ₂ | 0 | 21.87 | 172 | 0.08 | 97.6 | 8.56 | 7.91 | 46 | 46 |
| 48 | MnCl ₂ | 5 | 21.86 | 191 | 0.09 | 96.9 | 8.49 | 7.84 | | |
| 48 | MnCl ₂ | 10 | 21.74 | 210 | 0.1 | 97.3 | 8.55 | 7.78 | | |
| 48 | MnCl ₂ | 20 | 21.76 | 249 | 0.12 | 97.6 | 8.57 | 7.7 | | |
| 48 | MnCl ₂ | 40 | 21.72 | 325 | 0.15 | 97.3 | 8.54 | 7.62 | | |
| 48 | MnCl ₂ | 80 | 21.64 | 485 | 0.23 | 97.2 | 8.55 | 7.55 | | |
| 48 | MnCl ₂ | 160 | 21.66 | 787 | 0.39 | 97.6 | 8.57 | 7.49 | | |
| 48 | MnSO ₄ | 0 | 21.82 | 174 | 0.08 | 97.7 | 8.57 | 7.55 | 44 | 46 |
| 48 | MnSO ₄ | 5 | 21.67 | 190 | 0.09 | 96.9 | 8.52 | 7.48 | | |
| 48 | MnSO ₄ | 10 | 21.55 | 209 | 0.1 | 97.5 | 8.59 | 7.45 | | |
| 48 | MnSO ₄ | 20 | 21.75 | 242 | 0.11 | 97.5 | 8.56 | 7.46 | | |
| 48 | MnSO ₄ | 40 | 21.77 | 306 | 0.15 | 97.5 | 8.56 | 7.45 | | |
| 48 | MnSO ₄ | 80 | 21.71 | 426 | 0.2 | 97.4 | 8.56 | 7.43 | | |
| 48 | MnSO ₄ | 160 | 21.66 | 651 | 0.32 | 97.2 | 8.54 | 7.41 | | |
| 48 | MnCl ₂ | 0 | 21.75 | 168 | 0.08 | 97.4 | 8.55 | 8.1 | 45 | 48 |
| 48 | MnCl ₂ | 5 | 21.94 | 185 | 0.09 | 97.4 | 8.52 | 8.02 | | |
| 48 | MnCl ₂ | 10 | 21.88 | 207 | 0.1 | 97.9 | 8.57 | 7.93 | | |
| 48 | MnCl ₂ | 20 | 21.91 | 245 | 0.12 | 96.5 | 8.45 | 7.83 | | |
| 48 | MnCl ₂ | 40 | 21.8 | 323 | 0.15 | 97.3 | 8.53 | 7.71 | | |
| 48 | MnCl ₂ | 80 | 21.77 | 476 | 0.23 | 97.2 | 8.53 | 7.6 | | |
| 48 | MnCl ₂ | 160 | 21.78 | 776 | 0.38 | 97.2 | 8.52 | 7.5 | | |
| 48 | MnSO ₄ | 0 | 21.44 | 168 | 0.08 | 97.8 | 8.64 | 8.16 | 44 | 44 |
| 48 | MnSO ₄ | 5 | 21.73 | 181 | 0.08 | 98 | 8.61 | 8.07 | | |
| 48 | MnSO ₄ | 10 | 21.64 | 202 | 0.1 | 97.5 | 8.58 | 7.96 | | |
| 48 | MnSO ₄ | 20 | 21.79 | 234 | 0.11 | 97.7 | 8.57 | 7.86 | | |
| 48 | MnSO ₄ | 40 | 21.75 | 300 | 0.14 | 96.8 | 8.5 | 7.75 | | |

Table 13 continued

| | | | | | | | | | | |
|----|-------------------|-----|-------|-----|------|------|------|------|----|----|
| 48 | MnSO ₄ | 80 | 21.68 | 426 | 0.2 | 96.6 | 8.49 | 7.64 | | |
| 48 | MnSO ₄ | 160 | 21.78 | 632 | 0.31 | 97.3 | 8.53 | 7.56 | | |
| 96 | MnCl ₂ | 0 | 21.93 | 186 | 0.09 | 95.8 | 8.39 | 7.51 | 34 | 54 |
| 96 | MnCl ₂ | 5 | 21.8 | 195 | 0.09 | 96 | 8.44 | 7.46 | | |
| 96 | MnCl ₂ | 10 | 21.78 | 211 | 0.1 | 95.9 | 8.42 | 7.49 | | |
| 96 | MnCl ₂ | 20 | 21.76 | 249 | 0.12 | 96.2 | 8.45 | 7.47 | | |
| 96 | MnCl ₂ | 40 | 21.72 | 328 | 0.16 | 96.1 | 8.44 | 7.44 | | |
| 96 | MnCl ₂ | 80 | 21.7 | 484 | 0.23 | 96 | 8.43 | 7.4 | | |
| 96 | MnCl ₂ | 160 | 21.73 | 783 | 0.38 | 95.2 | 8.35 | 7.38 | | |
| 96 | MnSO ₄ | 0 | 21.81 | 186 | 0.09 | 95.4 | 8.38 | 7.97 | 60 | 54 |
| 96 | MnSO ₄ | 5 | 21.72 | 188 | 0.09 | 95.5 | 8.39 | 7.93 | | |
| 96 | MnSO ₄ | 10 | 21.68 | 207 | 0.1 | 95.4 | 8.39 | 7.86 | | |
| 96 | MnSO ₄ | 20 | 21.66 | 238 | 0.11 | 95.6 | 8.4 | 7.77 | | |
| 96 | MnSO ₄ | 40 | 21.66 | 303 | 0.14 | 95.1 | 8.36 | 7.67 | | |
| 96 | MnSO ₄ | 80 | 21.68 | 430 | 0.21 | 95.1 | 8.36 | 7.58 | | |
| 96 | MnSO ₄ | 160 | 21.72 | 639 | 0.31 | 98.6 | 8.64 | 7.52 | | |

Table 14. Water Chemistry data for *V. troostensis* juvenile acute toxicity tests

| Time Point (hr) | Toxicant | Conc. Mn (mg/L) | Temp. (°C) | Conductivity (µS/cm) | Salinity (ppt) | DO (%) | DO (mg/L) | pH | Alkalinity (mg/L) | Hardness (mg/L) |
|-----------------|-------------------|-----------------|------------|----------------------|----------------|--------|-----------|------|-------------------|-----------------|
| 0 | MnCl ₂ | 0 | 22.22 | 163 | 0.08 | 97.2 | 8.46 | 7.74 | 38 | 50 |
| 0 | MnCl ₂ | 5 | 22.1 | 186 | 0.09 | 97.4 | 8.5 | 7.59 | | |
| 0 | MnCl ₂ | 10 | 22.07 | 205 | 0.1 | 97.1 | 8.48 | 7.52 | | |
| 0 | MnCl ₂ | 20 | 22.13 | 243 | 0.11 | 97.1 | 8.46 | 7.47 | | |
| 0 | MnCl ₂ | 40 | 22.15 | 316 | 0.15 | 97.1 | 8.46 | 7.42 | | |
| 0 | MnCl ₂ | 80 | 22.2 | 467 | 0.22 | 96.5 | 8.4 | 7.35 | | |
| 0 | MnCl ₂ | 160 | 22.27 | 773 | 0.38 | 96.6 | 8.39 | 7.28 | | |
| 0 | MnSO ₄ | 0 | 22.28 | 166 | 0.08 | 96.1 | 8.36 | 7.95 | 42 | 54 |
| 0 | MnSO ₄ | 5 | 22.15 | 185 | 0.09 | 96.5 | 8.41 | 7.87 | | |
| 0 | MnSO ₄ | 10 | 22.2 | 204 | 0.1 | 96.3 | 8.38 | 7.77 | | |
| 0 | MnSO ₄ | 20 | 22.28 | 238 | 0.11 | 96.2 | 8.36 | 7.68 | | |
| 0 | MnSO ₄ | 40 | 22.17 | 298 | 0.14 | 96 | 8.37 | 7.59 | | |
| 0 | MnSO ₄ | 80 | 22.18 | 417 | 0.2 | 95.6 | 8.33 | 7.5 | | |
| 0 | MnSO ₄ | 160 | 22.16 | 637 | 0.31 | 95.9 | 8.34 | 7.43 | | |
| 48 | MnCl ₂ | 0 | 22.09 | 221 | 0.13 | 99.7 | 8.7 | 8.08 | 44 | 64 |
| 48 | MnCl ₂ | 5 | 22 | 197 | 0.09 | 99.4 | 8.69 | 8 | | |
| 48 | MnCl ₂ | 10 | 21.96 | 210 | 0.1 | 99 | 8.65 | 7.91 | | |
| 48 | MnCl ₂ | 20 | 21.88 | 245 | 0.12 | 99.2 | 8.68 | 7.81 | | |
| 48 | MnCl ₂ | 40 | 21.84 | 318 | 0.15 | 98.2 | 8.6 | 7.7 | | |
| 48 | MnCl ₂ | 80 | 21.79 | 472 | 0.23 | 97.7 | 8.55 | 7.61 | | |
| 48 | MnCl ₂ | 160 | 21.91 | 778 | 0.38 | 98 | 8.56 | 7.54 | | |
| 48 | MnSO ₄ | 0 | 21.83 | 172 | 0.08 | 96.9 | 8.5 | 7.76 | 38 | 62 |
| 48 | MnSO ₄ | 5 | 21.65 | 186 | 0.09 | 97.3 | 8.57 | 7.67 | | |
| 48 | MnSO ₄ | 10 | 21.56 | 205 | 0.1 | 97.1 | 8.53 | 7.6 | | |
| 48 | MnSO ₄ | 20 | 21.6 | 239 | 0.11 | 97.1 | 8.55 | 7.54 | | |
| 48 | MnSO ₄ | 40 | 21.6 | 300 | 0.14 | 97.1 | 8.55 | 7.51 | | |
| 48 | MnSO ₄ | 80 | 21.61 | 421 | 0.2 | 96.6 | 8.5 | 7.49 | | |
| 48 | MnSO ₄ | 160 | 21.68 | 640 | 0.31 | 96 | 8.42 | 7.48 | | |
| 48 | MnCl ₂ | 0 | 20.99 | 165 | 0.08 | 98 | 8.74 | 7.93 | 34 | 48 |
| 48 | MnCl ₂ | 5 | 20.97 | 181 | 0.09 | 97.4 | 8.69 | 7.83 | | |
| 48 | MnCl ₂ | 10 | 20.92 | 202 | 0.1 | 96.6 | 8.62 | 7.75 | | |
| 48 | MnCl ₂ | 20 | 20.97 | 241 | 0.11 | 97.3 | 8.68 | 7.65 | | |
| 48 | MnCl ₂ | 40 | 21.03 | 315 | 0.15 | 97 | 8.63 | 7.58 | | |
| 48 | MnCl ₂ | 80 | 21.1 | 469 | 0.23 | 97 | 8.62 | 7.48 | | |
| 48 | MnCl ₂ | 160 | 21.26 | 765 | 0.37 | 96.8 | 8.57 | 7.42 | | |
| 48 | MnSO ₄ | 0 | 21.12 | 167 | 0.08 | 97.6 | 8.68 | 8.1 | 36 | 48 |
| 48 | MnSO ₄ | 5 | 21.19 | 179 | 0.08 | 96.7 | 8.59 | 7.99 | | |
| 48 | MnSO ₄ | 10 | 21.09 | 196 | 0.09 | 96.8 | 8.61 | 7.89 | | |
| 48 | MnSO ₄ | 20 | 21.17 | 229 | 0.11 | 96.7 | 8.59 | 7.79 | | |
| 48 | MnSO ₄ | 40 | 21.17 | 293 | 0.14 | 96.6 | 8.58 | 7.67 | | |

Table 14 continued

| | | | | | | | | | | |
|-----|-------------------|-----|-------|-----|------|------|------|------|----|----|
| 48 | MnSO ₄ | 80 | 21.18 | 414 | 0.2 | 96.7 | 8.57 | 7.57 | | |
| 48 | MnSO ₄ | 160 | 21.24 | 625 | 0.3 | 96.4 | 8.55 | 7.49 | | |
| 96 | MnCl ₂ | 0 | 21.3 | 165 | 0.08 | 96.3 | 8.53 | 7.94 | 34 | 52 |
| 96 | MnCl ₂ | 5 | 21.36 | 183 | 0.09 | 97.2 | 8.6 | 7.96 | | |
| 96 | MnCl ₂ | 10 | 21.64 | 202 | 0.1 | 97.5 | 8.58 | 7.88 | | |
| 96 | MnCl ₂ | 20 | 21.2 | 244 | 0.12 | 96.5 | 8.57 | 7.77 | | |
| 96 | MnCl ₂ | 40 | 21.33 | 320 | 0.15 | 96.7 | 8.56 | 7.66 | | |
| 96 | MnCl ₂ | 80 | 21.4 | 476 | 0.23 | 97 | 8.57 | 7.56 | | |
| 96 | MnCl ₂ | 160 | 21.5 | 777 | 0.38 | 96.2 | 8.48 | 7.51 | | |
| 96 | MnSO ₄ | 0 | 21.38 | 198 | 0.09 | 97.4 | 8.61 | 7.58 | 44 | 54 |
| 96 | MnSO ₄ | 5 | 21.4 | 182 | 0.09 | 96.6 | 8.54 | 7.52 | | |
| 96 | MnSO ₄ | 10 | 21.32 | 200 | 0.09 | 96.7 | 8.56 | 7.49 | | |
| 96 | MnSO ₄ | 20 | 21.37 | 232 | 0.11 | 96.8 | 8.57 | 7.44 | | |
| 96 | MnSO ₄ | 40 | 21.68 | 426 | 0.2 | 96.6 | 8.49 | 7.5 | | |
| 96 | MnSO ₄ | 80 | 21.41 | 421 | 0.2 | 96.7 | 8.54 | 7.46 | | |
| 96 | MnSO ₄ | 160 | 21.49 | 635 | 0.31 | 96.5 | 8.51 | 7.44 | | |
| 96 | MnCl ₂ | 0 | 21.6 | 165 | 0.08 | 97.7 | 8.61 | 7.99 | 34 | 52 |
| 96 | MnCl ₂ | 5 | 21.56 | 185 | 0.09 | 98 | 8.64 | 7.96 | | |
| 96 | MnCl ₂ | 10 | 21.52 | 210 | 0.1 | 97.9 | 8.64 | 7.89 | | |
| 96 | MnCl ₂ | 20 | 21.55 | 245 | 0.12 | 98.3 | 8.66 | 7.79 | | |
| 96 | MnCl ₂ | 40 | 21.56 | 317 | 0.15 | 98.4 | 8.67 | 7.67 | | |
| 96 | MnCl ₂ | 80 | 21.61 | 478 | 0.23 | 98.6 | 8.67 | 7.56 | | |
| 96 | MnCl ₂ | 160 | 21.63 | 777 | 0.38 | 98.2 | 8.63 | 7.47 | | |
| 96 | MnSO ₄ | 0 | 21.49 | 165 | 0.08 | 98.2 | 8.67 | 8.02 | 50 | 42 |
| 96 | MnSO ₄ | 5 | 21.3 | 183 | 0.09 | 97.9 | 8.67 | 7.97 | | |
| 96 | MnSO ₄ | 10 | 21.34 | 201 | 0.09 | 98.3 | 8.71 | 7.88 | | |
| 96 | MnSO ₄ | 20 | 21.4 | 234 | 0.11 | 98.2 | 8.68 | 7.78 | | |
| 96 | MnSO ₄ | 40 | 21.45 | 297 | 0.14 | 98.9 | 8.73 | 7.67 | | |
| 96 | MnSO ₄ | 80 | 21.48 | 421 | 0.2 | 98.3 | 8.67 | 7.56 | | |
| 96 | MnSO ₄ | 160 | 21.52 | 639 | 0.31 | 98.5 | 8.68 | 7.49 | | |
| 144 | MnCl ₂ | 0 | 21.88 | 164 | 0.08 | 93.9 | 8.23 | 8.02 | 36 | 46 |
| 144 | MnCl ₂ | 5 | 21.83 | 185 | 0.09 | 94.6 | 8.3 | 7.96 | | |
| 144 | MnCl ₂ | 10 | 21.82 | 211 | 0.1 | 94.9 | 8.32 | 7.86 | | |
| 144 | MnCl ₂ | 20 | 21.86 | 246 | 0.12 | 94.3 | 8.27 | 7.78 | | |
| 144 | MnCl ₂ | 40 | 21.83 | 318 | 0.15 | 96.3 | 8.44 | 7.68 | | |
| 144 | MnCl ₂ | 80 | 21.83 | 478 | 0.23 | 94.4 | 8.28 | 7.6 | | |
| 144 | MnCl ₂ | 160 | 21.86 | 780 | 0.38 | 93.2 | 8.15 | 7.53 | | |
| 144 | MnSO ₄ | 0 | 22.18 | 171 | 0.08 | 94.7 | 8.25 | 7.64 | 40 | 44 |
| 144 | MnSO ₄ | 5 | 21.99 | 185 | 0.09 | 92.8 | 8.12 | 7.58 | | |
| 144 | MnSO ₄ | 10 | 21.85 | 203 | 0.1 | 94.3 | 8.27 | 7.52 | | |
| 144 | MnSO ₄ | 20 | 21.84 | 237 | 0.11 | 94.6 | 8.29 | 7.55 | | |
| 144 | MnSO ₄ | 40 | 21.92 | 298 | 0.14 | 93.8 | 8.21 | 7.52 | | |
| 144 | MnSO ₄ | 80 | 22.07 | 422 | 0.2 | 94.2 | 8.21 | 7.49 | | |
| 144 | MnSO ₄ | 160 | 22.01 | 639 | 0.31 | 94.6 | 8.26 | 7.47 | | |
| 144 | MnCl ₂ | 0 | 21.95 | 168 | 0.08 | 98 | 8.57 | 7.83 | 40 | 38 |
| 144 | MnCl ₂ | 5 | 21.76 | 191 | 0.09 | 96.9 | 8.51 | 7.77 | | |
| 144 | MnCl ₂ | 10 | 21.75 | 210 | 0.1 | 97.6 | 8.57 | 7.67 | | |
| 144 | MnCl ₂ | 20 | 21.8 | 248 | 0.12 | 96.1 | 8.43 | 7.57 | | |

Table 14 continued

| | | | | | | | | | | |
|-----|-------------------|-----|-------|-----|------|------|------|------|----|----|
| 144 | MnCl ₂ | 40 | 21.74 | 323 | 0.15 | 96.7 | 8.49 | 7.48 | | |
| 144 | MnCl ₂ | 80 | 21.76 | 478 | 0.23 | 96.7 | 8.48 | 7.42 | | |
| 144 | MnCl ₂ | 160 | 21.82 | 776 | 0.38 | 96.2 | 8.42 | 7.33 | | |
| 144 | MnSO ₄ | 0 | 21.94 | 170 | 0.08 | 95.9 | 8.39 | 7.49 | 36 | 96 |
| 144 | MnSO ₄ | 5 | 21.84 | 188 | 0.09 | 96 | 8.42 | 7.42 | | |
| 144 | MnSO ₄ | 10 | 21.79 | 205 | 0.1 | 95.8 | 8.41 | 7.41 | | |
| 144 | MnSO ₄ | 20 | 21.78 | 240 | 0.11 | 95.8 | 8.41 | 7.35 | | |
| 144 | MnSO ₄ | 40 | 21.83 | 302 | 0.14 | 95.6 | 8.38 | 7.3 | | |
| 144 | MnSO ₄ | 80 | 21.83 | 428 | 0.21 | 95.5 | 8.37 | 7.28 | | |
| 144 | MnSO ₄ | 160 | 21.83 | 639 | 0.31 | 95.5 | 8.36 | 7.27 | | |
| 192 | MnCl ₂ | 0 | 22.16 | 201 | 0.09 | 93.9 | 8.18 | 7.49 | 48 | 44 |
| 192 | MnCl ₂ | 5 | 22.04 | 193 | 0.09 | 94.6 | 8.27 | 7.42 | | |
| 192 | MnCl ₂ | 10 | 21.99 | 211 | 0.1 | 94.7 | 8.28 | 7.36 | | |
| 192 | MnCl ₂ | 20 | 22.04 | 250 | 0.12 | 95 | 8.31 | 7.4 | | |
| 192 | MnCl ₂ | 40 | 22.07 | 327 | 0.16 | 94.4 | 8.23 | 7.49 | | |
| 192 | MnCl ₂ | 80 | 22.06 | 484 | 0.23 | 94.1 | 8.21 | 7.47 | | |
| 192 | MnCl ₂ | 160 | 22.06 | 780 | 0.38 | 94 | 8.2 | 7.39 | | |
| 192 | MnSO ₄ | 0 | 22.07 | 169 | 0.08 | 93.9 | 8.2 | 7.96 | 44 | 52 |
| 192 | MnSO ₄ | 5 | 22 | 188 | 0.09 | 94.8 | 8.29 | 7.92 | | |
| 192 | MnSO ₄ | 10 | 21.87 | 206 | 0.1 | 95 | 8.32 | 7.83 | | |
| 192 | MnSO ₄ | 20 | 21.91 | 240 | 0.11 | 95.2 | 8.34 | 7.72 | | |
| 192 | MnSO ₄ | 40 | 21.94 | 306 | 0.15 | 95.1 | 8.32 | 7.62 | | |
| 192 | MnSO ₄ | 80 | 21.94 | 431 | 0.21 | 95.2 | 8.33 | 7.52 | | |
| 192 | MnSO ₄ | 160 | 22.14 | 644 | 0.31 | 94.1 | 8.19 | 7.45 | | |

Appendix B

Table 1. Juvenile *L. cardium* metrics for chronic toxicity test

| Sample ID | Treatment (mg/L) | Length (mm) | Wet Weight Shell+Tissue(g) | Wet Weight Tissue(g) | Wet Weight Shell(g) |
|-----------|------------------|-------------|----------------------------|----------------------|---------------------|
| B-1 | Baseline | 21.99 | 1.5064 | 0.3685 | 0.937 |
| B-2 | Baseline | 23.64 | 1.7908 | 0.6715 | 0.8094 |
| B-3 | Baseline | 17.97 | 0.8043 | 0.2096 | 0.4168 |
| B-4 | Baseline | 16.37 | 0.6513 | 0.1926 | 0.3711 |
| B-5 | Baseline | 17.42 | 0.6109 | 0.1167 | 0.2629 |
| 7-0-1 | 0 | 21.18 | 1.2884 | 0.4127 | 0.588 |
| 7-0-2 | 0 | 17.51 | 0.7372 | 0.1923 | 0.4179 |
| 7-0-3 | 0 | 18.2 | 0.8079 | 0.2508 | 0.3287 |
| 7-0-4 | 0 | 20.52 | 1.2028 | 0.3521 | 0.6311 |
| 7-0-5 | 0 | 19.92 | 1.0656 | 0.3332 | 0.493 |
| 7-0-6 | 0 | 18.83 | 0.8527 | 0.2399 | 0.4816 |
| 7-2.5-1 | 2.5 | 26.2 | 2.5718 | 1.1079 | 1.0352 |
| 7-2.5-2 | 2.5 | 21.71 | 1.4573 | 0.4588 | 0.8902 |
| 7-2.5-3 | 2.5 | 21.68 | 1.425 | 0.5414 | 0.5569 |
| 7-2.5-4 | 2.5 | 18.51 | 0.8788 | 0.2623 | 0.5684 |
| 7-2.5-5 | 2.5 | 19.04 | 1.0844 | 0.3857 | 0.4928 |
| 7-2.5-6 | 2.5 | 22.77 | 1.2751 | 0.4172 | 0.7642 |
| 7-5-1 | 5 | 19.62 | 1.0284 | 0.3391 | 0.4301 |
| 7-5-2 | 5 | 21.59 | 1.5233 | 0.5341 | 0.7924 |
| 7-5-3 | 5 | 18.86 | 1.0888 | 0.3789 | 0.5166 |
| 7-5-4 | 5 | 17.31 | 0.8242 | 0.2268 | 0.4856 |
| 7-5-5 | 5 | 22.59 | 1.3842 | 0.4326 | 0.6071 |
| 7-5-6 | 5 | 20.06 | 1.0317 | 0.3886 | 0.588 |
| 7-10-1 | 10 | 24.97 | 2.1963 | 0.8444 | 0.9296 |
| 7-10-2 | 10 | 20.29 | 1.0956 | 0.2976 | 0.6577 |
| 7-10-3 | 10 | 21.95 | 1.5846 | 0.6295 | 0.6367 |
| 7-10-4 | 10 | 18.05 | 0.86 | 0.2304 | 0.5767 |
| 7-10-5 | 10 | 15.35 | 0.5413 | 0.1338 | 0.2718 |
| 7-10-6 | 10 | 21 | 1.2866 | 0.4263 | 0.6091 |
| 7-30-1 | 30 | 19.1 | 1.112 | 0.3314 | 0.552 |
| 7-30-2 | 30 | 19.21 | 1.9088 | 0.2751 | 0.5117 |
| 7-30-3 | 30 | 20.76 | 1.2887 | 0.3593 | 0.5134 |
| 7-30-4 | 30 | 22.24 | 1.6081 | 0.5219 | 0.7955 |
| 7-30-5 | 30 | 19.6 | 1.0109 | 0.2963 | 0.5793 |
| 7-30-6 | 30 | 18.08 | 0.8605 | 0.2555 | 0.4526 |
| 7-60-1 | 60 | 20.54 | 1.3456 | 0.4069 | 0.6843 |
| 7-60-2 | 60 | 21.72 | 1.4777 | 0.5643 | 0.7325 |
| 7-60-3 | 60 | 23.33 | 2.0259 | 0.6535 | 1.0135 |

Table 1 continued

| | | | | | |
|----------|-----|-------|--------|--------|--------|
| 7-60-4 | 60 | 24.63 | 2.4234 | 1.0069 | 0.8819 |
| 7-60-5 | 60 | 24.62 | 1.967 | 0.6543 | 1.0289 |
| 7-60-6 | 60 | 19.92 | 1.254 | 0.4362 | 0.5813 |
| 14-0-1 | 0 | 20.85 | 1.2874 | 0.4835 | 0.6203 |
| 14-0-2 | 0 | 20.84 | 1.4145 | 0.6315 | 0.7129 |
| 14-0-3 | 0 | 21.53 | 1.3244 | 0.5177 | 0.719 |
| 14-0-4 | 0 | 18.59 | 1.0451 | 0.33 | 0.6868 |
| 14-0-5 | 0 | 17.9 | 0.9246 | 0.3529 | 0.5232 |
| 14-0-6 | 0 | 20.65 | 1.0335 | 0.3602 | 0.61 |
| 14-2.5-1 | 2.5 | 19.56 | 1.1621 | 0.4497 | 0.4828 |
| 14-2.5-2 | 2.5 | 19.08 | 1.0768 | 0.4001 | 0.7023 |
| 14-2.5-3 | 2.5 | 20.11 | 1.16 | 0.45 | 0.591 |
| 14-2.5-4 | 2.5 | 15.32 | 0.6754 | 0.2585 | 0.4368 |
| 14-2.5-5 | 2.5 | 19.67 | 1.1308 | 0.433 | 0.6051 |
| 14-2.5-6 | 2.5 | 17.64 | 0.75 | 0.2626 | 0.457 |
| 14-5-1 | 5 | 20.11 | 1.2306 | 0.4895 | 0.6293 |
| 14-5-2 | 5 | 18.37 | 0.9177 | 0.3512 | 0.5619 |
| 14-5-3 | 5 | 18.18 | 0.9314 | 0.352 | 0.4385 |
| 14-5-4 | 5 | 19.45 | 1.286 | 0.4454 | 0.7762 |
| 14-5-5 | 5 | 22.33 | 1.7325 | 0.7344 | 0.7909 |
| 14-5-6 | 5 | 17.02 | 0.8174 | 0.2976 | 0.6061 |
| 14-10-1 | 10 | 20.15 | 1.3081 | 0.5655 | 0.585 |
| 14-10-2 | 10 | 21.96 | 1.2496 | 0.3975 | 0.5813 |
| 14-10-3 | 10 | 18.2 | 0.869 | 0.295 | 0.4794 |
| 14-10-4 | 10 | 20.79 | 1.2918 | 0.433 | 0.6231 |
| 14-10-5 | 10 | 20.38 | 1.0518 | 0.3512 | 0.5506 |
| 14-10-6 | 10 | 17.47 | 0.8301 | 0.3146 | 0.4486 |
| 14-30-1 | 30 | 21.47 | 1.5228 | 0.5098 | 0.7714 |
| 14-30-2 | 30 | 18.81 | 1.0066 | 0.3354 | 0.5313 |
| 14-30-3 | 30 | 18.3 | 0.9764 | 0.412 | 0.4407 |
| 14-30-4 | 30 | 14.65 | 0.4566 | 0.1414 | 0.3149 |
| 14-30-5 | 30 | 20.24 | 1.344 | 0.52 | 0.619 |
| 14-30-6 | 30 | 23.92 | 1.9435 | 0.7748 | 1.0108 |
| 14-60-1 | 60 | 17.04 | 0.9111 | 0.3562 | 0.5496 |
| 14-60-2 | 60 | 17.07 | 0.8196 | 0.3606 | 0.4147 |
| 14-60-3 | 60 | 19.3 | 1.0349 | 0.409 | 0.5143 |
| 14-60-4 | 60 | 19.2 | 1.09 | 0.4389 | 0.5586 |
| 14-60-5 | 60 | 17 | 0.7288 | 0.2715 | 0.4435 |
| 14-60-6 | 60 | 19.15 | 1.1418 | 0.4196 | 0.5775 |
| 28-0-1 | 0 | 21.47 | 1.5305 | 0.5581 | 0.955 |
| 28-0-2 | 0 | 20.46 | 1.2805 | 0.554 | 0.6276 |

Table 1 continued.

| | | | | | |
|----------|-----|-------|--------|--------|--------|
| 28-0-3 | 0 | 20.96 | 1.2335 | 0.4322 | 0.7092 |
| 28-0-4 | 0 | 16.14 | 0.6891 | 0.3082 | 0.3322 |
| 28-0-5 | 0 | 21.11 | 1.2642 | 0.4548 | 0.7318 |
| 28-0-6 | 0 | 18.32 | 1.0294 | 0.4095 | 0.5654 |
| 28-2.5-1 | 2.5 | 19.71 | 1.3117 | 0.399 | 0.7155 |
| 28-2.5-2 | 2.5 | 20.27 | 1.2571 | 0.5262 | 0.6456 |
| 28-2.5-3 | 2.5 | 18.8 | 1.0859 | 0.448 | 0.6624 |
| 28-2.5-4 | 2.5 | 18.09 | 0.8783 | 0.363 | 0.4782 |
| 28-2.5-5 | 2.5 | 15.82 | 0.6973 | 0.2847 | 0.4778 |
| 28-2.5-6 | 2.5 | 15.72 | 0.5988 | 0.1742 | 0.4479 |
| 28-5-1 | 5 | 21.91 | 1.4584 | 0.5607 | 0.7252 |
| 28-5-2 | 5 | 20.7 | 1.1325 | 0.36 | 0.6637 |
| 28-5-3 | 5 | 17.14 | 0.8084 | 0.285 | 0.4802 |
| 28-5-4 | 5 | 18.58 | 0.9409 | 0.3448 | 0.4772 |
| 28-5-5 | 5 | 16.31 | 0.7279 | 0.2301 | 0.5059 |
| 28-5-6 | 5 | 18.27 | 0.9808 | 0.4239 | 0.4995 |
| 28-10-1 | 10 | 20.49 | 1.1772 | 0.4192 | 0.6483 |
| 28-10-2 | 10 | 15.6 | 0.6696 | 0.3073 | 0.3532 |
| 28-10-3 | 10 | 17.63 | 0.8851 | 0.3301 | 0.5319 |
| 28-10-4 | 10 | 17.7 | 0.8435 | 0.3254 | 0.5483 |
| 28-10-5 | 10 | 17.26 | 0.867 | 0.3776 | 0.442 |
| 28-10-6 | 10 | 21.92 | 1.4565 | 0.5767 | 0.8367 |
| 28-30-1 | 30 | 19 | 1.0414 | 0.4027 | 0.6112 |
| 28-30-2 | 30 | 19.15 | 1.1232 | 0.474 | 0.5983 |
| 28-30-3 | 30 | 17.93 | 0.8631 | 0.3124 | 0.5151 |
| 28-30-4 | 30 | 23.83 | 2.0722 | 0.862 | 0.7983 |
| 28-30-5 | 30 | 18.75 | 1.1489 | 0.4009 | 0.6416 |
| 28-30-6 | 30 | 17.27 | 0.9031 | 0.3294 | 0.5659 |
| 28-60-1 | 60 | 17.4 | 0.992 | 0.4138 | 0.5494 |
| 28-60-2 | 60 | 16.81 | 0.8392 | 0.324 | 0.543 |
| 28-60-3 | 60 | 20.69 | 1.5558 | 0.7078 | 0.7307 |
| 28-60-4 | 60 | 20.15 | 1.3451 | 0.5454 | 0.7377 |
| 28-60-5 | 60 | 21.17 | 1.7452 | 0.8007 | 0.751 |
| 28-60-6 | 60 | 23.07 | 2.1178 | 0.7493 | 1.1738 |

Appendix C

Table 1. Chronic Mn toxicity test juvenile *L. cardium* tissue ion concentrations.

| Sample ID | Time point (day) | Conc. Mn (mg/L) | Sodium (ug) | Magnesium (ug) | Calcium (ug) | Potassium (ug) | Sulfur (ug) | Strontium (ug) | Phosphorus (ug) | Manganese (ug) |
|-----------|------------------|-----------------|-------------|----------------|--------------|----------------|-------------|----------------|-----------------|----------------|
| B-1 | 0 | 0 | 74.1 | 64.8 | 757.6 | 90.5 | 356.0 | 0.2 | 716.6 | 53.5 |
| 7-0-1 | 7 | 0 | 88.2 | 65.9 | 646.3 | 85.5 | 403.7 | 0.1 | 671.3 | 44.4 |
| 7-0-5 | 7 | 0 | 70.0 | 54.3 | 717.9 | 68.7 | 314.8 | 0.2 | 633.4 | 51.2 |
| 7-2.5-3 | 7 | 2.5 | 108.8 | 63.5 | 601.0 | 92.5 | 410.7 | 0.1 | 687.9 | 124.6 |
| 7-2.5-5 | 7 | 2.5 | 60.0 | 44.7 | 498.3 | 59.7 | 271.2 | 0.1 | 520.0 | 100.7 |
| 7-2.5-2 | 7 | 2.5 | 98.4 | 69.1 | 1022.3 | 105.6 | 430.5 | 0.2 | 895.9 | 154.5 |
| 7-5-4 | 7 | 5 | 51.1 | 35.3 | 431.5 | 44.5 | 213.8 | 0.1 | 437.9 | 107.6 |
| 7-5-2 | 7 | 5 | 112.9 | 69.9 | 743.8 | 89.5 | 415.6 | 0.2 | 809.3 | 231.0 |
| 7-10-2 | 7 | 10 | 77.5 | 49.1 | 602.9 | 57.4 | 296.9 | 0.2 | 597.7 | 210.8 |
| 7-10-5 | 7 | 10 | 32.4 | 26.0 | 248.0 | 33.6 | 166.7 | 0.1 | 311.9 | 91.2 |
| 7-10-6 | 7 | 10 | 98.3 | 54.7 | 635.7 | 71.7 | 358.7 | 0.2 | 682.9 | 246.1 |
| 7-10-3 | 7 | 10 | 92.6 | 64.4 | 779.9 | 82.3 | 422.2 | 0.2 | 824.5 | 244.9 |
| 7-30-3 | 7 | 30 | 73.3 | 48.1 | 545.6 | 54.4 | 293.9 | 0.2 | 607.0 | 231.9 |
| 7-30-4 | 7 | 30 | 99.7 | 64.8 | 739.0 | 80.0 | 407.5 | 0.2 | 798.6 | 282.9 |
| 7-30-5 | 7 | 30 | 52.4 | 37.0 | 350.5 | 47.4 | 243.1 | 0.1 | 450.7 | 182.3 |
| 7-60-4 | 7 | 60 | 128.8 | 100.5 | 1034.2 | 142.7 | 631.6 | 0.3 | 1183.3 | 389.4 |
| 7-60-3 | 7 | 60 | 113.0 | 75.6 | 901.2 | 100.9 | 471.4 | 0.3 | 954.0 | 399.4 |
| 7-60-6 | 7 | 60 | 57.4 | 38.5 | 571.2 | 39.3 | 256.8 | 0.2 | 539.8 | 205.9 |
| 14-0-5 | 14 | 0 | 50.0 | 42.5 | 545.7 | 51.1 | 244.0 | 0.1 | 481.0 | 29.7 |
| 14-0-4 | 14 | 0 | 52.9 | 39.5 | 494.0 | 47.7 | 239.7 | 0.1 | 450.2 | 28.0 |
| 14-0-3 | 14 | 0 | 87.0 | 54.6 | 700.6 | 63.9 | 343.1 | 0.2 | 640.1 | 45.3 |
| 14-0-2 | 14 | 0 | 126.9 | 64.2 | 887.7 | 78.0 | 392.7 | 0.2 | 753.6 | 56.2 |
| 14-0-1 | 14 | 0 | 87.8 | 48.6 | 683.9 | 59.7 | 308.7 | 0.1 | 586.1 | 41.8 |
| 14-0-6 | 14 | 0 | 73.7 | 47.3 | 527.2 | 66.8 | 285.5 | 0.1 | 524.0 | 32.5 |
| 14-5-3 | 14 | 5 | 52.6 | 27.7 | 336.5 | 25.3 | 180.4 | 0.1 | 354.6 | 122.1 |
| 14-5-2 | 14 | 5 | 68.0 | 39.0 | 474.3 | 51.6 | 244.0 | 0.1 | 467.1 | 129.0 |
| 14-5-1 | 14 | 5 | 100.2 | 58.8 | 645.4 | 76.9 | 370.6 | 0.2 | 693.8 | 210.6 |
| 14-5-6 | 14 | 5 | 50.3 | 34.4 | 329.0 | 42.5 | 208.1 | 0.1 | 402.5 | 135.2 |
| 14-5-5 | 14 | 5 | 141.9 | 70.0 | 867.0 | 99.4 | 447.2 | 0.2 | 886.5 | 306.7 |
| 14-5-4 | 14 | 5 | 92.7 | 61.0 | 642.5 | 75.3 | 339.1 | 0.2 | 660.2 | 179.0 |
| 14-10-2 | 14 | 10 | 88.0 | 53.8 | 586.0 | 69.3 | 318.0 | 0.1 | 652.0 | 304.6 |
| 14-10-1 | 14 | 10 | 102.9 | 50.2 | 522.3 | 58.4 | 317.3 | 0.1 | 602.1 | 266.9 |
| 14-10-6 | 14 | 10 | 47.7 | 31.4 | 283.8 | 36.2 | 190.4 | 0.1 | 363.5 | 154.6 |
| 14-10-5 | 14 | 10 | 66.4 | 38.7 | 490.2 | 45.8 | 252.5 | 0.1 | 505.9 | 220.4 |
| 14-10-4 | 14 | 10 | 98.8 | 54.5 | 601.8 | 74.3 | 342.0 | 0.1 | 681.3 | 301.3 |
| 14-10-3 | 14 | 10 | 66.2 | 41.7 | 500.4 | 53.3 | 257.2 | 0.1 | 533.4 | 237.3 |
| 14-25-4 | 14 | 25 | 39.2 | 25.7 | 295.7 | 30.4 | 164.6 | 0.1 | 313.4 | 62.5 |

Table 1 continued

| | | | | | | | | | | |
|----------|----|-----|-------|------|--------|------|-------|-----|-------|-------|
| 14-25-3 | 14 | 25 | 84.7 | 52.6 | 670.4 | 66.6 | 324.0 | 0.1 | 641.4 | 130.7 |
| 14-25-2 | 14 | 25 | 73.5 | 46.2 | 668.5 | 60.6 | 296.7 | 0.1 | 595.7 | 144.6 |
| 14-25-1 | 14 | 25 | 88.6 | 33.6 | 599.4 | 41.0 | 246.4 | 0.1 | 435.6 | 108.7 |
| 14-25-6 | 14 | 25 | 50.5 | 30.5 | 414.9 | 37.1 | 184.6 | 0.1 | 385.5 | 75.7 |
| 14-25-5 | 14 | 25 | 79.8 | 36.9 | 545.0 | 42.6 | 241.4 | 0.1 | 492.0 | 119.7 |
| 14-30-6 | 14 | 30 | 119.7 | 60.3 | 809.1 | 79.9 | 381.9 | 0.2 | 837.8 | 399.2 |
| 14-30-4 | 14 | 30 | 20.8 | 13.3 | 175.3 | 12.2 | 92.2 | 0.0 | 206.0 | 101.6 |
| 14-30-3 | 14 | 30 | 62.1 | 37.3 | 417.2 | 41.9 | 235.6 | 0.1 | 473.9 | 197.0 |
| 14-30-2 | 14 | 30 | 63.7 | 40.1 | 476.9 | 45.2 | 259.2 | 0.1 | 545.5 | 262.3 |
| 14-30-1 | 14 | 30 | 80.5 | 63.4 | 761.6 | 75.8 | 378.8 | 0.2 | 808.4 | 327.7 |
| 14-30-5 | 14 | 30 | 76.8 | 46.1 | 592.7 | 49.7 | 285.3 | 0.2 | 637.2 | 331.6 |
| 14-60.4 | 14 | 60 | 49.1 | 32.5 | 503.8 | 27.2 | 218.3 | 0.1 | 489.7 | 235.5 |
| 14-60-3 | 14 | 60 | 52.8 | 37.1 | 371.8 | 40.3 | 250.1 | 0.1 | 460.6 | 175.0 |
| 14-60-2 | 14 | 60 | 43.4 | 29.1 | 341.5 | 31.7 | 185.0 | 0.1 | 374.3 | 153.5 |
| 14-60-1 | 14 | 60 | 48.0 | 28.6 | 378.8 | 32.0 | 192.4 | 0.1 | 391.2 | 175.4 |
| 14-60-5 | 14 | 60 | 33.0 | 25.7 | 355.2 | 28.6 | 154.7 | 0.1 | 374.1 | 224.2 |
| 14-60-6 | 14 | 60 | 54.8 | 43.5 | 436.7 | 47.8 | 243.0 | 0.1 | 517.7 | 212.5 |
| 28-0-5 | 28 | 0 | 90.7 | 39.2 | 741.1 | 35.6 | 245.6 | 0.1 | 542.4 | 37.5 |
| 28-0-4 | 28 | 0 | 35.6 | 17.2 | 1489.8 | 14.6 | 123.0 | 0.2 | 244.1 | 21.9 |
| 28-0-3 | 28 | 0 | 88.2 | 43.6 | 689.1 | 45.2 | 282.5 | 0.1 | 567.4 | 41.4 |
| 28-0-2 | 28 | 0 | 72.4 | 51.0 | 752.0 | 46.6 | 300.3 | 0.2 | 607.1 | 46.2 |
| 28-0-1 | 28 | 0 | 124.2 | 69.6 | 801.0 | 79.3 | 402.0 | 0.1 | 738.6 | 49.6 |
| 28-0-6 | 28 | 0 | 57.1 | 37.8 | 554.2 | 38.3 | 222.0 | 0.1 | 452.0 | 28.4 |
| 28-2.5-4 | 28 | 2.5 | 34.7 | 21.5 | 360.3 | 15.2 | 129.1 | 0.1 | 307.3 | 97.2 |
| 28-2.5-3 | 28 | 2.5 | 73.8 | 33.0 | 621.1 | 34.3 | 225.2 | 0.1 | 515.5 | 184.6 |
| 28-2.5-2 | 28 | 2.5 | 91.2 | 41.9 | 598.6 | 42.1 | 259.2 | 0.1 | 554.5 | 191.3 |
| 28-2.5-1 | 28 | 2.5 | 75.3 | 41.3 | 606.7 | 46.2 | 263.8 | 0.1 | 537.3 | 150.9 |
| 28-2.5-6 | 28 | 2.5 | 30.8 | 15.2 | 329.9 | 13.5 | 97.3 | 0.1 | 263.4 | 93.6 |
| 28-2.5-5 | 28 | 2.5 | 26.5 | 20.5 | 265.5 | 18.4 | 118.7 | 0.1 | 259.5 | 63.8 |
| 28-5-3 | 28 | 5 | 44.9 | 30.4 | 427.5 | 29.5 | 179.0 | 0.1 | 415.5 | 210.3 |
| 28-5-2 | 28 | 5 | 68.7 | 39.7 | 568.1 | 41.5 | 240.1 | 0.1 | 532.7 | 212.0 |
| 28-5-1 | 28 | 5 | 94.9 | 53.1 | 802.9 | 55.5 | 324.2 | 0.2 | 750.4 | 349.6 |
| 28-5-6 | 28 | 5 | 59.6 | 35.5 | 501.7 | 33.5 | 212.4 | 0.1 | 491.9 | 221.7 |
| 28-5-5 | 28 | 5 | 40.1 | 25.6 | 329.9 | 30.1 | 159.0 | 0.1 | 349.9 | 157.6 |
| 28-5-4 | 28 | 5 | 59.3 | 31.5 | 514.2 | 31.8 | 202.2 | 0.1 | 466.8 | 201.2 |
| 28-10-2 | 28 | 10 | 34.8 | 19.5 | 254.3 | 15.6 | 120.1 | 0.1 | 276.1 | 174.2 |
| 28-10-1 | 28 | 10 | 74.9 | 34.4 | 462.9 | 34.4 | 236.6 | 0.1 | 510.1 | 269.3 |
| 28-10-6 | 28 | 10 | 86.5 | 56.7 | 631.4 | 57.2 | 337.3 | 0.2 | 696.3 | 351.8 |
| 28-10-5 | 28 | 10 | 50.0 | 23.2 | 378.7 | 19.2 | 151.2 | 0.1 | 367.3 | 221.1 |
| 28-10-4 | 28 | 10 | 55.0 | 37.0 | 518.4 | 41.4 | 227.6 | 0.1 | 521.8 | 258.6 |
| 28-10-3 | 28 | 10 | 61.8 | 33.8 | 356.1 | 33.3 | 192.3 | 0.1 | 409.5 | 208.9 |

Table 1 continued

| | | | | | | | | | | |
|---------|----|----|-------|------|-------|------|-------|-----|--------|-------|
| 28-30-3 | 28 | 30 | 50.4 | 25.7 | 329.9 | 24.9 | 171.4 | 0.1 | 370.3 | 205.8 |
| 28-30-2 | 28 | 30 | 73.1 | 39.8 | 535.0 | 38.8 | 236.9 | 0.1 | 548.6 | 322.0 |
| 28-30-1 | 28 | 30 | 68.1 | 29.6 | 504.3 | 25.7 | 204.2 | 0.1 | 494.5 | 339.0 |
| 28-30-6 | 28 | 30 | 42.1 | 30.8 | 358.7 | 30.9 | 182.9 | 0.1 | 401.0 | 233.5 |
| 28-30-5 | 28 | 30 | 52.6 | 30.6 | 417.3 | 28.1 | 189.5 | 0.1 | 467.1 | 296.8 |
| 28-30-4 | 28 | 30 | 171.3 | 55.6 | 843.7 | 59.7 | 406.5 | 0.2 | 887.4 | 491.1 |
| 28-60-2 | 28 | 60 | 38.0 | 23.0 | 321.3 | 20.3 | 144.7 | 0.1 | 338.9 | 176.2 |
| 28-60-1 | 28 | 60 | 84.1 | 49.1 | 572.8 | 53.2 | 306.7 | 0.2 | 646.1 | 304.8 |
| 28-60-6 | 28 | 60 | 129.3 | 71.8 | 971.0 | 87.4 | 499.7 | 0.3 | 1010.4 | 500.4 |
| 28-60-5 | 28 | 60 | 100.7 | 53.9 | 688.6 | 55.4 | 362.0 | 0.2 | 728.4 | 319.5 |
| 28-60-4 | 28 | 60 | 82.1 | 45.1 | 498.9 | 49.0 | 289.6 | 0.1 | 591.1 | 275.2 |
| 28-60-3 | 28 | 60 | 87.1 | 39.5 | 663.3 | 32.2 | 268.2 | 0.2 | 639.5 | 360.0 |

Appendix D

Table 1. Nominal and measured concentrations (mg/L) of manganese in acute tests.
 G: Glochidia, J: Juvenile

| Species | Life Stage | Toxicant | Time Point (hr) | Conc. Mn (mg/L) | Mn Actual (mg/L) | % Recovery |
|-----------------------|-------------------|-------------------|------------------------|------------------------|-------------------------|-------------------|
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 0 | 0.00 | ---- |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 0 | 0.01 | ---- |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 0 | 0.07 | ---- |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 0 | 0.00 | ---- |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 0 | 0.03 | ---- |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 0 | 0.06 | ---- |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 0 | 0.19 | ---- |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 0 | 0.03 | ---- |
| <i>L. abrubta</i> | J | MnCl ₂ | 0 | 0 | 0.35 | ---- |
| <i>L. abrubta</i> | J | MnCl ₂ | 0 | 0 | 0.47 | ---- |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 0 | 0.16 | ---- |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 0 | 0.07 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 0 | 0.04 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 0 | 0.01 | ---- |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 5 | 4.75 | 95.00 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 5 | 5.06 | 101.20 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 5 | 4.78 | 95.60 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 5 | 4.96 | 99.20 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 5 | 4.23 | 84.53 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 5 | 5.16 | 103.20 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 5 | 5.22 | 104.33 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 5 | 4.06 | 81.15 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 5 | 4.63 | 92.61 |
| <i>L. abrubta</i> | J | MnCl ₂ | 0 | 5 | 5.17 | 103.48 |
| <i>L. abrubta</i> | J | MnCl ₂ | 0 | 5 | 5.30 | 106.10 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 5 | 5.82 | 116.48 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 5 | 5.48 | 109.60 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 5 | 5.54 | 110.80 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 10 | 9.79 | 97.90 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 10 | 10.67 | 106.70 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 10 | 9.45 | 94.50 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 10 | 9.82 | 98.20 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 10 | 9.46 | 94.64 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 10 | 9.92 | 99.20 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|---|----|-------|--------|
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 10 | 10.26 | 102.58 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 10 | 11.01 | 110.15 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 10 | 8.01 | 80.08 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 10 | 9.19 | 91.92 |
| <i>L. abruchta</i> | J | MnCl ₂ | 0 | 10 | 11.42 | 114.21 |
| <i>L. abruchta</i> | J | MnCl ₂ | 0 | 10 | 11.55 | 115.51 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 10 | 9.58 | 95.80 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 10 | 10.10 | 101.00 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 20 | 19.09 | 95.45 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 20 | 19.22 | 96.10 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 20 | 18.67 | 93.35 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 20 | 19.05 | 95.25 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 20 | 16.60 | 83.00 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 20 | 17.47 | 87.35 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 20 | 19.81 | 99.05 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 20 | 20.46 | 102.30 |
| <i>L. abruchta</i> | J | MnCl ₂ | 0 | 20 | 16.45 | 82.25 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 20 | 17.24 | 86.18 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 20 | 18.23 | 91.14 |
| <i>L. abruchta</i> | J | MnCl ₂ | 0 | 20 | 21.18 | 105.90 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 20 | 19.30 | 96.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 20 | 19.50 | 97.50 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 40 | 38.24 | 95.60 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 40 | 33.32 | 83.30 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 40 | 37.72 | 94.30 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 40 | 37.96 | 94.90 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 40 | 34.32 | 85.80 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 40 | 35.99 | 89.97 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 40 | 37.83 | 94.58 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 40 | 38.34 | 95.84 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 40 | 32.01 | 80.03 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 40 | 33.38 | 83.45 |
| <i>L. abruchta</i> | J | MnCl ₂ | 0 | 40 | 35.64 | 89.09 |
| <i>L. abruchta</i> | J | MnCl ₂ | 0 | 40 | 40.35 | 100.87 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 40 | 37.20 | 93.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 40 | 38.00 | 95.00 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 80 | 72.44 | 90.55 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 80 | 73.41 | 91.76 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 80 | 75.84 | 94.80 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 80 | 80.55 | 100.68 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 80 | 66.91 | 83.64 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|----------|------------|-------------|--------|
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 80 | 74.33 | 92.91 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 80 | 74.88 | 93.61 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 80 | 80.54 | 100.67 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 80 | 67.11 | 83.88 |
| <i>L. abrubta</i> | J | MnCl ₂ | 0 | 80 | 67.80 | 84.75 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 80 | 69.02 | 86.27 |
| <i>L. abrubta</i> | J | MnCl ₂ | 0 | 80 | 78.21 | 97.76 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 80 | 73.70 | 92.13 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 80 | 74.30 | 92.88 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 160 | 154.55 | 96.59 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 0 | 160 | 158.20 | 98.88 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 160 | 151.85 | 94.91 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 0 | 160 | 153.33 | 95.83 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 160 | 137.39 | 85.87 |
| <i>E. triquetra</i> | G | MnCl ₂ | 0 | 160 | 146.90 | 91.81 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 160 | 152.37 | 95.23 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 0 | 160 | 158.86 | 99.29 |
| <i>L. abrubta</i> | J | MnCl ₂ | 0 | 160 | 131.19 | 81.99 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 160 | 131.40 | 82.12 |
| <i>L. abrubta</i> | J | MnCl ₂ | 0 | 160 | 144.77 | 90.48 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 0 | 160 | 150.42 | 94.01 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 160 | 148.00 | 92.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 0 | 160 | 149.00 | 93.13 |
| Stock | | MnCl ₂ | 0 | 360 | 356.60 | 99.06 |
| Stock | | MnCl ₂ | 0 | 360 | 355.15 | 98.65 |
| Stock | | MnCl ₂ | 0 | 360 | 362.10 | 100.58 |
| Stock | | MnCl ₂ | 0 | 360 | 356.05 | 98.90 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 0 | 0.31 | ---- |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 0 | 0.02 | ---- |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 0 | 0.12 | ---- |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 0 | 0.44 | ---- |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 0 | 0.10 | ---- |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 0 | 0.27 | ---- |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 5 | 4.84 | 96.80 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 5 | 5.01 | 100.20 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 5 | 4.12 | 82.48 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 5 | 4.22 | 84.39 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 5 | 4.25 | 85.06 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 5 | 4.50 | 89.95 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 10 | 9.66 | 96.60 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 10 | 9.80 | 98.00 |

Table 1 continued

| | | | | | | |
|----------------------|---|-------------------|----|-----|--------|--------|
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 10 | 9.45 | 94.46 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 10 | 10.03 | 100.35 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 10 | 11.32 | 113.18 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 10 | 9.48 | 94.82 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 20 | 19.03 | 95.15 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 20 | 19.32 | 96.60 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 20 | 16.98 | 84.90 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 20 | 17.60 | 88.00 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 20 | 17.75 | 88.75 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 20 | 19.44 | 97.20 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 40 | 36.85 | 92.13 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 40 | 37.49 | 93.73 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 40 | 32.68 | 81.69 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 40 | 32.96 | 82.41 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 40 | 37.05 | 92.63 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 40 | 38.83 | 97.06 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 80 | 68.28 | 85.35 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 80 | 80.33 | 100.41 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 80 | 64.26 | 80.33 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 80 | 72.88 | 91.10 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 80 | 76.89 | 96.12 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 80 | 79.38 | 99.22 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 160 | 153.55 | 95.97 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 24 | 160 | 154.68 | 96.68 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 160 | 129.25 | 80.78 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 160 | 136.37 | 85.23 |
| <i>E. triquetra</i> | G | MnCl ₂ | 24 | 160 | 138.87 | 86.79 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 24 | 160 | 149.70 | 93.56 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 0 | 0.01 | ---- |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 0 | 0.01 | ---- |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 0 | 0.07 | ---- |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 0 | 0.01 | ---- |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 0 | 0.02 | ---- |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 0 | 0.17 | ---- |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 0 | 0.00 | ---- |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 0 | 0.20 | ---- |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 0 | 0.28 | ---- |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 0 | 0.02 | ---- |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 0 | 0.15 | ---- |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 0 | 0.18 | ---- |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 0 | 0.37 | ---- |

Table 1 continued.

| | | | | | | |
|-----------------------------|----------|-------------------|-----------|-----------|-------------|--------|
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 0 | 0.13 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 0 | 0.06 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 0 | 0.01 | ---- |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 5 | 4.01 | 80.20 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 5 | 4.97 | 99.40 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 5 | 4.55 | 91.00 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 5 | 4.91 | 98.20 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 5 | 4.66 | 93.15 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 5 | 4.67 | 93.31 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 5 | 4.95 | 99.00 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 5 | 5.01 | 100.30 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 5 | 5.14 | 102.86 |
| <i>L. aubruba</i> | J | MnCl ₂ | 48 | 5 | 4.45 | 88.93 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 5 | 4.90 | 98.00 |
| <i>L. aubruba</i> | J | MnCl ₂ | 48 | 5 | 4.94 | 98.80 |
| <i>L. aubruba</i> | J | MnCl ₂ | 48 | 5 | 5.17 | 103.41 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 5 | 5.89 | 117.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 5 | 5.48 | 109.60 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 5 | 5.51 | 110.20 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 10 | 9.59 | 95.90 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 10 | 9.60 | 96.00 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 10 | 9.36 | 93.60 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 10 | 9.65 | 96.50 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 10 | 8.40 | 84.00 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 10 | 8.71 | 87.10 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 10 | 9.35 | 93.50 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 10 | 11.03 | 110.28 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 10 | 11.30 | 113.00 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 10 | 11.31 | 113.07 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 10 | 9.17 | 91.68 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 10 | 8.48 | 84.76 |
| <i>L. aubruba</i> | J | MnCl ₂ | 48 | 10 | 8.85 | 88.49 |
| <i>L. aubruba</i> | J | MnCl ₂ | 48 | 10 | 9.30 | 92.99 |
| <i>L. aubruba</i> | J | MnCl ₂ | 48 | 10 | 9.34 | 93.40 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 10 | 11.66 | 116.61 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 10 | 9.45 | 94.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 10 | 10.00 | 100.00 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 20 | 19.35 | 96.75 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 20 | 19.37 | 96.85 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 20 | 19.00 | 95.00 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 20 | 19.23 | 96.15 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|----|----|-------|--------|
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 20 | 16.51 | 82.55 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 20 | 18.75 | 93.75 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 20 | 17.08 | 85.40 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 20 | 18.60 | 93.00 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 20 | 20.58 | 102.90 |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 20 | 16.27 | 81.36 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 20 | 17.46 | 87.28 |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 20 | 19.20 | 96.00 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 20 | 19.57 | 97.84 |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 20 | 19.66 | 98.30 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 20 | 19.40 | 97.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 20 | 19.70 | 98.50 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 40 | 37.10 | 92.75 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 40 | 37.72 | 94.30 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 40 | 37.96 | 94.90 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 40 | 38.22 | 95.55 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 40 | 36.50 | 91.25 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 40 | 36.79 | 91.98 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 40 | 39.25 | 98.14 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 40 | 39.37 | 98.42 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 40 | 39.65 | 99.13 |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 40 | 34.09 | 85.23 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 40 | 35.10 | 87.75 |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 40 | 37.80 | 94.50 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 40 | 39.45 | 98.62 |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 40 | 39.58 | 98.94 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 40 | 37.70 | 94.25 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 40 | 37.90 | 94.75 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 80 | 72.99 | 91.24 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 80 | 75.46 | 94.32 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 80 | 70.30 | 87.88 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 80 | 76.00 | 95.01 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 80 | 67.09 | 83.86 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 80 | 68.38 | 85.47 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 80 | 68.61 | 85.77 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 80 | 74.80 | 93.50 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 80 | 75.51 | 94.39 |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 80 | 65.22 | 81.53 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 80 | 74.88 | 93.60 |
| <i>L. abrubta</i> | J | MnCl ₂ | 48 | 80 | 74.90 | 93.63 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|------|-----|--------|--------|
| <i>L. abruchta</i> | J | MnCl ₂ | 48 | 80 | 77.34 | 96.68 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 80 | 80.46 | 100.58 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 80 | 74.40 | 93.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 80 | 74.80 | 93.50 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 160 | 154.34 | 96.46 |
| <i>U. imbecillis</i> | G | MnCl ₂ | 48 | 160 | 154.94 | 96.84 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 160 | 154.28 | 96.43 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48 | 160 | 155.94 | 97.46 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 160 | 129.71 | 81.07 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 160 | 135.03 | 84.40 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 160 | 139.94 | 87.46 |
| <i>O. subrotunda</i> | G | MnCl ₂ | 48 | 160 | 151.40 | 94.63 |
| <i>E. triquetra</i> | G | MnCl ₂ | 48 | 160 | 160.17 | 100.11 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 160 | 128.13 | 80.08 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48 | 160 | 141.12 | 88.20 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48 | 160 | 149.16 | 93.23 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48 | 160 | 150.00 | 93.75 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48 | 160 | 154.48 | 96.55 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 160 | 149.00 | 93.13 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48 | 160 | 151.00 | 94.38 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 0 | 0.04 | ---- |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 0 | 0.00 | ---- |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 0 | 0.04 | ---- |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 0 | 0.34 | ---- |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 0 | 0.14 | ---- |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 0 | 0.42 | ---- |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 0 | 0.49 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 0 | 0.05 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 0 | 0.00 | ---- |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 5 | 4.81 | 96.20 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 5 | 5.05 | 101.00 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 5 | 4.73 | 94.62 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 5 | 4.86 | 97.24 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 5 | 4.95 | 99.00 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 5 | 5.05 | 100.92 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 5 | 5.83 | 116.67 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 5 | 4.62 | 92.40 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 5 | 4.87 | 97.40 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 10 | 9.43 | 94.30 |

Table 1 continued.

| | | | | | | |
|-----------------------|---|-------------------|------|-----|--------|--------|
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 10 | 9.64 | 96.40 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 10 | 8.63 | 86.29 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 10 | 8.96 | 89.63 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 10 | 9.29 | 92.91 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 10 | 9.46 | 94.62 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 10 | 9.53 | 95.30 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 10 | 9.38 | 93.80 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 10 | 9.52 | 95.20 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 20 | 19.08 | 95.40 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 20 | 19.13 | 95.65 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 20 | 17.96 | 89.80 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 20 | 19.40 | 97.00 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 20 | 20.04 | 100.20 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 20 | 20.96 | 104.78 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 20 | 21.10 | 105.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 20 | 18.70 | 93.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 20 | 19.10 | 95.50 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 40 | 38.89 | 97.23 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 40 | 45.71 | 114.28 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 40 | 34.31 | 85.78 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 40 | 35.16 | 87.90 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 40 | 36.49 | 91.22 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 40 | 38.10 | 95.25 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 40 | 40.29 | 100.73 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 40 | 36.80 | 92.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 40 | 37.20 | 93.00 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 80 | 70.05 | 87.56 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 80 | 75.75 | 94.69 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 80 | 64.83 | 81.04 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 80 | 68.37 | 85.47 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 80 | 75.00 | 93.75 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 80 | 76.94 | 96.18 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 80 | 77.49 | 96.86 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 80 | 73.40 | 91.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 80 | 75.30 | 94.13 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 160 | 150.86 | 94.29 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 48.2 | 160 | 152.26 | 95.16 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 160 | 131.23 | 82.02 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 160 | 131.90 | 82.44 |
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 160 | 143.05 | 89.40 |

Table 1 continued.

| | | | | | | |
|-----------------------|---|-------------------|-------------|------------|--------------|--------|
| <i>L. abruchta</i> | J | MnCl ₂ | 48.2 | 160 | 148.00 | 92.50 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 48.2 | 160 | 155.68 | 97.30 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 160 | 147.00 | 91.88 |
| <i>V. troostensis</i> | J | MnCl ₂ | 48.2 | 160 | 148.00 | 92.50 |
| Stock | | MnCl ₂ | 48.2 | 360 | 353.79 | 98.28 |
| Stock | | MnCl ₂ | 48.2 | 360 | 354.34 | 98.43 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 0 | 0.08 | ---- |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 0 | 0.00 | ---- |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 0 | 0.13 | ---- |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 0 | 0.03 | ---- |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 0 | 0.50 | ---- |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 0 | 0.04 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 0 | 0.36 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 0 | 0.16 | ---- |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 5 | 4.93 | 98.60 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 5 | 5.05 | 101.00 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 5 | 4.43 | 88.56 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 5 | 4.57 | 91.34 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 5 | 4.95 | 99.05 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 5 | 6.23 | 124.68 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 5 | 4.58 | 91.60 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 5 | 4.93 | 98.60 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 10 | 9.44 | 94.40 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 10 | 9.54 | 95.40 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 10 | 8.89 | 88.86 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 10 | 9.68 | 96.78 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 10 | 10.22 | 102.24 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 10 | 10.40 | 104.02 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 10 | 9.40 | 94.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 10 | 9.58 | 95.80 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 20 | 18.74 | 93.70 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 20 | 19.39 | 96.95 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 20 | 16.69 | 83.47 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 20 | 18.93 | 94.65 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 20 | 20.10 | 100.51 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 20 | 23.75 | 118.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 20 | 18.60 | 93.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 20 | 19.20 | 96.00 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 40 | 39.61 | 99.03 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 40 | 45.77 | 114.43 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 40 | 37.01 | 92.53 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|------|-----|--------|--------|
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 40 | 37.53 | 93.83 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 40 | 38.02 | 95.06 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 40 | 39.02 | 97.54 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 40 | 36.70 | 91.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 40 | 37.40 | 93.50 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 80 | 70.89 | 88.61 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 80 | 78.80 | 98.50 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 80 | 65.17 | 81.46 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 80 | 71.44 | 89.30 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 80 | 74.60 | 93.25 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 80 | 77.75 | 97.19 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 80 | 73.50 | 91.88 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 80 | 74.80 | 93.50 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 160 | 152.07 | 95.04 |
| <i>O. pectorosa</i> | J | MnCl ₂ | 96 | 160 | 159.82 | 99.89 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 160 | 129.55 | 80.97 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 160 | 130.14 | 81.33 |
| <i>U. imbecillis</i> | J | MnCl ₂ | 96 | 160 | 148.58 | 92.86 |
| <i>L. abruchta</i> | J | MnCl ₂ | 96 | 160 | 149.88 | 93.68 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 160 | 148.00 | 92.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96 | 160 | 149.00 | 93.13 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 0 | 0.66 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 0 | 0.25 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 5 | 4.68 | 93.60 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 5 | 5.00 | 100.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 10 | 9.51 | 95.10 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 10 | 10.00 | 100.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 20 | 18.60 | 93.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 20 | 18.80 | 94.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 40 | 37.30 | 93.25 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 40 | 37.40 | 93.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 80 | 75.00 | 93.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 80 | 75.40 | 94.25 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 160 | 149.00 | 93.13 |
| <i>V. troostensis</i> | J | MnCl ₂ | 96.2 | 160 | 149.00 | 93.13 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 0 | 0.22 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 0 | 0.05 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 5 | 4.83 | 96.60 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 5 | 4.72 | 94.40 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|-------|-----|--------|--------|
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 10 | 9.66 | 96.60 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 10 | 10.10 | 101.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 20 | 16.40 | 82.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 20 | 19.92 | 99.60 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 40 | 37.10 | 92.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 40 | 38.00 | 95.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 80 | 76.20 | 95.25 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 80 | 77.00 | 96.25 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 160 | 150.00 | 93.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144 | 160 | 150.00 | 93.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144.2 | 0 | 0.58 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 144.2 | 5 | 5.00 | 100.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144.2 | 10 | 9.98 | 99.80 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144.2 | 20 | 19.30 | 96.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144.2 | 40 | 37.10 | 92.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144.2 | 80 | 75.60 | 94.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 144.2 | 160 | 148.00 | 92.50 |
| <i>V. troostensis</i> | J | MnCl ₂ | 192 | 0 | 0.29 | ---- |
| <i>V. troostensis</i> | J | MnCl ₂ | 192 | 5 | 5.17 | 103.40 |
| <i>V. troostensis</i> | J | MnCl ₂ | 192 | 10 | 9.84 | 98.40 |
| <i>V. troostensis</i> | J | MnCl ₂ | 192 | 20 | 18.80 | 94.00 |
| <i>V. troostensis</i> | J | MnCl ₂ | 192 | 40 | 37.50 | 93.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 192 | 80 | 75.80 | 94.75 |
| <i>V. troostensis</i> | J | MnCl ₂ | 192 | 160 | 148.00 | 92.50 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 0 | 0.01 | ---- |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 0 | 0.02 | ---- |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 0 | 0.00 | ---- |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 0 | 0.04 | ---- |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 0 | 0.18 | ---- |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 0 | 0.01 | ---- |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 0 | 0.23 | ---- |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 0 | 0.18 | ---- |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 0 | 0.21 | ---- |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 0 | 0.47 | ---- |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 0 | 0.24 | ---- |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 0 | 0.05 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 0 | 0.01 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 0 | 0.04 | ---- |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 5 | 4.69 | 93.80 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|---|----|--------------|--------|
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 5 | 4.63 | 92.60 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 5 | 4.63 | 92.60 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 5 | 4.59 | 91.80 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 5 | 4.26 | 85.18 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 5 | 4.45 | 89.02 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 5 | 4.46 | 89.12 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 5 | 5.33 | 106.52 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 5 | 4.04 | 80.85 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 5 | 4.17 | 83.44 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 5 | 4.70 | 94.10 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 5 | 5.01 | 100.22 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 5 | 5.32 | 106.40 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 5 | 5.47 | 109.40 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 10 | 8.16 | 81.60 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 10 | 9.31 | 93.10 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 10 | 8.65 | 86.50 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 10 | 9.43 | 94.30 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 10 | 8.14 | 81.44 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 10 | 8.73 | 87.27 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 10 | 11.09 | 110.89 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 10 | 9.12 | 91.15 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 10 | 8.53 | 85.33 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 10 | 9.16 | 91.62 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 10 | 11.75 | 117.50 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 10 | 12.46 | 124.57 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 10 | 10.70 | 107.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 10 | 10.70 | 107.00 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 20 | 16.80 | 84.00 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 20 | 18.18 | 90.90 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 20 | 16.99 | 84.95 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 20 | 18.59 | 92.95 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 20 | 16.45 | 82.25 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 20 | 17.79 | 88.95 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 20 | 20.09 | 100.45 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 20 | 18.32 | 91.60 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 20 | 16.57 | 82.85 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 20 | 17.27 | 86.35 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 20 | 17.31 | 86.57 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 20 | 19.85 | 99.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 20 | 19.80 | 99.00 |

| | | | | | | |
|-----------------------|---|-------------------|---|-----|--------|--------|
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 20 | 20.10 | 100.50 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 40 | 36.03 | 90.08 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 40 | 37.68 | 94.20 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 40 | 36.45 | 91.13 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 40 | 37.05 | 92.63 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 40 | 32.00 | 80.01 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 40 | 32.79 | 81.97 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 40 | 37.96 | 94.89 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 40 | 39.16 | 97.91 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 40 | 33.10 | 82.74 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 40 | 34.50 | 86.24 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 40 | 37.87 | 94.67 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 40 | 37.94 | 94.84 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 40 | 37.70 | 94.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 40 | 37.70 | 94.25 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 80 | 69.67 | 87.08 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 80 | 75.39 | 94.24 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 80 | 64.42 | 80.53 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 80 | 74.76 | 93.45 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 80 | 64.82 | 81.02 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 80 | 73.51 | 91.89 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 80 | 76.02 | 95.02 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 80 | 78.57 | 98.21 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 80 | 64.67 | 80.84 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 80 | 75.68 | 94.60 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 80 | 78.11 | 97.64 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 80 | 78.54 | 98.18 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 80 | 75.10 | 93.88 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 80 | 75.40 | 94.25 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 160 | 148.70 | 92.94 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 0 | 160 | 153.39 | 95.87 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 160 | 151.00 | 94.38 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 0 | 160 | 152.41 | 95.26 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 160 | 132.26 | 82.66 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 160 | 135.12 | 84.45 |
| <i>E. triquetra</i> | G | MnSO ₄ | 0 | 160 | 136.45 | 85.28 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 0 | 160 | 151.66 | 94.79 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 160 | 132.98 | 83.11 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 160 | 141.41 | 88.38 |
| <i>L. abrubta</i> | J | MnSO ₄ | 0 | 160 | 158.26 | 98.91 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 0 | 160 | 159.94 | 99.96 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|----------|------------|--------|--------|
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 160 | 150.00 | 93.75 |
| <i>V. troostensis</i> | J | MnSO ₄ | 0 | 160 | 151.00 | 94.38 |
| Stock | | MnSO ₄ | 0 | 360 | 352.55 | 97.93 |
| Stock | | MnSO ₄ | 0 | 360 | 352.55 | 97.93 |
| Stock | | MnSO ₄ | 0 | 360 | 356.12 | 98.92 |
| Stock | | MnSO ₄ | 0 | 360 | 357.60 | 99.33 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 0 | 0.00 | ---- |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 0 | 0.04 | ---- |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 0 | 0.03 | ---- |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 0 | 0.23 | ---- |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 0 | 0.30 | ---- |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 0 | 0.48 | ---- |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 5 | 4.61 | 92.20 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 5 | 4.80 | 96.00 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 5 | 4.13 | 82.64 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 5 | 4.26 | 85.19 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 5 | 4.69 | 93.75 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 5 | 5.05 | 101.00 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 10 | 9.04 | 90.40 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 10 | 9.51 | 95.10 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 10 | 8.94 | 89.43 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 10 | 9.38 | 93.80 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 10 | 9.99 | 99.88 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 10 | 9.26 | 92.57 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 20 | 18.24 | 91.20 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 20 | 18.38 | 91.90 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 20 | 16.19 | 80.95 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 20 | 17.34 | 86.70 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 20 | 18.51 | 92.55 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 20 | 21.65 | 108.25 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 40 | 36.85 | 92.13 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 40 | 37.22 | 93.05 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 40 | 32.62 | 81.54 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 40 | 36.42 | 91.05 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 40 | 37.54 | 93.84 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 40 | 40.03 | 100.06 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 80 | 72.00 | 90.00 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 80 | 73.88 | 92.36 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 80 | 74.19 | 92.73 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 80 | 75.30 | 94.13 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|----|-----|--------|--------|
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 80 | 76.13 | 95.16 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 80 | 80.19 | 100.24 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 160 | 153.04 | 95.65 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 24 | 160 | 153.56 | 95.98 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 160 | 129.47 | 80.92 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 160 | 131.85 | 82.41 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 24 | 160 | 148.73 | 92.96 |
| <i>E. triquetra</i> | G | MnSO ₄ | 24 | 160 | 153.71 | 96.07 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 0 | 0.01 | ---- |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 0 | 0.02 | ---- |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 0 | 0.00 | ---- |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 0 | 0.05 | ---- |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 0 | 0.03 | ---- |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 0 | 0.12 | ---- |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 0 | 0.44 | ---- |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 0 | 0.24 | ---- |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 0 | 0.38 | ---- |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 0 | 0.00 | ---- |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 0 | 0.07 | ---- |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 0 | 0.20 | ---- |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 0 | 0.20 | ---- |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 0 | 0.26 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 0 | 0.01 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 0 | 0.04 | ---- |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 5 | 4.75 | 95.00 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 5 | 4.78 | 95.60 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 5 | 4.72 | 94.40 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 5 | 4.96 | 99.20 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 5 | 4.83 | 96.70 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 5 | 4.87 | 97.49 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 5 | 5.11 | 102.24 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 5 | 5.27 | 105.33 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 5 | 5.82 | 116.40 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 5 | 4.32 | 86.44 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 5 | 4.43 | 88.64 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 5 | 5.08 | 101.60 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 5 | 5.09 | 101.76 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 5 | 5.66 | 113.29 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 5 | 5.36 | 107.20 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 5 | 5.49 | 109.80 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 10 | 9.16 | 91.60 |

Table 1 continued

| | | | | | | |
|-----------------------------|----------|-------------------------|-----------|-----------|-------|--------|
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 10 | 9.51 | 95.10 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 10 | 9.19 | 91.90 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 10 | 9.37 | 93.70 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 10 | 8.90 | 89.02 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 10 | 9.85 | 98.52 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 10 | 9.91 | 99.11 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 10 | 11.37 | 113.73 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 10 | 10.20 | 102.00 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 10 | 8.55 | 85.54 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 10 | 9.09 | 90.91 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 10 | 9.68 | 96.81 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 10 | 9.74 | 97.40 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 10 | 11.29 | 112.89 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 10 | 10.80 | 108.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 10 | 11.00 | 110.00 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 20 | 18.42 | 92.10 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 20 | 18.94 | 94.70 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 20 | 17.25 | 86.25 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 20 | 19.02 | 95.10 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 20 | 16.46 | 82.30 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 20 | 16.26 | 81.30 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 20 | 17.03 | 85.15 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 20 | 17.87 | 89.35 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 20 | 17.70 | 88.50 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 20 | 17.96 | 89.82 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 20 | 19.00 | 95.00 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 20 | 19.31 | 96.53 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 20 | 21.84 | 109.22 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 20 | 23.99 | 119.93 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 20 | 20.10 | 100.50 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 20 | 20.30 | 101.50 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 40 | 36.23 | 90.58 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 40 | 37.42 | 93.55 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 40 | 37.15 | 92.88 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 40 | 37.83 | 94.58 |
| <i>O. subrotunda</i> | G | MnSO₄ | 48 | 40 | 35.71 | 89.28 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 40 | 34.27 | 85.67 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 40 | 34.46 | 86.14 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 40 | 34.82 | 87.05 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 40 | 34.82 | 87.06 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|------|-----|--------|-------|
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 40 | 33.05 | 82.62 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 40 | 35.35 | 88.37 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 40 | 36.13 | 90.32 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 40 | 37.80 | 94.50 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 40 | 38.69 | 96.72 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 40 | 38.10 | 95.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 40 | 38.90 | 97.25 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 80 | 67.47 | 84.34 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 80 | 75.93 | 94.91 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 80 | 70.39 | 87.99 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 80 | 75.18 | 93.98 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 80 | 68.16 | 85.20 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 80 | 72.49 | 90.61 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 80 | 74.36 | 92.95 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 80 | 75.92 | 94.90 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 80 | 78.60 | 98.25 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 80 | 65.30 | 81.63 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 80 | 73.36 | 91.70 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 80 | 75.10 | 93.88 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 80 | 76.92 | 96.16 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 80 | 78.18 | 97.73 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 80 | 75.90 | 94.88 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 80 | 76.00 | 95.00 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 160 | 151.69 | 94.81 |
| <i>U. imbecillis</i> | G | MnSO ₄ | 48 | 160 | 156.07 | 97.54 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 160 | 155.12 | 96.95 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48 | 160 | 155.43 | 97.14 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 160 | 135.26 | 84.54 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 160 | 141.93 | 88.71 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 160 | 146.63 | 91.65 |
| <i>O. subrotunda</i> | G | MnSO ₄ | 48 | 160 | 152.00 | 95.00 |
| <i>E. triquetra</i> | G | MnSO ₄ | 48 | 160 | 152.32 | 95.20 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 160 | 136.55 | 85.34 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 160 | 143.22 | 89.51 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 160 | 151.00 | 94.38 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48 | 160 | 151.33 | 94.58 |
| <i>L. abrubta</i> | J | MnSO ₄ | 48 | 160 | 158.66 | 99.16 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 160 | 151.00 | 94.38 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48 | 160 | 152.00 | 95.00 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 0 | 0.01 | ---- |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 0 | 0.03 | ---- |

| | | | | | | |
|-----------------------|---|-------------------|------|----|-------|--------|
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 0 | 0.00 | ---- |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 0 | 0.29 | ---- |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 0 | 0.26 | ---- |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 0 | 0.34 | ---- |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 0 | 0.42 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 0 | 0.01 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 0 | 0.13 | ---- |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 5 | 4.04 | 80.80 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 5 | 4.52 | 90.40 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 5 | 4.17 | 83.41 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 5 | 4.40 | 88.00 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 5 | 5.64 | 112.87 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 5 | 6.24 | 124.76 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 5 | 6.24 | 124.89 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 5 | 4.66 | 93.20 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 5 | 4.73 | 94.60 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 10 | 8.60 | 86.00 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 10 | 9.56 | 95.60 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 10 | 9.04 | 90.40 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 10 | 11.12 | 111.15 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 10 | 11.30 | 113.05 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 10 | 11.47 | 114.70 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 10 | 11.60 | 115.95 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 10 | 8.80 | 88.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 10 | 9.01 | 90.10 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 20 | 17.34 | 86.70 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 20 | 18.87 | 94.35 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 20 | 17.70 | 88.48 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 20 | 17.90 | 89.50 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 20 | 18.68 | 93.38 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 20 | 19.92 | 99.61 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 20 | 20.98 | 104.92 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 20 | 17.80 | 89.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 20 | 17.80 | 89.00 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 40 | 37.52 | 93.80 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 40 | 38.20 | 95.50 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 40 | 33.86 | 84.65 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 40 | 34.29 | 85.72 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 40 | 34.54 | 86.36 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 40 | 35.85 | 89.63 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 40 | 37.30 | 93.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 40 | 36.40 | 91.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 40 | 36.50 | 91.25 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|-------------|------------|--------|--------|
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 80 | 65.90 | 82.37 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 80 | 80.72 | 100.90 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 80 | 67.97 | 84.96 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 80 | 71.44 | 89.31 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 80 | 74.13 | 92.66 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 80 | 74.47 | 93.09 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 80 | 76.20 | 95.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 80 | 74.60 | 93.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 80 | 76.10 | 95.13 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 160 | 149.66 | 93.54 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 48.2 | 160 | 152.88 | 95.55 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 160 | 147.38 | 92.12 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 160 | 148.00 | 92.50 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 160 | 152.63 | 95.40 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 48.2 | 160 | 154.99 | 96.87 |
| <i>L. abruchta</i> | J | MnSO ₄ | 48.2 | 160 | 158.82 | 99.27 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 160 | 148.00 | 92.50 |
| <i>V. troostensis</i> | J | MnSO ₄ | 48.2 | 160 | 149.00 | 93.13 |
| Stock | | MnSO ₄ | 48.2 | 360 | 354.70 | 98.53 |
| Stock | | MnSO ₄ | 48.2 | 360 | 355.78 | 98.83 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 0 | 0.03 | ---- |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 0 | 0.00 | ---- |
| <i>L. abruchta</i> | J | MnSO ₄ | 96 | 0 | 0.30 | ---- |
| <i>L. abruchta</i> | J | MnSO ₄ | 96 | 0 | 0.40 | ---- |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 0 | 0.18 | ---- |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 0 | 0.09 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 0 | 0.07 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 0 | 0.75 | ---- |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 5 | 4.11 | 82.20 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 5 | 4.83 | 96.60 |
| <i>L. abruchta</i> | J | MnSO ₄ | 96 | 5 | 4.36 | 87.24 |
| <i>L. abruchta</i> | J | MnSO ₄ | 96 | 5 | 5.15 | 102.93 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 5 | 5.55 | 110.94 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 5 | 6.16 | 123.27 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 5 | 4.59 | 91.80 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 5 | 4.87 | 97.40 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 10 | 8.61 | 86.10 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 10 | 9.40 | 94.00 |
| <i>L. abruchta</i> | J | MnSO ₄ | 96 | 10 | 9.34 | 93.45 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 10 | 11.62 | 116.20 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 10 | 11.84 | 118.39 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|------|-----|--------|--------|
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 10 | 12.04 | 120.42 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 10 | 8.88 | 88.80 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 10 | 9.10 | 91.00 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 20 | 17.75 | 88.75 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 20 | 18.90 | 94.50 |
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 20 | 17.14 | 85.69 |
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 20 | 17.65 | 88.27 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 20 | 19.78 | 98.91 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 20 | 20.19 | 100.97 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 20 | 18.00 | 90.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 20 | 18.10 | 90.50 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 40 | 37.82 | 94.55 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 40 | 38.35 | 95.88 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 40 | 32.11 | 80.27 |
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 40 | 35.84 | 89.59 |
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 40 | 38.34 | 95.85 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 40 | 38.71 | 96.77 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 40 | 36.90 | 92.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 40 | 37.30 | 93.25 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 80 | 67.75 | 84.69 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 80 | 75.90 | 94.88 |
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 80 | 66.82 | 83.53 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 80 | 70.97 | 88.72 |
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 80 | 71.78 | 89.72 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 80 | 77.82 | 97.27 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 80 | 75.60 | 94.50 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 80 | 76.80 | 96.00 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 160 | 150.57 | 94.11 |
| <i>O. pectorosa</i> | J | MnSO ₄ | 96 | 160 | 153.22 | 95.76 |
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 160 | 143.03 | 89.40 |
| <i>L. abrubta</i> | J | MnSO ₄ | 96 | 160 | 144.24 | 90.15 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 160 | 148.96 | 93.10 |
| <i>U. imbecillis</i> | J | MnSO ₄ | 96 | 160 | 150.53 | 94.08 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 160 | 149.00 | 93.13 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96 | 160 | 149.00 | 93.13 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 0 | 0.09 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 0 | 0.56 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 5 | 4.61 | 92.20 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 5 | 5.19 | 103.80 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 10 | 9.69 | 96.90 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 10 | 9.78 | 97.80 |

Table 1 continued

| | | | | | | |
|-----------------------|---|-------------------|-------|-----|--------|--------|
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 20 | 18.10 | 90.50 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 20 | 18.80 | 94.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 40 | 37.10 | 92.75 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 40 | 37.60 | 94.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 80 | 76.10 | 95.13 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 80 | 77.80 | 97.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 160 | 149.00 | 93.13 |
| <i>V. troostensis</i> | J | MnSO ₄ | 96.2 | 160 | 150.00 | 93.75 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 0 | 0.02 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 0 | 0.69 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 5 | 4.62 | 92.40 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 5 | 5.23 | 104.60 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 10 | 9.64 | 96.40 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 10 | 10.00 | 100.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 20 | 18.20 | 91.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 20 | 19.10 | 95.50 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 40 | 37.60 | 94.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 40 | 37.90 | 94.75 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 80 | 76.70 | 95.88 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 80 | 78.70 | 98.38 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 160 | 139.00 | 86.88 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144 | 160 | 151.00 | 94.38 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144.2 | 0 | 0.20 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 144.2 | 5 | 4.58 | 91.60 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144.2 | 10 | 9.44 | 94.40 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144.2 | 20 | 19.10 | 95.50 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144.2 | 40 | 38.10 | 95.25 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144.2 | 80 | 77.90 | 97.38 |
| <i>V. troostensis</i> | J | MnSO ₄ | 144.2 | 160 | 151.00 | 94.38 |
| <i>V. troostensis</i> | J | MnSO ₄ | 192 | 0 | 0.06 | ---- |
| <i>V. troostensis</i> | J | MnSO ₄ | 192 | 5 | 4.66 | 93.20 |
| <i>V. troostensis</i> | J | MnSO ₄ | 192 | 10 | 9.46 | 94.60 |
| <i>V. troostensis</i> | J | MnSO ₄ | 192 | 20 | 18.90 | 94.50 |
| <i>V. troostensis</i> | J | MnSO ₄ | 192 | 40 | 38.00 | 95.00 |
| <i>V. troostensis</i> | J | MnSO ₄ | 192 | 80 | 78.10 | 97.63 |
| <i>V. troostensis</i> | J | MnSO ₄ | 192 | 160 | 150.00 | 93.75 |