Analysis of Benthic Macroinvertebrate QC Detritus Samples from 2000-2011: Detection Probabilities and Potential Impacts to EII Scores

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Abstract

Since 1994 the City of Austin has monitored Austin-area streams to evaluate water quality. Benthic macroinvertebrate samples are included as part of this assessment to serve as an indicator of environmental stressors not measured by other analyses. Following macroinvertebrate sampling in the field, quality assurance protocols dictate periodic retention and laboratory inspection of the remaining sample detritus to assess percent recovery. This report summarizes the number and taxa of individuals remaining in QC samples relative to the corresponding Surber sample. From this summary, an estimate of the probabilities of detection of benthic macroinvertebrates across selected sites and across various taxa was computed. The dipteran family Chironomidae had the lowest mean detection probability while the genera Fallceon and Chimarra had the highest mean detection probabilities. The results were also used to examine the effect of varying probabilities of detection on the Benthic Macroinvertebrate subindex scores and total scores of the Environmental Integrity Index (EII), an assessment of stream ecological integrity in Austin. Simulations showed that there was a 1% chance that any error associated with the QC detritus organisms would have an impact of greater than 1 point to the total overall EII score. Based on this evaluation, it is recommended that QC detritus sample retention be eliminated from future sampling protocol.

Introduction

The City of Austin monitors and evaluates the ecological integrity of its streams through a scoring tool called the Environmental Integrity Index (EII). The EII assigns physical, chemical, and biological conditions within a stream segment a number between 1 and 100. This number can then be either compared temporally to previous scores or spatially among the scores of other stream segments in Austin. The result is a comprehensive assessment of Austin streams going back to the inception of the EII in 1994. The biological component of the EII, called the Aquatic Life sub-index, is an evaluation of the benthic macroinvertebrate and diatom communities for each site. Monitoring the biota of the stream screens for non-point source contaminants, changes to hydrology, and habitat alteration. Biological measures also integrate impacts over longer periods of time than instantaneous water chemistry measures. The COA method includes picking live macroinvertebrates in the field, from a kicknet, or a composite of three Surber samples collected at the bottom, middle and tip of a riffle; these specimens are then identified and enumerated in the laboratory (Clamann *et al*. 2007). Counts of the macroinvertebrates in the sample are entered into a database, where multiple univariate metrics are calculated (TCEQ, 2005) and incorporated into a multi-metric index score.

Characterizing stream macroinvertebrate communities does not require the collection of 100% of the individuals present, nor does it require that all taxa present be detected during each sampling event, as long as the community present can be adequately characterized. Furthermore, the COA Surber sampling methodology has been compared to the kicknet methodology used by the TCEQ, and it has been demonstrated that the probability of detection for discrete taxa was equal to, or in some cases greater than, the TCEQ method (Clamann *et al*. 2007). Collection of less than 100% of the macroinvertebrates from a Surber sample occurs because some organisms are very small, some adhere to rocks or detritus within a sample, and because some samples contain a very high density of individuals. Sites with varying population densities can introduce sample variability. This potential source of sample error has been ameliorated by training COA staff to thoroughly sort through sample detritus or to collect all organisms from a sub-sample when high density samples are generated. As a quality control check, the detritus remaining from a normally processed sample is preserved for a subset of COA Surber samples (~10%), and this material is later scrutinized in the laboratory to identify and enumerate the individuals that were not detected during routine sample collection.

The proportion of individuals detected in Surber samples can be determined for each taxa of macroinvertebrates collected at study sites. This can provide an indication of whether or not some taxa are detected more frequently or more accurately than others. In addition, for sites with repeated visits, the proportion of all individuals taken at that site can be estimated as well. This information can then be used in making recommendations for future benthic macroinvertebrate sampling. The goals of this report are to:

1. Evaluate the likely proportion of individual taxa detected in the field
2. Estimate the range of probabilities of detection for community assemblages of macroinvertebrates among EII sites
3. Determine whether lower estimates for detection probabilities have a significant impact on the EII scores.

Methods

Field

There were 62 sampling events for which the detritus was retained. Of the 62 QC detritus samples, 47 were examined for missed benthic macroinvertebrates with un-aided eye and 15 were examined using a microscope. Examination at the microscopic level would not provide a realistic check for field collection because it would often include minute individuals below the threshold of what is considered to represent a macroinvertebrate. Therefore, only the 47 QC detritus samples that were assessed with un-aided eye were used for this analysis. The 15 samples assessed using a microscope are somewhat useful in that they represent a more complete estimate of the population at a given site, but that data is not relevant to this analysis.

From these 47 QC detritus samples, 23 of them were collected at sites which were sampled more than once and 24 samples were from one site on one date (Tables 1 and 2).

Table 1: Sample Sites which included a single QC Detritus sample

Site Name	Site Number
Barton Creek @ Shield Ranch Pool	46
Short Spring Branch Trib in LC Estates (SSBE)	76
Shoal Creek @ 24th Street	116
Tributary 6 @ Bull Creek (EG)	151
Onion Creek @ Twin Creeks Road (OC1)	236
Onion Creek @ McKinney Falls ds Lower Falls	255
Blunn Creek @ Long Bow (Preserve at Little Bridge)	362
Blunn Creek Upstream of Big Stacy Pool	364
Walnut Creek @ Loyola Lane	465
Walnut Creek Upstream of Freescale	503
Waller Creek Upstream of 23rd Street	624
Waller Creek @ 51st Street	780
North Boggy Creek @ Nile Street	837
Tannehill Creek @ Lovell Drive	843
Bull Creek @ St. Edwards Park Upstream of dam	920
Harris Branch Creek @ Boyce Lane	1201
Bear Creek (West) @ Fritz Hughes Park Road	1224
East Bouldin Creek @ Post Oak	1338
Onion Creek at Pfulman Ranch	1365
Onion Creek @ South Austin Regional WWTP (SAR)	1366
Tannehill Creek @ Desirable Drive	1476
Decker Creek @ Gilbert Rd	1974
Little Walnut @ Cameron Rd	3857
Little Walnut Creek @ Georgian Dr	3860

Table 2: Sample Sites which included more than one QC Detritus sample

Site Name	Site Number
Shoal Creek Downstream of Crosscreek Drive	118
Onion Creek Upstream of Footbridge	241
Bull Creek Upstream of Tributary 7 (Franklin)	349
Walnut Creek Downstream of IH35	464
Walnut Creek @ Old Manor Road	502
Walnut Creek Downstream of Metric Blvd	895
Gilleland Creek @ FM 973	1192
Bull Creek Tributary 8 Upstream of Bull Creek	3977

Statistical Analysis

For each sample, the number of macroinvertebrates detected in the Surber sample and the number detected in the detritus QC sample were recorded. The proportion of individuals detected in the sample was calculated using the formula:

$$P_d = \frac{C_S}{C_S + C_Q} \tag{1}$$

where P_d is the proportion of individuals detected, C_S is the number of individuals counted in the Surber sample sorted in the field, and C_Q is the number of individuals counted remaining in the QC detritus sample after the Surber sample had been sorted. This proportion was used as a proxy for the probability of detection. Note that the probability of detection is a random variable and is considered a realization from some probabilistic mechanism. Thus, the proportion of individuals detected P_d is an estimate of the true *probability of detection, p,* and confidence intervals of the mean and prediction intervals for the next future detection probability can be constructed. For this report, these intervals were computed using Bayesian statistics and discussed along with the general theory in the next section.

Theory

The classical problem in ecological monitoring is to estimate the number of individuals, N, in a population based on the number of individuals, n, in a sample. The two are related by

$$E[n] = N \cdot p \tag{2}$$

where n follows a Binomial Distribution with N trials and p probability of detection. The problem becomes more complex when p is assumed to be non-constant. In fact, when sampling animals, p is a function of many factors, including the level of effort, the method, the environment, the observer, sampling intensity, and sampling area. Thus, the ecologist is typically faced with the problem of determining p and N through some conceptual model that might account for these factors.

This problem can be modified for the present case given that N and n are known. Thus, the goal of this analysis is to estimate the range of possible detection probabilities, p, given N and n. Placing this within a Binomial Distribution framework, can provide adequate intervals for p. However, this model can be improved further by stipulating that the detection probability is a random variable defined by a Beta Distribution within the closed interval [0, 1]. Given varying number of individuals in a population, N_i, and varying number of individuals in the sample, n_i, across sites $i = 1,2,\ldots S$ (where S is the number of sites), then the probability of detection, p, can be described via the mixture model known as the Beta-Binomial Distribution. Or, equivalently,

$$\begin{aligned} n_i \mid N_i, p &\sim \text{Bin}(N_i, p) \\ p &\sim \text{Beta}(\alpha,\beta) \end{aligned} \tag{3}$$

Note that for this model, the Binomial Distribution was retained to model the number of individuals in the sample but rather than assuming a constant probability (as is done under the Binomial Distribution framework), additional structure was given to the varying probabilities of detection in the form of a Beta Distribution giving us the Beta-Binomial model.

This method of determining the probability of detection can be applied at either the taxa level or at the community level[1]. That is, this method can be adapted to either scenario by assuming that the probability of detection, p, randomly varies across the population where the population can either be across all sites; across sites with repeated visits; or across taxa. In the first case, the population of interest is the macroinvertebrate community across the City of Austin. The second case consists of counts at the eight specific sites with repeated visits to estimate site-specific detection probabilities. The third case looks at the population of interest across Austin to examine taxa-specific detection probabilities.

Bayesian Theory

From the Beta-Binomial model (Equation 3), one can use the data n_i and N_i to determine p under each of the three scenarios described above. This determination is made using Bayesian statistics. This is performed by first specifying a wide distribution of values for α and β. This produces various Beta distributions (to mimic the possible distribution of detection probabilities, p). The Beta distributions that best fit the data are given higher likelihood values, which results in a posterior distribution of the detection probabilities. One of the advantages of Bayesian statistics is that the posterior distributions of any statistic can be determined. Thus, one may find the posterior distribution of the mean detection probability of any site with repeated visits or all sites. Similarly, one can input the resulting posterior distributions of α and β into the Beta distribution to obtain a posterior distribution of a single detection probability measurement. These posterior distributions will be denoted as Bayesian confidence and Bayesian prediction intervals, respectively.

Appendix A contains a list of the proportion of macroinvertebrate taxa detected at EII sites where replicate sample data are available.

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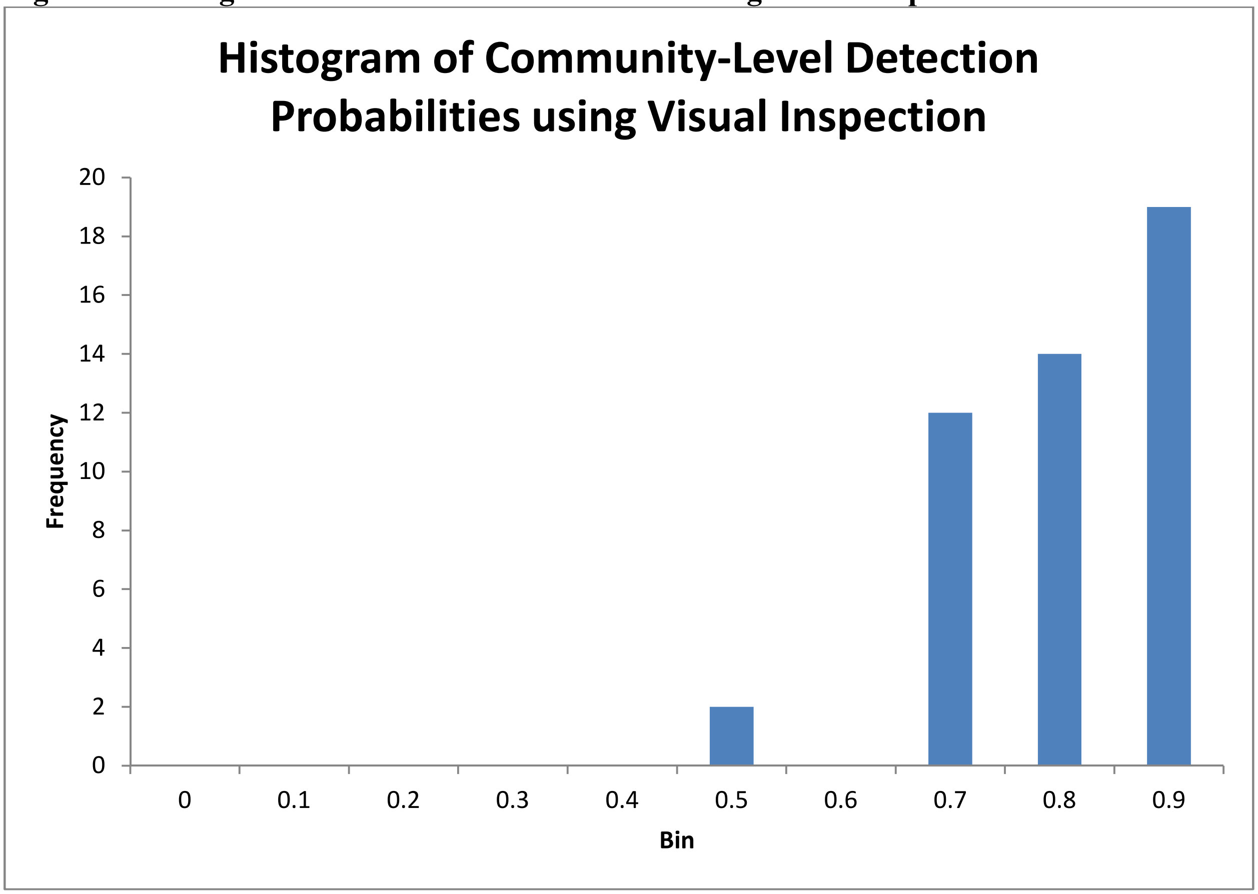
[1] Here, the definition of *community* that will be used is consistent with that of Royle and Dorazio (2008). This definition states that *community* is a “collection of spatially distinct, local communities composed of ‘trophically similar, sympatric species that actually or potentially compete in a local area for the same or similar resources’.”

Results

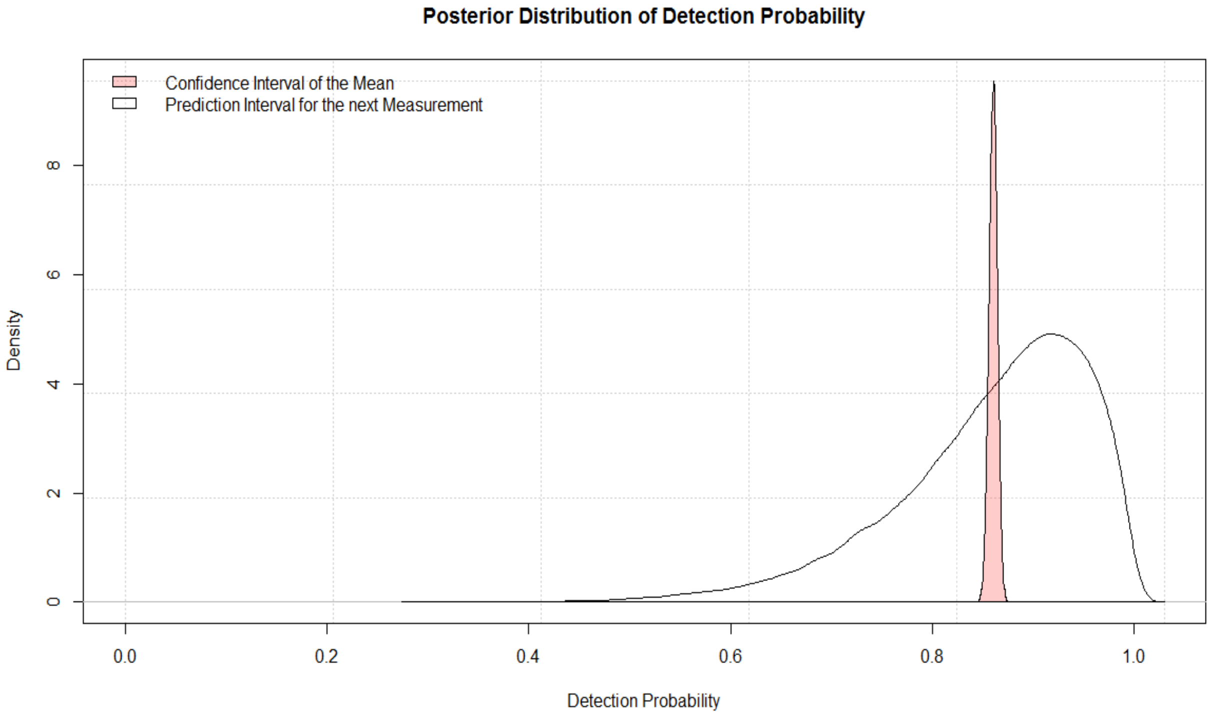
A histogram of the community-level probabilities of detection for each Surber sample is given in Figure 1. This figure shows that all but two Surber samples had a detection probability greater than 0.7.

Figure 1: Histogram of Detection of Probabilities using Visual Inspection



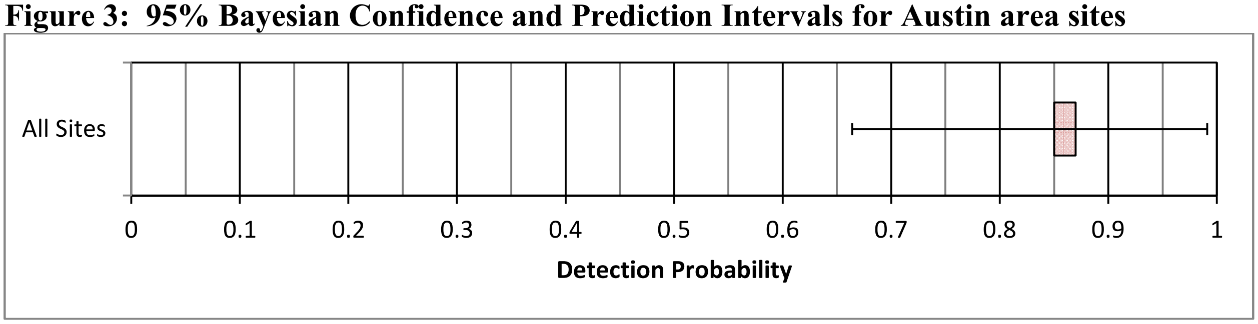
It is clear from Figure 1 that the detection probabilities are not normally distributed. Using all forty-seven sites across Austin as data and the Beta-Binomial model, the resulting posterior Bayesian confidence and Bayesian prediction intervals for all sites are shown below (Figure 2).

Figure 2: Distribution of Detection Probabilities for Austin area sites



From this, one can obtain the 2.5th and 97.5th percentiles for each distribution to come up with 95% Bayesian confidence and prediction intervals. Figure 3 displays the Bayesian confidence intervals (as a shaded box) and the Bayesian prediction intervals (as error bars).

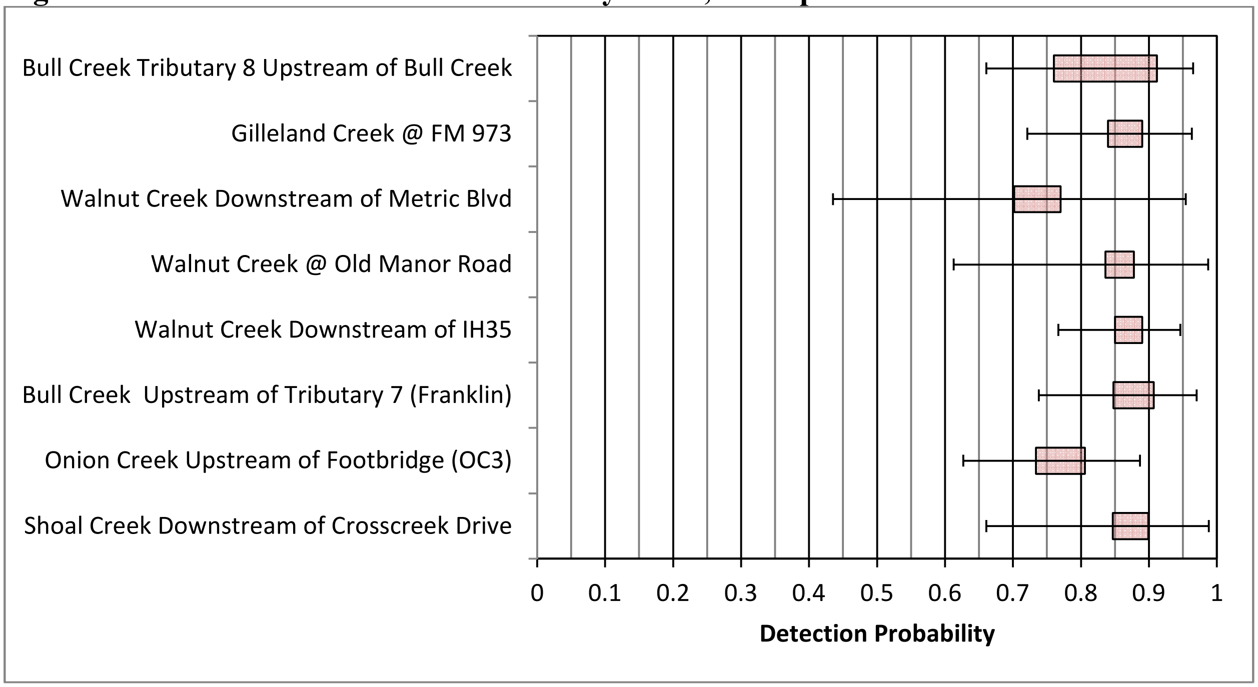
Figure 3: 95% Bayesian Confidence and Prediction Intervals for Austin area sites



Repeated Sites

This same process can be replicated for those sites with repeated visits (as identified in Table 2) The Bayesian confidence and Bayesian prediction intervals are shown in Figure 4 below; however, it should be noted that these were estimated from a small data set (typically between 2 and 5 site visits) and include the community-wide detection probability.

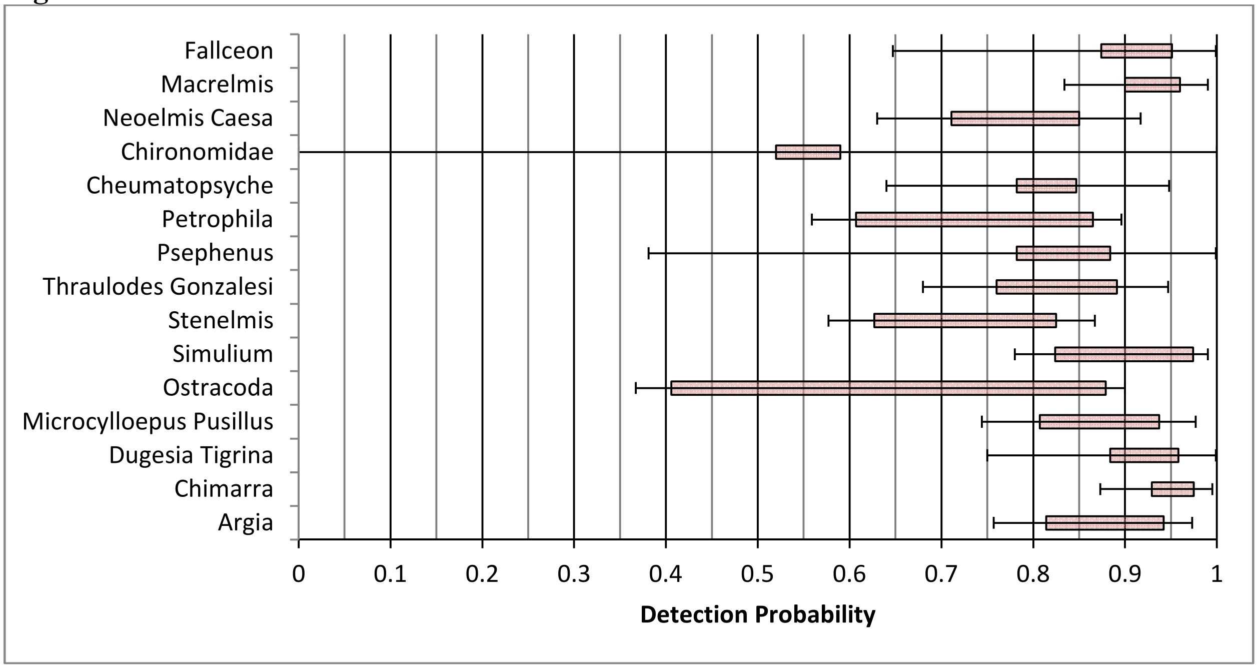
Figure 4: Statistical Intervals of Community-Level, Site-Specific Detection Probabilities



This table shows an interval for the mean detection probability at each site (as a shaded box) for the community along with an interval for the next measurement of detection probability at each site (as an error bar). Estimated mean detection probability for the overall benthic communities from the eight sites where QC detritus samples were collected ranged from 0.70 to 0.90, which refers to accuracy of determining the actual benthic community present at each site. Walnut Creek downstream of Metric Boulevard had the lowest mean detection probability and the highest variability in prediction for the next detection probability measurement.

For taxa-level data, 15 different species were counted more than once at eight of the repeated sites. Figure 5 shows the results from the Bayesian Beta-Binomial runs at the replicated sites.

Figure 5: Statistical Intervals of Taxa-Level Detection Probabilities



This figure shows the detection probability for taxa counted at several sites. *Macrelmis* and *Chimarra* had the highest mean detection probability. It should be noted that this variation in estimated means might not necessarily come from differences in site locations, but rather may come from differences between collectors or effort. Ostracoda and Chironomidae (both of which can be so small as to be at the threshold for what is considered to be a macroinvertebrate) had the lowest mean detection probabilities. The behavior of some taxa may also play a role in lowering detection. For example, many of the elmid beetles (*Macrelmis, Microcylloepus*) stop moving soon after being disturbed, and resemble small detritus in the sample.

Site detritus variability may explain the significant differences observed in detection probabilities for some taxa. For example, *Chimarra* and *Cheumatopsyche* will burrow into any available cover soon after being disturbed. These taxa are especially difficult to find at sites with filamentous algal blooms or dense detritus.

Impacts on Benthic Sub-index and Total EII score

To address the effect the proportion of individuals not detected by field processing of a Surber sample on the EII benthic sub-index score, the forty-seven sampled sites were evaluated comparing the data from the field-picked Surber counts and the data composite of the QC detritus and the field-picked Surber. The composite of the QC detritus and the field-picked Surber will be referred to as the “true count” or “true score”. The two data sets produced two benthic sub-index scores, which were then input into the EII scoring metric to produce two total overall EII scores. The difference in the two scores, called error, was used to evaluate whether or not the inclusion of non-detected macroinvertebrates (QC sample) would have a significant effect on the benthic sub-index score or the total overall EII score.

Consider a theoretical probability distribution function of the errors between "true scores" and field-picked Surber sample scores taken at all EII sites in Austin. The forty-seven sampled sites would represent forty-seven realizations from this probability density function. The resulting distribution of the errors (Figure 6) somewhat follows a normal distribution with a mean within the interval 0 to 2.

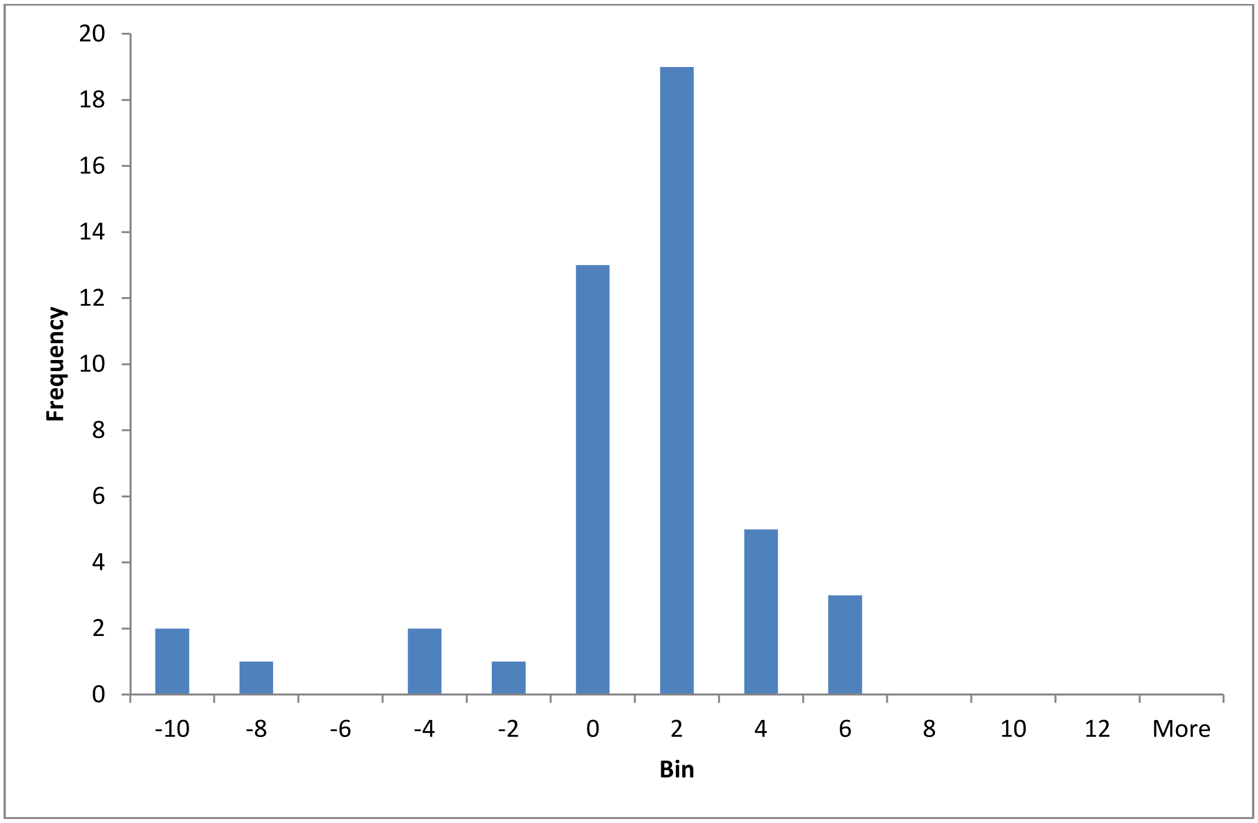


Figure 6: Histogram of Differences in Benthic Subindex Scores taken from 47 sites

This normal distribution can be attributed to the manner with which the score is computed. Scoring is based on a multiparametric calculation of the following nine metrics:

- Number of taxa,
- Hilsenhoff Biotic Index,
- Number of Ephemeroptera taxa,
- Percent of total individuals as Chironomidae,
- Number of Ephemeroptera / Plecoptera / Trichoptera (EPT) taxa,
- Percent of total as EPT,
- Percent of total as predators,
- Number of pollution intolerant taxa, and
- Percent dominance of the top three taxa in the sample.

The counts are then compared to counts in the 5th and 95th percentiles. A count above the 95th percentile is given a value of 100, a count below the 5th percentile is given a value of 0, and a count between the two values is interpolated between 5 and 95. These nine normalized scores are then averaged to produce the benthic sub-index score. Since the benthic sub-index is comprised of averages, one may then invoke the Central Limit Theorem to infer that the benthic sub-index scores are normally distributed assuming that each of the scores comes from identical and independent distributions.

The distribution of the errors (difference between two scores) for each of the nine metrics for the 47 samples is provided in Appendix B. The resulting difference in EII total score (Figure 7) between the sample and QC detritus is one-twelfth of the difference in the benthic sub-index score. As shown in Figure 7, only one of the 47 QC detritus samples resulted in a difference of more than one point to an EII total score. This indicates that if all of the individuals found in the QC detritus samples had been collected in the original site sample, there would have been very little impact to EII scoring.

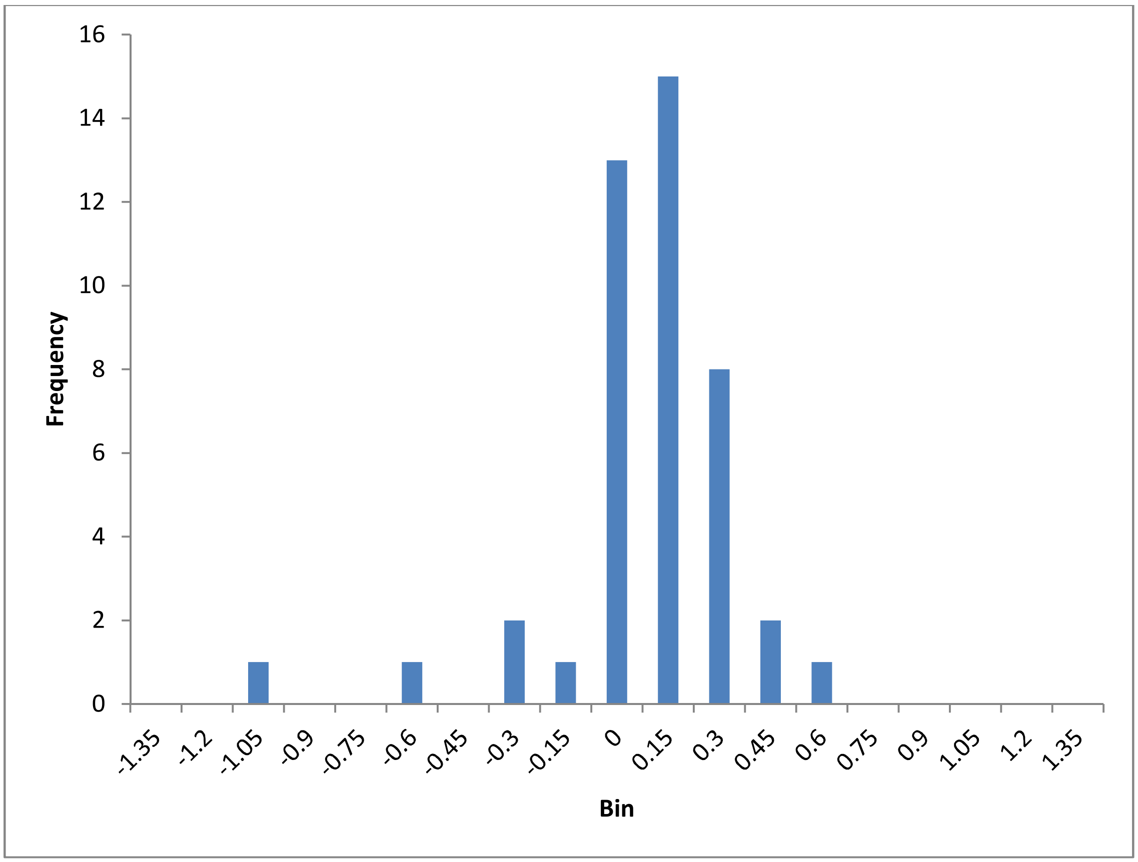


Figure 7: Histogram of Differences in Total EII Scores taken from 47 sites

Sensitivity Analysis

A sensitivity analysis can be used to identify which parameters in a model produce significant uncertainty in the output. In examining the scoring method for the benthic sub-index, the parameters of interest are the proportion of individuals detected for each taxon. The output in this case would be the errors in the scores. However, because each site has different taxa (typically between 10 and 30 different taxa), making an assessment on the sensitivity of the benthic sub-index from each taxon at every site can confound interpretation of results. One efficient way to proceed would be to conduct a sensitivity analysis for one of the fifteen sites sampled with a high benthic sub-index score and compare it with a sensitivity analysis for one of the fifteen sites sampled with a low benthic sub-index. This might effectively bracket the range of possible outputs. Another way to proceed would be to look at those taxa that show up multiple times in the scoring matrix.

For brevity, a combination of the two approaches mentioned above was utilized to conduct a sensitivity analysis for this report. Sample site 3860, Little Walnut Creek at Georgian Drive (sampled in June 2010), scored the lowest of the fifteen sampled sites in this report with a benthic sub-index of 71.4. Of the 20 taxa collected and identified at the site *Fallceon, Hydroptila,* and Chironomidae were ideal candidates for a sensitivity analysis.

Fallceon would be scored in four of the nine benthic sub-indices. It has a large number of individuals, is in the order Ephemeroptera, is an "EPT" taxa (E stands for Ephemeroptera), and has a low Pollution Tolerance Index score. Similarly, *Hydroptila* is an "EPT" taxa (T stands for Trichoptera, and has a low Pollution Tolerance Index score. Finally, Chironomidae was chosen because its detection probability could be anything between 0% and 100%. Thus, it's possible for this taxon to have been missed entirely in samples. Results from the sensitivity analysis of the benthic sub-index scores due to the proportion of individuals detected for *Fallceon, Hydroptila,* and Chironomidae are shown in Figure 8 below.

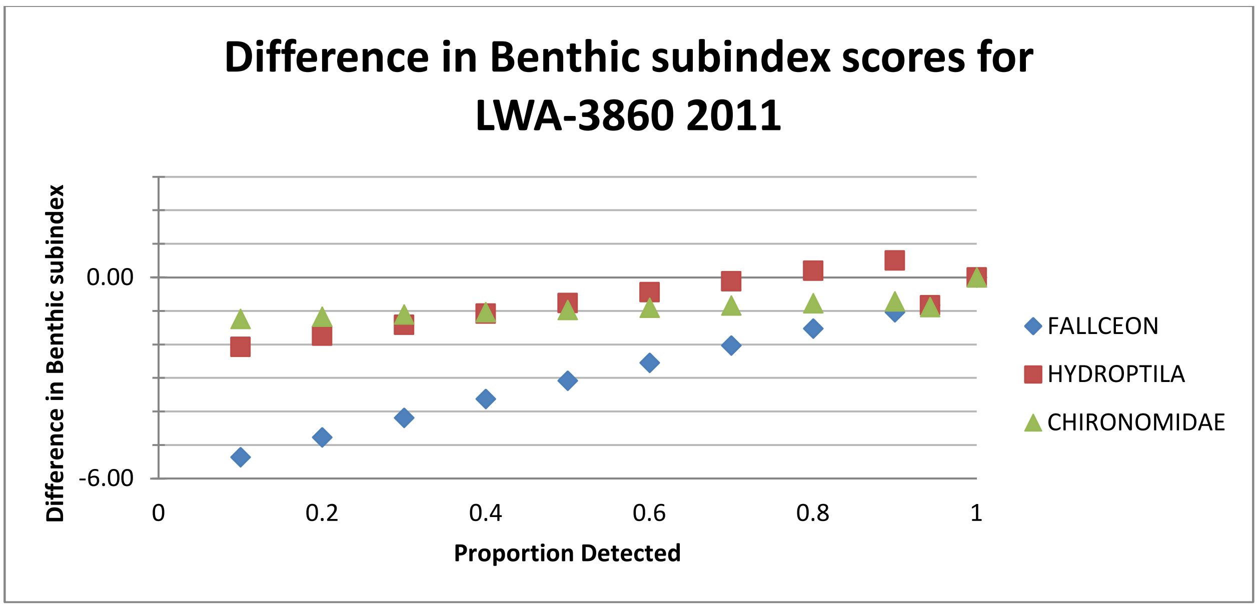


Figure 8: Results of Sensitivity Analysis on LWA-3860

Not surprisingly, this figure shows that when the proportion of individuals detected is 100% (that is, no error between the true count and the Surber counts), then the difference in benthic sub-index is nil. That difference increases to around 6 points for the benthic sub-index for *Fallceon* when the proportion of individuals detected is 10%. For *Hydroptila* and *Chironomidae* that difference is only about 2 points difference in scores. This indicates that *Fallceon* is a more sensitive parameter, which would require additional attention in detecting as many of the individuals as possible. However, note that the difference is only about 6 points for the Benthic Sub-index score, which translates to about 0.5 points in the overall EII score. This difference is negligible. Thus, if 10% of the *Fallceon* are detected in a given sample for Little Walnut Creek at Georgian Drive (Site 3860), the resulting difference in overall EII scores would be insignificant. Note that a detection probability of 10% for *Fallceon* is well below 65%, which is the 2.5th percentile of detection probabilities for *Fallceon* as characterized in the previous section (Figure 5). Therefore our confidence that *Fallceon* will be detected in a way that allows us to characterize the community at this site is sufficiently high.

While it is informative to see that there are trivial effects on the overall EII score due to detecting only 10% of an individual (and, from a model standpoint, sensitive) taxon, the above approach only considers changing the parameters one-at-a-time. Often times, if one taxon has a low proportion of detection, then other taxa might also have similar low detection rates. For example, a large amount of detritus at a site might obscure many other taxa. Thus, it is also relevant to use an uncertainty analysis in combination with the sensitivity analysis.

Uncertainty Analysis

In an uncertainty analysis, all of the parameters are varied according to some given probability distribution for each parameter. These distributions may be independent or correlated. This results in a probability distribution of the output. For this case, the parameters were the proportion of individuals detected for each species and the output is the difference in benthic sub-index scores. The probability distribution of the proportion of individuals detected was based on a uniform distribution with the ranges obtained from the calculations in Figure 5. For those taxa that were only detected at one site, the minimum and maximum proportions detected were assigned values of 0.00 and 1.00, respectively. For all other taxa, the endpoints of the uniform distribution matched the minimum and maximum proportions detected.

However, there is an additional complication. Using the taxa identified for any of the sample sites would not cover every possible permutation of taxa that might occur at a site. This would cause the output to be biased for that site. Thus, either an uncertainty analysis should be done for all fifteen sites or some neutral site must be considered.

For this report, a neutral site was simulated. First, between 10 and 35 taxa were chosen at random from the list of 82 taxa identified from the fifteen sites. Then, a total number of individuals were picked, also at random, based on the mean count of individuals for each taxon selected. Finally, a proportion of individuals detected was also acquired at random based on the uniform probability distribution given to each of the taxa selected. This process was run 100 times. The results are given in the Figure 9 below.

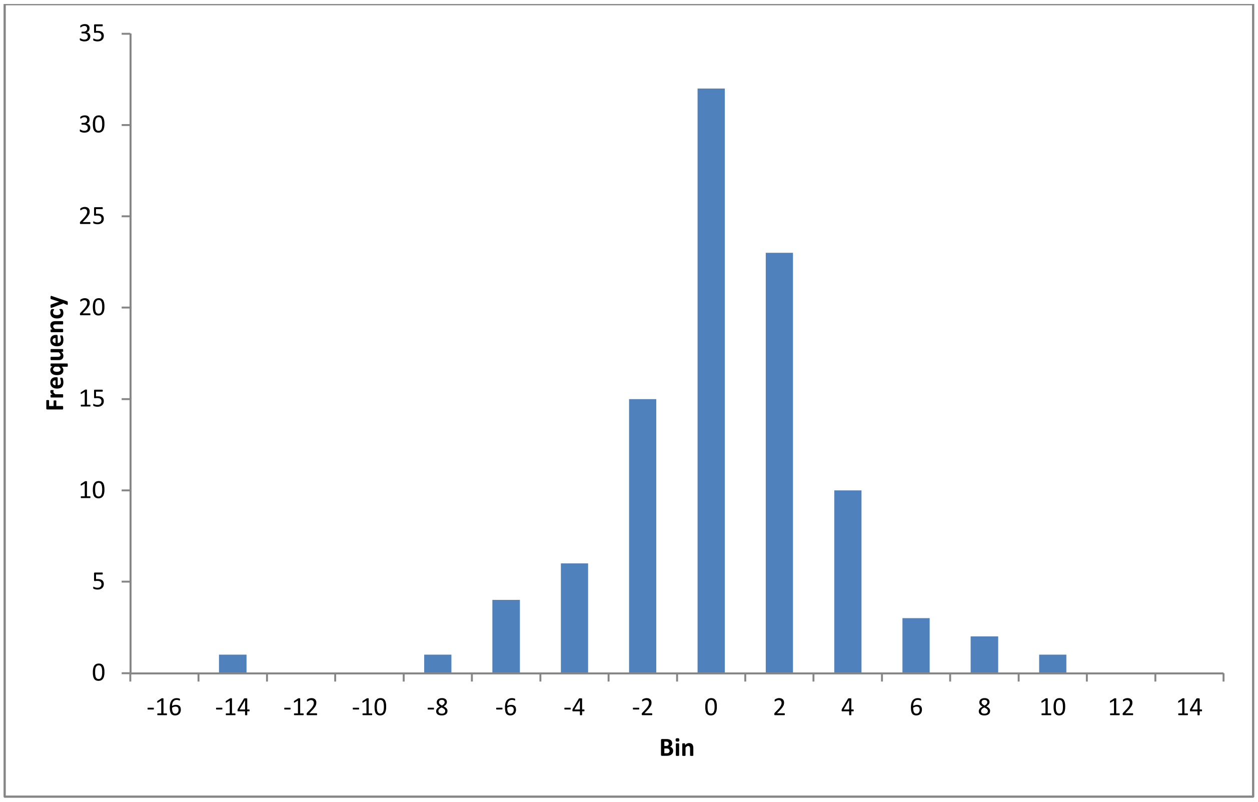


Figure 9: Histogram of Simulated Differences in Benthic Sub-index Scores over 100 Runs

This process is similar to simulating the sampling of 100 sites at random rather than examining the 47 sampled sites, as was done for Figure 6. In this case, out of the 100 simulated sample sites, one of them had a difference in benthic score of about 14 points. This translates to about a 1% probability of obtaining a difference in the Benthic Sub-index EII score greater than 1 point for any given site. If there are approximately 50 sites sampled annually, then by the Binomial Distribution, there is about a 40% probability of obtaining a difference in Benthic Sub-index EII score greater than 1 point in any given year[2].

Conclusion

Benthic macroinvertebrate sampling is an important component of the evaluation of aquatic integrity for the Environmental Integrity Index (EII). Rapid bioassessments have a certain amount of variability and no method can reasonably be expected to detect all individuals. However, field methods should be of sufficient quality and reproducibility to provide an assurance that the field sample is both representative of the site and reasonably thorough. In an effort to document and substantiate the quality of benthic macroinvertebrate sampling protocols, QC detritus samples have been collected during biological assessments to identify benthic macroinvertebrates inadvertently missed during the sorting of the field collection. This report assesses the data produced by the QC detritus samples in order to test the efficiency of the

[2] To see this, let p=0.01, n= 50, and k=1 and, using the Binomial Theorem, calculate the cumulative probability that $X \geq 1$. That is, calculate the probability that you will get one or more errors in fifty sites with the probability of getting an error at each site to be 1%.

detection of taxa and determine what impacts on EII scores would result from the individuals missed.

When evaluating the probabilities of detection for individual taxa it was apparent that very low probabilities of detection could occur in instances where densities for a given taxon were also very low. There were exceptions, most notably with the dipteran family Chironomidae, and also to a lesser extent with strongly adherent taxa or taxa that may have a behavioral tendency to burrow into thick detritus. The Chironomidae were missed entirely in some instances, even when they appeared to be at relatively high densities in a sample. This is a concern because the percent of the total sample represented by the Chironomidae is one of the nine scoring metrics used to derive the benthic sub-index score, however; the purpose of multiple metric scoring is to reduce the impact that errors for one can have on the overall score. As the density of individuals for a given taxon increased, the individual probability of detection for that taxon also generally increased. Even at low densities, larger taxa or highly motile taxa appear to have reasonably high probabilities of detection.

Probabilities of detection at a community level (with regard to taxa richness) ranged between 0.7 and 1.0, with the exception of two samples with detection probabilities of 0.5. In the two instances where probabilities of detection were less than 0.7 for the overall benthic community, samples were collected during 2003 and 2007. Since that time, improvements to the field protocol have included the additional assurance that at least one senior entomologist will always be present in the field crew. This may decrease the likelihood of having a community level probability of detection that is lower than 0.7. Analysis found significant differences in mean detection probabilities, indicating that no one probability detection can fit every site in Austin. For the purposes of City of Austin bioassessments, community level detection probabilities greater than 0.7 appear to be sufficient to adequately characterize the sites being sampled for EII scores.

The detection probabilities were used as input variables in sensitivity and uncertainty analyses. The results from these analyses showed that detection probabilities for the more pollution intolerant taxa can be as low as 10% without affecting the overall total EII score by more than 0.5 points (or equivalently, by more than 6 points in the Benthic Sub-index score. See Figure 8). Furthermore, by varying the detection probabilities of several taxa at once it was demonstrated that there was a 1% chance of deviating from the overall EII score by 1 point at any given site within a single year. Therefore, the impact on the overall EII scores, due to small to moderate errors for community level sampling of macroinvertebrates, was not significant based on preliminary sensitivity and uncertainty analyses. The resilience of the overall EII score is in part due to the use of more than one sub-index, which lowers the impact that an error within any one of them can have on the overall EII score.

Recommendations

Based on the findings of this report and input from senior field staff, the following items are recommended:

- Discontinue the collection of QC detritus samples
- Supplement the annual biology/habitat Staff training with additional instruction on sample collection, to include:
    - Dislodging of adherent taxa from substrate such as limpits, water pennies, chironomidae cases, etc.
    - Attention to small taxa such as chironomidae, ostracods and ceratopogonidae, etc.
    - Attention less motile taxa such as elmidae
- Revise the Standard Operating Procedures to include guidance/requirements for subsampling where an excessive amount of detritus or algae is present, in addition to the current requirements for samples with a high density of individuals.
- Initiate an analysis of the Diatom replicate samples to determine if similar conclusions/recommendations can be applied to diatom protocols (i.e. discontinue diatom replicates if historic data indicates sufficiently low variability and/or error).

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Appendix A: Probabilities of Detection for Individual Taxa at Sample Sites with Repeated Collection Efforts

Macroinvertebrate Taxon	Site #	Site Name	Date	Surber	Detritus QC	Total	% Detect
AMBRYSUS	118	Shoal Creek d/s Crosscreek Dr	12/13/05	2	0	2	1.000
AMBRYSUS	118	Shoal Creek d/s Crosscreek Dr	07/07/06	3	2	5	0.600
ARGIA	118	Shoal Creek d/s Crosscreek Dr	12/13/05	19	0	19	1.000
ARGIA	118	Shoal Creek d/s Crosscreek Dr	07/07/06	1	0	1	1.000
ARGIA	241	Onion Creek u/s Footbridge	08/16/06	18	2	20	0.900
ARGIA	241	Onion Creek u/s Footbridge	09/23/08	13	1	14	0.929
ARGIA	349	Bull Creek u/s Tributary 7	06/12/08	51	0	51	1.000
ARGIA	349	Bull Creek u/s Tributary 7	09/10/08	1	0	1	1.000
ARGIA	464	Walnut Creek d/s IH35	08/31/05	5	0	5	1.000
ARGIA	464	Walnut Creek d/s IH35	08/10/06	6	0	6	1.000
ARGIA	464	Walnut Creek d/s IH35	08/21/07	17	0	17	1.000
ARGIA	502	Walnut Creek @ Old Manor Rd	11/12/99	24	0	24	1.000
ARGIA	502	Walnut Creek @ Old Manor Rd	08/02/04	2	0	2	1.000
ARGIA	502	Walnut Creek @ Old Manor Rd	09/10/04	1	0	1	1.000
ARGIA	502	Walnut Creek @ Old Manor Rd	08/11/06	21	6	27	0.778
ARGIA	895	Walnut Creek d/s Metric Blvd	06/13/06	10	2	12	0.833
ARGIA	895	Walnut Creek d/s Metric Blvd	05/23/07	2	0	2	1.000
ARGIA	1192	Gilleland Creek @ FM 973	06/17/05	3	0	3	1.000
ARGIA	1192	Gilleland Creek @ FM 973	08/18/06	7	0	7	1.000
BRECHMORHOGA MENDAX	241	Onion Creek u/s Footbridge	08/16/06	1	0	1	1.000
BRECHMORHOGA MENDAX	241	Onion Creek u/s Footbridge	09/23/08	3	0	3	1.000
BRECHMORHOGA MENDAX	464	Walnut Creek d/s IH35	08/10/06	1	0	1	1.000
BRECHMORHOGA MENDAX	464	Walnut Creek d/s IH35	08/21/07	2	0	2	1.000
BRECHMORHOGA MENDAX	502	Walnut Creek @ Old Manor Rd	08/02/04	1	0	1	1.000
BRECHMORHOGA MENDAX	502	Walnut Creek @ Old Manor Rd	09/10/04	5	1	6	0.833
BRECHMORHOGA MENDAX	502	Walnut Creek @ Old Manor Rd	08/11/06	5	2	7	0.714
CAMELOBAETIDIUS	464	Walnut Creek d/s IH35	07/30/04	6	1	7	0.857
CAMELOBAETIDIUS	464	Walnut Creek d/s IH35	05/20/05	29	0	29	1.000
CAMELOBAETIDIUS	464	Walnut Creek d/s IH35	08/31/05	13	2	15	0.867
CAMELOBAETIDIUS	464	Walnut Creek d/s IH35	08/10/06	1	0	1	1.000
CAMELOBAETIDIUS	464	Walnut Creek d/s IH35	08/21/07	14	0	14	1.000
CAMELOBAETIDIUS	502	Walnut Creek @ Old Manor Rd	08/02/04	1	0	1	1.000
CAMELOBAETIDIUS	502	Walnut Creek @ Old Manor Rd	09/10/04	8	0	8	1.000
CAMELOBAETIDIUS	895	Walnut Creek d/s Metric Blvd	06/13/06	2	0	2	1.000
CAMELOBAETIDIUS	895	Walnut Creek d/s Metric Blvd	05/23/07	3	0	3	1.000
CAMELOBAETIDIUS	1192	Gilleland Creek @ FM 973	06/17/05	4	0	4	1.000
CAMELOBAETIDIUS	1192	Gilleland Creek @ FM 973	08/18/06	1	0	1	1.000
CHEUMATOPSYCHE	118	Shoal Creek d/s Crosscreek Dr	12/13/05	2	0	2	1.000
CHEUMATOPSYCHE	118	Shoal Creek d/s Crosscreek Dr	07/07/06	0	1	1	0.000
CHEUMATOPSYCHE	241	Onion Creek u/s Footbridge	08/16/06	9	0	9	1.000
CHEUMATOPSYCHE	241	Onion Creek u/s Footbridge	09/23/08	64	12	76	0.842
CHEUMATOPSYCHE	349	Bull Creek u/s Tributary 7	04/11/07	5	0	5	1.000
CHEUMATOPSYCHE	349	Bull Creek u/s Tributary 7	06/12/08	21	2	23	0.913
CHEUMATOPSYCHE	464	Walnut Creek d/s IH35	07/30/04	3	2	5	0.600
CHEUMATOPSYCHE	464	Walnut Creek d/s IH35	05/20/05	95	23	118	0.805
CHEUMATOPSYCHE	464	Walnut Creek d/s IH35	08/31/05	40	9	49	0.816
CHEUMATOPSYCHE	464	Walnut Creek d/s IH35	08/10/06	39	2	41	0.951
CHEUMATOPSYCHE	464	Walnut Creek d/s IH35	08/21/07	54	23	77	0.701
CHEUMATOPSYCHE	502	Walnut Creek @ Old Manor Rd	08/02/04	13	0	13	1.000
CHEUMATOPSYCHE	502	Walnut Creek @ Old Manor Rd	09/10/04	19	3	22	0.864
CHEUMATOPSYCHE	502	Walnut Creek @ Old Manor Rd	08/11/06	36	24	60	0.600
CHEUMATOPSYCHE	895	Walnut Creek d/s Metric Blvd	06/13/06	153	22	175	0.874
CHEUMATOPSYCHE	895	Walnut Creek d/s Metric Blvd	05/23/07	84	39	123	0.683
CHEUMATOPSYCHE	1192	Gilleland Creek @ FM 973	06/17/05	111	31	142	0.782
CHEUMATOPSYCHE	1192	Gilleland Creek @ FM 973	08/18/06	48	4	52	0.923
CHEUMATOPSYCHE	3977	Bull Creek Trib 8 u/s Bull Creek	04/05/07	1	0	1	1.000
CHEUMATOPSYCHE	3977	Bull Creek Trib 8 u/s Bull Creek	08/14/07	13	0	13	1.000

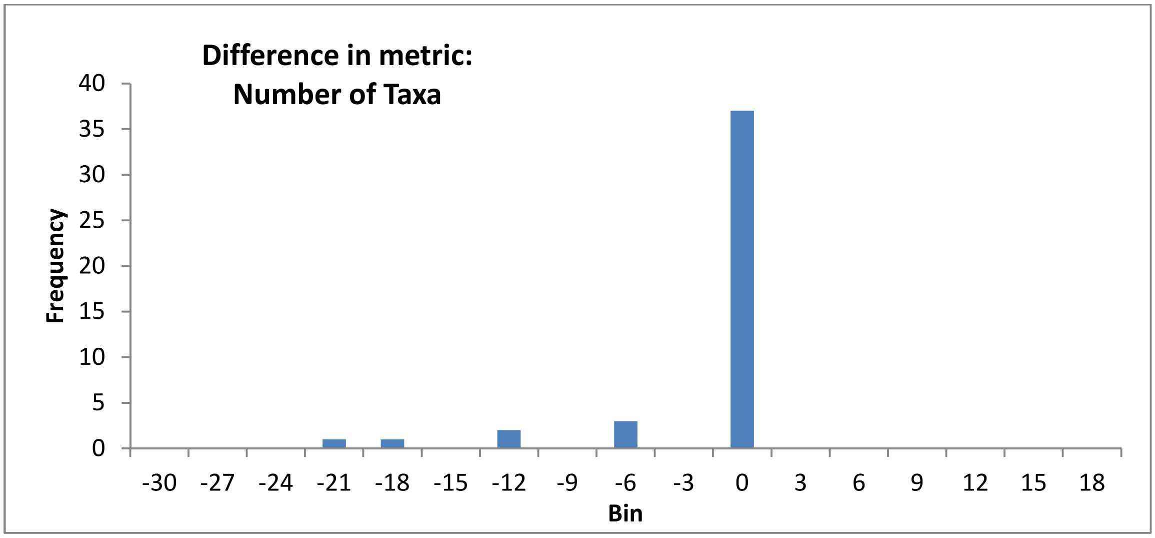
Macroinvertebrate Taxon	Site #	Site Name	Date	Surber	Detritus QC	Total	% Detect
CHIMARRA	464	Walnut Creek d/s IH35	07/30/04	5	1	6	0.833
CHIMARRA	464	Walnut Creek d/s IH35	05/20/05	7	1	8	0.875
CHIMARRA	464	Walnut Creek d/s IH35	08/31/05	118	6	124	0.952
CHIMARRA	464	Walnut Creek d/s IH35	08/10/06	27	1	28	0.964
CHIMARRA	464	Walnut Creek d/s IH35	08/21/07	323	3	326	0.991
CHIMARRA	502	Walnut Creek @ Old Manor Rd	11/12/99	35	0	35	1.000
CHIMARRA	502	Walnut Creek @ Old Manor Rd	02/22/00	1	0	1	1.000
CHIMARRA	502	Walnut Creek @ Old Manor Rd	08/02/04	2	0	2	1.000
CHIMARRA	502	Walnut Creek @ Old Manor Rd	09/10/04	104	9	113	0.920
CHIMARRA	502	Walnut Creek @ Old Manor Rd	08/11/06	22	1	23	0.957
CHIMARRA	3977	Bull Creek Trib 8 u/s Bull Creek	04/05/07	2	0	2	1.000
CHIMARRA	3977	Bull Creek Trib 8 u/s Bull Creek	08/14/07	16	0	16	1.000
CHIRONOMIDAE	118	Shoal Creek d/s Crosscreek Dr	12/13/05	74	12	86	0.860
CHIRONOMIDAE	118	Shoal Creek d/s Crosscreek Dr	07/07/06	52	27	79	0.658
CHIRONOMIDAE	241	Onion Creek u/s Footbridge	08/16/06	10	4	14	0.714
CHIRONOMIDAE	241	Onion Creek u/s Footbridge	09/23/08	15	1	16	0.938
CHIRONOMIDAE	349	Bull Creek u/s Tributary 7	04/11/07	0	25	25	0.000
CHIRONOMIDAE	349	Bull Creek u/s Tributary 7	06/12/08	11	5	16	0.688
CHIRONOMIDAE	349	Bull Creek u/s Tributary 7	09/10/08	20	9	29	0.690
CHIRONOMIDAE	464	Walnut Creek d/s IH35	07/30/04	0	1	1	0.000
CHIRONOMIDAE	464	Walnut Creek d/s IH35	05/20/05	66	35	101	0.653
CHIRONOMIDAE	464	Walnut Creek d/s IH35	08/31/05	28	1	29	0.966
CHIRONOMIDAE	464	Walnut Creek d/s IH35	08/10/06	2	0	2	1.000
CHIRONOMIDAE	464	Walnut Creek d/s IH35	08/21/07	66	0	66	1.000
CHIRONOMIDAE	502	Walnut Creek @ Old Manor Rd	11/12/99	26	10	36	0.722
CHIRONOMIDAE	502	Walnut Creek @ Old Manor Rd	02/22/00	0	32	32	0.000
CHIRONOMIDAE	502	Walnut Creek @ Old Manor Rd	08/02/04	0	1	1	0.000
CHIRONOMIDAE	502	Walnut Creek @ Old Manor Rd	09/10/04	0	4	4	0.000
CHIRONOMIDAE	502	Walnut Creek @ Old Manor Rd	08/11/06	0	3	3	0.000
CHIRONOMIDAE	1192	Gilleland Creek @ FM 973	06/17/05	15	21	36	0.417
CHIRONOMIDAE	1192	Gilleland Creek @ FM 973	08/18/06	1	0	1	1.000
CHIRONOMIDAE	3977	Bull Creek Trib 8 u/s Bull Creek	04/05/07	0	10	10	0.000
CHIRONOMIDAE	3977	Bull Creek Trib 8 u/s Bull Creek	08/14/07	0	3	3	0.000
CHIRONOMINAE	464	Walnut Creek d/s IH35	08/21/07	0	1	1	0.000
CHIRONOMINAE	464	Walnut Creek d/s IH35	08/21/07	0	85	85	0.000
CHIRONOMINAE	502	Walnut Creek @ Old Manor Rd	02/22/00	43	0	43	1.000
CHIRONOMINAE	502	Walnut Creek @ Old Manor Rd	09/10/04	4	2	6	0.667
Cincinnatia Cincinnatiensis	241	Onion Creek u/s Footbridge	08/16/06	3	0	3	1.000
Cincinnatia Cincinnatiensis	241	Onion Creek u/s Footbridge	09/23/08	1	2	3	0.333
CORBICULA FLUMINEA	241	Onion Creek u/s Footbridge	08/16/06	21	0	21	1.000
CORBICULA FLUMINEA	241	Onion Creek u/s Footbridge	09/23/08	0	1	1	0.000
CORYDALUS CORNUTUS	241	Onion Creek u/s Footbridge	08/16/06	1	0	1	1.000
CORYDALUS CORNUTUS	241	Onion Creek u/s Footbridge	09/23/08	1	0	1	1.000
DASYHELEA	118	Shoal Creek d/s Crosscreek Dr	12/13/05	3	0	3	1.000
DASYHELEA	118	Shoal Creek d/s Crosscreek Dr	07/07/06	1	2	3	0.333
DUGESIA TIGRINA	118	Shoal Creek d/s Crosscreek Dr	12/13/05	24	0	24	1.000
DUGESIA TIGRINA	118	Shoal Creek d/s Crosscreek Dr	07/07/06	41	3	44	0.932
DUGESIA TIGRINA	241	Onion Creek u/s Footbridge	08/16/06	2	2	4	0.500
DUGESIA TIGRINA	241	Onion Creek u/s Footbridge	09/23/08	14	3	17	0.824
DUGESIA TIGRINA	464	Walnut Creek d/s IH35	07/30/04	6	0	6	1.000
DUGESIA TIGRINA	464	Walnut Creek d/s IH35	05/20/05	47	0	47	1.000
DUGESIA TIGRINA	464	Walnut Creek d/s IH35	08/31/05	18	0	18	1.000
DUGESIA TIGRINA	464	Walnut Creek d/s IH35	08/10/06	6	0	6	1.000
DUGESIA TIGRINA	464	Walnut Creek d/s IH35	08/21/07	47	2	49	0.959
DUGESIA TIGRINA	502	Walnut Creek @ Old Manor Rd	11/12/99	44	0	44	1.000
DUGESIA TIGRINA	502	Walnut Creek @ Old Manor Rd	02/22/00	3	0	3	1.000
DUGESIA TIGRINA	502	Walnut Creek @ Old Manor Rd	08/02/04	3	0	3	1.000
DUGESIA TIGRINA	502	Walnut Creek @ Old Manor Rd	09/10/04	37	2	39	0.949
DUGESIA TIGRINA	502	Walnut Creek @ Old Manor Rd	08/11/06	5	3	8	0.625
DUGESIA TIGRINA	895	Walnut Creek d/s Metric Blvd	06/13/06	4	0	4	1.000
DUGESIA TIGRINA	895	Walnut Creek d/s Metric Blvd	05/23/07	7	3	10	0.700
DUGESIA TIGRINA	1192	Gilleland Creek @ FM 973	06/17/05	3	1	4	0.750

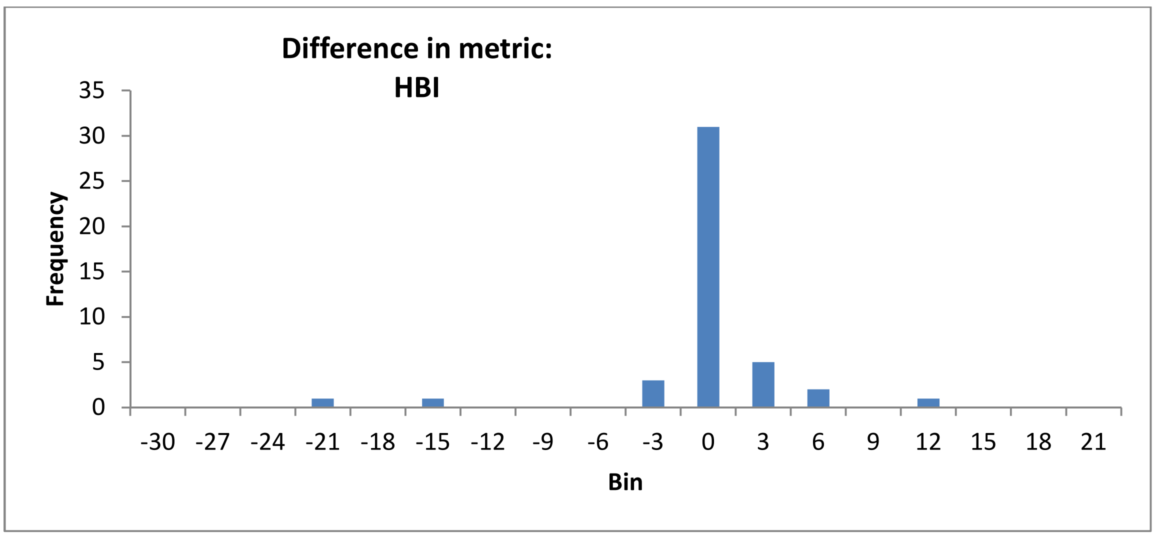
Macroinvertebrate Taxon	Site #	Site Name	Date	Surber	Detritus QC	Total	% Detect
DUGESIA TIGRINA	1192	Gilleland Creek @ FM 973	08/18/06	5	0	5	1.000
FALLCEON	118	Shoal Creek d/s Crosscreek Dr	12/13/05	6	0	6	1.000
FALLCEON	118	Shoal Creek d/s Crosscreek Dr	07/07/06	6	0	6	1.000
FALLCEON	349	Bull Creek u/s Tributary 7	04/11/07	34	0	34	1.000
FALLCEON	349	Bull Creek u/s Tributary 7	06/12/08	34	1	35	0.971
FALLCEON	464	Walnut Creek d/s IH35	07/30/04	1	0	1	1.000
FALLCEON	464	Walnut Creek d/s IH35	05/20/05	66	0	66	1.000
FALLCEON	464	Walnut Creek d/s IH35	08/31/05	21	0	21	1.000
FALLCEON	464	Walnut Creek d/s IH35	08/10/06	4	0	4	1.000
FALLCEON	464	Walnut Creek d/s IH35	08/21/07	18	1	19	0.947
FALLCEON	502	Walnut Creek @ Old Manor Rd	11/12/99	75	0	75	1.000
FALLCEON	502	Walnut Creek @ Old Manor Rd	08/02/04	4	1	5	0.800
FALLCEON	502	Walnut Creek @ Old Manor Rd	09/10/04	57	11	68	0.838
FALLCEON	502	Walnut Creek @ Old Manor Rd	08/11/06	6	4	10	0.600
FALLCEON	895	Walnut Creek d/s Metric Blvd	06/13/06	44	4	48	0.917
FALLCEON	895	Walnut Creek d/s Metric Blvd	05/23/07	4	4	8	0.500
FALLCEON	1192	Gilleland Creek @ FM 973	06/17/05	61	3	64	0.953
FALLCEON	1192	Gilleland Creek @ FM 973	08/18/06	11	0	11	1.000
FALLCEON	3977	Bull Creek Trib 8 u/s Bull Creek	04/05/07	7	0	7	1.000
FALLCEON	3977	Bull Creek Trib 8 u/s Bull Creek	08/14/07	1	0	1	1.000
FARRODES TEXANUS	464	Walnut Creek d/s IH35	08/31/05	2	0	2	1.000
FARRODES TEXANUS	464	Walnut Creek d/s IH35	08/10/06	2	0	2	1.000
FERRISSIA	241	Onion Creek u/s Footbridge	08/16/06	7	4	11	0.636
FERRISSIA	241	Onion Creek u/s Footbridge	09/23/08	1	1	2	0.500
GYRAULUS	118	Shoal Creek d/s Crosscreek Dr	12/13/05	1	0	1	1.000
GYRAULUS	118	Shoal Creek d/s Crosscreek Dr	07/07/06	20	3	23	0.870
HELICOPSYCHE	464	Walnut Creek d/s IH35	05/20/05	18	0	18	1.000
HELICOPSYCHE	464	Walnut Creek d/s IH35	08/31/05	2	0	2	1.000
HELICOPSYCHE	1192	Gilleland Creek @ FM 973	06/17/05	3	0	3	1.000
HELICOPSYCHE	1192	Gilleland Creek @ FM 973	08/18/06	14	0	14	1.000
HELISOMA ANCEPS	118	Shoal Creek d/s Crosscreek Dr	12/13/05	1	0	1	1.000
HELISOMA ANCEPS	118	Shoal Creek d/s Crosscreek Dr	07/07/06	24	1	25	0.960
HEMERODROMIA	464	Walnut Creek d/s IH35	05/20/05	1	0	1	1.000
HEMERODROMIA	464	Walnut Creek d/s IH35	08/21/07	1	0	1	1.000
HETERELMIS	1192	Gilleland Creek @ FM 973	06/17/05	11	0	11	1.000
HETERELMIS	1192	Gilleland Creek @ FM 973	08/18/06	1	0	1	1.000
Hexaculloepus Ferrugineus	1192	Gilleland Creek @ FM 973	06/17/05	32	0	32	1.000
Hexaculloepus Ferrugineus	1192	Gilleland Creek @ FM 973	08/18/06	7	1	8	0.875
HYALELLA	241	Onion Creek u/s Footbridge	08/16/06	2	0	2	1.000
HYALELLA	241	Onion Creek u/s Footbridge	09/23/08	1	0	1	1.000
HYALELLA	349	Bull Creek u/s Tributary 7	06/12/08	6	0	6	1.000
HYALELLA	349	Bull Creek u/s Tributary 7	09/10/08	20	0	20	1.000
HYDRACARINA	464	Walnut Creek d/s IH35	05/20/05	12	0	12	1.000
HYDRACARINA	464	Walnut Creek d/s IH35	08/10/06	3	0	3	1.000
HYDRACARINA	502	Walnut Creek @ Old Manor Rd	11/12/99	2	0	2	1.000
HYDRACARINA	502	Walnut Creek @ Old Manor Rd	02/22/00	1	0	1	1.000
HYDRACARINA	502	Walnut Creek @ Old Manor Rd	09/10/04	1	0	1	1.000
HYDRACARINA	502	Walnut Creek @ Old Manor Rd	08/11/06	37	2	39	0.949
HYDROPTILA	502	Walnut Creek @ Old Manor Rd	11/12/99	1	0	1	1.000
HYDROPTILA	502	Walnut Creek @ Old Manor Rd	02/22/00	2	0	2	1.000
HYDROPTILA	502	Walnut Creek @ Old Manor Rd	08/11/06	1	0	1	1.000
ISONYCHIA	1192	Gilleland Creek @ FM 973	06/17/05	1	0	1	1.000
ISONYCHIA	1192	Gilleland Creek @ FM 973	08/18/06	7	0	7	1.000
LIMONIA	118	Shoal Creek d/s Crosscreek Dr	12/13/05	9	0	9	1.000
LIMONIA	118	Shoal Creek d/s Crosscreek Dr	07/07/06	0	15	15	0.000
MACRELMIS	241	Onion Creek u/s Footbridge	08/16/06	5	0	5	1.000
MACRELMIS	241	Onion Creek u/s Footbridge	09/23/08	2	0	2	1.000
MACRELMIS	349	Bull Creek u/s Tributary 7	06/12/08	0	1	1	0.000
MACRELMIS	349	Bull Creek u/s Tributary 7	09/10/08	3	0	3	1.000
MACRELMIS	464	Walnut Creek d/s IH35	07/30/04	7	1	8	0.875
MACRELMIS	464	Walnut Creek d/s IH35	05/20/05	42	0	42	1.000
MACRELMIS	464	Walnut Creek d/s IH35	08/31/05	50	2	52	0.962

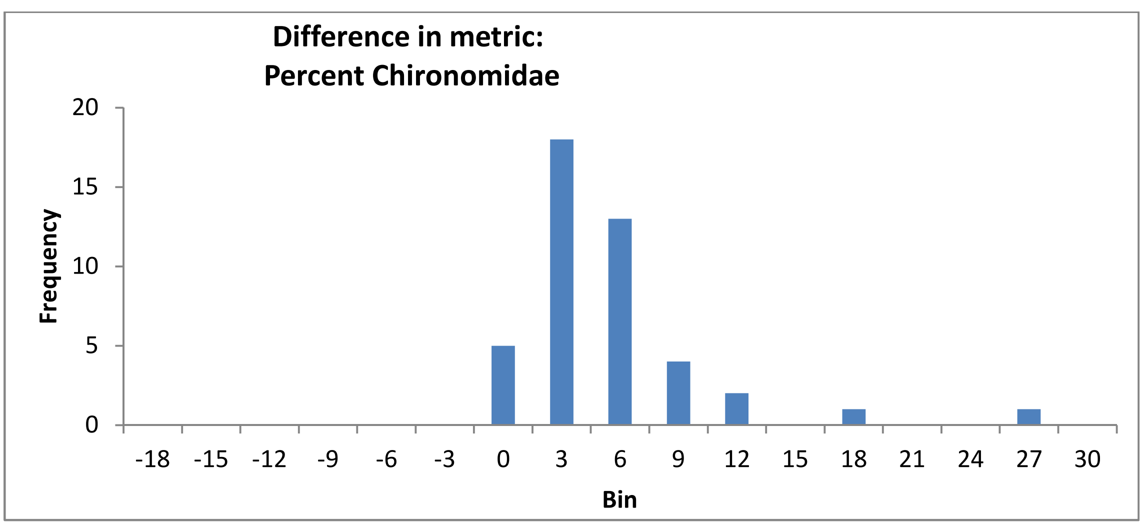
Macroinvertebrate Taxon	Site #	Site Name	Date	Surber	Detritus QC	Total	% Detect
MACRELMIS	464	Walnut Creek d/s IH35	08/10/06	27	3	30	0.900
MACRELMIS	464	Walnut Creek d/s IH35	08/21/07	73	2	75	0.973
MACRELMIS	502	Walnut Creek @ Old Manor Rd	11/12/99	15	0	15	1.000
MACRELMIS	502	Walnut Creek @ Old Manor Rd	08/02/04	11	0	11	1.000
MACRELMIS	502	Walnut Creek @ Old Manor Rd	09/10/04	39	2	41	0.951
MACRELMIS	502	Walnut Creek @ Old Manor Rd	08/11/06	25	7	32	0.781
MACRELMIS	895	Walnut Creek d/s Metric Blvd	06/13/06	1	0	1	1.000
MACRELMIS	895	Walnut Creek d/s Metric Blvd	05/23/07	2	0	2	1.000
METRICHIA	464	Walnut Creek d/s IH35	05/20/05	6	0	6	1.000
METRICHIA	464	Walnut Creek d/s IH35	08/31/05	1	0	1	1.000
METRICHIA	464	Walnut Creek d/s IH35	08/21/07	0	1	1	0.000
Microcylloepus Pusillus	241	Onion Creek u/s Footbridge	08/16/06	12	0	12	1.000
Microcylloepus Pusillus	241	Onion Creek u/s Footbridge	09/23/08	2	2	4	0.500
Microcylloepus Pusillus	464	Walnut Creek d/s IH35	07/30/04	0	1	1	0.000
Microcylloepus Pusillus	464	Walnut Creek d/s IH35	05/20/05	2	0	2	1.000
Microcylloepus Pusillus	464	Walnut Creek d/s IH35	08/31/05	4	2	6	0.667
Microcylloepus Pusillus	464	Walnut Creek d/s IH35	08/10/06	10	4	14	0.714
Microcylloepus Pusillus	464	Walnut Creek d/s IH35	08/21/07	14	1	15	0.933
Microcylloepus Pusillus	502	Walnut Creek @ Old Manor Rd	11/12/99	11	0	11	1.000
Microcylloepus Pusillus	502	Walnut Creek @ Old Manor Rd	02/22/00	15	0	15	1.000
Microcylloepus Pusillus	502	Walnut Creek @ Old Manor Rd	08/02/04	5	0	5	1.000
Microcylloepus Pusillus	502	Walnut Creek @ Old Manor Rd	09/10/04	4	0	4	1.000
Microcylloepus Pusillus	502	Walnut Creek @ Old Manor Rd	08/11/06	10	1	11	0.909
NEOELMIS CAESA	464	Walnut Creek d/s IH35	07/30/04	1	1	2	0.500
NEOELMIS CAESA	464	Walnut Creek d/s IH35	05/20/05	8	1	9	0.889
NEOELMIS CAESA	464	Walnut Creek d/s IH35	08/31/05	17	5	22	0.773
NEOELMIS CAESA	464	Walnut Creek d/s IH35	08/10/06	3	0	3	1.000
NEOELMIS CAESA	464	Walnut Creek d/s IH35	08/21/07	23	0	23	1.000
NEOELMIS CAESA	502	Walnut Creek @ Old Manor Rd	11/12/99	4	0	4	1.000
NEOELMIS CAESA	502	Walnut Creek @ Old Manor Rd	08/02/04	11	2	13	0.846
NEOELMIS CAESA	502	Walnut Creek @ Old Manor Rd	09/10/04	43	13	56	0.768
NEOELMIS CAESA	502	Walnut Creek @ Old Manor Rd	08/11/06	6	5	11	0.545
NEOELMIS CAESA	1192	Gilleland Creek @ FM 973	06/17/05	10	8	18	0.556
NEOELMIS CAESA	1192	Gilleland Creek @ FM 973	08/18/06	3	0	3	1.000
OECETIS	1192	Gilleland Creek @ FM 973	06/17/05	5	0	5	1.000
OECETIS	1192	Gilleland Creek @ FM 973	08/18/06	2	0	2	1.000
OSTRACODA	241	Onion Creek u/s Footbridge	08/16/06	1	0	1	1.000
OSTRACODA	241	Onion Creek u/s Footbridge	09/23/08	0	2	2	0.000
OSTRACODA	464	Walnut Creek d/s IH35	05/20/05	3	0	3	1.000
OSTRACODA	464	Walnut Creek d/s IH35	08/10/06	2	1	3	0.667
PETROPHILA (MOTH)	464	Walnut Creek d/s IH35	05/20/05	2	2	4	0.500
PETROPHILA (MOTH)	464	Walnut Creek d/s IH35	08/31/05	0	1	1	0.000
PETROPHILA (MOTH)	464	Walnut Creek d/s IH35	08/10/06	7	1	8	0.875
PETROPHILA (MOTH)	464	Walnut Creek d/s IH35	08/21/07	1	0	1	1.000
PETROPHILA (MOTH)	1192	Gilleland Creek @ FM 973	06/17/05	22	6	28	0.786
PETROPHILA (MOTH)	1192	Gilleland Creek @ FM 973	08/18/06	2	0	2	1.000
PHYLLOICUS ORNATUS	349	Bull Creek u/s Tributary 7	06/12/08	1	0	1	1.000
PHYLLOICUS ORNATUS	349	Bull Creek u/s Tributary 7	09/10/08	5	0	5	1.000
PHYSELLA	118	Shoal Creek d/s Crosscreek Dr	12/13/05	6	0	6	1.000
PHYSELLA	118	Shoal Creek d/s Crosscreek Dr	07/07/06	12	0	12	1.000
PSEPHENUS	241	Onion Creek u/s Footbridge	08/16/06	70	21	91	0.769
PSEPHENUS	241	Onion Creek u/s Footbridge	09/23/08	39	48	87	0.448
PSEPHENUS	349	Bull Creek u/s Tributary 7	04/11/07	16	0	16	1.000
PSEPHENUS	349	Bull Creek u/s Tributary 7	06/12/08	13	1	14	0.929
PSEPHENUS	349	Bull Creek u/s Tributary 7	09/10/08	82	2	84	0.976
PSEPHENUS	464	Walnut Creek d/s IH35	07/30/04	2	0	2	1.000
PSEPHENUS	464	Walnut Creek d/s IH35	08/31/05	2	1	3	0.667
PSEPHENUS	464	Walnut Creek d/s IH35	08/10/06	2	0	2	1.000
PSEPHENUS	464	Walnut Creek d/s IH35	08/21/07	14	1	15	0.933
PSEPHENUS	502	Walnut Creek @ Old Manor Rd	11/12/99	17	0	17	1.000
PSEPHENUS	502	Walnut Creek @ Old Manor Rd	02/22/00	1	0	1	1.000
PSEPHENUS	502	Walnut Creek @ Old Manor Rd	08/02/04	19	0	19	1.000

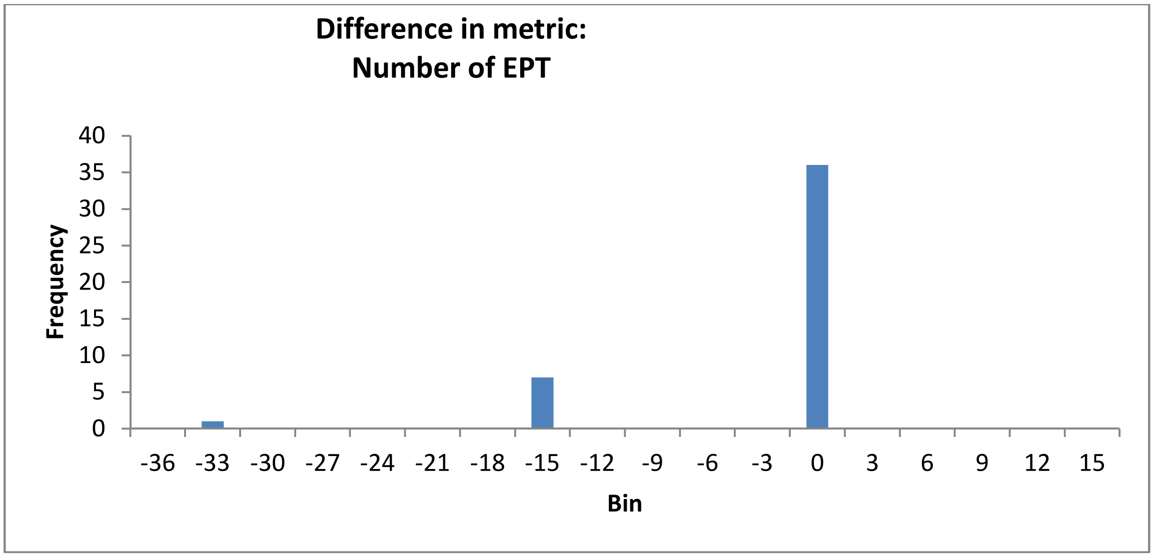
Macroinvertebrate Taxon	Site #	Site Name	Date	Surber	Detritus QC	Total	% Detect
PSEPHENUS	502	Walnut Creek @ Old Manor Rd	09/10/04	4	0	4	1.000
PSEPHENUS	502	Walnut Creek @ Old Manor Rd	08/11/06	0	3	3	0.000
PSEPHENUS	895	Walnut Creek d/s Metric Blvd	06/13/06	13	0	13	1.000
PSEPHENUS	895	Walnut Creek d/s Metric Blvd	05/23/07	5	1	6	0.833
PSEPHENUS	1192	Gilleland Creek @ FM 973	06/17/05	22	11	33	0.667
PSEPHENUS	1192	Gilleland Creek @ FM 973	08/18/06	19	4	23	0.826
RHAGOVELIA	464	Walnut Creek d/s IH35	08/31/05	2	0	2	1.000
RHAGOVELIA	464	Walnut Creek d/s IH35	08/10/06	10	0	10	1.000
RHAGOVELIA	464	Walnut Creek d/s IH35	08/21/07	2	0	2	1.000
SIMULIUM	349	Bull Creek u/s Tributary 7	04/11/07	17	0	17	1.000
SIMULIUM	349	Bull Creek u/s Tributary 7	06/12/08	7	0	7	1.000
SIMULIUM	464	Walnut Creek d/s IH35	05/20/05	1	0	1	1.000
SIMULIUM	464	Walnut Creek d/s IH35	08/21/07	2	0	2	1.000
SIMULIUM	502	Walnut Creek @ Old Manor Rd	11/12/99	7	0	7	1.000
SIMULIUM	502	Walnut Creek @ Old Manor Rd	02/22/00	12	0	12	1.000
SIMULIUM	502	Walnut Creek @ Old Manor Rd	09/10/04	0	1	1	0.000
SIMULIUM	895	Walnut Creek d/s Metric Blvd	06/13/06	15	1	16	0.938
SIMULIUM	895	Walnut Creek d/s Metric Blvd	05/23/07	13	1	14	0.929
SIMULIUM	3977	Bull Creek Trib 8 u/s Bull Creek	04/05/07	3	0	3	1.000
SIMULIUM	3977	Bull Creek Trib 8 u/s Bull Creek	08/14/07	2	0	2	1.000
SMICRIDEA	1192	Gilleland Creek @ FM 973	06/17/05	14	3	17	0.824
SMICRIDEA	1192	Gilleland Creek @ FM 973	08/18/06	22	3	25	0.880
STENELMIS	241	Onion Creek u/s Footbridge	08/16/06	15	5	20	0.750
STENELMIS	241	Onion Creek u/s Footbridge	09/23/08	1	1	2	0.500
STENELMIS	464	Walnut Creek d/s IH35	07/30/04	1	0	1	1.000
STENELMIS	464	Walnut Creek d/s IH35	05/20/05	1	0	1	1.000
STENELMIS	464	Walnut Creek d/s IH35	08/31/05	1	0	1	1.000
STENELMIS	464	Walnut Creek d/s IH35	08/21/07	3	0	3	1.000
STENELMIS	502	Walnut Creek @ Old Manor Rd	11/12/99	2	0	2	1.000
STENELMIS	502	Walnut Creek @ Old Manor Rd	08/02/04	1	0	1	1.000
STENELMIS	895	Walnut Creek d/s Metric Blvd	06/13/06	1	0	1	1.000
STENELMIS	895	Walnut Creek d/s Metric Blvd	05/23/07	5	0	5	1.000
STENELMIS	1192	Gilleland Creek @ FM 973	06/17/05	43	17	60	0.717
STENELMIS	1192	Gilleland Creek @ FM 973	08/18/06	5	0	5	1.000
TANYPODINAE	118	Shoal Creek d/s Crosscreek Dr	12/13/05	61	0	61	1.000
TANYPODINAE	118	Shoal Creek d/s Crosscreek Dr	07/07/06	10	5	15	0.667
TANYPODINAE	349	Bull Creek u/s Tributary 7	06/12/08	10	1	11	0.909
TANYPODINAE	349	Bull Creek u/s Tributary 7	09/10/08	2	1	3	0.667
TANYPODINAE	464	Walnut Creek d/s IH35	05/20/05	2	0	2	1.000
TANYPODINAE	464	Walnut Creek d/s IH35	08/31/05	3	1	4	0.750
TANYPODINAE	464	Walnut Creek d/s IH35	08/10/06	6	0	6	1.000
TANYPODINAE	464	Walnut Creek d/s IH35	08/21/07	0	1	1	0.000
TANYPODINAE	464	Walnut Creek d/s IH35	08/21/07	0	1	1	0.000
TANYPODINAE	502	Walnut Creek @ Old Manor Rd	02/22/00	5	0	5	1.000
TANYPODINAE	502	Walnut Creek @ Old Manor Rd	08/02/04	1	0	1	1.000
TANYPODINAE	502	Walnut Creek @ Old Manor Rd	08/11/06	5	2	7	0.714
TANYPODINAE	895	Walnut Creek d/s Metric Blvd	06/13/06	0	4	4	0.000
TANYPODINAE	895	Walnut Creek d/s Metric Blvd	05/23/07	1	0	1	1.000
THRAULODES GONZALESI	464	Walnut Creek d/s IH35	08/10/06	4	0	4	1.000
THRAULODES GONZALESI	464	Walnut Creek d/s IH35	08/21/07	3	0	3	1.000
THRAULODES GONZALESI	502	Walnut Creek @ Old Manor Rd	08/02/04	1	0	1	1.000
THRAULODES GONZALESI	502	Walnut Creek @ Old Manor Rd	09/10/04	11	2	13	0.846
THRAULODES GONZALESI	502	Walnut Creek @ Old Manor Rd	08/11/06	40	18	58	0.690
THRAULODES GONZALESI	1192	Gilleland Creek @ FM 973	06/17/05	27	4	31	0.871
THRAULODES GONZALESI	1192	Gilleland Creek @ FM 973	08/18/06	48	3	51	0.941
TRICORYTHODES	464	Walnut Creek d/s IH35	07/30/04	0	1	1	0.000
TRICORYTHODES	464	Walnut Creek d/s IH35	05/20/05	10	2	12	0.833
TRICORYTHODES	464	Walnut Creek d/s IH35	08/31/05	2	1	3	0.667
TRICORYTHODES	464	Walnut Creek d/s IH35	08/10/06	3	1	4	0.750
VACUPERNIUS PACKERI	241	Onion Creek u/s Footbridge	08/16/06	2	0	2	1.000
VACUPERNIUS PACKERI	241	Onion Creek u/s Footbridge	09/23/08	2	0	2	1.000

Appendix B: Impacts to Benthic Macroinvertebrate Metrics








Difference in metric:
Number of EPT
Frequency
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30
25
20
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10
5
0
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-33
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-21
-18
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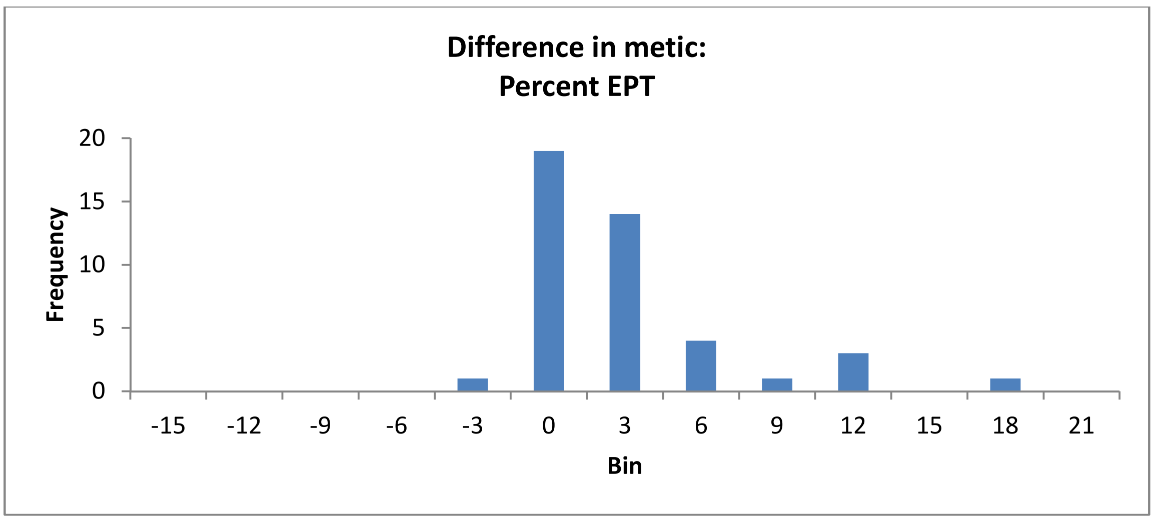
3
6
9
12
15
Bin


Difference in metic:
Percent EPT
Frequency
20
15
10
5
0
-15
-12
-9
-6
-3
0
3
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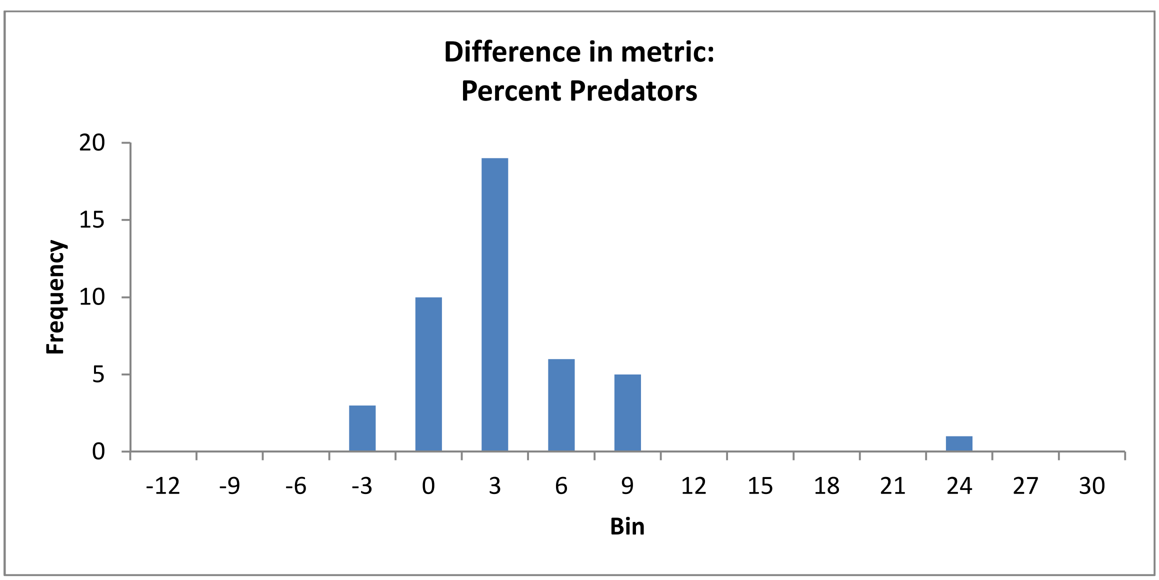
9
12
15
18
21
Bin


Difference in metric:
Percent Predators
Frequency
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15
10
5
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0
3
6
9
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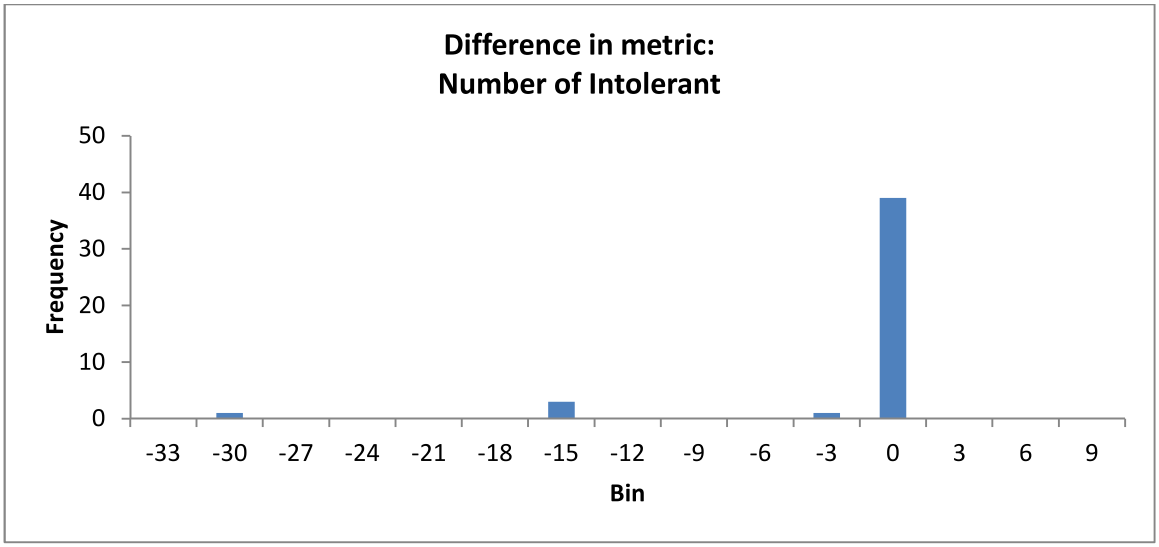
21
24
27
30
Bin


Difference in metric:
Number of Intolerant
Frequency
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30
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10
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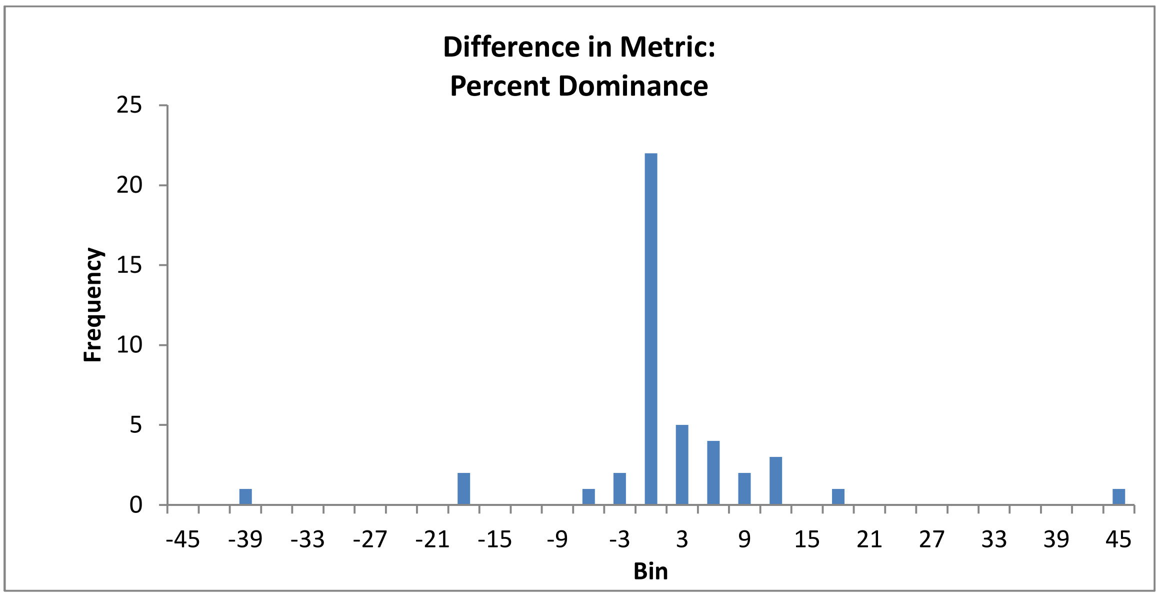
Bin


Difference in Metric:
Percent Dominance
Frequency
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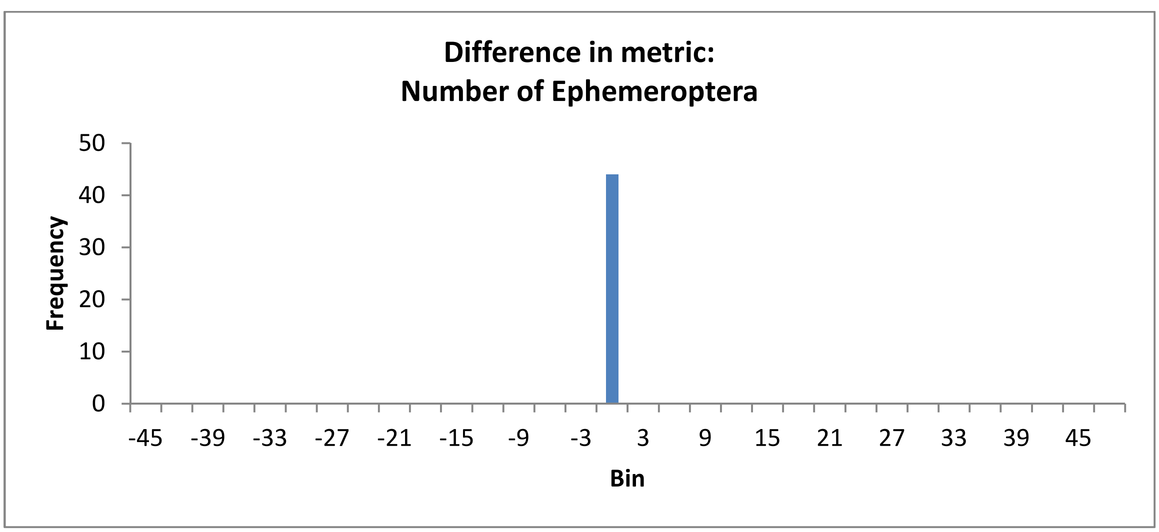
20
15
10
5
0
-45 -39 -33 -27 -21 -15 -9 -3 3 9 15 21 27 33 39 45
Bin


Difference in metric:
Number of Ephemeroptera
Frequency
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30
20
10
0
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Bin