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

| Variable | Marine Project Site | |
|---|---|---|
| | **RBE p-value** | **RBW p-value** |
| Aluminum (Al) | 0.8553 | 0.5525 |
| Alkalinity | . | . |
| Ammonia | 0.5496 | **<0.0001** |
| Arsenic (As) | 0.1298 | 0.7513 |
| Cyanide (CN) | . | . |
| Cadmium (Cd) | 0.2917 | 0.8408 |
| Copper (Cu) | 0.9917 | 0.4015 |
| Iron (Fe) | 0.8720 | 0.6168 |
| Hardness | . | . |
| Mercury (Hg) | 0.4761 | 0.9400 |
| Molybdenum (Mo) | 0.6676 | 0.2474 |
| Nickel (Ni) | 0.6912 | 0.9864 |
| Nitrate | 0.1951 | 0.5887 |
| Lead (Pb) | 0.7222 | 0.8273 |
| Radium-226 (Ra) | . | . |
| Total Suspended Solids (TSS) | 0.5176 | 0.5707 |
| Zinc (Zn) | 0.7300 | 0.4537 |
| pH | 0.9173 | 0.9346 |

*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**

| Variable | Small Lake Site | |
|---|---|---|
| | Little Roberts Proportion Censored | Reference D Proportion Censored |
| Aluminum (Al) | 0.00 | 0.00 |
| Alkalinity | 0.03 | 0.00 |
| Ammonia | 0.32 | **1.00** |
| Arsenic (As) | 0.09 | 0.25 |
| Cyanide (CN) | **0.85** | **1.00** |
| Cadmium (Cd) | **0.81** | **0.75** |
| Copper (Cu) | 0.00 | 0.00 |
| Iron (Fe) | 0.00 | 0.00 |
| Hardness | 0.00 | 0.00 |
| Mercury (Hg) | 0.53 | 0.25 |
| Molybdenum (Mo) | 0.06 | 0.25 |
| Nickel (Ni) | 0.03 | 0.00 |
| Nitrate | **0.70** | **1.00** |
| Lead (Pb) | 0.14 | 0.62 |
| Radium-226 (Ra) | **0.85** | **1.00** |
| Total Suspended Solids (TSS) | 0.11 | 0.50 |
| Zinc (Zn) | 0.30 | **1.00** |
| pH | 0.00 | 0.00 |

*Notes:*
*Dataset includes all baseline years up to and including 2009, and 2016.*
*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 |
| Reference D | Mo | 2016 | 11AUG16 | 1 | 0.001000 | 1 |
| Reference D | Mo | 2016 | 11AUG16 | 2 | 0.001000 | 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**

| | Small Lake Site | |
|---|---|---|
| | **Little Roberts p-value** | **Reference D p-value** |
| Aluminum (Al) | 0.4507 | . |
| Alkalinity | 0.9482 | . |
| Ammonia | 0.1430 | . |
| Arsenic (As) | 0.4523 | . |
| Cyanide (CN) | 0.2282 | . |
| Cadmium (Cd) | 0.8724 | . |
| Copper (Cu) | 0.7897 | . |
| Iron (Fe) | 0.1062 | . |
| Hardness | 0.8661 | . |
| Mercury (Hg) | 0.2953 | . |
| Molybdenum (Mo) | **0.0257** | . |
| Nickel (Ni) | 0.8171 | . |
| Nitrate | 0.2613 | . |
| Lead (Pb) | 0.5203 | . |
| Radium-226 (Ra) | 0.5946 | . |
| Total Suspended Solids (TSS) | 0.4467 | . |
| Zinc (Zn) | 0.3143 | . |
| pH | **0.0318** | . |

*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**

| Variable | Large Lake Site | | |
|---|---|---|---|
| | Doris North Proportion Censored | Doris South Proportion Censored | Reference B Proportion Censored |
| Aluminum (Al) | 0.00 | 0.05 | 0.00 |
| Alkalinity | 0.00 | 0.00 | 0.00 |
| Ammonia | 0.30 | 0.63 | 0.54 |
| Arsenic (As) | 0.08 | 0.23 | 0.15 |
| Cyanide (CN) | **0.81** | **1.00** | **1.00** |
| Cadmium (Cd) | **0.73** | **0.98** | **0.85** |
| Copper (Cu) | 0.01 | 0.00 | 0.08 |
| Iron (Fe) | 0.03 | 0.09 | 0.38 |
| Hardness | 0.00 | 0.00 | 0.00 |
| Mercury (Hg) | 0.47 | **0.87** | 0.69 |
| Molybdenum (Mo) | 0.07 | 0.33 | **0.77** |
| Nickel (Ni) | 0.00 | 0.23 | 0.38 |
| Nitrate | 0.68 | 0.59 | 0.69 |
| Lead (Pb) | 0.20 | 0.42 | 0.62 |
| Radium-226 (Ra) | **0.92** | **0.88** | **0.88** |
| Total Suspended Solids (TSS) | 0.08 | 0.18 | **1.00** |
| Zinc (Zn) | 0.17 | 0.53 | **0.85** |
| pH | 0.00 | 0.00 | 0.00 |

*Notes:*
*Dataset includes all baseline years up to and including 2009, and 2016.*
*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 | 1996 | 23APR96 | 1 | 0.000420 | 0 |
| 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 |

*(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 | 2 | 0.000025 | 1 |
| 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**

| | Large Lake Site | | |
|---|---|---|---|
| | **Doris North p-value** | **Doris South p-value** | **Reference B p-value** |
| Aluminum (Al) | 0.7413 | 0.7781 | 0.0764 |
| Alkalinity | 0.2138 | 0.1538 | **0.0073** |
| Ammonia | 0.0671 | 0.1201 | **<0.0001** |
| Arsenic (As) | **0.0016** | 0.4748 | **0.0147** |
| Cyanide (CN) | 0.5028 | **<0.0001** | . |
| Cadmium (Cd) | 0.6509 | 0.1728 | **<0.0001** |
| Copper (Cu) | 0.6994 | 0.5891 | 0.4226 |
| Iron (Fe) | 0.4725 | 0.6906 | 0.3387 |
| Hardness | 0.2141 | 0.0520 | **0.0175** |
| Mercury (Hg) | 0.3042 | **<0.0001** | **0.0002** |
| Molybdenum (Mo) | **0.0015** | 0.9791 | 0.5022 |
| Nickel (Ni) | 0.8920 | 0.9730 | 0.2406 |
| Nitrate | 0.1335 | 0.3101 | **<0.0001** |
| Lead (Pb) | 0.4397 | 0.3137 | **0.0330** |
| Radium-226 (Ra) | 0.7398 | . | . |
| Total Suspended Solids (TSS) | 0.7526 | 0.8269 | **<0.0001** |
| Zinc (Zn) | 0.5388 | 0.4308 | **<0.0001** |
| pH | 0.2788 | 0.4062 | 0.8243 |

*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

| Variable | Large Lake Site | |
|---|---|---|
| | Doris North p-value | Doris South p-value |
| Aluminum (Al) | 0.9835 | 0.9632 |
| Alkalinity | 0.7443 | 0.7675 |
| Ammonia | 0.2370 | 0.3381 |
| Arsenic (As) | **0.0209** | 0.5524 |
| Cyanide (CN) | . | . |
| Cadmium (Cd) | 0.8958 | 0.0827 |
| Copper (Cu) | 0.5384 | 0.4302 |
| Iron (Fe) | 0.6107 | 0.8602 |
| Hardness | 0.8143 | 0.9895 |
| Mercury (Hg) | **0.0372** | **0.0439** |
| Molybdenum (Mo) | 0.2657 | 0.9398 |
| Nickel (Ni) | 0.5500 | 0.6079 |
| Nitrate | 0.1856 | 0.0955 |
| Lead (Pb) | 0.2504 | **0.0294** |
| Radium-226 (Ra) | . | . |
| Total Suspended Solids (TSS) | 0.3958 | 0.1827 |
| Zinc (Zn) | 0.8248 | 0.5917 |
| pH | 0.5517 | 0.9945 |

*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 Project, 2016

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# 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 measurements 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.

## 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

Two statistical tests were 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 2016. 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 3.2.2. 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 2016 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 were 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 $\mu_{PA}$ is the mean variable reading in the *Project* class of sites *after* Project initiation, $\mu_{PB}$ is the mean variable reading in the *Project* class of sites *before* Project initiation, $\mu_{RA}$ is the mean variable reading in the *reference* class of sites *after* Project initiation, and $\mu_{RB}$ 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 3.2.2. 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.

# 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 Doris Outflow, Reference B Outflow, and Reference D Outflow). As a consequence, the results of the analyses for these variables are non-informative and should be discarded. 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, % sand, and cadmium in Doris OF; % gravel, % clay, % silt, % TOC, cadmium, chromium, copper, lead, and zinc in Little Roberts Outflow; and cadmium in Reference B Outflow.

The results of the BACI comparison (Table Stream-3) found evidence of a differential change in % sand in Doris Outflow; and % clay, % TOC, arsenic, chromium, 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 % gravel (at RBW and REF-Marine 1) and the results of the analyses for these variables are non-informative and should be discarded. Plots of the data showed no outliers.

BACI and before-after comparisons could not be done for RBE because sediment quality data were not collected pre-construction.

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 %TOC, arsenic, cadmium, copper, mercury, and zinc; and at REF-Marine 1 for % silt, %TOC, and arsenic.

The results of the BACI comparison (Table Marine-3) found evidence of a differential change in cadmium and mercury at RBW compared to the REF-Marine 1 over the before and after periods.

## 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 are non-informative and should be discarded. Plots of the data showed no evidence of outliers.

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

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

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# TABLES

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

| Variable | Stream Site | | | | |
|---|---|---|---|---|---|
| | Doris OF Proportion Censored | Little Roberts OF Proportion Censored | Reference B OF Proportion Censored | Reference D OF Proportion Censored | Roberts OF Proportion Censored |
| % Clay (<4 μm) | 0.33 | 0.00 | 0.17 | 0.00 | 0.00 |
| % Gravel (>2 mm) | 0.00 | 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) | **1.00** | **1.00** | **1.00** | **1.00** | **1.00** |
| 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) | 0.33 | 0.00 | 0.33 | 0.00 | 0.00 |
| Mercury (Hg) | **0.83** | 0.50 | **1.00** | **1.00** | 0.67 |
| 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 2016.*
*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**

| Variable | Stream Site | | | | |
|---|---|---|---|---|---|
| | Doris OF P-value | Little Roberts OF P-value | Reference B OF P-value | Reference D OF P-value | Roberts OF P-value |
| % Clay (<4 μm) | 0.4888 | **<0.0001** | 0.4547 | . | . |
| % Gravel (>2 mm) | **0.0197** | **0.0213** | 0.6267 | . | . |
| % Sand (2.0 mm - 0.063 mm) | **0.0008** | 0.5223 | 0.7212 | . | . |
| % Silt (0.063 mm - 4 μm) | 0.8705 | **0.0004** | 0.6465 | . | . |
| Arsenic (As) | 0.4886 | 0.0522 | 0.1823 | . | . |
| Cadmium (Cd) | **<0.0001** | **<0.0001** | **<0.0001** | . | . |
| Chromium (Cr) | 0.2594 | **0.0030** | 0.4513 | . | . |
| Copper (Cu) | 0.3917 | **0.0175** | 0.3288 | . | . |
| Lead (Pb) | 0.4922 | **0.0009** | 0.5531 | . | . |
| Mercury (Hg) | 0.3739 | . | . | . | . |
| Total Organic Carbon | 0.3597 | **0.0003** | 0.5391 | . | . |
| Zinc (Zn) | 0.3326 | **0.0023** | 0.4812 | . | . |

*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

| Variable | Stream Site | |
|---|---|---|
| | Doris OF p-value | Little Roberts OF p-value |
| % Clay (<4 μm) | 0.8491 | **0.0006** |
| % Gravel (>2 mm) | 0.1404 | 0.3583 |
| % Sand (2.0 mm - 0.063 mm) | **0.0388** | 0.5047 |
| % Silt (0.063 mm - 4 μm) | 0.6888 | 0.0585 |
| Arsenic (As) | 0.2545 | **0.0132** |
| Cadmium (Cd) | 0.7153 | 0.7153 |
| Chromium (Cr) | 0.1632 | **0.0014** |
| Copper (Cu) | 0.2357 | 0.2042 |
| Lead (Pb) | 0.3687 | **0.0025** |
| Mercury (Hg) | 0.3466 | **0.0003** |
| Total Organic Carbon | 0.2535 | **0.0001** |
| Zinc (Zn) | 0.2478 | **0.0002** |

*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 were available for this site.*

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

| Variable | Marine Site | | |
|---|---|---|---|
| | RBE Proportion Censored | RBW Proportion Censored | REF-Marine 1 Proportion Censored |
| % Clay (<4 μm) | 0.00 | 0.00 | 0.00 |
| % Gravel (>2 mm) | 0.33 | **0.76** | **0.70** |
| % 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** | **0.90** | 0.59 |
| Chromium (Cr) | 0.00 | 0.00 | 0.00 |
| Copper (Cu) | 0.00 | 0.00 | 0.00 |
| Lead (Pb) | 0.14 | 0.00 | 0.11 |
| Mercury (Hg) | **0.90** | 0.55 | 0.22 |
| Total Organic Carbon | 0.67 | 0.32 | 0.00 |
| Zinc (Zn) | 0.00 | 0.00 | 0.00 |

*Notes:*
*Dataset includes all baseline years up to and including 2009, and 2016.*
*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

| Variable | Marine Site | | |
|---|---|---|---|
| | RBE p-value | RBW p-value | REF-Marine 1 p-value |
| % Clay (<4 μm) | . | . | 0.4723 |
| % Gravel (>2 mm) | . | . | 0.1705 |
| % Sand (2.0 mm - 0.063 mm) | . | . | 0.0826 |
| % Silt (0.063 mm - 4 μm) | . | . | **0.0324** |
| Arsenic (As) | . | **0.0004** | **0.0215** |
| Cadmium (Cd) | . | **<0.0001** | 0.3947 |
| Chromium (Cr) | . | 0.2133 | 0.3666 |
| Copper (Cu) | . | **0.0027** | 0.4122 |
| Lead (Pb) | . | 0.1622 | 0.4699 |
| Mercury (Hg) | . | **0.0286** | 0.0960 |
| Total Organic Carbon | . | **<0.0001** | **0.0429** |
| Zinc (Zn) | . | 0.9330 | 0.4771 |

*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

| Variable | Marine Site | |
|---|---|---|
| | RBE p-value | RBW p-value |
| % Clay (<4 μm) | . | . |
| % Gravel (>2 mm) | . | . |
| % Sand (2.0 mm - 0.063 mm) | . | . |
| % Silt (0.063 mm - 4 μm) | . | . |
| Arsenic (As) | . | 0.2144 |
| Cadmium (Cd) | . | **0.0001** |
| Chromium (Cr) | . | 0.6271 |
| Copper (Cu) | . | 0.3820 |
| Lead (Pb) | . | 0.6917 |
| Mercury (Hg) | . | **0.0060** |
| Total Organic Carbon | . | 0.1431 |
| Zinc (Zn) | . | 0.5060 |

*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 were available for this site.*

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

| Variable | Lake Site | | | | |
|---|---|---|---|---|---|
| | Doris North Proportion censored | Doris South Proportion censored | Little Roberts Proportion censored | Reference B Proportion censored | Reference D Proportion censored |
| % Clay (<4 μm) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| % Gravel (>2 mm) | **0.83** | **1.00** | **1.00** | 0.67 | **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 | 0.29 | 0.00 | 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) | 0.00 | 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 2016.*
*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**

| Variable | Lake Site | | | | |
|---|---|---|---|---|---|
| | Doris North p-value | Doris South p-value | Little Roberts p-value | Reference B p-value | Reference D p-value |
| % Clay (<4 μm) | 0.0652 | 0.2146 | 0.3456 | . | . |
| % Gravel (>2 mm) | 0.2381 | **<0.0001** | **<0.0001** | . | . |
| % Sand (2.0 mm - 0.063 mm) | 0.2257 | 0.0803 | 0.3750 | . | . |
| % Silt (0.063 mm - 4 μm) | 0.0830 | 0.1079 | 0.4044 | . | . |
| Arsenic (As) | 0.0876 | 0.9149 | 0.0678 | . | . |
| Cadmium (Cd) | **0.0090** | 0.8630 | 0.6848 | . | . |
| Chromium (Cr) | 0.1355 | 0.5345 | 0.0687 | . | . |
| Copper (Cu) | **0.0015** | **<0.0001** | 0.2893 | . | . |
| Lead (Pb) | **0.0019** | **0.0239** | **<0.0001** | . | . |
| Mercury (Hg) | 0.0714 | 0.7981 | 0.7334 | . | . |
| Total Organic Carbon | **0.0188** | **<0.0001** | 0.2126 | . | . |
| Zinc (Zn) | **0.0148** | 0.3681 | **0.0334** | . | . |

*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 Project, 2016

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# 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.

## 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

Two statistical tests were 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 concentration for all years prior to 2010 (before initiation of construction) to the mean for 2016. 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 3.2.2. 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 2016 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:

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

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":

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

where $\mu_{PA}$ is the mean variable reading in the *Project* class of sites *after* Project initiation, $\mu_{PB}$ is the mean variable reading in the *Project* class of sites *before* Project initiation, $\mu_{RA}$ is the mean variable reading in the *reference* class of sites *after* Project initiation, and $\mu_{RB}$ 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 3.2.2. 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. 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 were 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. 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 | | | | |
|---|---|---|---|---|---|---|
| Variable | Proportion Censored | Doris OF p-value | Little Roberts OF p-value | Reference B OF p-value | Reference D OF p-value | Roberts OF p-value |
| logPeriphyton | 0.00 | 0.8030 | . | . | . | . |

*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 | |
|---|---|---|
| Variable | Doris OF p-value | Little Roberts OF p-value |
| logPeriphyton | 0.4043 | 0.1743 |

*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 data were collected pre-construction, so no BACI comparison is possible.*

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

| | Marine Site | | |
|---|---|---|---|
| Variable | RBE Proportion Censored | RBW Proportion Censored | REF-Marine 1 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 | |
|---|---|---|
| Variable | RBE p-value | RBW p-value |
| logPhytoplankton | 0.5330 | 0.9555 |

*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 | | |
|---|---|---|---|---|
| Variable | Proportion Censored | Doris North p-value | Doris South p-value | Reference B p-value |
| logPhytoplankton | 0.00 | 0.7475 | 0.1761 | . |

*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 | |
|---|---|---|
| Variable | Doris North p-value | Doris South p-value |
| logPhytoplankton | 0.7589 | 0.7912 |

*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 | |
|---|---|---|---|
| Variable | Proportion Censored | Little Roberts p-value | Reference D p-value |
| logPhytoplankton | 0.00 | 0.4682 | . |

*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 data were collected 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 Project, 2016

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# 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 3.2.2. 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.

# 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, Simpson's Evenness Index at Doris OF, and in the Bray-Curtis Index at Roberts OF.

Tables Stream-1a to Stream-1o show the statistical modelling coefficients for the level-by-time models. The *Class* term is labelled "SiteClassReference", the *Year* term is labelled "Year", and the site-specific response over time (level-by-time comparisons) are labelled "SiteClassReference:Year".

## 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 all benthos indicators at both RBE and RBW, except for density at site RBE. For the adult-only data, significant non-parallelism was detected for all evaluated indicators at RBE and RBW.

Tables Marine-1a to Marine-1j and Marine-2a to Marine-2j show the statistical modelling coefficients for the level-by-time models. The *Class* term is labelled "SiteClassReference", the *Year* term is labelled "Year", and the site-specific response over time (level-by-time comparisons) are labelled "SiteClassReference:Year".

## 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 except for family richness in Doris Lake North and Simson's Evenness Index in Doris Lake South.

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

Tables Large Lake-1a to Large Lake-1j and Small Lake-1a to Small Lake-1e show the statistical modelling coefficients for the level-by-time models. The *Class* term is labelled "SiteClassReference", the *Year* term is labelled "Year", and the site-specific response over time (level-by-time comparisons) are labelled "SiteClassReference:Year".

# 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

| Variable | Stream Site | | |
|---|---|---|---|
| | Doris OF p-value | Little Roberts OF p-value | Roberts OF p-value |
| Density | 0.2137 | **0.0495** | **0.0008** |
| Diversity | 0.5266 | 0.0797 | 0.9266 |
| Evenness | **0.0006** | 0.0851 | 0.6880 |
| Richness | 0.1403 | 0.2312 | 0.5132 |
| Bray-Curtis | 0.0525 | 0.2422 | **<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 Stream-1a. Statistical Modelling Coefficients for Density at Doris Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 5653.500 | 5481.444 |
| 2 | SiteClassReference | -3829.540 | 6713.370 |
| 3 | Year2011 | 2734.000 | 3774.899 |
| 4 | Year2012 | -1306.260 | 3774.899 |
| 5 | Year2013 | 18535.380 | 3774.899 |
| 6 | Year2014 | 123.583 | 3774.899 |
| 7 | Year2015 | 1602.060 | 3774.899 |
| 8 | Year2016 | 1571.500 | 3774.899 |
| 9 | SiteClassReference:Year2011 | -1087.460 | 4623.289 |
| 10 | SiteClassReference:Year2012 | 3497.930 | 4623.289 |
| 11 | SiteClassReference:Year2013 | -7232.950 | 4623.289 |
| 12 | SiteClassReference:Year2014 | 4027.457 | 4623.289 |
| 13 | SiteClassReference:Year2015 | -515.610 | 4623.289 |
| 14 | SiteClassReference:Year2016 | 3103.151 | 4623.289 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1b. Statistical Modelling Coefficients for Density at Little Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 1245.820 | 5474.048 |
| 2 | SiteClassReference | 578.140 | 6704.312 |
| 3 | Year2011 | 4894.460 | 3749.771 |
| 4 | Year2012 | 2268.060 | 3749.771 |
| 5 | Year2013 | 23796.540 | 3749.771 |
| 6 | Year2014 | 1805.569 | 3749.771 |
| 7 | Year2015 | 5860.460 | 3749.771 |
| 8 | Year2016 | 7301.402 | 3749.771 |
| 9 | SiteClassReference:Year2011 | -3247.920 | 4592.513 |
| 10 | SiteClassReference:Year2012 | -76.390 | 4592.513 |
| 11 | SiteClassReference:Year2013 | -12494.110 | 4592.513 |
| 12 | SiteClassReference:Year2014 | 2345.471 | 4592.513 |
| 13 | SiteClassReference:Year2015 | -4774.010 | 4592.513 |
| 14 | SiteClassReference:Year2016 | -2626.751 | 4592.513 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1c. Statistical Modelling Coefficients for Density at Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 4583.3200 | 5385.650 |
| 2 | SiteClassReference | -2759.3600 | 6596.047 |
| 3 | Year2011 | 2497.2400 | 3438.095 |
| 4 | Year2012 | -843.0200 | 3438.095 |
| 5 | Year2013 | 1505.5600 | 3438.095 |
| 6 | Year2014 | -224.2922 | 3438.095 |
| 7 | Year2015 | 11218.0800 | 3438.095 |
| 8 | Year2016 | 1470.8467 | 3438.095 |
| 9 | SiteClassReference:Year2011 | -850.7000 | 4210.789 |
| 10 | SiteClassReference:Year2012 | 3034.6900 | 4210.789 |
| 11 | SiteClassReference:Year2013 | 9796.8700 | 4210.789 |
| 12 | SiteClassReference:Year2014 | 4375.3322 | 4210.789 |
| 13 | SiteClassReference:Year2015 | -10131.6300 | 4210.789 |
| 14 | SiteClassReference:Year2016 | 3203.8044 | 4210.789 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1d. Statistical Modelling Coefficients for Diversity at Doris Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.7792 | 0.0600 |
| 2 | SiteClassReference | -0.0880 | 0.0735 |
| 3 | Year2011 | 0.0319 | 0.0803 |
| 4 | Year2012 | -0.0295 | 0.0803 |
| 5 | Year2013 | -0.0462 | 0.0803 |
| 6 | Year2014 | 0.0172 | 0.0803 |
| 7 | Year2015 | -0.0840 | 0.0803 |
| 8 | Year2016 | -0.1243 | 0.0803 |
| 9 | SiteClassReference:Year2011 | -0.1876 | 0.0984 |
| 10 | SiteClassReference:Year2012 | -0.0615 | 0.0984 |
| 11 | SiteClassReference:Year2013 | -0.0975 | 0.0984 |
| 12 | SiteClassReference:Year2014 | -0.0711 | 0.0984 |
| 13 | SiteClassReference:Year2015 | -0.0138 | 0.0984 |
| 14 | SiteClassReference:Year2016 | -0.0201 | 0.0984 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1e. Statistical Modelling Coefficients for Diversity at Little Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.6805 | 0.0627 |
| 2 | SiteClassReference | 0.0108 | 0.0768 |
| 3 | Year2011 | -0.1834 | 0.0851 |
| 4 | Year2012 | -0.0779 | 0.0851 |
| 5 | Year2013 | -0.2564 | 0.0851 |
| 6 | Year2014 | -0.0976 | 0.0851 |
| 7 | Year2015 | -0.1590 | 0.0851 |
| 8 | Year2016 | -0.4330 | 0.0851 |
| 9 | SiteClassReference:Year2011 | 0.0278 | 0.1042 |
| 10 | SiteClassReference:Year2012 | -0.0131 | 0.1042 |
| 11 | SiteClassReference:Year2013 | 0.1127 | 0.1042 |
| 12 | SiteClassReference:Year2014 | 0.0437 | 0.1042 |
| 13 | SiteClassReference:Year2015 | 0.0612 | 0.1042 |
| 14 | SiteClassReference:Year2016 | 0.2886 | 0.1042 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1f. Statistical Modelling Coefficients for Diversity at Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.6392 | 0.0631 |
| 2 | SiteClassReference | 0.0521 | 0.0773 |
| 3 | Year2011 | -0.0674 | 0.0858 |
| 4 | Year2012 | 0.0061 | 0.0858 |
| 5 | Year2013 | -0.0575 | 0.0858 |
| 6 | Year2014 | -0.0111 | 0.0858 |
| 7 | Year2015 | -0.0804 | 0.0858 |
| 8 | Year2016 | -0.0401 | 0.0858 |
| 9 | SiteClassReference:Year2011 | -0.0882 | 0.1051 |
| 10 | SiteClassReference:Year2012 | -0.0971 | 0.1051 |
| 11 | SiteClassReference:Year2013 | -0.0862 | 0.1051 |
| 12 | SiteClassReference:Year2014 | -0.0428 | 0.1051 |
| 13 | SiteClassReference:Year2015 | -0.0174 | 0.1051 |
| 14 | SiteClassReference:Year2016 | -0.1043 | 0.1051 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1g. Statistical Modelling Coefficients for Evenness at Doris Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3973 | 0.0410 |
| 2 | SiteClassReference | -0.0985 | 0.0502 |
| 3 | Year2011 | 0.2011 | 0.0580 |
| 4 | Year2012 | 0.0654 | 0.0580 |
| 5 | Year2013 | -0.0344 | 0.0580 |
| 6 | Year2014 | 0.0923 | 0.0580 |
| 7 | Year2015 | -0.0592 | 0.0580 |
| 8 | Year2016 | -0.0709 | 0.0580 |
| 9 | SiteClassReference:Year2011 | -0.2945 | 0.0710 |
| 10 | SiteClassReference:Year2012 | -0.1179 | 0.0710 |
| 11 | SiteClassReference:Year2013 | -0.0420 | 0.0710 |
| 12 | SiteClassReference:Year2014 | -0.1496 | 0.0710 |
| 13 | SiteClassReference:Year2015 | -0.0366 | 0.0710 |
| 14 | SiteClassReference:Year2016 | -0.0072 | 0.0710 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1h. Statistical Modelling Coefficients for Evenness at Little Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3405 | 0.0346 |
| 2 | SiteClassReference | -0.0418 | 0.0424 |
| 3 | Year2011 | -0.1318 | 0.0489 |
| 4 | Year2012 | -0.0070 | 0.0489 |
| 5 | Year2013 | -0.1329 | 0.0489 |
| 6 | Year2014 | -0.1178 | 0.0489 |
| 7 | Year2015 | -0.1341 | 0.0489 |
| 8 | Year2016 | -0.2237 | 0.0489 |
| 9 | SiteClassReference:Year2011 | 0.0385 | 0.0599 |
| 10 | SiteClassReference:Year2012 | -0.0455 | 0.0599 |
| 11 | SiteClassReference:Year2013 | 0.0565 | 0.0599 |
| 12 | SiteClassReference:Year2014 | 0.0605 | 0.0599 |
| 13 | SiteClassReference:Year2015 | 0.0383 | 0.0599 |
| 14 | SiteClassReference:Year2016 | 0.1457 | 0.0599 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1i. Statistical Modelling Coefficients for Evenness at Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3001 | 0.0373 |
| 2 | SiteClassReference | -0.0014 | 0.0457 |
| 3 | Year2011 | -0.0348 | 0.0527 |
| 4 | Year2012 | 0.0508 | 0.0527 |
| 5 | Year2013 | -0.0428 | 0.0527 |
| 6 | Year2014 | -0.0477 | 0.0527 |
| 7 | Year2015 | -0.0915 | 0.0527 |
| 8 | Year2016 | -0.0556 | 0.0527 |
| 9 | SiteClassReference:Year2011 | -0.0586 | 0.0646 |
| 10 | SiteClassReference:Year2012 | -0.1033 | 0.0646 |
| 11 | SiteClassReference:Year2013 | -0.0335 | 0.0646 |
| 12 | SiteClassReference:Year2014 | -0.0095 | 0.0646 |
| 13 | SiteClassReference:Year2015 | -0.0043 | 0.0646 |
| 14 | SiteClassReference:Year2016 | -0.0225 | 0.0646 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1j. Statistical Modelling Coefficients for Richness at Doris Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 11.8 | 1.3502 |
| 2 | SiteClassReference | 0.3 | 1.6536 |
| 3 | Year2011 | -2.6 | 1.2150 |
| 4 | Year2012 | -2.0 | 1.2150 |
| 5 | Year2013 | -0.8 | 1.2150 |
| 6 | Year2014 | -1.6 | 1.2150 |
| 7 | Year2015 | -1.2 | 1.2150 |
| 8 | Year2016 | -2.0 | 1.2150 |
| 9 | SiteClassReference:Year2011 | 1.6 | 1.4880 |
| 10 | SiteClassReference:Year2012 | 1.5 | 1.4880 |
| 11 | SiteClassReference:Year2013 | -0.4 | 1.4880 |
| 12 | SiteClassReference:Year2014 | 2.2 | 1.4880 |
| 13 | SiteClassReference:Year2015 | 3.6 | 1.4880 |
| 14 | SiteClassReference:Year2016 | 2.0 | 1.4880 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1k. Statistical Modelling Coefficients for Richness at Little Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 10.2 | 1.3462 |
| 2 | SiteClassReference | 1.9 | 1.6488 |
| 3 | Year2011 | -0.4 | 1.2047 |
| 4 | Year2012 | -2.2 | 1.2047 |
| 5 | Year2013 | -1.4 | 1.2047 |
| 6 | Year2014 | 1.4 | 1.2047 |
| 7 | Year2015 | 0.6 | 1.2047 |
| 8 | Year2016 | 1.4 | 1.2047 |
| 9 | SiteClassReference:Year2011 | -0.6 | 1.4754 |
| 10 | SiteClassReference:Year2012 | 1.7 | 1.4754 |
| 11 | SiteClassReference:Year2013 | 0.2 | 1.4754 |
| 12 | SiteClassReference:Year2014 | -0.8 | 1.4754 |
| 13 | SiteClassReference:Year2015 | 1.8 | 1.4754 |
| 14 | SiteClassReference:Year2016 | -1.4 | 1.4754 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1l. Statistical Modelling Coefficients for Richness at Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 10.4 | 1.3586 |
| 2 | SiteClassReference | 1.7 | 1.6639 |
| 3 | Year2011 | -0.8 | 1.2367 |
| 4 | Year2012 | -2.0 | 1.2367 |
| 5 | Year2013 | -0.6 | 1.2367 |
| 6 | Year2014 | 1.8 | 1.2367 |
| 7 | Year2015 | 1.4 | 1.2367 |
| 8 | Year2016 | 1.0 | 1.2367 |
| 9 | SiteClassReference:Year2011 | -0.2 | 1.5147 |
| 10 | SiteClassReference:Year2012 | 1.5 | 1.5147 |
| 11 | SiteClassReference:Year2013 | -0.6 | 1.5147 |
| 12 | SiteClassReference:Year2014 | -1.2 | 1.5147 |
| 13 | SiteClassReference:Year2015 | 1.0 | 1.5147 |
| 14 | SiteClassReference:Year2016 | -1.0 | 1.5147 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1m. Statistical Modelling Coefficients for the Bray-Curtis Index at Doris Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.6460 | 0.0752 |
| 2 | SiteClassReference | -0.3208 | 0.0921 |
| 3 | Year2011 | -0.0315 | 0.1063 |
| 4 | Year2012 | -0.0954 | 0.1063 |
| 5 | Year2013 | -0.0213 | 0.1063 |
| 6 | Year2014 | -0.1108 | 0.1063 |
| 7 | Year2015 | -0.1368 | 0.1063 |
| 8 | Year2016 | -0.0641 | 0.1063 |
| 9 | SiteClassReference:Year2011 | 0.0054 | 0.1302 |
| 10 | SiteClassReference:Year2012 | 0.1606 | 0.1302 |
| 11 | SiteClassReference:Year2013 | 0.2875 | 0.1302 |
| 12 | SiteClassReference:Year2014 | 0.3364 | 0.1302 |
| 13 | SiteClassReference:Year2015 | 0.1188 | 0.1302 |
| 14 | SiteClassReference:Year2016 | 0.2727 | 0.1302 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1n. Statistical Modelling Coefficients for the Bray-Curtis Index at Little Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.4758 | 0.0773 |
| 2 | SiteClassReference | -0.1505 | 0.0947 |
| 3 | Year2011 | -0.1050 | 0.1093 |
| 4 | Year2012 | -0.1232 | 0.1093 |
| 5 | Year2013 | 0.1033 | 0.1093 |
| 6 | Year2014 | -0.0450 | 0.1093 |
| 7 | Year2015 | -0.0236 | 0.1093 |
| 8 | Year2016 | 0.2207 | 0.1093 |
| 9 | SiteClassReference:Year2011 | 0.0790 | 0.1339 |
| 10 | SiteClassReference:Year2012 | 0.1883 | 0.1339 |
| 11 | SiteClassReference:Year2013 | 0.1629 | 0.1339 |
| 12 | SiteClassReference:Year2014 | 0.2705 | 0.1339 |
| 13 | SiteClassReference:Year2015 | 0.0056 | 0.1339 |
| 14 | SiteClassReference:Year2016 | -0.0121 | 0.1339 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Stream-1o. Statistical Modelling Coefficients for the Bray-Curtis Index at Roberts Outflow

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.5782 | 0.0728 |
| 2 | SiteClassReference | -0.2530 | 0.0892 |
| 3 | Year2011 | -0.0929 | 0.1030 |
| 4 | Year2012 | -0.1668 | 0.1030 |
| 5 | Year2013 | -0.2865 | 0.1030 |
| 6 | Year2014 | -0.1336 | 0.1030 |
| 7 | Year2015 | 0.1283 | 0.1030 |
| 8 | Year2016 | 0.0147 | 0.1030 |
| 9 | SiteClassReference:Year2011 | 0.0668 | 0.1261 |
| 10 | SiteClassReference:Year2012 | 0.2319 | 0.1261 |
| 11 | SiteClassReference:Year2013 | 0.5528 | 0.1261 |
| 12 | SiteClassReference:Year2014 | 0.3592 | 0.1261 |
| 13 | SiteClassReference:Year2015 | -0.1463 | 0.1261 |
| 14 | SiteClassReference:Year2016 | 0.1939 | 0.1261 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

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

| Variable | Marine Site | |
|---|---|---|
| | RBE p-value | RBW p-value |
| Density | 0.6325 | **<0.0001** |
| Diversity | **0.0026** | **0.0459** |
| Evenness | **0.0159** | **<0.0001** |
| Richness | **<0.0001** | **<0.0001** |
| Bray-Curtis | **<0.0001** | **0.0003** |

*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-1a. Statistical Modelling Coefficients for Density at RBE (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 880.500 | 1176.344 |
| 2 | SiteClassReference | 5094.340 | 1663.601 |
| 3 | Year2011 | -637.040 | 1663.601 |
| 4 | Year2012 | -851.460 | 1663.601 |
| 5 | Year2013 | -805.140 | 1663.601 |
| 6 | Year2014 | 597.761 | 1663.601 |
| 7 | Year2015 | 3258.630 | 1663.601 |
| 8 | Year2016 | -857.311 | 1663.601 |
| 9 | SiteClassReference:Year2011 | 1062.200 | 2352.688 |
| 10 | SiteClassReference:Year2012 | 2562.540 | 2352.688 |
| 11 | SiteClassReference:Year2013 | 2763.640 | 2352.688 |
| 12 | SiteClassReference:Year2014 | 2389.718 | 2352.688 |
| 13 | SiteClassReference:Year2015 | 4427.399 | 2352.688 |
| 14 | SiteClassReference:Year2016 | 1491.167 | 2352.688 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-1b. Statistical Modelling Coefficients for Density at RBW (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 29842.76 | 1597.226 |
| 2 | SiteClassReference | -23867.92 | 2258.819 |
| 3 | Year2011 | -19373.22 | 2258.819 |
| 4 | Year2012 | -20659.76 | 2258.819 |
| 5 | Year2013 | -19051.46 | 2258.819 |
| 6 | Year2014 | -22399.28 | 2258.819 |
| 7 | Year2015 | -18607.98 | 2258.819 |
| 8 | Year2016 | -18758.70 | 2258.819 |
| 9 | SiteClassReference:Year2011 | 19798.38 | 3194.452 |
| 10 | SiteClassReference:Year2012 | 22370.84 | 3194.452 |
| 11 | SiteClassReference:Year2013 | 21009.96 | 3194.452 |
| 12 | SiteClassReference:Year2014 | 25386.76 | 3194.452 |
| 13 | SiteClassReference:Year2015 | 26294.01 | 3194.452 |
| 14 | SiteClassReference:Year2016 | 19392.56 | 3194.452 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-1c. Statistical Modelling Coefficients for Diversity at RBE (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.2134 | 0.0823 |
| 2 | SiteClassReference | 0.1752 | 0.1163 |
| 3 | Year2011 | 0.4279 | 0.1163 |
| 4 | Year2012 | 0.1573 | 0.1343 |
| 5 | Year2013 | -0.0149 | 0.1163 |
| 6 | Year2014 | -0.0749 | 0.1234 |
| 7 | Year2015 | 0.1205 | 0.1163 |
| 8 | Year2016 | -0.0801 | 0.1163 |
| 9 | SiteClassReference:Year2011 | -0.0219 | 0.1645 |
| 10 | SiteClassReference:Year2012 | 0.1669 | 0.1777 |
| 11 | SiteClassReference:Year2013 | 0.5119 | 0.1645 |
| 12 | SiteClassReference:Year2014 | 0.5088 | 0.1696 |
| 13 | SiteClassReference:Year2015 | 0.3420 | 0.1645 |
| 14 | SiteClassReference:Year2016 | 0.4670 | 0.1645 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-1d. Statistical Modelling Coefficients for Diversity at RBW (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3545 | 0.0395 |
| 2 | SiteClassReference | 0.0341 | 0.0558 |
| 3 | Year2011 | 0.3157 | 0.0558 |
| 4 | Year2012 | 0.4845 | 0.0558 |
| 5 | Year2013 | 0.4634 | 0.0558 |
| 6 | Year2014 | 0.3885 | 0.0558 |
| 7 | Year2015 | 0.4166 | 0.0558 |
| 8 | Year2016 | 0.3044 | 0.0558 |
| 9 | SiteClassReference:Year2011 | 0.0902 | 0.0789 |
| 10 | SiteClassReference:Year2012 | -0.1603 | 0.0789 |
| 11 | SiteClassReference:Year2013 | 0.0337 | 0.0789 |
| 12 | SiteClassReference:Year2014 | 0.0454 | 0.0789 |
| 13 | SiteClassReference:Year2015 | 0.0459 | 0.0789 |
| 14 | SiteClassReference:Year2016 | 0.0825 | 0.0789 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-1e. Statistical Modelling Coefficients for Evenness at RBE (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.7199 | 0.0809 |
| 2 | SiteClassReference | -0.3797 | 0.1145 |
| 3 | Year2011 | -0.0934 | 0.1145 |
| 4 | Year2012 | 0.2333 | 0.1322 |
| 5 | Year2013 | 0.1462 | 0.1145 |
| 6 | Year2014 | -0.1371 | 0.1214 |
| 7 | Year2015 | -0.1637 | 0.1145 |
| 8 | Year2016 | 0.2801 | 0.1145 |
| 9 | SiteClassReference:Year2011 | 0.0912 | 0.1619 |
| 10 | SiteClassReference:Year2012 | -0.3988 | 0.1749 |
| 11 | SiteClassReference:Year2013 | -0.1070 | 0.1619 |
| 12 | SiteClassReference:Year2014 | 0.0543 | 0.1669 |
| 13 | SiteClassReference:Year2015 | 0.0596 | 0.1619 |
| 14 | SiteClassReference:Year2016 | -0.3636 | 0.1619 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-1f. Statistical Modelling Coefficients for Evenness at RBW (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.1260 | 0.0263 |
| 2 | SiteClassReference | 0.2142 | 0.0372 |
| 3 | Year2011 | 0.0834 | 0.0372 |
| 4 | Year2012 | 0.1657 | 0.0372 |
| 5 | Year2013 | 0.0801 | 0.0372 |
| 6 | Year2014 | 0.1461 | 0.0372 |
| 7 | Year2015 | 0.1127 | 0.0372 |
| 8 | Year2016 | 0.0175 | 0.0372 |
| 9 | SiteClassReference:Year2011 | -0.0855 | 0.0526 |
| 10 | SiteClassReference:Year2012 | -0.3312 | 0.0526 |
| 11 | SiteClassReference:Year2013 | -0.0409 | 0.0526 |
| 12 | SiteClassReference:Year2014 | -0.2288 | 0.0526 |
| 13 | SiteClassReference:Year2015 | -0.2169 | 0.0526 |
| 14 | SiteClassReference:Year2016 | -0.1010 | 0.0526 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-1g. Statistical Modelling Coefficients for Richness at RBE (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 2.0 | 1.0488 |
| 2 | SiteClassReference | 3.2 | 1.4832 |
| 3 | Year2011 | 3.2 | 1.4832 |
| 4 | Year2012 | -0.8 | 1.4832 |
| 5 | Year2013 | -0.2 | 1.4832 |
| 6 | Year2014 | 0.4 | 1.4832 |
| 7 | Year2015 | 3.8 | 1.4832 |
| 8 | Year2016 | -0.6 | 1.4832 |
| 9 | SiteClassReference:Year2011 | 6.6 | 2.0976 |
| 10 | SiteClassReference:Year2012 | 16.0 | 2.0976 |
| 11 | SiteClassReference:Year2013 | 18.6 | 2.0976 |
| 12 | SiteClassReference:Year2014 | 17.4 | 2.0976 |
| 13 | SiteClassReference:Year2015 | 20.0 | 2.0976 |
| 14 | SiteClassReference:Year2016 | 16.8 | 2.0976 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-1h. Statistical Modelling Coefficients for Richness at RBW (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 12.6 | 1.2683 |
| 2 | SiteClassReference | -7.4 | 1.7936 |
| 3 | Year2011 | 2.2 | 1.7936 |
| 4 | Year2012 | 9.0 | 1.7936 |
| 5 | Year2013 | 14.6 | 1.7936 |
| 6 | Year2014 | 7.0 | 1.7936 |
| 7 | Year2015 | 8.4 | 1.7936 |
| 8 | Year2016 | 8.2 | 1.7936 |
| 9 | SiteClassReference:Year2011 | 7.6 | 2.5366 |
| 10 | SiteClassReference:Year2012 | 6.2 | 2.5366 |
| 11 | SiteClassReference:Year2013 | 3.8 | 2.5366 |
| 12 | SiteClassReference:Year2014 | 10.8 | 2.5366 |
| 13 | SiteClassReference:Year2015 | 15.4 | 2.5366 |
| 14 | SiteClassReference:Year2016 | 8.0 | 2.5366 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-1i. Statistical Modelling Coefficients for the Bray-Curtis Index at RBE (Adults and Juveniles Pooled)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.7955 | 0.0309 |
| 2 | SiteClassReference | -0.5138 | 0.0437 |
| 3 | Year2011 | 0.1769 | 0.0437 |
| 4 | Year2012 | 0.1999 | 0.0437 |
| 5 | Year2013 | 0.2007 | 0.0437 |
| 6 | Year2014 | 0.1855 | 0.0437 |
| 7 | Year2015 | 0.1479 | 0.0437 |
| 8 | Year2016 | 0.1970 | 0.0437 |
| 9 | SiteClassReference:Year2011 | -0.3219 | 0.0617 |
| 10 | SiteClassReference:Year2012 | -0.3615 | 0.0617 |
| 11 | SiteClassReference:Year2013 | -0.1915 | 0.0617 |
| 12 | SiteClassReference:Year2014 | -0.2070 | 0.0617 |
| 13 | SiteClassReference:Year2015 | -0.1244 | 0.0617 |
| 14 | SiteClassReference:Year2016 | -0.1209 | 0.0617 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

**Table Marine-1j. Statistical Modelling Coefficients for the Bray-Curtis Index at RBW (Adults and Juveniles Pooled)**

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.9469 | 0.0361 |
| 2 | SiteClassReference | -0.6651 | 0.0510 |
| 3 | Year2011 | -0.2056 | 0.0510 |
| 4 | Year2012 | -0.3609 | 0.0510 |
| 5 | Year2013 | -0.2753 | 0.0510 |
| 6 | Year2014 | -0.2735 | 0.0510 |
| 7 | Year2015 | -0.2708 | 0.0510 |
| 8 | Year2016 | -0.1794 | 0.0510 |
| 9 | SiteClassReference:Year2011 | 0.0606 | 0.0721 |
| 10 | SiteClassReference:Year2012 | 0.1994 | 0.0721 |
| 11 | SiteClassReference:Year2013 | 0.2845 | 0.0721 |
| 12 | SiteClassReference:Year2014 | 0.2519 | 0.0721 |
| 13 | SiteClassReference:Year2015 | 0.2943 | 0.0721 |
| 14 | SiteClassReference:Year2016 | 0.2555 | 0.0721 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

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

| Variable | Marine Site | |
|---|---|---|
| | RBE p-value | RBW p-value |
| Density | **0.0001** | **<0.0001** |
| Diversity | **0.0032** | **0.0002** |
| Evenness | **0.0027** | **<0.0001** |
| Richness | **<0.0001** | **<0.0001** |
| Bray-Curtis | **<0.0001** | **0.0014** |

*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-2a. Statistical Modelling Coefficients for Density at RBE (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 282.9800 | 743.8383 |
| 2 | SiteClassReference | 1116.4000 | 1051.9463 |
| 3 | Year2011 | -56.9200 | 1051.9463 |
| 4 | Year2012 | -268.4800 | 1051.9463 |
| 5 | Year2013 | -236.5800 | 1051.9463 |
| 6 | Year2014 | 119.9186 | 1051.9463 |
| 7 | Year2015 | 1586.5852 | 1051.9463 |
| 8 | Year2016 | -259.7914 | 1051.9463 |
| 9 | SiteClassReference:Year2011 | 4463.3400 | 1487.6767 |
| 10 | SiteClassReference:Year2012 | 6334.1000 | 1487.6767 |
| 11 | SiteClassReference:Year2013 | 5706.7600 | 1487.6767 |
| 12 | SiteClassReference:Year2014 | 6950.2667 | 1487.6767 |
| 13 | SiteClassReference:Year2015 | 8254.6145 | 1487.6767 |
| 14 | SiteClassReference:Year2016 | 5129.9650 | 1487.6767 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-2b. Statistical Modelling Coefficients for Density at RBW (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 25015.72 | 1265.601 |
| 2 | SiteClassReference | -23616.34 | 1789.831 |
| 3 | Year2011 | -15682.40 | 1789.831 |
| 4 | Year2012 | -17084.90 | 1789.831 |
| 5 | Year2013 | -14862.12 | 1789.831 |
| 6 | Year2014 | -19476.59 | 1789.831 |
| 7 | Year2015 | -15528.76 | 1789.831 |
| 8 | Year2016 | -15276.66 | 1789.831 |
| 9 | SiteClassReference:Year2011 | 20088.82 | 2531.203 |
| 10 | SiteClassReference:Year2012 | 23150.52 | 2531.203 |
| 11 | SiteClassReference:Year2013 | 20332.30 | 2531.203 |
| 12 | SiteClassReference:Year2014 | 26546.78 | 2531.203 |
| 13 | SiteClassReference:Year2015 | 25369.96 | 2531.203 |
| 14 | SiteClassReference:Year2016 | 20146.84 | 2531.203 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-2c. Statistical Modelling Coefficients for Diversity at RBE (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.2712 | 0.0780 |
| 2 | SiteClassReference | 0.3179 | 0.1103 |
| 3 | Year2011 | 0.3948 | 0.1103 |
| 4 | Year2012 | -0.1231 | 0.1273 |
| 5 | Year2013 | -0.1516 | 0.1103 |
| 6 | Year2014 | -0.1232 | 0.1273 |
| 7 | Year2015 | 0.0970 | 0.1103 |
| 8 | Year2016 | -0.1379 | 0.1103 |
| 9 | SiteClassReference:Year2011 | -0.1944 | 0.1559 |
| 10 | SiteClassReference:Year2012 | 0.2353 | 0.1684 |
| 11 | SiteClassReference:Year2013 | 0.4315 | 0.1559 |
| 12 | SiteClassReference:Year2014 | 0.3460 | 0.1684 |
| 13 | SiteClassReference:Year2015 | 0.1501 | 0.1559 |
| 14 | SiteClassReference:Year2016 | 0.3141 | 0.1559 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-2d. Statistical Modelling Coefficients for Diversity at RBW (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3405 | 0.0370 |
| 2 | SiteClassReference | 0.2486 | 0.0523 |
| 3 | Year2011 | 0.2845 | 0.0523 |
| 4 | Year2012 | 0.4865 | 0.0523 |
| 5 | Year2013 | 0.4734 | 0.0523 |
| 6 | Year2014 | 0.4228 | 0.0523 |
| 7 | Year2015 | 0.4044 | 0.0523 |
| 8 | Year2016 | 0.2395 | 0.0523 |
| 9 | SiteClassReference:Year2011 | -0.0842 | 0.0740 |
| 10 | SiteClassReference:Year2012 | -0.3742 | 0.0740 |
| 11 | SiteClassReference:Year2013 | -0.1935 | 0.0740 |
| 12 | SiteClassReference:Year2014 | -0.2001 | 0.0740 |
| 13 | SiteClassReference:Year2015 | -0.1573 | 0.0740 |
| 14 | SiteClassReference:Year2016 | -0.0633 | 0.0740 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-2e. Statistical Modelling Coefficients for Evenness at RBE (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.9124 | 0.0713 |
| 2 | SiteClassReference | -0.2892 | 0.1008 |
| 3 | Year2011 | -0.2490 | 0.1008 |
| 4 | Year2012 | 0.0542 | 0.1164 |
| 5 | Year2013 | -0.0269 | 0.1008 |
| 6 | Year2014 | -0.3269 | 0.1164 |
| 7 | Year2015 | -0.3139 | 0.1008 |
| 8 | Year2016 | 0.0876 | 0.1008 |
| 9 | SiteClassReference:Year2011 | -0.0363 | 0.1425 |
| 10 | SiteClassReference:Year2012 | -0.5015 | 0.1540 |
| 11 | SiteClassReference:Year2013 | -0.2550 | 0.1425 |
| 12 | SiteClassReference:Year2014 | -0.0479 | 0.1540 |
| 13 | SiteClassReference:Year2015 | -0.0817 | 0.1425 |
| 14 | SiteClassReference:Year2016 | -0.4622 | 0.1425 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-2f. Statistical Modelling Coefficients for Evenness at RBW (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.1265 | 0.0297 |
| 2 | SiteClassReference | 0.4968 | 0.0420 |
| 3 | Year2011 | 0.0604 | 0.0420 |
| 4 | Year2012 | 0.1638 | 0.0420 |
| 5 | Year2013 | 0.0788 | 0.0420 |
| 6 | Year2014 | 0.1693 | 0.0420 |
| 7 | Year2015 | 0.0965 | 0.0420 |
| 8 | Year2016 | -0.0058 | 0.0420 |
| 9 | SiteClassReference:Year2011 | -0.3457 | 0.0594 |
| 10 | SiteClassReference:Year2012 | -0.6110 | 0.0594 |
| 11 | SiteClassReference:Year2013 | -0.3608 | 0.0594 |
| 12 | SiteClassReference:Year2014 | -0.5442 | 0.0594 |
| 13 | SiteClassReference:Year2015 | -0.4921 | 0.0594 |
| 14 | SiteClassReference:Year2016 | -0.3688 | 0.0594 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-2g. Statistical Modelling Coefficients for Richness at RBE (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 1.8 | 0.9993 |
| 2 | SiteClassReference | 2.6 | 1.4132 |
| 3 | Year2011 | 3.4 | 1.4132 |
| 4 | Year2012 | -1.0 | 1.4132 |
| 5 | Year2013 | -0.4 | 1.4132 |
| 6 | Year2014 | -0.2 | 1.4132 |
| 7 | Year2015 | 3.4 | 1.4132 |
| 8 | Year2016 | -0.4 | 1.4132 |
| 9 | SiteREF-Marine:Year 2011 | 6.8 | 1.9986 |
| 10 | SiteREF-Marine:Year 2012 | 16.2 | 1.9986 |
| 11 | SiteREF-Marine:Year 2013 | 19.0 | 1.9986 |
| 12 | SiteREF-Marine:Year 2014 | 18.0 | 1.9986 |
| 13 | SiteREF-Marine:Year 2015 | 19.6 | 1.9986 |
| 14 | SiteREF-Marine:Year 2016 | 17.4 | 1.9986 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-2h. Statistical Modelling Coefficients for Richness at RBW (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 12.2 | 1.2346 |
| 2 | SiteClassReference | -7.8 | 1.7460 |
| 3 | Year2011 | 2.4 | 1.7460 |
| 4 | Year2012 | 8.0 | 1.7460 |
| 5 | Year2013 | 14.6 | 1.7460 |
| 6 | Year2014 | 6.2 | 1.7460 |
| 7 | Year2015 | 8.2 | 1.7460 |
| 8 | Year2016 | 7.8 | 1.7460 |
| 9 | SiteClassReference:Year 2011 | 7.8 | 2.4692 |
| 10 | SiteClassReference:Year 2012 | 7.2 | 2.4692 |
| 11 | SiteClassReference:Year 2013 | 4.0 | 2.4692 |
| 12 | SiteClassReference:Year 2014 | 11.6 | 2.4692 |
| 13 | SiteClassReference:Year 2015 | 14.8 | 2.4692 |
| 14 | SiteClassReference:Year 2016 | 9.2 | 2.4692 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Marine-2i. Statistical Modelling Coefficients for the Bray-Curtis Index at RBE (Adults Only)

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.7267 | 0.0388 |
| 2 | SiteClassReference | -0.3665 | 0.0549 |
| 3 | Year2011 | 0.2503 | 0.0549 |
| 4 | Year2012 | 0.2695 | 0.0549 |
| 5 | Year2013 | 0.2681 | 0.0549 |
| 6 | Year2014 | 0.2559 | 0.0549 |
| 7 | Year2015 | 0.2260 | 0.0549 |
| 8 | Year2016 | 0.2652 | 0.0549 |
| 9 | SiteClassReference:Year 2011 | -0.4721 | 0.0776 |
| 10 | SiteClassReference:Year 2012 | -0.5055 | 0.0776 |
| 11 | SiteClassReference:Year 2013 | -0.3658 | 0.0776 |
| 12 | SiteClassReference:Year 2014 | -0.3535 | 0.0776 |
| 13 | SiteClassReference:Year 2015 | -0.2716 | 0.0776 |
| 14 | SiteClassReference:Year 2016 | -0.2579 | 0.0776 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

**Table Marine-2j. Statistical Modelling Coefficients for the Bray-Curtis Index at RBW (Adults Only)**

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.9755 | 0.0365 |
| 2 | SiteClassReference | -0.6153 | 0.0516 |
| 3 | Year2011 | -0.2400 | 0.0516 |
| 4 | Year2012 | -0.4116 | 0.0516 |
| 5 | Year2013 | -0.3120 | 0.0516 |
| 6 | Year2014 | -0.3187 | 0.0516 |
| 7 | Year2015 | -0.3229 | 0.0516 |
| 8 | Year2016 | -0.1860 | 0.0516 |
| 9 | SiteClassReference:Year 2011 | 0.0182 | 0.0729 |
| 10 | SiteClassReference:Year 2012 | 0.1755 | 0.0729 |
| 11 | SiteClassReference:Year 2013 | 0.2143 | 0.0729 |
| 12 | SiteClassReference:Year 2014 | 0.2211 | 0.0729 |
| 13 | SiteClassReference:Year 2015 | 0.2773 | 0.0729 |
| 14 | SiteClassReference:Year 2016 | 0.1934 | 0.0729 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

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

| Variable | Large Lake Site | |
|---|---|---|
| | Doris North p-value | Doris South p-value |
| Density | **<0.0001** | **<0.0001** |
| Diversity | **0.0003** | **0.0176** |
| Evenness | **0.0320** | 0.0615 |
| Richness | 0.0708 | **0.0037** |
| Bray-Curtis | **<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-1a. Statistical Modelling Coefficients for Density at Doris North

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 2082.980 | 389.2247 |
| 2 | SiteClassReference | 965.900 | 550.4469 |
| 3 | Year2011 | 1143.680 | 550.4469 |
| 4 | Year2012 | -53.340 | 550.4469 |
| 5 | Year2013 | 1108.120 | 550.4469 |
| 6 | Year2014 | 2269.613 | 550.4469 |
| 7 | Year2015 | 2435.540 | 550.4469 |
| 8 | Year2016 | 2894.798 | 550.4469 |
| 9 | SiteClassReference:Year 2011 | -2062.180 | 778.4495 |
| 10 | SiteClassReference:Year 2012 | -1078.520 | 778.4495 |
| 11 | SiteClassReference:Year 2013 | -477.000 | 778.4495 |
| 12 | SiteClassReference:Year 2014 | -3371.826 | 778.4495 |
| 13 | SiteClassReference:Year 2015 | -3828.120 | 778.4495 |
| 14 | SiteClassReference:Year 2016 | -4041.456 | 778.4495 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1b. Statistical Modelling Coefficients for Density at Doris South

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 601.480 | 251.4576 |
| 2 | SiteClassReference | 1528.900 | 355.6147 |
| 3 | Year2012 | 322.980 | 355.6147 |
| 4 | Year2013 | 284.460 | 355.6147 |
| 5 | Year2014 | 1842.965 | 355.6147 |
| 6 | Year2015 | 1146.660 | 355.6147 |
| 7 | Year2016 | 1007.409 | 355.6147 |
| 8 | SiteClassReference:Year 2012 | -536.340 | 502.9152 |
| 9 | SiteClassReference:Year 2013 | 1265.160 | 502.9152 |
| 10 | SiteClassReference:Year 2014 | -2026.678 | 502.9152 |
| 11 | SiteClassReference:Year 2015 | -1620.740 | 502.9152 |
| 12 | SiteClassReference:Year 2016 | -1235.567 | 502.9152 |

*The Class*Year estimate (rows 8 to 12) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1c. Statistical Modelling Coefficients for Diversity at Doris North

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3315 | 0.0460 |
| 2 | SiteClassReference | 0.2831 | 0.0651 |
| 3 | Year2011 | -0.2548 | 0.0651 |
| 4 | Year2012 | -0.2153 | 0.0651 |
| 5 | Year2013 | -0.1125 | 0.0651 |
| 6 | Year2014 | 0.0418 | 0.0651 |
| 7 | Year2015 | 0.0811 | 0.0651 |
| 8 | Year2016 | -0.0754 | 0.0651 |
| 9 | SiteClassReference:Year 2011 | 0.2815 | 0.0920 |
| 10 | SiteClassReference:Year 2012 | 0.1460 | 0.0920 |
| 11 | SiteClassReference:Year 2013 | 0.1314 | 0.0920 |
| 12 | SiteClassReference:Year 2014 | -0.1276 | 0.0920 |
| 13 | SiteClassReference:Year 2015 | -0.1142 | 0.0920 |
| 14 | SiteClassReference:Year 2016 | 0.0783 | 0.0920 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1d. Statistical Modelling Coefficients for Diversity at Doris South

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3475 | 0.0547 |
| 2 | SiteClassReference | 0.2937 | 0.0774 |
| 3 | Year2012 | 0.0364 | 0.0774 |
| 4 | Year2013 | 0.2204 | 0.0774 |
| 5 | Year2014 | 0.1236 | 0.0774 |
| 6 | Year2015 | -0.1651 | 0.0774 |
| 7 | Year2016 | 0.0073 | 0.0774 |
| 8 | SiteClassReference:Year2012 | -0.1323 | 0.1095 |
| 9 | SiteClassReference:Year2013 | -0.2281 | 0.1095 |
| 10 | SiteClassReference:Year2014 | -0.2361 | 0.1095 |
| 11 | SiteClassReference:Year2015 | 0.1053 | 0.1095 |
| 12 | SiteClassReference:Year2016 | -0.0310 | 0.1095 |

*The Class*Year estimate (rows 8 to 12) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1e. Statistical Modelling Coefficients for Evenness at Doris North

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3896 | 0.0600 |
| 2 | SiteClassReference | 0.2371 | 0.0849 |
| 3 | Year2011 | 0.0409 | 0.0849 |
| 4 | Year2012 | -0.0695 | 0.0849 |
| 5 | Year2013 | -0.0159 | 0.0849 |
| 6 | Year2014 | 0.1991 | 0.0849 |
| 7 | Year2015 | 0.1433 | 0.0849 |
| 8 | Year2016 | -0.0302 | 0.0849 |
| 9 | SiteClassReference:Year2011 | -0.0108 | 0.1200 |
| 10 | SiteClassReference:Year2012 | 0.0705 | 0.1200 |
| 11 | SiteClassReference:Year2013 | -0.0097 | 0.1200 |
| 12 | SiteClassReference:Year2014 | -0.1433 | 0.1200 |
| 13 | SiteClassReference:Year2015 | -0.2916 | 0.1200 |
| 14 | SiteClassReference:Year2016 | 0.0974 | 0.1200 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1f. Statistical Modelling Coefficients for Evenness at Doris South

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.5450 | 0.0589 |
| 2 | SiteClassReference | 0.1117 | 0.0833 |
| 3 | Year2012 | -0.1074 | 0.0833 |
| 4 | Year2013 | 0.1289 | 0.0833 |
| 5 | Year2014 | -0.1090 | 0.0833 |
| 6 | Year2015 | -0.0514 | 0.0833 |
| 7 | Year2016 | -0.0314 | 0.0833 |
| 8 | SiteClassReference:Year2012 | 0.0784 | 0.1178 |
| 9 | SiteClassReference:Year2013 | -0.1845 | 0.1178 |
| 10 | SiteClassReference:Year2014 | 0.1347 | 0.1178 |
| 11 | SiteClassReference:Year2015 | -0.1269 | 0.1178 |
| 12 | SiteClassReference:Year2016 | 0.0685 | 0.1178 |

*The Class*Year estimate (rows 8 to 12) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1g. Statistical Modelling Coefficients for Richness at Doris North

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 4.0 | 0.3761 |
| 2 | SiteClassReference | 0.4 | 0.5318 |
| 3 | Year2011 | -1.4 | 0.5318 |
| 4 | Year2012 | -0.4 | 0.5318 |
| 5 | Year2013 | -0.4 | 0.5318 |
| 6 | Year2014 | -1.0 | 0.5318 |
| 7 | Year2015 | -0.6 | 0.5318 |
| 8 | Year2016 | 0.0 | 0.5318 |
| 9 | SiteClassReference:Year2011 | 1.4 | 0.7521 |
| 10 | SiteClassReference:Year2012 | -0.4 | 0.7521 |
| 11 | SiteClassReference:Year2013 | 0.6 | 0.7521 |
| 12 | SiteClassReference:Year2014 | 0.2 | 0.7521 |
| 13 | SiteClassReference:Year2015 | 1.4 | 0.7521 |
| 14 | SiteClassReference:Year2016 | -0.4 | 0.7521 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1h. Statistical Modelling Coefficients for Richness at Doris South

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 3.2 | 0.3937 |
| 2 | SiteClassReference | 1.2 | 0.5568 |
| 3 | Year2012 | 0.6 | 0.5568 |
| 4 | Year2013 | 0.4 | 0.5568 |
| 5 | Year2014 | 1.2 | 0.5568 |
| 6 | Year2015 | -0.4 | 0.5568 |
| 7 | Year2016 | 0.0 | 0.5568 |
| 8 | SiteClassReference:Year2012 | -1.4 | 0.7874 |
| 9 | SiteClassReference:Year2013 | -0.2 | 0.7874 |
| 10 | SiteClassReference:Year2014 | -2.0 | 0.7874 |
| 11 | SiteClassReference:Year2015 | 1.2 | 0.7874 |
| 12 | SiteClassReference:Year2016 | -0.4 | 0.7874 |

*The Class*Year estimate (rows 8 to 12) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1i. Statistical Modelling Coefficients for the Bray-Curtis Index at Doris North

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3333 | 0.0368 |
| 2 | SiteClassReference | -0.0736 | 0.0520 |
| 3 | Year2011 | 0.5100 | 0.0520 |
| 4 | Year2012 | 0.0146 | 0.0520 |
| 5 | Year2013 | 0.2888 | 0.0520 |
| 6 | Year2014 | 0.4139 | 0.0520 |
| 7 | Year2015 | 0.4255 | 0.0520 |
| 8 | Year2016 | 0.3924 | 0.0520 |
| 9 | SiteClassReference:Year2011 | -0.6166 | 0.0736 |
| 10 | SiteClassReference:Year2012 | -0.2028 | 0.0736 |
| 11 | SiteClassReference:Year2013 | -0.3796 | 0.0736 |
| 12 | SiteClassReference:Year2014 | -0.5486 | 0.0736 |
| 13 | SiteClassReference:Year2015 | -0.4474 | 0.0736 |
| 14 | SiteClassReference:Year2016 | -0.5473 | 0.0736 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Large Lake-1j. Statistical Modelling Coefficients for the Bray-Curtis Index at Doris South

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.7021 | 0.0356 |
| 2 | SiteClassReference | -0.5489 | 0.0504 |
| 3 | Year2012 | -0.5027 | 0.0504 |
| 4 | Year2013 | -0.0125 | 0.0504 |
| 5 | Year2014 | -0.0275 | 0.0504 |
| 6 | Year2015 | -0.1522 | 0.0504 |
| 7 | Year2016 | -0.1617 | 0.0504 |
| 8 | SiteClassReference:Year2012 | 0.4210 | 0.0712 |
| 9 | SiteClassReference:Year2013 | 0.0282 | 0.0712 |
| 10 | SiteClassReference:Year2014 | -0.0007 | 0.0712 |
| 11 | SiteClassReference:Year2015 | 0.2369 | 0.0712 |
| 12 | SiteClassReference:Year2016 | 0.1133 | 0.0712 |

*The Class*Year estimate (rows 8 to 12) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

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

| | Small Lake Site |
|---|---|
| Variable | Little Roberts p-value |
| Density | **0.0008** |
| Diversity | 0.1432 |
| Evenness | **0.0042** |
| Richness | **0.0021** |
| Bray-Curtis | **0.0372** |

*Note:*
*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-1a. Statistical Modelling Coefficients for Density at Little Roberts

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 14198.520 | 2753.138 |
| 2 | SiteClassReference | -2103.700 | 3893.526 |
| 3 | Year2011 | -1813.320 | 3893.526 |
| 4 | Year2012 | 7798.520 | 3893.526 |
| 5 | Year2013 | -5407.420 | 3893.526 |
| 6 | Year2014 | -6000.002 | 3893.526 |
| 7 | Year2015 | -628.140 | 3893.526 |
| 8 | Year2016 | 8319.998 | 3893.526 |
| 9 | SiteClassReference:Year2011 | -1481.520 | 5506.277 |
| 10 | SiteClassReference:Year2012 | 3084.460 | 5506.277 |
| 11 | SiteClassReference:Year2013 | 4459.280 | 5506.277 |
| 12 | SiteClassReference:Year2014 | 20717.033 | 5506.277 |
| 13 | SiteClassReference:Year2015 | 7439.980 | 5506.277 |
| 14 | SiteClassReference:Year2016 | -4800.004 | 5506.277 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Small Lake-1b. Statistical Modelling Coefficients for Diversity at Little Roberts

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.2883 | 0.0582 |
| 2 | SiteClassReference | 0.2502 | 0.0823 |
| 3 | Year2011 | 0.0773 | 0.0823 |
| 4 | Year2012 | -0.0996 | 0.0823 |
| 5 | Year2013 | -0.0853 | 0.0823 |
| 6 | Year2014 | -0.0140 | 0.0823 |
| 7 | Year2015 | -0.0065 | 0.0823 |
| 8 | Year2016 | 0.0235 | 0.0823 |
| 9 | SiteClassReference:Year2011 | 0.0227 | 0.1163 |
| 10 | SiteClassReference:Year2012 | -0.1260 | 0.1163 |
| 11 | SiteClassReference:Year2013 | 0.0784 | 0.1163 |
| 12 | SiteClassReference:Year2014 | -0.2021 | 0.1163 |
| 13 | SiteClassReference:Year2015 | -0.1427 | 0.1163 |
| 14 | SiteClassReference:Year2016 | -0.1535 | 0.1163 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Small Lake-1c. Statistical Modelling Coefficients for Evenness at Little Roberts

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.2618 | 0.0350 |
| 2 | SiteClassReference | 0.0844 | 0.0495 |
| 3 | Year2011 | 0.0299 | 0.0495 |
| 4 | Year2012 | 0.0401 | 0.0495 |
| 5 | Year2013 | 0.0336 | 0.0495 |
| 6 | Year2014 | 0.0471 | 0.0495 |
| 7 | Year2015 | -0.0497 | 0.0495 |
| 8 | Year2016 | -0.0147 | 0.0495 |
| 9 | SiteClassReference:Year2011 | 0.0684 | 0.0700 |
| 10 | SiteClassReference:Year2012 | -0.1314 | 0.0700 |
| 11 | SiteClassReference:Year2013 | -0.0541 | 0.0700 |
| 12 | SiteClassReference:Year2014 | -0.2023 | 0.0700 |
| 13 | SiteClassReference:Year2015 | 0.0079 | 0.0700 |
| 14 | SiteClassReference:Year2016 | -0.1153 | 0.0700 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Small Lake-1d. Statistical Modelling Coefficients for Richness at Little Roberts

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 5.6 | 0.5043 |
| 2 | SiteClassReference | 1.2 | 0.7131 |
| 3 | Year2011 | 0.0 | 0.7131 |
| 4 | Year2012 | -1.0 | 0.7131 |
| 5 | Year2013 | -1.2 | 0.7131 |
| 6 | Year2014 | -0.8 | 0.7131 |
| 7 | Year2015 | 1.4 | 0.7131 |
| 8 | Year2016 | 0.4 | 0.7131 |
| 9 | SiteClassReference:Year2011 | -0.4 | 1.0085 |
| 10 | SiteClassReference:Year2012 | 0.0 | 1.0085 |
| 11 | SiteClassReference:Year2013 | 2.0 | 1.0085 |
| 12 | SiteClassReference:Year2014 | 2.0 | 1.0085 |
| 13 | SiteClassReference:Year2015 | -2.0 | 1.0085 |
| 14 | SiteClassReference:Year2016 | 1.0 | 1.0085 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*

## Table Small Lake-1e. Statistical Modelling Coefficients for the Bray-Curtis Index at Little Roberts

| Row | VariableName | Estimate | SE |
|---|---|---|---|
| 1 | (Intercept) | 0.3837 | 0.0548 |
| 2 | SiteClassReference | -0.2395 | 0.0774 |
| 3 | Year2011 | 0.0534 | 0.0774 |
| 4 | Year2012 | -0.1704 | 0.0774 |
| 5 | Year2013 | 0.0161 | 0.0774 |
| 6 | Year2014 | 0.1525 | 0.0774 |
| 7 | Year2015 | -0.0431 | 0.0774 |
| 8 | Year2016 | -0.1618 | 0.0774 |
| 9 | SiteClassReference:Year2011 | 0.0121 | 0.1095 |
| 10 | SiteClassReference:Year2012 | 0.0992 | 0.1095 |
| 11 | SiteClassReference:Year2013 | 0.1013 | 0.1095 |
| 12 | SiteClassReference:Year2014 | -0.1685 | 0.1095 |
| 13 | SiteClassReference:Year2015 | 0.1848 | 0.1095 |
| 14 | SiteClassReference:Year2016 | 0.1626 | 0.1095 |

*The Class*Year estimate (rows 9 to 14) is the effect of interest representing non-parallel changes over time between the site classes.*
*SE = Standard Error*