APPENDIX D

DEVELOPMENT OF FINAL SEDIMENT QUALITY BENCHMARKS

SCIENCE INTEGRITY KNOWLEDGE

ESTABLISHMENT OF FINAL SEDIMENT QUALITY AQUATIC EFFECTS MONITORING PROGRAM BENCHMARKS

FINAL REPORT

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ESTABLISHMENT OF FINAL SEDIMENT QUALITY AQUATIC EFFECTS MONITORING PROGRAM BENCHMARKS

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EXECUTIVE SUMMARY

This report provides an evaluation of sediment benchmarks which can be used to assess sediment chemistry data collected under the Aquatic Effects Monitoring Program (AEMP) for the Mary River Mine, in Baffin Island. The development of these benchmarks involved an evaluation of baseline sediment chemistry data, collected prior to commencement of mining, and various effect-based sediment quality guidelines. The selection of the final sediment quality benchmarks for selected metals of interest was based on the higher of either the 97.5th percentile of baseline, or the sediment quality benchmark from reputed regulatory agencies, or 3 times the method detection limit, in instances were all data were non-detect.

ESTABLISHMENT OF FINAL SEDIMENT QUALITY AQUATIC EFFECTS MONITORING PROGRAM BENCHMARKS

1.0 INTRODUCTION

Baffinland Iron Ore Mines Corporation (Baffinland) operates the Mary River Mine in northern Baffin Island. As part of their license to operate, Baffinland is required to have an Aquatic Effects Monitoring Program (AEMP), to monitor the receiving environment for change, related to mining activities. The AEMP is multifaceted, and provides an over-arching umbrella for a number of sub-monitoring programs or studies, including the Core Receiving Environment Monitoring Program (CREMP), the Environmental Effects Monitoring (EEM) program, under the Federal Metal Mining Effluent Regulations (MMER), a Lake Sedimentation Monitoring Program, a Dustfall Monitoring Program, and a Stream Diversion Barrier Study. These programs are described in detail in the AEMP (Baffinland, 2014).

1.1 Background on the CREMP

The CREMP is designed to assess the potential for both long and short term changes in the environment, and will be used to evaluate the accuracy of predictions made in the Final Environmental Impact Statement (FEIS). It can also be used to assess the effectiveness of mitigations which are implemented to reduce change. Within the CREMP, there are two main aspects, as follows:

- A sediment and water quality monitoring program in lakes and rivers near to, and distant to the mine;
- A biological monitoring program which includes fish, benthos, and phytoplankton species in the same lakes and rivers as the sediment and water quality program is undertaken.

As part of the AEMP (Baffinland, 2014), an Assessment Approach and Response Framework was developed to explain the data evaluation process, to outline various management response actions as a result of mine-related change being detected in the environment. This assessment framework is presented in Figure 1-1. This approach clearly identifies that once mine-related change is identified for a given parameter, comparisons to an AEMP benchmark will take place, and actions resulting from that comparison will occur.

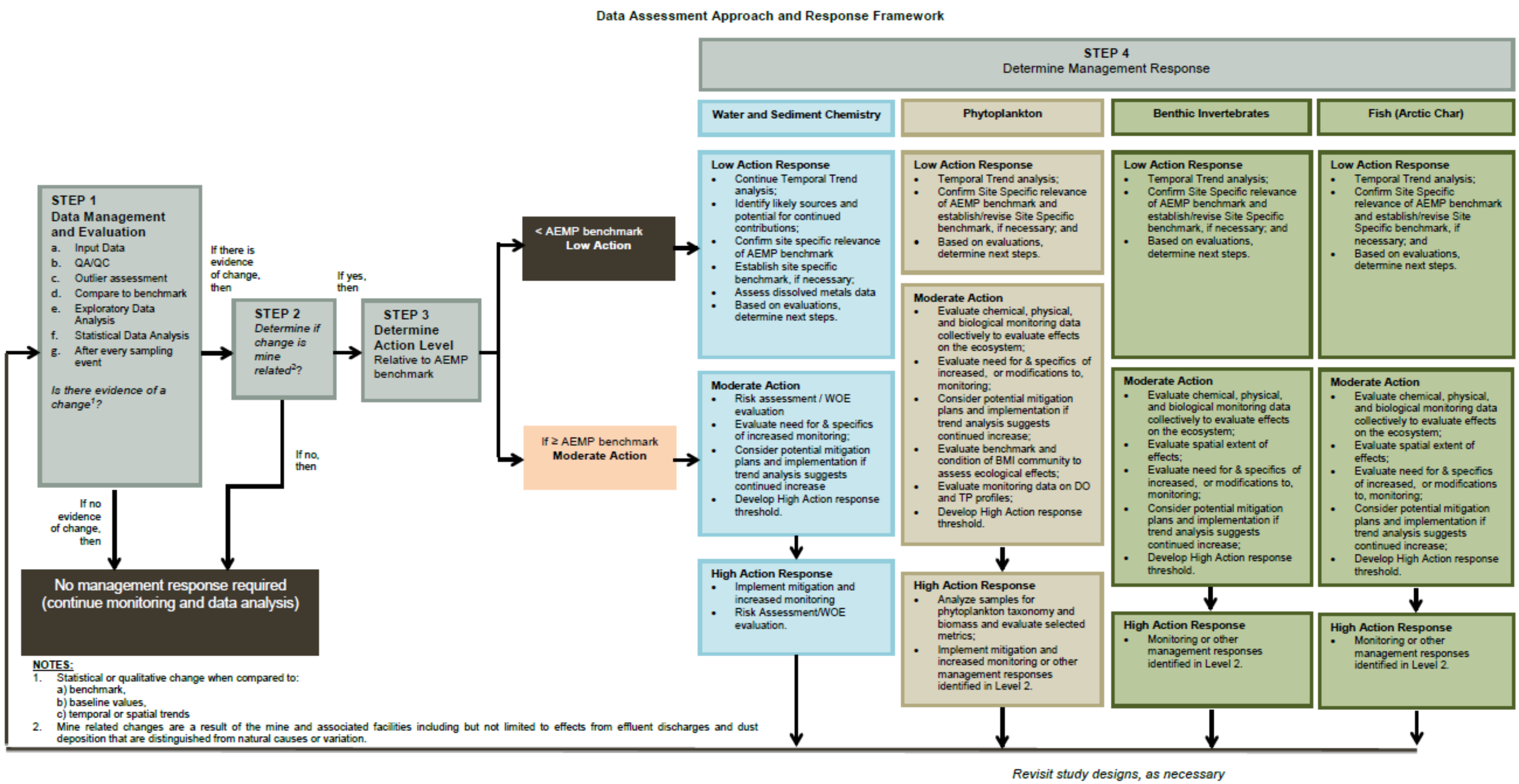


Figure 1-1 Data Assessment Approach and Response Framework

As part of this process, AEMP benchmarks were established for surface water quality (Baffinland, 2014). The process used to develop these benchmarks involved the assessment of baseline water chemistry for various metals, nutrients, and other water quality parameters, as well as the identification of water quality guidelines from regulatory agencies, such as the Canadian Council for Ministers of the Environment (CCME), and the British Columbia Ministry of Environment (BC MOE). Where an upper percentile of baseline (the 97.5^{th}%ile) was greater than a regulatory guideline, this metric of baseline was chosen to represent the AEMP benchmark. Where the regulatory guideline was greater than baseline, it was selected. If data were largely non-detect, a multiplier of the reported detection limit was selected as the benchmark. Further details, and surface water benchmarks, are presented in Baffinland (2014). In addition to surface water benchmark, sediment benchmarks were also developed. The benchmarks established for sediments in Baffinland (2014) were considered “interim” as several of the lakes had limited baseline data Camp Lake, N = 9; Mary Lake, N = 6; Sheardown Lake South East, N = 6, and Sheardown Lake North west, N = 25). The small number of baseline samples limited the ability to statistically evaluate whether any of the water bodies of interest should have separate benchmarks, or whether the lakes were similar enough to have identical benchmarks. The interim sediment benchmarks were established based on all lakes combined, using the approach outlined in Figure 1-2.

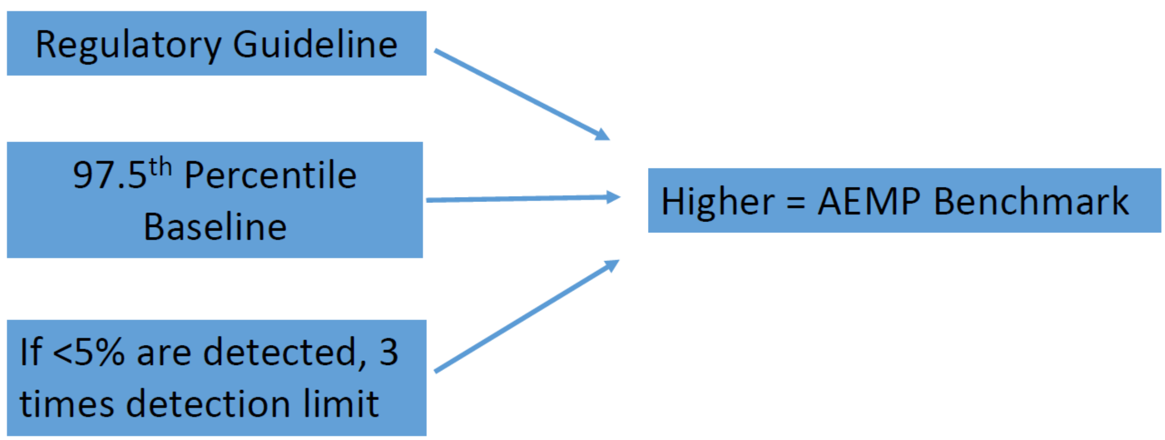


Figure 1-2 Process Used to Derive AEMP Sediment Benchmarks

Objective of Current Report

One of the goals of the 2014 sampling program was to increase the understanding of baseline sediment concentrations within each of the lakes of interest, by increasing the number of samples taken. Sediment (and water quality) monitoring in 2014 was undertaken during the late winter, spring, summer and fall, with the latter concluding prior to the start of mining. Therefore, all 2014 water and sediment quality sampling was conducted concurrent with construction activities at the mine site, but without the potential influence of mining activities (which was initiated in mid-September, 2014).

In this report, the 2014 sediment quality data are evaluated to determine whether they can be considered "baseline" or whether the activities at the site in 2013 and 2014 may have influenced some of the metals concentrations.

2.0 ASSESSMENT OF 2014 SEDIMENT DATA AND ESTABLISHMENT OF SEDIMENT BENCHMARKS

As established in the AEMP (Baffinland, 2014), sediment data collected in the 2014 field season were initially evaluated based on Total Organic Carbon (TOC) content, as per the screening process developed in 2014. Samples with less than 0.6% TOC and > 80% sand, or where sand was > 90% were excluded from development of baseline AEMP benchmarks, as they were not considered to have characteristics wherein metals would tend to accumulate (ie. Depositional stations), and hence, were not considered further.

The retained depositional stations for Mary Lake, Camp Lake, Sheardown Lake NW, tributaries of Sheardown Lake and Sheardown Lake SE were examined, and Log10 histograms of the dataset (2007 – 2014) suggest that the data are largely log normally distributed (Figure A-1), with the exception of cadmium, and mercury, which were excluded from further analysis due to the large proportion of non-detects (2 detected out of 74 samples for cadmium, with a method detection limit of 0.05 mg/kg; and none detected for mercury, with a detection limit of 0.1 mg/kg). The raw data from 2014, relative to baseline data, are presented and discussed in detail in the Core Receiving Environment Monitoring Program report (CREMP; Knight Piésold, 2015).

The stability of sediment metal concentrations in each lake over time was investigated by plotting the reported concentrations for each metal of interest against the year of sampling for the period between 2007 and 2014 (Figure A-2). Note, following the TOC and sand content screening described above, there were only seven sediment samples remaining from the Tributaries of Sheardown Lake for this time period. Due to this limited data, it was not possible to evaluate trends over time in the Tributaries of Sheardown Lake and data from this area were excluded from further baseline statistical evaluations. For Camp Lake, Mary Lake and Sheardown Lake SE, a visual evaluation of the graphs suggested that metals within these lakes did not increase over time (see Figure A-2). Therefore, all years of data for these lakes were considered representative of baseline conditions and were retained for further consideration in the sediment benchmark development process. With respect to Sheardown Lake NW, the available data for some metals of interest (e.g., chromium, copper, nickel and zinc) indicated possible increases in sediment concentrations over time, whereas the trend figures for other key metals of interest (e.g., arsenic, iron, and manganese), indicate a peak in 2008, followed by lower levels between 2011 and 2014 (Figure A-2). In light of these results, a review of historic activities near Sheardown Lake NW was conducted and events were identified that may have impacted Sheardown Lake NW sediment metal concentrations (i.e., historical crushing of a bulk sample of ore in 2008 and associated dusting events). Additionally, the sediment sampling approach was changed in 2012 from a 5 cm depth ponar grab sample to a 2 cm depth core sample, which limits the comparability between pre-2012 sediments to post 2012 sediments. In addition, some historical stations were not included in the 2014 sampling program, in an effort to align with other monitoring programs, which limits temporal trend analysis within the lake at these stations. With this in mind, the 2008 data for Sheardown Lake NW were eliminated from consideration in the development of baseline for this lake, but at this stage, other Sheardown Lake NW data were retained for further statistical analyses.

In order to determine whether each lake required separate sediment metal concentration benchmarks, separate analyses of variance (ANOVAs) of the log-transformed sediment metal concentrations were performed to investigate differences between lakes for each of the following metals (arsenic, chromium, copper, iron, manganese, nickel, phosphorus, lead and zinc). For the reasons described above, this analysis included data for all years (2007 – 2014) for Sheardown Lake SE, Mary Lake, and Camp Lake and excluded 2008 data for Sheardown Lake NW. Mercury and cadmium were non-detect, and therefore were not analyzed using this approach. Statistical outcomes are presented in Table A-1. Significant ANOVA test results ($p<0.05$) were followed by Tukey multiple comparison tests to determine which sites differed from each other. No significant differences ($p>0.05$) between lakes were noted for chromium, iron, nickel, phosphorus, and lead. However, for arsenic, copper, manganese and zinc, the Tukey multiple comparison tests revealed that Sheardown Lake SE had significantly lower ($p<0.05$) sediment metal concentrations than at least one other lake (lower than all other lakes for arsenic and copper, less than Camp and Mary Lake for manganese, and less than Mary and Sheardown Lake NW for zinc). Therefore no significant differences ($p>0.05$) between any of the other lakes for these metals.

Consideration of all of this information, led to the following decisions:

- Sheardown Lake SE would have lake-specific benchmarks, based on the dataset of 2007 – 2014;
- Mary Lake and Camp Lake would have combined, lake-specific benchmarks, based on the dataset of 2007 – 2014:
- Due to complicating factors related to the Sheardown Lake data set, it is difficult to determine, based on the available dataset, whether recent construction-related activities have influenced sediment chemistry in this lake. The main factors include the change in sediment sampling protocol (ponar grab of top 5 cm in early years, versus a 0 – 2 cm coring approach since 2012), the lack of monitoring of several long standing stations in 2014, which limits temporal comparisons at specific locations. As a result, further study is recommended in 2015 for Sheardown Lake NW, and the interim benchmarks are suggested for comparison purposes for the 2014 dataset.

Based on this approach, a 97.5^{th}%ile of the combined datasets for each of these lake scenarios are presented in Table 1, in conjunction with sediment quality guidelines. The higher of either the 97.5^{th}%ile of baseline, the CCME or Ontario Ministry of the Environment sediment quality guidelines, or 3 times the detection limit was selected as the lake-specific benchmarks, as per the Figure 1-2.

Table 1 provides appropriate regulatory sediment quality guidelines, the 97.5^{th} percentiles of sediment data for area lakes and the proposed AEMP benchmark for Mary Lake, Camp Lake and Sheardown Lake NW, as well as Sheardown Lake SE.

Table 2-1 Development of Area-Specific Aquatic Effects Sediment Benchmarks, based on Area-Specific Baseline Calculations and Relevant Sediment Quality Guidelines (mg/kg; dw)

Jurisdiction, Type of Guideline and Statistical Metric		Hg	As	Cd	Cr	Cu	Fe	Mn	Ni	P*	Pb	Zn
CCME (2014)	**ISQG**	0.17	5.9	0.6	37.3	35.7	NGA	NGA	NGA	NGA	35	123
	PEL	0.486	17	3.5	90	197	NGA	NGA	NGA	NGA	91.3	315
Ontario (OMOE, 2008)	**LEL**	0.2	6	0.6	26	16	20000	460	16	600	31	120
	SEL	2	33	10	110	110	40000	1100	75	2000	250	820
97.5th%iles of Lake Areas and Lake-Specific Benchmarks by Area												
97.5th%ile: Mary Lake (2007 – 2014) and Camp Lake (2007 – 2014) (N = 31)		<0.1	5.3	<0.5	98	50	52,400	4,370	72	1580	25	135
Proposed AEMP Benchmark – Mary Lake and Camp Lake		**0.17^A^**	**5.9^A^**	**1.5^C^**	**98^B^**	**50^B^**	**52,400^B^**	**4,370^B^**	**72^B^**	**1580^B^**	**35^A^**	**135^B^**
97.5th %ile: Sheardown Lake SE (2007 – 2014) (N = 11)		<0.1	2	1	79	56	34,400	657	66	1278	18	63
Proposed AEMP Benchmark –Sheardown Lake SE		**0.17^A^**	**5.9^A^**	**1.5^C^**	**79^B^**	**56^B^**	**34,400^B^**	**657^B^**	**66^B^**	1278^B^	**35^A^**	**123^A^**
97.5th%ile of Sheardown Lake NW (2007 – 2014, excluding 2008) (N = 25)		<0.1	6.4	<0.5	96	62	53,000	4,300	84	1100	24	107
Interim AEMP Benchmark –Sheardown Lake NW (from Baffinland, 2014; Appendix C)		**0.17^A^**	**6.2^B^**	**1.5^C^**	**97^B^**	**58^B^**	**52,200^B^**	**4,530^B^**	**77^B^**	**1958^B^**	**35^A^**	**123^A^**

Notes:
* = N for phosphorus is lower than other elements.
A = guideline is based on sediment quality guideline; B = guideline is based on 97.5th%ile of baseline data; C= guideline is based on 3 times MDL
Where mercury and cadmium were not detected in any samples in a given area; the detection limit is used to represent the 97.5th percentiles.

3.0 REFERENCES

Baffinland, 2014. Baffinland Iron Mines Corporation. Aquatic Effects Monitorinjg Program. BAF-Ph1-830-P16-0039. Rev 0. Prepared By: Jim Millard, Baffinland Iron Mines. Part 1, Item 2 of Type A Water Licence No. 2AM-MRY1325

CCME, 2014. Canadian Council of Ministers of the Environment. Sediment Quality Guidelines Summary Table: http://st-ts.ccme.ca/en/index.html

Knight Piésold, 2015. Core Receiving Environment Monitoring Program Report. 2014 Water and Sediment CREMP Monitoring Report. NB102-181/34-6. March, 2015.

OMOE, 2008. Guidelines for Identifying, Assessing and Managing Contaminated Sediments in Ontario: An Integrated Approach. May, 2008. R. Fletcher, P. Welsh, and T. Fletcher.Standards Development Branch. PIBS 6658e.

ATTACHMENT A

SUPPORTING FIGURES AND STATISTICAL ANALYSIS OUTCOMES

Figure A-1: Log 10 Histograms of All Sediment Data (2007 – 2014) for Camp Lake, Mary Lake, Sheardown Lake SE, Sheardown Lake NW

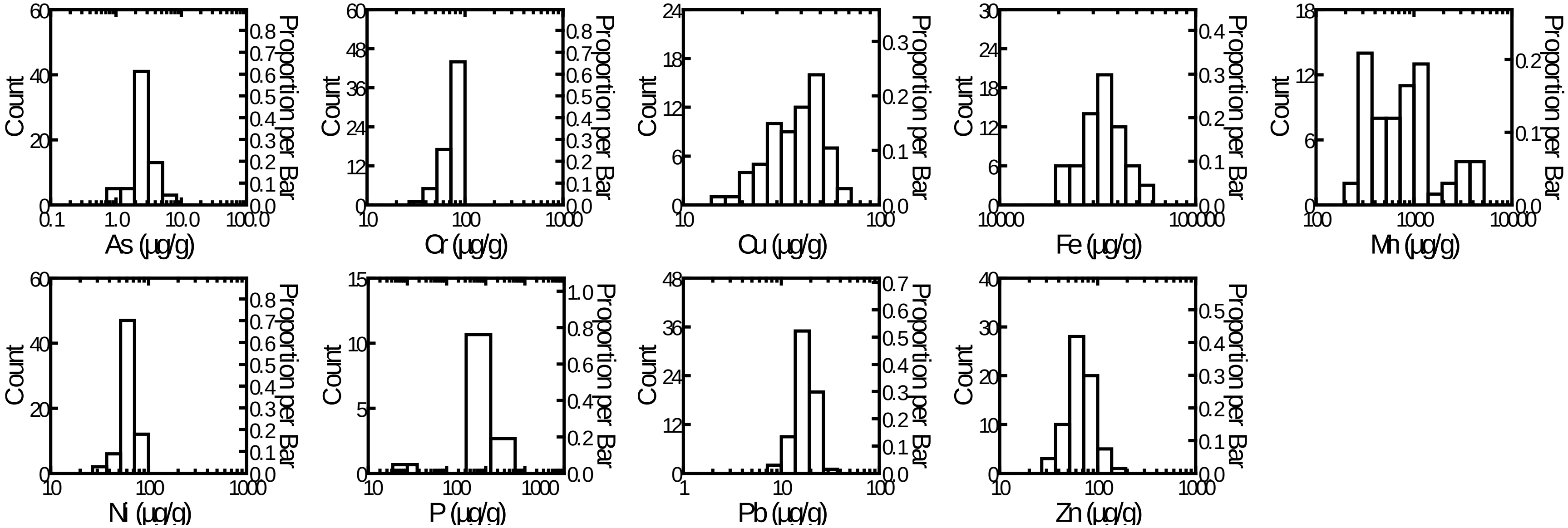


Figure A-2: Trend Analysis of All Lakes (2007 – 2014). Plotted data indicate mean ± standard error for each sampled year.

Figure A-2.1 Mary Lake (2007 – 2014)

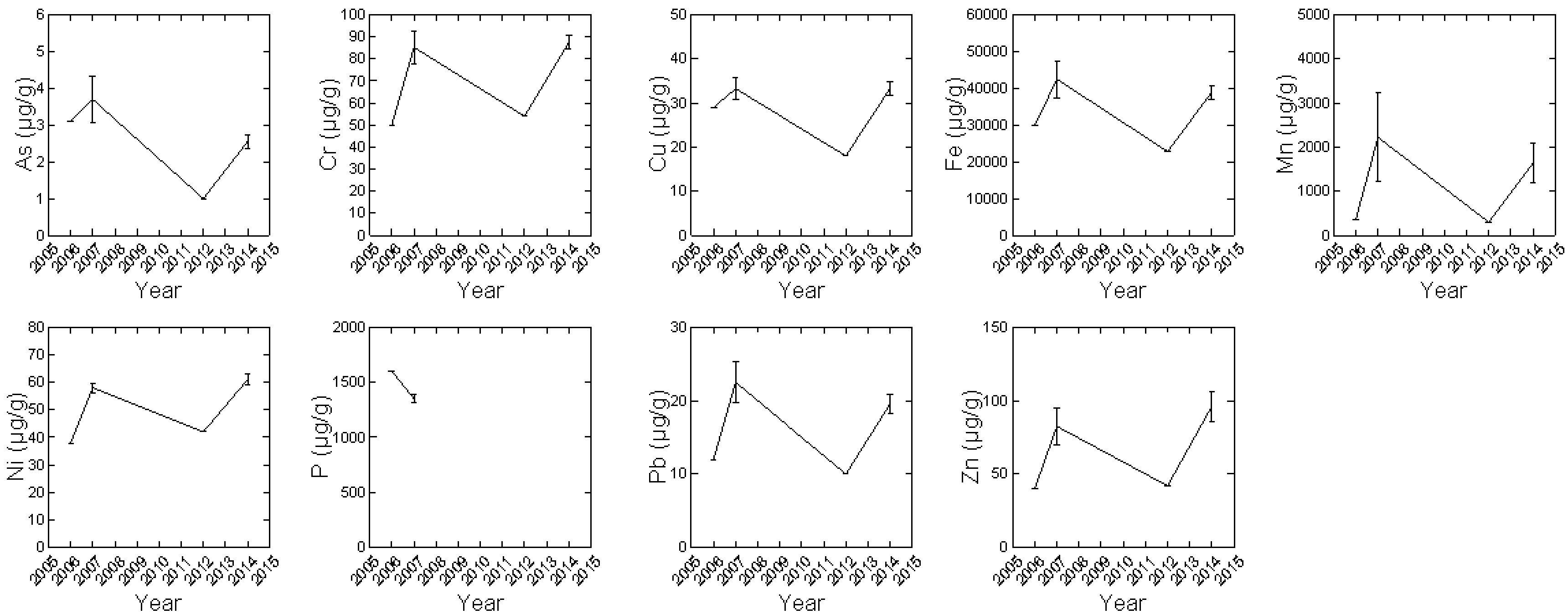


Figure A-2.2 Camp Lake (2007 – 2014)

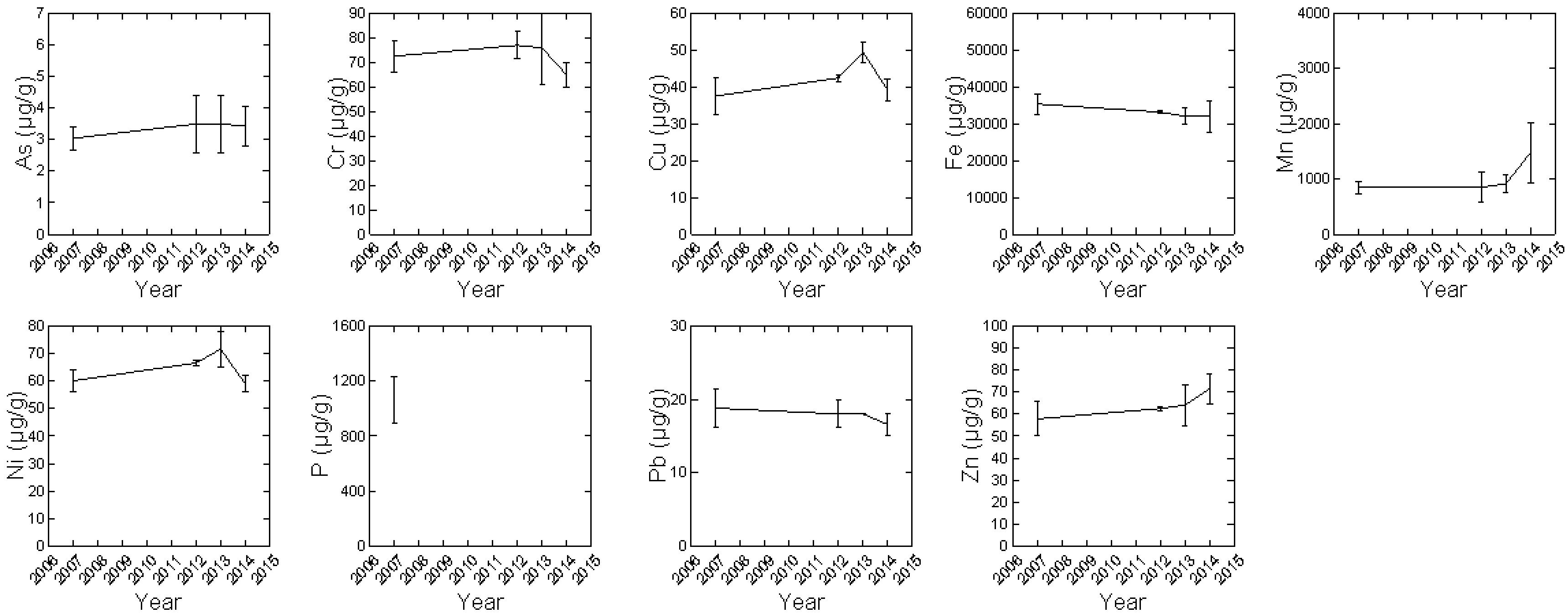


Figure A-2.3 Sheardown Lake NW (2007 – 2014)

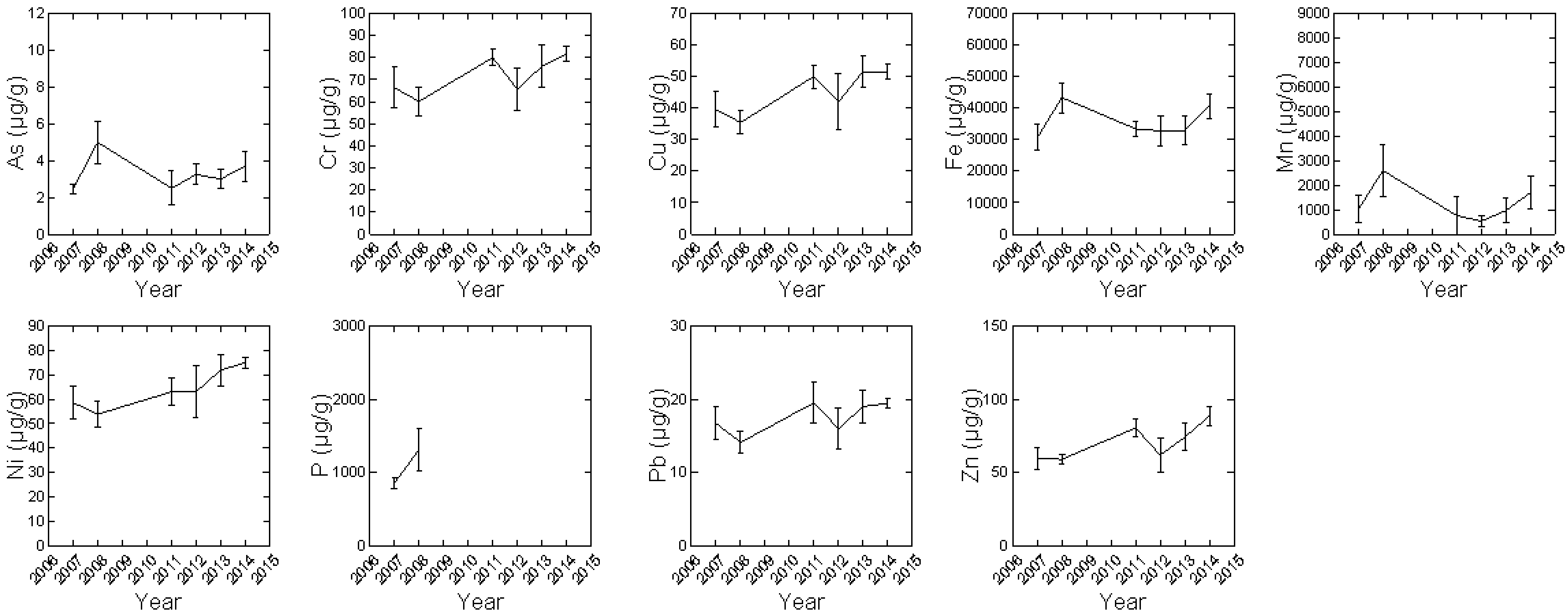


Figure A-2.4 Sheardown Lake SE (2007 – 2014)

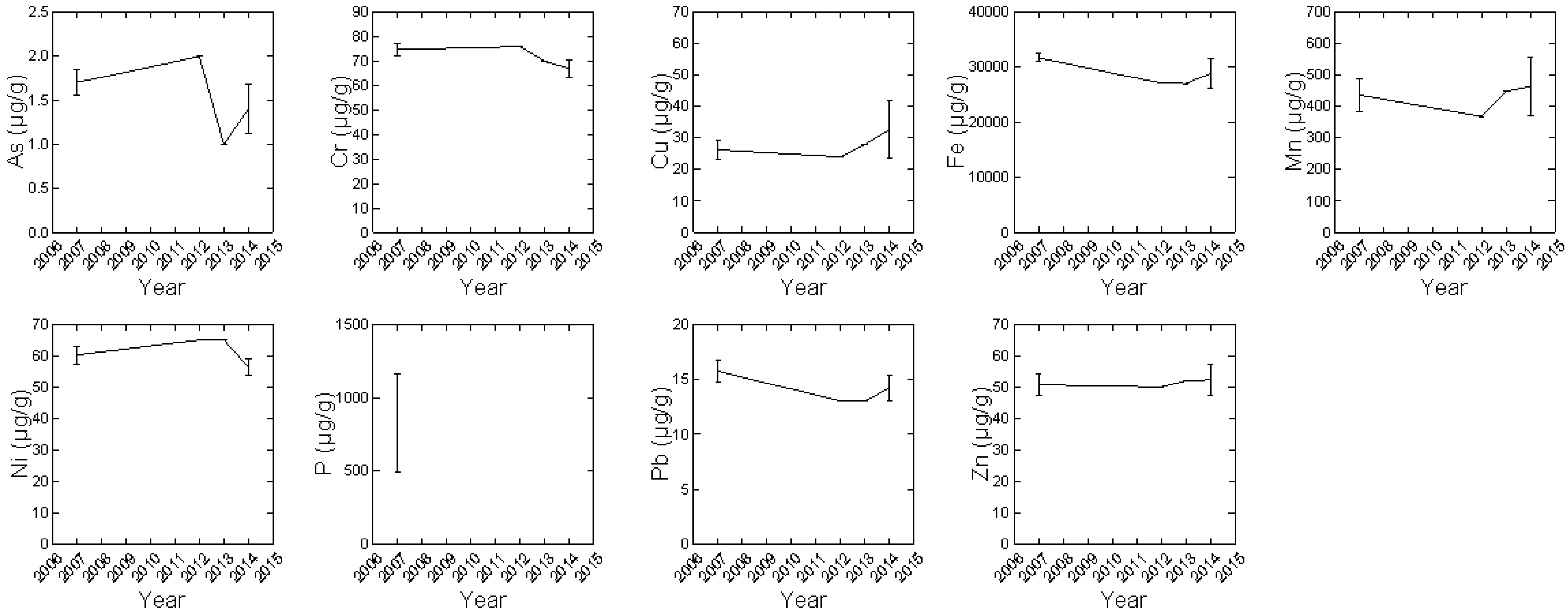
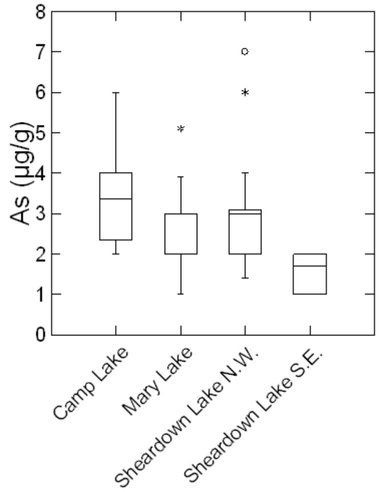
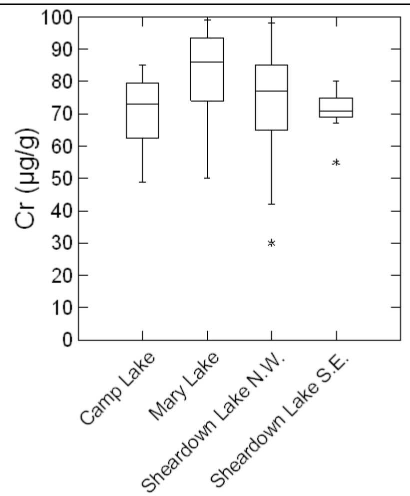
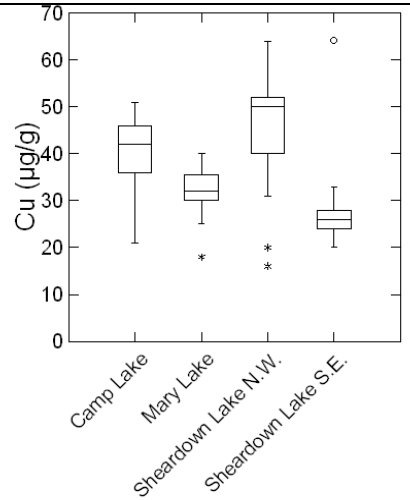
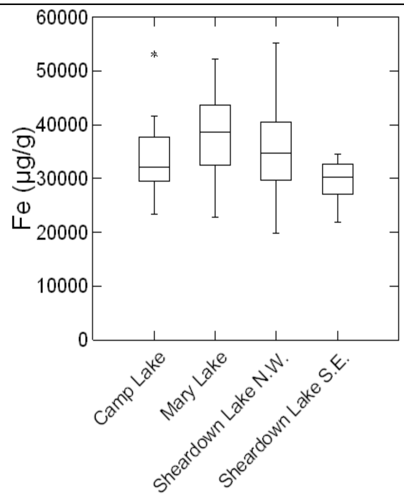
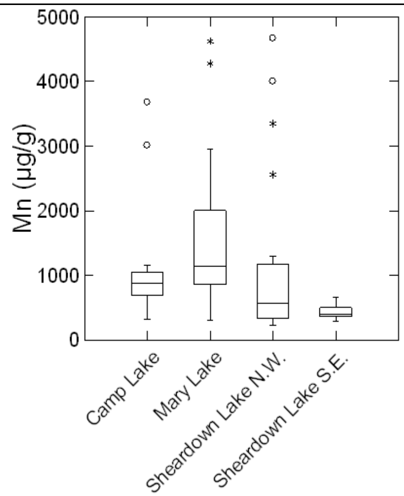
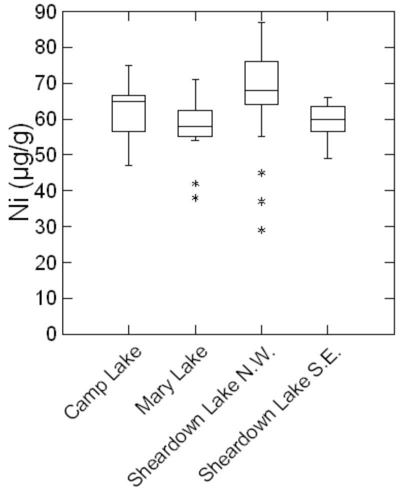
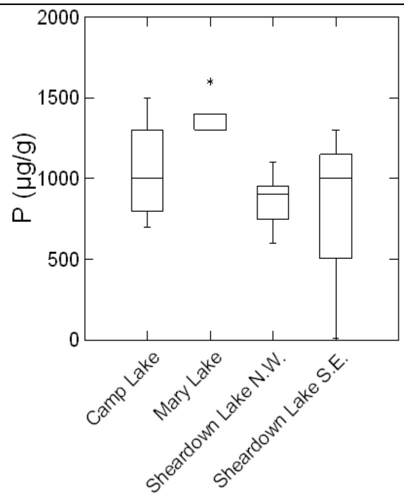


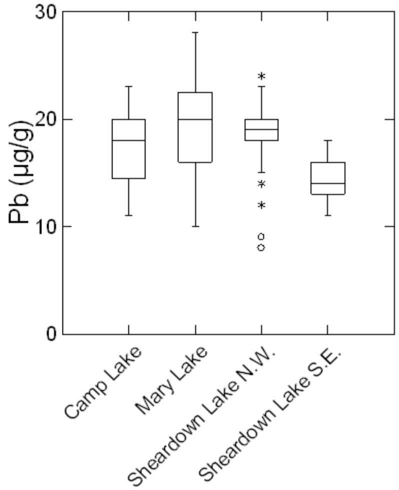
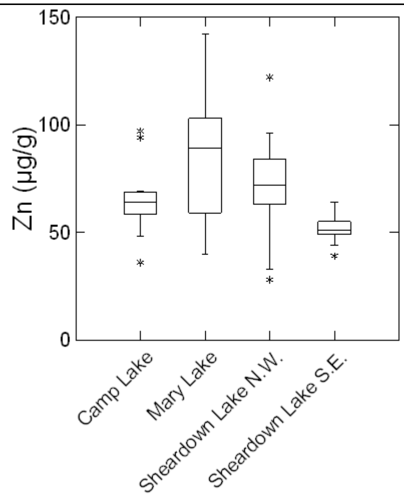
Table A-1: Boxplots and Statistical Comparisons By Site using Data for Camp Lake (2007 – 2014), Mary Lake (2007 – 2014), Sheardown Lake SE (2007 – 2014) and Sheardown Lake NW (2007 – 2014, excluding 2008)

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Arsenic		**<0.001**	0.468	0.774	**<0.001**	0.909	**<0.001**	**<0.001**

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Chromium		0.222	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Copper		**<0.001**	0.108	0.503	**0.008**	**0.001**	0.627	**<0.001**

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Iron		0.073	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Manganese		**0.006**	0.785	0.654	**0.047**	0.143	**0.005**	0.257

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Nickel		0.147	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Phosphorus		0.233	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]

Analyte	Boxplot[b]	ANOVA[b] Results (p-value)	Tukey Test Results (p-values)					
			Camp Lake vs. Mary Lake	Camp Lake vs. Sheardown Lake N.W.	Camp Lake vs. Sheardown Lake S.E.	Mary Lake vs. Sheardown Lake N.W.	Mary Lake vs. Sheardown Lake S.E.	Sheardown Lake N.W. vs. Sheardown Lake S.E.
Lead		0.071	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]	NA[c]
Zinc		**0.003**	0.153	0.784	0.244	0.485	**0.002**	**0.028**

Analyte	**Boxplot[b]**	**ANOVA[b] Results (p-value)**	**Tukey Test Results (p-values)**					
			Camp Lake vs. Mary Lake	**Camp Lake vs. Sheardown Lake N.W.**	**Camp Lake vs. Sheardown Lake S.E.**	**Mary Lake vs. Sheardown Lake N.W.**	**Mary Lake vs. Sheardown Lake S.E.**	**Sheardown Lake N.W. vs. Sheardown Lake S.E.**

Notes –

[a] The top and bottom of each box indicate the 75th and 25th percentiles of the data, respectively. The middle line in each box indicates the median (50th percentile). The whiskers indicate the lowest datum that is within 1.5 times the interquartile range (IQR, which equals the 75th percentile minus the 25th percentile) from the bottom of the box and the highest datum that is within 1.5 IQR from the top of the box. Values that are greater than 1.5 IQR but less than or equal to 3 IQR from the box are indicated with asterisks. Values that are more than 3 IQR from the box are indicated by empty circles.

[b] Data were log-transformed prior to analysis to improve data normality

[c] NA = not applicable. Tukey test comparison not performed since ANOVA was not significant.