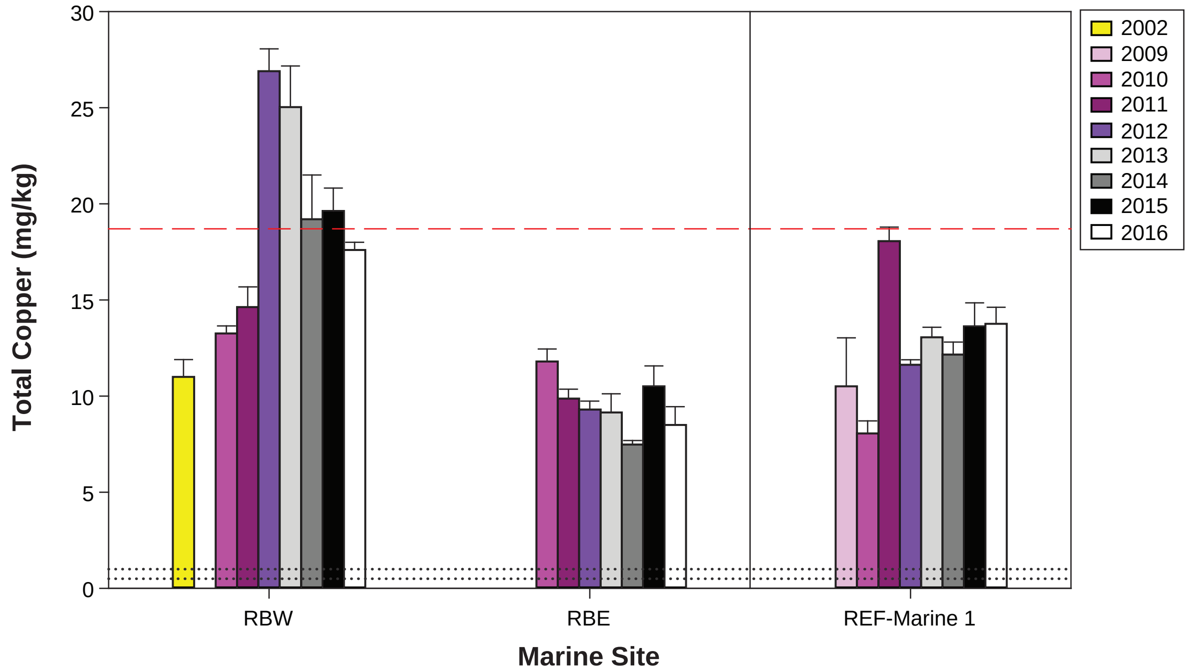
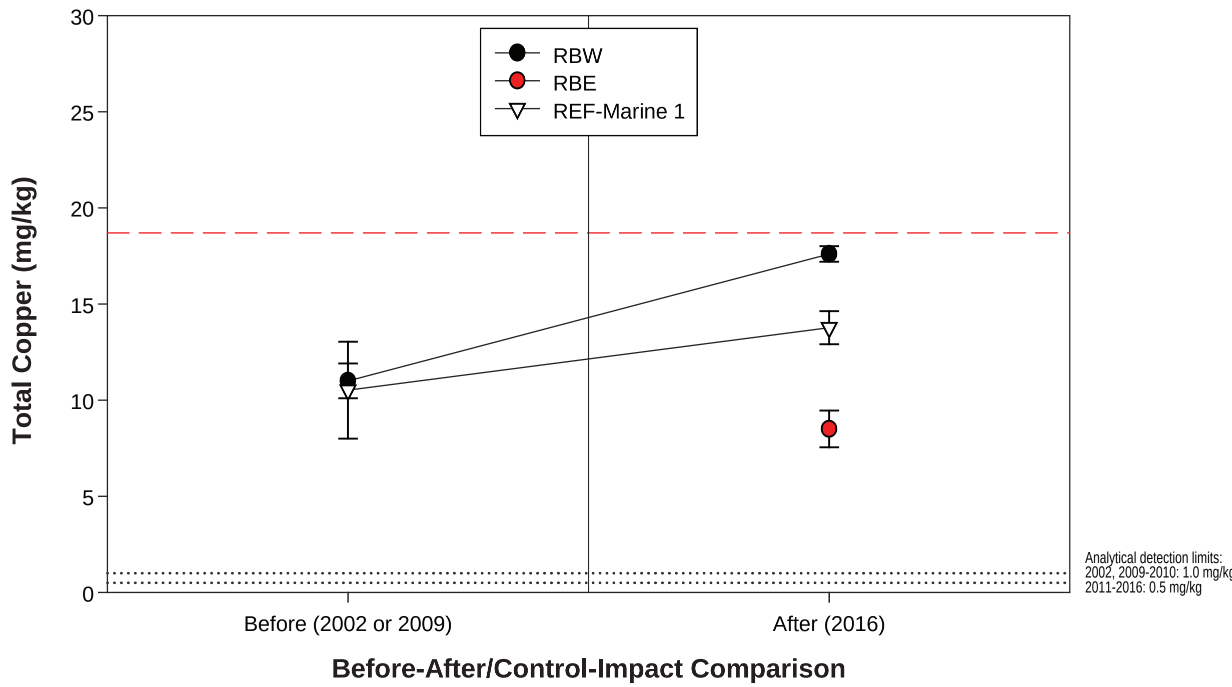
Total Copper Concentrations in AEMP Marine Sediments, Doris Project, 2002 to 2016

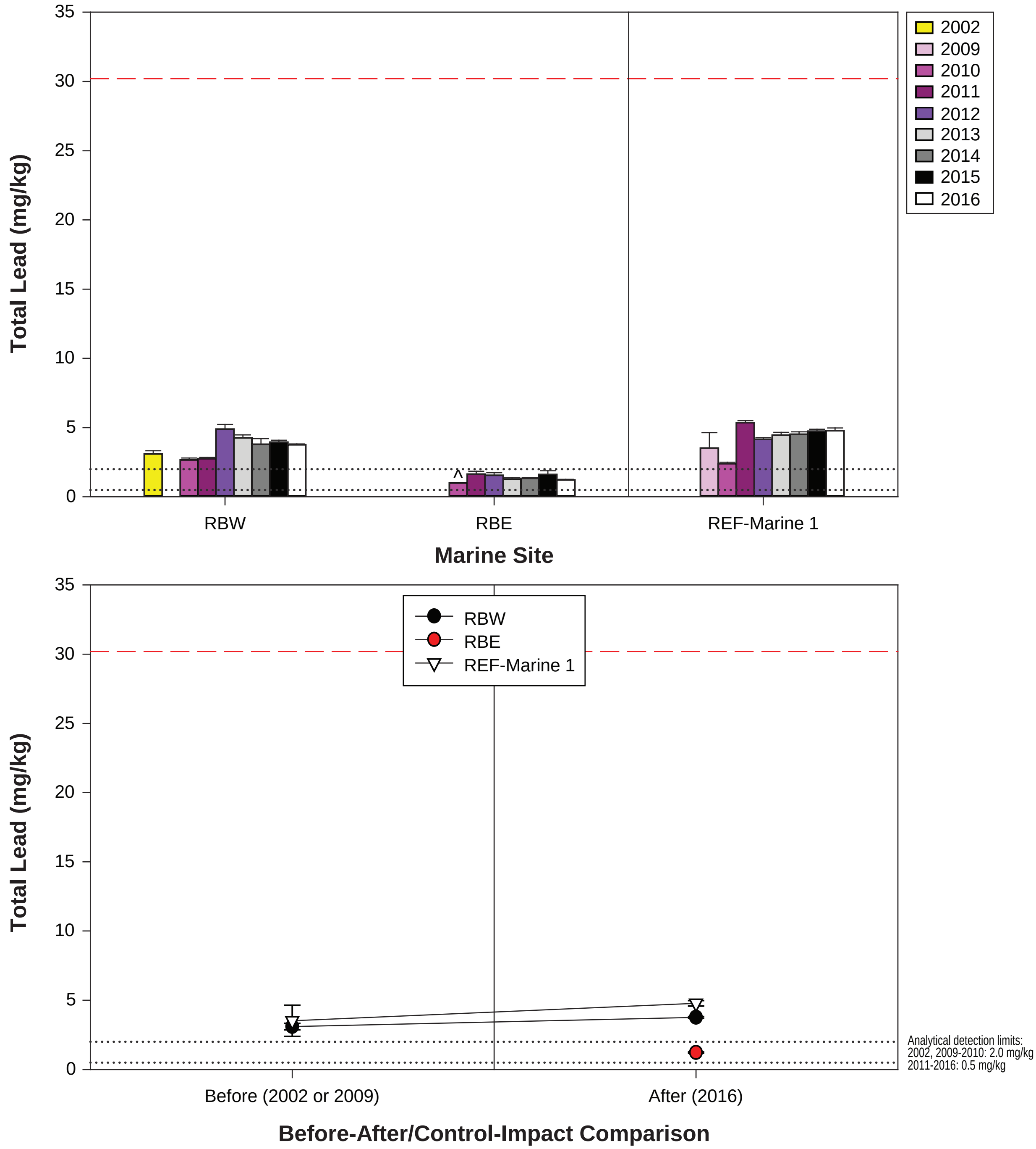




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for copper (18.7 mg/kg); the probable effects level (PEL) for copper (108 mg/kg) is not shown.

Figure 3.4-25

Total Lead Concentrations in AEMP Marine Sediments, Doris Project, 2002 to 2016



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for lead (30.2 mg/kg); the probable effects level (PEL) for lead (112 mg/kg) is not shown.

3.4.3.8 *Total Mercury*

Mercury concentrations in all exposure and reference site sediments collected in 2016 were well below the CCME ISQG of 0.13 mg/kg and the PEL of 0.7 mg/kg (Figure 3.4-26). At site RBW, the mean mercury concentrations in sediments was lower in 2016 than in 2002 (Figure 3.4-26), and the before-after analysis showed that this decrease in mercury was statistically significant ($p = 0.029$). A decrease in sediment mercury concentration is not of concern. Accordingly, there is no evidence of an adverse effect of Project activities on sediment mercury concentrations at site RBW.

Concentrations of mercury from RBE sediments in 2016 were below the analytical detection limit of 0.005 mg/kg. There was no evidence that 2016 Project activities adversely affected mercury concentrations in the sediments at this site.

3.4.3.9 *Total Zinc*

Mean 2016 zinc concentrations in the sediments of marine exposure sites were well below the CCME ISQG of 124 mg/kg and the PEL of 271 mg/kg (Figure 3.4-27). The mean 2016 zinc concentration in sediments from RBW (28.4 mg/kg) was similar to the mean baseline (2002) concentration (28.0 mg/kg; Figure 3.4-27), and the before-after analysis showed that there was no significant difference between the baseline and 2016 means ($p = 0.93$). Therefore, there was no apparent effect of 2016 Project activities on sediment zinc concentrations at this exposure site.

Although no baseline data are available for RBE, sediments from RBE had the lowest mean 2016 concentration of zinc (13.6 mg/kg) compared to the other marine sites, and zinc concentrations at RBE also appeared to be consistent through time (Figure 3.4-27). The relatively low zinc concentrations observed at RBE is consistent with the coarser nature of the sediments at this site. There was no apparent adverse effect of 2016 Project activities on sediment zinc concentrations at site RBE.

3.5 PRIMARY PRODUCERS

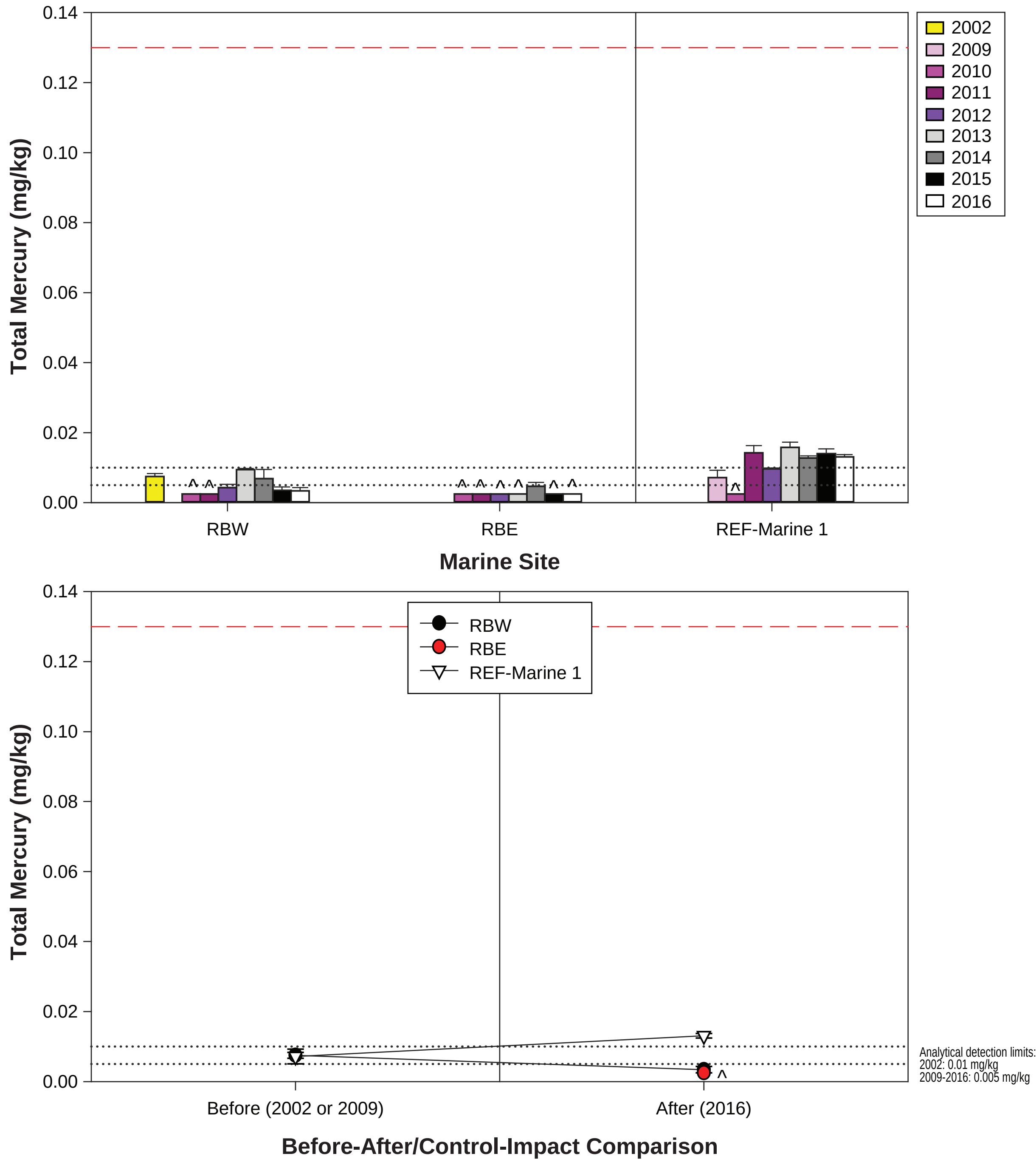
Primary producer biomass (as chlorophyll *a*) samples were collected in streams, lakes, and the marine environment to assess potential changes due to eutrophication or toxicity.

Historical primary producer (phytoplankton and periphyton) biomass sampling has been conducted in the Project area since 1996. The main criteria for the selection of relevant baseline periphyton and phytoplankton biomass data for inclusion in the effects analysis were the proximity of baseline sampling sites to 2016 sampling sites and the use of comparable sampling methodologies.

Graphical analyses, before-after comparisons, and BACI analyses (where possible) were used to determine whether there were changes in primary producer biomass in the Project area. For all graphical and statistical analyses, replicate samples collected on the same date were averaged prior to analysis. The complete results of all statistical methods and analyses are provided in Appendix B.

Figure 3.4-26

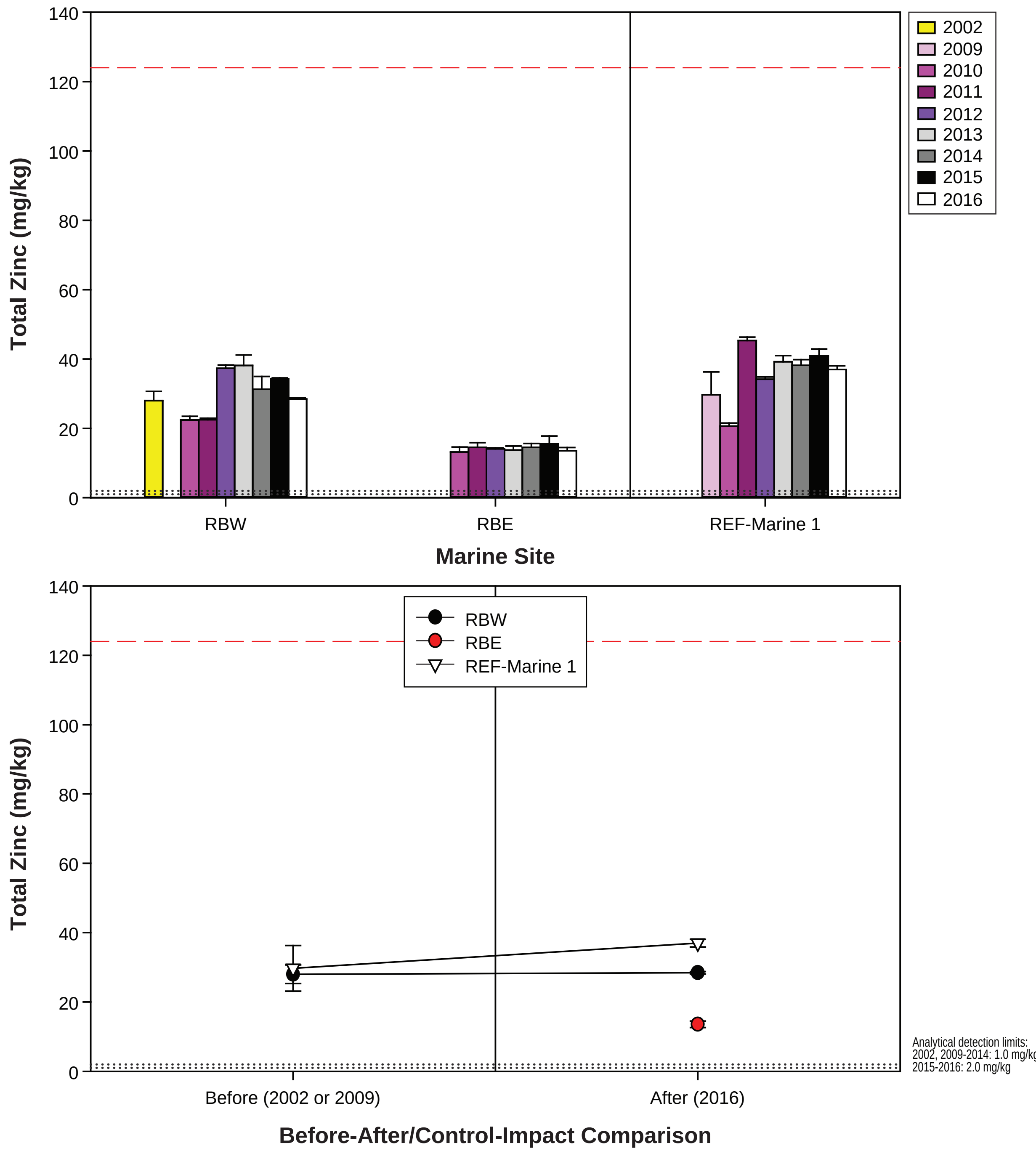
Total Mercury Concentrations in AEMP Marine Sediments, Doris Project, 2002 to 2016



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for mercury (0.13 mg/kg); the probable effects level (PEL) for mercury (0.7 mg/kg) is not shown.

Figure 3.4-27

Total Zinc Concentrations in AEMP Marine Sediments, Doris Project, 2002 to 2016



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent 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.

Periphyton biomass data and statistical analysis results for Roberts Outflow are shown in the following figures and in Appendices A and B, but this stream is not discussed in the following sections. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

3.5.1 Stream Periphyton Biomass

Stream periphyton biomass samples were collected from three exposure streams (Doris, Roberts, and Little Roberts outflows) and two reference streams (Reference B and Reference D outflows). Baseline data for stream periphyton biomass that were comparable to 2016 data in terms of sampling locations and methodologies are available from 1997, 2000, and 2009 for Doris Outflow, and from 2009 for Little Roberts and Reference B Outflows (Appendix B). There were too few degrees of freedom in the before period for Little Roberts and Reference B outflows, so before-after analyses could not be performed for periphyton data from these streams; however, there were sufficient degrees of freedom to conduct a BACI analysis.

Periphyton biomass was highly variable over time, particularly at Doris Outflow, where several years of baseline data are available (Figure 3.5-1). Periphyton biomass at this stream site decreased by an order of magnitude between 1997 and 2009, before the commencement of any Project activities. This degree of natural variability makes it difficult to isolate trends from natural background variability. Mean 2016 periphyton biomass at Doris Outflow was within the range of baseline biomass levels, and the before-after analysis confirmed that there was no significant difference between the baseline mean biomass and the 2016 mean biomass at this site (p = 0.80).

At Little Roberts Outflow, mean periphyton biomass was higher in 2016 than 2009 (Figure 3.5-1). Although a before-after analysis could not be performed, the BACI analysis indicated that a parallel increase from 2009 to 2016 was apparent for the reference streams (p = 0.17), so there was no evidence of a Project-related effect on periphyton biomass in Little Roberts Outflow. Additionally, there were no Project-related changes in water quality in Little Roberts Outflow that would have resulted in a change in periphyton biomass. Thus, the difference in biomass levels at Little Roberts Outflow between 2009 and 2016 was likely unrelated to Project activities.

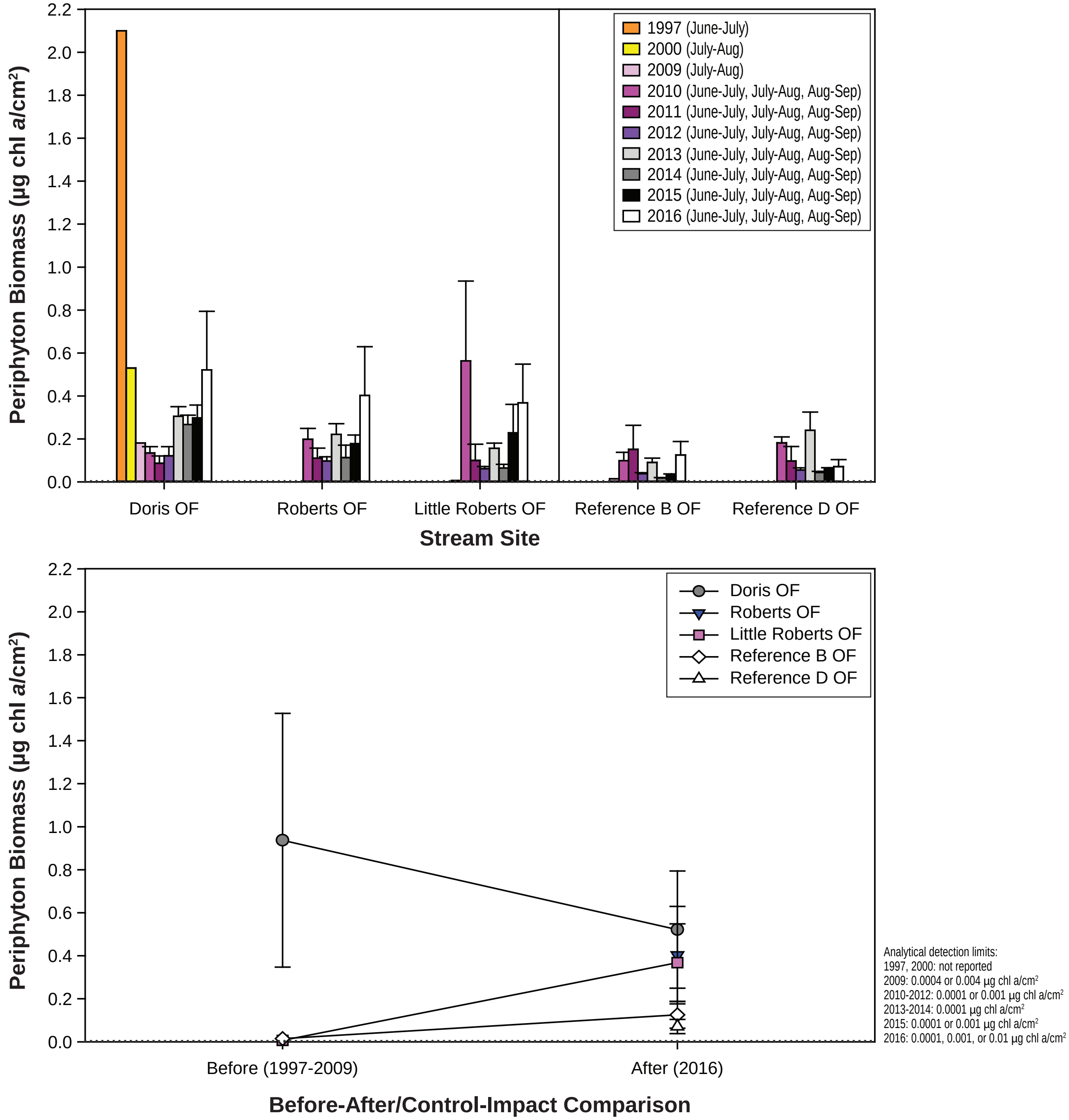
There was no indication that Project activities had any effect on periphyton biomass in exposure streams.

3.5.2 Lake Phytoplankton Biomass

Phytoplankton biomass samples were collected from three exposure lake sites (Doris Lake South, Doris Lake North, and Little Roberts Lake) and two reference lake sites (Reference Lake B and Reference Lake D) in 2016. Baseline data for lake phytoplankton biomass that were comparable to 2016 data in terms of sampling locations and methodologies are available from 1997, 2000, and 2009 for Doris Lake South, 1997 and 2009 for Little Roberts Lake, and 2009 for Doris Lake North and Reference Lake B (Appendix B). No baseline data are available for Reference Lake D, so a BACI analysis could not be performed for Little Roberts Lake.

Figure 3.5-1

Periphyton Biomass (as Chlorophyll *a*) in AEMP Stream Sites, Doris Project, 1997 to 2016



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
The anomalously high periphyton biomass of 194.4 µg chl a/cm² reported for Doris Outflow in July-August 1997 was considered an outlier and was excluded from plots and statistical analyses.

At the exposure lake sites Doris South and Doris North, mean 2016 phytoplankton biomass levels were higher than baseline means, while at Little Roberts Lake, the mean biomass in 2016 was within the range of baseline biomass levels (Figure 3.5-2). However, the before-after analysis showed that the mean 2016 phytoplankton biomass was not significantly different from the mean baseline biomass at any exposure lake site ($p = 0.18$ for Doris Lake South, $p = 0.75$ for Doris Lake North, and $p = 0.47$ for Little Roberts Lake). Thus, there was no apparent effect of 2016 Project activities on phytoplankton biomass in exposure lakes.

3.5.3 Marine Phytoplankton Biomass

Phytoplankton biomass samples from marine areas were collected from two exposure sites in Roberts Bay (RBW and RBE) and one reference site in Ida Bay (REF-Marine 1) in 2016. Historical phytoplankton biomass data have been collected in Roberts Bay since 2006. However, only baseline data from 2009 were considered comparable to 2016 data. Historical data collected between 2006 and 2008 were excluded because of differences in sampling methodology (Appendix B). Baseline data from 2009 are available for all marine exposure and reference sites.

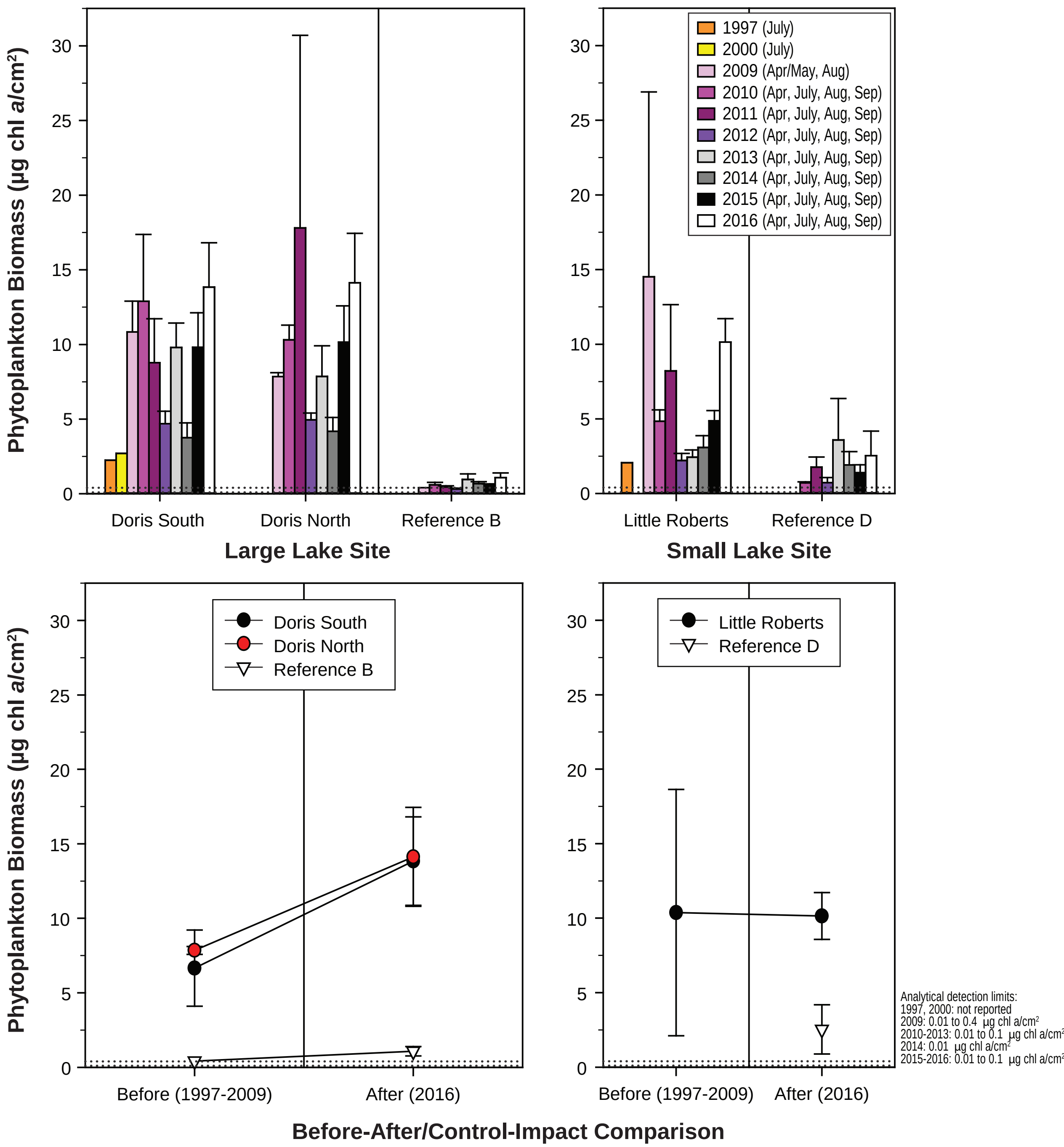
Marine phytoplankton biomass concentrations were lower at all sites in 2009 than in 2016 (Figure 3.5-3). Mean phytoplankton biomass concentrations measured in 2009 were below the detection limit (< 0.04 µg chl *a*/L) at both RBE and RBW and slightly above the detection limit at REF-Marine 1 (0.045 µg chl *a*/L). In 2016, mean biomass concentrations at the marine sites were: 0.58 µg chl *a*/L at RBW, 3.26 µg chl *a*/L at RBE, and 0.58 µg chl *a*/L at REF-Marine 1 (Figure 3.5-3). The apparent increase in biomass levels between 2009 and 2016 may be related to natural seasonal differences, as samples collected in 2009 were collected only during one month (August) compared to four months in 2016 (April, July, August, and September). Although, it was not possible to perform before-after analyses on marine phytoplankton data (there were too few degrees of freedom to fit the model; Appendix B), the BACI analysis indicated that the 2009 to 2016 changes observed at the exposure sites were parallel to the 2009 to 2016 change observed at the reference site ($p = 0.96$ for RBW and $p = 0.53$ for RBE). Therefore, the apparent increases in phytoplankton biomass at RBW and RBE were unrelated to 2016 Project activities.

3.6 BENTHOS

As required in Schedule 5 of the MMER, benthic invertebrate community surveys were conducted in 2016 at stream, lake, and marine sites, and the data gathered were used to calculate benthos density, evenness (Simpson's Evenness Index), taxa richness, and a similarity index (Bray-Curtis Index). Simpson's Diversity Index, which incorporates taxa richness and evenness, was also calculated. The level of taxonomic resolution used to calculate community descriptors was family level, as recommended by Environment Canada's *Metal Mining Technical Guidance for Environmental Effects Monitoring* (2012). All summary statistics for these community descriptors are provided in Appendix A.

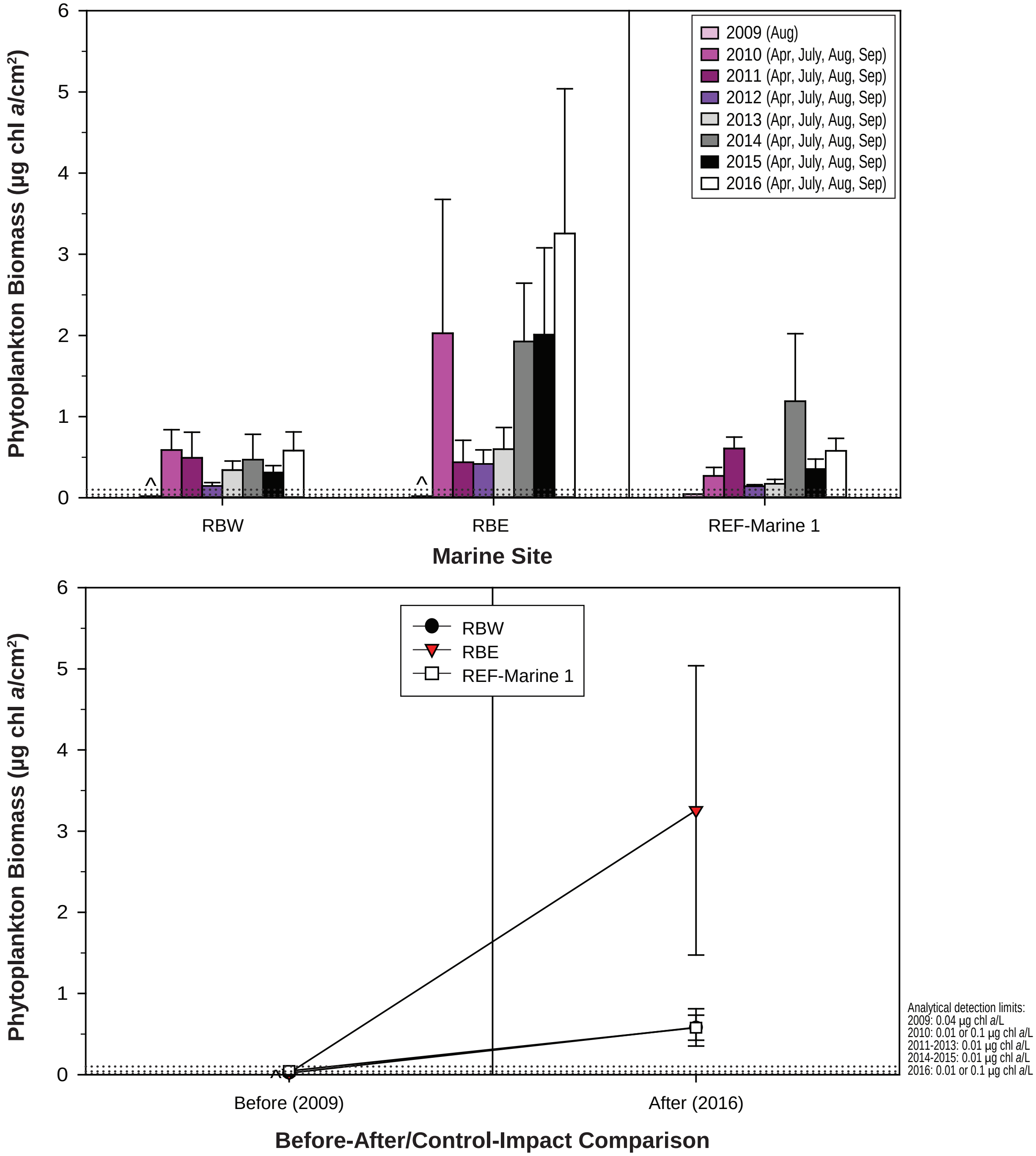
Figure 3.5-2

Phytoplankton Biomass (as Chlorophyll *a*) in AEMP Lake Sites, Doris Project, 1997 to 2016



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.

Phytoplankton Biomass (as Chlorophyll *a*) in AEMP Marine Sites, Doris Project, 2009 to 2016



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.

The effects analysis for benthos requires a different approach than that used for the other evaluated variables because of the lack of comparable baseline data for benthos. The method used to collect benthos samples from 2010 to 2016 involved the pooling of three subsamples for each of five replicate samples; therefore, data collected since 2010 were not considered comparable to baseline data (as replicates collected during baseline studies were not composite samples). Instead of employing before-after or BACI comparisons for benthos data, an impact level-by-time analysis was used, whereby the change in benthos at exposure sites between 2010 and 2016 was compared to the change in benthos at reference sites to test for non-parallelism over time. The results of the analysis of effects for benthos are discussed below, and complete statistical methodology and results are presented in Appendix B.

3.6.1 Stream Benthos

Note that benthos data and statistical analysis results for Roberts Outflow are shown in the following figures and in Appendices A and B, but this stream is not discussed in the following sections. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

3.6.1.1 Density

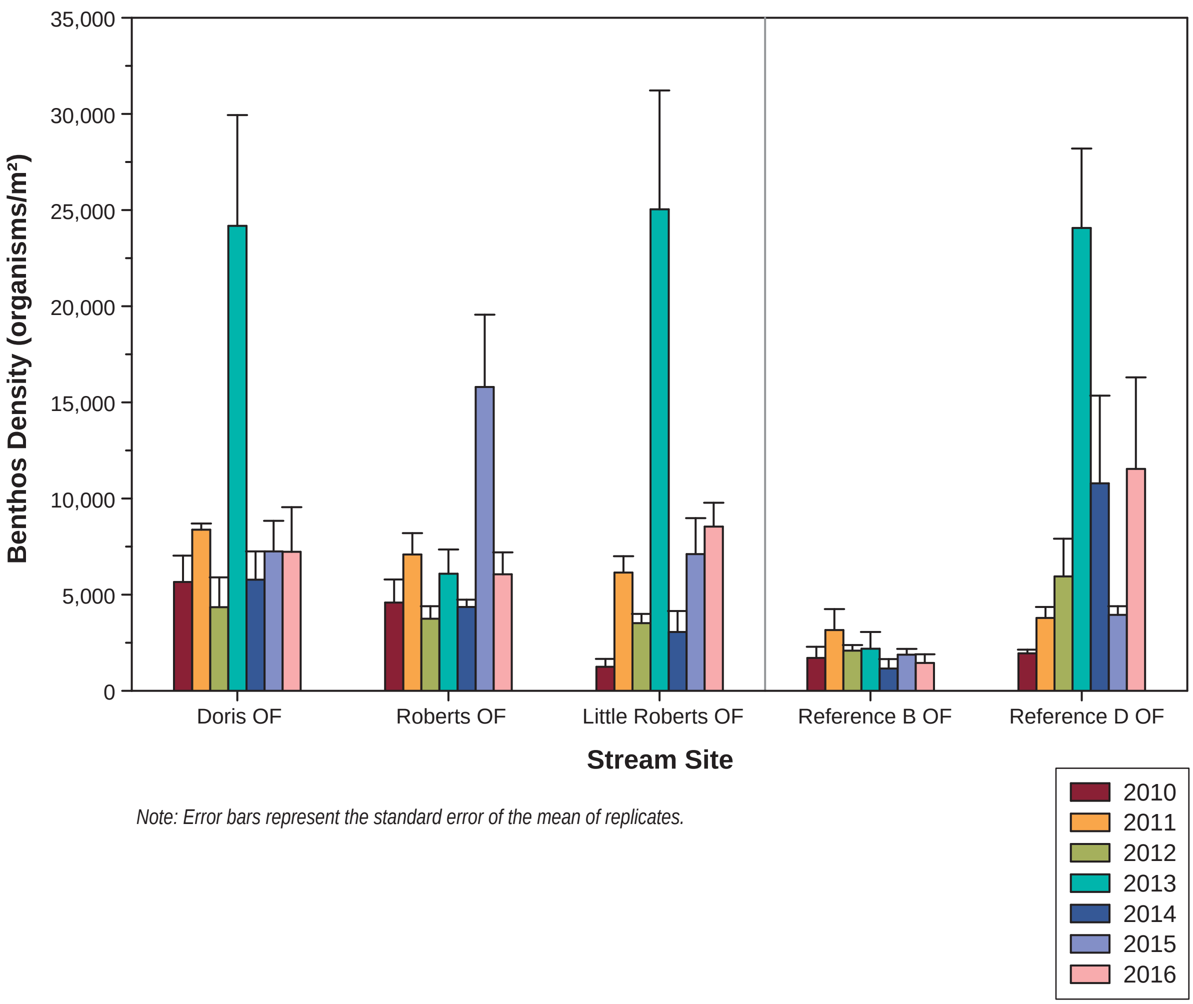
Stream benthos density is naturally a highly variable parameter, ranging over an order of magnitude from year to year at some exposure and reference sites. This high variability makes it difficult to determine whether Project activities may be affecting stream benthos density. At all sites, mean 2016 benthic invertebrate density was within the range of mean densities recorded from 2010 to 2015 (Figure 3.6-1). There was no evidence of significant non-parallelism between the reference streams and Doris Outflow ($p = 0.21$), but there was evidence of significant non-parallelism between the reference streams and Little Roberts Outflow ($p = 0.0495$). The largest modelling coefficient for Little Roberts Outflow benthos density was for the 2013 observation (Appendix B), which likely drove the non-parallelism detected by the impact level-by-time analysis. 2013 density was anomalously high at some sites, including Little Roberts Outflow and Reference Lake D, compared to other years. There was no consistent directional trend in the annual site-specific modelling coefficient, which suggests that any variation in density between Little Roberts Outflow and the reference sites over the monitoring period was not due to Project activities.

3.6.1.2 Community Richness, Evenness, and Diversity

2016 benthos family richness was generally similar to previous years in all exposure streams (Figure 3.6-2). There was no evidence of significant non-parallelism relative to the reference streams for either Doris Outflow ($p = 0.14$) or Little Roberts Outflow ($p = 0.23$).

Figure 3.6-1

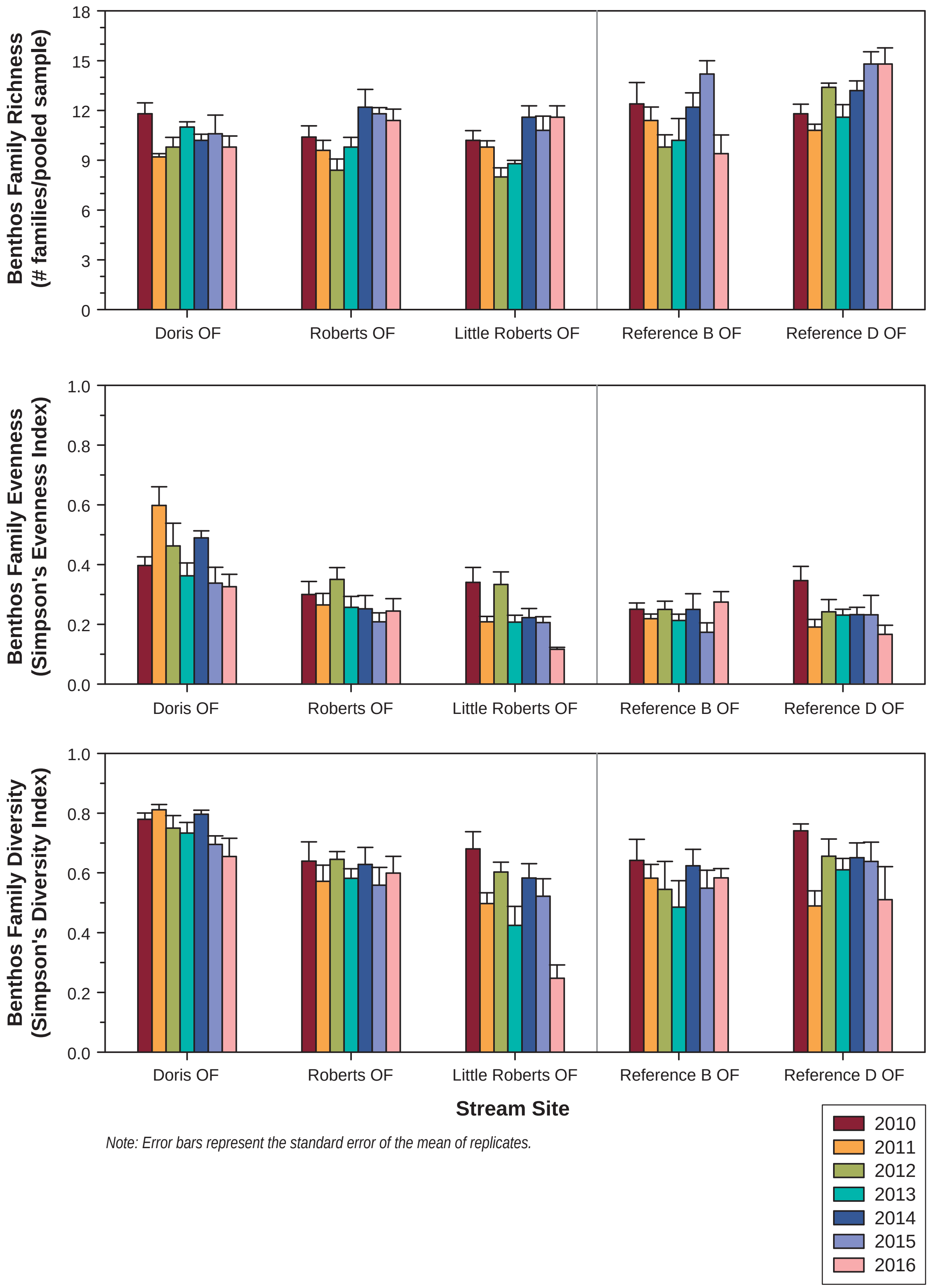
Benthos Density in AEMP Stream Sites, Doris Project, 2010 to 2016



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

Figure 3.6-2

Benthos Richness, Evenness, and Diversity in AEMP Stream Sites, Doris Project, 2010 to 2016



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

Mean benthos family evenness was lower in 2016 than in previous years at Doris, Little Roberts, and Reference D outflows, while the mean 2016 evenness at Reference B Outflow was slightly higher than previous years. Relative to evenness in the reference streams, there was evidence of significant non-parallelism for Doris Outflow evenness ($p = 0.0006$), but not for Little Roberts Outflow evenness ($p = 0.085$). Given that a decrease in evenness was also observed at one of the reference streams in 2016, and there were no apparent Project-reated effects on water and sediment quality, there is no reason to believe that any decrease in evenness in the exposure streams was due to the Project. The largest modelling coefficients for benthos evenness at Doris Outflow were associated with the 2011 and 2014 evenness observations (Appendix B), which were relatively high compared to other observations and likely drove the observed non-parallelism compared to the reference streams. There was no consistent directional trend in the annual site-specific modelling coefficients, suggesting that any variation between Doris Outflow and the reference sites over the monitoring period was not due to Project activities.

In both Doris and Little Roberts outflows, mean benthos family diversity in 2016 was lower than mean diversity levels from 2010 to 2015 (Figure 3.6-2). However, relative to diversity in the reference streams, there was no evidence of non-parallelism for either Doris Outflow ($p = 0.53$) or Little Roberts Outflow ($p = 0.080$). This suggests that there were no Project effects on benthos family diversity in the exposure streams in 2016.

3.6.1.3 Bray-Curtis Index

The Bray-Curtis Index is a measure of the percentage of difference between exposure site benthos community composition and the median reference benthos community composition. For Doris Outflow, the mean 2016 Bray-Curtis Index was within range of 2010 to 2015 indices, and there was no evidence of non-parallelism relative to the reference streams (Figure 3.6-3; $p = 0.053$). The Bray-Curtis Index for Little Roberts Outflow in 2016 was higher than previous years, which suggests that the benthic assemblage in this stream is becoming increasingly dissimilar to the median reference community (Figure 3.6-3). However, the Bray-Curtis Index for Reference D Outflow was also higher than previous years (Figure 3.6-3). Accordingly, there was no evidence of non-parallelism between Little Roberts Outflow and the reference streams ($p = 0.24$). There was no apparent effect of Project activities on the Bray-Curtis Index for the exposure streams.

3.6.2 Lake Benthos

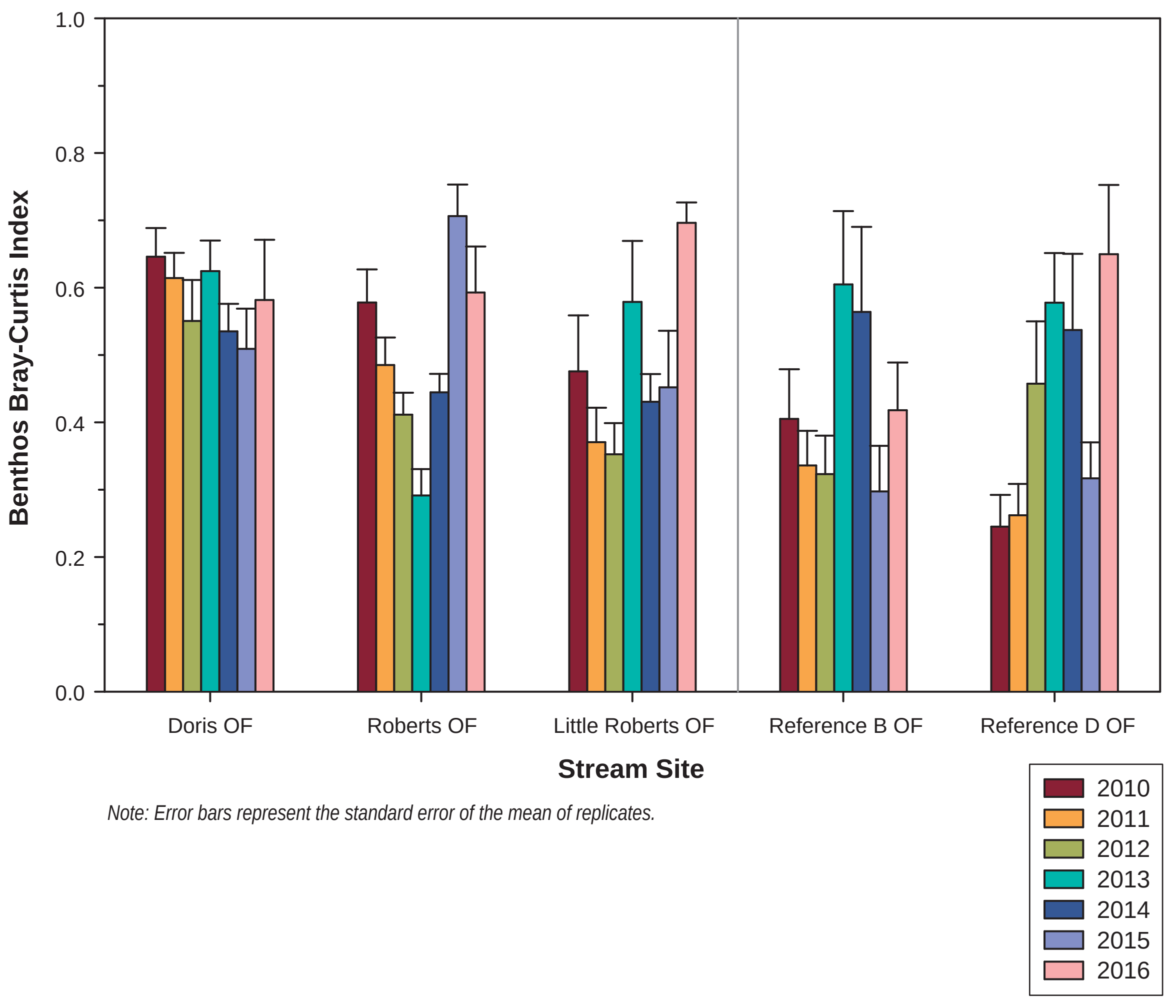
At Doris Lake South, 2010 data were collected from a shallow site, whereas 2011 to 2016 data were collected from a deep site in the southern section of Doris Lake. Therefore, 2010 data are excluded from the analyses.

3.6.2.1 Density

Benthic invertebrate density was consistently higher at the small lake sites (Little Roberts Lake and Reference Lake D) than at the large lake sites (Doris Lake South, Doris Lake North, and Reference Lake B) between 2010 and 2016 (Figure 3.6-4). Mean 2016 densities at Doris Lake North and Little Roberts Lake were slightly higher than the site-specific 2010 to 2015 ranges, and the mean 2016 density at Doris Lake South was within the 2010 to 2015 range (Figure 3.6-4). There was evidence of non-parallelism in density trends over time for all exposure lake sites compared to reference lake sites ($p < 0.0001$ for both Doris Lake South and Doris Lake North, $p = 0.0008$ for Little Roberts Lake).

Figure 3.6-3

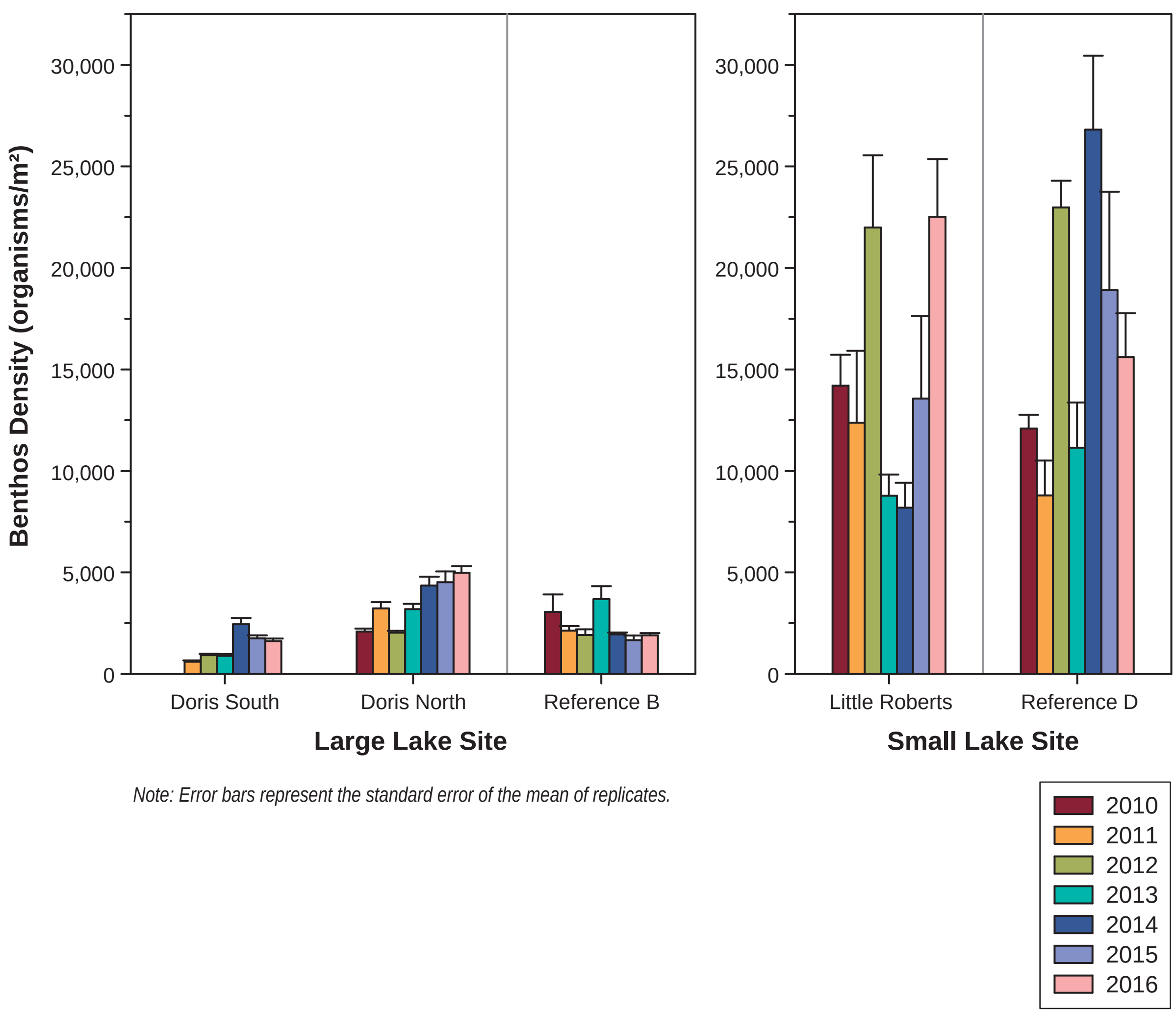
Benthos Bray-Curtis Index for AEMP Stream Sites, Doris Project, 2010 to 2016



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

Figure 3.6-4

Benthos Density in AEMP Lake Sites, Doris Project, 2010 to 2016



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

For Doris Lake North, the largest site-specific modelling coefficient was the 2016 coefficient (Appendix B). However, the coefficients from 2014 and 2015 were very similar to the 2016 coefficient and there was no consistent directional pattern in the annual site-specific response, which suggests that any variation between the Doris Lake North and Reference Lake B over the monitoring period was not due to Project activities.

For Doris Lake South, mean 2016 benthos density was similar to mean 2016 Reference Lake B density (Figure 3.6-4). The largest modelling coefficient was associated with the 2014 mean density, which was relatively high at Doris Lake South compared to the reference site (Appendix B; Figure 3.6-4). There was no consistent directional trend in the annual site-specific modelling coefficients, and the non-parallelism detected by the impact level-by-time analysis was likely caused by natural inter-annual variability in the data.

The largest modelling coefficient for benthos density at Little Roberts Lake was associated with the density observation from 2014. Compared to the site-specific benthos density ranges from 2010 to 2016, 2014 density represented the lowest observation for Little Roberts Lake but the highest observation for Reference Lake D (Figure 3.6-4). This anomalous year likely drove the non-parallelism detected by the statistical analysis. There was no consistent temporal pattern in the site-specific response, which suggests that any variation between Little Roberts Lake and the reference sites over the monitoring period was not related to Project activities.

3.6.2.2 Community Richness, Evenness, and Diversity

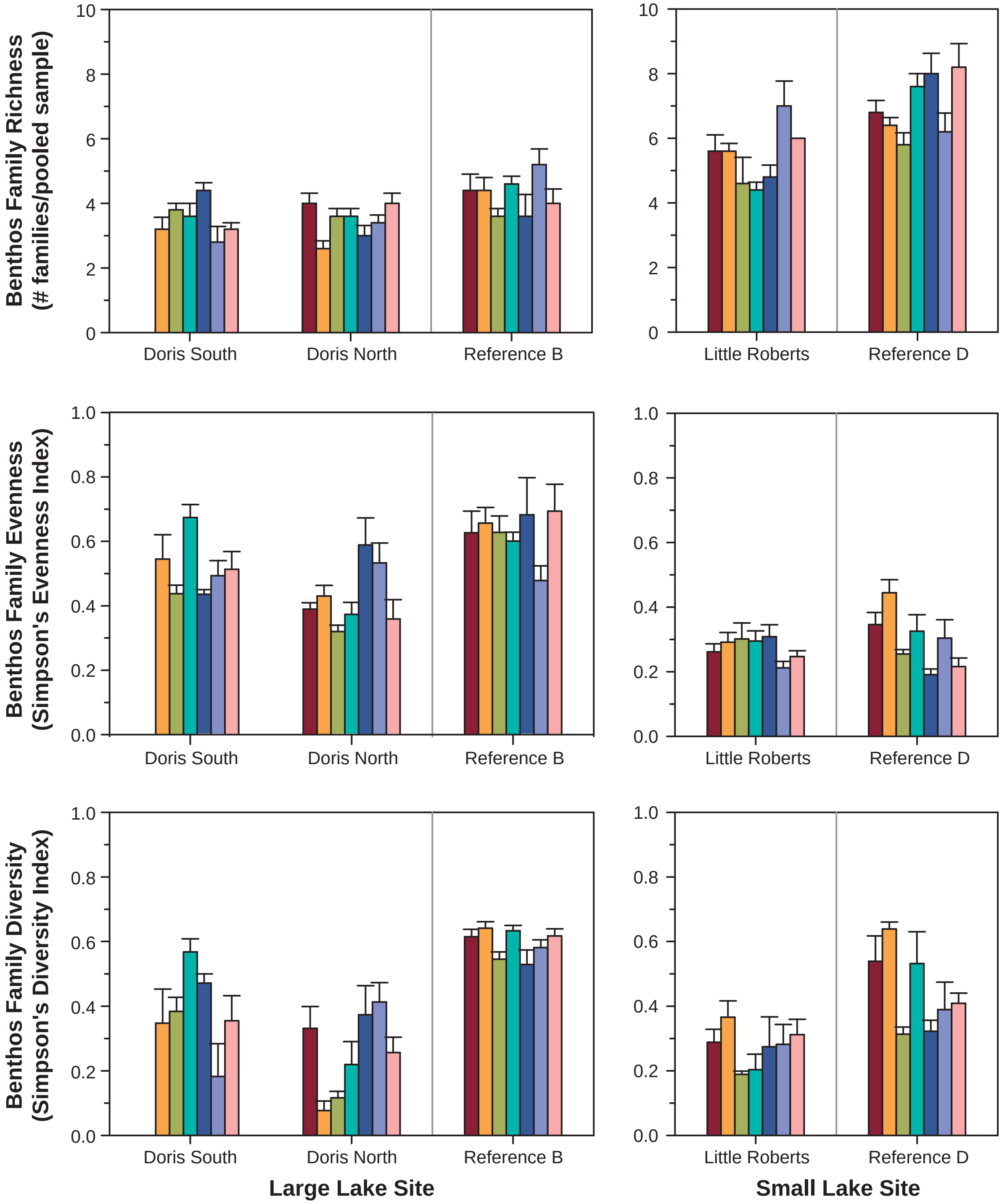
Benthos family richness tended to be higher at the small lakes sites than the large lake sites between 2010 and 2016 (Figure 3.6-5). Family richness was relatively similar over time at each site (Figure 3.6-5). However, there was some evidence of non-parallelism in trends for Doris Lake South ($p = 0.0037$) and Little Roberts Lake ($p = 0.0021$) relative to reference lakes, but not for Doris Lake North ($p = 0.071$).

For Doris Lake South, the largest site-specific modelling coefficient for richness was associated with 2014 levels, which were relatively high in Doris Lake South compared to Reference Lake B (Appendix B; Figure 3.6-5). The 2014 richness likely drove the detected non-parallelism, and there was no consistent temporal pattern in the site-specific response, which suggests that any variation between Doris Lake South and Reference Lake B over the monitoring period was not due to Project activities. For Little Roberts Outflow, there was evidence of non-parallelism in benthos richness relative to Reference Lake D. However, the largest modelling coefficients (which were associated with 2013, 2014, and 2015 site-specific richness levels) were similar in magnitude and there was no consistent temporal trend in the site-specific response. Therefore, there was no evidence that 2016 project activities adversely affected benthos family richness in the exposure lake sites.

For each exposure lake site, the mean 2016 Simpson's Evenness Index calculated for the benthos community was generally similar to the evenness calculated in previous years (Figure 3.6-2). There was evidence of non-parallelism in benthos evenness trends compared to reference lakes for Doris Lake North ($p = 0.032$) and for Little Roberts Lake ($p = 0.0042$), but not for Doris Lake South ($p = 0.062$). For both Doris Lake North and Little Roberts Lake, the modelling coefficients showed that this non-parallelism was driven by a single year (2015 for Doris Lake North, and 2014 for Little Roberts Lake; Appendix B). There was also no evidence of a temporal trend in the annual site-specific coefficient for either exposure lake site. Therefore, there was no evidence of a Project effect on benthos family evenness at the exposure lake sites.

Figure 3.6-5

Benthos Richness, Evenness, and Diversity in AEMP Lake Sites, Doris Project, 2010 to 2016



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

In each exposure lake site, the mean Simpson's Diversity Index calculated for 2016 was within the range observed in previous years (Figure 3.6-5). There was no evidence of non-parallelism in diversity between Little Roberts Lake and Reference Lake D ($p = 0.14$). However, for both Doris Lake sampling sites, there was evidence of non-parallelism in diversity relative to Reference Lake B ($p = 0.018$ for Doris Lake South and $p = 0.0003$ for Doris Lake North). The modelling coefficients show that this non-parallelism was driven by the relatively high 2013 and 2014 diversity levels in Doris Lake South and by the relatively low 2011 diversity in Doris Lake North (Appendix B). As well, for both Doris Lake South and Doris Lake North, there were no apparent directional trends in the annual site-specific coefficients. Thus, there was no evidence that Project activities affected benthos family diversity in exposure lake sites.

3.6.2.3 Bray-Curtis Index

The Bray-Curtis Index was highly inter-annually variable at all sites (Figure 3.6-6). For the exposure lakes, 2016 Bray-Curtis Index values were within the range of previous years (Figure 3.6-6), suggesting that there was no effect of 2016 Project activities on the benthos community composition at these sites. However, there was evidence of non-parallelism in the Bray-Curtis Index trends for all exposure lake sites compared to the reference lake sites ($p < 0.0001$ for both Doris Lake South and Doris Lake North, and $p = 0.037$ for Little Roberts Lake).

For both Doris Lake North and Little Roberts Lake, the annual site-specific modelling coefficient was not particular large for any given year compared to other years, and there was no discernible directional trend in the magnitude of the coefficients (Appendix B). This suggests that the annual differences were more likely due to natural inter-annual variability rather than Project effects. For Doris Lake South, the largest modelling coefficient was associated with the unusually low 2012 Bray-Curtis (indicating that the 2012 community composition in Doris Lake South was more similar to the reference community than other years; Figure 3.6-6). The 2012 Bray-Curtis Index largely drove the non-parallelism detected between Doris Lake South and Reference Lake B. There were no apparent effects of Project activities on the 2016 Bray-Curtis indices calculated for the exposure lake sites.

3.6.3 Marine Benthos

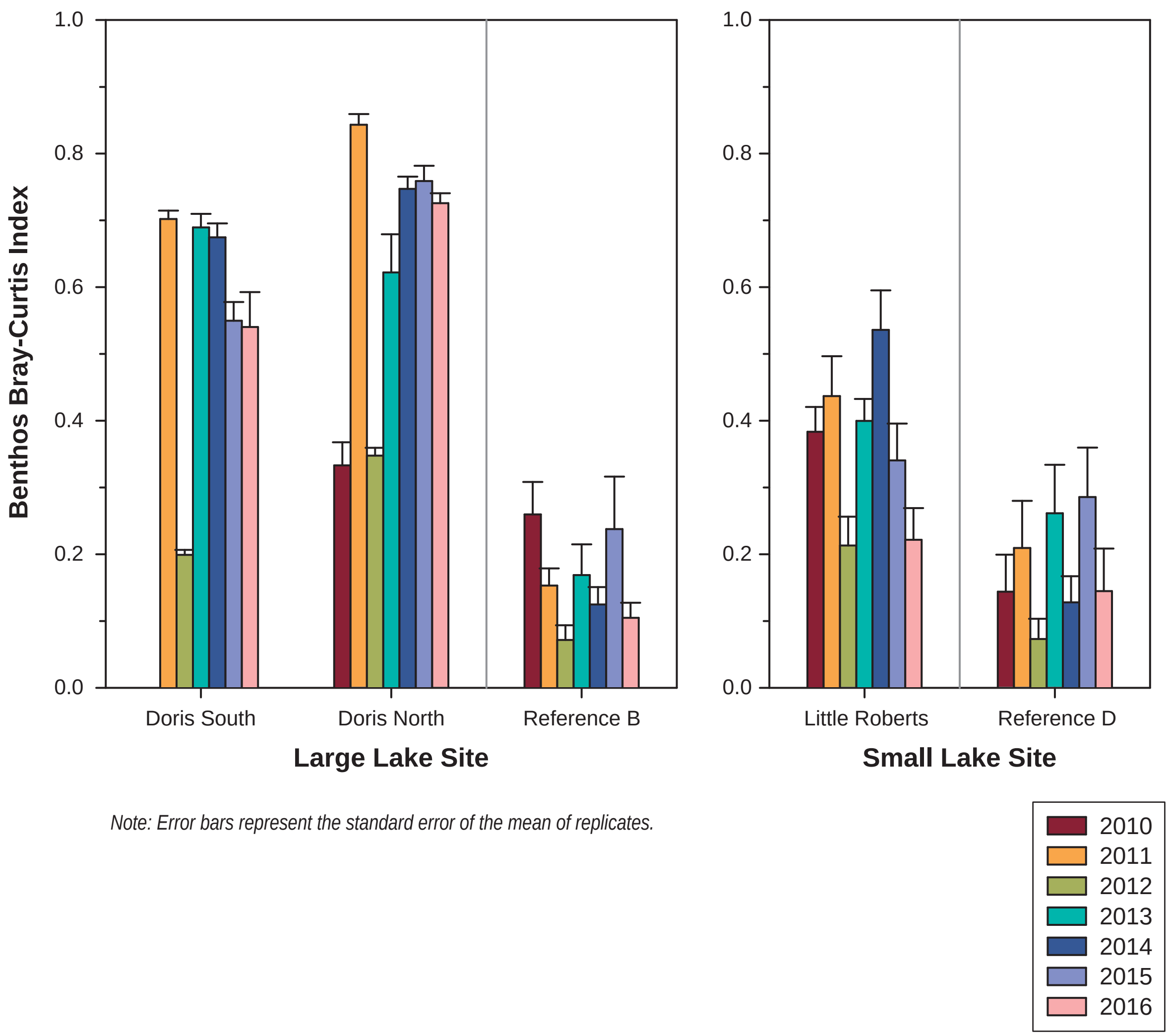
As recommended in the EEM guidance document (Environment Canada 2012), the marine benthos community was analyzed for the whole community (adults and juveniles) as well as for the adult community subset because juvenile benthos can respond differently to environmental disturbances than adult benthos.

3.6.3.1 Density

In both the whole community and the adult subset, there was evidence of non-parallelism in the 2010 to 2016 benthos density trends between RBW and REF-Marine 1 (both $p < 0.0001$). In 2010, benthos density was unusually high at site RBW and unusually low (for the adult community only) at site REF-Marine 1 (Figure 3.6-7). Between 2011 and 2016, whole community and adult mean densities at RBW were relatively consistent; however, at REF-Marine 1, densities seemed to increase slightly but steadily between 2010 and 2015, with 2016 mean densities returning to densities observed in the earlier years of monitoring (Figure 3.6-7). The annual site-specific modelling coefficients reflect this observation, as the coefficients tended to increase between 2010 and 2015 and decreased in 2016 (Appendix B).

Figure 3.6-6

Benthos Bray-Curtis Index for AEMP Lake Sites, Doris Project, 2010 to 2016



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

The 2016 data suggest that there is no ongoing directional trend in the modelling coefficients, and the variability between RBW and the marine reference site is likely attributable to natural variability rather than Project effects. As well, the density changes that appear to be causing the non-parallelism are occurring largely at the reference site, while density at RBW has been relatively consistent since 2011.

Both whole community and adult densities at site RBE were consistently lower than densities at RBW and REF-Marine 1 over the entire monitoring period (Figure 3.6-7; note the different y-axis scale used to plot density at RBE). Compared to RBW and REF-Marine 1, there was relatively high variability in the density data for RBE, both inter-annually (e.g., range of 23 to 4,139 organisms/m^2 for the whole community density) and intra-annually (e.g., range of 14 to 16,290 organisms/m^2 for the whole community in the 5 replicates collected in 2015). This high variability makes it difficult to determine whether Project activities may be affecting benthos density at this site. There was no evidence of non-parallelism in benthos density between RBE and REF-Marine 1 for the whole-community dataset ($p = 0.63$); however, there was evidence of non-parallelism for adult densities ($p = 0.0001$). However, the annual site-specific modelling coefficients did not follow a directional trend, suggesting that the inter-annual variability in benthos density at RBE was not related to Project activities over the monitoring period.

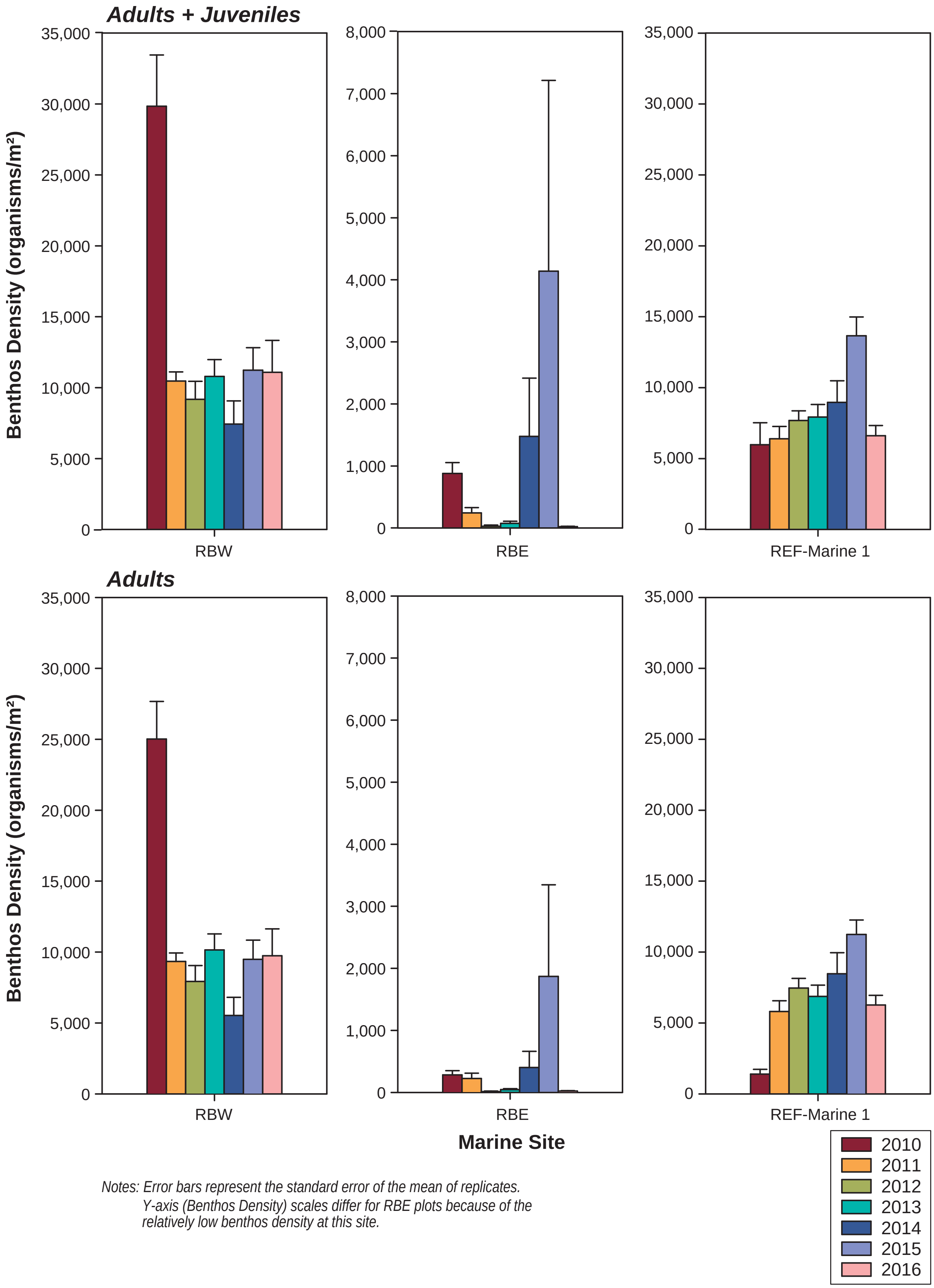
3.6.3.2 Community Richness, Evenness, and Diversity

At sites RBW and RBE, mean 2016 family richness was within the range observed in previous years for both the whole benthos community and the adult subset (Figures 3.6-8a and 3.6-8b). However, compared to family richness at REF-Marine 1, there was evidence of non-parallelism for the whole benthos community and the adults at both RBW and RBE ($p < 0.0001$ for both the whole community and the adult subsets). As was observed for benthos density, the non-parallelism in benthos richness between exposure and reference sites may be partially attributable to the apparent increasing trend in richness at the reference site between 2010 and 2015. The annual site-specific modelling coefficients reflect this observation, as the coefficients tended to increase between 2010 and 2015, particularly in the comparisons between RBE and the reference site (Appendix B). The 2016 data suggest that there is no ongoing directional trend in the modelling coefficients, and the variability between the exposure and reference sites is likely attributable to natural variability rather than Project effects.

Between 2010 and 2016, benthos family evenness was consistently highest at site RBE compared to RBW and REF-Marine 1 for both the whole community and the adult subset (Figures 3.6-8a and 3.6-8b). There was evidence of non-parallelism in family evenness between the marine exposure sites and the reference site for both the whole community dataset ($p = 0.0159$ for RBE; $p < 0.0001$ for RBW) and the adult subset ($p = 0.0027$ for RBE; $p < 0.0001$ for RBW). At site RBE, 2016 family evenness reached the maximum of one, indicating complete evenness. This was largely attributable to the very low numbers of organisms in the samples collected from RBE, as four out of the five replicates collected at RBE contained either one or two organisms belonging to the same family, and the remaining replicate contained three organisms, each belonging to a different family (excluding nematodes; Annex A.6-5). Evenness was similarly high in 2012 when benthos density at RBE was low (Figures 3.6-8a and 3.6-8b). The site-specific modelling coefficients were largest for 2012 and 2016, indicating that the relatively high evenness at RBE in 2012 and 2016 drove the observed non-parallelism (Appendix B). At site RBW, evenness in 2016 was similar to 2010 evenness, but was relatively low compared to other monitoring years (Figures 3.6-8a and 3.6-8b). There were no obvious trends in whole community and adult evenness over time at either RBW or RBE compared to the reference site, and the annual modelling coefficients did not follow a directional trend (Appendix B), suggesting that the non-parallelisms were not related to Project activities over the monitoring period.

Figure 3.6-7

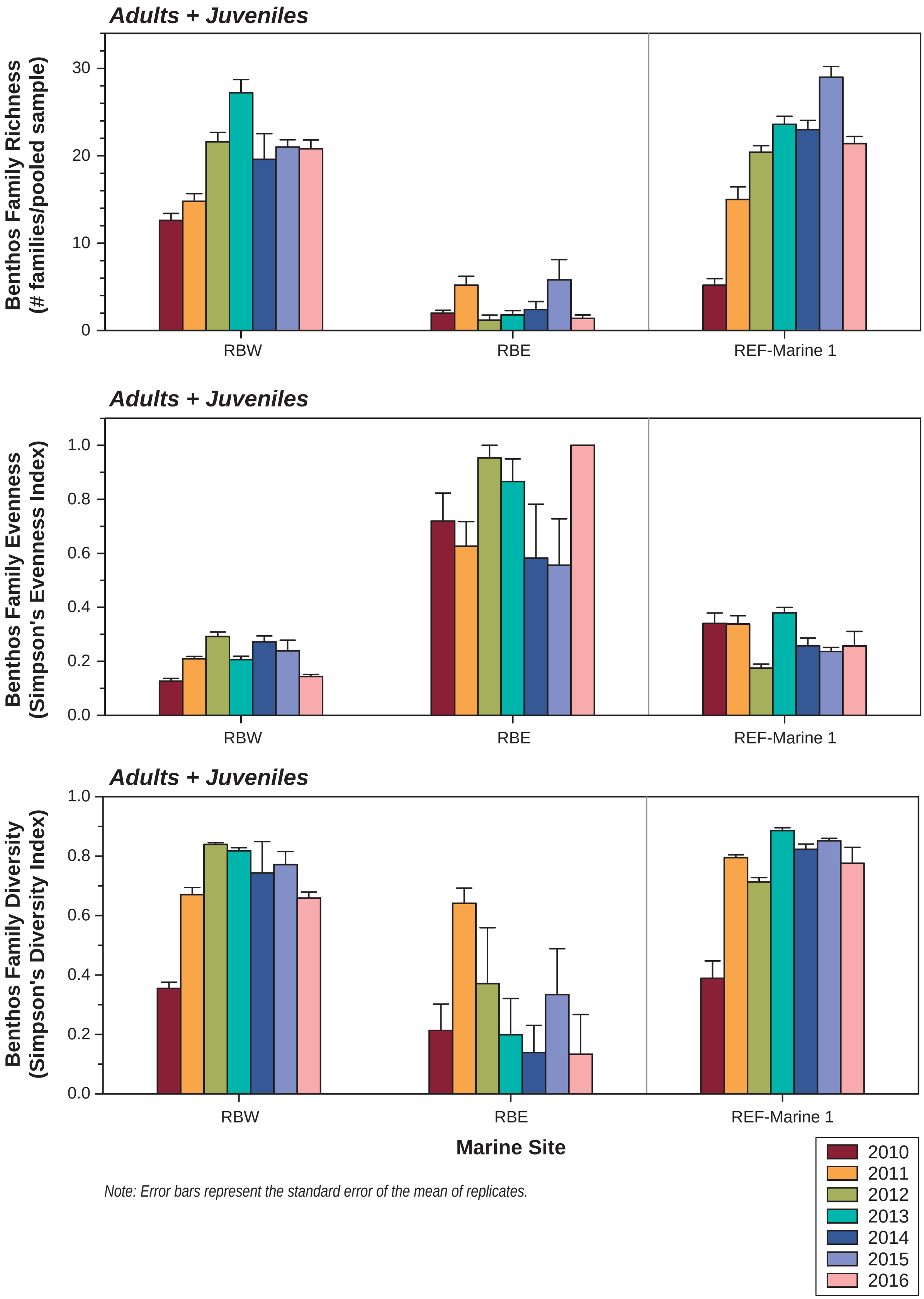
Benthos Density in AEMP Marine Sites, Doris Project, 2010 to 2016



Notes: Error bars represent the standard error of the mean of replicates.
Y-axis (Benthos Density) scales differ for RBE plots because of the relatively low benthos density at this site.

Figure 3.6-8a

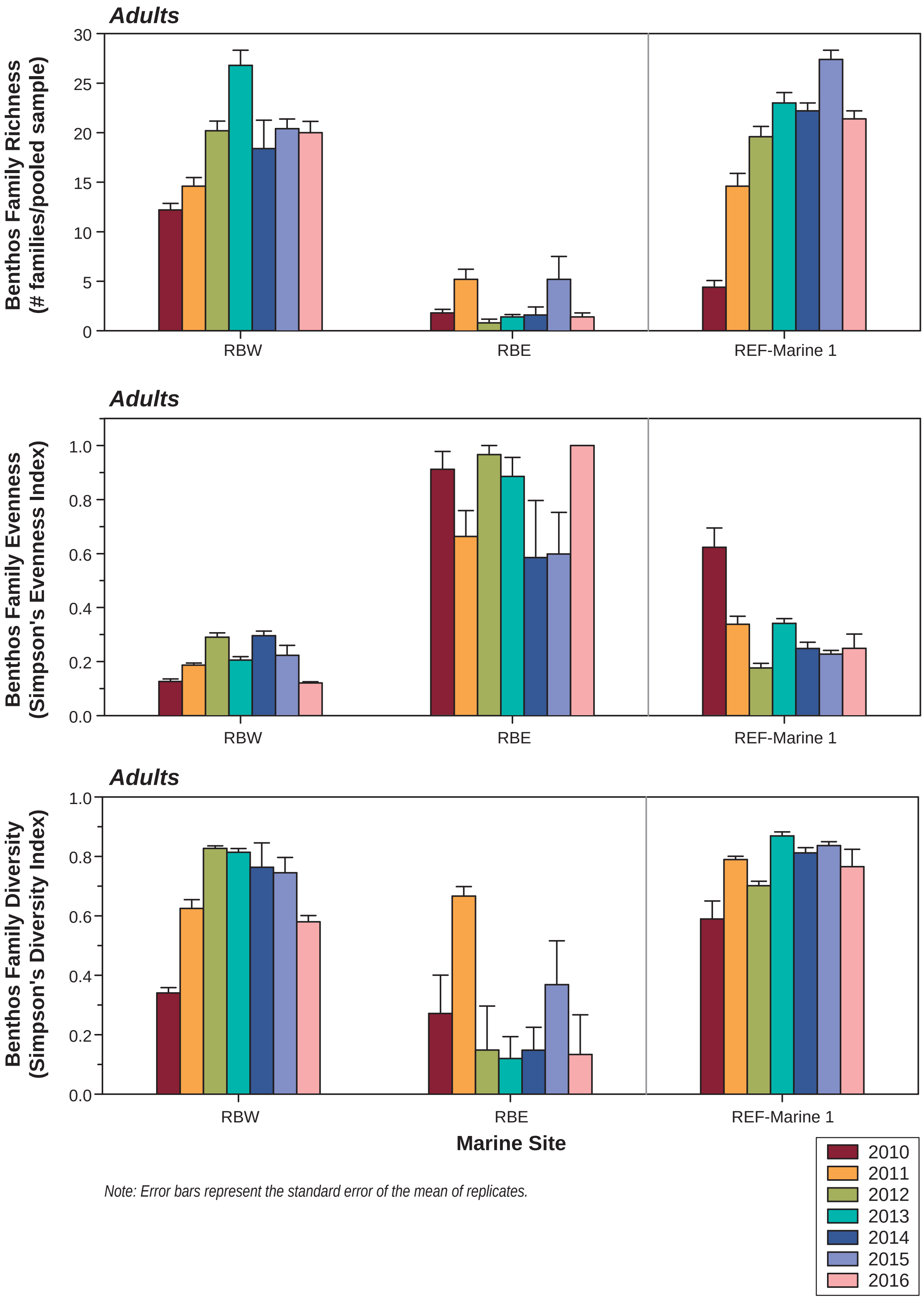
Richness, Evenness, and Diversity in AEMP Marine Sites, Doris Project, 2010 to 2016



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

Figure 3.6-8b

Richness, Evenness, and Diversity in AEMP Marine Sites, Doris Project, 2010 to 2016



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

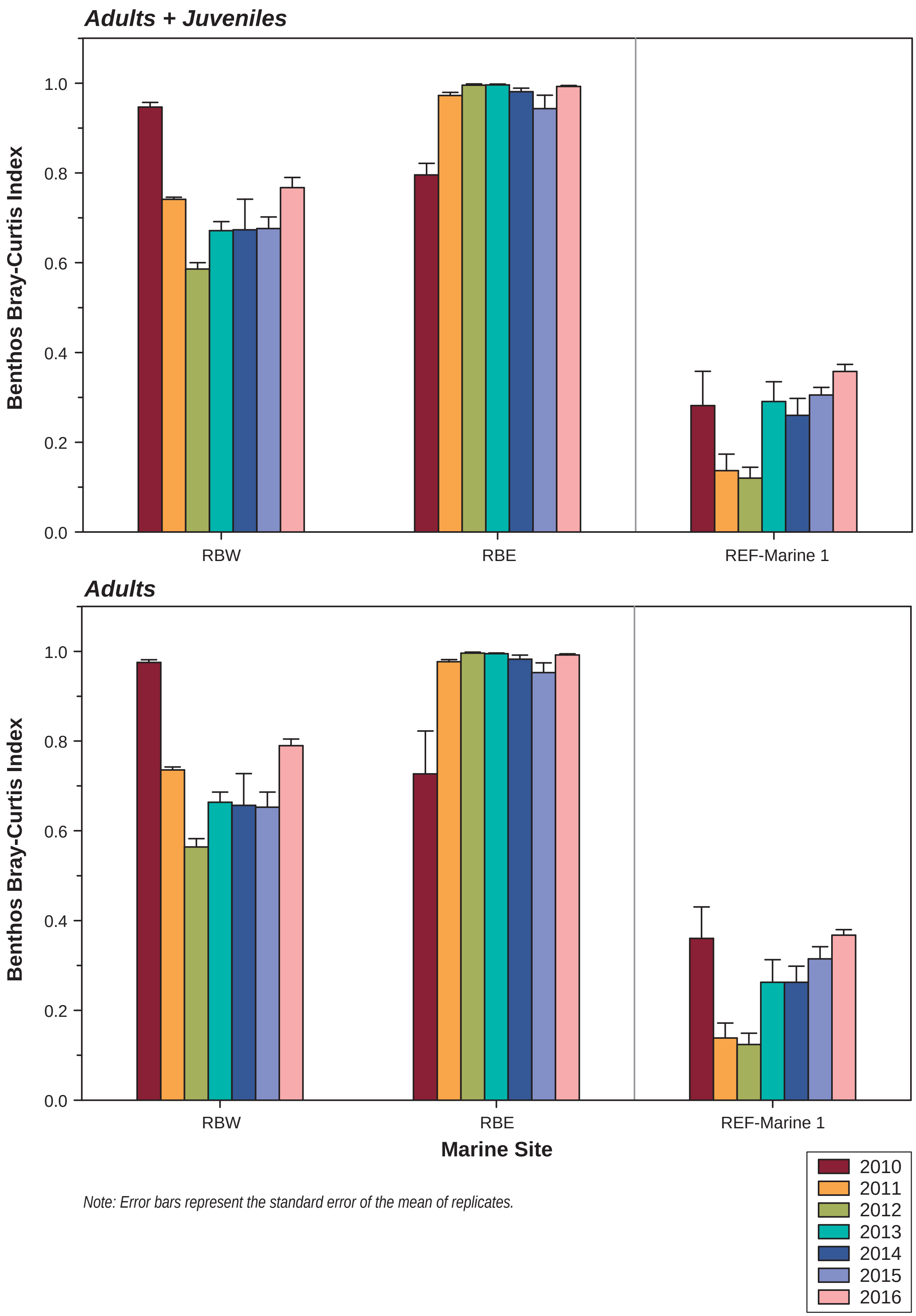
Between 2010 and 2016, benthos family diversity was generally lowest at site RBE for both the whole community and the adult subset (Figures 3.6-8a and 3.6-8b). For the whole benthos community, diversity was similar between RBW and REF-Marine 1 for each monitoring year (Figure 3.6-8a). This was confirmed by the statistical output as the modelling coefficients were largest for the year effect, and relatively small for the annual site-specific interaction terms (Appendix B). The only exception to this was the 2012 diversity estimate, which was relatively high at RBW compared to REF-Marine 1, and this likely drove the non-parallelism detected by the impact level-by-time analysis ($p = 0.046$). For the adult subset, diversity was less similar over time between RBW and REF-Marine 1 (Figure 3.6-8b). There was also evidence of non-parallelism between RBW and REF-Marine 1 adult diversity ($p = 0.0002$), but there was no directional trend in the annual site-specific modelling coefficients, suggesting the non-parallelism was likely caused by natural inter-annual variability rather than Project activities. Whole community and adult diversity were highly inter-annually variable at RBE (Figures 3.6-8a and 3.6-8b), and there was evidence of non-parallelism compared to REF-Marine 1 ($p = 0.0026$ for whole community; $p = 0.0032$ for adults). This non-parallelism was likely due to natural variability rather than Project effects as there was no consistent trend in the site-specific annual modelling coefficients (Appendix B).

3.6.3.3 Bray-Curtis Index

There was evidence of significant non-parallelism in the Bray-Curtis Index over time for both RBW ($p = 0.0003$ for the whole community; $p = 0.0014$ for the adult subset) and RBE ($p < 0.0001$ for both the whole community and the adult subset) compared to the median reference community. With the exception of 2010, the Bray-Curtis Index calculated for site RBE was relatively consistent over time, approaching one (Figure 3.6-9). A Bray-Curtis Index of one indicates that there is 100% dissimilarity with the reference site benthos family composition and that RBE and REF-Marine 1 don’t share any common families. Compared to RBW benthos community composition between 2011 and 2016, the RBE benthos community was consistently more dissimilar to the reference community (Figure 3.6-9). The relative consistency in the Bray-Curtis Index over time within each marine exposure site suggests that there were no Project-related effects on the benthos Bray-Curtis Index in the marine exposure sites. However, the site-specific annual modelling coefficients for the impact level-by-time analysis for the Bray-Curtis Index for RBE benthos (both whole community and adult subset) tended to decrease over time (Appendix B). This decrease was caused by the apparent increase in the Bray-Curtis Index at REF-Marine 1 between 2011 and 2016 rather than any change in the community composition at RBE (Figure 3.6-9). For site RBW, there was no consistent directional change in the annual site-specific modelling coefficient (Appendix B), suggesting that the non-parallelism was likely caused by natural inter-annual variability rather than Project activities.

Figure 3.6-9

Benthos Bray-Curtis Index for AEMP Marine Sites, Doris Project, 2010 to 2016



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

4. SUMMARY OF EFFECTS ANALYSIS

The effects analysis employed graphical and statistical methods to identify potential effects to the aquatic environment that may have resulted from Project activities in 2016. When historical information was available, before (baseline, 1995 to 2009 or 2010) and after (evaluation year, 2016) data for specific variables were first compared at each of the exposure sites to determine whether there was a discernible change in evaluated variables in 2016 compared to baseline years. If there was a change, before-after trends in the exposure sites were compared to those at the reference sites (BACI design) to determine if parallel changes occurred (no effect) or if there was a differential change between the exposure and reference waterbodies (potential effect). Graphical analysis was used to supplement statistical results and to aid in the interpretation of temporal trends. Professional judgment was always used for the evaluation of effects to determine whether effects likely resulted from natural inter-annual variability or Project activities.

4.1 STREAMS

A summary of the 2016 effects analysis for the AEMP exposure streams is presented in Table 4.1-1. There was sufficient historical information to evaluate potential Project-related effects on water and sediment quality, periphyton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in exposure streams. Data for Roberts Outflow are shown in the report figures and in Appendices A and B, but this stream is not discussed here. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

The water quality effects analysis found that mean 2016 pH levels and mean concentrations of evaluated nutrients and metals in exposure streams were all below CCME guidelines, except for total aluminum at Little Roberts Outflow. However, the total aluminum guideline was frequently exceeded in all exposure streams during baseline years, suggesting that the exposure streams contain naturally high concentrations of aluminum. Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of exposure streams as a result of 2016 Project activities.

Mean 2016 sediment quality variable concentrations in AEMP exposure streams were always below CCME ISQGs and PELs. At Doris and Little Roberts outflows, there were some differences in the particle size composition of sediment samples collected in 2016 compared to the particle size composition of baseline samples. Variation in sediment particle size composition was likely unrelated to 2016 Project activities, and probably reflected natural spatial heterogeneity in stream sediments. At Little Roberts Outflow, sediments in 2016 contained significantly lower concentrations of TOC, chromium, copper, lead, and zinc than did baseline sediments. These decreases were likely attributable to the significant decrease in the proportion of fine sediments in 2016 samples compared to baseline samples, since fine sediments tend to be associated with higher concentrations of TOC and metals than coarse sediments. Decreases in sediment metal concentrations are not of concern; therefore, there were no apparent adverse effects of 2016 Project activities on the sediment quality of exposure streams.

There was no indication that 2016 Project activities affected periphyton biomass in the exposure streams.

There was no evidence of Project-related effects on benthos density, richness, evenness, diversity, or similarity to the median reference community (Bray-Curtis Index) in exposure streams despite significant evidence of non-parallelism in trends in benthos family evenness between Doris Outflow and the reference streams, and total density between Little Roberts Outflow and the reference streams. Benthos community descriptors tended to be highly variable over time in both the exposure and reference streams, and the 2016 results were generally similar to previous years or within the range expected given these high levels of natural variability. The non-parallelism in trends between the exposure and reference sites was likely a result of the naturally high variability in the data, and there were no apparent Project-related adverse effects on stream benthos communities.

4.2 LAKES

Table 4.2-1 presents the summary of the 2016 effects analysis for the AEMP exposure lakes. There was sufficient historical information to evaluate potential Project-related effects on under-ice dissolved oxygen concentrations, Secchi depth, water and sediment quality, phytoplankton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in the AEMP exposure lakes.

There was no evidence of an effect of 2016 Project activities on under-ice dissolved oxygen concentrations in the exposure lakes. Under-ice dissolved oxygen concentrations recorded in April 2016 were above the CCME freshwater cold-water guideline for early life stages of 9.5 mg/L in all three exposure lake sites. At Doris Lake North, dissolved oxygen concentrations decreased at depth to a minimum of 9.3 mg/L, which is just below the CCME guideline of 9.5 mg/L. A decrease in under-ice dissolved oxygen concentrations at depth is a common phenomenon in seasonally stratified lakes, and was also observed in Reference Lake B.

Secchi depth was evaluated for the large lake sites (Doris Lake South, Doris Lake North, and Reference Lake B) only as the Secchi disk reached the lake bottom in the small lake sites (Little Roberts Lake and Reference Lake D) during all monitoring periods. There was no evidence of an effect of 2016 Project activities on Secchi depth in the large lake exposure sites.

The water quality effects analysis found that mean 2016 pH levels and mean concentrations of evaluated nutrients and metals in exposure lakes were all below CCME guidelines, except total copper which was slightly above the CCME guideline in Little Roberts Lake. However, the baseline mean total copper concentration at Little Roberts Lake was also above this CCME guideline, suggesting that copper concentrations are naturally elevated in this lake.

Table 4.1-1. Summary of Evaluation of Effects, AEMP Streams, Doris Project, 2016

Variable	Method of Evaluation	Within Waterbody Before-After Difference (BA analysis)[a]				Before-After Trend Relative to Reference Sites (BACI analysis)[a]		Conclusion of Effect[b, c]	
		Doris OF	Little Roberts OF	Reference B OF	Reference D OF	Doris OF	Little Roberts OF	Doris OF	Little Roberts OF
Water Quality									
pH	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Alkalinity, Total	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	Parallel	No effect	No effect
Hardness	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Total Suspended Solids	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Ammonia (as N)	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Nitrate (as N)	GA, BA	-	-	No difference	-	-	-	No effect	No effect
Cyanide, Total	GA	-	-	-	-	-	-	No effect	No effect
Radium-226	GA	-	-	-	-	-	-	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Arsenic , Total	GA, BA	No difference	No difference	**Increase**	-	☐	☐	No effect	No effect
Cadmium, Total	GA, BA	-	No difference	-	-	-	☐	No effect	No effect
Copper, Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Lead, Total	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Mercury, Total	GA, BA	-	-	-	-	-	-	No effect	No effect
Molybdenum, Total	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Nickel, Total	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Zinc, Total	GA, BA	No difference	No difference	-	-	☐	☐	No effect	No effect
Sediment Quality									
% Gravel (>2 mm)	GA, BA, BACI	**Decrease**	**Increase**	No difference	-	Parallel	Parallel	No effect	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA, BACI	**Increase**	No difference	No difference	-	**Non-parallel**	☐	No effect[d]	No effect
% Silt (0.063 mm - 4 µm)	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	Parallel	No effect	No effect
% Clay (<4 µm)	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	**Non-parallel**	No effect	No effect[d]
Total Organic Carbon	GA, BA, BACI	No difference	**Decrease**	No difference	-	☐	**Non-parallel**	No effect	No effect[d]
Arsenic	GA, BA	No difference	No difference	No difference	-	☐	☐	No effect	No effect
Cadmium	GA	-	-	-	-	-	-	No effect	No effect
Chromium	GA, BA	No difference	**Decrease**	No difference	-	☐	☐	No effect	No effect
Copper	GA, BA	No difference	**Decrease**	No difference	-	☐	☐	No effect	No effect
Lead	GA, BA	No difference	**Decrease**	No difference	-	☐	☐	No effect	No effect
Mercury	GA	-	-	-	-	-	-	No effect	No effect
Zinc	GA, BA	No difference	**Decrease**	No difference	-	☐	☐	No effect	No effect
Periphyton									
Biomass	GA, BA, BACI	No difference	-	-	-	☐	Parallel	No effect	No effect
Variable	**Method of Evaluation**	**Within Waterbody Before-After Difference (BA analysis)[a]**				**2010 to 2016 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]**		**Conclusion of Effect[b, c]**	
		Doris OF	**Little Roberts OF**	**Reference B OF**	**Reference D OF**	**Doris OF**	**Little Roberts OF**	**Doris OF**	**Little Roberts OF**
Benthic Invertebrates									
Total Density	GA, ILBT	-	-	-	-	Parallel	**Non-parallel**	No effect	No effect[d]
Family Richness	GA, ILBT	-	-	-	-	Parallel	Parallel	No effect	No effect
Simpson's Evenness Index	GA, ILBT	-	-	-	-	**Non-parallel**	Parallel	No effect[d]	No effect
Simpson's Diversity Index	GA, ILBT	-	-	-	-	Parallel	Parallel	No effect	No effect
Bray-Curtis Index	GA, ILBT	-	-	-	-	Parallel	Parallel	No effect	No effect

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at $p<0.05$, marginal difference at $p = 0.05$.*

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, periphyton biomass, and benthos community descriptors, a change in any direction is considered to be an effect. For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there was a significant difference, this change was not attributed to Project activities.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, or the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite).

Square (☐) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2016 means.

Table 4.2-1. Summary of Evaluation of Effects, AEMP Lakes, Doris Project, 2016

Variable	Method of Evaluation	Within Waterbody Before-After Difference (BA analysis)[a]					Before-After Trend Relative to Reference Site (BACI analysis)[a]			Conclusion of Effect[b, c]		
		Doris South	Doris North	Reference B	Little Roberts	Reference D	Doris South	Doris North	Little Roberts	Doris South	Doris North	Little Roberts
Physical Limnology												
Winter Dissolved Oxygen	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Secchi Depth	GA, BA	No difference	No difference	-	-	-	□	□	-	No effect	No effect	No effect
Water Quality												
pH	GA, BA	No difference	No difference	No difference	**Increase**	-	□	□	-	No effect	No effect	No effect[d]
Alkalinity, Total	GA, BA	No difference	No difference	**Increase**	No difference	-	□	□	-	No effect	No effect	No effect
Hardness	GA, BA	No difference	No difference	**Increase**	No difference	-	□	□	-	No effect	No effect	No effect
Total Suspended Solids	GA, BA	No difference	No difference	-	No difference	-	□	□	-	No effect	No effect	No effect
Ammonia (as N)	GA, BA	No difference	No difference	**Decrease**	No difference	-	□	□	-	No effect	No effect	No effect
Nitrate (as N)	GA, BA	No difference	No difference	-	-	-	□	□	-	No effect	No effect	No effect
Cyanide, Total	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Radium-226	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Arsenic , Total	GA, BA	No difference	**Decrease**	**Increase**	No difference	-	□	□	-	No effect	No effect	No effect
Cadmium, Total	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Copper, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Lead, Total	GA, BA	No difference	No difference	**Decrease**	No difference	-	□	□	-	No effect	No effect	No effect
Mercury, Total	GA, BA	-	No difference	**Decrease**	No difference	-	-	□	-	No effect	No effect	No effect
Molybdenum, Total	GA, BA, BACI	No difference	**Increase**	-	**Increase**	-	□	Parallel	-	No effect	No effect	No effect[d]
Nickel, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	-	No effect	No effect	No effect
Zinc, Total	GA, BA	No difference	No difference	**-**	No difference	-	□	□	-	No effect	No effect	No effect
Sediment Quality												
% Gravel (>2 mm)	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
% Silt (0.063 mm - 4 µm)	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
% Clay (<4 µm)	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Total Organic Carbon	GA, BA	**Decrease**	**Decrease**	-	No difference	-	-	-	-	No effect	No effect	No effect
Arsenic	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Cadmium	GA, BA	No difference	**Decrease**	-	No difference	-	-	-	-	No effect	No effect	No effect
Chromium	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Copper	GA, BA	**Decrease**	**Decrease**	-	No difference	-	-	-	-	No effect	No effect	No effect
Lead	GA, BA	**Decrease**	**Decrease**	-	**Decrease**	-	-	-	-	No effect	No effect	No effect
Mercury	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Zinc	GA, BA	No difference	**Decrease**	-	**Decrease**	-	-	-	-	No effect	No effect	No effect
Phytoplankton												
Biomass	GA, BA	No difference	No difference	-	No difference	-	□	□	-	No effect	No effect	No effect

Variable	Method of Evaluation	Within Waterbody Before-After Difference (BA analysis)[a]					2010 to 2016 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]			Conclusion of Effect[b, c]		
		Doris South	Doris North	Reference B	Little Roberts	Reference D	Doris South	Doris North	Little Roberts	Doris South	Doris North	Little Roberts
Benthic Invertebrates												
Total Density	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]	No effect[d]
Family Richness	GA, ILBT	-	-	-	-	-	**Non-parallel**	Parallel	**Non-parallel**	No effect[d]	No effect	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	-	-	Parallel	**Non-parallel**	**Non-parallel**	No effect	No effect[d]	No effect[d]
Simpson's Diversity Index	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	Parallel	No effect[d]	No effect[d]	No effect
Bray-Curtis Index	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]	No effect[d]

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at $p<0.05$.*

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, periphyton biomass, and benthos community descriptors, a change in any direction is considered to be an effect. For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there is a significant difference, this change is not attributed to Project activities or is not considered to be environmentally important.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, or the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite).

Square (□) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2016 means.

Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of exposure streams as a result of 2016 Project activities. Although the mean pH of 7.53 at Little Roberts Lake in 2016 was significantly higher than the baseline mean of 7.22, a pH of 7.53 is within the optimal pH range for the protection of freshwater aquatic life (CCME 2016b) and is identical to mean pH levels recorded during individual baseline years (7.5 in 1996 and 7.53 in 2003). Therefore, there is no evidence of an adverse, Project-related change in pH in Little Roberts Lake. There was also a slight increase in the mean total molybdenum concentration in Little Roberts Lake between baseline years and 2016 (from 0.00019 to 0.00022 mg/L). Although this increase in molybdenum was statistically significant, it is not considered environmentally or biologically important since the increase was slight and 2016 concentrations remained well below the CCME guideline of 0.073 mg/L. Also, molybdenum concentrations increased slightly in Reference Lake B from baseline years to 2016, suggesting that increases can occur naturally even in areas far-removed from potential Project effects.

Mean 2016 concentrations of sediment quality variables were generally below CCME ISQGs in the exposure lake sites, except for arsenic in Doris Lake South, chromium at all sites (as well as in Reference Lake B), and copper at Doris Lake South and Doris Lake North. Arsenic, chromium, and copper concentrations in the sediments of these lake sites were higher than CCME ISQGs during nearly all years of monitoring, including baseline years, which suggests that these metals are naturally elevated in the sediments of these exposure sites. Mean 2016 concentrations of sediment quality variables always remained below CCME PEL guidelines. There were no significant differences in the particle size composition of sediments collected in 2016 compared to the particle size composition of baseline samples, which simplified the comparison of sediment quality variables between baseline years and 2016. Concentrations of several sediment quality variables decreased in the sediments of exposure lakes in 2016, including TOC in Doris Lake South and Doris Lake North, cadmium in Doris Lake North, copper in Doris Lake South and Doris Lake North, lead, and zinc in Doris Lake North; copper in Doris Lake South and North, lead in all three exposure sites, and zinc in Doris Lake North and Little Roberts Lake. Decreases in the concentrations of metals in sediments are not a cause for concern; therefore, there were no apparent adverse effects of 2016 Project activities on sediment quality in exposure lake sites.

There was no indication of a Project-related effect on 2016 phytoplankton biomass in the exposure lakes.

In lake exposure sites, there was non-parallelism in 2010 to 2016 trends for nearly all benthos community descriptors when compared to the reference sites. There was evidence of significant non-parallelism for benthos density and the Bray Curtis Index for all exposure lake sites relative to reference lake sites. Compared to the reference lake sites, benthos family richness trends were also non-parallel for Doris Lake South and Little Roberts Lake, Simpson's Evenness Index trends were non-parallel for Doris Lake North and Little Roberts Lake, and Simpson's Diversity Index trends were non-parallel for Doris Lake North and South. Benthos community descriptors tended to be highly variable over time in both the exposure and reference lakes, and the 2016 results were generally similar to previous years or within the range expected given these high levels of natural variability. The non-parallelism in trends between the exposure and reference sites was likely a result of the naturally high variability in the data, and there were no apparent Project-related adverse effects on lake benthos communities.

4.3 MARINE

Table 4.3-1 presents the summary of the 2016 effects analysis for the AEMP marine exposure sites. There was sufficient historical information to evaluate potential Project-related effects on under-ice dissolved oxygen concentrations, water and sediment quality, phytoplankton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in the marine exposure sites.

There was no evidence of an effect of 2016 Project activities on under-ice dissolved oxygen concentrations at the marine exposure sites in Roberts Bay, and 2016 concentrations remained above the CCME interim guideline for the minimum concentration of dissolved oxygen in marine and estuarine waters (8.0 mg/L).

The water quality effects analysis found that mean 2016 pH levels and mean concentrations of evaluated nutrients and metals in marine exposure sites were all below CCME guidelines. Based on the 18 water quality variables that were evaluated, there were no apparent adverse changes to the water quality of marine exposure sites that can be attributed to the Project.

Mean 2016 concentrations of sediment quality variables at the marine exposure sites were always below CCME ISQGs and PELs. Although there were no suitable baseline data to compare against 2016 sediment quality data from site RBE, concentrations of sediment quality variables were consistently lowest at this site, likely due to the greater levels of sand compared to the finer sediments at sites RBW and REF-Marine 1. At site RBW, there were significant increases in TOC, arsenic, and copper concentrations in sediments, but these increases were found to be parallel to the changes at the reference site, suggesting that the observed changes from baseline levels were unrelated to the Project.

There was no indication of a Project-related effect on 2016 phytoplankton biomass at the marine exposure sites.

In the whole benthos community (adults and juveniles) and the adult subset of the community, significant non-parallelisms were detected for all evaluated benthos community descriptors at RBW and RBE relative to the REF-Marine 1, except for whole community benthos density at RBE. Most 2016 benthos community descriptors were within range of previous years, and there was no indication that benthos communities in 2016 at RBW or RBE were adversely affected by Project activities. Non-parallelisms in trends in the benthos communities were likely attributable to high spatial heterogeneity in benthos distribution and inter-annual variability of all community descriptors at the exposure and reference sites.

Table 4.3-1. Summary of Evaluation of Effects, AEMP Marine Sites, Doris Project, 2016

		Within Waterbody Before-After Difference (BA analysis)[a]			Before-After Trend Relative to Reference Site (BACI analysis)[a]		Conclusion of Effect[b, c]	
Variable	Method of Evaluation	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Ida Bay (REF-Marine 1)	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Roberts Bay West (RBW)	Roberts Bay East (RBE)
Physical Oceanography								
Winter Dissolved Oxygen	GA	-	-	-	-	-	No effect	No effect
Water Quality								
pH	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Alkalinity, Total	GA, BA	-	No difference	-	-	-	No effect	No effect
Hardness	GA, BA	No difference	No difference	-	-	-	No effect	No effect
Total Suspended Solids	GA, BA	**Decrease**	No difference	-	☐	☐	No effect	No effect
Ammonia (as N)	GA, BA	-	No difference	-	-	☐	No effect	No effect
Nitrate (as N)	GA, BA	**Decrease**	-	-	☐	-	No effect	No effect
Cyanide, Total	GA	-	-	-	-	-	No effect	No effect
Radium-226	GA	-	-	-	-	-	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Arsenic , Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Cadmium, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Copper, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Lead, Total	GA, BA	-	No difference	-	-	☐	No effect	No effect
Mercury, Total	GA	-	-	-	-	-	No effect	No effect
Molybdenum, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Nickel, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Zinc, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Sediment Quality								
% Gravel (>2 mm)	GA	-	-	-	-	-	No effect	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA	-	-	No difference	-	-	No effect	No effect
% Silt (0.063 mm - 4 µm)	GA, BA	-	-	**Increase**	-	-	No effect	No effect
% Clay (<4 µm)	GA, BA	-	-	No difference	-	-	No effect	No effect
Total Organic Carbon	GA, BA, BACI	**Increase**	-	**Increase**	Parallel	-	No effect	No effect
Arsenic	GA, BA, BACI	**Increase**	-	**Increase**	Parallel	-	No effect	No effect
Cadmium	GA, BA	-	-	No difference	-	-	No effect	No effect
Chromium	GA, BA	No difference	-	No difference	☐	-	No effect	No effect
Copper	GA, BA, BACI	**Increase**	-	No difference	Parallel	-	No effect	No effect
Lead	GA, BA	No difference	-	No difference	☐	-	No effect	No effect
Mercury	GA, BA	**Decrease**	-	No difference	☐	-	No effect	No effect
Zinc	GA, BA	No difference	-	No difference	☐	-	No effect	No effect
Phytoplankton								
Biomass	GA, BACI	-	-	-	Parallel	Parallel	No effect	No effect

(continued)

Table 4.3-1. Summary of Evaluation of Effects, AEMP Marine Sites, Doris Project, 2016 (completed)

		Within Waterbody Before-After Difference (BA analysis)[a]			2010 to 2016 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]		Conclusion of Effect[b, c]	
Variable	Method of Evaluation	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Ida Bay (REF-Marine 1)	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Roberts Bay West (RBW)	Roberts Bay East (RBE)
Benthic Invertebrates (Adults + Juveniles)								
Total Density	GA, ILBT	-	-	-	**Non-parallel**	Parallel	No effect[d]	No effect
Family Richness	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Diversity Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Bray-Curtis Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Benthic Invertebrates (Adults)								
Total Density	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Family Richness	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Diversity Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Bray-Curtis Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at* $p<0.05$.

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, phytoplankton biomass, and benthos community descriptors, a change in any direction is considered to be an For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there was a significant or marginal difference, this change was not attributed to Project activities.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite), or non-comparability of before and after data.

Square (☐) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2016 means.

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Definitions of the acronyms and abbreviations used in this reference list can be found in the Glossary and Abbreviations section.

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Appendix A

2016 Data Report

DORIS PROJECT

2016 Aquatic Effects Monitoring Program Report

Appendix A. 2016 Data Report

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Annex A.6-7. Results of Benthos QA/QC Sorting Efficiencies, Doris Project, 2016

APPENDIX A. 2016 DATA REPORT

This report presents the sampling methodology, the raw data, and summary graphs and tables of the results of the 2016 Aquatic Effects Monitoring Program (AEMP) for the Doris Gold Mine Project. The 2016 AEMP included the following: physical profiles of temperature, dissolved oxygen, and salinity (marine sites only); Secchi depths; water quality; sediment quality; primary producer biomass; and benthic invertebrate (benthos) taxonomy and density. The evaluation of effects is provided in the main body of the report.

A.1 SAMPLING METHODOLOGY AND DATA ANALYSIS

A.1.1 Sampling Locations

Figure A.1-1 provides an overview of sampling sites included in the 2016 AEMP and Figures A.1-2 to A.1-7 show detailed maps of each lake and marine sampling site, including sampling details and bathymetric contours (if available).

Figure A.1-1
AEMP Sampling Locations, Doris Project, 2016

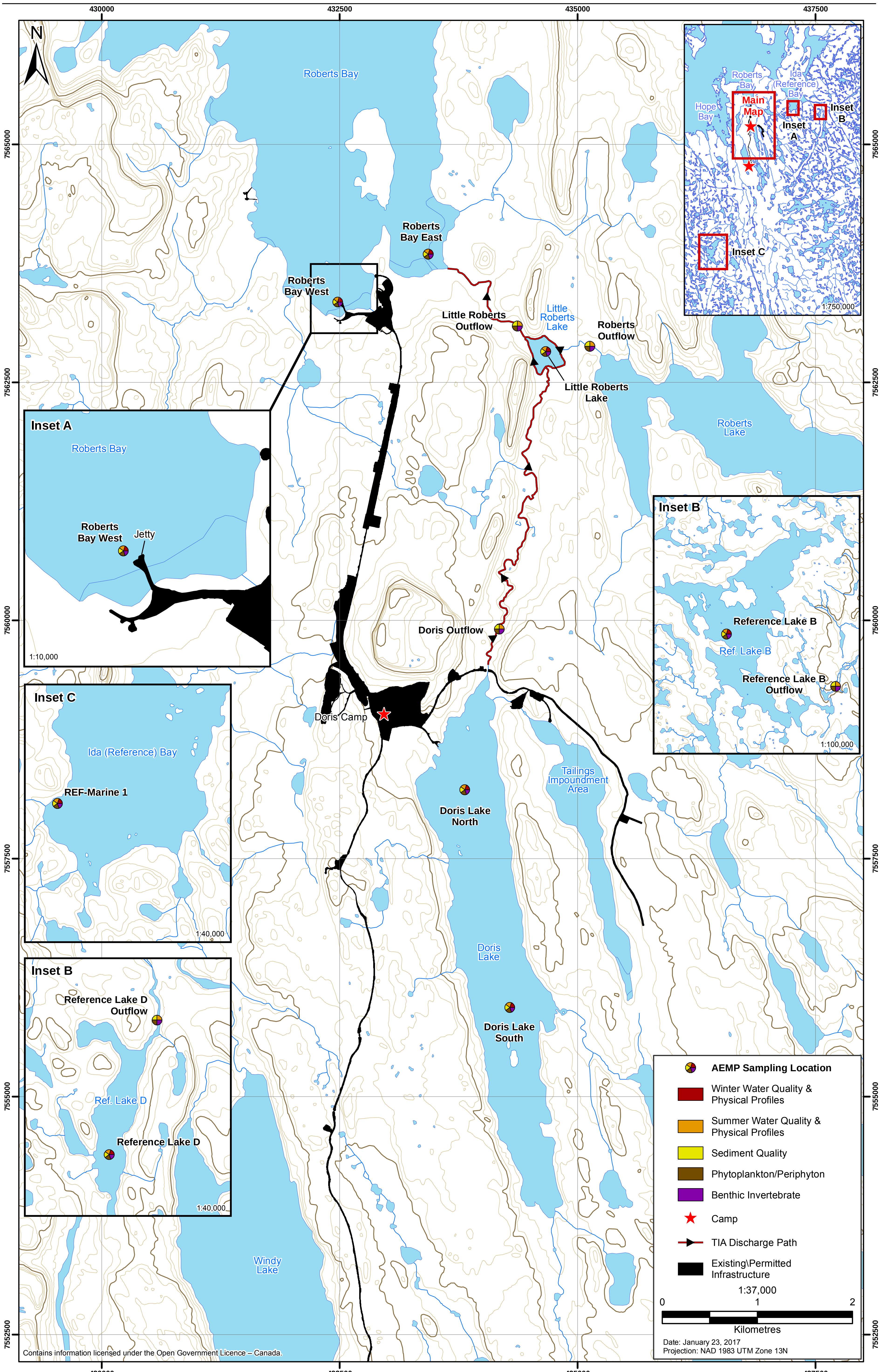
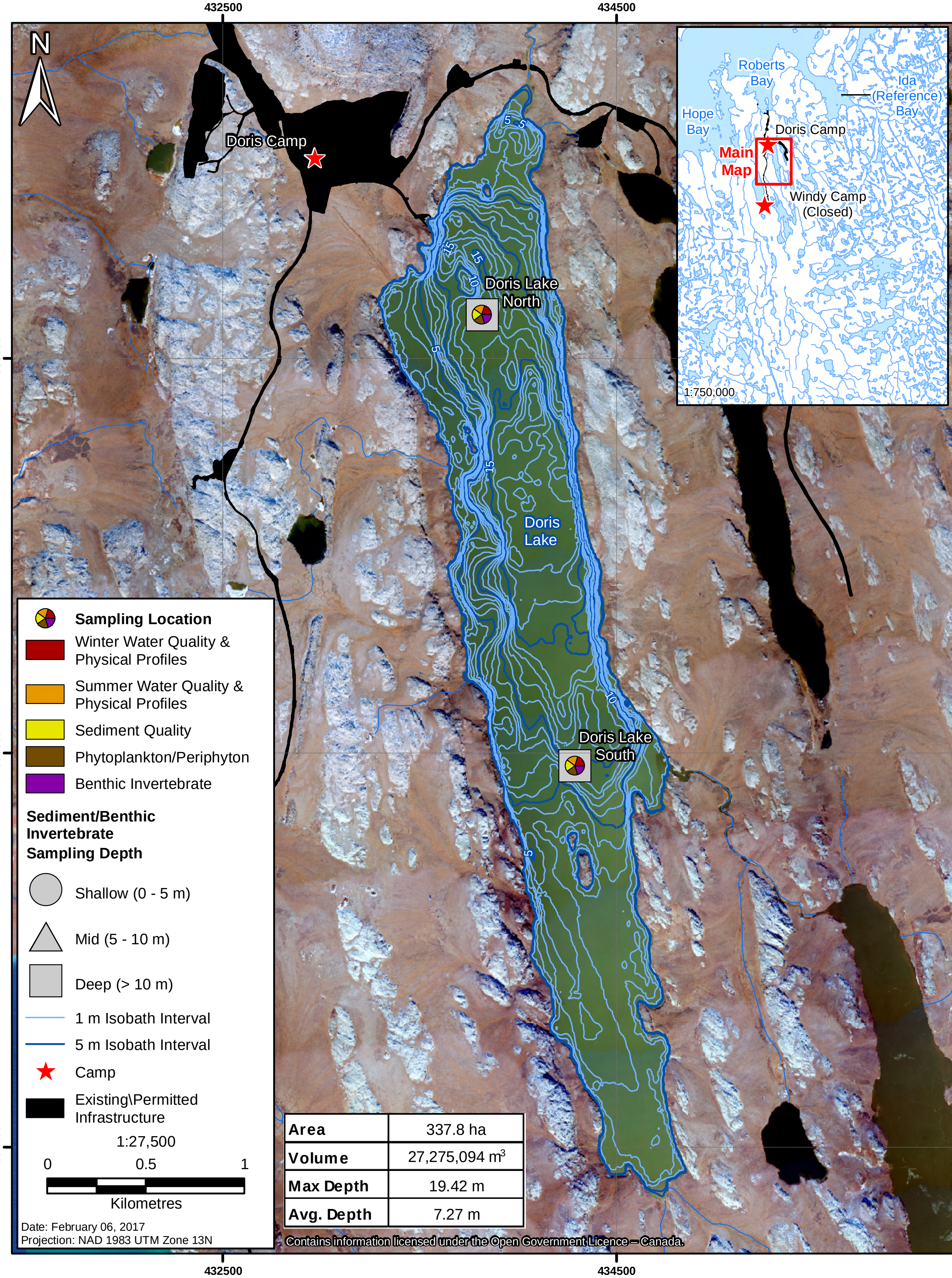


Figure A.1-2

Sampling Locations in Doris Lake, Doris Project, 2016



Area	337.8 ha
Volume	27,275,094 m^3
Max Depth	19.42 m
Avg. Depth	7.27 m

Figure A.1-3

Sampling Locations in Little Roberts Lake, Doris Project, 2016

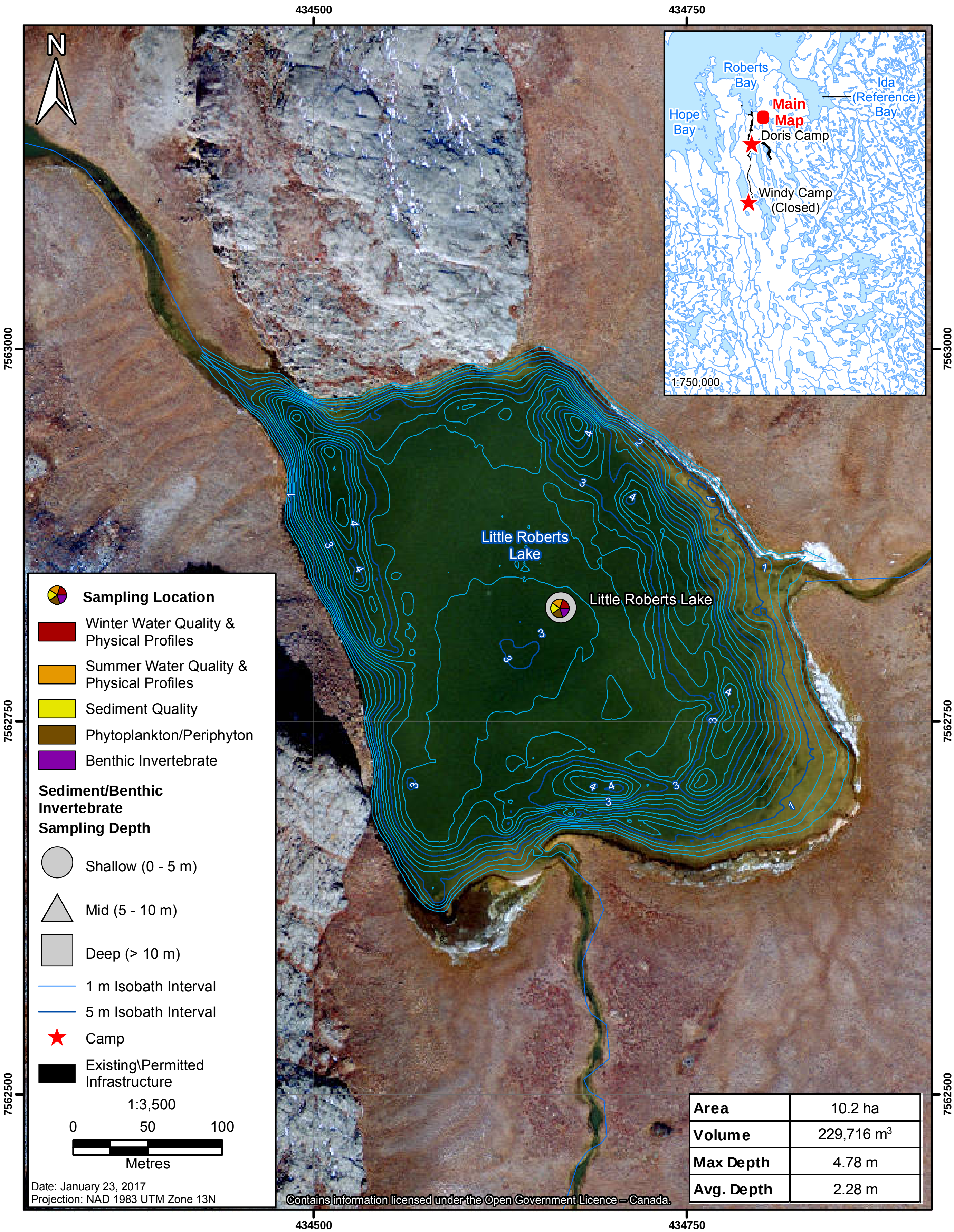


Figure A.1-4
Sampling Location in Reference Lake B, Doris Project, 2016