Annex A.4-1. Stream Sediment Quality Data, Doris North Project, 2015

Site ID:		CCME Guidelines for the Protection of Aquatic Life[a]		Realized Detection Limit	Doris OF	Doris OF	Doris OF	Roberts OF	Roberts OF	Roberts OF	Little Roberts OF	Little Roberts OF	Little Roberts OF	Reference B OF	Reference B OF	Reference B OF	Reference D OF	Reference D OF	Reference D OF
Replicate:					1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Date Sampled:					15-Aug-15	15-Aug-15	15-Aug-15	15-Aug-15	15-Aug-15	15-Aug-15	14-Aug-15	14-Aug-15	14-Aug-15	13-Aug-15	13-Aug-15	13-Aug-15	16-Aug-15	16-Aug-15	16-Aug-15
ALS Sample ID:	Unit	ISQG[b]	PEL[c]		L1659334-4	L1659334-5	L1659334-6	L1659334-7	L1659334-8	L1659334-9	L1659334-1	L1659334-2	L1659334-3	L1658147-4	L1658147-5	L1658147-6	L1659334-10	L1659334-11	L1659334-12
Physical Tests																			
Moisture	%			0.25	-	-	-	-	-	-	-	-	-	32.6	13.4	61.8	-	-	-
pH	pH			0.10	7.28	6.84	6.29	7.47	7.29	6.86	7.67	8.01	6.36	5.96	6.00	5.94	5.53	5.78	6.22
Particle Size																			
% Gravel (>2 mm)	%			0.10	26.7	30.2	<0.10	0.27	48.7	27.4	51.5	50.1	38.6	59.0	52.1	45.8	37.7	37.8	40.5
% Sand (2.0 mm - 0.063 mm)	%			0.10	27.4	68.0	30.4	5.21	32.0	56.3	47.3	41.9	52.5	35.2	39.7	43.8	31.0	54.0	51.2
% Silt (0.063 mm - 4 µm)	%			0.10	25.8	1.18	55.0	48.0	10.0	9.17	0.75	5.14	7.02	4.65	6.82	9.19	22.2	6.31	6.68
% Clay (<4 µm)	%			0.10	20.1	0.60	14.7	46.5	9.23	7.21	0.38	2.82	1.95	1.19	1.38	1.22	9.11	1.89	1.58
Texture	-			-	Loam	Sand	Silt loam	Silty clay	Sandy loam	Sandy loam	Sand	Loamy sand	Sand / Loamy sand	Sand / Loamy sand	Loamy sand	Loamy sand	Loam	Sand	Sand
Anions & Nutrients																			
Total Nitrogen	%			0.020	0.087	0.048	0.433	0.117	0.058	0.060	0.040	0.053	0.070	0.063	0.072	0.154	0.284	0.091	0.082
Organic / Inorganic Carbon																			
Total Organic Carbon	%			0.10	0.62	0.23	5.45	0.92	0.27	0.37	0.15	0.32	0.39	0.36	0.74	1.75	3.58	1.03	0.78
Plant Available Nutrients																			
Available Ammonium-N	mg/kg			1.0 or 1.6	6.4	4.1	8.1	2.0	2.6	4.6	1.0	1.9	3.6	2.1	2.6	4.3	11.5	4.9	2.9
Nitrate+Nitrite-N	mg/kg			2.0 or 4.0	<2.0	<2.0	<4.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Available Nitrate-N	mg/kg			2.0 or 4.0	<2.0	<2.0	<4.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Available Nitrite-N	mg/kg			0.4 or 0.8	<0.40	<0.40	<0.80	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
Available Phosphate-P	mg/kg			2.0	2.7	4.3	5.9	2.2	3.2	2.9	2.3	2.9	2.4	2.6	2.6	4.6	2.2	3.2	2.2
Metals																			
Aluminum (Al)	mg/kg			50	24000	6680	14800	22800	14800	11400	6380	10300	8720	9620	6770	8520	15300	8050	7910
Antimony (Sb)	mg/kg			0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Arsenic (As)	mg/kg	5.9	17	0.10	3.64	0.80	3.09	3.18	2.57	1.69	1.66	2.97	2.3	1.67	1.11	1.3	1.95	0.96	1.01
Barium (Ba)	mg/kg			0.50	137	12.9	77.2	129	75.2	53.4	18.6	44	34.6	28.3	22.6	27.3	73.2	29.2	29
Beryllium (Be)	mg/kg			0.10	0.71	0.11	0.43	0.66	0.39	0.30	0.12	0.26	0.22	0.20	0.15	0.20	0.48	0.21	0.21
Bismuth (Bi)	mg/kg			0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	mg/kg			5.00	17.6	<5.0	12.5	18.6	10.8	7.9	<5.0	7.7	5.6	<5.0	<5.0	<5.0	11.2	<5.0	<5.0
Cadmium (Cd)	mg/kg	0.6	3.5	0.050	0.079	<0.050	0.075	0.052	<0.050	<0.050	<0.050	0.067	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Calcium (Ca)	mg/kg			50	8240	1800	6040	7840	4950	3800	2780	4950	2770	2660	2140	2850	4090	2460	2480
Chromium (Cr)	mg/kg	37.3	90	0.50	66.6	13.7	40.8	61.1	39.7	26.5	14.5	26.9	22.4	28.9	18.6	28.5	42.1	16.9	18.7
Cobalt (Co)	mg/kg			0.10	15.9	5.10	8.36	14.2	9.98	7.60	5.30	7.31	6.11	6.68	5.00	6.15	7.75	5.69	5.41
Copper (Cu)	mg/kg	35.7	197	0.50	37.7	11.0	29.1	31.9	21.0	14.8	6.42	11.7	10.5	14.2	12.7	18.7	32.5	14.5	30.4
Iron (Fe)	mg/kg			50	35100	12400	19800	31700	22500	17300	12400	15600	13800	16000	10700	13900	19100	12400	10800
Lead (Pb)	mg/kg	35	91.3	0.50	8.27	1.15	5.74	7.53	4.69	3.34	1.31	3.06	2.64	3.12	1.98	2.70	5.14	2.12	2.16
Lithium (Li)	mg/kg			2.0	43.8	11.3	22.0	39.5	23.0	19.7	10.9	16.3	14.3	15.6	11.7	15.3	24.3	15.2	15.6
Magnesium (Mg)	mg/kg			20	16400	4400	8680	14900	9960	7540	5240	6680	5800	5670	4200	5410	8410	5290	5350
Manganese (Mn)	mg/kg			1.0	567	139	330	444	351	266	229	276	213	185	132	157	229	144	174
Mercury (Hg)	mg/kg	0.17	0.486	0.0050	0.0062	<0.0050	0.0237	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0073	0.0132	0.0065	0.0057
Molybdenum (Mo)	mg/kg			0.10	0.84	0.11	1.29	0.70	0.47	0.35	0.20	0.69	0.56	0.30	0.28	0.41	0.67	0.29	0.33
Nickel (Ni)	mg/kg			0.50	37.0	9.56	23.1	32.7	21.8	15.6	9.62	15.3	13.2	16.3	11.6	16.2	22.4	11.9	12.7
Phosphorus (P)	mg/kg			50	694	295	634	618	494	408	354	366	346	396	363	415	484	324	317
Potassium (K)	mg/kg			100	6470	550	3100	6400	3710	2570	860	2200	1570	1030	750	1020	2650	1200	990
Selenium (Se)	mg/kg			0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silver (Ag)	mg/kg			0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sodium (Na)	mg/kg			50	1430	132	863	1960	1010	581	126	482	357	162	141	202	559	269	245
Strontium (Sr)	mg/kg			0.50	49.0	7.97	34.0	46.2	30.3	23.1	9.83	31.0	15.6	13.6	9.5	14.0	26.1	14.5	14.1
Sulphur (S)	mg/kg			500	<500	<500	1500	<500	<500	<500	<500	<500	<500	1000	700	900	800	<500	<500
Thallium (Tl)	mg/kg			0.050	0.264	<0.050	0.152	0.244	0.145	0.106	0.050	0.100	0.082	0.060	0.052	0.067	0.150	0.059	0.055
Tin (Sn)	mg/kg			2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (Ti)	mg/kg			1.0	1710	367	993	1740	1150	835	408	739	621	684	470	613	984	544	474
Uranium (U)	mg/kg			0.050	1.82	0.273	1.42	1.65	1.11	0.764	0.373	1.36	0.848	0.76	0.736	1.59	2.38	1.09	1.41
Vanadium (V)	mg/kg			0.20	79.5	24.1	50.4	74.6	50.5	36.7	24.5	38.5	31.4	31.7	22.5	28.5	50.0	31.1	26.3
Zinc (Zn)	mg/kg	123	315	1.0	78.5	21.4	56.2	68.4	47.5	39.4	22.7	36.6	31.1	30.6	23.3	31.6	45.8	28.1	23.0

Notes:

Shaded cells indicate values that exceed CCME guidelines (light grey ISQG, dark grey PEL).

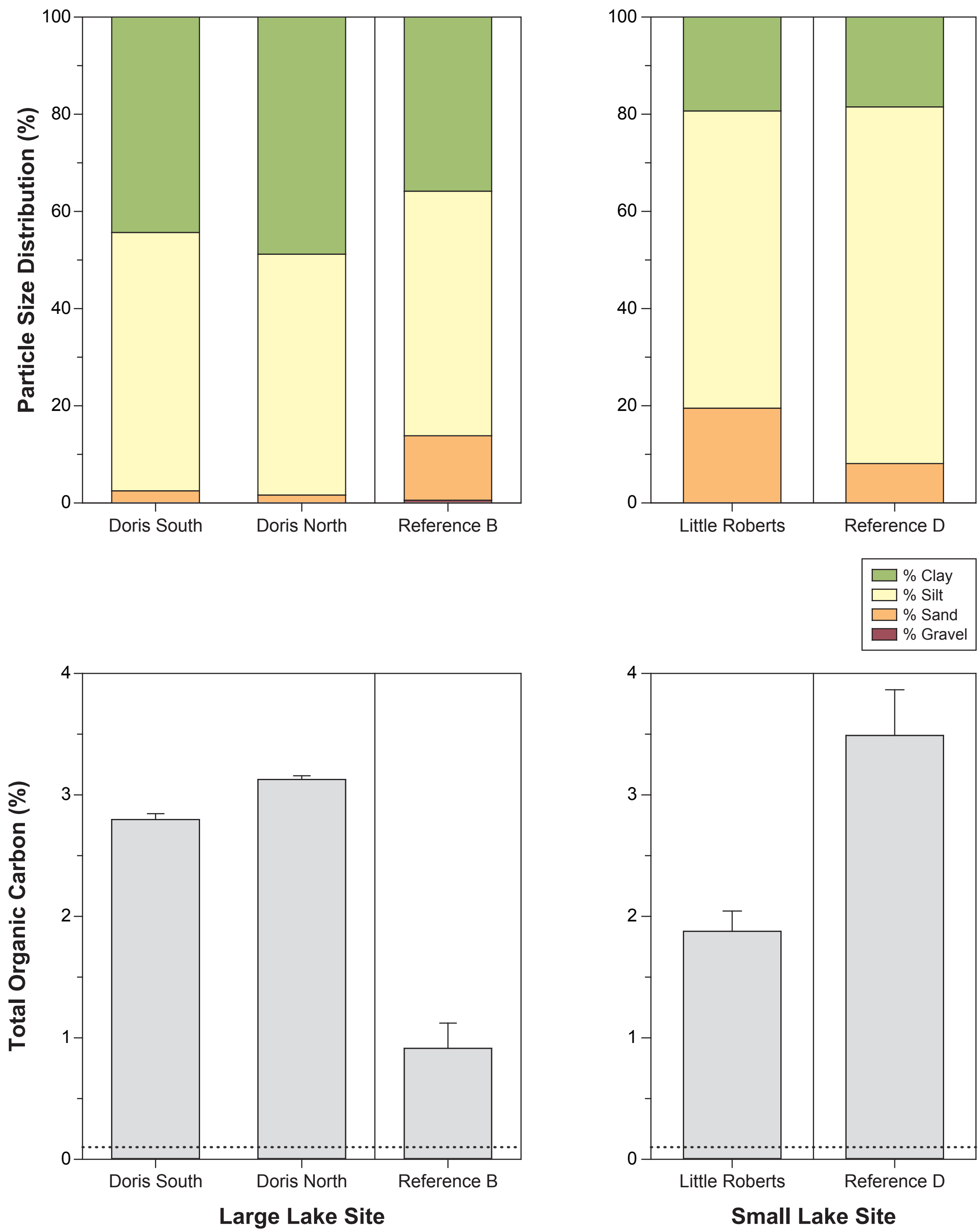
[a] *Canadian sediment quality guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment, Accessed 2015.*

[b] *ISQG = Interim Sediment Quality Guideline*

[c] *PEL = Probable Effects Level*

Figure A.4-6

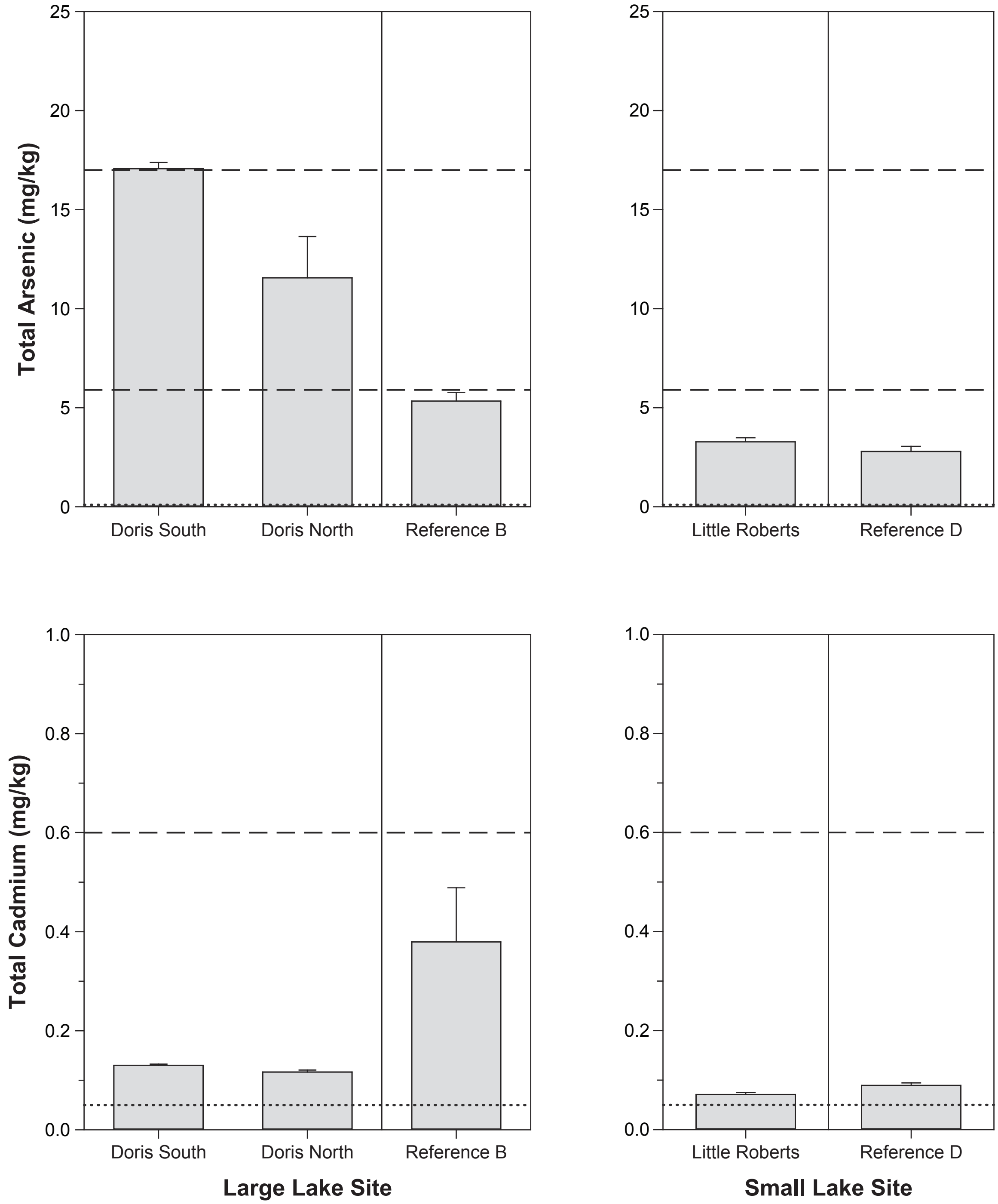
Particle Size Distribution and Total Organic Carbon Concentration in Lake Sediments, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Stacked bars represent the mean of replicate samples.
Dotted line represents the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Particle size distribution and total organic carbon content of sediments are required parameters as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure A.4-7

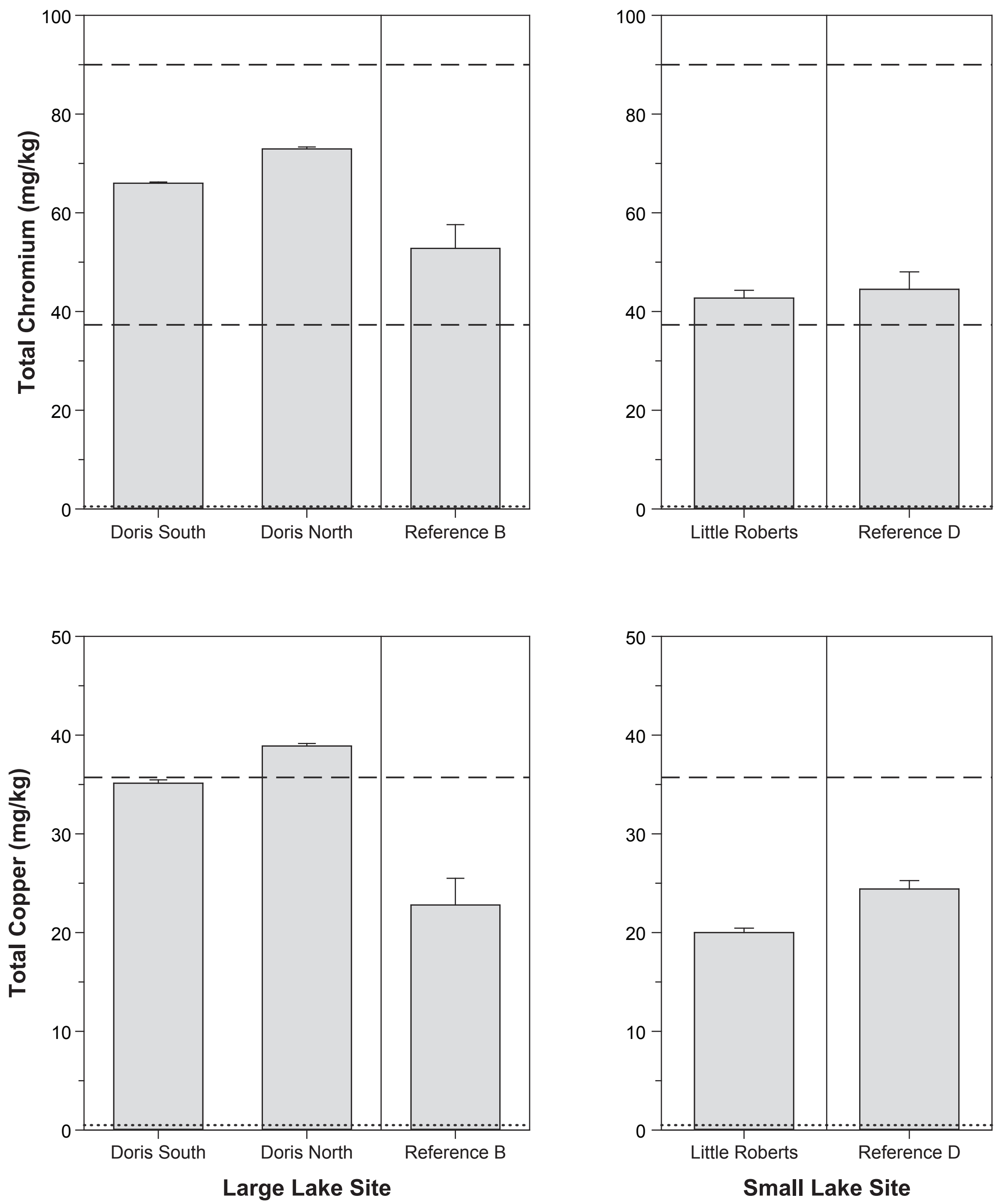
Total Arsenic and Total Cadmium Concentrations in Lake Sediments, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the detection limit.
Dashed lines represent the CCME freshwater interim sediment quality guidelines (ISQGs) for arsenic (5.9 mg/kg) and cadmium (0.6 mg/kg) and the probable effects level (PEL) for arsenic (17 mg/kg); the PEL for cadmium (3.5 mg/kg) is not shown.

Figure A.4-8

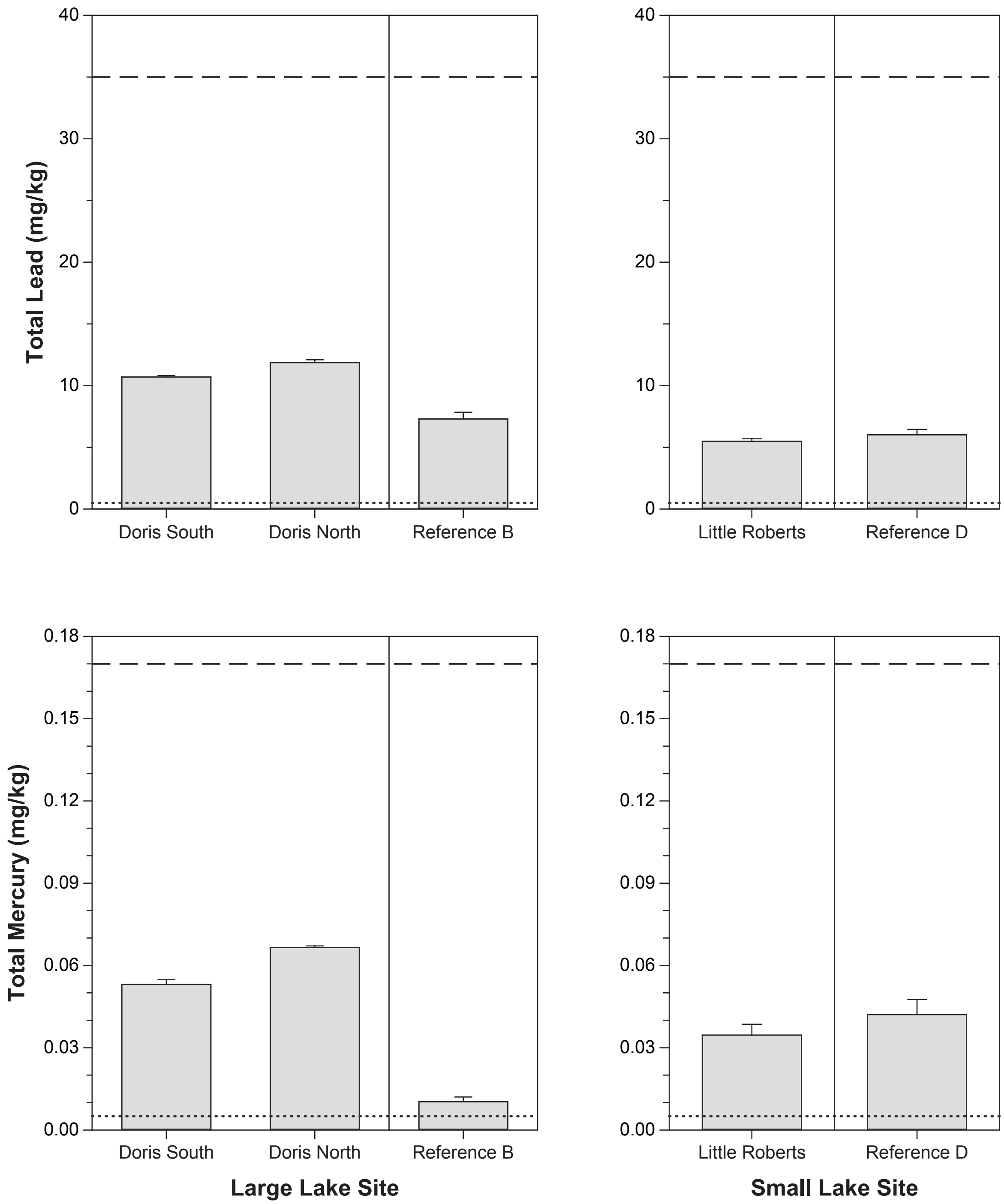
Total Chromium and Total Copper Concentrations in Lake Sediments, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the detection limit.
Dashed lines represent the CCME freshwater interim sediment quality guidelines (ISQGs) for chromium (37.3 mg/kg) and copper (35.7 mg/kg) and the probable effects level (PEL) for chromium (90 mg/kg); the PEL for copper (197 mg/kg) is not shown.

Figure A.4-9

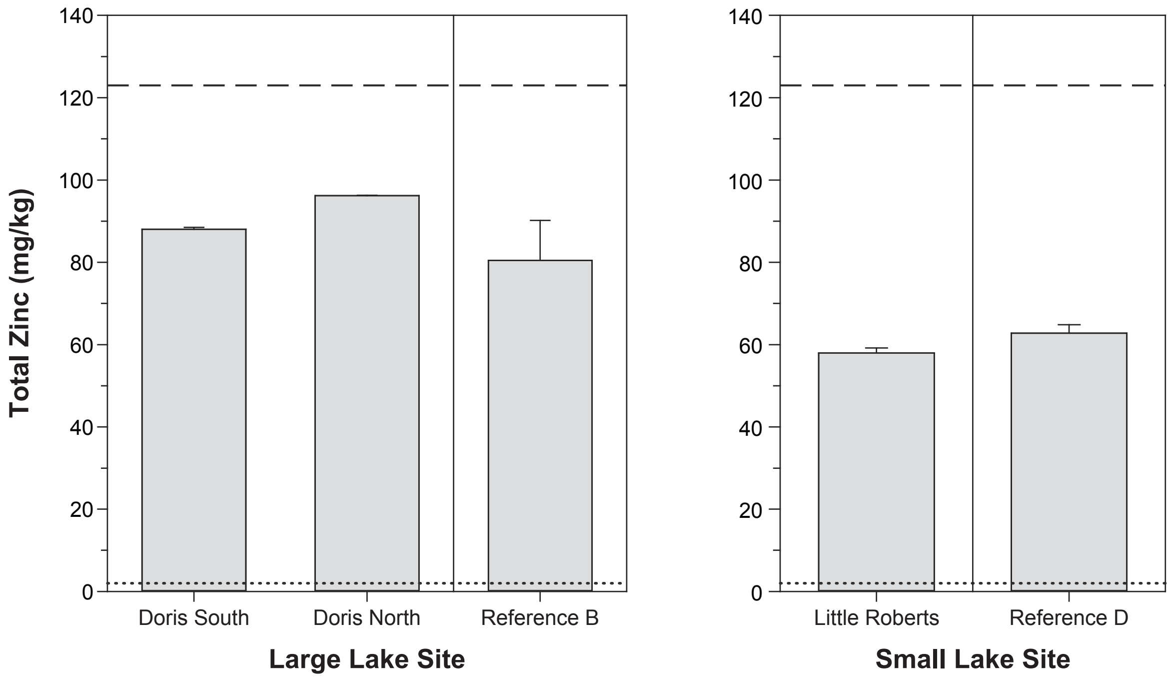
Total Lead and Total Mercury Concentrations in Lake Sediments, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the detection limit.
Dashed lines represent the CCME freshwater interim sediment quality guidelines (ISQGs) for lead (35 mg/kg) and mercury (0.17 mg/kg); probable effects levels (PELs) for lead (91.3 mg/kg) and mercury (0.486 mg/kg) are not shown.

Figure A.4-10

Total Zinc Concentrations in Lake Sediments, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the detection limit.
Dashed line represents the CCME freshwater interim sediment quality guideline (ISQG) for zinc (123 mg/kg); the probable effects level (PEL) for zinc (315 mg/kg) is not shown.

Annex A.4-2. Lake Sediment Quality Data, Doris North Project, 2015

Site ID:		CCME Guidelines for the Protection of Aquatic Life[a]		Realized Detection Limit	Doris South	Doris South	Doris South	Doris North	Doris North	Doris North	Reference B	Reference B	Reference B	Little Roberts	Little Roberts	Little Roberts	Reference D	Reference D	Reference D
Date Sampled:					5-Aug-15	5-Aug-15	5-Aug-15	5-Aug-15	5-Aug-15	5-Aug-15	11-Aug-15	11-Aug-15	11-Aug-15	10-Aug-15	10-Aug-15	10-Aug-15	9-Aug-15	9-Aug-15	9-Aug-15
Replicate:					1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Depth Sampled (m):					11.0	10.0	9.9	14.0	14.0	14.0	10.0	10.0	10.0	2.7	2.7	2.3	2.5	4.0	2.7
ALS Sample ID:	Unit	ISQG[b]	PEL[c]		L1654844-4	L1654844-5	L1654844-6	L1654844-1	L1654844-2	L1654844-3	L1658147-1	L1658147-2	L1658147-3	L1656633-4	L1656633-5	L1656633-6	L1656633-1	L1656633-2	L1656633-3
Physical Tests																			
Moisture	%			0.25	75.7	75.7	73.8	74.4	74.8	75.9	41.7	63.2	68.0	69.2	59.8	62.4	74.5	74.4	64.6
pH	pH			0.10	6.33	6.44	6.47	6.08	6.12	6.06	5.61	5.07	5.39	6.19	6.17	6.22	5.66	5.67	5.74
Particle Size																			
% Gravel (>2 mm)	%			0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.36	0.16	1.24	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
% Sand (2.0 mm - 0.063 mm)	%			0.10	1.90	2.11	3.34	1.50	1.48	1.85	12.0	16.7	11.1	14.3	19.6	24.5	5.85	11.7	6.64
% Silt (0.063 mm - 4 µm)	%			0.10	51.5	54.5	53.5	50.8	48.6	49.3	57.2	45.0	48.8	65.6	60.3	57.6	79.2	72.4	68.6
% Clay (<4 µm)	%			0.10	46.6	43.4	43.2	47.7	50	48.9	30.5	38.2	38.8	20.1	20.1	17.9	14.9	15.9	24.7
Texture	-			-	Silt Clay loam / Silty clay	Silty clay loam	Silty clay loam	Silty clay	Silty clay	Silty clay	Silt loam	Silty clay loam	Silty clay loam	Silt loam	Silt loam	Silt loam	Silt	Silt loam	Silt loam
Anions and Nutrients																			
Total Nitrogen	%			0.020	0.351	0.352	0.290	0.323	0.378	0.376	0.090	0.144	0.176	0.237	0.236	0.249	0.345	0.458	0.288
Organic / Inorganic Carbon																			
Total Organic Carbon	%			0.10	2.85	2.84	2.70	3.07	3.14	3.17	0.50	1.09	1.15	1.70	1.72	2.21	3.82	3.91	2.74
Plant Available Nutrients																			
Available Ammonium-N	mg/kg			1.0 or 1.6	34.8	28.9	26.0	37.7	39.0	38.9	5.4	6.2	3.9	9.5	10.3	17.9	17.0	37.2	24.5
Nitrate+Nitrite-N	mg/kg			2.0 or 4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<2.0	<2.0	<2.0	<2.0	<2.0	<4.0	<4.0	<4.0	<4.0
Available Nitrate-N	mg/kg			2.0 or 4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<2.0	<2.0	<2.0	<2.0	<2.0	<4.0	<4.0	<4.0	<4.0
Available Nitrite-N	mg/kg			0.4 or 0.8	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	<0.40	<0.40	<0.40	<0.40	<0.40	<0.80	<0.80	<0.80	<0.80
Available Phosphate-P	mg/kg			2.0	2.2	2.1	2.1	2.3	2.2	2.4	2.9	22.2	7.2	3.6	4.7	3.4	9.5	8.3	3.9
Metals																			
Aluminum (Al)	mg/kg			50	22700	23000	23100	24900	25200	24800	15800	20700	23400	16100	15200	13700	14500	15800	17800
Antimony (Sb)	mg/kg			0.10	<0.10	0.10	<0.10	0.11	<0.10	0.10	0.18	0.22	0.13	<0.10	<0.10	<0.10	<0.10	<0.10	0.10
Arsenic (As)	mg/kg	5.9	17	0.10	17.7	16.7	16.8	15.1	7.89	11.7	6.02	5.49	4.49	3.19	2.97	3.68	2.44	2.66	3.29
Barium (Ba)	mg/kg			0.50	169	164	168	160	153	154	89.2	128	145	88.7	89.3	78.9	80.4	82.8	108
Beryllium (Be)	mg/kg			0.10	0.78	0.80	0.77	0.89	0.86	0.87	0.55	0.67	0.73	0.47	0.46	0.41	0.48	0.48	0.57
Bismuth (Bi)	mg/kg			0.20	0.25	0.25	0.24	0.28	0.26	0.27	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	mg/kg			5.00	18.2	18.7	18.4	20.2	20.1	18.9	14.2	15.7	15.4	11.7	11.4	10.5	11.6	12.1	13.6
Cadmium (Cd)	mg/kg	0.6	3.5	0.050	0.126	0.133	0.132	0.123	0.110	0.117	0.210	0.345	0.583	0.078	0.070	0.065	0.096	0.092	0.080
Calcium (Ca)	mg/kg			50	5770	6070	5930	6220	6380	6130	4210	4720	4570	5220	5030	4510	5150	5150	5690
Chromium (Cr)	mg/kg	37.3	90	0.50	66.3	65.6	66.2	73.3	72.1	73.4	43.6	54.9	59.9	45.1	43.4	39.7	40.0	42.0	51.5
Cobalt (Co)	mg/kg			0.10	15.2	15.3	14.8	15.8	14.9	15.6	16.2	16.6	14.4	9.74	9.23	9.09	8.94	8.71	10.2
Copper (Cu)	mg/kg	35.7	197	0.50	35.3	35.6	34.5	38.5	38.8	39.4	17.9	23.3	27.2	20.8	19.3	19.9	22.7	25.0	25.5
Iron (Fe)	mg/kg			50	56000	55900	54200	57100	47200	53900	25900	26600	35500	23600	22800	23300	19100	21400	24500
Lead (Pb)	mg/kg	35	91.3	0.50	10.9	10.7	10.5	12.1	11.4	12.1	6.34	7.36	8.21	5.88	5.39	5.24	5.56	5.58	6.90
Lithium (Li)	mg/kg			2.0	36.5	36.5	35.1	41.8	43	41.8	27.2	40.4	39.2	25.2	24.1	22.3	24.1	24.3	30.6
Magnesium (Mg)	mg/kg			20	12700	13200	12700	13900	14600	14000	8150	10200	10700	10200	9800	8850	8410	8900	11100
Manganese (Mn)	mg/kg			1.0	2260	2370	2160	1070	574	816	249	285	384	315	301	313	274	275	305
Mercury (Hg)	mg/kg	0.17	0.486	0.0050	0.0558	0.0535	0.0500	0.0664	0.0676	0.0657	0.0069	0.0125	0.0115	0.0267	0.0390	0.0381	0.0530	0.0381	0.0351
Molybdenum (Mo)	mg/kg			0.10	2.39	2.76	2.66	1.46	1.07	1.30	2.10	2.18	3.88	1.03	0.93	0.82	0.82	1.13	1.19
Nickel (Ni)	mg/kg			0.50	43.0	43.5	42.2	46.0	44.9	46.0	27.1	31.9	32.3	24.4	23.6	21.8	23.4	24.2	27.6
Phosphorus (P)	mg/kg			50	1250	1220	1250	1410	1180	1320	630	722	869	735	736	743	751	851	662
Potassium (K)	mg/kg			100	5780	5820	5830	6460	6280	6070	3990	4700	4720	3870	3820	3640	3490	3580	4900
Selenium (Se)	mg/kg			0.20	0.39	0.40	0.35	0.37	0.34	0.37	0.39	0.58	0.60	<0.20	<0.20	<0.20	0.21	0.23	0.22
Silver (Ag)	mg/kg			0.10	0.11	0.12	0.11	0.22	0.26	0.32	<0.10	0.11	0.12	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sodium (Na)	mg/kg			50	1530	1500	1470	1560	1580	1550	516	529	428	942	858	796	832	764	886
Strontium (Sr)	mg/kg			0.50	40.2	42.7	43.1	42.9	42.4	41.5	31.3	34.6	35.6	28.1	27.8	25.2	29.5	29.5	32.9
Sulphur (S)	mg/kg			500	1400	1300	1200	1200	1300	1400	1700	5300	2500	1100	900	1500	2900	2100	1300
Thallium (Tl)	mg/kg			0.050	0.288	0.291	0.285	0.301	0.305	0.301	0.252	0.367	0.406	0.198	0.172	0.159	0.165	0.168	0.207
Tin (Sn)	mg/kg			2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (Ti)	mg/kg			1.0	1280	1320	1300	1400	1460	1370	1090	1260	1320	1180	1160	1050	1070	1100	1410
Uranium (U)	mg/kg			0.050	2.60	2.62	2.56	2.63	2.42	2.59	1.66	2.22	3.56	1.42	1.29	1.36	2.19	2.23	2.27
Vanadium (V)	mg/kg			0.20	77.9	79.6	77.5	84.6	82.3	82.5	48.5	62.7	69.8	54.3	52.1	49.6	46.9	50.1	63.2
Zinc (Zn)	mg/kg	123	315	1.0	87.9	88.9	87.3	96.1	96.4	96.1	61.1	91.7	88.6	60.3	57.5	56.2	60.8	60.6	66.9

Notes:

Shaded cells indicate values that exceed CCME guidelines (light grey ISQG, dark grey PEL).

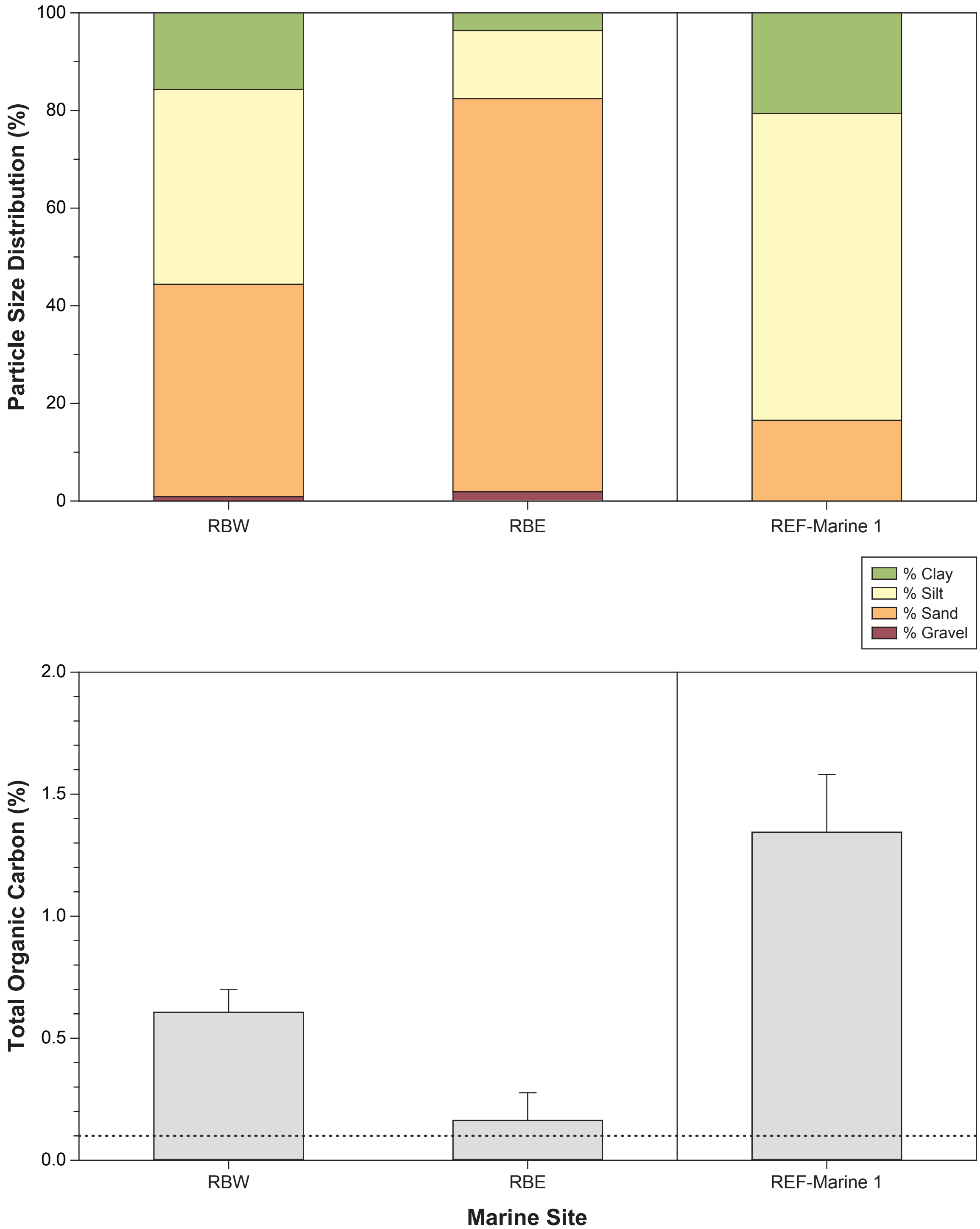
[a] *Canadian sediment quality guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment, Accessed 2015.*

[b] *ISQG = Interim Sediment Quality Guideline*

[c] *PEL = Probable Effects Level*

Figure A.4-11

Particle Size Distribution and Total Organic Carbon Concentration in Marine Sediments, Doris North Project, August 2015

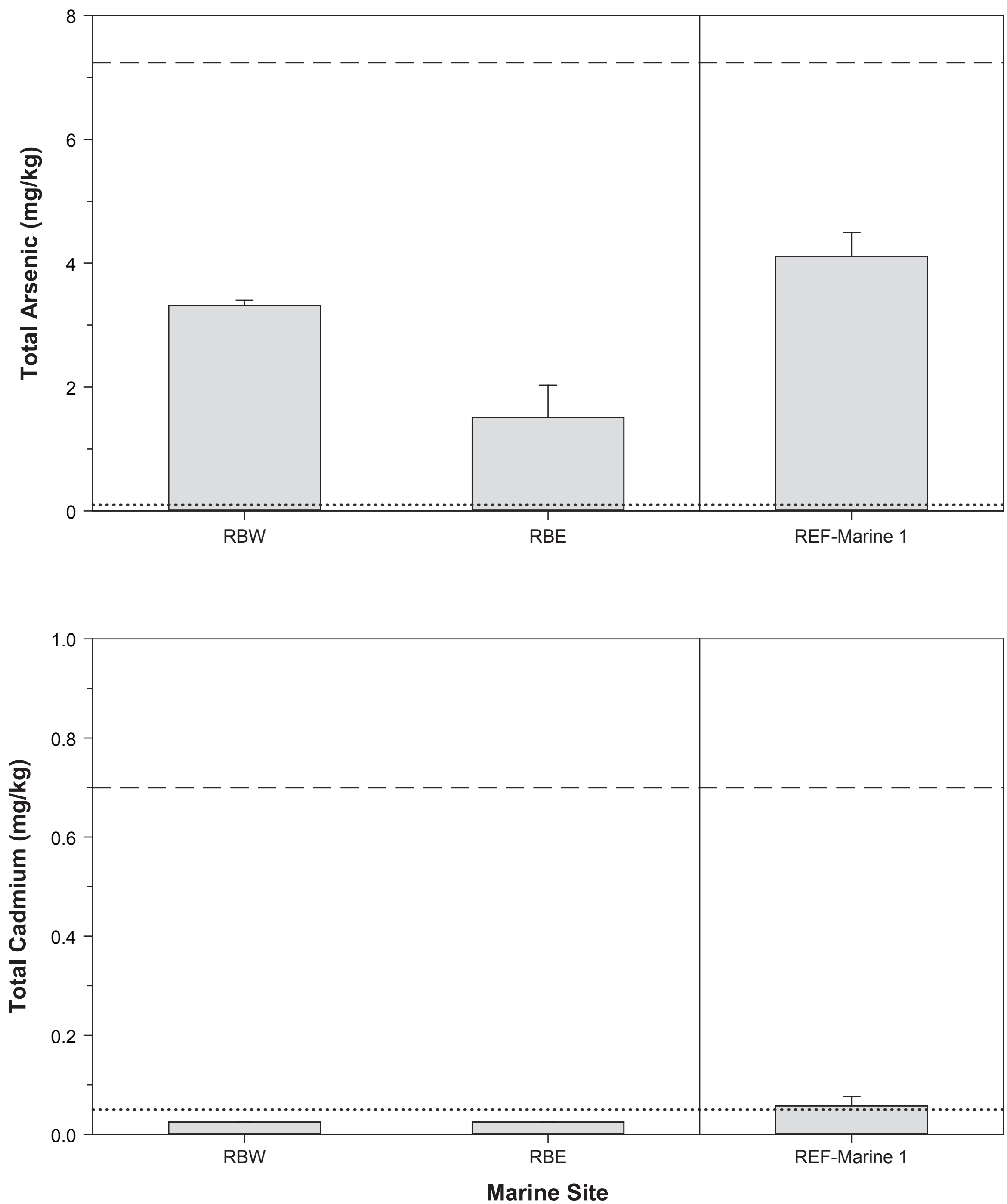


Notes: Error bars represent the standard error of the mean of replicates.
Stacked bars represent the mean of replicate samples.
Dotted line represents the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Particle size distribution and total organic carbon content of sediments are required parameters as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure A.4-12

Total Arsenic and Total Cadmium Concentrations in Marine Sediments, Doris North Project, August 2015

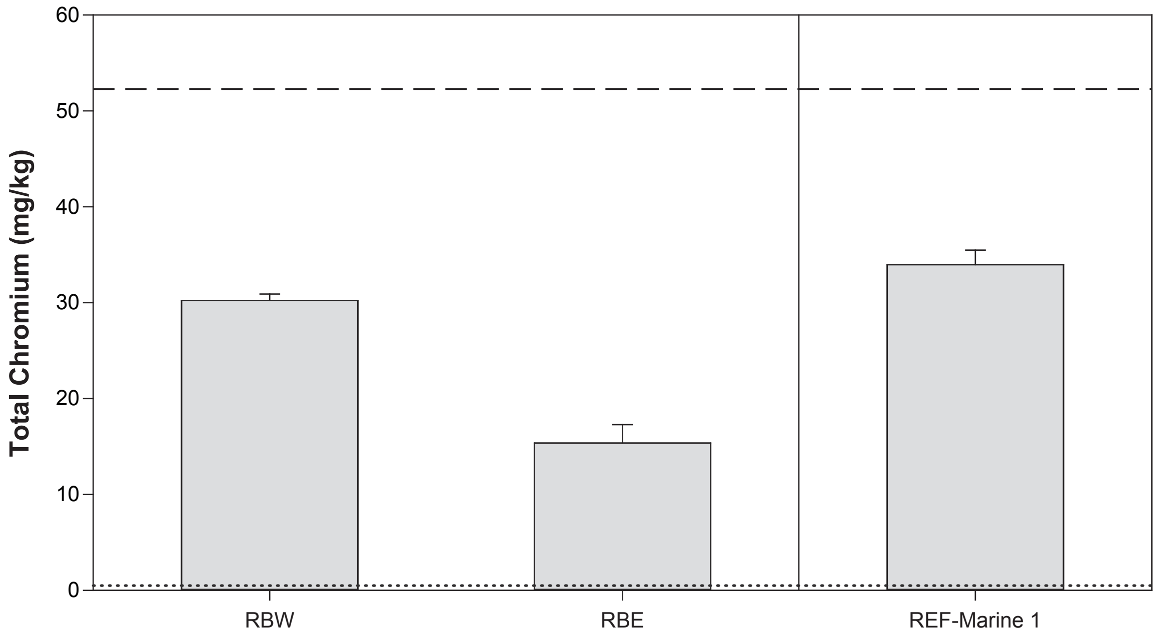
ERM

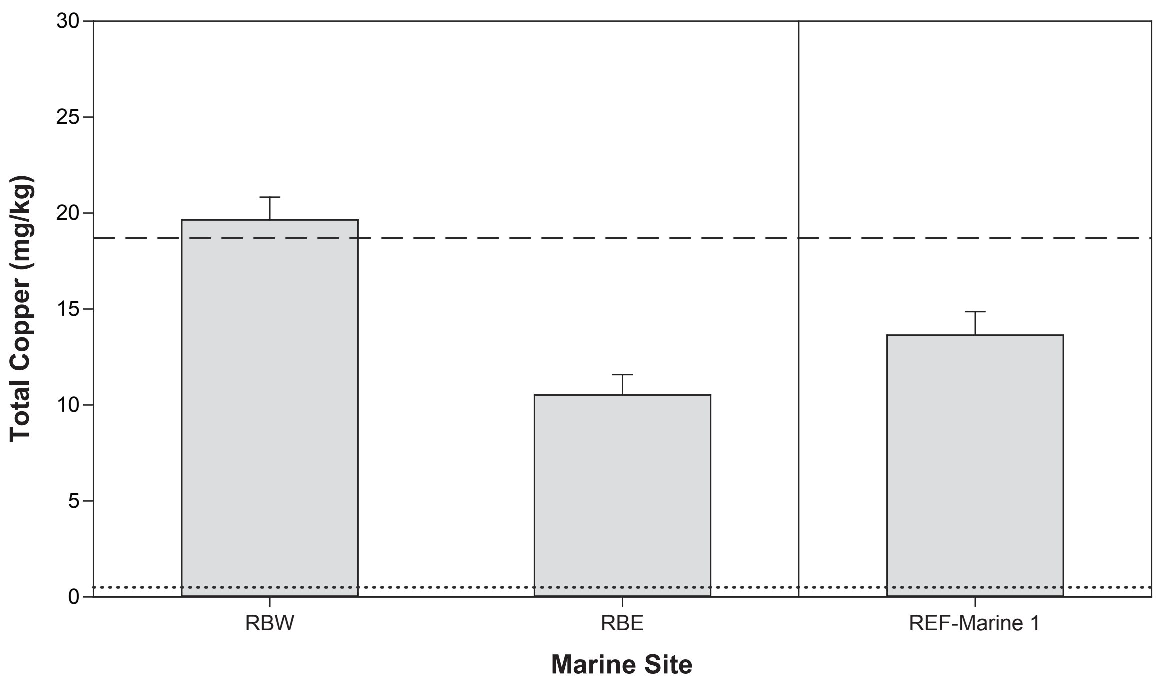


Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the detection limit.
Dashed lines represent the CCME marine and estuarine interim sediment quality guidelines (ISQGs) for arsenic (7.24 mg/kg) and cadmium (0.7 mg/kg); probable effects levels (PELs) for arsenic (41.6 mg/kg) and cadmium (4.2 mg/kg) are not shown.

Figure A.4-13

Total Chromium and Total Copper Concentrations in Marine Sediments, Doris North Project, August 2015

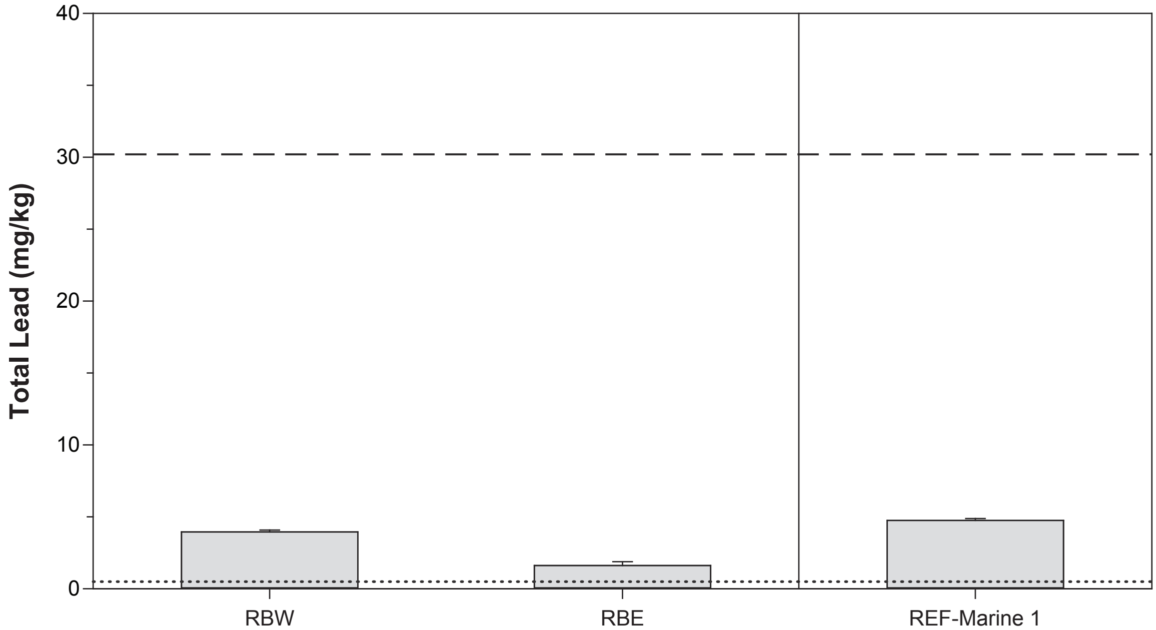


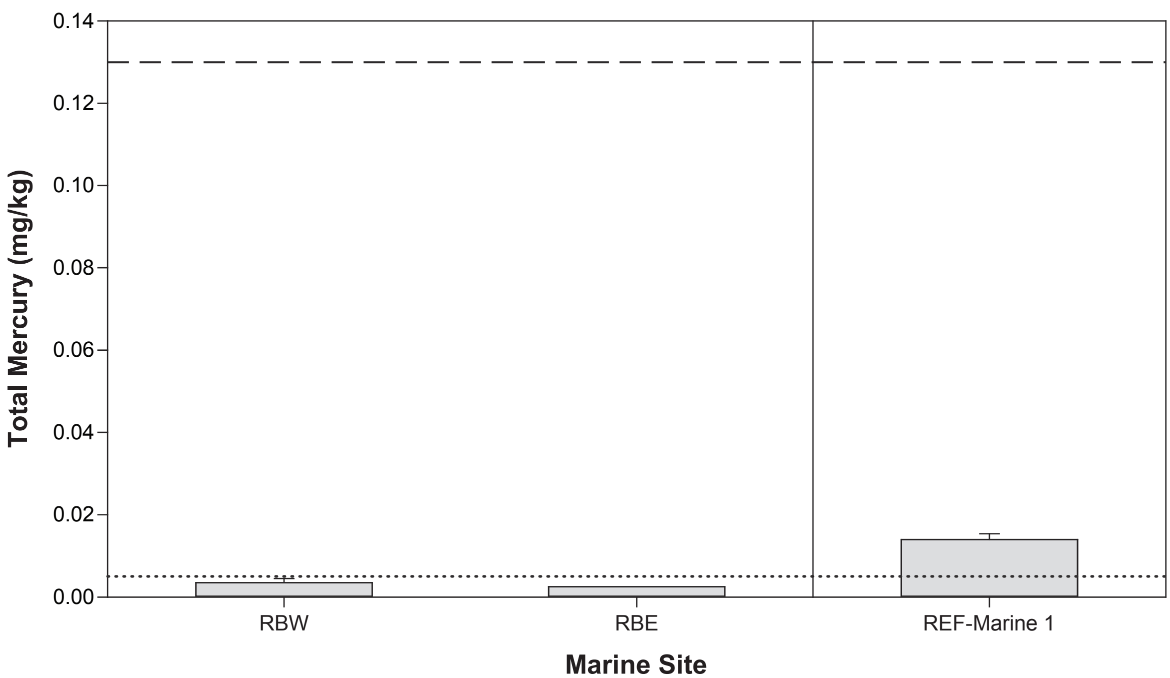


Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the detection limit.
Dashed lines represent the CCME marine and estuarine interim sediment quality guidelines (ISQGs) for chromium (52.3 mg/kg) and copper (18.7 mg/kg); probable effects levels (PELs) for chromium (160 mg/kg) and copper (108 mg/kg) are not shown.

Figure A.4-14

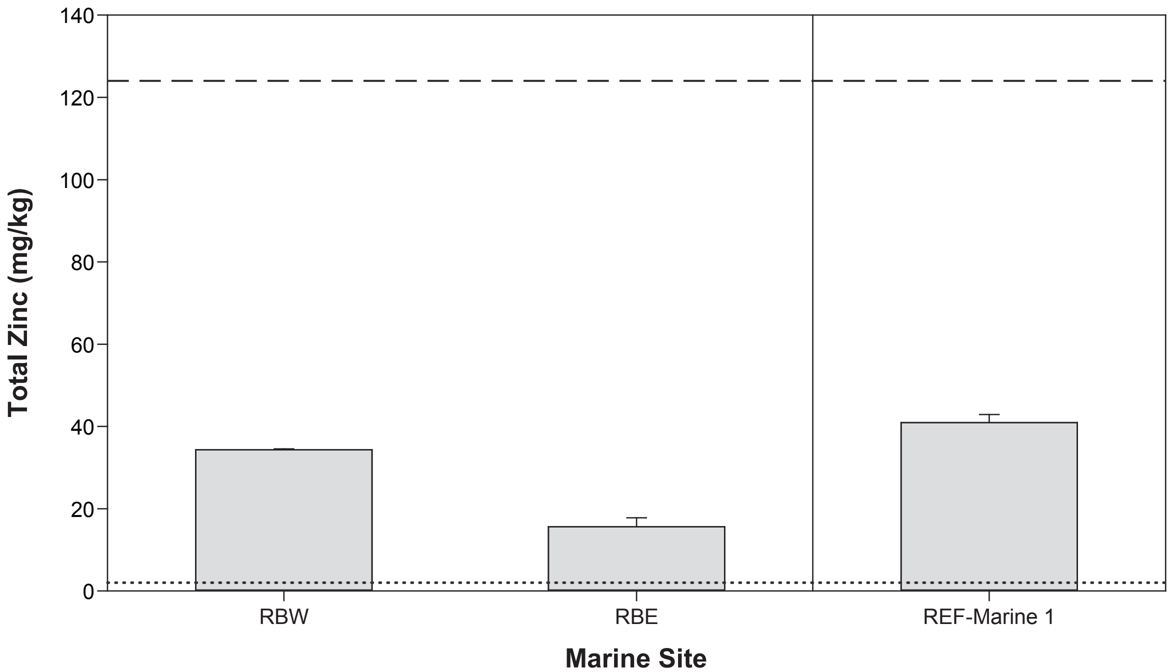
Total Lead and Total Mercury Concentrations in Marine Sediments, Doris North Project, August 2015





Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the detection limit.
Dashed lines represent the CCME marine and estuarine interim sediment quality guidelines (ISQGs) for lead (30.2 mg/kg) and mercury (0.13 mg/kg); probable effects levels (PELs) for lead (112 mg/kg) and mercury (0.7 mg/kg) are not shown.

Total Zinc Concentrations in Marine Sediments, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the detection limit.
Dashed line represents the CCME marine and estuarine interim sediment quality guideline (ISQG) for zinc (124 mg/kg); the probable effects level (PEL) for zinc (271 mg/kg) is not shown.

Annex A.4-3. Marine Sediment Quality Data, Doris North Project, 2015

Site ID:		CCME Guidelines for the Protection of Aquatic Life[a]		Realized Detection Limit	RBW	RBW	RBW	RBE	RBE	RBE	REF- Marine 1	REF- Marine 1	REF- Marine 1
Date Sampled:					6-Aug-15	6-Aug-15	6-Aug-15	7-Aug-15	7-Aug-15	7-Aug-15	8-Aug-15	8-Aug-15	8-Aug-15
Replicate:					1	2	3	1	2	3	1	2	3
Depth Sampled (m):					4.9	5.2	5.3	0.5	0.8	1.8	6.2	8.5	9.8
ALS Sample ID:	Unit	ISQG[b]	PEL[c]		L1654855-1	L1654855-2	L1654855-3	L1654855-4	L1654855-5	L1654855-6	L1656626-1	L1656626-2	L1656626-3
Physical Tests													
Moisture	%			0.25	26.2	39.5	32.0	15.3	17.8	39.6	51.7	43.9	58.1
pH	pH			0.10	8.11	7.72	7.65	6.96	7.24	7.75	7.56	7.51	7.59
Particle Size													
% Gravel (>2 mm)	%			0.10	1.79	<0.10	0.86	1.82	3.84	<0.10	<0.10	<0.10	<0.10
% Sand (2.0 mm - 0.063 mm)	%			0.10	41.1	45.5	44.0	93.7	88.7	59.2	17.1	17.4	15.0
% Silt (0.063 mm - 4 µm)	%			0.10	40.1	39.2	40.3	3.3	6.2	32.4	63.5	64.8	60.3
% Clay (<4 µm)	%			0.10	17.0	15.2	14.8	1.2	1.3	8.4	19.4	17.8	24.7
Texture	-			-	Loam	Loam / Sandy loam	Loam / Sandy loam	Sand	Sand	Sandy loam	Silt loam	Silt loam	Silt loam
Anions and Nutrients													
Total Nitrogen	%			0.020	0.04	0.04	0.03	<0.020	<0.020	0.04	0.19	0.14	0.23
Organic / Inorganic Carbon													
Total Organic Carbon	%			0.10	0.75	0.64	0.43	<0.10	<0.10	0.39	1.49	0.88	1.66
Plant Available Nutrients													
Available Ammonium-N	mg/kg			1.0 or 1.6	7.8	16.9	6.4	<1.0	<1.0	4.1	11.6	5.8	14.9
Nitrate+Nitrite-N	mg/kg			2.0 or 4.0	<4.0	<4.0	<4.0	<2.0	<2.0	<4.0	<4.0	<2.0	2.0
Available Nitrate-N	mg/kg			2.0 or 4.0	<4.0	<4.0	<4.0	<2.0	<2.0	<4.0	<4.0	<2.0	2.0
Available Nitrite-N	mg/kg			0.4 or 0.8	<0.80	<0.80	<0.80	<0.40	<0.40	<0.80	<0.80	<0.40	<0.40
Available Phosphate-P	mg/kg			2.0	16.4	24.6	17.5	3.7	3.2	14.7	35.3	30.8	27.3
Metals													
Aluminum (Al)	mg/kg			50	9680	9310	9120	4040	3440	6140	12800	11200	12900
Antimony (Sb)	mg/kg			0.10	0.11	0.19	<0.10	<0.10	<0.10	<0.10	0.13	0.13	0.17
Arsenic (As)	mg/kg	7.24	41.6	0.10	3.32	3.46	3.17	0.95	1.04	2.55	3.88	3.59	4.87
Barium (Ba)	mg/kg			0.50	41.2	38.7	40.4	9.41	11.1	22.6	59.5	51.7	62.0
Beryllium (Be)	mg/kg			0.10	0.26	0.24	0.26	<0.10	<0.10	0.17	0.37	0.33	0.39
Bismuth (Bi)	mg/kg			0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)	mg/kg			5.0	14.0	14.1	14.0	<5.0	<5.0	8.9	28.8	24.8	38.0
Cadmium (Cd)	mg/kg	0.7	4.2	0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.056	<0.050	0.091
Calcium (Ca)	mg/kg			50	4620	3910	4110	1680	1720	3230	5560	5140	5680
Chromium (Cr)	mg/kg	52.3	160	0.50	31.6	29.6	29.5	12.5	14.6	19.0	34.0	31.3	36.6
Cobalt (Co)	mg/kg			0.10	7.02	6.58	6.20	3.78	4.86	4.61	6.60	6.21	7.17
Copper (Cu)	mg/kg	18.7	108	0.50	20.4	21.2	17.3	12.2	8.55	10.8	13.9	11.4	15.6
Iron (Fe)	mg/kg			50	17800	16500	15700	9360	12200	11600	17900	16800	19200
Lead (Pb)	mg/kg	30.2	112	0.50	4.11	4.07	3.68	1.26	1.47	2.13	4.77	4.50	4.97
Lithium (Li)	mg/kg			2.0	14.7	13.6	14.8	7.0	6.4	10.0	22.8	20.2	24.1
Magnesium (Mg)	mg/kg			20	7560	7340	6990	3470	3010	4690	9320	8390	10500
Manganese (Mn)	mg/kg			1.0	196	179	173	88.7	81.8	116	205	180	203
Mercury (Hg)	mg/kg	0.13	0.7	0.0050	0.0055	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	0.0159	0.0113	0.0148
Molybdenum (Mo)	mg/kg			0.10	0.57	0.58	0.70	0.13	0.32	0.67	0.76	0.69	1.94
Nickel (Ni)	mg/kg			0.50	16.3	15.9	15.1	7.92	7.57	10.1	16.4	15.2	18.2
Phosphorus (P)	mg/kg			50	584	569	563	257	293	526	889	844	939
Potassium (K)	mg/kg			100	2670	2730	2790	600	590	1600	4300	3630	4740
Selenium (Se)	mg/kg			0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	0.32	0.22	0.47
Silver (Ag)	mg/kg			0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Sodium (Na)	mg/kg			50	3070	6280	4510	1090	1470	3630	8420	8520	14000
Strontium (Sr)	mg/kg			0.50	21.0	21.9	22.7	7.57	7.82	18.6	41.4	34.1	47.3
Sulphur (S)	mg/kg			500	1300	1400	1300	800	800	1200	2000	1500	3200
Thallium (Tl)	mg/kg			0.050	0.103	0.094	0.099	<0.050	<0.050	0.065	0.143	0.136	0.151
Tin (Sn)	mg/kg			2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Titanium (Ti)	mg/kg			1.0	804	758	770	330	353	531	1010	913	988
Uranium (U)	mg/kg			0.050	0.701	0.715	0.743	0.362	0.392	0.562	1.23	1.05	1.80
Vanadium (V)	mg/kg			0.20	40.4	38.5	38.0	21.6	31.9	27.5	44.3	41.1	48.7
Zinc (Zn)	mg/kg	124	271	2.0	34.2	34.0	34.8	13.8	13.0	20.0	40.6	37.7	44.5

Notes:

Shaded cells indicate values that exceed CCME guidelines (light grey ISQG, dark grey PEL).

[a] *Canadian sediment quality guidelines for the protection of marine aquatic life, Canadian Council of Ministers of the Environment, Accessed 2015.*

[b] *ISQG = Interim Sediment Quality Guideline*

[c] *PEL = Probable Effects Level*

A.5 2015 PRIMARY PRODUCERS

The following sections present the periphyton and phytoplankton biomass (as chlorophyll *a*) data collected from April to September 2015 at stream, lake, and marine sites.

A.5.1 Stream Data

Stream periphyton sampling plates were installed three times in AEMP streams in 2015 (in June, July, and August), and were retrieved after approximately one month (in July, August, and September, respectively). Figure A.5-1 shows the average periphyton biomass measured in streams. Annex A.5-1 presents the full periphyton biomass dataset.

A.5.2 Lake Data

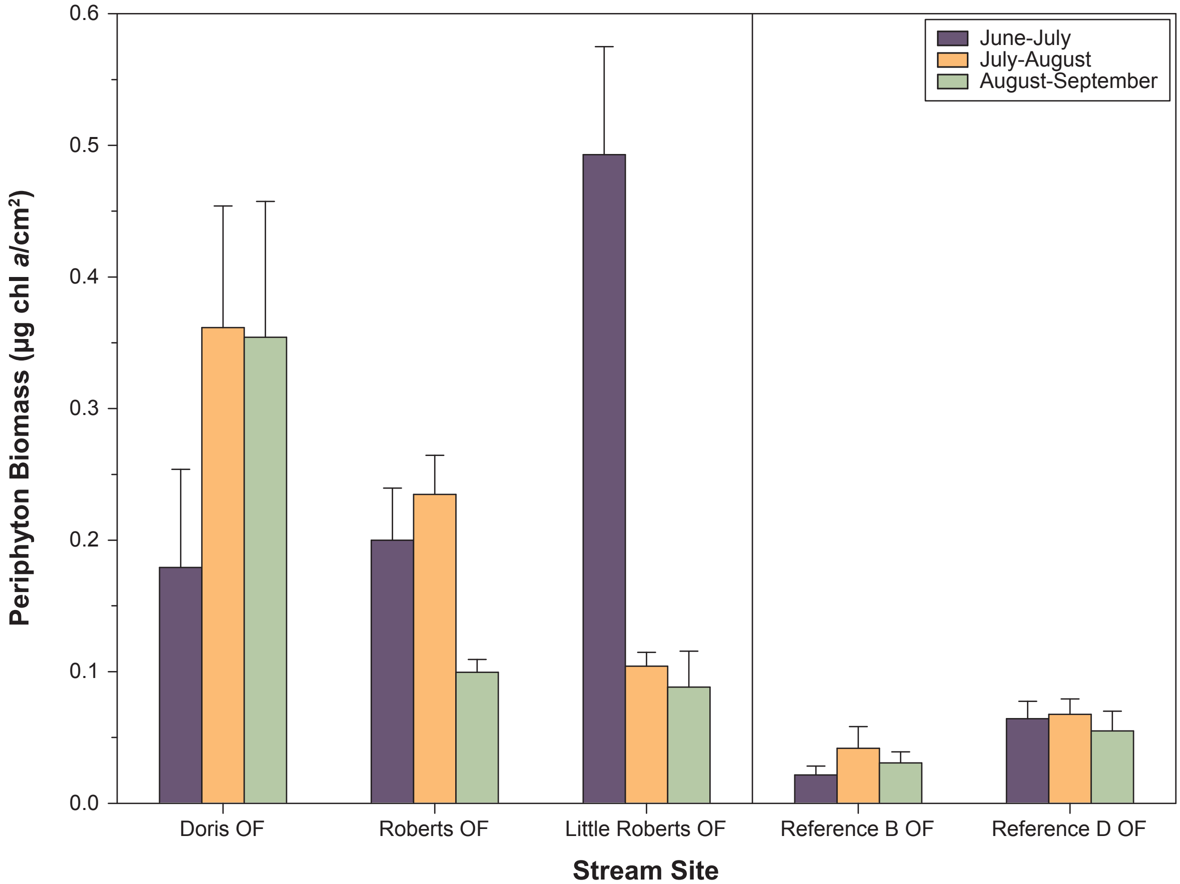
Lake phytoplankton samples were collected in April (under-ice sampling) and monthly from July to September 2015. Figure A.5-2 shows the average phytoplankton biomass measured in lakes. Annex A.5-2 presents the full phytoplankton biomass dataset.

A.5.3 Marine Data

Marine phytoplankton samples were collected in April (under-ice sampling) and monthly from July to September 2015. Figure A.5-3 shows the average phytoplankton biomass measured at marine sites. Annex A.5-3 presents the full phytoplankton biomass dataset.

Figure A.5-1

Periphyton Biomass (as Chlorophyll *a*) in Stream Sites, Doris North Project, 2015



Notes: Error bars represent the standard error of the mean.
The analytical detection limit for chlorophyll a was either 0.01 or 0.1 µg; all chlorophyll a concentrations were higher than detection limits.

Annex A.5-1. Stream Periphyton Biomass Data, Doris North Project, 2015

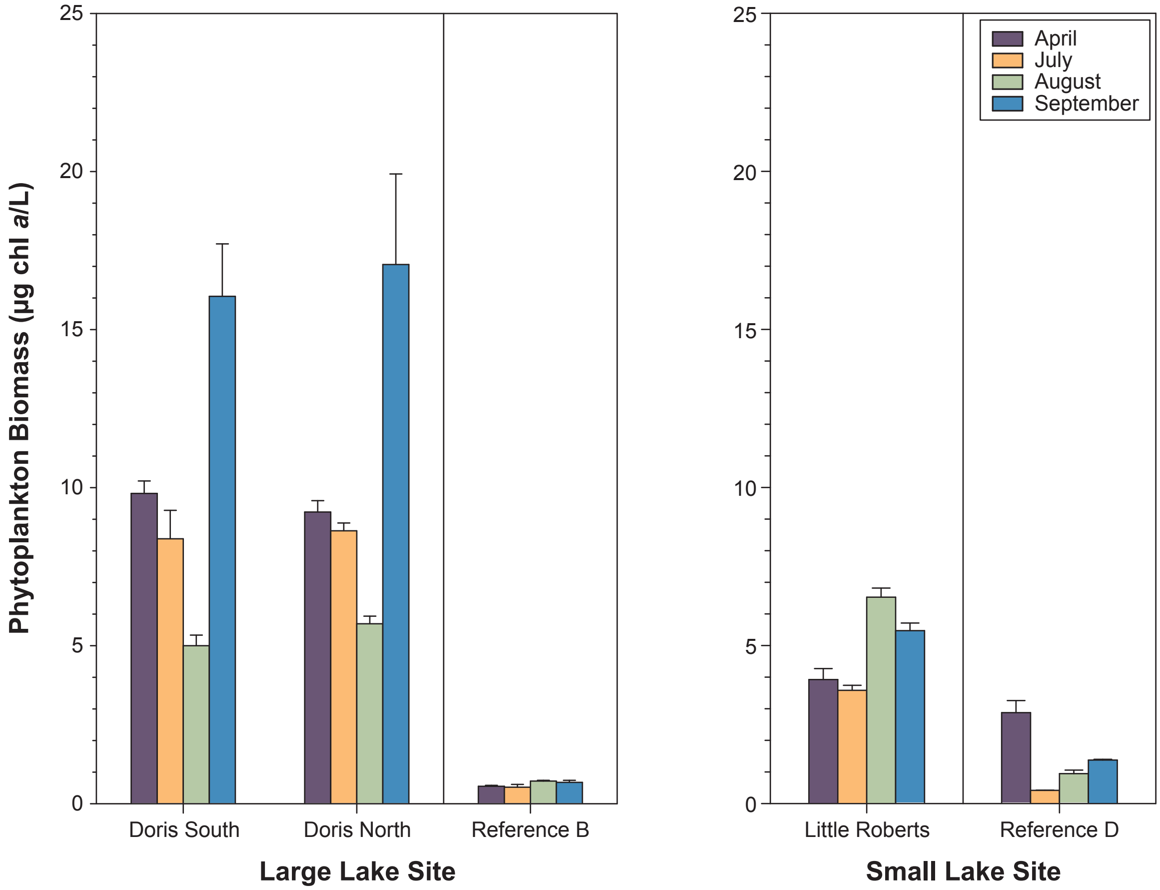
Stream Site	Date Sampler Installed	Date Sampler Retrieved	Number of Days Immersed	Area sampled (cm^2)	ALS Sample ID	Replicate #	Periphyton Biomass (µg chl *a* /cm^2)	Mean	SE
Doris OF	14-Jun-15	17-Jul-15	33	100	L1646380-19	1	0.123	0.179	0.074
Doris OF	14-Jun-15	17-Jul-15	33	100	L1646380-20	2	0.089		
Doris OF	14-Jun-15	17-Jul-15	33	100	L1646380-21	3	0.327		
Doris OF	17-Jul-15	15-Aug-15	29	100	L1660732-7	1	0.363	0.362	0.092
Doris OF	17-Jul-15	15-Aug-15	29	100	L1660732-8	2	0.201		
Doris OF	17-Jul-15	15-Aug-15	29	100	L1660732-9	3	0.521		
Doris OF	15-Aug-15	17-Sep-15	33	100	L1677514-28	1	0.227	0.354	0.103
Doris OF	15-Aug-15	17-Sep-15	33	100	L1677514-29	2	0.559		
Doris OF	15-Aug-15	17-Sep-15	33	100	L1677514-30	3	0.277		
Roberts OF	13-Jun-15	18-Jul-15	35	100	L1646380-16	1	0.199	0.200	0.040
Roberts OF	13-Jun-15	18-Jul-15	35	100	L1646380-17	2	0.132		
Roberts OF	13-Jun-15	18-Jul-15	35	100	L1646380-18	3	0.269		
Roberts OF	18-Jul-15	15-Aug-15	28	100	L1660732-10	1	0.179	0.235	0.030
Roberts OF	18-Jul-15	15-Aug-15	28	100	L1660732-11	2	0.280		
Roberts OF	18-Jul-15	15-Aug-15	28	100	L1660732-12	3	0.246		
Roberts OF	15-Aug-15	20-Sep-15	36	100	L1677514-37	1	0.086	0.099	0.010
Roberts OF	15-Aug-15	20-Sep-15	36	100	L1677514-38	2	0.119		
Roberts OF	15-Aug-15	20-Sep-15	36	100	L1677514-39	3	0.094		
Little Roberts OF†	13-Jun-15	17-Jul-15	34	100	L1646380-28	1	0.411	0.493	0.082
Little Roberts OF†	13-Jun-15	17-Jul-15	34	100	L1646380-29	2	0.575		
Little Roberts OF	17-Jul-15	14-Aug-15	28	100	L1660732-4	1	0.092	0.104	0.010
Little Roberts OF	17-Jul-15	14-Aug-15	28	100	L1660732-5	2	0.125		
Little Roberts OF	17-Jul-15	14-Aug-15	28	100	L1660732-6	3	0.095		
Little Roberts OF	14-Aug-15	16-Sep-15	33	100	L1677514-25	1	0.086	0.088	0.027
Little Roberts OF	14-Aug-15	16-Sep-15	33	100	L1677514-26	2	0.137		
Little Roberts OF	14-Aug-15	16-Sep-15	33	100	L1677514-27	3	0.042		
Reference B OF	14-Jun-15	16-Jul-15	32	100	L1646380-25	1	0.015	0.022	0.007
Reference B OF	14-Jun-15	16-Jul-15	32	100	L1646380-26	2	0.015		
Reference B OF	14-Jun-15	16-Jul-15	32	100	L1646380-27	3	0.035		
Reference B OF	16-Jul-15	13-Aug-15	28	100	L1660732-1	1	0.013	0.042	0.016
Reference B OF	16-Jul-15	13-Aug-15	28	100	L1660732-2	2	0.042		
Reference B OF	16-Jul-15	13-Aug-15	28	100	L1660732-3	3	0.070		
Reference B OF	13-Aug-15	18-Sep-15	36	100	L1677514-34	1	0.015	0.031	0.008
Reference B OF	13-Aug-15	18-Sep-15	36	100	L1677514-55	2	0.034		
Reference B OF	13-Aug-15	18-Sep-15	36	100	L1677514-56	3	0.043		
Reference D OF	14-Jun-15	17-Jul-15	33	100	L1646380-22	1	0.082	0.064	0.013
Reference D OF	14-Jun-15	17-Jul-15	33	100	L1646380-23	2	0.073		
Reference D OF	14-Jun-15	17-Jul-15	33	100	L1646380-24	3	0.038		
Reference D OF	17-Jul-15	16-Aug-15	30	100	L1660732-13	1	0.053	0.068	0.012
Reference D OF	17-Jul-15	16-Aug-15	30	100	L1660732-14	2	0.091		
Reference D OF	17-Jul-15	16-Aug-15	30	100	L1660732-15	3	0.059		
Reference D OF	16-Aug-15	16-Sep-15	31	100	L1677514-10	1	0.081	0.055	0.015
Reference D OF	16-Aug-15	16-Sep-15	31	100	L1677514-11	2	0.030		
Reference D OF	16-Aug-15	16-Sep-15	31	100	L1677514-12	3	0.054		

SE = standard error of the mean

† *Only two replicates were retrieved, the remaining plates installed in Little Roberts OF in June had flipped upside down, and were unusable.*

Figure A.5-2

Phytoplankton Biomass (as Chlorophyll *a*) in Lake Sites, Doris North Project, 2015



Notes: Error bars represent the standard error of the mean.
The analytical detection limit for chlorophyll a was either 0.01 or 0.1 µg; all chlorophyll a concentrations were higher than detection limits.

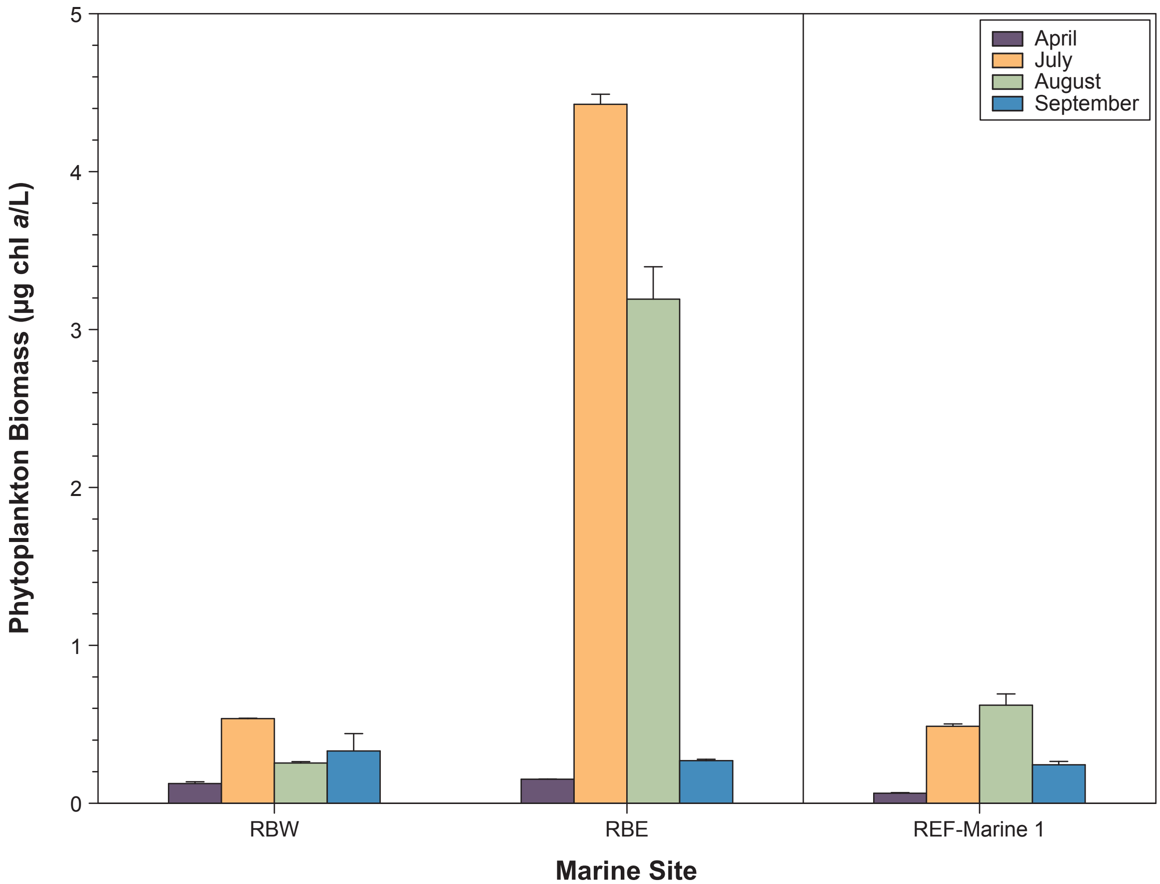
Annex A.5-2. Lake Phytoplankton Biomass Data, Doris North Project, 2015

Lake Site	Date Sampled	Depth Sampled (m)	ALS Sample ID	Replicate #	Phytoplankton Biomass (µg chl *a*/L)	Mean	SE
Doris Lake South	25-Apr-15	3	L1611669-13	1	10.0	9.82	0.40
Doris Lake South	25-Apr-15	3	L1611669-14	2	9.06		
Doris Lake South	25-Apr-15	3	L1611669-15	3	10.4		
Doris Lake South	18-Jul-15	1	L1646380-13	1	9.44	8.39	0.90
Doris Lake South	18-Jul-15	1	L1646380-14	2	6.60		
Doris Lake South	18-Jul-15	1	L1646380-15	3	9.12		
Doris Lake South	5-Aug-15	1	L1660702-4	1	5.18	5.00	0.33
Doris Lake South	5-Aug-15	1	L1660702-5	2	5.46		
Doris Lake South	5-Aug-15	1	L1660702-6	3	4.36		
Doris Lake South	17-Sep-15	1	L1677514-52	1	18.3	16.1	1.66
Doris Lake South	17-Sep-15	1	L1677514-53	2	12.8		
Doris Lake South	17-Sep-15	1	L1677514-54	3	17.1		
Doris Lake North	25-Apr-15	3	L1611669-10	1	9.94	9.23	0.36
Doris Lake North	25-Apr-15	3	L1611669-11	2	8.98		
Doris Lake North	25-Apr-15	3	L1611669-12	3	8.78		
Doris Lake North	18-Jul-15	1	L1646380-10	1	8.60	8.64	0.24
Doris Lake North	18-Jul-15	1	L1646380-11	2	9.08		
Doris Lake North	18-Jul-15	1	L1646380-12	3	8.24		
Doris Lake North	5-Aug-15	1	L1660702-1	1	5.22	5.69	0.24
Doris Lake North	5-Aug-15	1	L1660702-2	2	5.92		
Doris Lake North	5-Aug-15	1	L1660702-3	3	5.94		
Doris Lake North	17-Sep-15	1	L1677514-46	1	15.6	17.1	2.87
Doris Lake North	17-Sep-15	1	L1677514-47	2	22.6		
Doris Lake North	17-Sep-15	1	L1677514-48	3	13.0		
Reference Lake B	24-Apr-15	2.5	L1611669-4	1	0.5	0.550	0.029
Reference Lake B	24-Apr-15	2.5	L1611669-5	2	0.6		
Reference Lake B	24-Apr-15	2.5	L1611669-6	3	0.5		
Reference Lake B	16-Jul-15	1	L1646380-7	1	0.4	0.518	0.093
Reference Lake B	16-Jul-15	1	L1646380-8	2	0.5		
Reference Lake B	16-Jul-15	1	L1646380-9	3	0.7		
Reference Lake B	11-Aug-15	1	L1660702-13	1	0.8	0.715	0.023
Reference Lake B	11-Aug-15	1	L1660702-14	2	0.7		
Reference Lake B	11-Aug-15	1	L1660702-15	3	0.7		
Reference Lake B	18-Sep-15	1	L1677514-31	1	0.6	0.676	0.061
Reference Lake B	18-Sep-15	1	L1677514-32	2	0.8		
Reference Lake B	18-Sep-15	1	L1677514-33	3	0.6		
Little Roberts Lake	24-Apr-15	2.25	L1611669-7	1	4.52	3.92	0.35
Little Roberts Lake	24-Apr-15	2.25	L1611669-8	2	3.32		
Little Roberts Lake	24-Apr-15	2.25	L1611669-9	3	3.92		
Little Roberts Lake	15-Jul-15	1	L1646380-1	1	3.30	3.58	0.16
Little Roberts Lake	15-Jul-15	1	L1646380-2	2	3.84		
Little Roberts Lake	15-Jul-15	1	L1646380-3	3	3.60		
Little Roberts Lake	10-Aug-15	1	L1660702-10	1	5.96	6.53	0.29
Little Roberts Lake	10-Aug-15	1	L1660702-11	2	6.88		
Little Roberts Lake	10-Aug-15	1	L1660702-12	3	6.74		
Little Roberts Lake	19-Sep-15	1	L1677514-49	1	5.16	5.47	0.24
Little Roberts Lake	19-Sep-15	1	L1677514-50	2	5.30		
Little Roberts Lake	19-Sep-15	1	L1677514-51	3	5.94		
Reference Lake D	23-Apr-15	2	L1611669-1	1	2.73	2.87	0.39
Reference Lake D	23-Apr-15	2	L1611669-2	2	2.29		
Reference Lake D	23-Apr-15	2	L1611669-3	3	3.60		
Reference Lake D	16-Jul-15	1	L1646380-4	1	0.40	0.412	0.010
Reference Lake D	16-Jul-15	1	L1646380-5	2	0.43		
Reference Lake D	16-Jul-15	1	L1646380-6	3	0.41		
Reference Lake D	9-Aug-15	1	L1660702-7	1	0.73	0.947	0.108
Reference Lake D	9-Aug-15	1	L1660702-8	2	1.02		
Reference Lake D	9-Aug-15	1	L1660702-9	3	1.09		
Reference Lake D	19-Sep-15	1	L1677514-40	1	1.41	1.37	0.02
Reference Lake D	19-Sep-15	1	L1677514-41	2	1.37		
Reference Lake D	19-Sep-15	1	L1677514-42	3	1.33		

SE = standard error of the mean

April depths are recorded as depth from water surface and equal approximately 0.25 to 1 m below ice.

Phytoplankton Biomass (as Chlorophyll *a*) in Marine Sites, Doris North Project, 2015



Notes: Error bars represent the standard error of the mean.
The analytical detection limit for chlorophyll a was 0.01 µg; all chlorophyll a concentrations were higher than detection limits.

Annex A.5-3. Marine Phytoplankton Biomass Data, Doris North Project, 2015

Marine Site	Date Sampled	Depth Sampled	ALS Sample ID	Replicate #	Phytoplankton Biomass (µg chl *a*/L)	Mean	SE
RBW	23-Apr-15	3	L1611724-1	1	0.124	0.125	0.011
RBW	23-Apr-15	3	L1611724-2	2	0.106		
RBW	23-Apr-15	3	L1611724-3	3	0.144		
RBW	20-Jul-15	1	L1646380-33	1	0.536	0.536	0.003
RBW	20-Jul-15	1	L1646380-34	2	0.540		
RBW	20-Jul-15	1	L1646380-35	3	0.531		
RBW	6-Aug-15	1	L1660726-1	1	0.262	0.254	0.009
RBW	6-Aug-15	1	L1660726-2	2	0.265		
RBW	6-Aug-15	1	L1660726-3	3	0.236		
RBW	15-Sep-15	1	L1677514-4	1	0.520	0.331	0.109
RBW	15-Sep-15	1	L1677514-5	2	0.332		
RBW	15-Sep-15	1	L1677514-6	3	0.141		
RBE	23-Apr-15	2	L1611724-4	1	0.150	0.152	0.001
RBE	23-Apr-15	2	L1611724-5	2	0.152		
RBE	23-Apr-15	2	L1611724-6	3	0.154		
RBE	20-Jul-15	surface	L1646380-30	1	4.420	4.43	0.06
RBE	20-Jul-15	surface	L1646380-31	2	4.540		
RBE	20-Jul-15	surface	L1646380-32	3	4.320		
RBE	6-Aug-15	1	L1660726-4	1	3.600	3.19	0.21
RBE	6-Aug-15	1	L1660726-5	2	3.040		
RBE	6-Aug-15	1	L1660726-6	3	2.940		
RBE	16-Sep-15	1	L1677514-1	1	0.254	0.270	0.009
RBE	16-Sep-15	1	L1677514-2	2	0.284		
RBE	16-Sep-15	1	L1677514-3	3	0.272		
REF-Marine 1	23-Apr-15	3	L1611724-7	1	0.070	0.0627	0.0047
REF-Marine 1	23-Apr-15	3	L1611724-8	2	0.064		
REF-Marine 1	23-Apr-15	3	L1611724-9	3	0.054		
REF-Marine 1	20-Jul-15	1	L1646380-36	1	0.460	0.487	0.014
REF-Marine 1	20-Jul-15	1	L1646380-37	2	0.508		
REF-Marine 1	20-Jul-15	1	L1646380-38	3	0.494		
REF-Marine 1	8-Aug-15	1	L1660726-7	1	0.595	0.621	0.070
REF-Marine 1	8-Aug-15	1	L1660726-8	2	0.514		
REF-Marine 1	8-Aug-15	1	L1660726-9	3	0.754		
REF-Marine 1	16-Sep-15	1	L1677514-7	1	0.265	0.243	0.022
REF-Marine 1	16-Sep-15	1	L1677514-8	2	0.264		
REF-Marine 1	16-Sep-15	1	L1677514-9	3	0.200		

SE = standard error of the mean

RBE site was too shallow for sampling at 1 m depth in July.

April depths are recorded as depth from water surface and equal approximately 0.25 to 1 m below ice.

A.6 2015 Benthic Invertebrates

The following sections present the benthic invertebrate taxonomy data collected in August 2015 from stream, lake, and marine sites. Benthos data were used to calculate several community descriptors including: total density, taxa richness, evenness, diversity, and the Bray-Curtis Index. Details of these calculations are provided in the main body of the report.

A.6.1 Stream Data

Figure A.6-1 presents the average density and taxonomic composition of benthos community at stream sites. Figure A.6-2 presents the average family richness, Simpson's Evenness Index, and Simpson's Diversity Index. Figure A.6-3 presents the average Bray-Curtis Index. Annex A.6-1 provides the full stream benthos taxonomy dataset, and Annex A.6-2 presents the summary statistics calculated for the community descriptors.

A.6.2 Lake Data

Figure A.6-4 presents the average density and taxonomic composition of the lake benthos community at lake sites. Figure A.6-5 presents the average family richness, Simpson's Evenness Index, and Simpson's Diversity Index. Figure A.6-6 presents the average Bray-Curtis Index. Annex A.6-3 provides the full lake benthos taxonomy dataset, and Annex A.6-4 presents the summary statistics calculated for the community descriptors.

A.6.3 Marine Data

Figure A.6-7 presents the average density and taxonomic composition of the benthos community at marine sites. Figure A.6-8 presents the average family richness, Simpson's Evenness Index, and Simpson's Diversity Index. Figure A.6-9 presents the average Bray-Curtis Index. Annex A.6-5 provides the full marine benthos taxonomy dataset, and Annex A.6-6 presents the summary statistics calculated for the community descriptors.

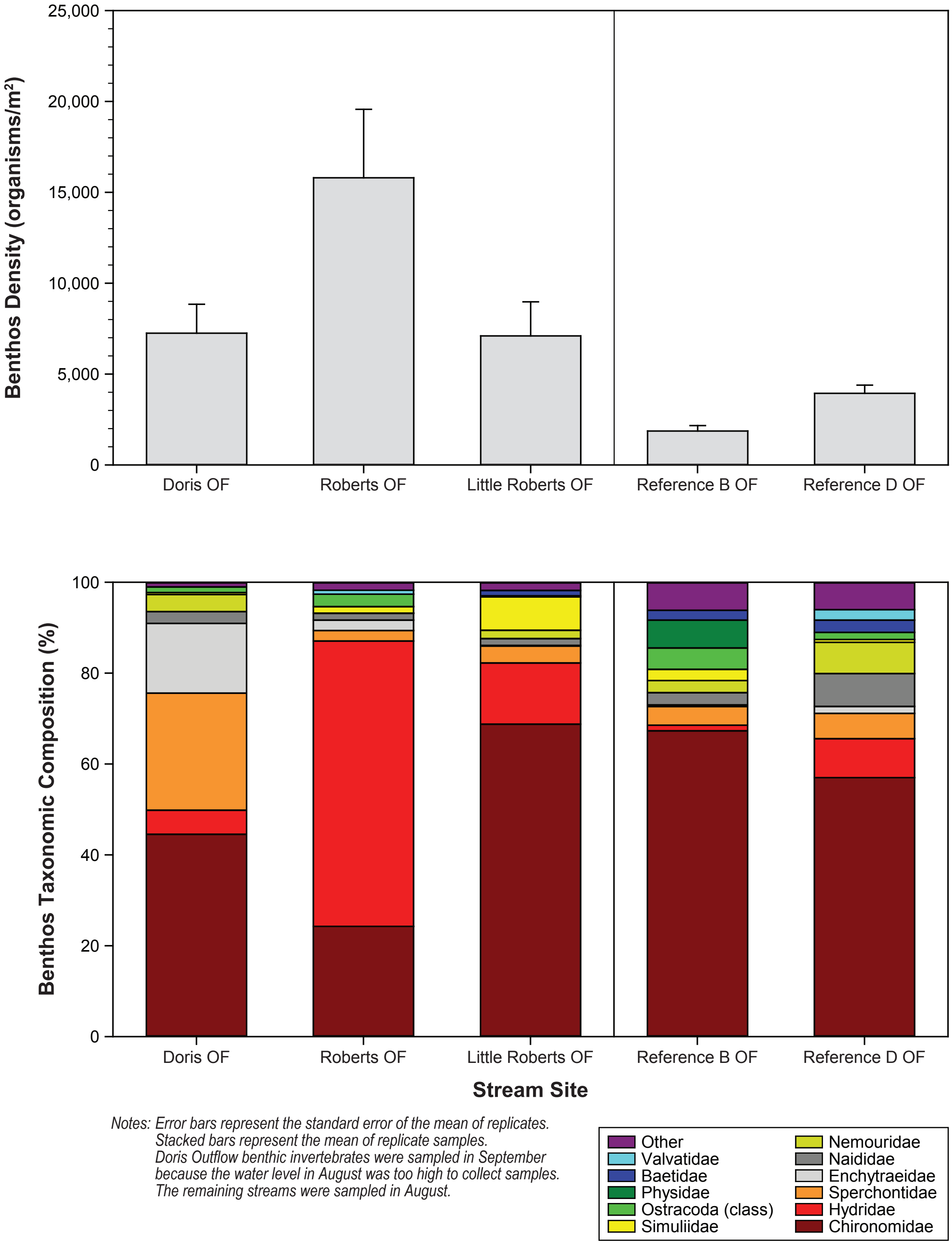
A.6.4 Quality Assurance/Quality Control (QA/QC) Data

A re-sorting of randomly selected sample residues was conducted by taxonomists on a minimum of 10% of the benthos samples to determine the level of sorting efficiency. Results of this QA/QC procedure are provided in Annex A.6-7.

Figure A.6-1

Benthos Density and Taxonomic Composition in Stream Sites, Doris North Project, August 2015

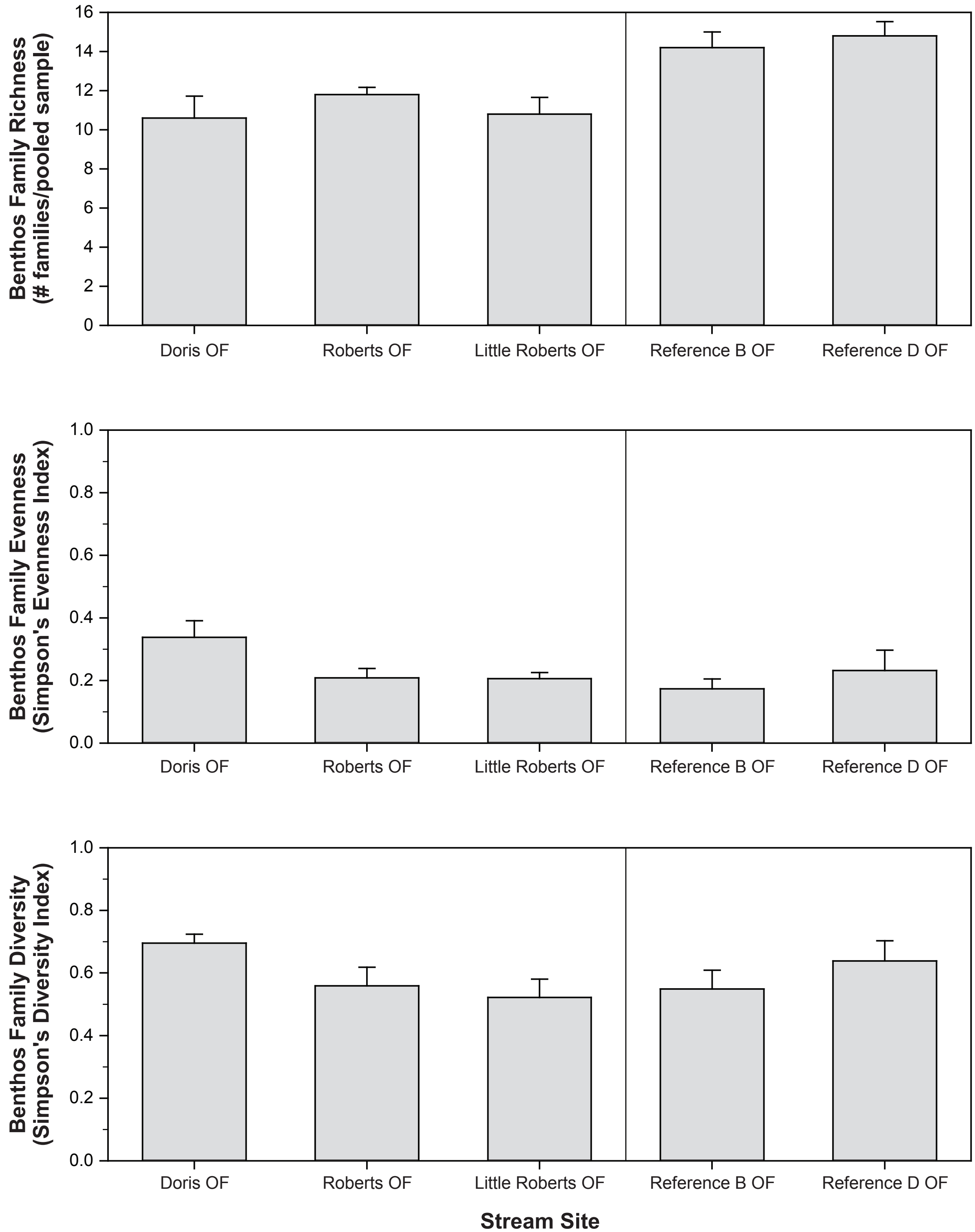
ERM



Notes: Error bars represent the standard error of the mean of replicates.
Stacked bars represent the mean of replicate samples.
Doris Outflow benthic invertebrates were sampled in September because the water level in August was too high to collect samples.
The remaining streams were sampled in August.

Figure A.6-2

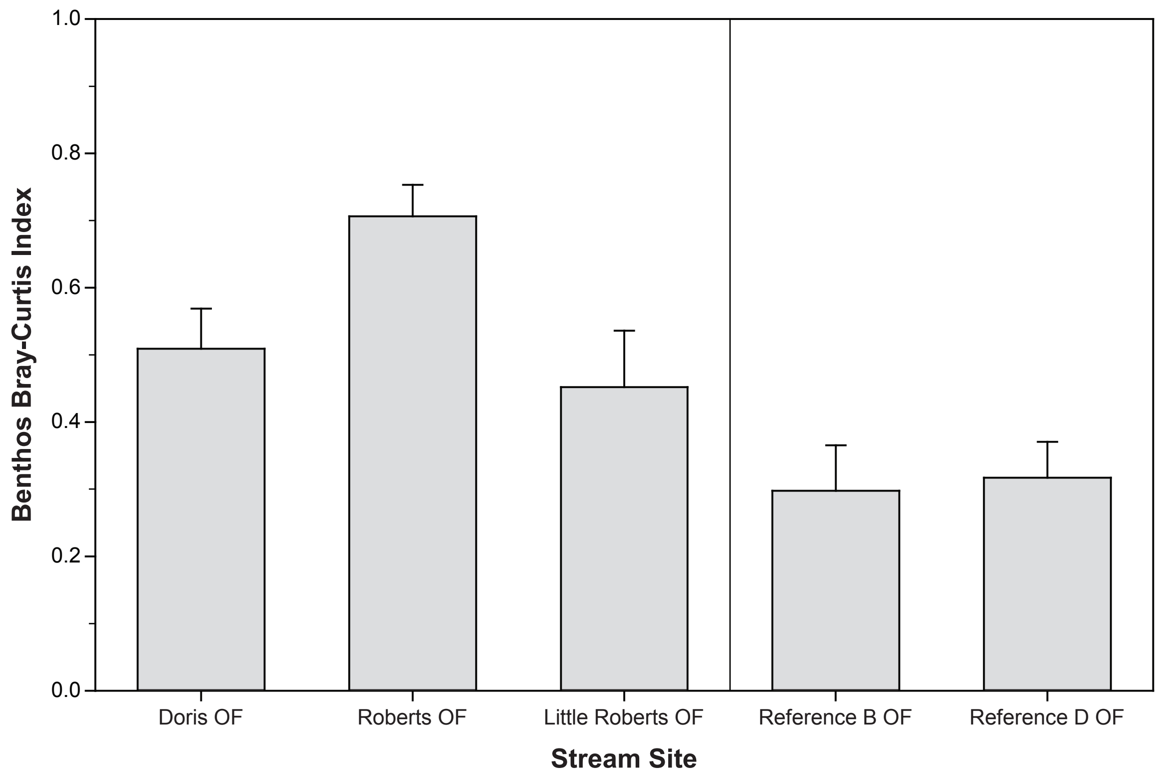
Benthos Richness, Evenness, and Diversity in Stream Sites, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Doris Outflow benthic invertebrates were sampled in September because the water level in August was too high to collect samples.
The remaining streams were sampled in August.

Figure A.6-3

Benthos Bray-Curtis Index for Stream Sites, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Doris Outflow benthic invertebrates were sampled in September because the water level in August was too high to collect samples.
The remaining streams were sampled in August.

Annex A.6-1. Stream Benthos Taxonomy Data, Doris North Project, 2015

					Doris Outflow 20-Sep-15					Roberts Outflow 15-Aug-15					Little Roberts Outflow 14-Aug-15					Reference B Outflow 13-Aug-15					Reference D Outflow 16-Aug-15				
Major Group	**Family**	**Subfamily**	**Tribe**	**Genus**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**
Coelenterata	Hydridae	-	-	*Hydra*		73	120	150	210	1560	1729	3221	6742	1040	368	95	153	480	280	5	4	4	20		153	70	169	48	48
Microturbellaria	-	-	-	-		2				21		24	27	21						11		16	4	24					
Nematoda*	-	-	-	-	332	9	123	243	39	285	132	45	30	20	77	20	53	200	82	17	24	16	12	12	26	5	24	71	42
Oligochaeta - cocoon*	-	-	-							6	10		1	2	5	11								3					
Oligochaeta	Enchytraeidae	-	-	-	278	117	199	514	497		24		180	320	8		8			2				8		20		67	
	Lumbriculidae	-	-	-		9	2	1	2	23	9	2	23	26	23	7	2	2	34	1	8	4		27	4	7	3	36	47
	Naididae	Naidinae	-	-					100				20										4					1	
	Naididae	Naidinae	-	*Nais*																3	36	12		4	48	10	8	232	72
	Naididae	Tubificinae	-	-	11	9	18	93	41	88	37	61	63	70	97	12			43			1		12				40	2
Gastropoda*	-	-	-	(i/d)*																									
Gastropoda	Physidae	-	-	*Physa*																16	50	38	14	48					
	Valvatidae	-	-	*Valvata sincera*									200												22	3	6	15	85
Pelecypoda	Pisidiidae	-	-	(i/d)																									
		-	-	*Sphaerium*																									
		-	-	*Pisidium*																									
Hydracarina*	-	-	-	(i/d)*																									
Hydracarina	Hygrobatidae	-	-	*Hygrobates*											2							1			1	15		1	41
	Lebertiidae	-	-	*Lebertia*		1				10	8	4	18		8		4		4	1	2	8	10	7	8		8	22	9
	Oxidae	-	-	*Oxus*																									
	Pionidae	-	-	*Tiphys*																									
	Sperchontidae	-	-	*Sperchon*	220	386	665	530	891	92	105	116	160	51	79	41	62	145	58	12	8	41	24	26	83	76	72	47	37
Copepoda - Calanoida*	-	-	-	-	232	256	144	50	250		16		20					20											
Copepoda - Cyclopoida*	-	-	-	-		8	8		10										20					8					
Ostracoda	-	-	-	-		24	56	20	30	80	24	280	100	140	16	5	8			27	40	28	4	28	8		8	16	56
Cladocera*	Chydoridae*	-	-	*Eurycercus**											8	1			82	1				37					
	Daphnidae*	-	-	*Daphnia**					10										20										
Amphipoda	Epimeriidae	-	-	*Epimeria loricata*										1															
	Gammaridae	-	-	*Gammarus lacustris*					1																				
Malacostraca	Mysidae	-	-	*Mysis relicta*		2																							
Notostraca	Triopsidae	-	-	*Lepidurus*																									
Isopoda	Chaetiliidae	-	-	*Saduria entomon*								6	4																
Collembola	Sminthuridae	-	-	-						1																			
Ephemeroptera	Baetidae	-	-	(i/d)																							1		
	Baetidae	-	-	*Baetis*											15	8	8	10	8	15	13	12	16	2	36	28	65	7	11
	Baetidae	-	-	*Baetis bicaudatus*												8	22	22	17								4	1	1
	Ephemerellidae	-	-	*Ephemerella*					1											3		1	5		4		8		
Plecoptera	Perlodidae	-	-	*Isoperla*																3			1				3		
	Nemouridae	-	-	*Nemoura*	95	77	102	48	71	1	9			1	40	23	31	46	49	16	9	11	6	30	80	57	98	43	113
Trichoptera	Apataniidae			*Apatania*													2		1										
	Brachycentridae	-	-	*Brachycentrus*																					2		1	8	
		-	-	*Micrasema*																					1				1
	Limnephilidae	-	-	(i/d)																									1
		-	-	*Grensia praeterita*				1	1												3								1
Coleoptera	Dytiscidae	-	-	(i/d)																								1	
	Dytiscidae	-	-	*Oreodytes*																		1							2
Diptera	Chironomidae	-	-	(pupa)						96	125	88	44	85	137	45	186	610	129	6	5	16	1	4	8	15	16	9	8
		Tanypodinae	Pentaneurini	*Ablabesmyia*																									
				Thienemannimyia group	29	69	9	110	114	207	110	23	223	60	90	49	75	41	103	21	72	77	58	33	101	67	82	32	24
			Procladiini	*Procladius*																	1		1						
		Diamesinae	Diamesini	*Potthastia longimana* group																								9	

Notes:

i/d = immature or damaged

** Taxa marked with an asterisk were excluded from total counts and from all benthos analyses.*

Calanoid and cyclopoid copepods and cladocerans were excluded because they are generally planktonic.

Nematodes were excluded because they are meiofauna and are not adequately sampled using a 500 mm sieve bucket.

Terrestrial organisms were excluded because they are not aquatic invertebrates.

Immature (e.g., oligochaete cocoons) or damaged organisms that were not identiable to the family level were excluded from analyses.

Individuals within the major groups Ostracoda and Microturbellaria were not identifiable to family, so they are included at the next lowest taxonomic category (class).

The total number of individuals was divided by 3 times the surface are of the Hess sampler (i.e., 3 x 0.096 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of 3 pooled Hess samples).

Annex A.6-1. Stream Benthos Taxonomy Data, Doris North Project, 2015

					Doris Outflow 20-Sep-15					Roberts Outflow 15-Aug-15					Little Roberts Outflow 14-Aug-15					Reference B Outflow 13-Aug-15					Reference D Outflow 16-Aug-15				
Major Group	**Family**	**Subfamily**	**Tribe**	**Genus**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**
Diptera (*cont'd*)				*Pseudokiefferiella parva*	113	233	1453	155	656	79	139	139	164	40	4	32	12	167	70			18	9	1	240	120	274	81	31
			Protanypini	*Protanypus*																									
		Prodiamesinae		*Monodiamesa*																									
		Orthocladiinae	Orthocladiini	(i/d)		8		20	10												4	10			8	5		9	
				Abyskomyia																									
				Cricotopus / Orthocladius	158	204	232	181	474	363	145	220	303	80	8		17		20	7	36	104	29		104	65	8	179	16
				Corynoneura						40											4	8							
				Doncricotopus								20																	
				Eukiefferiella	1										8	5		21	20	4	12	40	64	4	40	21		24	1
				Euryhapsis	38	12	8									3		2	1	26	19	78	56	34	240	166	168	21	16
				Hydrosmittia		8															8	4						32	
				Heterotrissocladius																									
				Mesocricotopus																									
				Nanocladius																1	4	8							
				Parametriocnemius																1									
				Parakiefferiella	16				30		16						8												
				Psectrocladius																		8		57				8	
				Synorthocladius semivirens		16		10	10																				
				Thienemanniella																								8	
				Tvetenia						357	437	131	89	483	522	291	825	2114	949	63	13	33	39	4	123	79	162	12	16
				Zalutschia																1								32	
		Chironominae	Chironomini	(i/d)																	1								
				Chironomus																				1					
				Cladopelma																									
				Cryptochironomus																								1	
				Demicryptochironomus																2								8	
				Dicrotendipes											1						109	47	1	20	1			70	43
				Glyptotendipes								1																	
				Microtendipes																									
				Parachironomus																									
				Polypedilum				20																	8	15			
				Sergenta																									
				Stictochironomus			1			130	62	670	4	20	52	2	1		24		13			4				3	
			Tanytarsini	(i/d)		8																							8
				Cladotanytarsus	1						16				8		16											8	
				Constempellina		8		10	10													4						16	
				Corynocera																									
				Micropsectra						80	24	60	20				16												
				Paratanytarsus	1					60	8	20			16		8		24	6	88	66	24	50			16	45	16
				Rheotanytarsus		19	1								8	11	56	104	60	5					104	42	95	24	8
				Stempellinella																									
				Tanytarsus	16		8	10	161	20			20		24	5	16	20		35	84	80	48	20		5	8	8	8
	Simuliidae	-	-	*adult*			17										1	2	2	18	10	14	6	8	1	1			1
	Simuliidae	-	-	*pupa*		1	8		10	27	35	41	27	122	59	50	29	68	120	6			2		1		22	2	6
		-	-	*Metacnephia*	1				10																				1
		-	-	*Simulium*						5	1	23	27	15	48	38	21	107	204	3					1		1		
	Tipulidae	-	-	*Tipula*	3	5	6	29	39	25	8	52	57	26	23	4	2	8	57	6	4	14	1		14	12	19	19	43
Terrestrial*	-	-	-	-							8									6		6	1			6			
Total					**981**	**1291**	**2905**	**1902**	**3369**	**3365**	**3071**	**5202**	**8515**	**2601**	**1664**	**734**	**1589**	**3969**	**2277**	**326**	**660**	**807**	**447**	**456**	**1444**	**899**	**1325**	**1245**	**773**

Notes:

i/d = immature or damaged

** Taxa marked with an asterisk were excluded from total counts and from all benthos analyses.*

Calanoid and cyclopoid copepods and cladocerans were excluded because they are generally planktonic.

Nematodes were excluded because they are meiofauna and are not adequately sampled using a 500 mm sieve bucket.

Terrestrial organisms were excluded because they are not aquatic invertebrates.

Immature (e.g., oligochaete cocoons) or damaged organisms that were not identiable to the family level were excluded from analyses.

Individuals within the major groups Ostracoda and Microturbellaria were not identifiable to family, so they are included at the next lowest taxonomic category (class).

The total number of individuals was divided by 3 times the surface are of the Hess sampler (i.e., 3 x 0.096 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of 3 pooled Hess samples).

Annex A.6-2. Stream Benthos Summary Statistics, Doris North Project, 2015

	Doris OF					
	Min	**Max**	**Median**	**Mean**	**SD**	**SE**
Density (#/m^2)	3,406	11,698	6,604	7,256	3,560	1,592
Family Richness	7	13	10	10.6	2.5	1.1
Simpson's Diversity Index	0.59	0.77	0.71	0.70	0.06	0.03
Simpson's Evenness Index	0.25	0.50	0.27	0.34	0.12	0.05
Bray-Curtis Index	0.32	0.66	0.49	0.51	0.13	0.06

	Little Roberts OF					
	Min	**Max**	**Median**	**Mean**	**SD**	**SE**
Density (#/m^2)	2,549	13,781	5,778	7,106	4,191	1,874
Family Richness	8	13	11	10.8	1.9	0.9
Simpson's Diversity Index	0.38	0.66	0.58	0.52	0.13	0.06
Simpson's Evenness Index	0.13	0.25	0.22	0.21	0.04	0.02
Bray-Curtis Index	0.20	0.71	0.42	0.45	0.19	0.08

	Roberts OF					
	Min	**Max**	**Median**	**Mean**	**SD**	**SE**
Density (#/m^2)	9,031	29,566	11,684	15,801	8,423	3,767
Family Richness	11	13	12	11.8	0.8	0.4
Simpson's Diversity Index	0.36	0.73	0.56	0.56	0.13	0.06
Simpson's Evenness Index	0.12	0.31	0.21	0.21	0.07	0.03
Bray-Curtis Index	0.60	0.85	0.67	0.71	0.10	0.05

	Reference B OF					
	Min	**Max**	**Median**	**Mean**	**SD**	**SE**
Density (#/m^2)	1,132	2,802	1,583	1,872	666	298
Family Richness	12	16	14	14.2	1.79	0.80
Simpson's Diversity Index	0.44	0.71	0.47	0.55	0.13	0.06
Simpson's Evenness Index	0.11	0.29	0.15	0.17	0.07	0.03
Bray-Curtis Index	0.12	0.49	0.28	0.30	0.15	0.07

	Reference D OF					
	Min	**Max**	**Median**	**Mean**	**SD**	**SE**
Density (#/m^2)	2,684	5,014	4,323	3,949	998	446
Family Richness	12	16	15	14.8	1.6	0.7
Simpson's Diversity Index	0.52	0.87	0.58	0.64	0.14	0.06
Simpson's Evenness Index	0.14	0.49	0.18	0.23	0.15	0.06
Bray-Curtis Index	0.16	0.49	0.31	0.32	0.12	0.05

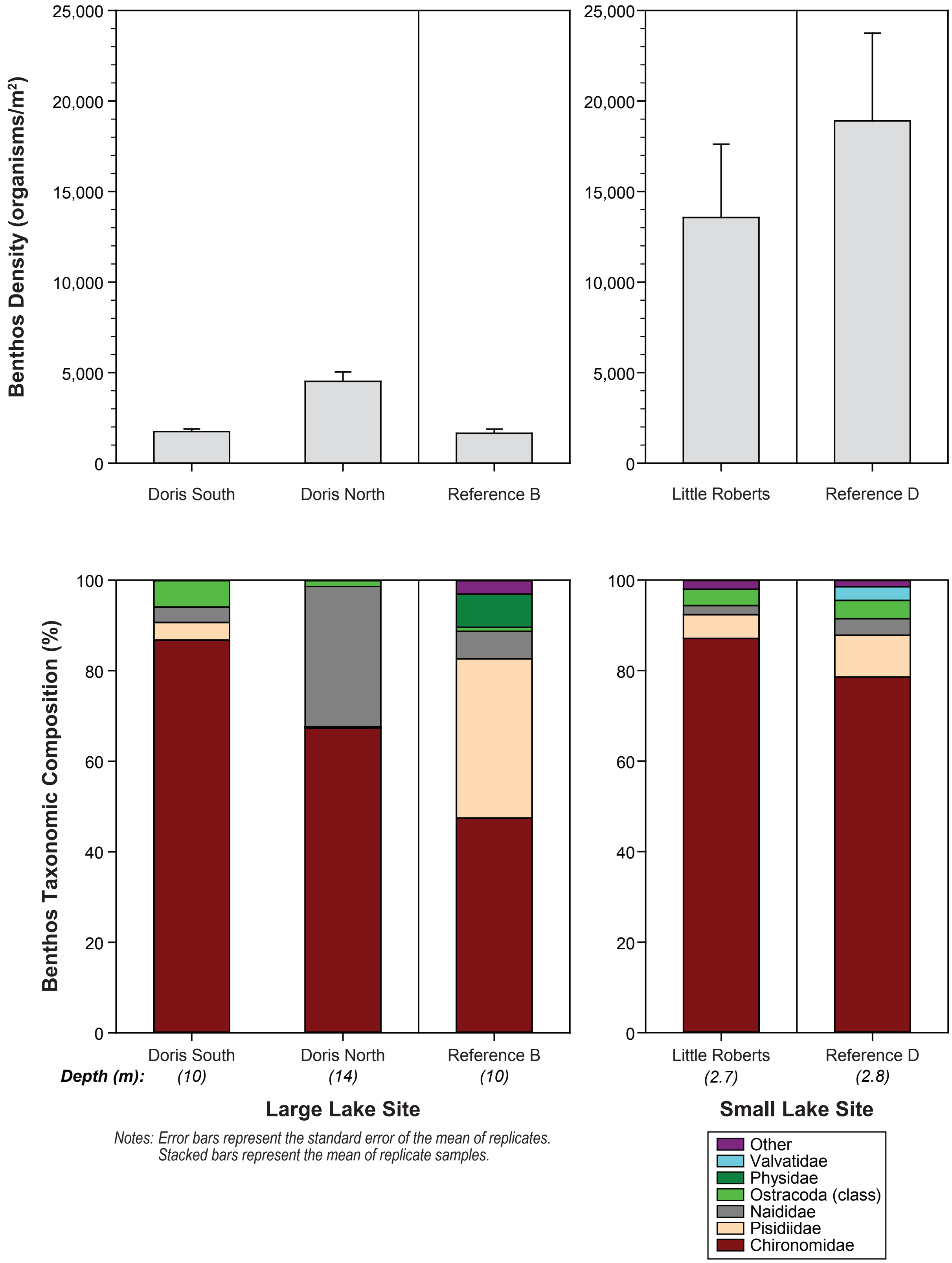
Notes:

SD - Standard deviation of the mean

SE - Standard error of the mean

Figure A.6-4

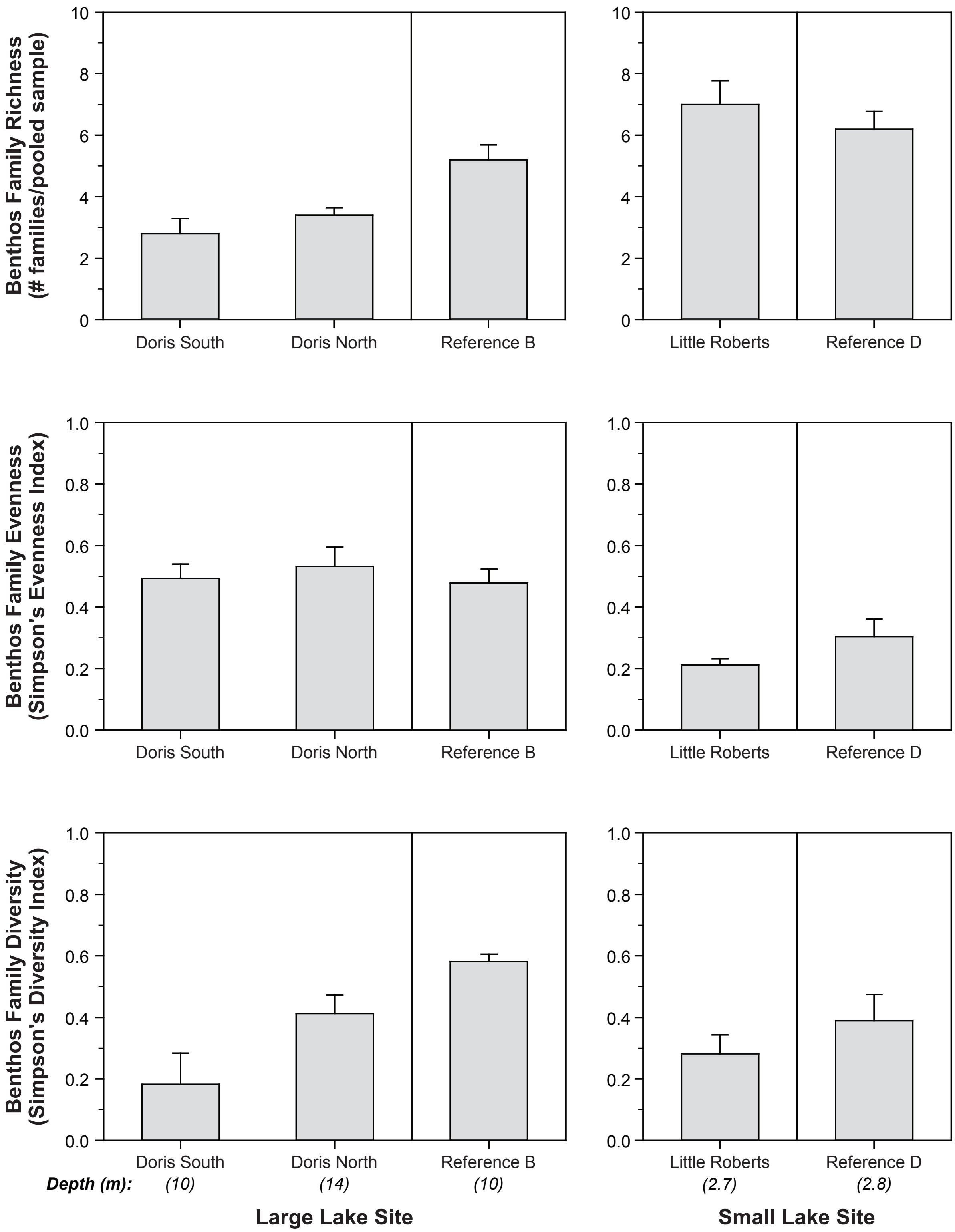
Benthos Density and Taxonomic Composition in Lake Sites, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Stacked bars represent the mean of replicate samples.

Figure A.6-5

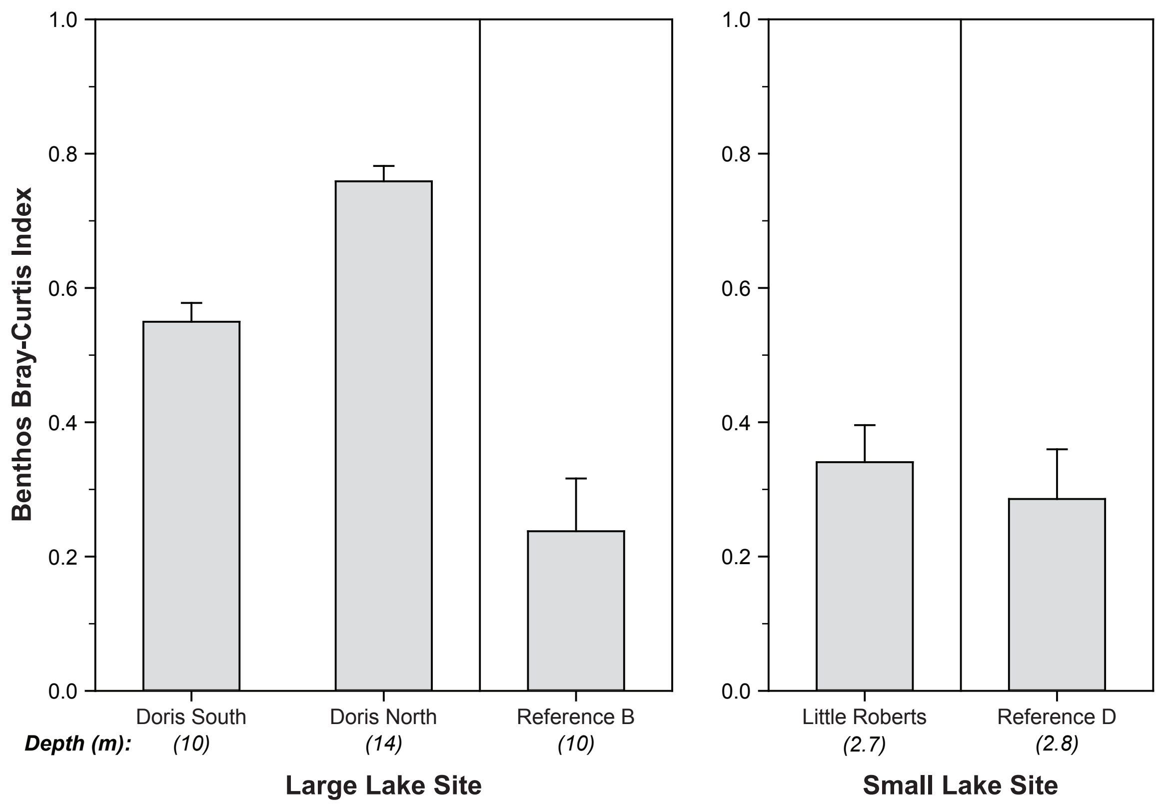
Benthos Richness, Evenness, and Diversity in Lake Sites, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.

Figure A.6-6

Benthos Bray-Curtis Index for Lake Sites, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.

Annex A.6-3. Lake Benthos Taxonomy Data, Doris North Project, 2015

					Doris Lake South					Doris Lake North					Reference Lake B					Little Roberts Lake					Reference Lake D				
				Sampling Date:	**5-Aug-15**					**5-Aug-15**					**11-Aug-15**					**10-Aug-15**					**9-Aug-15**				
				Sampling Depth:	**11 m**	**10 m**	**9.9 m**	**9.5 m**	**8.1 m**	**14 m**	**14 m**	**14 m**	**14 m**	**14 m**	**10 m**	**10 m**	**10 m**	**9.5 m**	**10 m**	**2.7 m**	**2.7 m**	**2.3 m**	**2.8 m**	**2.9 m**	**2.5 m**	**4.0 m**	**2.0 m**	**2.7 m**	**3.0 m**
Major Group	**Family**	**Subfamily**	**Tribe**	**Genus**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**
Coelenterata	Hydridae	-	-	*Hydra*																									
Microturbellaria	-	-	-	-																									
Nematoda*	-	-	-	-											9	8			4	8	7	24	50	33	200	65	58	17	80
Oligochaeta - cocoon*	-	-	-		19	11	8			11	12	39	91	51						1		4		32					
Oligochaeta	Enchytraeidae	-	-	-																		4							
	Lumbriculidae	-	-	-												1	2	4	1	7	18	10			11				
	Naididae	Naidinae	-	-							1																		
	Naididae	Naidinae	-	*Nais*																									
	Naididae	Tubificinae	-	-	15	5				60	22	114	164	112	15	13	2		4	17	9	31	26	8	17	63	79	34	40
Gastropoda*	-	-	-	(i/d)*											37							12							
Gastropoda	Physidae	-	-	*Physa*											41														
	Valvatidae	-	-	*Valvata sincera*																					53	42	20	42	36
Pelecypoda	Pisidiidae	-	-	(i/d)	11	2								1	1	30	18	16	19	5	12	1	32	8	39		70	20	87
		-	-	*Sphaerium*													3		1						6	1	15	12	13
		-	-	*Pisidium*	10					2				1		37	25	14	33	31	27	34	55	36	18	4	151	87	69
Hydracarina*	-	-	-	(i/d)*												1	1						8		8	8	8		
Hydracarina	Hygrobatidae	-	-	*Hygrobates*																									
	Lebertiidae	-	-	*Lebertia*																		1	9				39	3	15
	Oxidae	-	-	*Oxus*																10	4		8				8		
	Pionidae	-	-	*Tiphys*																					16				1
	Sperchontidae	-	-	*Sperchon*																			9						
Copepoda - Calanoida*	-	-	-	-	4	9	10	11	18	4	3	1		2															
Copepoda - Cyclopoida*	-	-	-	-																65	48	28	8	16	16				8
Ostracoda	-	-	-	-	22	5	1	5	2		4	10	4	2	1	3			1	50	8	28	80		104		48	10	96
Cladocera*	Chydoridae*	-	-	*Eurycercus**																									
	Daphnidae*	-	-	*Daphnia**											1	1													
Amphipoda	Epimeriidae	-	-	*Epimeria loricata*																									
	Gammaridae	-	-	*Gammarus lacustris*												2	2	4											
Malacostraca	Mysidae	-	-	*Mysis relicta*							1					1													
Notostraca	Triopsidae	-	-	*Lepidurus*																4	2	3	1	1					
Isopoda	Chaetiliidae	-	-	*Saduria entomon*																1									
Collembola	Sminthuridae	-	-	-																									
Ephemeroptera	Baetidae	-	-	(i/d)																									
	Baetidae	-	-	*Baetis*																									
	Baetidae	-	-	*Baetis bicaudatus*																									
	Ephemerellidae	-	-	*Ephemerella*																									
Plecoptera	Perlodidae	-	-	*Isoperla*																									
	Nemouridae	-	-	*Nemoura*																									
Trichoptera	Apataniidae			*Apatania*																									
	Brachycentridae	-	-	*Brachycentrus*																									
		-	-	*Micrasema*																									
	Limnephilidae	-	-	(i/d)																									
		-	-	*Grensia praeterita*																									
Coleoptera	Dytiscidae	-	-	(i/d)																									
	Dytiscidae	-	-	*Oreodytes*																									
Diptera	Chironomidae	-	-	(pupa)	9	11	11	18	13	8	13	9	9	4	1								1		8				
		Tanypodinae	Pentaneurini	*Ablabesmyia* *Thienemannimyia* group											1							1			4				1
			Procladiini	*Procladius*		5	12	14	30			1		2	1	6	2	4	1	35	9	16	108	25	30		18	24	36
		Diamesinae	Diamesini	*Potthastia longimana* group																1			8		8				

Notes:

i/d = immature or damaged

** Taxa marked with an asterisk were excluded from total counts and from all benthos analyses.*

Calanoid and cyclopoid copepods and cladocerans were excluded because they are generally planktonic.

Nematodes were excluded because they are meiofauna and are not adequately sampled using a 500 mm sieve bucket.

Terrestrial organisms were excluded because they are not aquatic invertebrates.

Immature (e.g., oligochaete cocoons) or damaged organisms that were not identiable to the family level were excluded from analyses.

Individuals within the major groups Ostracoda and Microturbellaria were not identifiable to family, so they are included at the next lowest taxonomic category (class).

The total number of individuals was divided by 3 times the surface are of the Ekman sampler (i.e., 3 x 0.0225 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of 3 pooled Ekman grabs).

Annex A.6-3. Lake Benthos Taxonomy Data, Doris North Project, 2015

					Doris Lake South					Doris Lake North					Reference Lake B					Little Roberts Lake					Reference Lake D				
				Sampling Date:	**5-Aug-15**					**5-Aug-15**					**11-Aug-15**					**10-Aug-15**					**9-Aug-15**				
				Sampling Depth:	**11 m**	**10 m**	**9.9 m**	**9.5 m**	**8.1 m**	**14 m**	**14 m**	**14 m**	**14 m**	**14 m**	**10 m**	**10 m**	**10 m**	**9.5 m**	**10 m**	**2.7 m**	**2.7 m**	**2.3 m**	**2.8 m**	**2.9 m**	**2.5 m**	**4.0 m**	**2.0 m**	**2.7 m**	**3.0 m**
Major Group	**Family**	**Subfamily**	**Tribe**	**Genus**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**	**Rep-1**	**Rep-2**	**Rep-3**	**Rep-4**	**Rep-5**
Diptera (*cont'd*)				*Pseudokiefferiella parva*																									
			Protanypini	*Protanypus*											1	4	2	2	1					40		4			
		Prodiamesinae		*Monodiamesa*	14	21	12	16	4	1		1		1	1	3	2		1										
		Orthocladiinae	Orthocladiini	(i/d)																		4							
				Abyskomyia											1								8						
				Cricotopus / Orthocladius																									
				Corynoneura																									
				Doncricotopus																									
				Eukiefferiella																									
				Euryhapsis																									
				Hydrosmittia																									
				Heterotrissocladius	1	2	2		1	1	1				1	5			1			4							
				Mesocricotopus		2				1																			
				Nanocladius																									
				Parametriocnemius																									
				Parakiefferiella																									
				Psectrocladius	2	2		1						1	2		2			5		2	8				14		
				Synorthocladius semivirens																									
				Thienemanniella																									
				Tvetenia																									
				Zalutschia											16	21	11	11	78			8							
		Chironominae	Chironomini	(i/d)																							10		
				Chironomus	3	1				136	241	246	213	130						55	72	79	36	54	14	39	4	29	16
				Cladopelma																							4		1
				Cryptochironomus																							2		
				Demicryptochironomus																									
				Dicrotendipes																									
				Glyptotendipes																									
				Microtendipes																							8		
				Parachironomus																								24	
				Polypedilum																									
				Sergenta																186	148	131	9	149	11		31	121	98
				Stictochironomus	59	41	53	36	22	1			1				2	4	1	2				5	4				
			Tanytarsini	(i/d)																									
				Cladotanytarsus																									
				Constempellina		1					1																		
				Corynocera											1				2								10		2
				Micropsectra																									
				Paratanytarsus											3					309	29	5	842	94	1880	467	117	483	1334
				Rheotanytarsus																									
				Stempellinella															1										
				Tanytarsus	6	13	33	24	17	1		2	1	1	12	16	18	14	9	31	46	57	609	759		8	63	34	51
	Simuliidae	-	-	*adult*																									
	Simuliidae	-	-	*pupa*																									
		-	-	*Metacnephia*																									
		-	-	*Simulium*																									
	Tipulidae	-	-	*Tipula*																									
Terrestrial*	-	-	-	-	1										1			1	1										
Total					**152**	**111**	**124**	**114**	**89**	**211**	**284**	**383**	**392**	**255**	**99**	**142**	**91**	**73**	**154**	**749**	**384**	**419**	**1849**	**1179**	**2223**	**628**	**711**	**923**	**1896**

Notes:

i/d = immature or damaged

** Taxa marked with an asterisk were excluded from total counts and from all benthos analyses.*

Calanoid and cyclopoid copepods and cladocerans were excluded because they are generally planktonic.

Nematodes were excluded because they are meiofauna and are not adequately sampled using a 500 mm sieve bucket.

Terrestrial organisms were excluded because they are not aquatic invertebrates.

Immature (e.g., oligochaete cocoons) or damaged organisms that were not identiable to the family level were excluded from analyses.

Individuals within the major groups Ostracoda and Microturbellaria were not identifiable to family, so they are included at the next lowest taxonomic category (class).

The total number of individuals was divided by 3 times the surface are of the Ekman sampler (i.e., 3 x 0.0225 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of 3 pooled Ekman grabs).

Annex A.6-4. Lake Benthos Summary Statistics, Doris North Project, 2015

	Doris Lake South					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	1,319	2,252	1,689	1,748	339	152
Family Richness	2	4	2	2.8	1.1	0.5
Simpson's Diversity Index	0.02	0.57	0.08	0.18	0.23	0.10
Simpson's Evenness Index	0.31	0.58	0.52	0.49	0.10	0.05
Bray-Curtis Index	0.46	0.62	0.54	0.55	0.06	0.03

	Doris Lake North					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	3,126	5,807	4,207	4,519	1,181	528
Family Richness	3	4	3	3.4	0.5	0.2
Simpson's Diversity Index	0.18	0.51	0.45	0.41	0.13	0.06
Simpson's Evenness Index	0.31	0.66	0.58	0.53	0.14	0.06
Bray-Curtis Index	0.69	0.81	0.76	0.76	0.05	0.02

	Little Roberts Lake					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	5,689	27,393	11,096	13,570	9,065	4,054
Family Richness	4	8	8	7.0	1.7	0.8
Simpson's Diversity Index	0.09	0.45	0.30	0.28	0.14	0.06
Simpson's Evenness Index	0.16	0.27	0.22	0.21	0.04	0.02
Bray-Curtis Index	0.16	0.47	0.38	0.34	0.12	0.06

	Reference Lake B					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	1,081	2,281	1,467	1,656	513	229
Family Richness	4	7	5	5.2	1.1	0.5
Simpson's Diversity Index	0.50	0.63	0.60	0.58	0.05	0.02
Simpson's Evenness Index	0.37	0.62	0.45	0.48	0.10	0.05
Bray-Curtis Index	0.032	0.52	0.20	0.24	0.18	0.08

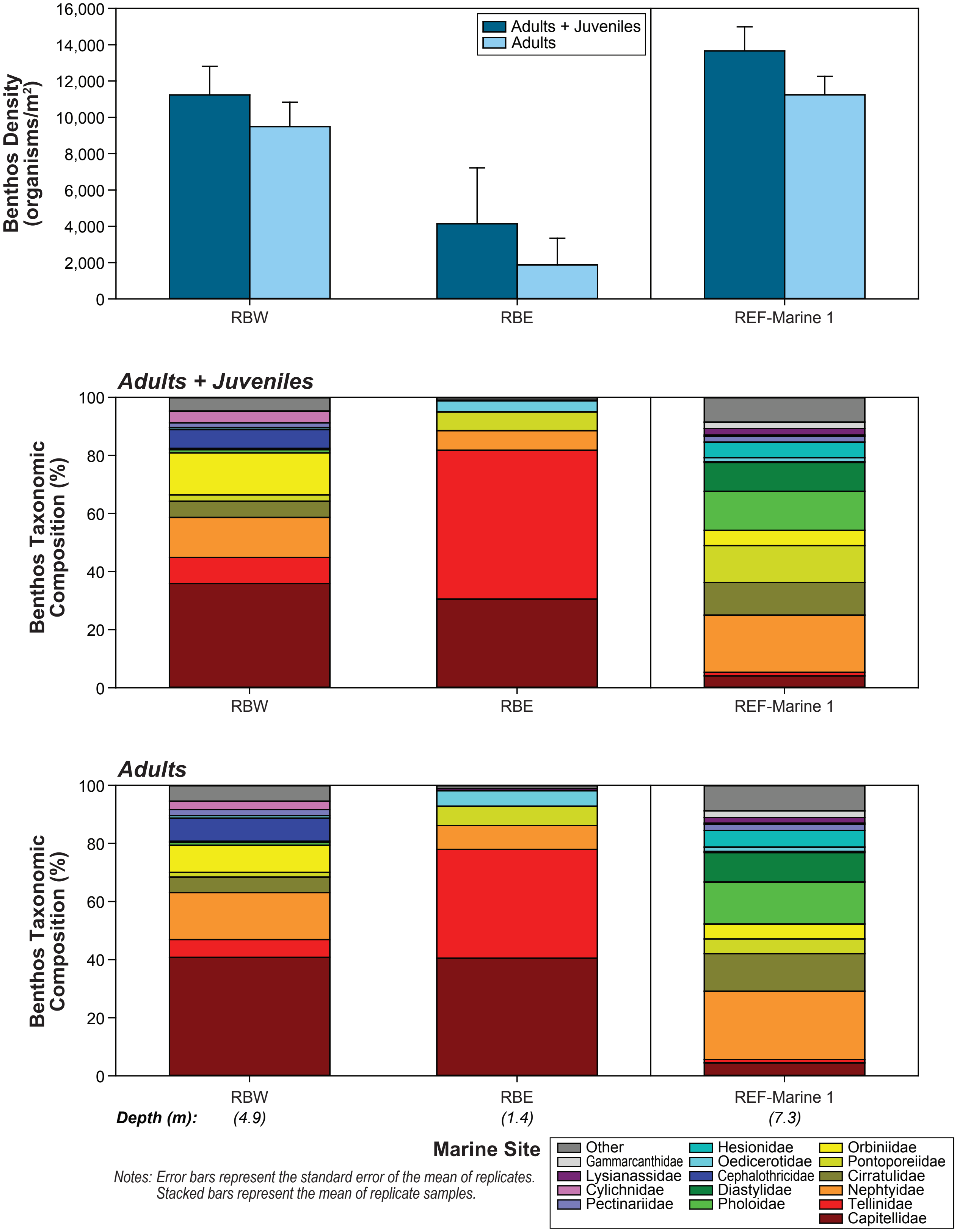
	Reference Lake D					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	9,304	32,933	13,674	18,907	10,849	4,852
Family Richness	4	7	7	6.2	1.3	0.6
Simpson's Diversity Index	0.22	0.71	0.33	0.39	0.19	0.08
Simpson's Evenness Index	0.18	0.50	0.27	0.30	0.13	0.06
Bray-Curtis Index	0.02	0.45	0.33	0.29	0.17	0.07

Notes:

SD - Standard deviation of the mean

SE - Standard error of the mean

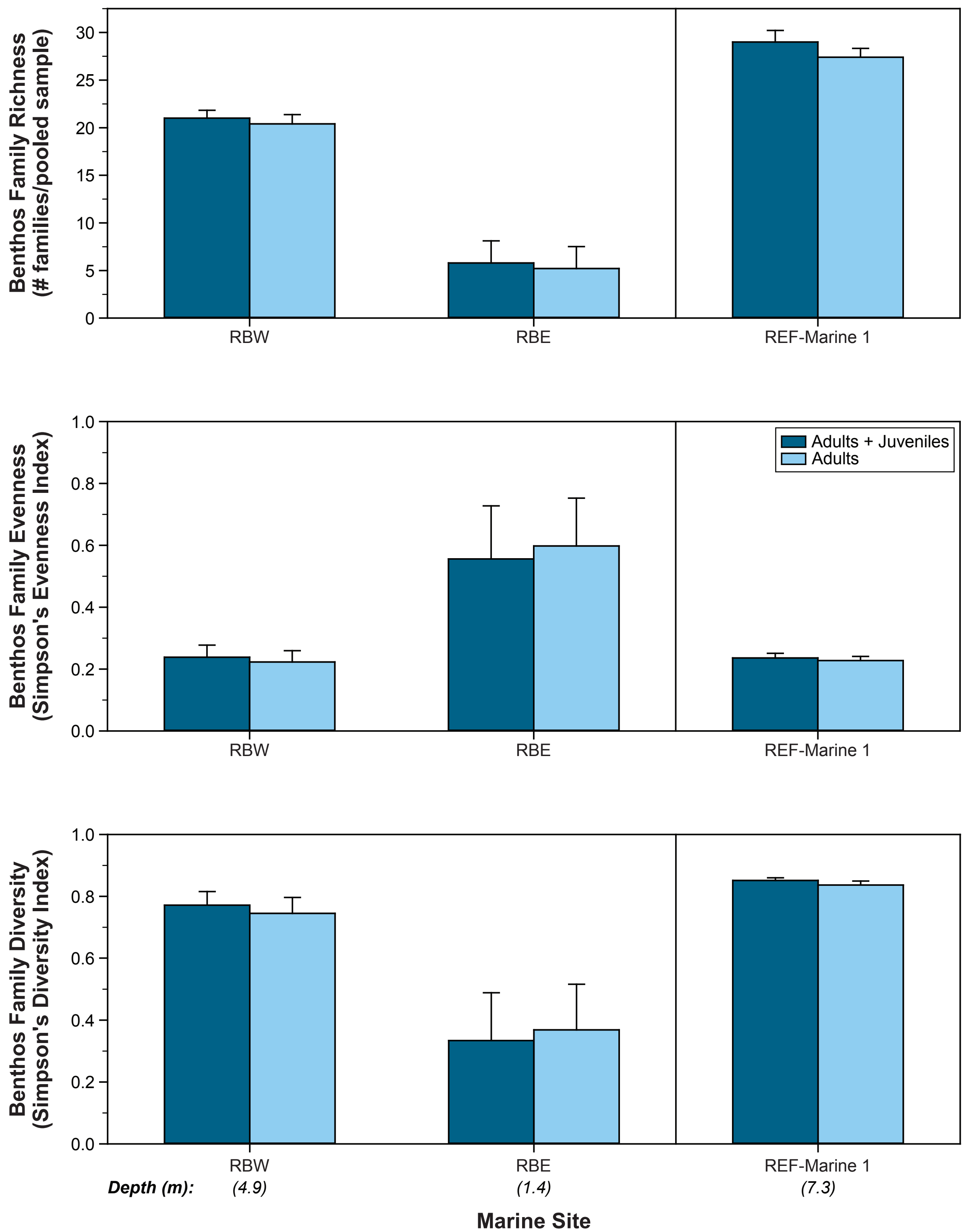
Benthos Density and Taxonomic Composition in Marine Sites, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.
Stacked bars represent the mean of replicate samples.

Figure A.6-8

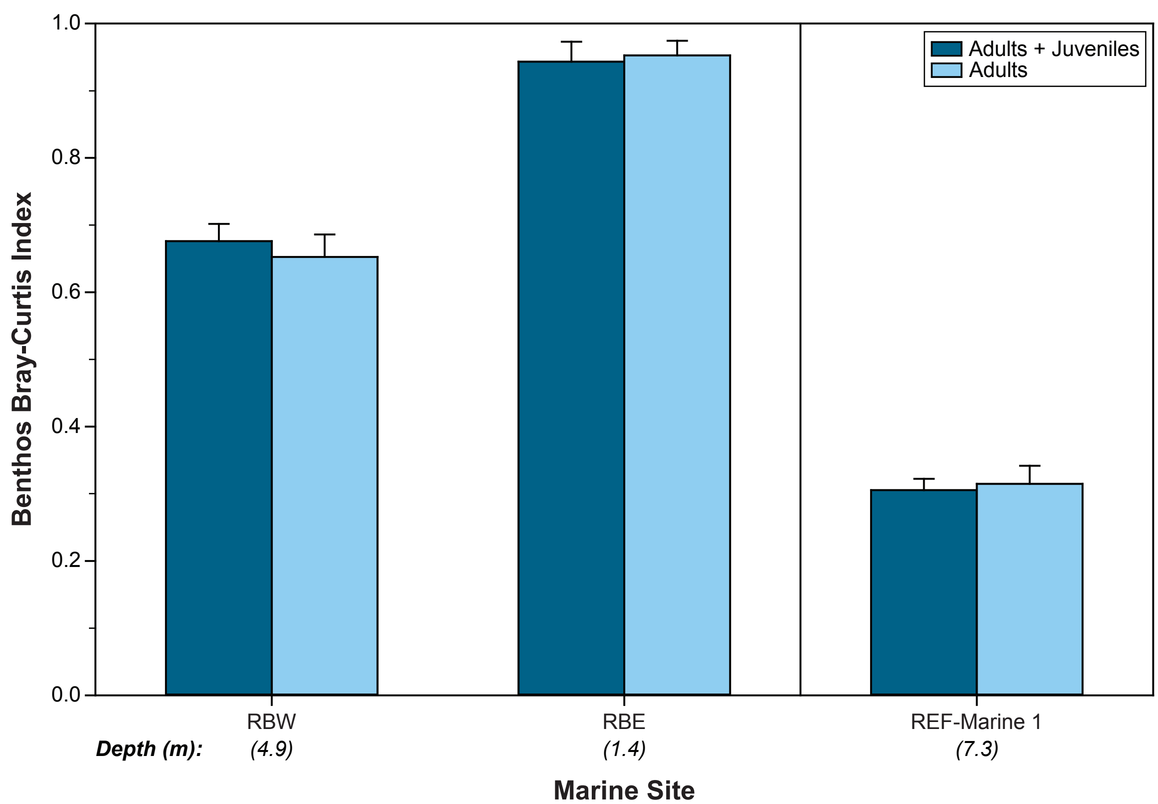
Benthos Richness, Evenness, and Diversity in Marine Sites, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.

Figure A.6-9

Benthos Bray-Curtis Index for Marine Sites, Doris North Project, August 2015



Notes: Error bars represent the standard error of the mean of replicates.

Annex A.6-5. Marine Benthos Taxonomy Data, Doris North Project, 2015

Station ID		REF-Marine 1										RBE										RBW									
Sampling Date		8-Aug-15										7-Aug-15										6-Aug-15									
Replicate		1		2		3		4		5		1		2		3		4		5		1		2		3		4		5	
Sampling Depth		6.2 m		8.5 m		9.8 m		7.0 m		5.0 m		0.5 m		0.8 m		1.8 m		2.3 m		1.5 m		4.9 m		5.2 m		5.3 m		5.2 m		4.0 m	
Adult (A)/Juvenile (J)		A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J
TAXA	Family																														
FORAMINIFERA																															
Cornuspira sp.	Cornuspiridae	2		3		2		5		3														2		2				1	
NEMERTEA																															
Anopla indet*	Class*			3																											
Cephalothrix nr linearis	Cephalothricidae			10		1		1		4								1				21		58		72		13		98	
Cerebratulus sp	Lineidae	1																				1									
Heteronemertea*	Sub-Class*																							2		6				1	
Lineidae indet	Lineidae					1																									
Nemertea sp indet*	Phylum*			6																						1					
ANNELIDA																															
Polychaeta Errantia																															
Arcteobia spinelytrus	Polynoidae			1																											
Bipalponephtys neotena	Nephtyidae	152		229		113	3	49	4	337	7	2						5				42		107	12	84		95		198	11
Erinaceusyllis nr erinaceus	Syllidae			4						1																					
Eteone longa	Phyllodocidae									1								5								3		3		1	
Eteone sp	Phyllodocidae			1																				1		2					
Eulalia bilineata	Phyllodocidae																											1			
Harmothoe imbricata Cmplx	Polynoidae	2		4						1														1							
Lumbrineris fragilis	Lumbrineridae			3		5		1																							
Nephtys sp	Nephtyidae					1																									
Nereimya nr aphroditoides	Hesionidae	2		68	7	38	23	131	4	8	1																	1			
Pholoe inornata	Pholoidae	145	8	32		7		257	7	79	15							1	1			2		4				3		2	
Pholoe nr longa	Pholoidae	8				11		12		8	4											6	6	4		1	2	1		1	
Polynoidae sp indet	Polynoidae					2		1		1																					
Polychaeta Sedentaria																															
Ampharete lindstroemi group	Ampharetidae																													1	
Aphelochaeta nr marioni	Cirratulidae	46	5	100	2	167	7	95	2	92	19											15		62		48		30		5	
Aricidea catherinae	Paraonidae	13		6	1	7				29	1															8		9		7	
Aricidea nolani	Paraonidae	1																				3		5		11		10		1	
Capitella capitata Cmplx	Capitellidae	3		1		9				2												2				2					
Cirratulidae indet	Cirratulidae																						21						1		
Cistenides granulata	Pectinariidae	15		2		2		18	3	17														8		5		1		31	
Cistenides hyperborea	Pectinariidae	1		10	1			13		6												1		2	1	10		2		15	
Cistenides sp	Pectinariidae						3																								
Clymenura polaris	Maldanidae	3		1	1	1		1		6																		3			
Diplocirrus longisetosus	Flabelligeridae					8		1																							
Flabelligeridae indet	Flabelligeridae									1																					
Laonome kroyeri	Sabellidae	1		1		2																									
Leitoscoloplos sp	Orbiniidae	7	2	26	7	25	11	1		129	34											31	23	30	36	52	7	84	30	111	184
Levinsenia gracilis	Orbiniidae			1		16																				1					
Marenzellaria wireni	Spionidae																	10	1												
Mediomastus sp	Capitellidae	10		4		16		139	12	11	2	1		1				324		10		139		162		530		438		122	
Monticellina sp	Cirratulidae																							3		2		2			
Pygospio elegans	Spionidae	1				2		1																							
Terebellides sp	Trichobranchidae	23		1		2	1	20	10	16												2				1		8			

Notes:

** Taxa marked with an asterisk were excluded from total counts and from all benthos analyses.*

Nematodes and harpacticoid copepods were excluded because they are meiofauna and are not adequately sampled using a 500 mm sieve bucket.

Fish and fish eggs were excluded because they are not benthic invertebrates.

Individuals that were not identiable to the family level were excluded from analyses.

The total number of individuals was divided by 3 times the surface are of the Petite Ponar (i.e., 3 x 0.023 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of 3 pooled Petite Ponar grabs).

Annex A.6-5. Marine Benthos Taxonomy Data, Doris North Project, 2015

Station ID		REF-Marine 1										RBE										RBW									
Sampling Date		8-Aug-15										7-Aug-15										6-Aug-15									
Replicate		1		2		3		4		5		1		2		3		4		5		1		2		3		4		5	
Sampling Depth		6.2 m		8.5 m		9.8 m		7.0 m		5.0 m		0.5 m		0.8 m		1.8 m		2.3 m		1.5 m		4.9 m		5.2 m		5.3 m		5.2 m		4.0 m	
Adult (A)/Juvenile (J)		A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J	A	J
TAXA	Family																														
ARTHROPODA																															
Amphipoda																															
Apherusa glacialis	Calliopiidae	2		18	2	6		4		3	1							1								1					
Corophiidae indet	Corophiidae										1																				
Deflexilodes nr uncinatus	Oedicerotidae																			3											
Gammaracanthus loricatus	Gammarcanthidae	55		1				3		9	6																				
Gammarus sp	Gammaridae							1																							
Gammarus setosus	Gammaridae																									1					
Hippomedon sp	Lysianassidae					1																									
Metopa sp	Stenothoidae			2																											
Monoculopsis longirostris	Oedicerotidae											1																			
Onisimus sp	Lysianassidae			4																											
Orchomenella minuta	Lysianassidae			3	11	49	19	13	7	3						1				1											
Paroediceros lynceus	Oedicerotidae	1		3		8		45	3	8	1											6		5		1		2		9	
Pleustes panoplus	Pleustidae																						1								
Pontoporeia femorata	Pontoporeiidae	18	25	77	183	45	80	38	80	16	57	1						46	70	2	5	8	3	16	4	13	9	11	9	1	2
Weyprechtia pinguis	Calliopiidae	4	2	4																											
Copepoda																															
Harpacticoida indet*	Order*									2		3		18		9				98						1					
Ostracoda																															
Cytheridae indet	Cytheridae	4		3		15												7						1						7	
Cumacea																															
Brachydiastylis resima	Diastylidae	1		135	21	145	59	1		1												2		3				1			
Cumella sp	Nannastacidae						1																								
Diastylis rathkei	Diastylidae	5		2		4		93		15	12											1		1		1		1	2	2	
Isopoda																															
Saduria entomon	Idoteidae																	1	1		1								1		
Mysidacea																															
Mysis oculata	Mysidae							12		4																					
Tanaidacea																															
Akanthophoreus sp	Akanthophoreidae					4																									
MOLLUSCA																															
Gastropoda																															
Admete sp	Cancellariidae			1																				1		1				2	
Alvania sp	Rissoidae																	1													
Cylichna occulta	Cylichnidae			3		1				14	6											14	2	14	22	17	16	2		42	32
Haminoea sp	Haminoeidae																									1					
Retusa obtusa	Retusidae																							2				1		7	1
Turridae indet	Turridae					3																									
Bivalvia																															
Astarte borealis	Astartidae	1		4				2														5				1					
Astarte montagui	Astartidae	1		1		1																9		9		7				2	
Hiatella arctica	Hiatellidae	14		2	1			2	5	8	6											11		4		1					
Macoma balthica	Tellinidae	6	1	5		3		8	5	16	2					58	99	127	511	30	86	32	11	41	38	24	46	7	6	52	63
Macoma calcarea	Tellinidae			3		2		3														4		5		6		3		2	

Notes:

** Taxa marked with an asterisk were excluded from total counts and from all benthos analyses.*

Nematodes and harpacticoid copepods were excluded because they are meiofauna and are not adequately sampled using a 500 mm sieve bucket.

Fish and fish eggs were excluded because they are not benthic invertebrates.

Individuals that were not identiable to the family level were excluded from analyses.

The total number of individuals was divided by 3 times the surface are of the Petite Ponar (i.e., 3 x 0.023 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of 3 pooled Petite Ponar grabs).

Annex A.6-5. Marine Benthos Taxonomy Data, Doris North Project, 2015

Station ID		**REF-Marine 1**										**RBE**										**RBW**									
Sampling Date		**8-Aug-15**										**7-Aug-15**										**6-Aug-15**									
Replicate		**1**		**2**		**3**		**4**		**5**		**1**		**2**		**3**		**4**		**5**		**1**		**2**		**3**		**4**		**5**	
Sampling Depth		**6.2 m**		**8.5 m**		**9.8 m**		**7.0 m**		**5.0 m**		**0.5 m**		**0.8 m**		**1.8 m**		**2.3 m**		**1.5 m**		**4.9 m**		**5.2 m**		**5.3 m**		**5.2 m**		**4.0 m**	
Adult (A)/Juvenile (J)		**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**	**A**	**J**
TAXA	**Family**																														
MOLLUSCA *(cont'd)*																															
Bivalvia *(cont'd)*																															
Macoma sp.	Tellinidae						7						1																		
Musculus discors	Mytilidae	2									3																				
Mya truncata	Myidae				10		2		1		1																			1	
Mytilus trossulus	Mytilidae		1		3			4			3							3	6		1				1						
Serripes groenlandicus	Cardiidae																													1	
CEPHALORHYNCHA																															
Halicryptus spinulosus	Priapulidae																	2													
CHORDATA																															
Rhizomolgula globularis	Molgulidae																					1		1							
MISCELLANEOUS																															
Diptera larva*	Insecta (Class)*																														
NOTES (not part of data)																															
Flatfish unid juvenile*																					1										
Nematoda*												1		5		1		273		66											
Unid fish eggs*																					3										
Unid invertebrate eggs*					1		1																								
TOTAL		550	44	779	250	725	216	975	143	849	182	5	1	1	0	59	99	534	590	46	93	358	67	552	114	909	80	732	49	722	293

Notes:

** Taxa marked with an asterisk were excluded from total counts and from all benthos analyses.*

Nematodes and harpacticoid copepods were excluded because they are meiofauna and are not adequately sampled using a 500 mm sieve bucket.

Fish and fish eggs were excluded because they are not benthic invertebrates.

Individuals that were not identiable to the family level were excluded from analyses.

The total number of individuals was divided by 3 times the surface are of the Petite Ponar (i.e., 3 x 0.023 m^2) to determine the benthos density in units of organisms/m^2 (because each replicate consisted of 3 pooled Petite Ponar grabs).

Annex A.6-6. Marine Benthos Summary Statistics, Doris North Project, 2015

	Roberts Bay West (RBW) - Adults and Juveniles					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	6,159	14,710	11,319	11,235	3,534	1,580
Family Richness	19	23	22	21	1.9	0.8
Simpson's Diversity Index	0.65	0.86	0.83	0.77	0.10	0.04
Simpson's Evenness Index	0.14	0.32	0.26	0.24	0.09	0.04
Bray-Curtis Index	0.57	0.72	0.69	0.68	0.06	0.026

	Roberts Bay West (RBW) - Adults					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	5,188	13,174	10,464	9,487	3,021	1,351
Family Richness	18	22	22	20	2.2	1.0
Simpson's Diversity Index	0.84	0.61	0.80	0.74	0.11	0.05
Simpson's Evenness Index	0.12	0.29	0.28	0.22	0.08	0.04
Bray-Curtis Index	0.53	0.71	0.68	0.65	0.07	0.03

	Roberts Bay East (RBE) - Adults and Juveniles					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	14	16,290	2,014	4,139	6,874	3,074
Family Richness	1	14	5	5.8	5.2	2.3
Simpson's Diversity Index	0.00	0.78	0.30	0.33	0.34	0.15
Simpson's Evenness Index	0.17	1.00	0.51	0.56	0.38	0.17
Bray-Curtis Index	0.83	1.00	0.97	0.94	0.07	0.03

	Roberts Bay East (RBE) - Adults					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	14	7,739	667	1,870	3,301	1,476
Family Richness	1	14	4	5.2	5.2	2.3
Simpson's Diversity Index	0.00	0.72	0.52	0.37	0.33	0.15
Simpson's Evenness Index	0.17	1.00	0.52	0.60	0.34	0.15
Bray-Curtis Index	0.88	1.00	0.97	0.95	0.05	0.02

	Ida Bay (REF-Marine 1) - Adults and Juveniles					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	8,609	16,203	14,913	13,661	2,966	1,327
Family Richness	25	32	29	29	2.7	1.2
Simpson's Diversity Index	0.83	0.87	0.84	0.85	0.02	0.01
Simpson's Evenness Index	0.20	0.28	0.24	0.24	0.03	0.02
Bray-Curtis Index	0.26	0.34	0.33	0.31	0.04	0.02

	Ida Bay (REF-Marine 1) - Adults					
	Min	Max	Median	Mean	SD	SE
Density (#/m^2)	7,971	14,130	11,290	11,241	2,276	1,018
Family Richness	25	30	27	27	2.1	0.9
Simpson's Diversity Index	0.79	0.86	0.84	0.84	0.03	0.01
Simpson's Evenness Index	0.19	0.26	0.23	0.23	0.03	0.01
Bray-Curtis Index	0.23	0.39	0.32	0.31	0.06	0.03

Notes:

SD - Standard deviation of the mean

SE - Standard error of the mean

Annex A.6-7. Results of Benthos QA/QC Sorting Efficiencies, Doris North Project, 2015

Sample ID	# from First Sort	1st QAQC Re-sort # Found	Initial Sort Efficiency (%)	Re-sort Required?	2nd QAQC Re-sort # Found	Final Efficiency (%)
Freshwater						
Roberts Outflow, rep 2	3,237	37	98.9	N	-	98.9
Little Roberts Outflwo, rep 3	1,642	29	98.2	N	-	98.2
Reference D Outflow, rep 5	815	18	97.8	N	-	97.8
Reference B Outflow, rep 4	460	11	97.7	N	-	97.7
Reference Lake D, rep 3	777	19	97.6	N	-	97.6
Marine						
REF-Marine 1, rep 1	594	0	100	N	-	100
REF-Marine 1, rep 2	1,038	0	100	N	-	100
REF-Marine 1, rep 3	941	0	100	N	-	100
REF-Marine 1, rep 4	1,118	0	100	N	-	100
REF-Marine 1, rep 5	1,033	0	100	N	-	100
RBE, rep 1	9	0	100	N	-	100
RBE, rep 2	19	0	100	N	-	100
RBE, rep 3	167	0	100	N	-	100
RBE, rep 4	1,124	0	100	N	-	100
RBE, rep 5	237	0	100	N	-	100
RBW, rep 1	425	0	100	N	-	100
RBW, rep 2	668	0	100	N	-	100
RBW, rep 3	997	0	100	N	-	100
RBW, rep 4	781	0	100	N	-	100
RBW, rep 5	1,016	0	100	N	-	100

Notes:

If the efficiency is 90% or better nothing further is done and the QA/QC invertebrates are not added to the data.

If the efficiency is less than 90%, the QA/QC invertebrates are added to the sample, it is re-sorted, and a second 20% QA/QC is performed.

*Freshwater data: % Sorting Efficiency = [1- {# in QA/QC re-sort/(# sorted originally + # in QA/QC re-sort)}]*100*

*Marine data (20% of sample is re-sorted): % Sorting Efficiency = [1- {(5 x # in QA/QC re-sort)/(# sorted originally + (5 x # in QA/QC re-sort))}]*100*

Appendix B

2015 Evaluation of Effects Supporting Information

DORIS NORTH PROJECT

2015 Aquatic Effects Monitoring Program Report

APPENDIX B. 2015 EVALUATION OF EFFECTS SUPPORTING INFORMATION

B.1 BASELINE DATA SELECTION RATIONALE FOR EVALUATION OF EFFECTS

The tables presented in this section present a summary of the baseline water quality, sediment quality, and primary producer biomass data collected at the AEMP sites, as well as the rationale for the inclusion or exclusion of certain baseline data from the 2015 evaluation of effects.

B.1.1 Water Quality Data

Table B.1-1 presents a summary of the baseline water quality data collected at AEMP stream, lake, and marine sites, and the rationale for the inclusion or exclusion of certain baseline data from the 2015 evaluation of effects. The selection of historical data to include in the water quality evaluation of effects was mainly based on similarity of baseline sampling locations to 2015 sampling locations, methodology, and sampling depth.

B.1.2 Sediment Quality Data

Table B.1-2 presents a summary of the baseline sediment quality data collected at AEMP stream, lake, and marine sites, and the rationale for the inclusion or exclusion of certain baseline data from the 2015 evaluation of effects. The selection of historical data to include in the sediment quality evaluation of effects was mainly based on the comparability of the depth strata sampled between baseline and 2015 samples, the proximity of baseline sampling sites to the 2015 sites, and the similarity of sampling techniques.

B.1.3 Phytoplankton and Periphyton Biomass Data

Table B.1-3 presents a summary of the baseline phytoplankton and periphyton biomass data collected at AEMP stream, lake, and marine sites, and the rationale for the inclusion or exclusion of certain baseline data from the 2015 evaluation of effects. The main criteria for the selection of historical phytoplankton and periphyton biomass data for inclusion in the evaluation of effect were the proximity of baseline sampling sites to 2015 AEMP sampling sites, and the comparability of sampling methodologies.

Table B.1-1. Baseline Data Selection Rationale for Water Quality, Doris North Project, 2015

Sampling Sites	Years Sampled	Months Sampled	Data Included in Historical Graphs and Statistical Analyses	Data Excluded from Historical Graphs and Statistical Analyses	Rationale for Exclusion
Streams					
Doris OF	1996	June, August	All	None	
	1997	June July, August	All	None	
	2000	June, September	All	None	
	2003	July, August, September	All	None	
	2004	June, July, August, September	All	None	
	2005	June, July, August, September	All	None	
	2006	June, July, August, September	All	None	
	2007	June, July, August, September	All	None	
	2008	June, July, August, September	All	None	
	2009	June, August, September	All	None	
Roberts OF	2004	June, July, August, September	All	None	
	2005	June, July, August, September	All	None	
	2006	June, July, August, September	All	None	
	2007	June, July, August, September	All	None	
	2008	June, July, August, September	All	None	
Little Roberts OF	1996	June, August	None	All	1996-1997 sampling site was further downstream than the 2003-2015 sampling site.
	1997	June, July, August	None	All	1996-1997 sampling site was further downstream than the 2003-2015 sampling site.
	2003	July, August, September	All	None	
	2004	June, July, August, September	All	None	
	2005	June, July, August, September	All	None	
	2006	June, July, August, September	All	None	
	2007	June, July, August, September	All	None	
	2008	June, July, August, September	All	None	
	2009	June, August, September	All	None	
Reference B OF	2009	June, August, September	All	None	
Reference D OF	no pre-2010 baseline data available				

Table B.1-1. Baseline Data Selection Rationale for Water Quality, Doris North Project, 2015

Sampling Sites	Years Sampled	Months Sampled	Data Included in Historical Graphs and Statistical Analyses	Data Excluded from Historical Graphs and Statistical Analyses	Rationale for Exclusion
Lakes					
Doris South	1995	May, June, July, August	Included May and June under-ice samples and August samples collected from boat at site SW4	Excluded shoreline grabs from July and August	Shoreline grabs from July and August were from a near-shore site that is not comparable to the 2015 Doris South site.
	1996	April, August	All	None	
	1997	April, July, August	All	None	
	1998	April	All	None	
	2000	July, August	All	None	
	2009	April, August	All	None	
Doris North	1995	May, June, July, August	Included May and June under-ice samples and August samples collected	Excluded shoreline grabs from July and August	Shoreline grabs from July and August are from a shallow, near-shore site that is not comparable to the 2015 Doris North site.
	2003	July, August, September	All	None	
	2004	June, July, August, September	All	None	
	2005	July, August, September	All	None	
	2006	May, July, August, September	All	None	
	2007	May, July, August, September	All	None	
	2008	May, July, August, September	All	None	
	2009	April, August	All	None	
Little Roberts	1995	May, June, July, August	Included May and June under-ice samples	Excluded shoreline grabs from July and August	Shoreline grabs from July and August are from a near-shore site that is not comparable to the 2015 Little Roberts Lake site.
	1996	August	All	None	
	1997	July	All	None	
	2003	July, August, September	All	None	
	2004	July, August, September	All	None	
	2005	July, August, September	All	None	
	2006	May, July, August, September	All	None	
	2007	May, July, August, September	All	None	
	2008	May, July, August, September	All	None	
	2009	April, August	All	None	
Reference B	2009	April, August	All	None	
Reference D	no pre-2010 baseline data available				

Table B.1-1. Baseline Data Selection Rationale for Water Quality, Doris North Project, 2015

Sampling Sites	Years Sampled	Months Sampled	Data Included in Historical Graphs and Statistical Analyses	Data Excluded from Historical Graphs and Statistical Analyses	Rationale for Exclusion
Marine Sites					
RBW	1996	August	None	All	1996-1998 sampling sites were >1 km away from 2015 RBW site.
	1997	August	None	All	1996-1998 sampling sites were >1 km away from 2015 RBW site.
	1998	July	None	All	1996-1998 sampling sites were >1 km away from 2015 RBW site.
	2009	April, August	Included surface samples from sites WT1 and ST2	Exluded samples from sites: WT2, WT4, WT6, ST1, ST3, ST4, ST5, ST6, and deep sample from site ST2	Excluded sites that were >1 km away from 2015 RBW site, and excluded deep samples because only surface samples were collected in 2015.
RBE	1996	August	Included single site that was in the eastern basin	None	
	1997	August	None	All	1997-1998 sampling site in eastern basin was closer to the mouth of Little Roberts Outflow than the 2015 RBE site (greater freshwater influence).
	1998	July	None	All	1997-1998 sampling site in eastern basin was closer to the mouth of Little Roberts Outflow than the 2015 RBE site (greater freshwater influence).
	2004	July, August, September	All	None	
	2005	July, August, September	All	None	
	2006	May, July, August, September	All	None	
	2007	May, July, August, September	All	None	
	2008	July, August, September	All	None	
	2009	April, August	All	None	
REF-Marine 1	2009	April, August	Included surface samples from site RP3	Excluded samples from sites: REF-W and REF-4, and deep samples from site RP3	Excluded sites that were >1 km away from 2015 REF-Marine 1 site, and excluded deep samples because only surface samples were collected in 2015.

Table B.1-2. Baseline Data Selection Rationale for Sediment Quality, Doris North Project, 2015

Sampling sites	Years Sampled	Month Sampled	Data Included in Historical Graphs and Statistical Analyses	Data Excluded from Historical Graphs and Statistical Analyses	Rationale for Exclusion
Streams					
Doris OF	2009	August	All	None	
Roberts OF	no pre-2010 baseline data available				
Little Roberts OF	2009	August	All	None	
Reference B OF	2009	August	All	None	
Reference D OF	no pre-2010 baseline data available				
Lakes					
Doris South (deep)	1996	August	None	All	Sediment sample was separated into layers (0-1 cm and 1-3 cm).
	1997	July	All	None	
	2009	August	Included deep site	Excluded shallow site	Shallow site was sampled.
Doris North (deep)	2009	August	Included deep site	Excluded shallow site	Shallow site was sampled.
Little Roberts (shallow)	1996	August	None	All	Sediment sample was separated into layers (0-1 cm and 1-3 cm).
	1997	July	All	None	
	2009	August	All	None	
Reference B (deep)	2009	August	None	All	Shallow/mid depth sites and located at opposite end of lake relative to 2015 site.
Reference D (shallow)	no pre-2010 baseline data available				
Marine Sites					
RBW (shallow)	1997	August	None	All	Mid-depth/deep sites and located >1 km from 2015 RBW site.
	2002	August	Included shallow site RB4	Excluded sites RB1, RB2, RB3	RB1 and RB2 were >1 km from 2015 RBW site; RB3 was a mid-depth site.
	2009	August	None	All	Sites were all ~0.4 km or more away from 2015 RBW site.
RBE (shallow)	1997	August	None	All	Sampling site in eastern basin was closer to the mouth of Little Roberts Outflow than the 2015 RBE site (greater freshwater influence, and depositional zone).
REF-Marine 1 (mid-depth)	2009	August	Included mid-depth site RP2	Excluded sites RP1, RP3	RP1 was a shallow site and RP3 was a deep site. RP2 (mid-depth) was most comparable to the mid-depth site sampled in 2015.

Table B.1-3. Baseline Data Selection Rationale for Primary Producer Biomass (as Chlorophyll *a*), Doris North Project, 2015

Sampling Sites	Years Sampled	Months Sampled	Data Included in Historical Graphs and Statistical Analyses	Data Excluded from Historical Graphs and Statistical Analyses	Rationale for Exclusion
Streams (Periphyton)					
Doris OF	1996	August	None	All	An instantaneous sample was collected, and chlorophyll *a* concentrations were not measured (only abundance and taxonomy data).
	1997	June-July, July-August	All	None	
	2000	July-August	All	None	
	2009	July-August	All	None	
Roberts OF	no pre-2010 baseline data available				
Little Roberts OF	1996	August	None	All	1996 sampling site was further downstream than 2009-2015 sampling site, an instantaneous sample was collected, and chlorophyll a concentrations were not measured (only abundance and taxonomy data).
	1997	June-July, July-August	None	All	1997 sampling site was further downstream than 2009-2015 sampling site.
	2009	July-August	All	None	
Reference B OF	2009	July-August	All	None	
Reference D OF	no pre-2010 baseline data available				
Lakes (Phytoplankton)					
Doris South	1996	August	None	All	Chlorophyll *a* concentrations were not measured (only abundance and taxonomy data).
	1997	July	All	None	
	2000	July	All	None	
	2009	April, August	All	None	
Doris North	2003	July, August, September	None	All	Each sample consisted of a composite of 5 subsamples collected throughout the euphotic zone (not comparable to discrete surface samples collected in 2015).
	2006	September	None	All	Phytoplankton biomass sampling method not described in report.
	2007	July, August, September	None	All	Phytoplankton biomass samples were collected using an integrated tube sampler deployed throughout the euphotic zone (not comparable to discrete surface samples collected in 2015).
	2008	July, August, September	None	All	Phytoplankton biomass samples were collected using an integrated tube sampler deployed throughout the euphotic zone (not comparable to discrete surface samples collected in 2015).
	2009	April, August	All	None	

Table B.1-3. Baseline Data Selection Rationale for Primary Producer Biomass (as Chlorophyl *a*), Doris North Project, 2015

Sampling Sites	Years Sampled	Months Sampled	Data Included in Historical Graphs and Statistical Analyses	Data Excluded from Historical Graphs and Statistical Analyses	Rationale for Exclusion
Lakes (Phytoplankton; *cont'd*)					
Little Roberts	1996	August	None	All	Chlorophyll *a* concentrations were not measured (only abundance and taxonomy data).
	1997	July	All	None	
	2003	July, August, September	None	All	Each sample consisted of a composite of 5 subsamples collected throughout the euphotic zone (not comparable to discrete surface samples collected in 2015).
	2006	September	None	All	Phytoplankton biomass sampling method not described in report.
	2007	July, August, September	None	All	Phytoplankton biomass samples were collected using an integrated tube sampler deployed throughout the euphotic zone (not comparable to discrete surface samples collected in 2015).
	2008	July, August, September	None	All	Phytoplankton biomass samples were collected using an integrated tube sampler deployed throughout the euphotic zone (not comparable to discrete surface samples collected in 2015).
	2009	April, August	All	None	
Reference B	2009	August	All	None	
Reference D	no pre-2010 baseline data available				
Marine Sites (Phytoplankton)					
RBW	2009	August	Included surface samples from site ST2	Exluded samples from sites: ST1, ST3, ST4, ST5, ST6, and deep samples from site ST2	Excluded sites that were >1 km away from 2015 RBW site, and excluded deep samples because only surface samples were collected in 2015.
RBE	2006	September	None	All	Phytoplankton biomass sampling method not described in report.
	2007	July, August, September	None	All	Phytoplankton biomass samples were collected using an integrated tube sampler deployed throughout the euphotic zone (not comparable to discrete surface samples collected in 2015).
	2008	July, August, September	None	All	Phytoplankton biomass samples were collected using an integrated tube sampler deployed throughout the euphotic zone (not comparable to discrete surface samples collected in 2015).
	2009	August	All	None	
REF-Marine 1	2009	August	Included surface samples from site RP3	Excluded samples from site REF-4, and deep samples from site RP3	Excluded sites that were >1 km away from 2015 REF-Marine 1 site, and excluded deep samples because only surface samples were collected in 2015.

APPENDIX B. 2015 EVALUATION OF EFFECTS SUPPORTING INFORMATION

B.2 STATISTICAL METHODOLOGY AND RESULTS FOR EVALUATION OF EFFECTS

The following reports present the statistical methodology and results, including lists of outliers and statistical outputs, for the evaluation of effects on Secchi depth, water quality, sediment quality, phytoplankton and periphyton biomass, and benthic invertebrates:

- Appendix B.2.1. Statistical Methodology and Results for Secchi Depth Evaluation of Effects, Doris North Project, 2015
- Appendix B.2.2. Statistical Methodology and Results for Water Quality Evaluation of Effects, Doris North Project, 2015
- Appendix B.2.3. Statistical Methodology and Results for Sediment Quality Evaluation of Effects, Doris North Project, 2015
- Appendix B.2.4. Statistical Methodology and Results for Phytoplankton and Periphyton Evaluation of Effects, Doris North Project, 2015
- Appendix B.2.5. Statistical Methodology and Results for Benthos Evaluation of Effects, Doris North Project, 2015

Appendix B.2.1. Statistical Methodology and Results for Secchi Depth Evaluation of Effects, Doris North Project, 2015

TABLE OF CONTENTS

1. ANALYSIS METHODS

1.1 ASSUMPTIONS

The key assumption was that the Secchi depth measurements included in this analysis were representative of each lake site's Secchi depth for that monitoring period.

1.2 TRANSFORMATIONS

No transformation was needed.

1.3 OUTLINE OF ANALYSIS PLAN

There are several classes of statistical tests that can be done to assess evidence of change in the Secchi depth over time and to assess if changes may reflect an impact of the Project.

1.3.1 Before vs. After Analysis

The first analysis compared the mean Secchi depth for all years prior to 2010 (before initiation of construction) to the mean for 2015. Each lake site was treated independently.

The final statistical model (in standard shorthand notation) was:

*Y = Period Season Period*Season Year(period)-R*

where *Y* is the mean Secchi depth for a year; *Period* is the effect of before vs. after Project initiation (which is the effect of interest); *Season* is the effect of season (three seasons in the sampling year: 1) July, 2) August, and 3) September); *Period*Season* is an interaction effect between period and season; and *Year(Period)* is a random year effect (applicable if more than one year was sampled during each period). If the data were too sparse (e.g., not all seasons measured in all periods), then the *Period*Season* interaction effect could not be estimated and was dropped.

This model is preferable to simply treating all measurement within a period (e.g., over two years pre-construction) as having the same mean and assuming that they are completely independent of each other. This model also "averages" the Secchi depth data in way that weights each baseline year equally rather than weighting by the sample size. For example, suppose that the Secchi depth measured in 2008 was 22 m, while the two Secchi depths measured in 2009 were 25 m and 27 m. The simple mean (22+25+27)/3=24.7 m would be more heavily weighted toward the mean in the second year. In order to give each year's data equal weight, the reading over both years should be computed as an average of averages:

$$\frac{\frac{22}{1}+\frac{25+27}{2}}{2}=24.0$$

This could be extended to multiple years in a similar fashion.

This model was fit using R version 3.1.3. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. A nominal significance level of 0.05 was used when reviewing the results.

The key disadvantage of this model was that changes in Secchi depth over time may be unrelated to the effects of the Project, e.g., the average Secchi depth in 2015 could be shallower than expected because of long term climate change that is unrelated to the Project. Consequently, if a statistically significant effect was detected, it would require further investigation.

1.3.2 BACI Analysis

Before-After-Control-Impact (BACI) analysis is the standard method used to assess a potential environmental impact (Smith 2002). BACI designs evaluate potential non-parallelism in response over time between exposure and reference waterbodies.

A BACI analysis was performed for each large Project lake (Doris Lake North and Doris Lake South) versus the corresponding reference lake (Reference Lake B). A BACI analysis was not performed for Little Roberts Lake (small lake) because there is no pre-construction data for Reference Lake D.

The formal statistical model (in standard shorthand notation) was:

Y = *Period Class Period*Class Season Period*SeasonYear(Period)-R*

where *Y* is the variable of interest; *Period* is the effect of period (before or after construction); *Class* is the effect of the site classification (Project or reference); *Period*Class* is the BACI effect of interest (i.e., is the effect of *Period* the same (parallel) for both classes of sites); *Season* is the seasonal (sampling month) effect; *Period*Season* is an interaction effect between period and season; and *Year(Period)* is the random year effect within each period (applicable if more than one year was sampled during each period). If the data were too sparse (e.g., not all seasons measured in all periods), then the *Period*Season* interaction effect could not be estimated and was dropped. Sites that were measured only in one period (i.e., pre- or post-construction) contribute some information on the year-effect which improves precision of the BACI estimate and were, therefore, included.

The key variable of interest was the *Period*Class* effect as this measures the amount of non-parallelism between the changes in the mean (Before-After) over the two classes of sites (exposure or reference). The BACI estimate was computed as the "difference in the differences":

$$BACI = (\mu_{PA} - \mu_{PB}) - (\mu_{RA} - \mu_{RB})$$

where μ_{PA} is the mean variable reading in the *Project* class of sites *after* Project initiation, μ_{PB} is the mean variable reading in the *Project* class of sites *before* Project initiation, μ_{RA} is the mean variable reading in the *reference* class of sites *after* Project initiation, and μ_{RB} is the mean variable reading in the *reference* class of sites *before* Project initiation. The BACI contrast was estimated by replacing the population means above by the model-based estimates. Estimated differences close to 0 would indicate no evidence of non-parallelism.

Note that the hypothesis that the BACI contrast has the value of zero is identical to the hypothesis that the *Period*Class* interaction is zero with identical p-values. Consequently, only the results for the BACI contrast were reported here.

The BACI model was fit using R version 3.1.3.

2. RESULTS

There was no censoring of the Secchi depth data, and preliminary plots of the data showed no obvious outliers.

The lakes were divided into small lakes (Little Roberts Lake and Reference Lake D) and large lakes (Doris Lake North, Doris Lake South, and Reference Lake B) and separate results are presented for each size class of lake. The results from the analysis that compared the mean prior to 2010 (before initiation of construction) to the mean for 2015 are presented in Tables Large Lake-1 and Small Lake-1. There was no evidence of a change in the mean Secchi depth for any exposure lake between the before and after periods.

There was no evidence of a differential before-after response in the mean Secchi depth in large Project lakes compared to Reference Lake B (Table Large Lake-2). Because no Secchi depth measurements were made in Reference Lake D prior to construction, no BACI comparison can be made for Little Roberts Lake (small lake).

REFERENCES

Helsel, D.R. 2005. *Nondetects and data analysis.* Wiley: New York.

McBride, G.B. 2005. *Using statistical methods for water quality management.* Wiley: New York.

Smith, E. P. 2002. BACI Design. *Encyclopedia of Environmetrics.* Wiley: New York.

TABLES

Table Large Lake-1. Summary of Test for No Difference in Mean between Before and After Periods for Large Lake Secchi Depth

Variable	Large Lake Site Doris North p-value	Large Lake Site Doris South p-value	Large Lake Site Reference B p-value
Secchi Depth	0.5561	0.7611	-

Notes:
A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
A before-after analysis was not possible for Reference Lake B.

Table Small Lake-1. Summary of Test for No Difference in Mean between Before and After Periods for Small Lake Secchi Depth

Variable	Small Lake Site Little Roberts p-value	Small Lake Site Reference D p-value
Secchi Depth	0.9684	-

Notes:
A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
No pre-construction Secchi depth readings were collected at Reference Lake D, so no before-after comparison was possible.

Table Large Lake-2. Summary of BACI Comparison of Large Lake Secchi Depth for Individual Project Sites

Variable	Large Lake Site Doris North p-value	Large Lake Site Doris South p-value
Secchi Depth	0.0687	0.2413

Note:
A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Appendix B.2.2. Statistical Methodology and Results for Water Quality Evaluation of Effects, Doris North Project, 2015

TABLE OF CONTENTS

1. ANALYSIS METHODS

1.1 ASSUMPTIONS

There are several assumptions made for the analyses of water quality. The key assumption is that the samples taken are a random sample of the site's water for that monitoring period (e.g., for that month in that year when measured).

Another necessary assumption is that missing data (e.g., a stream was not measured in a month in a particular year) is missing completely at random (MCAR), so that there is no information about the water quality from the "missingness". This assumption could be violated if, for example, samples were not taken because it was known that water quality was compromised on the selected sampling date. There is no way to assess this assumption except by carefully considering why data was not collected on a particular date. If, for example, data were not collected because the sampling vial broke in transit, this is likely a case of MCAR.

It is further assumed that the water columns of all sampled waterbodies are completely mixed so that depth effects can be ignored. This assumption was verified by examining the raw sample means at various depths and fitting statistical models to examine the effects of depth, and few depth effects were seen.

1.2 REPLICATE SAMPLES

Replicate samples collected within the same day and at the same depth were treated as pseudo-replicates (Hurlbert 1984) and values were averaged before further analyses. This will be an approximate analysis (compared to actually modelling replicated values as nested within a particular day), but given the high variability seen for most of the readings, the reported results should be insensitive to this averaging.

1.3 DEALING WITH CENSORING (VALUES BELOW DETECTION LIMITS)

The proportion of data with readings below the detection limit varies by waterbody and by water quality variable. The analyses below follow the advice of McBride (2005; Section 11.4.3).

- When the dataset includes a small number of below detection values, these values will be replaced by ½ of the detection limit for the analysis.
- When the majority of the dataset consists of values below the detection limit (e.g., more than about 70% below detection limit), there is very little that can be done as there is essentially no information (other than the values are below the detection limit). The analyses will be performed as above, but interpreting the results should be done carefully. Helsel (2005) has other suggestions for analysis (e.g., comparing the proportions below the detection limits) but these tests will require much larger sample sizes than available here.

- When there is an intermediate amount of censoring, a more complex analysis can be conducted that fully integrates the information from the censored values with the known values. This is most easily done using Bayesian Markov chain Monte Carlo (MCMC) methods. Complex integration is required for estimation using frequentist approaches. There is, currently, no readily available software available for the latter.

Fortunately, most water quality variables fall into one of the two first categories.

It should be noted that for data collected in the late 1990s, the detection limits were often considerably higher than the detection limits available for more recent sampling (often 5× or 6× higher). Consequently, there is little to be gained from using this very early data and it was often removed prior to analysis and treated as outliers as noted in the sections below.

1.4 TRANSFORMATIONS

For all water quality variables, the values were fairly homogeneous and no obvious transformation was suggested, i.e., metals analyzed on the parts per million (ppm) scale and pH measured on the log-scale.

1.5 DEALING WITH SPARSE DATA IN SOME CLASSIFICATIONS SUCH AS SEASON

In models with season effects, samples were not always collected during all seasons of all years or periods. In these cases, interaction effects involving season cannot be fit but additive models can still be fit.

1.6 OUTLINE OF ANALYSIS PLAN

There are several classes of statistical tests that can be done to assess evidence of change in the mean of the water quality variable over time and to assess if changes in the means may reflect an impact of the Project.

1.6.1 Before vs. After Analysis

The first analysis conducted compares the mean readings for all years prior to 2010 (before initiation of construction) to the mean for 2015. Each waterbody is treated independently, and each water quality variable is treated separately.

The final statistical model (in standard shorthand notation) is:

*Y = Period Season Period*Season Year(Period)-R*

where *Y* is the (mean) variable reading for a date within a year; *Period* is the effect of before vs. after Project initiation (which is the effect of interest); *Season* is the effect of early or late in the year; *Period*Season* represents the interaction between Project and season effects (i.e., is the effect of the period consistent in both seasons); and *Year(Period)* is a random year effect (applicable if more than one year was sampled during each period). This separates the variation in water quality into components representing variation within a season in a year and year-to-year variation. If the data are too sparse (e.g., not all seasons measured in all periods), then the *Period*Season* interaction effect cannot be estimated and is dropped.

This model is preferable to simply treating all measurement within a period (e.g., over several years pre-construction) as having the same mean and assuming that they are completely independent of each other. This model also "averages" the water quality values collected over the baseline years in way that weights each year equally rather than weighting by the sample size. For example, suppose that the water quality variable measured in 2008 was 22 ppm, while the two readings measured in year 2009 were 25 and 27 µg/L. The simple mean (22+25+27)/3=24.7 µg/L would be more heavily weighted toward the mean in 2009. In order to give each year's data equal weight, the reading over both years is computed as an average of averages:

$$\frac{\frac{22}{1}+\frac{25+27}{2}}{2} = 24.0\ \mu g/L$$

This can be extended to multiple years in a similar fashion.

The model was fit using R version 3.1.3. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. A nominal significance level of 0.05 was used when reviewing the results.

The key disadvantage of this model is that changes over time may be unrelated to the effects of the Project, e.g., the mean water quality readings in 2015 could be worse than expected because of long term climate change that is unrelated to the Project. Consequently, if a statistically significant effect is detected, it will require further investigation.

1.6.2 BACI Analysis

The standard method to assess an environmental impact is through a Before-After-Control-Impact (BACI) analysis (Smith 2002). The analysis of these designs looks for non-parallelism in response over time between the Project and reference waterbodies. A BACI analysis was performed for each Project waterbody versus the corresponding reference waterbody.

The formal statistical model (in standard shorthand notation) is:

*Y = Period Season Period*Season Class Period*Class Year(Period)-R*

where *Y* is the variable of interest; *Period* is the effect of period (before or after construction); *Season* is the effect of season (early (June or earlier) or late (July or later)); *Period*Season* represents the interaction between Project and season effects (i.e., is the effect of the period consistent in both seasons); *Class* is the effect of the site classification (Project or reference); *Period*Class* is the BACI effect of interest (i.e., is the effect of Period the same (parallel) for both classes of sites); and *Year(Period)* is the random year effect within each period (applicable if more than one year was sampled during each period). If the data are too sparse (e.g., not all seasons measured in all periods), then the *Period*Season* interaction effect cannot be estimated and is dropped. If there were multiple reference waterbodies (as is the case for streams), a term *Body(Class)-R* (the random site effect within each class) would also be added to the model so that the change in the mean for the Project site is compared to the average change in the mean for the reference bodies. Sites that were measured only in one period (e.g., Reference D OF measured only post-construction) contribute some information on the year-effect which improves precision of the BACI estimate.

Not all sites were measured in all years and only those Project-reference pairs of sites that were measured both in the before and after period can be used to estimate this BACI contrast. The results from this comparison are specific to the particular Project-reference sites.

The key variable of interest is the *Period*Class* effect as this measures the amount of non-parallelism between the changes in the mean (Before-After) over the two classes of sites (Project or reference). The BACI estimate is computed as the "difference in the differences":

$$BACI = \left(\mu_{PA} - \mu_{PB}\right) - \left(\mu_{RA} - \mu_{RB}\right)$$

where μ_{PA} is the mean variable reading in the *Project* class of sites *after* Project initiation, μ_{PB} is the mean variable reading in the *Project* class of sites *before* Project initiation, μ_{RA} is the mean variable reading in the *reference* class of sites *after* Project initiation, and μ_{RB} is the mean variable reading in the *reference* class of sites *before* Project initiation. The BACI contrast is estimated by replacing the population means above by the model-based estimates. Estimated differences close to 0 would indicate no evidence of non-parallelism.

Note that the hypothesis that the BACI contrast has the value of zero is identical to the hypothesis that the *Period*Class* interaction is zero with identical p-values. Consequently, only the results for the BACI contrast are reported here.

The model was fit using R version 3.1.3. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. A nominal significance level of 0.05 was used when reviewing the results.

1.6.3 Multivariate Approaches

All of the approaches above analyze each water quality variable independently of any other. However, the chemical constituents do not occur independently of each other, and presumably higher power would result if a multivariate approach were used. However, because of the censoring and missing data, no simple multivariate approach is possible and such an analysis would likely require the use of a full Bayesian MCMC approach. This has not been attempted in this report.

2. RESULTS

2.1 STREAM DATA

A summary of the amount of censoring (values below the detection limit) for the stream data is found in Table Stream-1. High levels of censoring in all streams were found for cadmium, nitrate, cyanide, and radium-226 variables and the results of the analyses for these variables will be non-informative and should be discarded.

Preliminary plots of the data showed some outliers, primarily from readings in the late 1990s where the detection limit was much higher than in recent times (Table Stream-2). These were discarded as such a large detection limit compared to more recent data provides little information on the actual value. Some other outliers that were not related to high detection limits were also discarded.

The results from the analysis that compared the means before and after Project construction are presented in Table Stream-3. There was evidence of a change in the mean between the before and after periods for radium-226 and copper in Little Roberts OF; and arsenic, molybdenum, and radium-226 in Roberts OF.

The results of the BACI comparison of each Project stream against the reference streams (Table Stream-4) found evidence of a differential response in the mean total mercury concentration between Roberts Outflow and reference streams over the before and after periods.

2.2 MARINE DATA

A summary of the amount of censoring (values below the detection limit) for the site data is found in Table Marine-1. High levels of censoring in all marine exposure sites were found for cyanide and radium-226 and the results of the analyses for these variables will be non-informative and should be discarded.

Preliminary plots of the data showed some outliers which were removed prior to analysis (Table Marine-2). Of particular concern are the arsenic readings at the RBE site, which were substantially elevated between 2004 and 2006, but then fell to near or below detection limits from 2007 to 2015. The elevated readings prior to 2007 were treated as outliers and removed from the analysis to ensure that these observations did not artificially inflate the variance estimates, leading to a reduced power to detect effects.

The results from the analysis that compared the means before and after Project construction are presented in Table Marine-3. There was evidence of a change in the mean between the before and after periods for pH, ammonia, and mercury at RBW. The results of the BACI comparison (Table Marine-4) found evidence of a differential response in the mean mercury concentration between RBW and the reference site over the before and after periods.

2.3 SMALL LAKE DATA

A summary of the amount of censoring (values below the detection limit) for the small lake data is found in Table Small Lake-1. High levels of censoring in all streams were found for cadmium, cyanide, and radium-226 variables and the results of the analyses for these variables will be non-informative and should be discarded.

Preliminary plots of the data showed some outliers that were primarily censored data from the early 1990s. The observations listed in Table Small Lake-2 were discarded prior to analysis to ensure that these observations did not artificially inflate the variance estimates leading to a reduced power to detect effects.

The results from the analysis that compared the means before and after Project construction are presented in Table Small Lake-3. There was evidence of a change in the mean between the before and after periods for pH and molybdenum variables. Because water quality samples were not collected at Reference Lake D before construction started, no BACI analysis is possible.

2.4 LARGE LAKE DATA

A summary of the amount of censoring (values below the detection limit) for the large lake data is found in Table Large Lake-1. High levels of censoring in all lakes were found for cadmium, cyanide, and radium-226 variables and the results of the analyses for these variables will be non-informative and should be discarded.

Preliminary plots of the data showed some potential outliers that were excluded from the analysis (Table Large Lake-2).

There was evidence of a difference in the means between the before and after periods for arsenic in Doris North; and hardness, cyanide, and mercury in Doris Lake South. The BACI comparison found evidence of a differential response for arsenic and mercury in Doris North, and for mercury and lead in Doris South compared to the reference site over the before and after periods (Table Large Lake-4).

REFERENCES

Helsel, D.R. (2005). Nondetects and Data Analysis.Wiley: New York.

Hurlbert, S.H. (1984) Pseudoreplication and the Design of Ecological Field Experiments. Ecological Monographs 54: 187-211.

McBride, G.B. (2005). Using Statistical Methods for Water Quality Management. Wiley: New York.

Smith, E. P. (2002). BACI Design. Encyclopedia of Environmetrics. Wiley: New York.

TABLES

Table Stream-1. Summary of the Proportion of Measurements that were Below Detection Limit (Before Outliers Removed) for Stream Sampling

	Stream Site				
	Doris OF	**Little Roberts OF**	**Ref. B OF**	**Ref. D OF**	**Roberts OF**
Variable	**Proportion Censored**	**Proportion Censored**	**Proportion Censored**	**Proportion Censored**	**Proportion Censored**
Aluminum (Al)	0.00	0.00	0.00	0.00	0.00
Alkalinity	0.00	0.00	0.00	0.00	0.00
Ammonia	0.30	0.36	**0.79**	**0.75**	0.32
Arsenic (As)	0.06	0.03	0.00	0.00	0.00
Cyanide (CN)	**0.88**	**0.77**	**1.00**	**1.00**	**0.81**
Cadmium (Cd)	**0.78**	0.67	**1.00**	**1.00**	**0.71**
Copper (Cu)	0.00	0.00	0.07	0.00	0.00
Iron (Fe)	0.00	0.00	0.07	0.00	0.00
Hardness	0.00	0.00	0.00	0.00	0.00
Mercury (Hg)	**0.75**	0.68	0.57	0.00	0.58
Molybdenum(Mo)	0.05	0.00	**1.00**	0.25	0.00
Nickel (Ni)	0.05	0.00	0.36	0.00	0.00
Nitrate	**0.86**	**0.95**	0.29	**1.00**	**0.84**
Lead (Pb)	0.22	0.23	**1.00**	**0.75**	0.19
Radium-226 (Ra)	**0.91**	**0.94**	**0.88**	**1.00**	**0.94**
Total Suspended Solids (TSS)	0.14	0.05	**1.00**	0.38	0.03
Zinc (Zn)	0.28	0.33	**1.00**	**1.00**	0.29
pH	0.00	0.00	0.00	0.00	0.00

Notes: Dataset includes all baseline years up to and including 2009, and 2015.
Proportions ≥0.70 are bolded.

Table Stream-2. Summary of Potential Outliers from the Stream Data

Stream	Variable	Year	Date	Rep	Value	Censored (1=yes 0=no)
Doris OF	Ammonia	1997	19JUL97	1	1.359800	0
Doris OF	Ammonia	1997	19JUL97	2	1.402400	0
Doris OF	Ammonia	1997	20AUG97	1	1.353300	0
Doris OF	As	1996	23JUN96	1	0.002000	1
Doris OF	As	1996	22AUG96	1	0.003000	0
Doris OF	Cd	1996	23JUN96	1	0.000190	0
Doris OF	Cd	1996	22AUG96	1	0.000025	1
Doris OF	Cd	1997	19JUN97	1	0.000100	1
Doris OF	Cd	1997	19JUL97	1	0.000100	1
Doris OF	Cd	1997	19JUL97	2	0.000100	1
Doris OF	Cd	1997	20AUG97	1	0.000100	1
Doris OF	Cd	2000	20JUN00	1	0.000025	1
Doris OF	Cd	2000	20JUN00	2	0.000025	1
Doris OF	Cd	2000	14SEP00	1	0.000025	1
Doris OF	Cd	2000	14SEP00	2	0.000025	1
Doris OF	Cd	2004	24JUN04	1	0.000025	1
Doris OF	Hg	1997	20AUG97	1	0.000025	1
Doris OF	Hg	2000	20JUN00	1	0.000025	1
Doris OF	Hg	2000	20JUN00	2	0.000025	1
Doris OF	Hg	2000	14SEP00	1	0.000025	1
Doris OF	Hg	2000	14SEP00	2	0.000025	1
Doris OF	Hg	2003	28JUL03	1	0.000025	1
Doris OF	Mo	1997	19JUN97	1	0.000500	1
Doris OF	Mo	1997	19JUL97	1	0.000500	1
Doris OF	Mo	1997	19JUL97	2	0.000500	1
Doris OF	Mo	1997	20AUG97	1	0.000500	1
Doris OF	Pb	1997	19JUN97	1	0.000500	1
Doris OF	Pb	1997	19JUL97	1	0.000500	1
Doris OF	Pb	1997	19JUL97	2	0.000500	1
Doris OF	Pb	1997	20AUG97	1	0.000500	1
Little Roberts OF	Hg	2003	28JUL03	1	0.000025	1

Notes: Censored values were replaced by ½ of the detection limit.

Table Steam-3. Summary of Test for No Difference in Mean between Before and After Periods for Stream Water Quality Variables

	Effect				
	Period Stream Site				
	Doris OF	Little Roberts OF	Ref. B OF	Ref. D OF	Roberts OF
Variable	p-value	p-value	p-value	p-value	p-value
Aluminum (Al)	0.6970	0.0537	0.1510	.	0.0731
Alkalinity	0.5226	0.3579	0.0896	.	0.0610
Ammonia	0.5730	0.5082	**0.0231**	.	0.7888
Arsenic (As)	0.3388	0.2382	0.2843	.	**0.0047**
Cyanide (CN)	0.6344	0.3238	.	.	0.3110
Cadmium (Cd)	0.6952	0.9897	**<0.0001**	.	0.7195
Copper (Cu)	0.6586	**0.0246**	0.4753	.	0.1428
Iron (Fe)	0.2081	0.4029	0.8197	.	0.0973
Hardness	0.9676	0.7198	0.3462	.	0.5399
Mercury (Hg)	0.9778	0.9771	**0.0001**	.	0.1021
Molybdenum (Mo)	0.8368	0.0746	**<0.0001**	.	**0.0013**
Nickel (Ni)	0.3772	0.9827	0.6990	.	0.8011
Nitrate	0.4294	0.5926	0.5761	.	0.2316
Lead (Pb)	0.5654	0.2221	**<0.0001**	.	0.0952
Radium-226 (Ra)	0.2144	**0.0030**	.	.	**0.0023**
Total Suspended Solids (TSS)	0.9321	0.5646	**<0.0001**	.	0.9666
Zinc (Zn)	0.5902	0.3005	**<0.0001**	.	0.2991
pH	0.4973	0.4309	0.6457	.	0.4913

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Table Stream-4. Summary of BACI Comparison of Water Quality Variables for Individual Project Stream Sites

	Stream Site		
	Doris OF	Little Robert OF	Roberts OF
Variable	p-value	p-value	p-value
Aluminum (Al)	0.8926	0.3841	0.3880
Alkalinity	0.5493	0.5937	0.5135
Ammonia	0.5815	0.6996	0.8785
Arsenic (As)	0.7100	0.5002	0.0538
Cyanide (CN)	.	.	.
Cadmium (Cd)	0.4546	0.6073	0.8801
Copper (Cu)	0.6965	0.3451	0.7148
Iron (Fe)	0.5350	0.9765	0.8060
Hardness	0.8923	0.6352	0.9876
Mercury (Hg)	0.3550	0.4693	**0.0003**
Molybdenum (Mo)	0.9389	0.3113	0.1448
Nickel (Ni)	0.5211	0.6683	0.9480
Nitrate	0.8677	0.4345	0.6707
Lead (Pb)	0.7455	0.4088	0.2981
Radium-226 (Ra)	.	.	.
Total Suspended Solids (TSS)	0.6992	0.4112	0.5549
Zinc (Zn)	0.5634	0.4690	0.3031
pH	0.6700	0.8060	0.7358

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Table Marine-1. Summary of the Proportion of Measurements that were Below Detection Limit (Before Outliers Removed) for Marine Sampling

	Site		
	RBE	**RBW**	**REF-Marine 1**
Variable	**Proportion Censored**	**Proportion Censored**	**Proportion Censored**
Aluminum (Al)	0.10	0.36	0.22
Alkalinity	0.00	0.00	0.00
Ammonia	0.45	**1.00**	**0.89**
Arsenic (As)	0.10	0.00	0.00
Cyanide (CN)	**0.82**	**1.00**	**1.00**
Cadmium (Cd)	0.30	0.00	0.00
Copper (Cu)	0.00	0.00	0.00
Iron (Fe)	0.10	0.27	0.22
Hardness	0.00	0.00	0.00
Mercury (Hg)	0.63	**1.00**	**0.78**
Molybdenum (Mo)	0.10	0.09	0.00
Nickel (Ni)	0.10	0.00	0.00
Nitrate	0.68	0.36	0.44
Lead (Pb)	0.47	0.55	**0.78**
Radium-226 (Ra)	**0.93**	**0.88**	**0.75**
Total Suspended Solids (TSS)	0.14	0.36	0.56
Zinc (Zn)	0.20	0.64	0.67
pH	0.00	0.00	0.00

Notes: Dataset includes all baseline years up to and including 2009, and 2015.
Proportions ≥0.70 are bolded.

Table Marine-2. Summary of Potential Outliers from the Marine Data

Site	Variable	Year	Date	Rep	Value	Censored (1=yes 0=no)
RBE	Ammonia	1996	28AUG96	1	2.500000	1
RBE	Ammonia	2007	23JUL07	1	0.214000	0
RBE	As	1996	28AUG96	1	0.002500	1
RBE	As	2004	19JUL04	1	0.008020	0
RBE	As	2004	14AUG04	1	0.015200	0
RBE	As	2004	16AUG04	1	0.013100	0
RBE	As	2004	09SEP04	1	0.022300	0
RBE	As	2005	21JUL05	1	0.004730	0
RBE	As	2005	18AUG05	1	0.022100	0
RBE	As	2005	14SEP05	1	0.021200	0
RBE	As	2006	31MAY06	1	0.015200	0
RBE	As	2006	20JUL06	1	0.013300	0
RBE	As	2006	12AUG06	1	0.025600	0
RBE	As	2006	11SEP06	1	0.023680	0
RBE	Cyanide	2007	27MAY07	1	0.250000	1
RBE	Cyanide	2007	23JUL07	1	2.500000	1
RBE	Cd	1996	28AUG96	1	0.003480	0
RBE	Ni	1996	28AUG96	1	0.021500	0
RBE	Nitrate	1996	28AUG96	1	2.500000	1

Notes: Censored values were replaced by ½ of the detection limit.

Table Marine-3. Summary of Test for No Difference in Mean between Before and After Periods for Marine Water Quality Variables

	Effect		
	Period Marine Site		
	RBE	RBW	REF-Marine 1
Variable	p-value	p-value	p-value
Aluminum (Al)	0.7310	0.6180	0.5650
Alkalinity	0.1995	.	.
Ammonia	0.2768	**<0.0001**	**<0.0001**
Arsenic (As)	0.7496	0.3083	0.2101
Cyanide (CN)	0.6805	.	.
Cadmium (Cd)	0.8024	0.2142	0.4756
Copper (Cu)	0.6899	0.6291	0.1937
Iron (Fe)	0.6461	0.5866	0.5620
Hardness	0.8175	0.9255	.
Mercury (Hg)	0.3075	**<0.0001**	**0.0017**
Molybdenum (Mo)	0.8450	0.4002	0.9655
Nickel (Ni)	0.7820	0.5981	0.3512
Nitrate	0.9362	0.3734	0.4521
Lead (Pb)	0.6690	0.8294	0.4490
Radium-226 (Ra)	0.9343	.	.
Total Suspended Solids (TSS)	0.3087	0.3332	0.9607
Zinc (Zn)	0.4023	0.6267	0.8919
pH	0.8609	**0.0372**	0.8524

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Table Marine-4. Summary of BACI Comparison of Water Quality Variables for Individual Project Marine Sites

	Marine Project Site	
	RBE	**RBW**
Variable	**p-value**	**p-value**
Aluminum (Al)	0.6745	0.7903
Alkalinity	.	.
Ammonia	0.4844	**<0.0001**
Arsenic (As)	0.1498	0.7106
Cyanide (CN)	.	.
Cadmium (Cd)	0.3736	0.9022
Copper (Cu)	0.7269	0.5876
Iron (Fe)	0.5848	0.8228
Hardness	.	.
Mercury (Hg)	0.4768	0.6919
Molybdenum (Mo)	0.8764	0.1709
Nickel (Ni)	0.6654	0.6408
Nitrate	0.5603	0.8408
Lead (Pb)	0.5353	0.9332
Radium-226 (Ra)	.	.
Total Suspended Solids (TSS)	0.3933	0.9547
Zinc (Zn)	0.7944	0.4642
pH	0.8804	0.8331

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Table Small Lake-1. Summary of the Proportion of Measurements that were Below Detection Limit (Before Outliers Removed) for Small Lake Sampling

	Small Lake Site	
	Little Roberts	Reference D
Variable	Proportion Censored	Proportion Censored
Aluminum (Al)	0.00	0.00
Alkalinity	0.03	0.00
Ammonia	0.30	**0.78**
Arsenic (As)	0.09	0.00
Cyanide (CN)	**0.85**	**1.00**
Cadmium (Cd)	**0.76**	**0.89**
Copper (Cu)	0.00	0.00
Iron (Fe)	0.00	0.00
Hardness	0.00	0.00
Mercury (Hg)	0.50	0.56
Molybdenum (Mo)	0.06	0.22
Nickel (Ni)	0.03	0.00
Nitrate	0.68	**0.89**
Lead (Pb)	0.22	0.56
Radium-226 (Ra)	**0.85**	**0.78**
Total Suspended Solids (TSS)	0.11	**0.78**
Zinc (Zn)	0.30	**1.00**
pH	0.00	0.00

Notes: Dataset includes all baseline years up to and including 2009, and 2015.
Proportions ≥0.70 are bolded.

Table Small Lake-2. Summary of Potential Outliers from the Small Lake Data

Lake	Variable	Year	Date	Rep	Reading	Censored (1=yes 0=no)
Little Roberts	Ammonia	2007	24MAY07	1	0.240000	0
Little Roberts	Cd	1995	07MAY95	1	0.000100	1
Little Roberts	Cd	1995	07JUN95	1	0.000100	1
Little Roberts	Cd	1996	27AUG96	1	0.000025	1
Little Roberts	Cd	1996	27AUG96	2	0.000025	1
Little Roberts	Cd	1997	15JUL97	1	0.000100	1
Little Roberts	Cd	1997	15JUL97	2	0.000100	1
Little Roberts	Hg	2003	27JUL03	1	0.000230	0
Little Roberts	Mo	1997	15JUL97	1	0.000500	1
Little Roberts	Mo	1997	15JUL97	2	0.000500	1
Little Roberts	Nitrate	2004	13SEP04	1	5.300000	0
Little Roberts	Zn	1995	07MAY95	1	0.327000	0

Notes: Censored values were replaced by ½ of the detection limit.

Table Small Lake-3. Summary of Test for No Difference in Mean between Before and After Periods for Small Lake Water Quality Variables

	Effect	
	Period Small Lake Site	
	Little Roberts	Reference D
Variable	**p-value**	**p-value**
Aluminum (Al)	0.4597	.
Alkalinity	0.9124	.
Ammonia	0.1404	.
Arsenic (As)	0.4826	.
Cyanide (CN)	0.2282	.
Cadmium (Cd)	0.8085	.
Copper (Cu)	0.6177	.
Iron (Fe)	0.2725	.
Hardness	0.8404	.
Mercury (Hg)	0.2985	.
Molybdenum (Mo)	**0.0271**	.
Nickel (Ni)	0.6992	.
Nitrate	0.2764	.
Lead (Pb)	0.4853	.
Radium-226 (Ra)	0.5946	.
Total Suspended Solids (TSS)	0.2419	.
Zinc (Zn)	0.3141	.
pH	**0.0015**	.

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Table Large Lake-1. Summary of the Proportion of Measurements that were Below Detection Limit (Before Outliers Removed) for Large Lake Sampling

	Large Lake Site		
	Doris North	**Doris South**	**Reference B**
Variable	**Proportion Censored**	**Proportion Censored**	**Proportion Censored**
Aluminum (Al)	0.00	0.05	0.00
Alkalinity	0.00	0.00	0.00
Ammonia	0.29	0.63	0.64
Arsenic (As)	0.08	0.23	0.14
Cyanide (CN)	**0.82**	**1.00**	**1.00**
Cadmium (Cd)	**0.73**	**0.98**	**0.86**
Copper (Cu)	0.01	0.00	0.07
Iron (Fe)	0.05	0.14	0.36
Hardness	0.00	0.00	0.00
Mercury (Hg)	0.48	**0.77**	0.64
Molybdenum (Mo)	0.07	0.33	**1.00**
Nickel (Ni)	0.00	0.23	0.57
Nitrate	0.68	0.59	**0.71**
Lead (Pb)	0.19	0.42	0.57
Radium-226 (Ra)	**0.92**	**0.75**	**0.89**
Total Suspended Solids (TSS)	0.08	0.18	**1.00**
Zinc (Zn)	0.19	0.53	**0.79**
pH	0.00	0.00	0.00

Notes: Dataset includes all baseline years up to and including 2009, and 2015.
Proportions ≥0.70 are bolded.

Table Large Lake-2. Summary of Potential Outliers from the Large Lake Data

Lake	Variable	Year	Date	Rep	Reading	Censored (1=yes 0=no)
Doris North	As	1995	20AUG95	1	0.003000	0
Doris South	As	1996	28AUG96	1	0.005000	0
Doris South	As	1996	28AUG96	1	0.004000	0
Doris South	As	1996	28AUG96	1	0.007000	0
Doris South	As	1996	28AUG96	1	0.015000	0
Doris North	Cd	1995	04MAY95	1	0.000100	1
Doris North	Cd	1995	07JUN95	1	0.000100	1
Doris North	Cd	1995	20AUG95	1	0.000050	1
Doris North	Cd	1995	20AUG95	1	0.000050	1
Doris North	Cd	1995	20AUG95	1	0.000050	1
Doris North	Cd	1995	20AUG95	1	0.000050	1
Doris North	Cd	1995	20AUG95	1	0.000050	1
Doris South	Cd	1995	04MAY95	1	0.000100	1
Doris South	Cd	1995	07JUN95	1	0.000100	1
Doris South	Cd	1995	20AUG95	1	0.000050	1
Doris South	Cd	1995	20AUG95	1	0.000050	1
Doris South	Cd	1995	20AUG95	1	0.000050	1
Doris South	Cd	1995	20AUG95	2	0.000050	1
Doris South	Cd	1997	18APR97	1	0.000100	1
Doris South	Cd	1997	18JUL97	1	0.000100	1
Doris South	Cd	1997	18JUL97	1	0.000100	1
Doris South	Cd	1997	18JUL97	2	0.000100	1
Doris South	Cd	1997	18JUL97	2	0.000100	1
Doris South	Cd	1997	22AUG97	1	0.000100	1
Doris South	Cd	1997	22AUG97	1	0.000100	1
Doris South	Cd	1998	25APR98	1	0.000100	1
Doris South	Cd	1998	25APR98	2	0.000100	1
Doris South	Cd	1998	25APR98	3	0.000100	1
Doris South	Hg	1997	22AUG97	1	0.000025	1
Doris South	Hg	1997	22AUG97	1	0.000025	1
Doris South	Hg	1998	25APR98	1	0.000025	1
Doris South	Hg	1998	25APR98	2	0.000025	1
Doris South	Hg	1998	25APR98	3	0.000025	1
Doris South	Hg	2000	24JUL00	1	0.000025	1
Doris South	Hg	2000	24JUL00	2	0.000025	1

(continued)

Table Large Lake-2. Summary of Potential Outliers from the Large Lake Data (completed)

Lake	Variable	Year	Date	Rep	Reading	Censored (1=yes 0=no)
Doris South	Hg	2000	24JUL00	1	0.000025	1
Doris South	Hg	2000	24JUL00	2	0.000025	1
Doris South	Hg	2000	22AUG00	1	0.000025	1
Doris South	Hg	2000	22AUG00	2	0.000025	1
Doris South	Mo	1997	18APR97	1	0.000500	1
Doris South	Mo	1997	18JUL97	1	0.000500	1
Doris South	Mo	1997	18JUL97	1	0.000500	1
Doris South	Mo	1997	18JUL97	2	0.000500	1
Doris South	Mo	1997	18JUL97	2	0.000500	1
Doris South	Mo	1997	22AUG97	1	0.000500	1
Doris South	Mo	1997	22AUG97	1	0.000500	1
Doris South	Mo	1998	25APR98	1	0.000500	1
Doris South	Mo	1998	25APR98	2	0.000500	1
Doris South	Mo	1998	25APR98	3	0.000500	1
Doris North	Ni	2005	19JUL05	1	0.028300	0
Doris North	Pb	2004	05JUN04	1	0.006690	0
Doris South	Nitrate	1996	28AUG96	1	4.510000	0

Notes: Censored values were replaced by ½ of the detection limit.

Table Large Lake-3. Summary of Test for No Difference in Mean between Before and After Periods for Large Lake Water Quality Variables

	Effect		
	Period		
	Large Lake Site		
	Doris North	**Doris South**	**Reference B**
Variable	**p-value**	**p-value**	**p-value**
Aluminum (Al)	0.9118	0.7003	0.3796
Alkalinity	0.0877	0.0885	**0.0278**
Ammonia	0.1052	0.1233	**<0.0001**
Arsenic (As)	**0.0019**	0.4224	0.1477
Cyanide (CN)	0.3736	**<0.0001**	.
Cadmium (Cd)	0.6509	0.3995	**<0.0001**
Copper (Cu)	0.2653	0.1987	0.4135
Iron (Fe)	0.4917	0.6831	0.1923
Hardness	0.0828	**0.0267**	0.4675
Mercury (Hg)	0.2807	**<0.0001**	**0.0003**
Molybdenum (Mo)	0.9610	0.5632	**<0.0001**
Nickel (Ni)	0.8777	0.6173	0.3333
Nitrate	0.1335	0.3101	**<0.0001**
Lead (Pb)	0.7069	0.3201	0.6927
Radium-226 (Ra)	0.7398	.	.
Total Suspended Solids (TSS)	0.7606	0.9094	**<0.0001**
Zinc (Zn)	0.5227	0.4308	**<0.0001**
pH	0.1949	0.1643	**0.0425**

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Table Large Lake-4. Summary of BACI Comparison of Water Quality Variables for Individual Project Large Lake Sites

	Large Lake Site	
	Doris North	**Doris South**
Variable	**p-value**	**p-value**
Aluminum (Al)	0.4682	0.9238
Alkalinity	0.4516	0.6217
Ammonia	0.6976	0.4601
Arsenic (As)	**0.0247**	0.5013
Cyanide (CN)	.	.
Cadmium (Cd)	0.8958	0.6888
Copper (Cu)	0.2261	0.2609
Iron (Fe)	0.3344	0.8995
Hardness	0.7560	0.6930
Mercury (Hg)	**0.0395**	**0.0411**
Molybdenum (Mo)	0.8512	0.7176
Nickel (Ni)	0.6137	0.6395
Nitrate	0.1489	0.0994
Lead (Pb)	0.6461	**0.0217**
Radium-226 (Ra)	.	.
Total Suspended Solids (TSS)	0.4008	0.2321
Zinc (Zn)	0.2309	0.3431
pH	0.7766	0.8837

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Appendix B.2.3. Statistical Methodology and Results for Sediment Quality Evaluation of Effects, Doris North Project, 2015

TABLE OF CONTENTS

1. ANALYSIS METHODS

1.1 ASSUMPTIONS

There are several assumptions made for the analyses in this section. The key assumption is that the samples taken are a random sample of the site's sediment for that monitoring period.

Samples were typically collected only once per year (usually August). Consequently no information is available on month-to-month variation in sediment variables, and inference will be limited to the sampled months.

For the marine environment, the sampling years before construction are quite different (2002 and 2009) for the two sites for which historical data are available (RBW and REF-Marine 1). Consequently, care must be taken in the interpretation of any comparisons between sites as the results may be artifacts of the specific years chosen.

1.2 DEALING WITH CENSORING (VALUES BELOW DETECTION LIMITS)

The proportion of data with readings below the detection limit varies by waterbody and by chemical variable. The analyses below follow the advice of McBride (2005; Section 11.4.3).

- When the dataset includes a small number of below detection values, these values will be replaced by ½ of the detection limit for the analysis.
- When the majority of the dataset consists of values below the detection limit (e.g., more than about 70% below detection limit), there is very little that can be done as there is essentially no information (other than the values are below the detection limit). The analyses will be performed as above, but interpreting the results should be done carefully. Helsel (2005) has other suggestions for analysis (e.g., comparing the proportions below the detection limits) but these tests will require much larger sample sizes than available here.
- When there is an intermediate amount of censoring, a more complex analysis can be conducted that fully integrates the information from the censored values with the known values. This is most easily done using Bayesian Markov chain Monte Carlo (MCMC) methods. Complex integration is required for estimation using frequentist approaches. There is currently, no readily available software available for the latter.

Fortunately, most sediment quality variables fall into one of the two first categories.

1.3 TRANSFORMATIONS

For most variables, the values were fairly homogeneous and no obvious transformation was suggested, i.e., metals analyzed on the ppm scale (mg/kg).

1.4 COMPOSITIONAL DATA

The measurements of the particle size composition of the sediment (sand, gravel, etc.) are compositional with the values necessarily adding to 100%. Each component has been analyzed separately, but it is impossible to have changes in the percent composition of one component without changes in other components. Alternative methods dealing with compositional data are available (Aitchison 1986), but have not been used in this report because they cannot easily deal with censoring and because the number of samples is limited.

1.5 OUTLINE OF ANALYSIS PLAN

There are several classes of statistical tests that can be done to assess evidence of change in the mean of the sediment quality variable over time and to assess if changes in the means may reflect an impact of the Project.

1.5.1 Before vs. After Analysis

The first analysis conducted compares the mean readings for all years prior to 2010 (before initiation of construction) to the mean for 2015. Each waterbody is treated independently, and each sediment quality variable is treated separately.

The final statistical model (in standard shorthand notation) is:

$$Y = Period\ Year(period)\text{-}R$$

where Y is the (mean) variable reading in a year; *Period* is the effect of before vs. after Project initiation (which is the effect of interest), and *Year(Period)* is a random year effect (applicable if more than one year was sampled during each period).

This model is preferable to simply treating all measurement within a period (e.g., over all baseline years) as having the same mean and assuming that they are completely independent of each other. This model also "averages" the sediment quality values collected over the baseline years in a way that weights each year equally rather than weighting by the sample size. For example, suppose that the sediment quality variable measured in 2008 was 22 mg/kg, while the two readings measured in 2009 were 25 and 27 mg/kg. The simple mean (22+25+27)/3=24.7 mg/kg would be more heavily weighted toward the mean in the second year. In order to give each year's data equal weight, the reading over both years is computed as an average of averages:

$$\frac{\frac{22}{1}+\frac{25+27}{2}}{2} = 24.0 \text{ mg/kg}$$

This can be extended to multiple years in a similar fashion. Note that in the case of balanced data, i.e. equal number of replicates in all years, the average-of-the-averages and simple-average will be identical. The model with a random year effect is still preferred in the case of balanced data because the readings within a year may be correlated due to year-specific random factors that cause all the readings within a year to increase or decrease in step.

The model was fit using R version 3.1.3. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. A nominal significance level of 0.05 was used when reviewing the results.

The key disadvantage of this model is that changes over time may be unrelated to the effects of the Project, e.g., the mean sediment quality readings 2015 could be worse than expected because of long term climate change that is unrelated to the Project. Consequently, if a statistically significant effect is detected, it will require further investigation.

1.5.2 BACI Analysis

The standard method to assess an environmental impact is through a Before-After-Control-Impact (BACI) analysis (Smith 2002). The analysis of these designs looks for non-parallelism in response over time between the Project and reference waterbodies.

For the lake environments, no "before" sediment quality data was available for the reference lakes. Consequently, no BACI analysis can be performed for the lake environments.

For marine and stream environments, the formal statistical model (in standard shorthand notation) is:

$$Y = Period\ Class\ Period{*}Class$$

where Y is the sediment quality variable reading; *Period* is the effect of period (before or after construction); *Class* is the effect of water body classification (Project or reference); and *Period*Class* is the BACI effect of interest, i.e., is the effect of *Period* the same (parallel) for both classes of waterbody. For the stream environments, a term *Body(Class)-R* (the random site effect within each class) would also be added to the model so that the change in the mean for each Project stream is compared to the average change in the mean for the reference bodies. Sites that were measured only in one period (e.g., Reference D OF measured only post-construction) contribute some information on the year-effect which improves precision of the BACI estimate. Only one year of baseline data are available for stream and marine sites; therefore, the model does not include a random year effect.

The key variable of interest is the *Period*Class* effect as this measures the amount of non-parallelism between the changes in the mean (Before-After) over the two classes of waterbodies (Project or reference).

The BACI estimate is computed as the "difference in the differences":

$$BACI = \left(\mu_{PA} - \mu_{PB}\right) - \left(\mu_{RA} - \mu_{RB}\right)$$

where μ_{PA} is the mean variable reading in the *Project* class of sites *after* Project initiation, μ_{PB} is the mean variable reading in the *Project* class of sites *before* Project initiation, μ_{RA} is the mean variable reading in the *reference* class of sites *after* Project initiation, and μ_{RB} is the mean variable reading in the *reference* class of sites *before* Project initiation. The BACI contrast is estimated by replacing the population means above by the model-based estimates. Estimated differences close to 0 would indicate no evidence of non-parallelism.

Note that the hypothesis that the BACI contrast has the value of zero is identical to the hypothesis that the Period*Class interaction is zero with identical p-values. Consequently, only the results for the BACI contrast are reported in here.

The model was fit using R version 3.1.3. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. A nominal significance level of 0.05 was used when reviewing the results.

1.5.3 Multivariate Approaches

All of the approaches above analyze each sediment quality variable independently of any other. However, the chemical constituents do not occur independently of each other, and presumably higher power would result if a multivariate approach were used. However, because of the censoring and missing data, no simple multivariate approach is possible and such an analysis would likely require the use of a full Bayesian MCMC approach. This has not been attempted in this report.

2. RESULTS

2.1 STREAM DATA

A summary of the amount of censoring (values below the detection limit) for the stream data is found in Table Stream-1. High levels of censoring were found for cadmium (at all sites) and mercury (at Roberts Outflow and Reference B Outflow). As a consequence, the results of the analyses for these variables will be non-informative. Preliminary plots of the data failed to show any outliers.

The results from the analysis that compared the means before and after Project construction are presented in Table Stream-2. Differences between before and after means were detected for % gravel in Doris OF; % gravel, % clay, % silt, % TOC, copper, lead, and mercury in Little Roberts Outflow; and arsenic and cadmium in Reference B Outflow.

The results of the BACI comparison (Table Stream-3) found evidence of a differential change in % gravel in Doris Outflow; and % clay, % silt, % TOC, chromium, copper, lead, mercury, and zinc in Little Roberts Outflow compared to the reference streams over the before and after periods.

2.2 MARINE DATA

A summary of the amount of censoring (values below the detection limit) for the marine data is found in Table Marine-1. High levels of censoring were found for cadmium (at RBE and RBW), mercury (at RBE and RBW), and % gravel (at RBW and REF-Marine 1) and the results of the analyses for these variables will be non-informative. Preliminary plots of the data showed no outliers.

The results from the analysis that compared the means before and after Project construction are presented in Table Marine-2. There was evidence of a difference in means across the periods at RBW for % clay, % sand, % silt, % TOC, arsenic, cadmium, chromium, copper, lead, and zinc; and at REF-Marine 1 for % gravel, % silt, chromium, and lead.

A BACI analysis could not be done for RBW because of a lack of degrees of freedom in the before periods. Additionally, BACI and before-after comparisons could not be done for RBE because sediment quality data was not collected pre-construction.

2.3 LAKE DATA

A summary of the amount of censoring (values below the detection limit) for the lake data is found in Table Lake-1. High levels of censoring were found for the % gravel variable (at all sites except Reference Lake B) and the results of the analyses for this variable will be non-informative. Preliminary plots of the data showed no evidence of outliers.

There was evidence of a change between the before and after periods for % gravel, % sand, copper, and lead in Doris Lake South; % sand, % TOC, cadmium, copper, lead, and zinc concentration in Doris Lake North; and % gravel, % sand, % clay, lead, and zinc concentration in Little Roberts Lake (Table Lake-2). Because no reference lakes were measured in the before period, no BACI comparisons were possible.

REFERENCES

Aitchison, J. (1986). *The Statistical Analysis of Compositional Data*.Chapman & Hall.

Helsel, D.R. (2005). *Nondetects and data analysis*.Wiley:New York.

McBride, G.B. (2005). *Using statistical methods for water quality management*. Wiley: New York.

Smith, E. P. (2002). *BACI Design.Encyclopedia of Environmetrics*. Wiley: New York.

TABLES

Table Stream-1. Summary of the Proportion of Measurements that were Below Detection Limit

	Stream Site				
	Doris OF	Little Roberts OF	Reference B OF	Reference D OF	Roberts OF
Variable	Proportion Censored	Proportion Censored	Proportion Censored	Proportion Censored	Proportion Censored
% Clay (<4 µm)	0.33	0.00	0.17	0.00	0.00
% Gravel (>2 mm)	0.17	0.33	0.00	0.00	0.00
% Sand (2.0 mm - 0.063 mm)	0.00	0.00	0.00	0.00	0.00
% Silt (0.063 mm – 4 µm)	0.17	0.00	0.00	0.00	0.00
Arsenic (As)	0.00	0.00	0.00	0.00	0.00
Cadmium (Cd)	0.67	**0.83**	**1.00**	**1.00**	0.67
Chromium (Cr)	0.00	0.00	0.00	0.00	0.00
Copper (Cu)	0.00	0.00	0.00	0.00	0.00
Lead (Pb)	0.33	0.00	0.33	0.00	0.00
Mercury (Hg)	0.50	0.50	**0.83**	0.00	**1.00**
Total Organic Carbon	0.17	0.00	0.00	0.00	0.00
Zinc (Zn)	0.00	0.00	0.00	0.00	0.00

Notes: Dataset includes all baseline years up to and including 2009, and 2015.
Proportions ≥0.70 are bolded.

Table Stream-2. Summary of Test for No Difference in Mean between Before and After Periods for Stream Sediment Quality Variables

	Stream Site				
	Doris OF	Little Roberts OF	Reference B OF	Reference D OF	Roberts OF
Variable	P-value	P-value	P-value	P-value	P-value
% Clay (<4 µm)	0.2606	**0.0002**	0.5203	.	.
% Gravel (>2 mm)	**0.0104**	**0.0004**	0.3158	.	.
% Sand (2.0 mm - 0.063 mm)	0.2463	0.5316	0.2847	.	.
% Silt (0.063 mm - 4 µm)	0.2173	**0.0003**	0.5184	.	.
Arsenic (As)	0.3129	0.7422	**0.0497**	**.**	.
Cadmium (Cd)	0.6076	0.4760	**<0.0001**	.	.
Chromium (Cr)	0.5057	0.0696	0.2702	.	.
Copper (Cu)	0.2901	**0.0155**	0.2978	.	.
Lead (Pb)	0.4403	**0.0273**	0.1910	.	.
Mercury (Hg)	0.3604	**0.0039**	0.3739	.	.
Total Organic Carbon	0.3498	**0.0005**	0.2595	.	.
Zinc (Zn)	0.3768	0.0527	0.1011	.	.

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Table Stream-3. Summary of BACI Comparison of Sediment Quality Variables for Individual Project Stream Sites

	Stream Site	
	Doris OF	Little Roberts OF
Variable	p-value	p-value
% Clay (<4 µm)	0.1856	**0.0005**
% Gravel (>2 mm)	**0.0067**	0.0948
% Sand (2.0 mm - 0.063 mm)	0.1098	0.4536
% Silt (0.063 mm - 4 µm)	0.1433	**0.0238**
Arsenic (As)	0.5970	0.4098
Cadmium (Cd)	0.0811	0.3466
Chromium (Cr)	0.6609	**0.0256**
Copper (Cu)	0.4740	**0.0176**
Lead (Pb)	0.6568	**0.0085**
Mercury (Hg)	0.4629	**0.0009**
Total Organic Carbon	0.4988	**0.0013**
Zinc (Zn)	0.5127	**0.0097**

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
A BACI analysis could not be performed for Roberts OF as no "before" data was available for this site.

Table Marine-1. Summary of the Proportion of Measurements that were Below Detection Limit

	Marine Site		
	RBE	RBW	REF-Marine 1
Variable	Proportion Censored	Proportion Censored	Proportion Censored
% Clay (<4 µm)	0.00	0.00	0.00
% Gravel (>2 mm)	0.33	0.62	**1.00**
% Sand (2.0 mm - 0.063 mm)	0.00	0.00	0.00
% Silt (0.063 mm - 4 µm)	0.00	0.00	0.00
Arsenic (As)	0.00	0.00	0.00
Cadmium (Cd)	**1.00**	**1.00**	0.50
Chromium (Cr)	0.00	0.00	0.00
Copper (Cu)	0.00	0.00	0.00
Lead (Pb)	0.00	0.00	0.00
Mercury (Hg)	**1.00**	**0.75**	0.00
Total Organic Carbon	0.67	0.62	0.00
Zinc (Zn)	0.00	0.00	0.00

Notes: Dataset includes all baseline years up to and including 2009, and 2015.
Proportions ≥0.70 are bolded.

Table Marine-2. Summary of Test for No Difference in Mean between Before and After Periods for Marine Sediment Quality Variables

	Marine Site		
	RBE	RBW	REF-Marine 1
Variable	p-value	p-value	p-value
% Clay (<4 µm)	.	**0.0059**	0.0757
% Gravel (>2 mm)	.	0.6480	**<0.0001**
% Sand (2.0 mm - 0.063 mm)	.	**0.0012**	0.0679
% Silt (0.063 mm - 4 µm)	.	**<0.0001**	**0.0192**
Arsenic (As)	.	**<0.0001**	0.0628
Cadmium (Cd)	.	**<0.0001**	0.7311
Chromium (Cr)	.	**<0.0001**	**0.0481**
Copper (Cu)	.	**<0.0001**	0.1184
Lead (Pb)	.	**0.0074**	**0.0014**
Mercury (Hg)	.	0.1512	0.1934
Total Organic Carbon	.	**0.0020**	0.0704
Zinc (Zn)	.	**<0.0001**	0.1907

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Table Marine-3. Summary of BACI Comparison of Sediment Quality Variables for Individual Project Marine Sites

	Marine Site	
	RBE	RBW
Variable	p-value	p-value
% Clay (<4 µm)	.	0.6607
% Gravel (>2 mm)	.	0.3742
% Sand (2.0 mm - 0.063 mm)	.	0.2381
% Silt (0.063 mm - 4 µm)	.	0.3793
Arsenic (As)	.	0.2760
Cadmium (Cd)	.	**0.0121**
Chromium (Cr)	.	**<0.0001**
Copper (Cu)	.	**<0.0001**
Lead (Pb)	.	**0.0001**
Mercury (Hg)	.	0.0526
Total Organic Carbon	.	0.3123
Zinc (Zn)	.	**<0.0001**

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
A BACI analysis could not be performed for RBE as no "before" data was available for this site.

Table Lake-1. Summary of the Proportion of Measurements that were Below Detection Limit

	Lake Site				
	Doris North	**Doris South**	**Little Roberts**	**Reference B**	**Reference D**
Variable	**Proportion censored**	**Proportion censored**	**Proportion censored**	**Proportion censored**	**Proportion censored**
% Clay (<4 µm)	0.00	0.00	0.00	0.00	0.00
% Gravel (>2 mm)	**0.83**	**1.00**	**1.00**	0.00	**1.00**
% Sand (2.0 mm - 0.063 mm)	0.17	0.17	0.00	0.00	0.00
% Silt (0.063 mm - 4 µm)	0.00	0.00	0.00	0.00	0.00
Arsenic (As)	0.00	0.00	0.00	0.00	0.00
Cadmium (Cd)	0.00	0.14	0.14	0.00	0.00
Chromium (Cr)	0.00	0.00	0.00	0.00	0.00
Copper (Cu)	0.00	0.00	0.00	0.00	0.00
Lead (Pb)	0.00	0.00	0.00	0.00	0.00
Mercury (Hg)	0.00	0.00	0.00	0.00	0.00
Total Organic Carbon	0.00	0.00	0.00	0.00	0.00
Zinc (Zn)	0.00	0.00	0.00	0.00	0.00

Notes: Dataset includes all baseline years up to and including 2009, and 2015.
Proportions ≥0.70 are bolded.

Table Lake-2. Summary of Test for No Difference in Mean between Before and After Periods for Lake Sediment Quality Variables

	Lake Site				
	Doris North	**Doris South**	**Little Roberts**	**Reference B**	**Reference D**
Variable	**p-value**	**p-value**	**p-value**	**p-value**	**p-value**
% Clay (<4 µm)	0.7666	0.4201	**0.0031**	.	.
% Gravel (>2 mm)	0.2381	**<0.0001**	**<0.0001**	.	.
% Sand (2.0 mm - 0.063 mm)	**0.0194**	**0.0279**	**0.0252**	.	.
% Silt (0.063 mm - 4 µm)	0.9690	0.6745	0.4908	.	.
Arsenic (As)	0.4954	0.3349	0.2513	.	.
Cadmium (Cd)	**0.0207**	0.8773	0.7702	.	.
Chromium (Cr)	0.1727	0.4692	0.0795	.	.
Copper (Cu)	**<0.0001**	**<0.0001**	0.2709	.	.
Lead (Pb)	**0.0108**	**0.0432**	**<0.0001**	.	.
Mercury (Hg)	0.8300	0.7682	0.1799	.	.
Total Organic Carbon	**0.0049**	0.9720	0.3538	.	.
Zinc (Zn)	**0.0007**	0.3330	**<0.0001**	.	.

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In some cases, no analysis can be done because of the high degree of censoring, the lack of variation in a variable over time, or data are only available from one period (i.e., no "before" data available).

Appendix B.2.4. Statistical Methodology and Results for Phytoplankton and Periphyton Evaluation of Effects, Doris North Project, 2015

TABLE OF CONTENTS

1. ANALYSIS METHODS

1.1 ASSUMPTIONS

The key assumption of this analysis is that the samples collected are representative of each site's periphyton or phytoplankton biomass (estimated from chlorophyll *a* levels) for that monitoring period.

1.2 REPLICATE SAMPLES

Replicate samples collected on the same date were averaged prior to analysis. For some historical data, only the mean value was available.

1.3 DEALING WITH CENSORING (VALUES BELOW DETECTION LIMITS)

Some phytoplankton chlorophyll *a* concentrations in the marine environment were below analytical detection limits. The analyses below follow the advice of McBride (2005; Section 11.4.3).

- When the dataset includes a small number of below detection values, these values will be replaced by ½ of the detection limit for the analysis.
- When the majority of the dataset consists of values below the detection limit (e.g., more than about 70% below detection limit), there is very little that can be done as there is essentially no information (other than the values are below the detection limit). The analyses will be performed as above, but interpreting the results should be done carefully. Helsel (2005) has other suggestions for analysis (e.g., comparing the proportions below the detection limits) but these tests will require much larger sample sizes than available here.
- When there is an intermediate amount of censoring, a more complex analysis can be conducted that fully integrates the information from the censored values with the known values. This is most easily done using Bayesian Markov chain Monte Carlo (MCMC) methods. Complex integration is required for estimation using frequentist approaches. There is currently, no readily available software available for the latter.

Fortunately, the marine phytoplankton biomass dataset falls into the first category (few censored values), and the lake and stream datasets did not contain censored values.

1.4 TRANSFORMATIONS

A preliminary analysis found that the variance of the periphyton and phytoplankton biomass values tended to increase with the mean and that the distribution of values was skewed. This suggested that a logarithmic transformation was appropriate.

1.5 OUTLINE OF ANALYSIS PLAN

There are several classes of statistical tests that can be done to assess evidence of change in the mean periphyton or phytoplankton biomass over time and to assess if changes in the means may reflect an impact of the Project.

1.5.1 Before vs. After Analysis

The first analysis conducted compares the mean readings for all years prior to 2010 (before initiation of construction) to the mean for 2015. Each waterbody is treated independently.

The final statistical model (in standard shorthand notation) is:

$$Y = Period\ Season\ Year(period)\text{-}R$$

where *Y* is the biomass reading of periphyton or phytoplankton in a year; *Period* is the effect of before vs. after Project initiation (which is the effect of interest); *Season* is the effect of season (4 seasons in the sampling year: 1) April or May (under-ice), 2) July, 3) August, 4) September); and *Year(Period)* is a random year effect (applicable if more than one year was sampled during each period).

This model is preferable to simply treating all measurement within a period (e.g., over the baseline years) as having the same mean and assuming that they are completely independent of each other. This model also "averages" the phytoplankton values collected over the baseline years in a way that weights each year equally rather than weighting by the sample size. For example, suppose that the phytoplankton biomass measured in 2008 was 22µg chl *a*/L, while the two readings measured in 2009 were 25 and 27µg chl *a*/L. The simple mean (22+25+27)/3=24.7 µg chl *a*/L would be more heavily weighted toward the mean in the second year. In order to give each year's data equal weight, the reading over both years is computed as an average of averages:

$$\frac{\frac{22}{1}+\frac{25+27}{2}}{2}=24.0$$

This can be extended to multiple years in a similar fashion. Note that in the case of balanced data, i.e., equal number of replicates in all years, the average-of-the-averages and simple-average will be identical. The model with a random year effect is still preferred in the case of balanced data because the readings within a year may be correlated due to year-specific random factors that cause all the readings within a year to increase or decrease in step.

This model was fit using R version 3.1.3. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. A nominal significance level of 0.05 was used when reviewing the results.

The key disadvantage of this model is that changes over time may be unrelated to the effects of the Project, e.g., the average periphyton or phytoplankton biomass readings in 2015 could be higher or lower than expected because of long term climate change that is unrelated to the Project. Consequently, if a statistically significant effect is detected, it will require further investigation.

1.5.2 BACI Analysis

The standard method to assess an environmental impact is through a Before-After-Control-Impact (BACI) analysis (Smith 2002). The analysis of these designs looks for non-parallelism in response over time between the Project and reference waterbodies. A BACI analysis was performed for each Project waterbody versus the corresponding reference waterbody.

The formal statistical model (in standard shorthand notation) is:

*Y = Period Season Class Period*Class Year(Period)-R*

where *Y* is the variable of interest; *Period* is the effect of period (before or after construction); *Season* is the effect of season (4 seasons in the sampling year: 1) April or May (under-ice), 2) July, 3) August, 4) September); *Class* is the effect of waterbody classification (Project or reference); *Period*Class* is the BACI effect of interest (i.e., is the effect of *Period* the same (parallel) for both classes of sites); and *Year(Period)* is the random year effect within each period (applicable if more than one year was sampled during each period). Not all sites were measured in all years and only those Project-reference pairs of sites that were measured both in the before and after period can be used to estimate this BACI contrast. The results from this comparison are specific to the particular Project-reference sites. If there were multiple reference waterbodies (as is the case for streams), a term *Body(Class)-R* (the random site effect within each class) would also be added to the model so that the change in the mean for the Project site is compared to the average change in the mean for the reference bodies. Sites that were measured only in one period (e.g., Reference D OF measured only post-construction) contribute some information on the year-effect which improves precision of the BACI estimate.

The key variable of interest is the *Period*Class* effect as this measures the amount of non-parallelism between the changes in the mean (Before-After) over the two classes of sites (Project or reference).The BACI estimate is computed as the "difference in the differences":

$$BACI = (\mu_{PA} - \mu_{PB}) - (\mu_{RA} - \mu_{RB})$$

where μ_{PA} is the mean variable reading in the *Project* class of sites *after* Project initiation, μ_{PB} is the mean variable reading in the *Project* class of sites *before* Project initiation, μ_{RA} is the mean variable reading in the *reference* class of sites *after* Project initiation, and μ_{RB} is the mean variable reading in the *reference* class of sites *before* Project initiation. The BACI contrast is estimated by replacing the population means above by the model-based estimates. Estimated differences close to 0 would indicate no evidence of non-parallelism.

Note that the hypothesis that the BACI contrast has the value of zero is identical to the hypothesis that the *Period*Class* interaction is zero with identical p-values. Consequently, only the results for the BACI contrast are reported here.

The model was fit using R version 3.1.3. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. A nominal significance level of 0.05 was used when reviewing the results.

For all environments, caution should be used in interpreting the results from the BACI analysis because there was only one reading for phytoplankton or periphyton biomass in one reference site before Project initiation.

2. RESULTS

2.1 STREAM DATA

There was no censoring of the stream periphyton biomass values. Preliminary plots of the data showed one outlier from 1997 which was removed (Table Stream-1).

The results from the analysis that compared the means before and after Project construction are presented in Table Stream-2. Because of the absence of baseline data for Roberts OF and Reference D OF, and a lack of degrees of freedom in the before period for Little Roberts OF and Reference B OF, before-after comparisons were not possible for these streams. There was no evidence of a change in the mean *log(periphyton)* for Doris OF.

The BACI comparison failed to detect evidence of a differential change in before-after trends for either Little Roberts OF or Doris OF compared to the reference streams (Table Stream-3). A BACI analysis could not be conducted for Roberts OF because there was no baseline periphyton data available.

2.2 MARINE DATA

A few marine phytoplankton biomass values were censored (Table Marine-1). No outliers were detected. Because of the scarcity of baseline data available for all marine sites, before-after comparisons could not be conducted (too few degrees of freedom to fit the model).

BACI comparisons for both RBE and RBW sites failed to detect evidence of a differential change compared to the reference site (Table Marine-2).

2.3 LAKE DATA

The lake data was divided into small lakes (Little Roberts and Reference D) and large lakes (Doris South, Doris North, and Reference B). No censoring was observed for the lake phytoplankton data. Preliminary plots of the data did not show any evidence of outliers.

There was no evidence of a change in the mean *log(phytoplankton)* in any lake between the before and after period (Tables Large Lake-1 and Small Lake-1). Because of a lack of degrees of freedom in the before period for Reference Lake B, a before-after comparison was not possible for this lake. However, there was also no evidence of a differential change in the mean *log(phytoplankton)* levels between before/after periods in the large Project lakes compared to Reference Lake B (Table Lake-Large-2). Because phytoplankton biomass levels in Reference Lake D were not measured pre-construction, no BACI comparison is possible for small lakes.

REFERENCES

Helsel, D.R. (2005). *Nondetects and data analysis*.Wiley:New York.

McBride, G.B. (2005). *Using statistical methods for water quality management*. Wiley: New York.

Smith, E. P. (2002). *BACI Design.Encyclopedia of Environmetrics*. Wiley: New York.

TABLES

Table Stream-1. Outlier Periphyton Biomass Values

Site	Variable	Year	Date	Rep	Value	Censored (1=yes 0=no)
Doris OF	Periphyton	1997	19-Jul-1997	1	194.4	0
Doris OF	logPeriphyton	1997	19-Jul-1997	1	5.27	0

Table Stream-2. Summary of Test for No Difference in Mean between Before and After Periods for Stream Periphyton Biomass

		Stream Site				
		Doris OF	Little Roberts OF	Reference B OF	Reference D OF	Roberts OF
Variable	Proportion Censored	p-value	p-value	p-value	p-value	p-value
logPeriphyton	0.00	0.3677	.	.	.	.

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Table Stream-3. Summary of BACI Comparison of Stream Periphyton Biomass for Individual Project Sites

	Stream Site	
	Doris OF	Little Roberts OF
Variable	p-value	p-value
logPeriphyton	0.4834	0.0510

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In Roberts OF stream, no readings were taken pre-construction, so no BACI comparison is possible.

Table Marine-1. Summary of the Amount of Censoring in the Marine Sites

	Marine Site		
	RBE	RBW	REF-Marine 1
Variable	Proportion Censored	Proportion Censored	Proportion Censored
logPhytoplankton	0.2	0.2	0.0

Table Marine-2. Summary of BACI Comparison of Marine Phytoplankton Biomass for Individual Project Sites

	Marine Site	
	RBE	RBW
Variable	p-value	p-value
logPhytoplankton	0.7980	0.1370

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Table Large Lake-1. Summary of Test for No Difference in Mean between Before and After Periods for Large Lake Phytoplankton Biomass

		Large Lake Site		
		Doris North	Doris South	Reference B
Variable	Proportion Censored	p-value	p-value	p-value
logPhytoplankton	0.00	0.8680	0.5378	.

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Table Large Lake-2. Summary of BACI Comparison of Large Lake Phytoplankton Biomass for Individual Project Sites

	Large Lake Site	
	Doris North	Doris South
Variable	p-value	p-value
logPhytoplankton	0.7468	0.5509

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Table Small Lake-1. Summary of Test for No Difference in Mean between Before and After Periods for Small Lake Phytoplankton Biomass

		Period	
		Little Roberts	Reference D
Variable	Proportion Censored	p-value	p-value
logPhytoplankton	0.00	0.9241	.

Notes: A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.
In Reference D, no readings were taken pre-construction, so no before-after analysis or BACI comparison is possible.

Appendix B.2.5. Statistical Methodology and Results for Benthos Evaluation of Effects, Doris North Project, 2015

TABLE OF CONTENTS

1. ANALYSIS METHODS

1.1 ASSUMPTIONS

The key assumption of this analysis was that the samples collected were representative samples of the site and year of sampling. Since all samples were taken at the same time of year (August), inference was restricted to comparisons during this period.

1.2 TRANSFORMATIONS

No transformation was needed.

1.3 OUTLINE OF ANALYSIS PLAN

1.3.1 Impact Level-by-time Analysis

Benthos data have only been collected since 2010 (post-construction); there is no information available pre-construction. Consequently, before/after or BACI comparisons cannot be done.

In cases where no pre-Project data are available, Wiens and Parker (1995) suggest several alternatives, especially for long-term monitoring. One of their suggestions was the level-by-time comparisons where the trend-lines for exposure and reference waterbodies are compared to see if there is evidence of non-parallelism over time.

The final statistical model (in standard shorthand notation) is:

$$Y = Class\ Year\ Class*Year$$

where *Y* is the reading for the benthic variable; *Class* is the effect of waterbody classification (Project or reference); *Year* is the effect of year; and *Class*Year* is the non-parallelism in the response over time. For marine and lake sites, there was a single site in each class and separate comparisons were made for each site against its corresponding reference site. For streams, multiple reference waterbodies were available for comparison against a single Project waterbody; therefore, the term *Body(Class)-R* (the random site effect within each class) was added for the multiple sites within the classification.

The Class*Year term was the effect of interest representing non-parallel changes over time between the site classes.

The model was fit using R version 3.1.3. In the monitoring context, a false positive (i.e., type I error, determining impact when none exists) is more tolerable than a false negative (i.e., type II error, determining no effect when in fact there is one). There is a direct trade-off between the two error rates, as reducing one type of error generally results in an increase in the other type of error. No correction for the large number of statistical tests was applied to the false positive (type I) error rate. A nominal significance level of 0.05 was used when reviewing the results.

1.3.2 Multivariate Approaches

The approach outlined above analyzes each benthic variable independently. However, the variables are likely not independent of each other, and presumably higher power would result if a multivariate approach were used. This has not been attempted in this report.

2. RESULTS

2.1 STREAM DATA

Results of the analyses that test for parallelism in the mean variable value over time are presented in Table Stream-1. There was evidence of significant non-parallelism in benthos density at Roberts OF and Little Roberts OF, family richness at Doris Outflow, Simpson's Evenness Index at Doris OF, and in the Bray-Curtis Index at Doris OF and Roberts OF.

2.2 MARINE DATA

The marine data was analyzed in two ways: 1) with data for adults and juveniles pooled together and 2) with data for adults only. Results of the tests for parallelism are presented in Tables Marine-1 and Marine-2.

For the pooled adult and juvenile data, significant non-parallelism was detected for the Bray-Curtis Index, Simpson's Diversity Index, and family richness at both RBE and RBW. There was also evidence of significant non-parallelism for the benthos density at RBW and Simpson's Evenness at RBW.

For the adult-only data, significant non-parallelism was detected in all evaluated variables at RBE and RBW.

2.3 LAKE DATA

The lakes data was divided into large lakes (Doris Lake South, Doris Lake North, and Reference Lake B) and small lakes (Little Roberts Lake and Reference Lake D). Results of the tests for parallelism are presented in Tables Large Lake-1 and Small Lake-1.

For the large lake benthos data, there was evidence of significant non-parallelism for all evaluated parameters in Doris Lake South, and all evaluated parameters except for family richness in Doris Lake North.

In the small lake (Little Roberts Lake) there was evidence of significant non-parallelism for all evaluated parameters except for Simpson's Diversity Index.

REFERENCES

Wiens, J. A., and K. R. Parker. 1995. Analyzing the effects of accidental environmental impacts: approaches and assumptions. *Ecological Applications* 5(4), 1069–1083.

TABLES

Table Stream-1. Summary of Tests for Parallelism for the Stream Benthos Data

	Stream Site		
	Doris OF	**Little Roberts OF**	**Roberts OF**
Variable	**p-value**	**p-value**	**p-value**
Bray-Curtis	**0.0318**	0.2541	**<0.0001**
Density	0.1673	**0.0264**	**0.0003**
Diversity	0.3772	0.8403	0.8903
Evenness	**0.0011**	0.4820	0.5564
Richness	**0.0499**	0.2323	0.3965

Note:
A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Table Marine-1. Summary of Tests for Parallelism for the Marine Benthos Data (Adults and Juveniles Pooled)

	Marine Site	
	RBE	RBW
Variable	p-value	p-value
Bray-Curtis	**<0.0001**	**0.0006**
Density	0.5992	**<0.0001**
Diversity	**0.0020**	**0.0429**
Evenness	0.1231	**<0.0001**
Richness	**<0.0001**	**<0.0001**

Note:
A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Table Marine-2. Summary of Tests for Parallelism for the Marine Benthos Data (Adults Only)

	Marine Site	
	RBE	RBW
Variable	p-value	p-value
Bray-Curtis	**<0.0001**	**0.0025**
Density	**0.0001**	**<0.0001**
Diversity	**0.0013**	**0.0002**
Evenness	**0.0362**	**<0.0001**
Richness	**<0.0001**	**<0.0001**

Note:
A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Table Large Lake-1. Summary of Tests for Parallelism for the Large Lake Benthos Data

	Large Lake Site	
	Doris North	**Doris South**
Variable	**p-value**	**p-value**
Bray-Curtis	**<0.0001**	**<0.0001**
Density	**<0.0001**	**<0.0001**
Diversity	**0.0003**	**0.0113**
Evenness	**0.0376**	**0.0352**
Richness	0.0985	**0.0028**

Note:
A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.

Table Lake-Small-1. Summary of Tests for Parallelism for the Small Lake Benthos Data

	Small Lake Site
	Little Roberts
Variable	**p-value**
Bray-Curtis	**0.0438**
Density	**0.0034**
Diversity	0.1631
Evenness	**0.0065**
Richness	**0.0015**

Note:
A significance level (alpha) of 0.05 was used to screen for effects and p-values less than 0.05 are bolded.