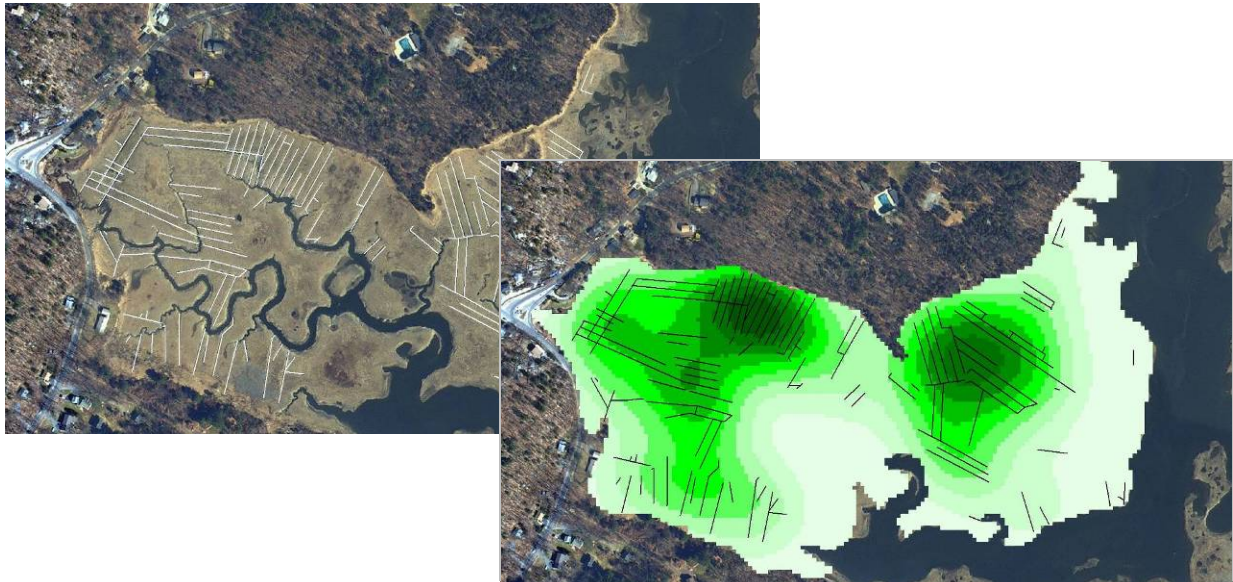# Developing Tools for More Effective Assessment of Wetlands and Aquatic Ecosystems

Final Report for Project 09-01/ARRA604



August 18, 2010

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# Developing Tools for More Effective Assessment of Wetlands and Aquatic Ecosystems

## INTRODUCTION

This report documents ongoing efforts to develop a landscape level assessment method that will inform MassDEP's wetland and water quality sampling programs. The method under development is the Conservation Assessment and Prioritization System (CAPS) developed by the University of Massachusetts at Amherst. CAPS is a central element in the developing Wetlands Assessment and Monitoring Program for Massachusetts.

The report is presented in three chapters organized around the three principle tasks and related sub-tasks.

1. Use of CAPS to identify reference sites and use of MassDEP water quality and invertebrate datasets to test CAPS metrics and test IBIs used by MassDEP

2. Development of Tidal Restriction and Salt Marsh Ditching metrics for CAPS

3. Development of Invertebrate and Algae IBIs for Forested Wetlands: Sample Identification

Project deliverables are included zip files on an accompanying DVD, and include:

- IBI Program: scripts and files for applied our IBI to stream invertebrate data

- CAPS ARRA Data: GIS data grids for the following
    - Salt marsh ditching metric results
    - Tidal restrictions metric results
    - Minimally disturbed reference sites for wetland and aquatic ecological communities
    - Least disturbed reference sites for wetland and aquatic ecological communities

- CAPS Land Cover: Not a deliverable for this project but a useful data layer for interpreting GIS grids for minimally disturbed and least disturbed reference sites. The Land Cover grid will allow users to link reference sites to the ecological communities they belong to and creation of screens (filters) to focus on particular ecological communities.

# Chapter 1

# Using CAPS to Identify Reference Sites and Use of MassDEP Water Quality and Invertebrate Data to Test CAPS Metrics and IBIs Used by MassDEP

This task involved the utilization of existing MassDEP water quality and macro invertebrate data sets for streams to test CAPS metrics. These data were also used to create a new Index of Biological Integrity (IBI) that was closely linked to CAPS IEI scores. Further, CAPS IEI data were used to test a variety of published IBIs currently in use by MassDEP and other agencies. Finally, CAPS analyses were used to identify reference conditions for future MassDEP water quality sampling and watershed assessments. Importantly, this task builds on other ongoing efforts to test CAPS metrics for upland forests, forested wetlands and salt marsh communities.

## USE OF CAPS TO IDENTIFY REFERENCE SITES

Reference sites serve as a benchmark for evaluating the degree to which other, similar sites have been altered by human activity. EPA refers to Reference Condition for Biological Integrity – "the biological condition of a [wetland or] water body undisturbed by human activity" – as a useful concept, but one that is largely hypothetical. Given that there are no places left in the world that have not been affected by human activity, such as global climate change and the atmospheric transport and deposition of human-generated contaminants, the best that we can hope to attain are sites that are minimally disturbed. Minimally disturbed reference conditions are those that occur in places with a minimal amount of human disturbance. In substantially altered landscapes there may be few, if any, sites that meet the definition of minimally disturbed. In these areas least disturbed conditions – conditions found at sites with the least amount of human disturbance – are likely to be the best reference conditions available. (Definitions from EPA's Biological Indicators of Watershed Health web site: http://www.epa.gov/bioiweb1/html/reference_condition_types.html).

The Conservation Assessment and Prioritization System (CAPS) is a tool ideally suited for identifying sites that are likely to meet the definitions of "minimally disturbed" and "least disturbed." The Conservation Assessment and Prioritization System (CAPS) is an ecosystem-based (coarse-filter) approach for assessing the ecological integrity of lands and waters and subsequently identifying and prioritizing land for habitat and biodiversity conservation. We define *ecological integrity* as the ability of an area to support biodiversity and the ecosystem processes necessary to sustain biodiversity, over the long term.

CAPS is a computer software program and an approach to prioritizing land for conservation based on the assessment of ecological integrity for various ecological communities (e.g. forest, shrub swamp, headwater stream) within an area. This approach combines principles of landscape ecology and conservation biology with the capacity of modern computers to compile spatial data and characterize landscape patterns. It is an objective and credible approach for assessing ecological integrity and supporting decision-making for land protection, habitat management, ecological restoration, project review and permitting to protect habitat and biodiversity.

The first step in the CAPS approach is the characterization of both the developed and undeveloped elements of the landscape. With a computer base map depicting various classes of developed and undeveloped land, we evaluate a variety of landscape-based variables ("metrics") to calculate an index of ecological integrity for every point in the landscape. This process results in a final "Index of Ecological Integrity" (IEI) for each point in the landscape. The CAPS IEI maps allow for the identification of those areas that are most buffered from human disturbance. CAPS generated IEI values are depended on the scale of analysis. We used IEI values from both statewide and watershed scale analyses for identification of "minimally disturbed" and "least disturbed" reference conditions.

Massachusetts has a number of areas across the state that are currently well-buffered from human activity. As a result we proceeded from an assumption that there are sites in Massachusetts that meet the definition for "minimally disturbed" for all wetland and aquatic ecological communities. We used the June 2009 statewide IEI map as the basis for identifying "minimally disturbed" sites for wetland and aquatic ecological communities in Massachusetts. Those areas that fell within the top 5% of statewide IEI values for each wetland and aquatic community were selected as "minimally disturbed" reference sites. This is equal to roughly 5% of the land area for each wetland and aquatic ecological community (a total of 5.9% of all wetland and aquatic communities combined).

To identify "least disturbed" reference sites we used June 2009 IEI data rescaled for each of the state's 28 major watersheds. We used the same cut-off of top 5%. This effectively identified the top 5% of each wetland and aquatic community, for each watershed. The definitions of "minimally disturbed" and "least disturbed" suggests that "minimally disturbed is a higher standard for reference condition. Therefore, we included all areas identified as "minimally disturbed" within the category "least disturbed." As a result areas defined as "least disturbed" account for 8.2% of wetland and aquatic communities statewide. "Least disturbed" reference sites are all areas defined as "minimally disturbed" plus any other areas that fall within the top 5% of IEI scaled by watershed.

Figure 1.1 shows the distribution of "minimally disturbed" and "least disturbed" wetland and aquatic sites for the area in and around Hubbardston in Central Massachusetts.

The GIS grid coverages for "minimally disturbed" and "least disturbed" wetlands and water bodies for Massachusetts are included on the accompanying DVD.
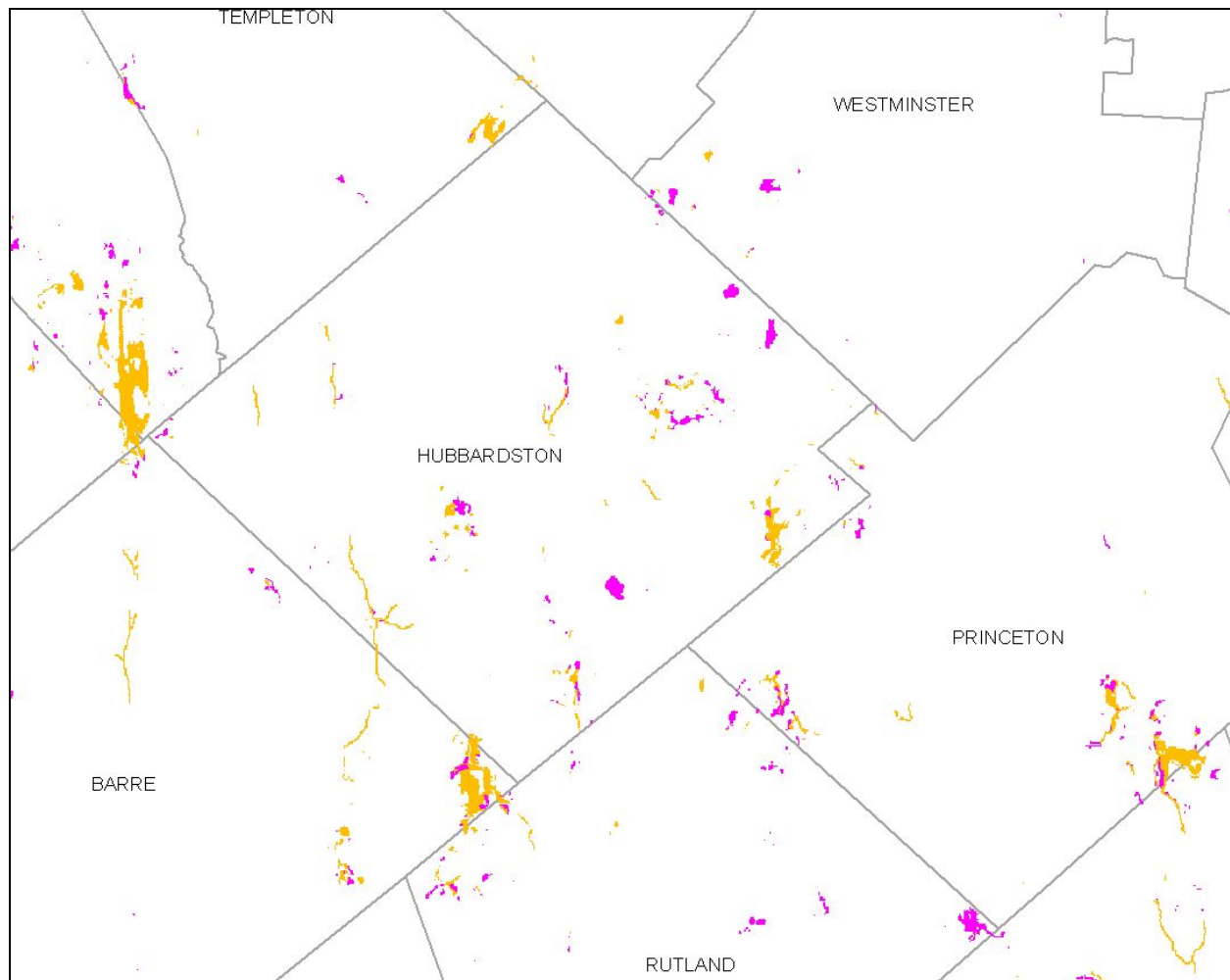


*Figure 1.1. Distribution of "minimally disturbed" (yellow) and "least disturbed" (magenta) wetlands and water bodies in and round Hubbardston, MA.*

There are some important caveats to keep in mind when considering the reference sites identified by CAPS. The Massachusetts landscape has changed dramatically over the past 500 years, including a period of European colonization, intensive land clearing and agricultural activity, widespread use of hydro power for small and large-scale industrial uses, as well as a period of substantial ecological recovery following farm abandonment and less intensive use of many rivers and streams. Areas that appear "natural" now may still be affected by past land use activity (land clearing, loss of topsoil, plowing, soil disturbance from pastured livestock, erosion, drainage). We currently lack GIS data that will allow us to account for past land use in determining those areas that should be considered "minimally

disturbed" and "least disturbed." Site-based assessments to determine the extent of human disturbance from past land use will be necessary before using these areas as reference sites.

## USE OF MASSDEP WATER QUALITY DATA TO TEST CAPS METRICS

CAPS metrics are essentially models that predict the magnitude of impact from human stressors on ecological integrity. The models are created and parameterized based on information available in the scientific literature and expert opinion. Where field-based data are available it is important to test these metrics to verify that they are effectively modeling what they are intended to model. MassDEP water quality data from rivers and streams offered an opportunity for us to test and eventually improve one of our ecological condition variables (calcium carbonate content) and three of our metrics (nutrient loading, road salt and road-based sedimentation).

We looked at histograms of the untransformed and log transformed data for each parameter side by side and then for each parameter we used for our comparisons the option which was less skewed (see figure 1.2 for an example).
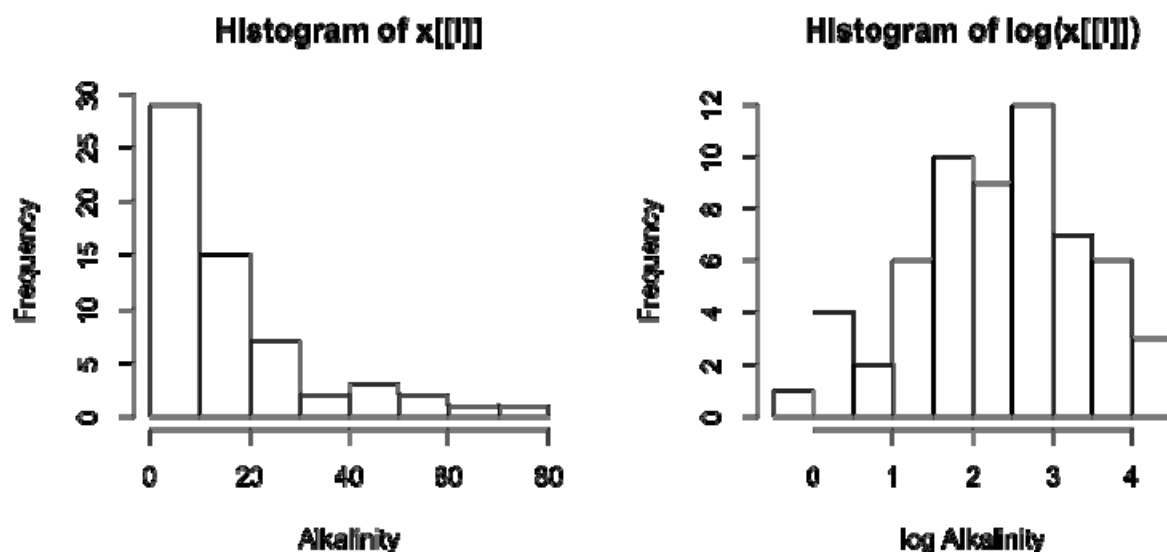


*Figure 1.2. Histograms of alkalinity and the log of alkalinity values. In this case the log transformed data are less skewed and were the values used for our comparisons.*

### Calcium Carbonate

As one of the variables CAPS uses to characterize the landscape, calcium carbonate content is modeled from bedrock lithology and a flow grid created from digital elevation models. We tested the values predicted by CAPS against two variables from the MassDEP water quality data: alkalinity (figure 1.3) and calcium (figure 1.4).

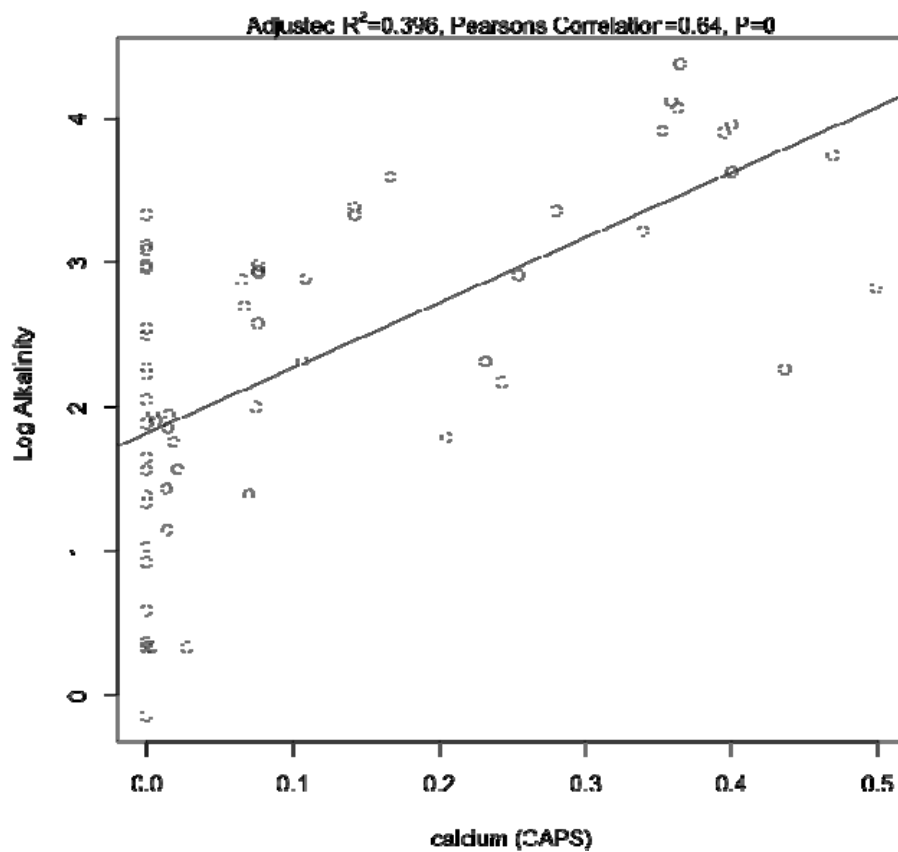*Figure 1.3. Relationship between CAPS predicted calcium carbonate and the log of Alkalinity values from MassDEP's water quality dataset. ($R^2$ = 0.396; p<0.001)*
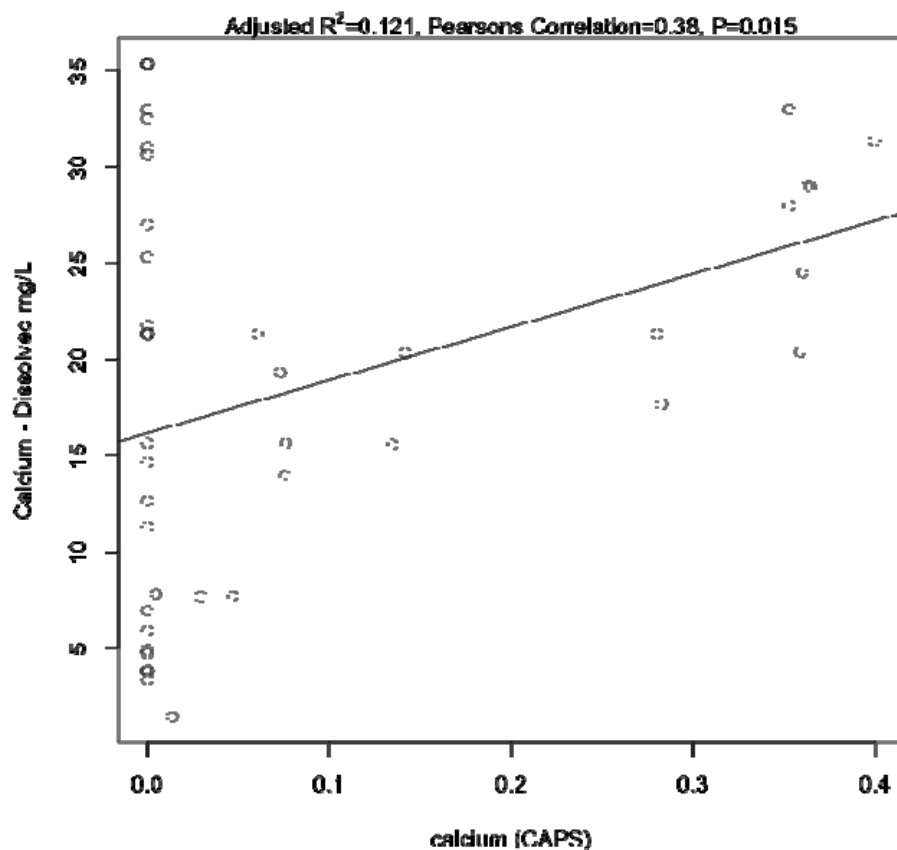
*Figure 1.4. Relationship between CAPS predicted calcium carbonate and dissolved calcium values from MassDEP's water quality dataset. ($R^2$ = 0.121; p=015)*

In both cases the correlations between the CAPS variable and MassDEP data are significant. The correlation with alkalinity is fairly strong (R2=0.396); the correlation with dissolved Ca somewhat weaker (R2=0.121). At this point we are pleased with the performance of this modeled variable. We look forward to working with a proposed expert team for river and stream systems to better understand whether alkalinity or dissolved calcium would be the more important data to use to improve this ecological settings variable.

**Road Salt Metric**

We used two chemical parameters from the MassDEP water quality dataset, chloride (figure 1.5) and specific conductance (figure 1.6), to evaluate our metric for predicting the effects of road salt.
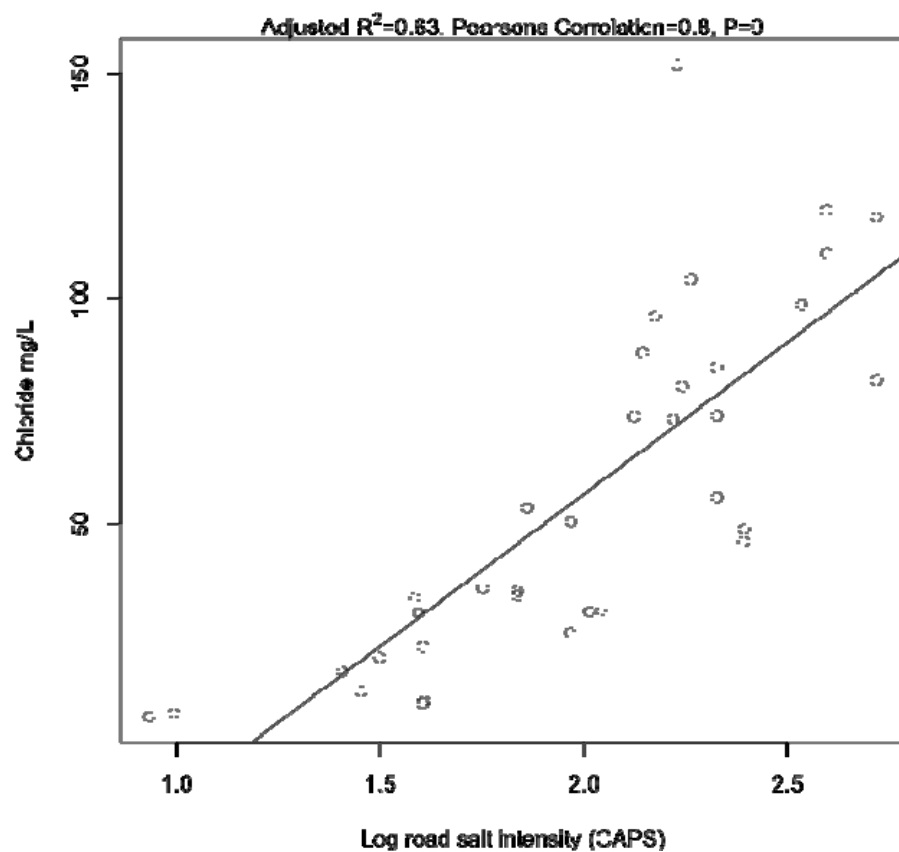
*Figure 1.5. Relationship between the log of the CAPS road salt metric and Chloride values
from MassDEP's water quality dataset. ($R^2$ = 0.63; p<0.001)*
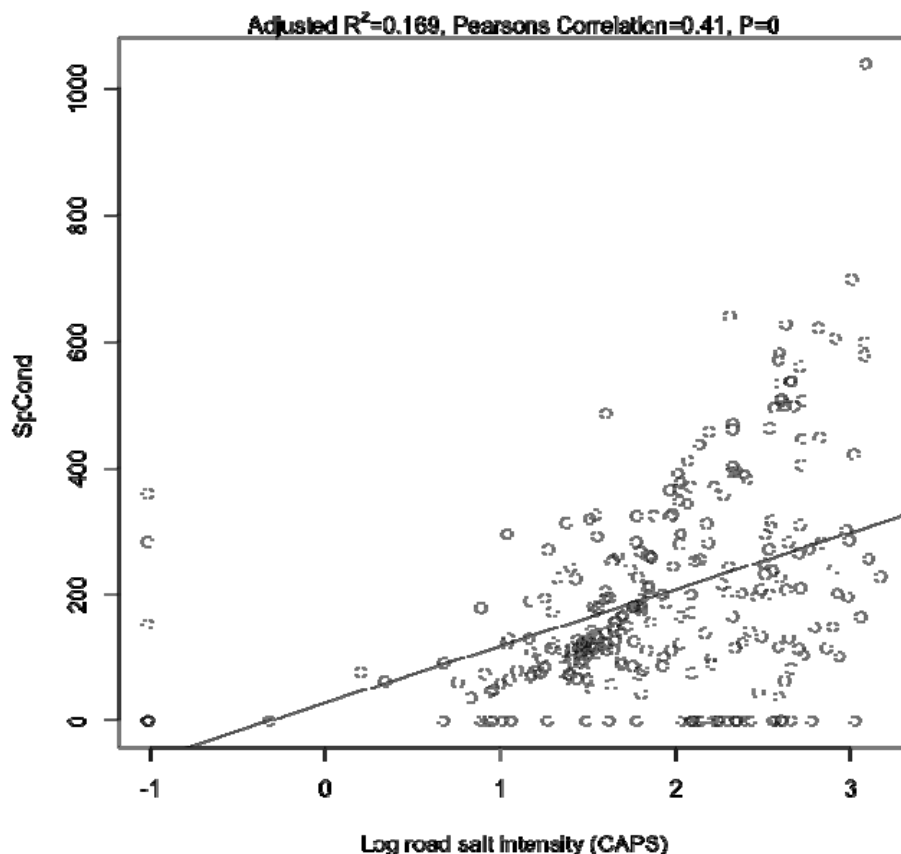
*Figure 1.6. Relationship between the log of the CAPS road salt metric and specific conductance values from MassDEP's water quality dataset. ($R^2$ = 0.169; p<0.001)*

For both chloride and specific conductance the correlation with CAPS road salt metric values were highly significant (p<0.001). The correlation with chloride was very strong ($R^2$=0.63); less so for specific conductance ($R^2$=0.169). We are quite satisfied with the strong correlation between our road salt metric and chloride values from the MassDEP water quality dataset. We are uncertain why the $R^2$ values for chloride and specific conductance were so different. However, we are heartened that the correlations were highly significant in both cases.

**Road-based Sedimentation Metric**

To evaluate our road-based sedimentation metric we tested it against two parameters from the MassDEP dataset: turbidity (figure 1.7) and total suspended solids (figure 1.8).
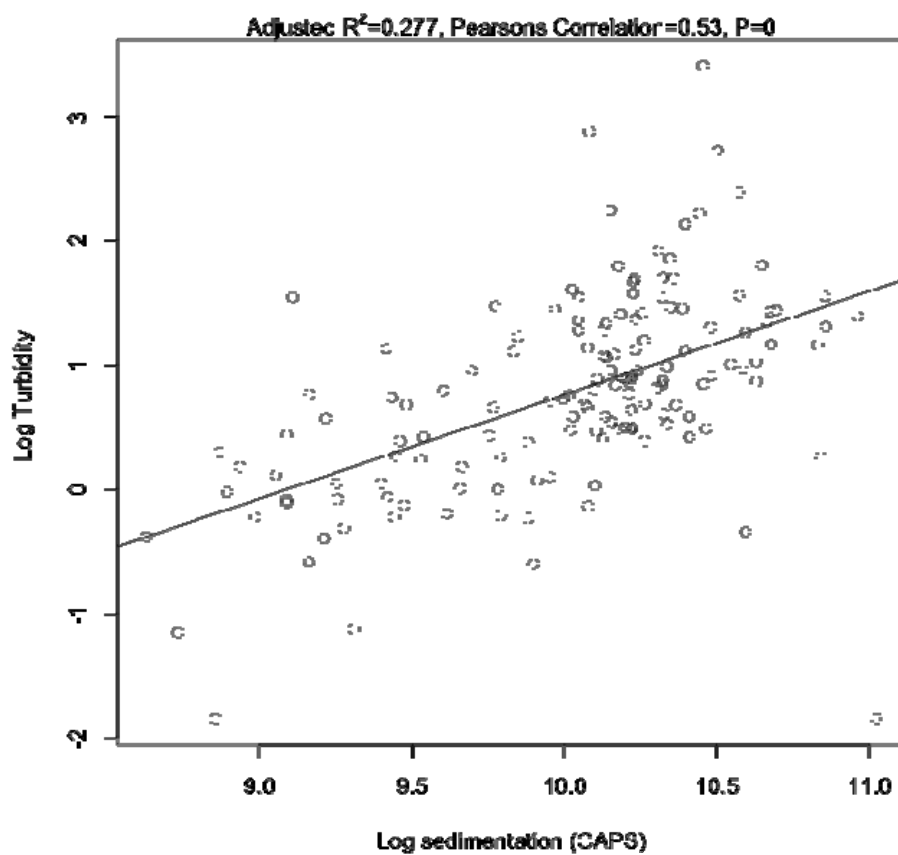
*Figure 1.7. Relationship between the log of the CAPS sedimentation metric and the log of turbidity values from MassDEP's water quality dataset. ($R^2$ = 0.227; p<0.001)*
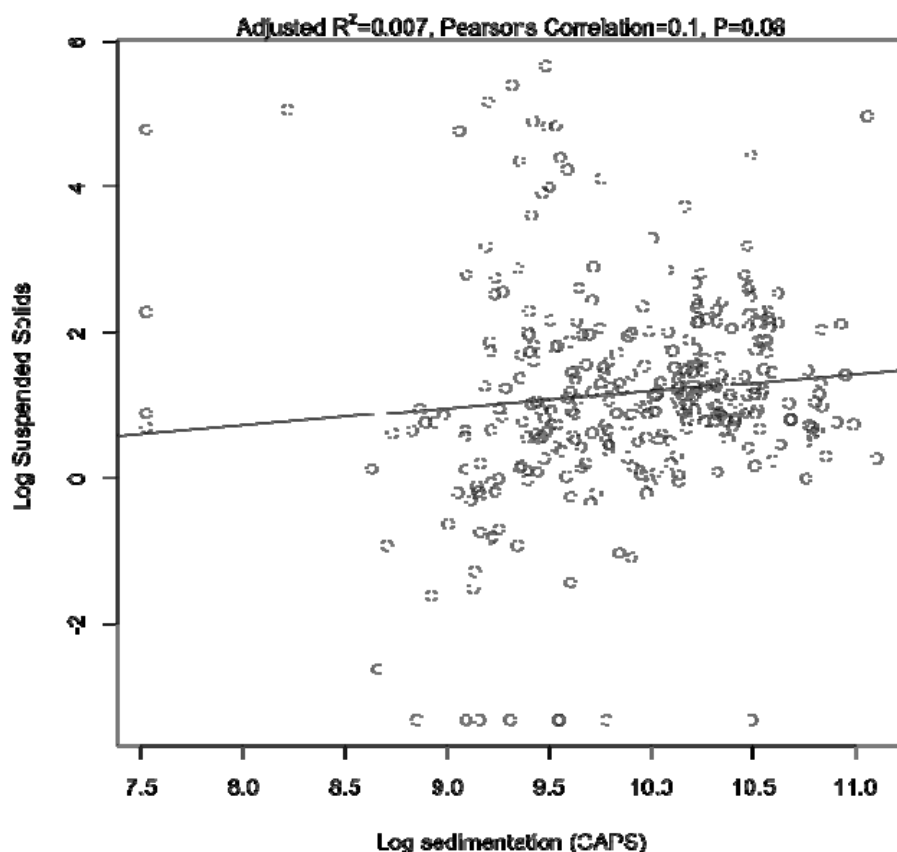
*Figure 1.8. Relationship between the log of the CAPS sedimentation metric and the log of suspended solids values from MassDEP's water quality dataset. ($R^2$ = 0.007; p=0.08)*

The CAPS road-based sedimentation metric was significantly correlated with turbidity ($R^2$ = 0.227; p<0.001) but not with suspended solids ($R^2$ = 0.007; p=0.08). There are a lot of site-specific conditions (road characteristics, BMPs, road maintenance practices) that could conceivably affect the amount of road-based sediment that enters adjacent waterways. As a result we were pleased to get a significant correlation between our metric and turbidity. We are somewhat puzzled as to why we would get a reasonably good correlation ($R^2$=0.227) with one of these parameters but not the other.

**Nutrient Loading Metric**

There were a variety of water quality parameters available to test our nutrient loading metric, including total phosphorus, dissolved reactive phosphorus, total nitrogen, ammonium-N, nitrate/nitrite-N, dissolved oxygen ($DO_2$) and dissolved oxygen saturation ($DO_2$ sat). Figures 1.9-1.15 show the relationships between the metric and each of the chemical parameters. The results are summarized in Table 1.1.

*Figure 1.9. Relationship between the CAPS nutrient loading metric and the log of total
nitrogen values from MassDEP's water quality dataset. ($R^2$ = 0.209; p<0.001)*

Figure 1.10. Relationship between the CAPS nutrient loading metric and the log of
nitrate/nitrite nitrogen values from MassDEP's water quality dataset. ($R^2$ = 0.196; p<0.001)

*Figure 1.11. Relationship between the CAPS nutrient loading metric and the log of
ammonium-nitrogen values from MassDEP's water quality dataset. ($R^2$ = 0.173; p<0.001)*
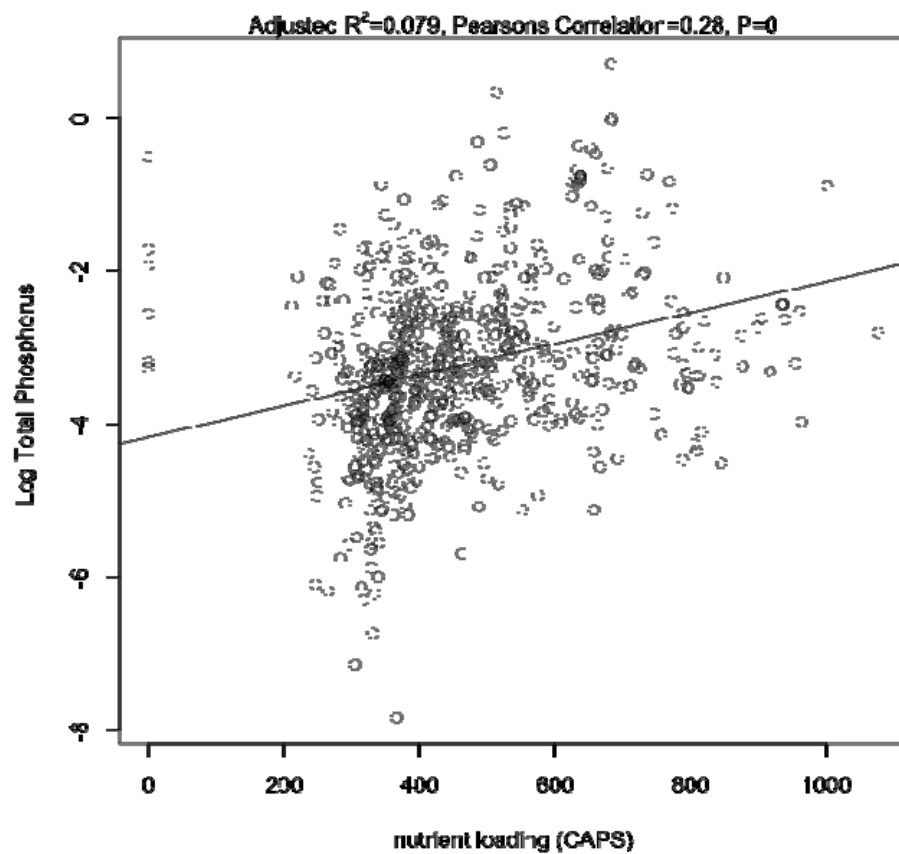
*Figure 1.12. Relationship between the CAPS nutrient loading metric and the log of total phosphorus values from MassDEP's water quality dataset. ($R^2$ = 0.079; p<0.001)*
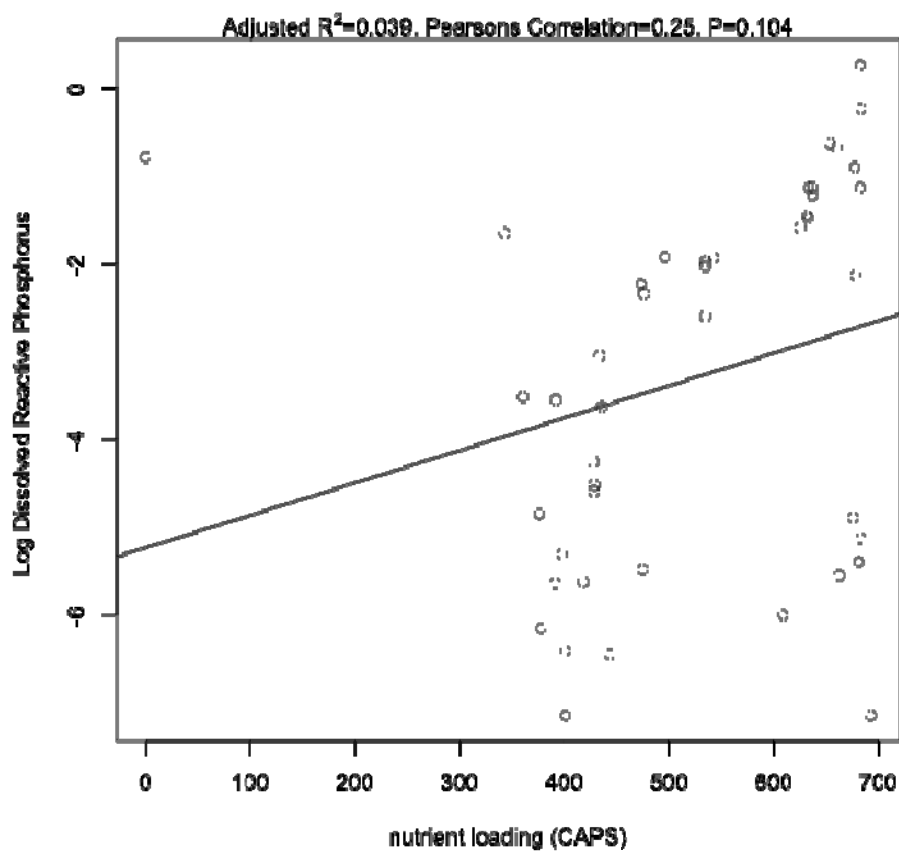
*Figure 1.13. Relationship between the CAPS nutrient loading metric and the log of dissolved reactive phosphorus values from MassDEP's water quality dataset. ($R^2$ = 0.039; p=0.104)*
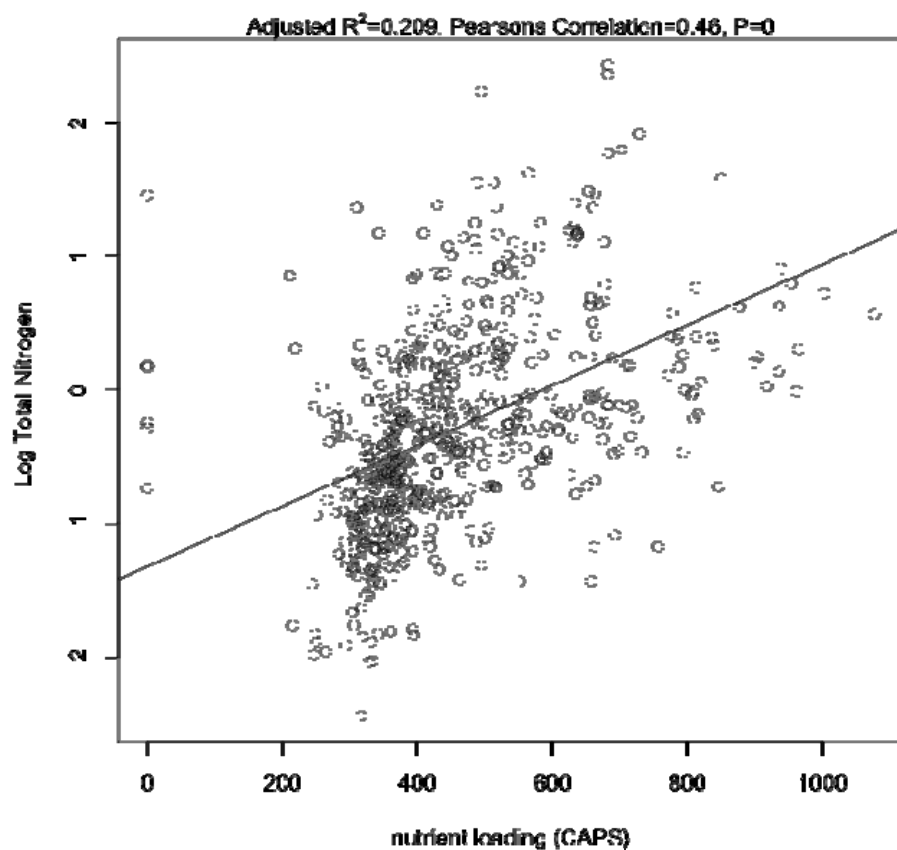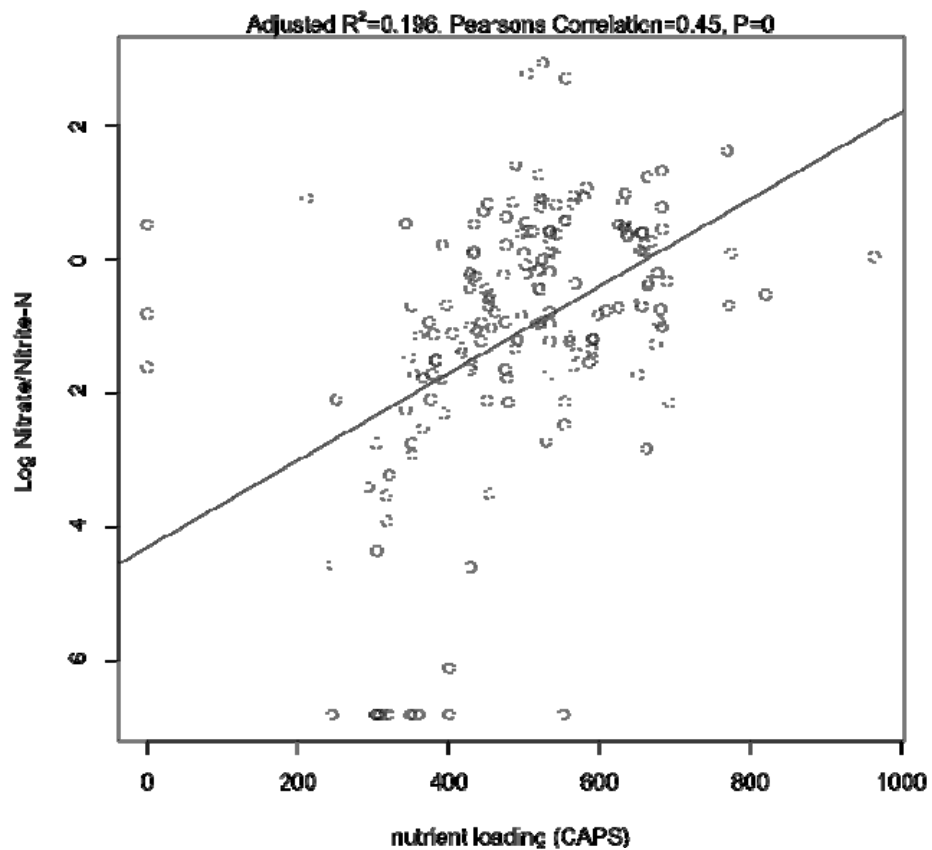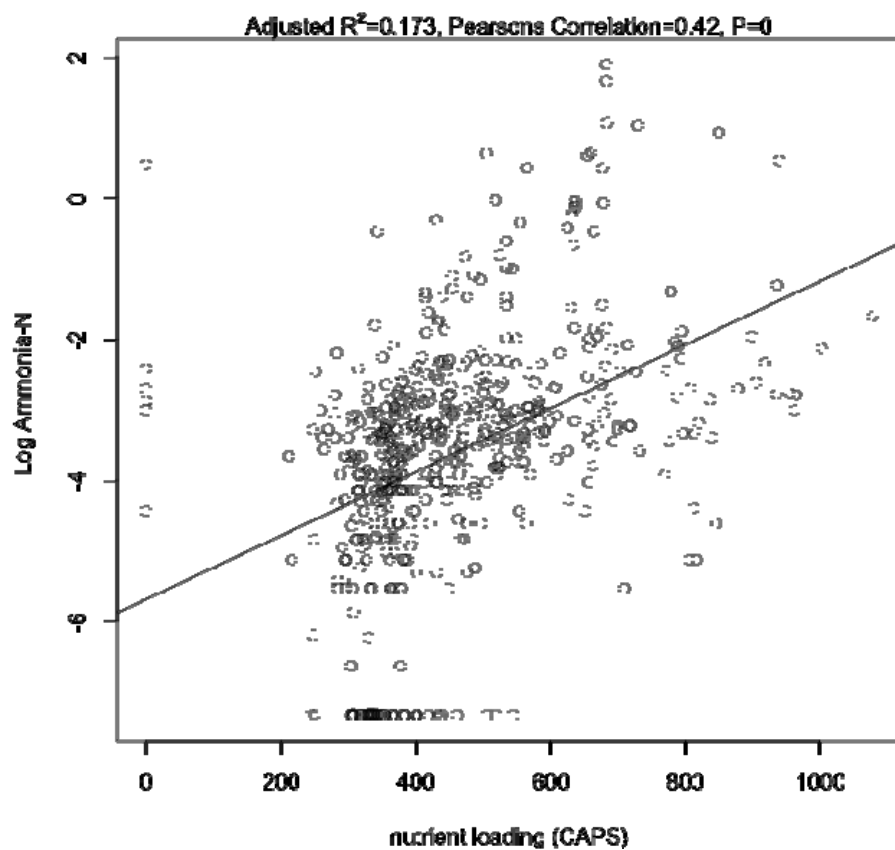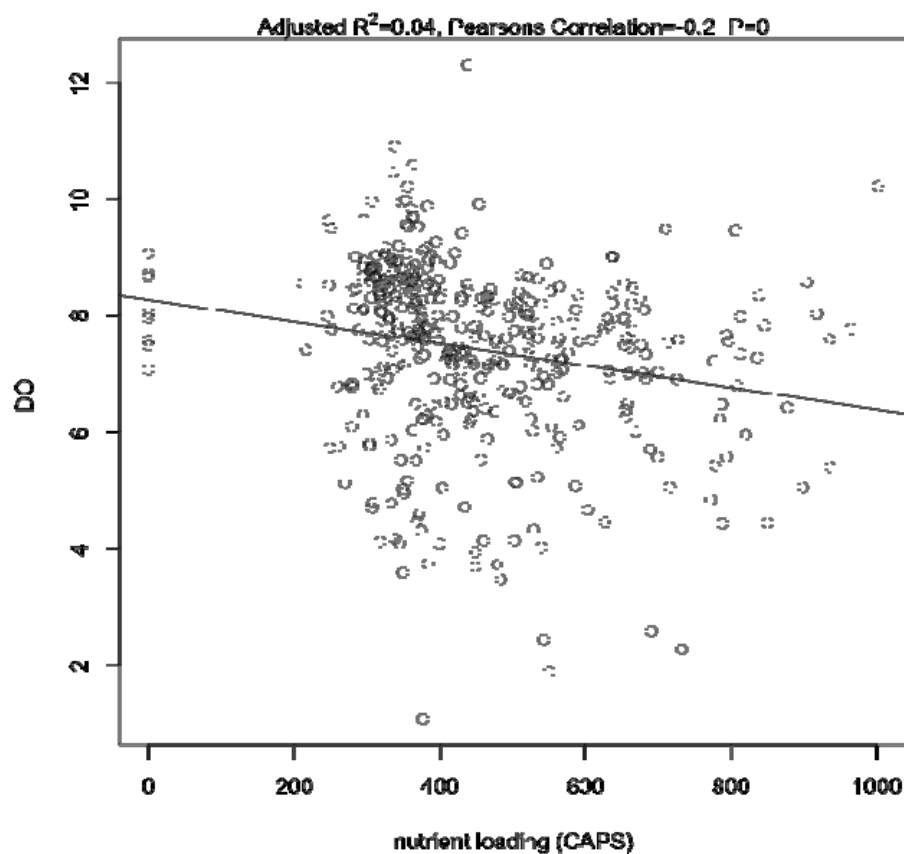
Figure 1.14. Relationship between the CAPS nutrient loading metric and dissolved oxygen
values from MassDEP's water quality dataset. ($R^2$ = 0.04; p<0.001)
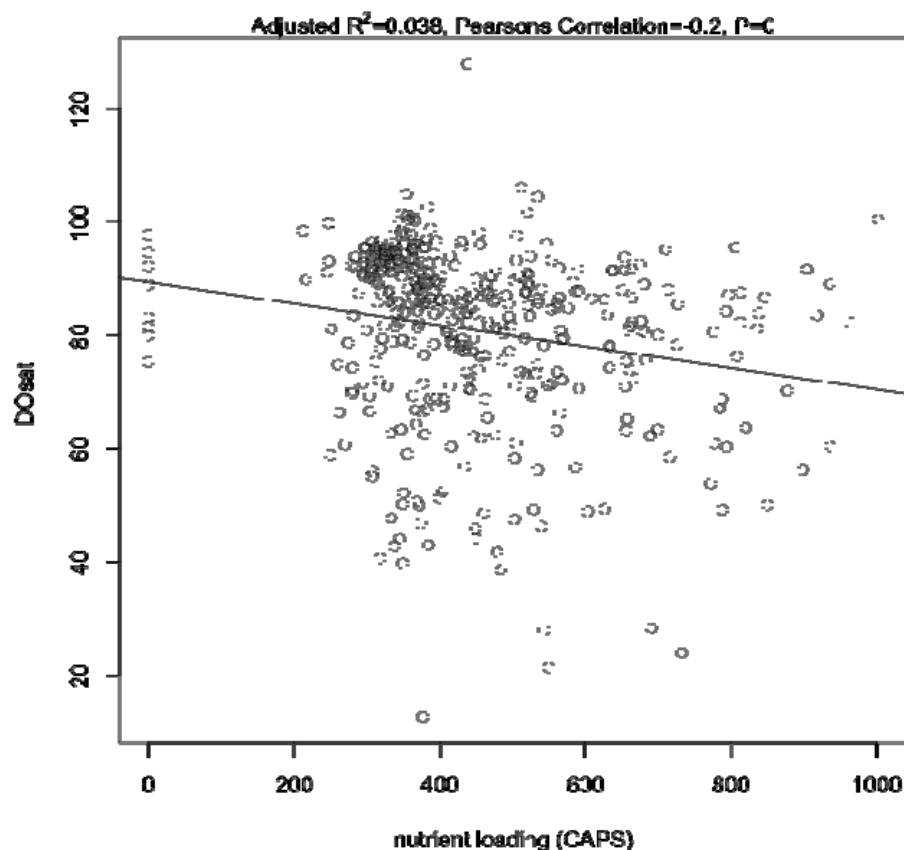
*Figure 1.15. Relationship between the CAPS nutrient loading metric and dissolved oxygen saturation values from MassDEP's water quality dataset. ($R^2$ = 0.038; p<0.001)*

*Table 1.1. Pearson's Correlation, Adjusted $R^2$, P-value, and the number of samples (in parenthesis) based on regression of CAPS nutrient loading and point-source pollution metrics (left margin) against water quality measures (top margin). If the slope of the regression was significant ($\alpha$ = 0.05) the text is in **boldface**.*

| | | Log Total P | Log Dissolved Reactive P | Log Total N | Log Ammonia-N | Log Nitrate/Nitrite-N | $DO_2$ | $DO_2$ Saturation |
|---|---|---|---|---|---|---|---|---|
| Nutrient Loading | PC | **0.284** | 0.248 | **0.458** | **0.418** | **0.448** | **-0.205** | **-0.201** |
| | Adj $R^2$ | **0.079** | 0.039 | **0.209** | **0.173** | **0.196** | **0.04** | **0.038** |
| | p | **<0.001** | 0.104 | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **<0.001** |
| | n | **(615)** | (44) | **(563)** | **(525)** | **(175)** | **(400)** | **(396)** |
| Log Point-Source Pollution | PC | **0.234** | **0.402** | **0.437** | **0.466** | **0.546** | **-0.19** | **-0.15** |
| | Adj $R^2$ | **0.053** | **0.142** | **0.19** | **0.216** | **0.294** | **0.034** | **0.02** |
| | p | **<0.001** | **0.007** | **<0.001** | **<0.001** | **<0.001** | **<0.001** | **0.003** |
| | n | **(615)** | **(44)** | **(563)** | **(525)** | **(175)** | **(400)** | **(396)** |

The CAPS nutrient loading metric is based on a model for predicting nitrogen built into Watershed Analyst distributed by MassGIS. Therefore, the best tests for this metric are the three nitrogen parameters. The correlations for these three parameters were all highly

significant (p<0.001); the $R^2$ values were reasonable but not very strong (ranging from 0.173 to 0.209). Significant correlations were also found for total phosphorus, dissolved oxygen, and saturation of dissolved oxygen although the $R^2$ values were fairly weak (0.038-0.079). We are encouraged that the metric was significantly correlated with all three nitrogen parameters and six out of seven of the parameters we compared it with. We noted relatively strong correlations also between our point-source pollution metric and the seven nutrient-related parameters. In an effort to strengthen the nutrient loading metric we will work with MassDEP personnel to incorporate wastewater treatment plants (point sources) into our existing metric.

## USE OF CAPS TO DEVELOP AN IBI FROM MASSDEP INVERTEBRATE DATA

We use CAPS IEI and individual metric grids to create new IBIs from MassDEP invertebrate data.

### Methods

At each taxonomic level we created counts of each taxon's abundance including all individuals in each sample that were in that taxon regardless of the level to which it was identified. This means that a sample, if it was identified to species, was counted at five levels (species, genus, family, order, class). Then we dropped all taxa that were observed at less than ten sites. This left 278 taxa in the analysis.

We created an IBI (Index of Biological Integrity) by fitting models that predict the CAPS metrics or IEI (Index of Ecological Integrity) from taxa abundances. The steps in this process were (1) fit individual responses for each taxon, (2) use models from step 1 to predict the likelihood of different IEI values at each site based on the abundance of taxa, and (3) select the group of taxa that produce the most accurate predictions. There were two additional techniques woven through this process with the goal of optimizing reproducibility and reducing over fitting: (1) cross validation and (2) testing the significance of each taxon's fit against pseudospecies.

We modeled the relationship between each species and IEI with two functional forms and eight error models. The three parameter logistic function (Equation 1; Crawley 2007) allowed for threshold responses of taxa to the gradient while the constrained exponential quadratic (Equation 2) allowed for Gaussian and exponential responses to the gradient.

(1)
$$y = \frac{a}{1 + b \times e^{-cx}}$$

(2)
$$y = e^{(a + bx + cx^2)}$$

where x is constrained to always be negative.

We modeled error with the Binomial, Beta Binomial, Poisson, and Negative Binomial distributions along with zero inflated (Zuur 2009) versions of those distributions. We included all these models to make sure that we had an error model in the mix that approximated the true error distribution for each taxon. The zero inflated models added a parameter to each model that allowed zeros to be modeled separately, helping to model taxa that occur infrequently and consequently have more zeros than otherwise expected by the distributions. With eight error models and two functional forms we had 16 models for each taxon. We used AIC weights to estimate the relative quality of each of the models based on how many parameters they had and how well they fit the data.

In model calibration, the second step, we predicted the log likelihood of every IEI at each site (or metric) from the error distribution and fit of each model given the abundance of the taxon at the sites. The predictions from the 16 different models were then averaged (based on the AIC weights) to make a single IEI log likelihood profile for each site and taxa.

Finally, in step three, we added together the log likelihood profiles of individual taxa to make a prediction for the site based on multiple taxa; the IEI with the greatest log likelihood was the predicted IEI. We used a stepwise procedure to select the taxa in which we started with the taxon that, by itself, produced the most accurate IEI prediction (highest concordance) and then incrementally added the taxon that increased the concordance correlation coefficient (Lin 1989, 2000) of the prediction the most. We used concordance because it reflects both the correlation and the agreement of the metric and the IBI.

To reduce the potential to over fit the data we performed steps one through three (above) on 20 cross validation groups; in each group a different 5% of the sites was omitted and thus withheld from the model fitting process. The IEI of each site was then predicted (step 2) for each taxon based on the models from which the site was omitted. And in step 3 the taxa were selected based on how well they improved the cross validated prediction of IEI.

As an additional hedge against over fitting we created 1000 pseudospecies by permuting the data from the original species. For each pseudospecies we performed the same model fitting (step 1) and calibration (step 2) as the real species. Then during taxon selection (step 3) we compared each selected taxon's improvement in fit to the improvement in fit garnered by each of the 1000 pseudospecies to estimate the significance of the improvement in fit of each taxon. We used this significance test to decide how many taxa to include in the final prediction set; we included all taxa up until the first taxon that didn't produce a significant increase in prediction accuracy.

We completed the whole process with both IEI and the following CAPS metrics: connect (connectedness), fertilize (nutrient loading), sediment (road-based sedimentation), imperviousness, and whabloss (watershed habitat loss) as response variables.

**Results**

We created an IBI that predicts IEI (as estimated by CAPS) with a concordance of 0.65 (figure 1.16). It relies on 18 taxa (figure 1.17): 4 orders, 3 families, 1 genus, and 10 species (Table 1.2).

An IBI based on the sedimentation (sediment) CAPS metric predicted the metric with a concordance of 0.77 (figure 1.18). An IBI based on connectivity (connect) had a concordance of 0.41 (figure 1.19); nutrient loading (fertilize), 0.78 (figure 1.20); percent impervious surface (imperv), 0.66 (figure 1.21); and watershed habitat loss (whabloss), 0.80 (figure 1.22).

All of the IBIs we created had relatively high correlation with at least some published IBIs (Table 1.3). The three published IBIs that were most correlated to our IBIs were the mean tolerance value, EPT, and the Hilsenhoff Biotic index. The watershed habitat loss IBI and mean tolerance value IBI had a correlation of 0.78, the highest correlation between any of our IBIs and the published IBIs.

*Table 1.2. The taxa included in the IEI based IBI listed in the order they were added to the model. Adding each taxon on this list to a model that contained all the preceding taxa improved concordance more than adding any other taxon. The P value is based on a comparison to pseudospecies.*

| Step | Taxa | Level | P |
|---:|---|---|---:|
| 1 | Plecoptera | Order | < 0.001 |
| 2 | *Helicopsyche borealis* | Species | < 0.001 |
| 3 | Ephemeroptera | Order | < 0.001 |
| 4 | Odontoceridae | Family | < 0.001 |
| 5 | Amphipoda | Order | < 0.001 |
| 6 | *Simulium tuberosum* complex | Species | < 0.001 |
| 7 | *Optioservus trivittatus* | Species | 0.008 |
| 8 | *Optioservus ovalis* | Species | 0.004 |
| 9 | Hydropsychidae | Family | 0.008 |
| 10 | *Nais behningi* | Species | 0.014 |
| 11 | *Polypedilum tritum* | Species | 0.008 |
| 12 | Trichoptera | Order | < 0.001 |
| 13 | *Eukiefferiella claripennis* gr. | Species | 0.028 |
| 14 | *Nigronia serricornis* | Species | 0.012 |
| 15 | Maccaffertium | Genus | 0.032 |
| 16 | *Sublettea coffmani* | Species | 0.008 |
| 17 | Glossiphoniidae | Family | 0.030 |
| 18 | *Eukiefferiella brehmi* gr. | Species | 0.042 |

*Table 1.3. Correlations between IBIs derived from CAPS (column headings) and other published IBIs (row headings). The rows are ordered such that higher mean, absolute correlations appear first.*

| | iei.ibi | sediment.ibi | connect.ibi | whabloss.ibi | imperv.ibi | fertilize.ibi |
|---|---|---|---|---|---|---|
| mean.tolval | -0.68 | 0.71 | -0.58 | 0.78 | 0.55 | 0.77 |
| EPT | 0.70 | -0.72 | 0.68 | -0.74 | -0.50 | -0.72 |
| hilsenhoff.bi | -0.62 | 0.61 | -0.52 | 0.68 | 0.54 | 0.67 |
| n.no.co | 0.62 | -0.61 | 0.64 | -0.64 | -0.45 | -0.66 |
| n.ephemeroptera | 0.57 | -0.63 | 0.71 | -0.64 | -0.43 | -0.62 |
| ptv.0.to.5.9 | 0.58 | -0.60 | 0.55 | -0.67 | -0.52 | -0.68 |
| pct.non.insect | -0.55 | 0.63 | -0.62 | 0.65 | 0.44 | 0.62 |
| pct.sensitive.ept.abun | 0.61 | -0.60 | 0.56 | -0.63 | -0.44 | -0.62 |
| pct.sensative.abun | 0.69 | -0.63 | 0.43 | -0.67 | -0.38 | -0.60 |
| n.plecoptera | 0.69 | -0.61 | 0.36 | -0.64 | -0.35 | -0.58 |
| pct.shellfish | -0.50 | 0.61 | -0.51 | 0.62 | 0.36 | 0.57 |
| dom.3.f.abun | -0.59 | 0.53 | -0.55 | 0.56 | 0.37 | 0.57 |
| diversity.f | 0.57 | -0.51 | 0.55 | -0.56 | -0.38 | -0.58 |
| n.taxa | 0.56 | -0.54 | 0.57 | -0.55 | -0.35 | -0.55 |
| becks.i | 0.65 | -0.58 | 0.34 | -0.63 | -0.34 | -0.55 |
| pct.ephemeroptera | 0.42 | -0.52 | 0.60 | -0.54 | -0.35 | -0.54 |
| n.trichoptera | 0.46 | -0.50 | 0.50 | -0.52 | -0.40 | -0.54 |
| n.scraper | 0.42 | -0.45 | 0.65 | -0.44 | -0.35 | -0.47 |
| ept.chiro.stand | 0.34 | -0.36 | 0.30 | -0.41 | -0.34 | -0.45 |
| diversity.o | 0.39 | -0.28 | 0.34 | -0.32 | -0.26 | -0.38 |
| pct.scraper.abun | 0.25 | -0.26 | 0.60 | -0.28 | -0.25 | -0.31 |
| ept.chiro.ratio | 0.30 | -0.32 | 0.16 | -0.37 | -0.22 | -0.38 |
| pct.abun.oligochaeta | -0.23 | 0.22 | -0.32 | 0.24 | 0.39 | 0.32 |
| n.diptera | 0.33 | -0.30 | 0.34 | -0.29 | -0.16 | -0.27 |
| n.gc | 0.31 | -0.31 | 0.33 | -0.28 | -0.14 | -0.28 |
| pct.ept.abun | 0.16 | -0.28 | 0.28 | -0.28 | -0.30 | -0.29 |
| dom.3.o.abun | -0.34 | 0.23 | -0.25 | 0.26 | 0.18 | 0.29 |
| n.chironomidae | 0.27 | -0.25 | 0.31 | -0.24 | -0.14 | -0.22 |
| ept.chiro.abun.stand | 0.07 | -0.16 | 0.26 | -0.17 | -0.23 | -0.21 |
| shredders | 0.24 | -0.20 | -0.12 | -0.22 | -0.06 | -0.20 |
| pct.chironomidae | -0.08 | 0.05 | -0.02 | 0.11 | 0.13 | 0.16 |
| scraper.to.filter.collector. ratio | 0.11 | -0.10 | 0.12 | -0.10 | -0.03 | -0.05 |
| pct.tanytarsini | -0.01 | 0.03 | 0.04 | 0.10 | 0.07 | 0.12 |
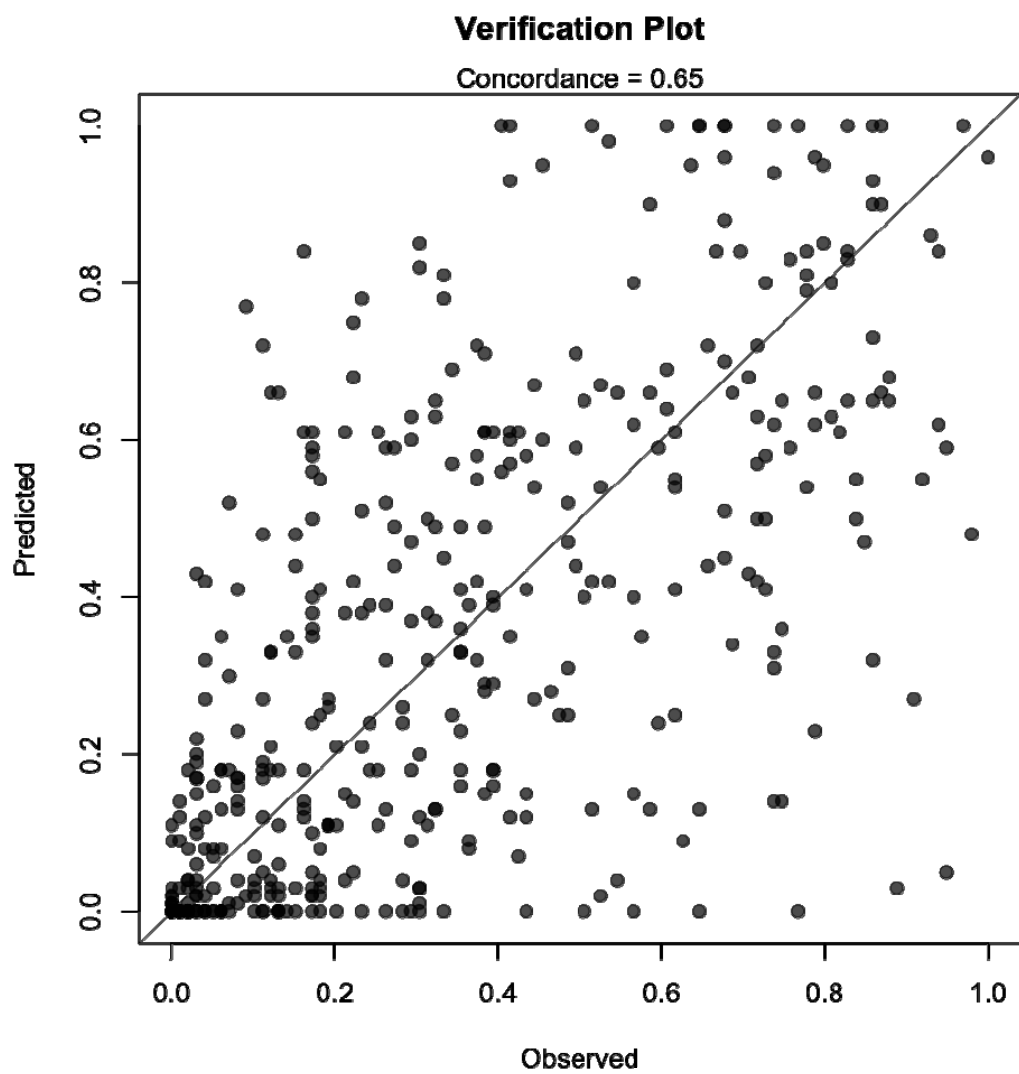
*Figure 1.16. The predicted IEI (our IBI) matches the observed IEI of each site with a
concordance of 0.65. Concordance measures both the strength of the relationship between
the two axes as well as how close the slope of the relationship is to 1.*
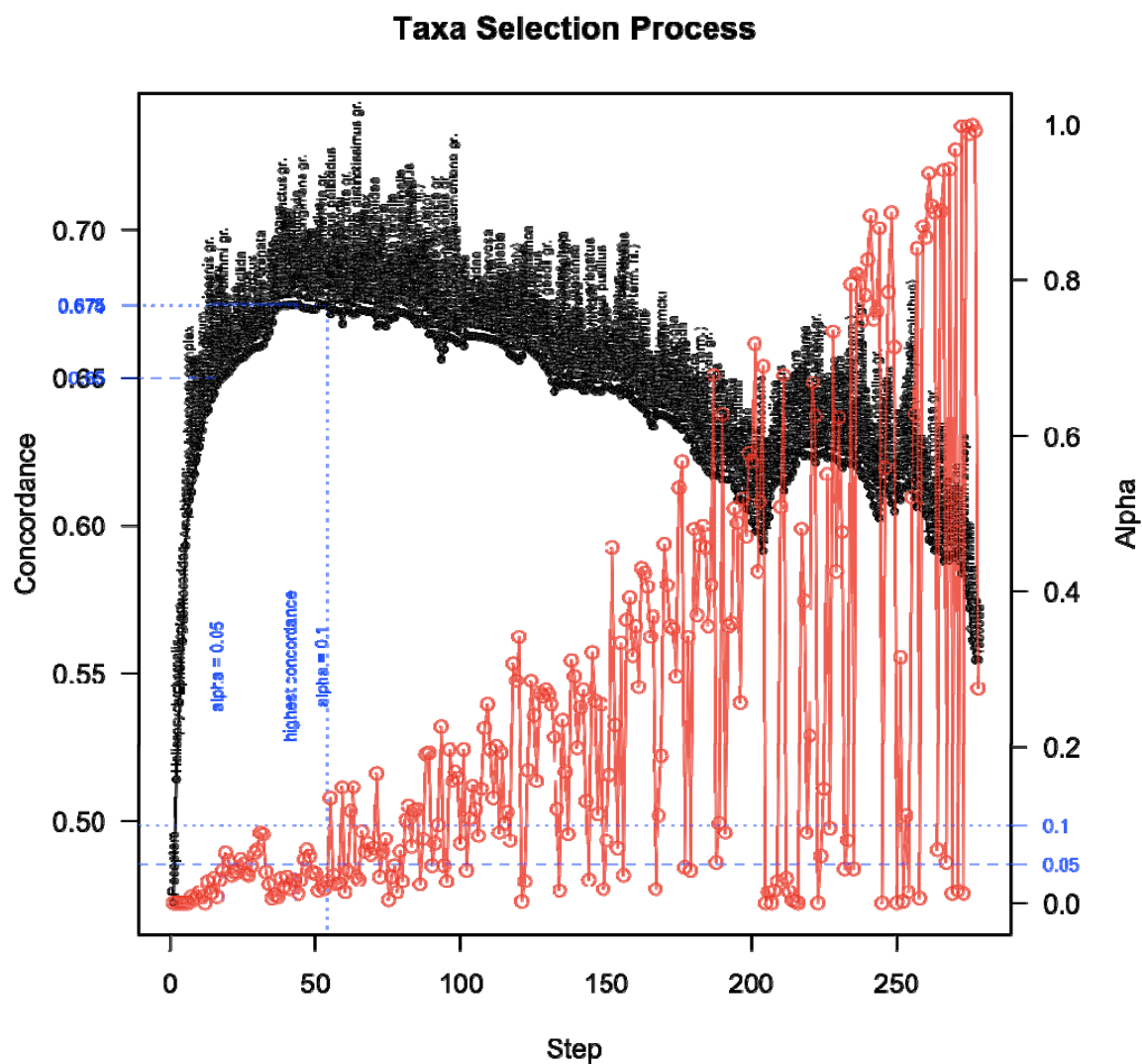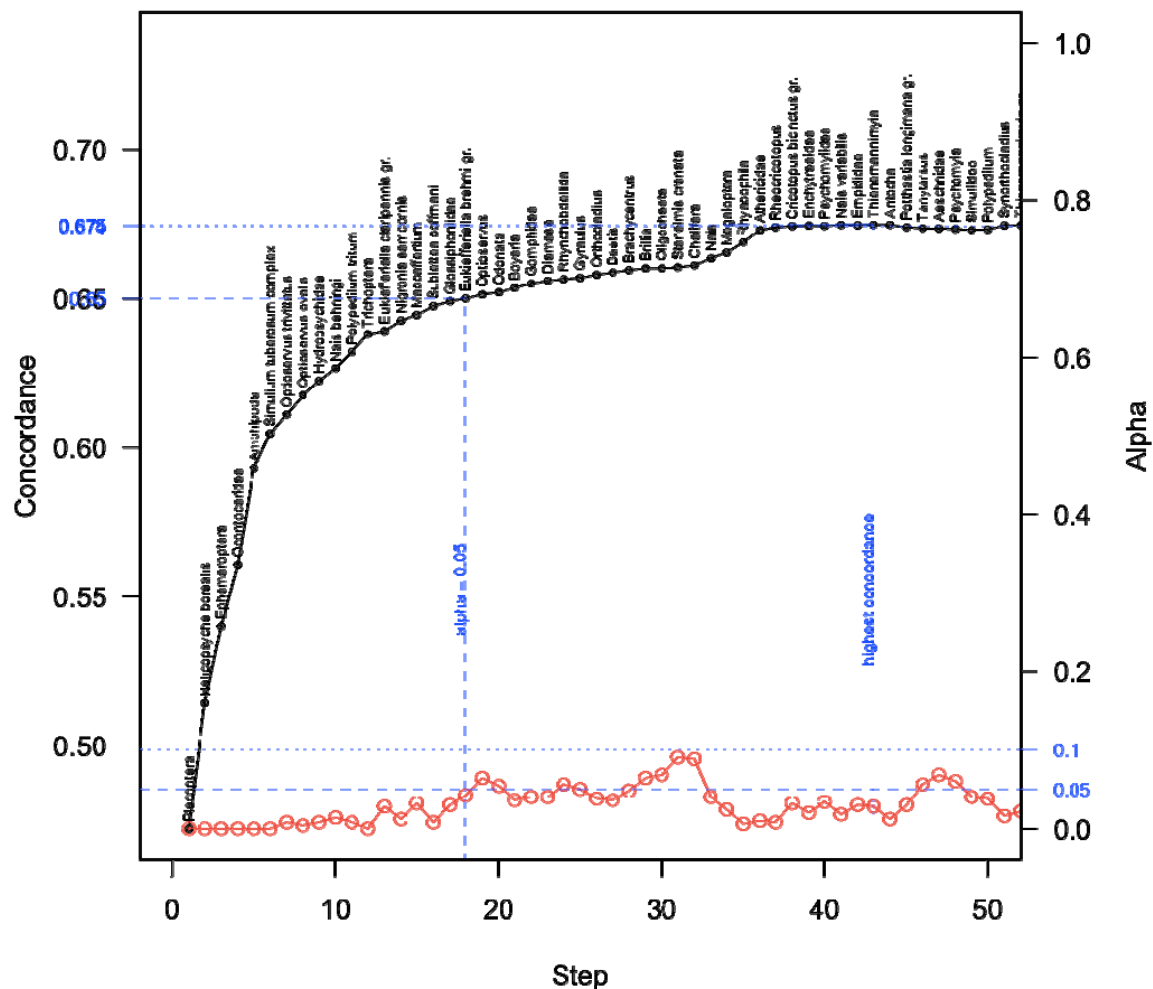
*Figure 1.17. The concordance between the predicted and observed IEI as more taxa are added to the model is indicated by the black dots (the text is the taxa added at each step). The concordance initially increases as informative taxa are added and then falls off after when the remaining taxa are non-informative. The red line indicated the P value associating with adding the taxa at each step based on how much the model is improved by that taxa compared to the pseudospecies. The blue lines indicate the models chosen based on an alpha = 0.05, an alpha=0.10, and the maximum concordance.*
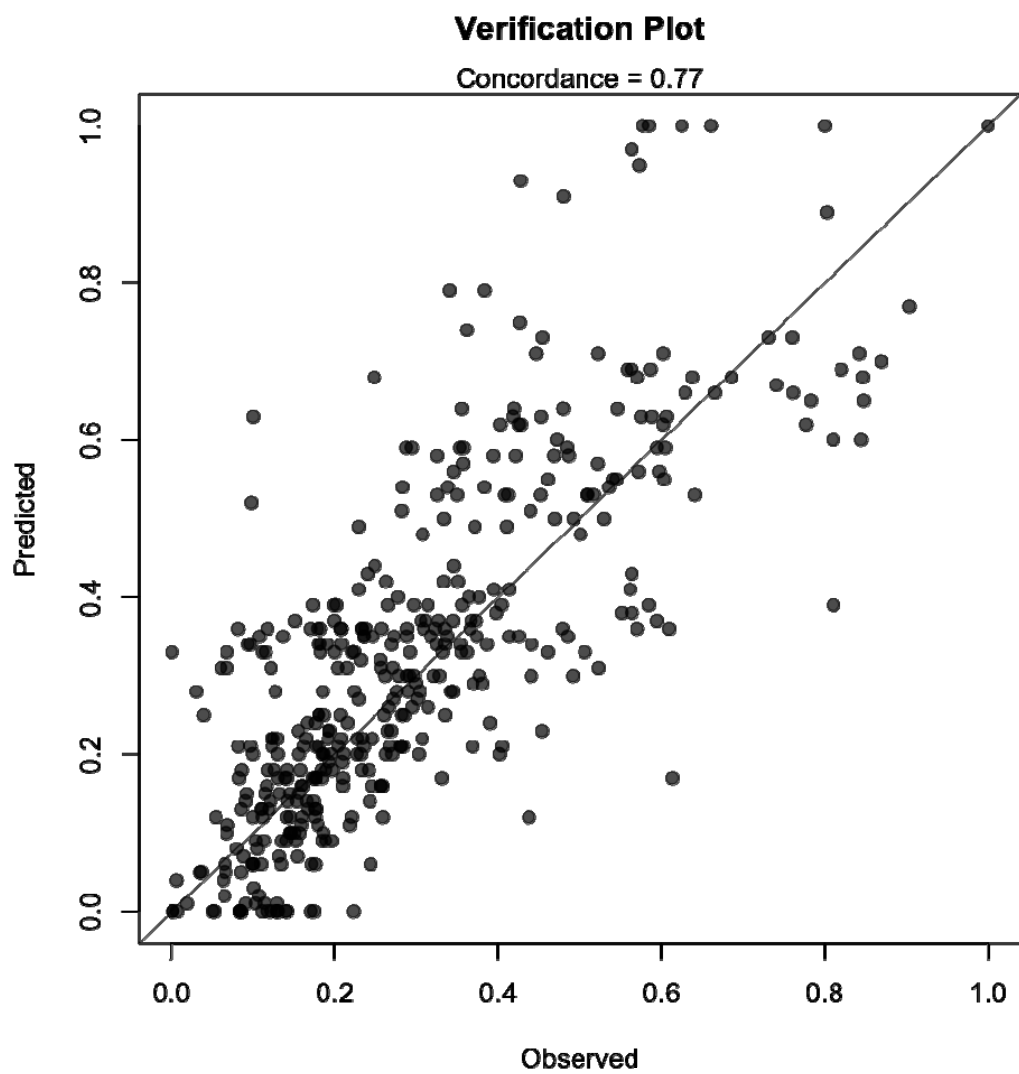
*Figure 1.18. Predicted and observed (CAPS) Sedimentation levels*

**Verification Plot**

Concordance = 0.41
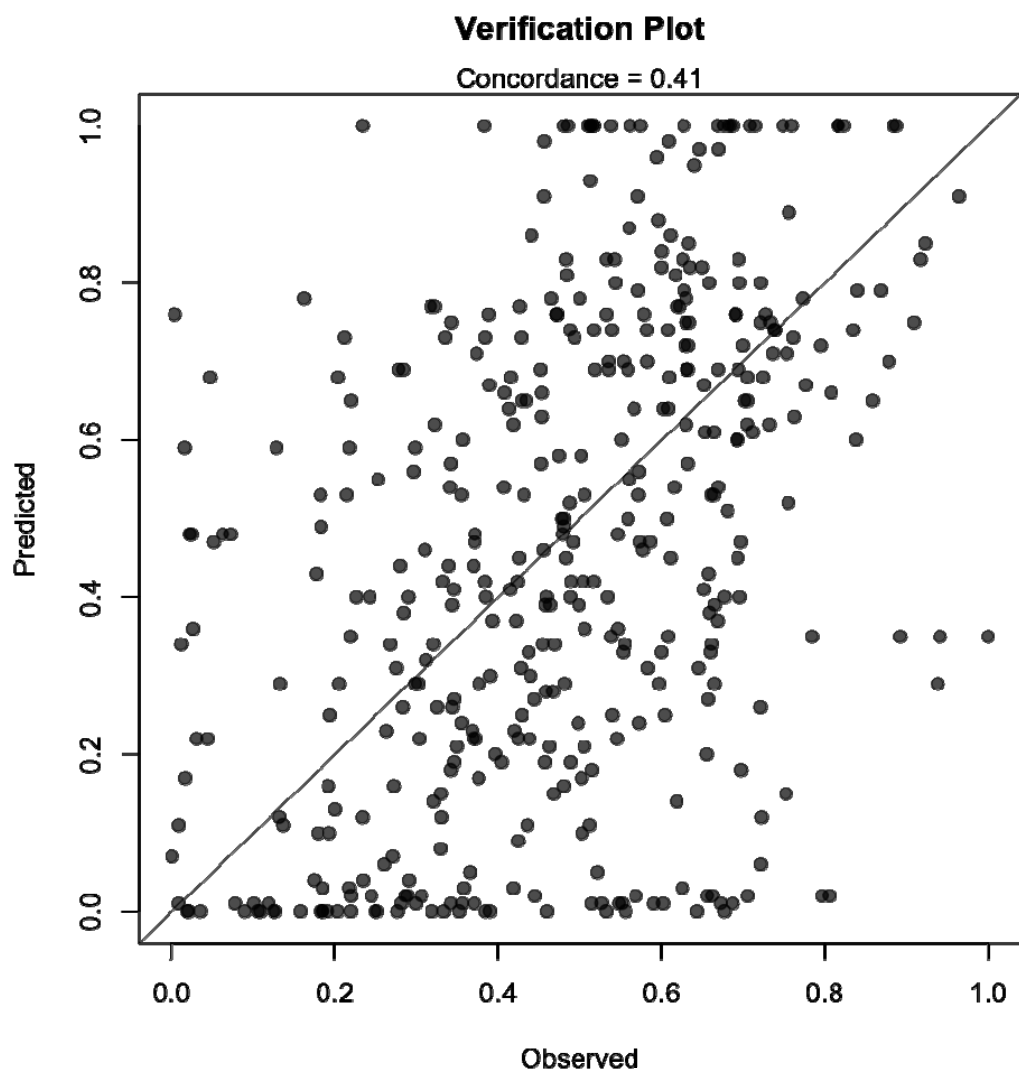


*Figure 1.19. Verification plot for an IBI based on the connectivity CAPS metric*
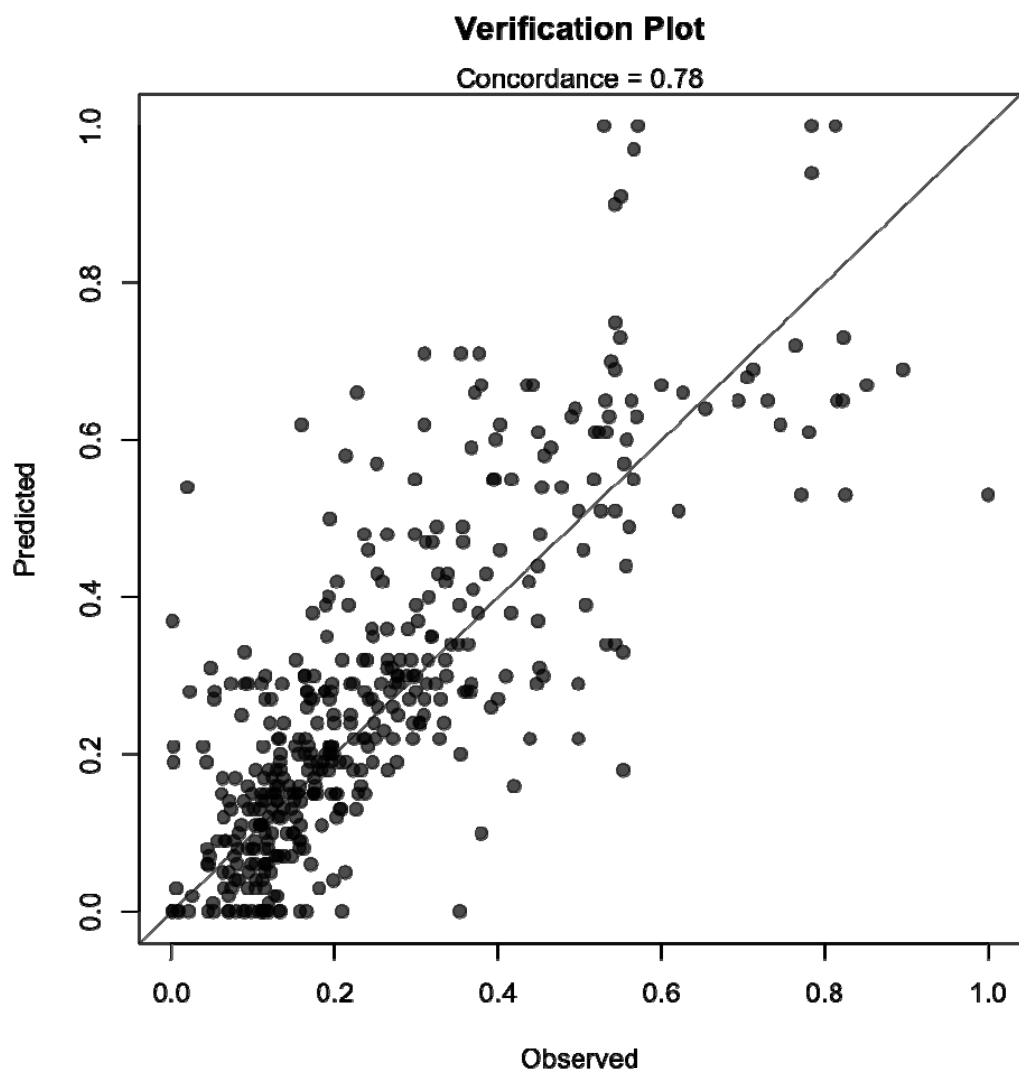
*Figure 1-20. Verification plot for the IBI based on the nutrient loading CAPS metric*
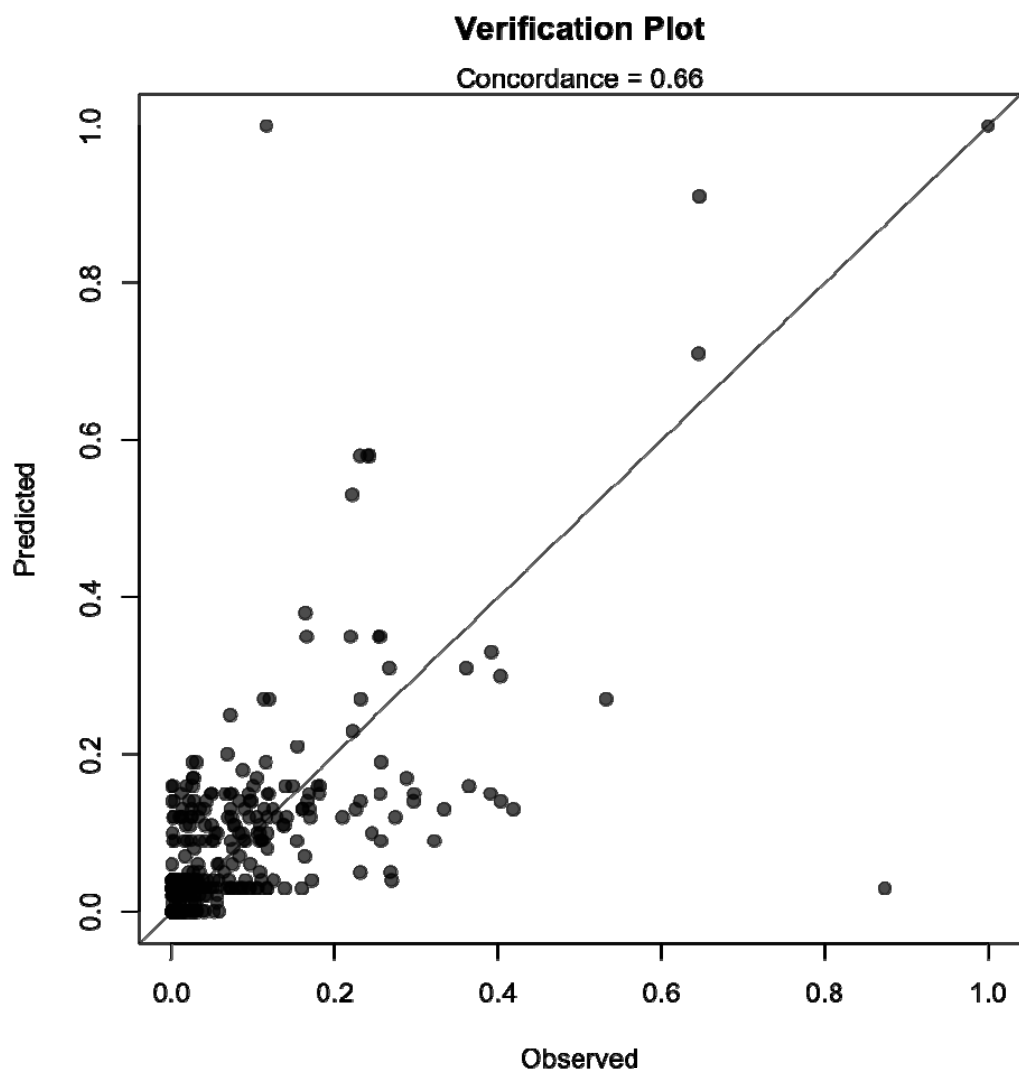
*Figure 1-21. Verification plot for the IBI based on the percent impervious surface CAPS metric*
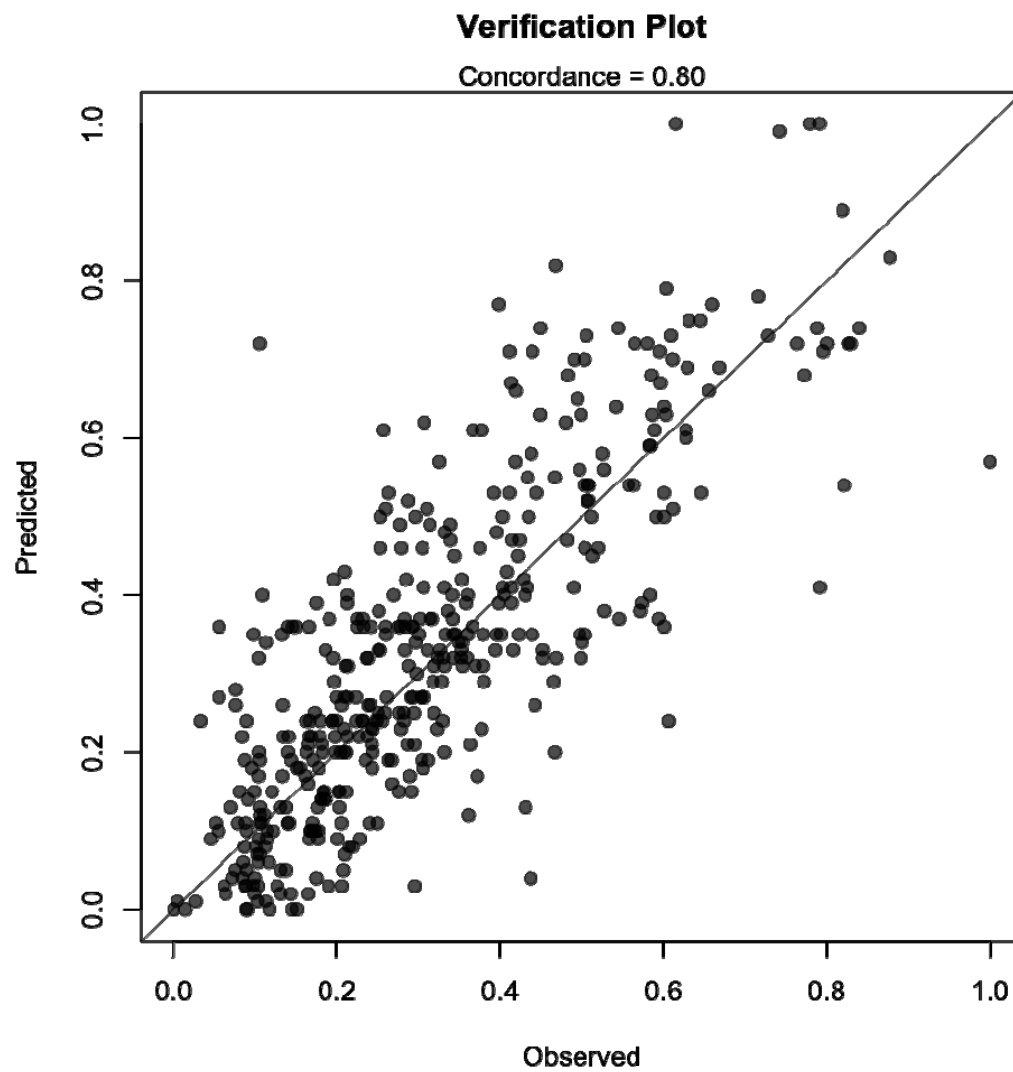
*Figure 1-22. Verification plot for the IBI based on the watershed habitat loss CAPS metric*

## Discussion

We were able to predict the sedimentation, nutrient loading, percent impervious surface, and watershed habitat loss CAPS metrics with greater accuracy than IEI. Connectivity had lower accuracy and we did not make IBIs based on the other CAPS metrics that contribute to IEI in riverine systems (edge predators, invasive plants, point source pollution, impoundment, traffic, dam intensity). We suspect that the invertebrate community would not respond as strongly to these metrics and thus they would result in lower concordances. This is probably one reason why the concordance of IEI is lower than for the individual metrics we did model. We also suspect that combining many different aspects of habitat degradation (metrics) into an average (IEI) makes it harder to predict IEI because individual

taxa probably respond to some but not all of the metrics; a low IEI may or not reflect the distribution of a particular taxon depending on which of the metrics makes the IEI low.

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Lin, L. 1989. A concordance correlation coefficient to evaluate reproducibility. Biometrics 45: 255 - 268.

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## TESTING OF PUBLISHED IBIS AGAINST CAPS IEI SCORE

MassDEP uses a variety of published invertebrate Indices of Biological Integrity (IBIs) to assess the condition of rivers and streams. These IBIs were developed to reflect the impact of human stressors on aquatic systems. However, there are questions about the applicability of IBIs that may have been developed in other states for assessing Massachusetts streams.

In addition to identifying "minimally disturbed" and "least disturbed" reference sites CAPS is well suited for evaluating relationships between human disturbance and IBIs. Individual CAPS stressor metrics as well as IEI scores (an index of human disturbance) were used as a basis for evaluating a variety of IBIs for use in Massachusetts.

**Methods**

Data Preparation

We used data from the MABenthos database and incorporated it into the CAPS Master Database. We limited ourselves to sites sampled with the RBP kicknet method and also excluded sites in which certain taxa were labled "Too numerous to count"; these were sites where a single taxa was extremely abundant and overwhelmed the rest of the taxa.
For each site we found the nearest stream cell in the CAPS database and extracted the caps metrics and index of ecological integrity (IEI) at these sites. Eleven sites where the nearest CAPS stream cellwas over 150 meters away were dropped from the analysis. This left 589 samples at 420 sites. The total abundance in each sample ranged from 35 to 155 with a mean of 101.8 and a standard deviation of 8.3.

Calculating IBIs

From the abundance data we calculated 33 IBIs (Appendix B). In all cases when numbers of taxa were part of an IBI we calculated for each sample the minimum number of distinct taxa guaranteed to be present based on the macroinvertebrates identified in that sample. Given that individuals were identified to different taxanomic levels; we counted every taxa present in a sample as long as there were no other taxa identified in the sample within the same taxanomic group. For example if at a sample contained Hydropsychidae (family) and *Hydropsyche morose* (a species within the same family) then "Hydropsychidae" would not be included in the taxa count because that family is already represented in that sample. After calculating the IBIs for each sample we averaged the scores across mutiple samples in a site to get a score for each site (many sites had only one sample).

Analyzing the results

We used two statistical methods to understand how the IBIs relate. (1) We calculated correlations among the IBIs, CAPS metrics, and IEI. (2) We performed principle component analysis (PCA) on the IBIs and made a plot based on the first two axes of the PCA that show how the IBIs relate to each other, the CAPS metrics, and IEI. The first method has the benefit of being methodologically and conceptually simple while the second relies on complex statistics to create a single plot that shows visually how the IBIs, metrics, IEI, and CAPS settings variables relate to each other.

For each IBI we calculated the mean absolute correlation it had with each of the other IBIs, the correlation it had with IEI and the highest absolute correlation it had with any CAPS metric. We also calculated for IEI the mean absolute correlation it had with all IBIs.

We used PCA to collapse as much of the information as possible from all IBIs into two dimensions. Each IBI is a dimension in the dataset so we had 33 dimensions in the original dataset. PCA finds an axis through that space such that the distance from each site's location in IBI space to the axis is minimized. This also guarantees that the spacing of the sites along the axis is maximized or, in statistical terms, that the variance explained by the axis is maximized. Additional axes are then identified such that each axis is both perpendicular to the preceding axes and also captures as much of the remaining variance in the data as possible (by minimizing the spacing between the points and the axis). If there is high correlation among the IBIs then the first few axes are likely to explain much of the variance in the dataset in much the same way that a linear regression with a good fit allows one to predict one variable from the other. We plotted the first two axes from the PCA showing both the sites and how each IBI varied across the sites. Then using the location of sites on the plot and the values of the CAPS metrics, IEI, and ecological settings at each site we plotted arrows representing how each CAPS metric, IEI, and the ecological settings variables varied across the plot as well.

**Results**

The mean absolute correlation between IEI and the IBIs was 0.295. The mean absolute correlation among IBIs was 0.360. The IBIs that were most strongly correlated with IEI were mean.tolval, pct.sensative.abun, n.plecoptera, ept, and becks.i (Table 1.4). IBIs with high correlation to IEI also tended to have high average correlations with other IBIs and IBIs with low correlations to IEI also tended to have low correlations with other IBIs (Table 1.4).

The first two axes of the PCA explained 38.6 and 18.6% of the variation (collectively 57.2%); the remaining axes each explained less than 9% of the variation.

With few exceptions IBIs that indicate high habitat quality fall out positively on the first PCA axis while IBIs that indicate degregated habitat have negative scores on the first axis (figure 1.23).

The three IBIs that weigh heavily on the negative end of the second axis (pct.chiromidae, n.chironomidae, and n.diptera) all indicate poor quality habitat while the three that score highest on this axis all indicate good habitat quality (ept.chiro.ratio, ept.chiro.stand, and ept.chiro.abun.stand) and all six use the Chironomidae as part of the IBI calculation. There are other IBIs (pct.tanytarsini, n.gc, n.taxa, pct.shellfish, pct.non.insect) that, although not as strongly associated with that axis, do not support an interpretation that the Chironomidae are a dominant factor in axis 2.

The water temperature (watertemp) settings variable is aligned with axis 1 with lower water temps found at higher scores along axis 1. Calcium is associated with lower scores on axis 2 and (to a lesser extant) higher scores on axis 1. Volume (stream size) isn't associated with either axis.

*Table 1.4. Correlations among IBIs, IEI, and CAPS metrics. IBIs are listed in order of their correlation with IEI (higher correlations first).*

| IBI | Correlation with IEI | Mean absolute correlation with other IBIs | Best metric[1] | Correlation with best metric[1] |
|---|---|---|---|---|
| mean.tolval | -0.509 | 0.486 | whabloss | 0.673 |
| pct.sensative.abun | 0.496 | 0.419 | whabloss | -0.571 |
| n.plecoptera | 0.472 | 0.371 | whabloss | -0.532 |
| ept | 0.471 | 0.516 | whabloss | -0.637 |
| becks.i | 0.464 | 0.386 | whabloss | -0.521 |
| ptv.0.to.5.9 | 0.439 | 0.460 | sediment | -0.602 |
| n.no.co | 0.422 | 0.501 | sediment | -0.555 |
| hilsenhoff.bi | -0.420 | 0.468 | whabloss | 0.575 |
| pct.non.insect | -0.396 | 0.379 | salt | 0.561 |
| pct.sensitive.ept.abun | 0.389 | 0.457 | whabloss | -0.579 |
| dom.3.o.abun | -0.387 | 0.462 | whabloss | 0.493 |
| diversity.f | 0.386 | 0.473 | whabloss | -0.495 |
| pct.shellfish | -0.376 | 0.327 | salt | 0.509 |
| n.taxa | 0.375 | 0.425 | sediment | -0.453 |
| n.ephemeroptera | 0.370 | 0.450 | sediment | -0.570 |
| n.trichoptera | 0.322 | 0.398 | sediment | -0.449 |
| diversity.o | 0.286 | 0.350 | whabloss | -0.315 |
| n.scraper | 0.284 | 0.368 | salt | -0.400 |
| pct.ephemeroptera | 0.273 | 0.395 | sediment | -0.511 |
| pct.scraper.abun | 0.249 | 0.261 | connect | 0.279 |
| dom.3.f.abun | -0.232 | 0.293 | whabloss | 0.247 |
| n.diptera | 0.224 | 0.306 | salt | -0.222 |
| pct.abun.oligochaeta | -0.219 | 0.188 | imperv | 0.257 |
| ept.chiro.stand | 0.214 | 0.431 | sediment | -0.408 |
| shredders | 0.208 | 0.134 | roadx | -0.237 |
| n.gc | 0.196 | 0.287 | sediment | -0.225 |
| n.chironomidae | 0.190 | 0.287 | roadx | -0.193 |
| ept.chiro.ratio | 0.187 | 0.339 | sediment | -0.343 |
| scraper.to.filter.collector.ratio | 0.157 | 0.076 | connect | 0.171 |
| pct.chironomidae | -0.039 | 0.333 | pointsource | 0.157 |
| ept.chiro.abun.stand | -0.036 | 0.313 | impound | 0.213 |
| pct.ept.abun | 0.019 | 0.297 | whabloss | -0.234 |
| pct.tanytarsini | 0.015 | 0.240 | connect | 0.123 |
| Column Mean Absolute value | 0.295 | 0.360 | | 0.403 |

[1] the best metric is the metric with the highest absolute correlation with that IBI.
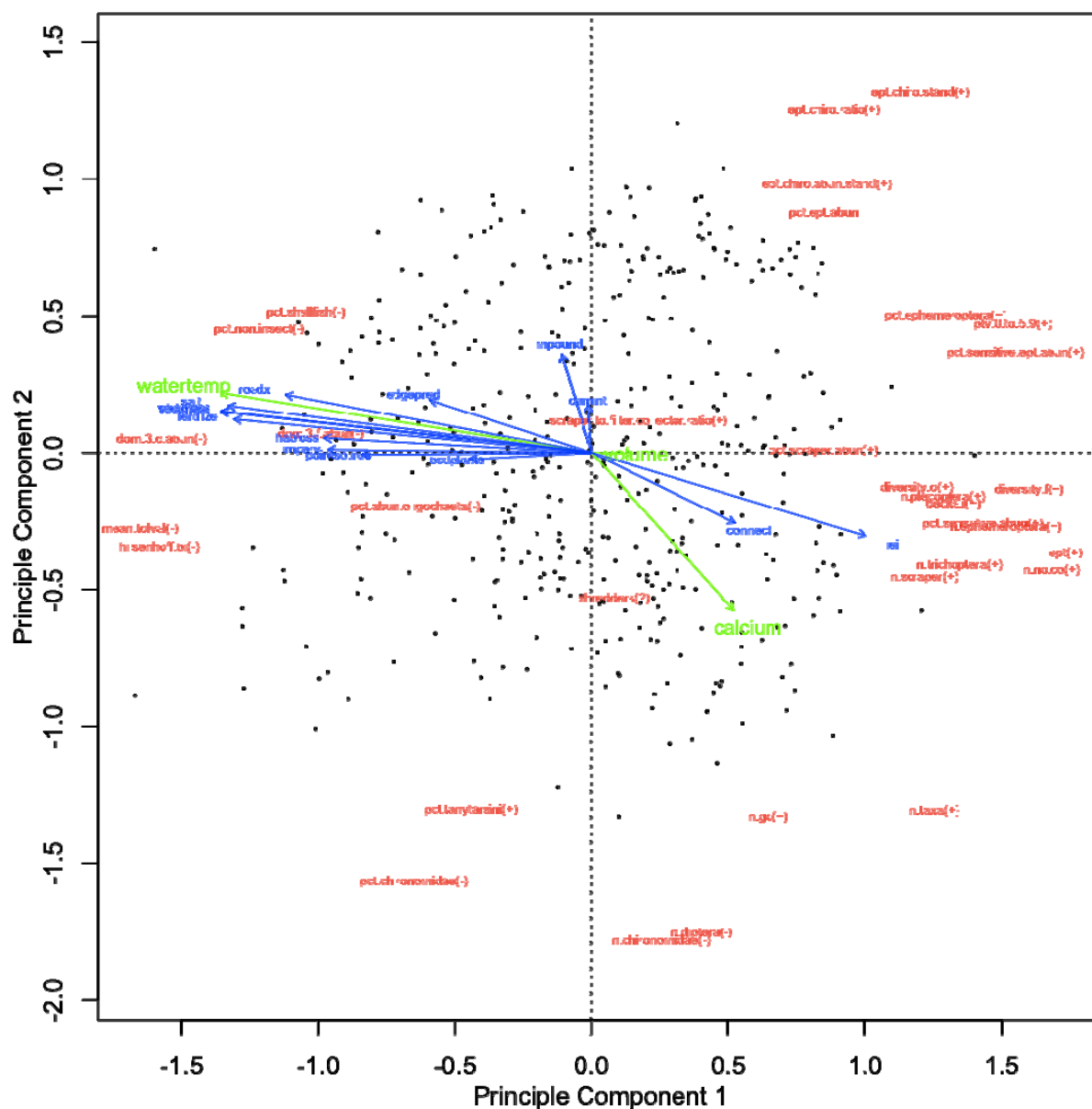
*Figure 1.23. First two axis of a PCA showing how sites (black dots) relate to each other in IBI space. The red text indicates the orientation of the IBIs in this space. Blue text and arrows show how CAPS metrics and IEI vary across the sites while the green text and arrows show how the CAPS settings variables vary across the sites. The two most important things to interpret with each element in the graph are the orientation relative to the origin: similar orientation of graphical items suggests correlation, directly opposing orientation suggests negative correlation, orthogonal orientation suggests no correlation ; and the distance of each graphical item from the center: further from the origin indicates stronger relationships. The (+) and (-) after each IBI indicate whether that IBI is expected to increase or decrease with habitat quality. The fact that most IBIs on the right have pluses and most on the left have minuses suggests that PC1 is oriented with habitat quality.*

**Discussion**

Overall the IBIs supported IEI as estimated by the CAPS model. This was evident in both the correlations in Table 2 and the alignment of IEI with the first principle component in the PCA (figure 1.23). Most of the CAPS metrics also aligned with the first principle component suggesting that they are also correlated with habitat quality as measured by the IBIs. The metrics that don't align with principle component 1 are impoundment and damint (dam intensity); both were skewed by one extreme value, a site in which a small watershed contains a relatively large dam and impoundment.

The weighting of each IBI on the first principle component almost perfectly indicates whether the IBI is an indicator of good or bad habitat quality. This suggests that the first principle component is reflecting habitat quality as measured by the suite of IBIs. That IEI weights strongly on this principle component suggest that it is a strong indication that IEI corresponds with habitat quality as measured by the suite of IBIs.

That many of the IBIs that weighted heavily on the second principle component involve Chironmids in their calculation suggest that Chironomidae may be driving this axis. This may be a statistical artifact (created by many similar metrics) or it may be that Chironomidae respond either to different aspects of habitat degradation or other environmental settings. Calcium also weighted heavily on this axis with higher calcium levels associated with lower scores on this axis and lower Chironomid abundance and richness. It is possible that calcium levels are driving the relative abundance of Chironomids and thus the scoring along this axis.

# Chapter 2

# Development of Tidal Restriction and Salt Marsh Ditching Metrics for CAPS

## INTRODUCTION

This task involved field data collection and aerial photo interpretation and creation of two new metrics for use in assessing salt marsh condition in CAPS. This work was conducted in cooperation with MassDEP and the Massachusetts Office of Coastal Zone Management (CZM).

## SALT MARSH DITCHING METRIC

### Purpose

Many, if not most, salt marshes in Massachusetts have had ditches cut into them, mainly in an attempt to control mosquito populations. There is no known data set that documents the extent and density of that ditching. This mapping project provides those data by digitizing ditch locations on color orthophoto base maps.

### Definition

The purpose of the project was to map anthropogenic ditches. Such ditches do not include naturally developed water channels such as creeks, rivers, etc. A ditch was defined as a narrow (generally 3 meters or less in width) channel, that had been cut into the salt marsh. Ditches are essentially straight and occasionally exhibit sharp (almost right angle) turns. On the source imagery, ditches appeared as dark grey to black lines. A creek was differentiated from a ditch in that the creek exhibited a sinuous flow path, including meanders, branching, and/or other features consistent with naturally flowing water. For the purposes of this mapping project, any narrow, straight, water feature was mapped as a ditch. Portions of naturally occurring creeks which have been channelized and straightened were mapped as ditches. Conversely, channels which are curved or contain meanders, etc. were not mapped as ditches.

### Delineation

The source imagery for mapping ditches was the MassGIS 2005 color orthophotos (technical specifications and metadata available at MassGIS). Salt marsh polygons were extracted from the MassDEP Wetlands Data layer (technical specifications and metadata available at MassGIS) and projected onto the source imagery. Photointerpeters reviewed each polygon for the presence of ditching. Ditches were digitized using ArcMap 9.2. The output was a linear shapefile. The name of the photointerpreter and the date of photointerpretation were recorded in the attribute fields of the shapefile. The monitor was a 15 inch LCD screen.

All photointerpretation occurred at a nominal scale of 1:3000. Only features that are visible at
this scale on the source imagery were mapped. Photointerpreters did not zoom in to more
accurately place linework, nor did they zoom out to increase the work rate. Photointerpreters
digitized the centerline of the ditch. All line work that connected ditches to other ditches, or
connected to the edge of the salt marsh feature, were snapped (lines connected via a shared
vertex). Photointerpreters did not map ditches that appear to be less than 30 meters in length.

Due to the limitations of aerial photointerpretation, it is understood that not all ditches were
captured. In some cases vegetation may have obscured the ditch, thus it would not be visible
on the source imagery. In other cases the ditching was so dense and extensive that it could not
all be captured within a reasonable time frame. The project emphasis was on capturing the
density of ditching in each salt marsh polygon, not capturing the specific features of each
individual ditch.

**Metric Creation**

The ditching metric starts with linework for all salt marsh ditches, converted to a 30 m grid
(figure 2.1). A standard kernel is built for each ditch cell, with a bandwidth of 200 m, and these
kernels are added to build a ditch density surface. A similar density surface is built for salt
marsh cells. The resulting metric is the ratio of ditch density to salt marsh density (figure 2.2).



*Figure 2.1. Linework for salt marsh ditching.*
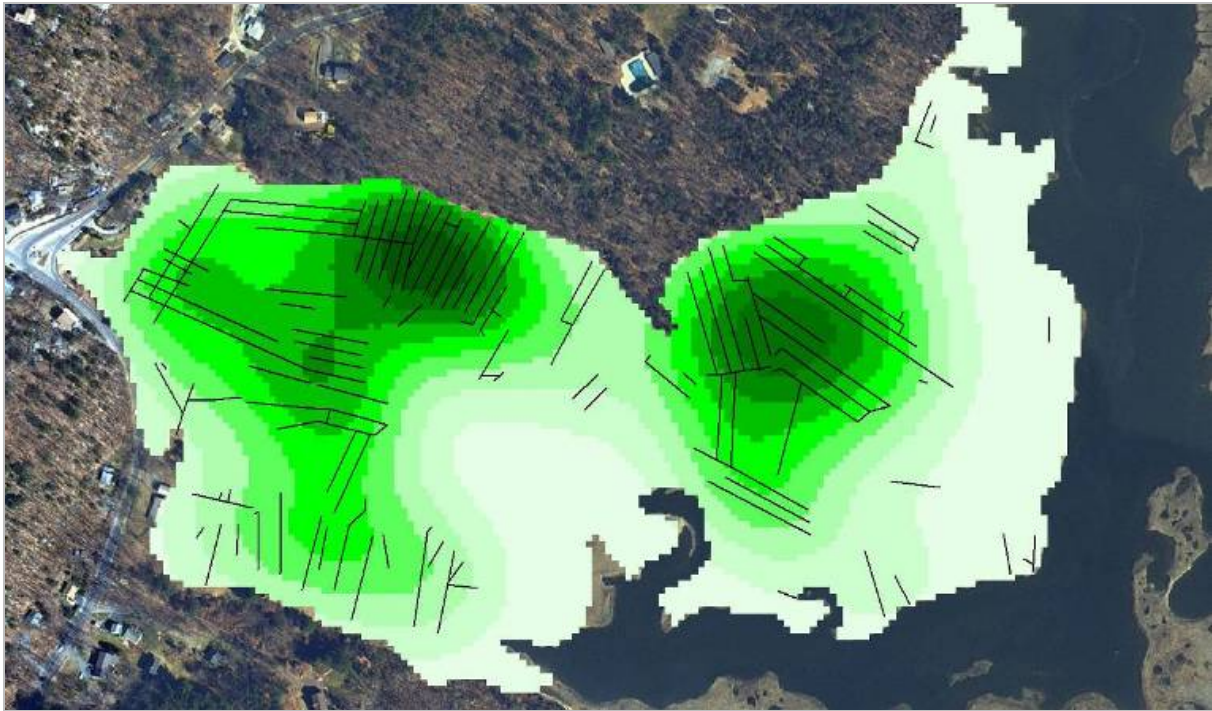
*Figure 2.2. Ditch density surface, the basis for the salt marsh ditching metric*

## TIDAL RESTRICTIONS METRIC

### Purpose

Many of the coastal wetlands in Massachusetts are degrading due to infrastructure crossings
such as roads and railroads that, when improperly designed, restrict tidal flow. Except for Cape
Cod, we lack good records of tidal restriction locations or the magnitude of the restrictions in
Massachusetts' coastal wetlands. This project generated a point data set of potential restriction
locations and restriction severity affecting salt marshes in Massachusetts. This dataset was then
used to create a tidal restriction metric for CAPS that will be used to assess salt marsh
ecological integrity.

### Definition

A tidal restriction is defined as a man-made feature (e.g. roads, railroads, bridges, culverts,
dams or other barriers) that constrains the natural flooding and ebb flow of water through
marsh habitat historically inundated by the tide. For this project, potential tidal restrictions
were limited to locations where roads and railroads cross tidal waters and marshes. These
features cross water using either a culvert or a bridge. For purposes of this project a culvert is a
structure with a bottom and bridge has no bottom leaving the natural streambed intact.

**Approach**

Our initial approach was a tiered system of assessing the severity of tidal restrictions based on available data.

1. Where detailed tide data were available for known restriction sites they would be used to characterize restriction severity.

2. Among sites that lacked detailed data, fifty sites associated with large areas of salt marsh would be assessed in the field to characterize restriction severity. Severity would based on the relative difference in peak tide elevation up gradient and down gradient of the potential restriction.

3. For all other sites aerial photo-interpretation would be used to score sites using an approach verified by comparison with field based data from steps 1 and 2 above.

Ultimately step 3 turned out to be unworkable; we were not able to create any model based on photo-interpreted data that yielded results consistent with field-based data. Instead, an alternative approach was developed using MassDEP's wetlands data, data from NOAA tide stations, a 5m digital elevation model, and field data from steps 2 & 3 above to model tidal restriction severity and create a suitable metric for tidal restrictions in CAPS.

The following describes the work completed, including the aerial photo-interpretation that ultimately was of no use to us in developing a tidal restriction metric.

<u>Potential Tidal Restriction Identification</u>

Potential tidal restrictions were identified by finding points where roads and railroads (from MassGIS) cross streams (MassGIS centerlines) in the vicinity of salt marshes (figure 2.3). We compared these points to the 75 measured tidal restrictions, and found that about 80% of restrictions were captured (in mainland Massachusetts; we still need to develop streams data for the Cape and islands). Potential restrictions that we did not identify may include tide gates, dikes, abandoned railroad beds and perhaps restrictions on salt ponds where there are no streams. It might be worthwhile in the future to look for these missing restrictions using aerial photos.
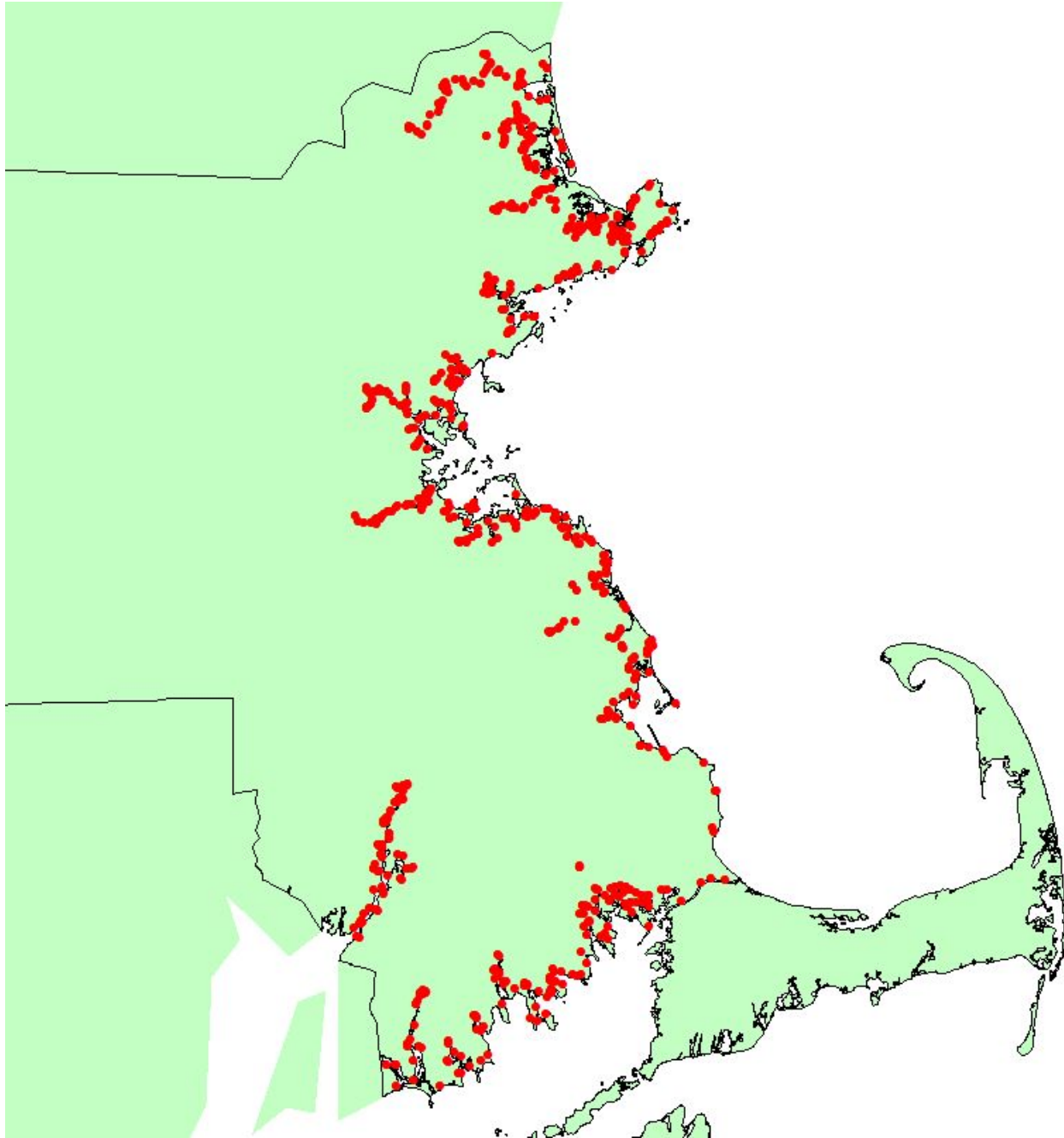
*Figure 2.3. Potential tidal restriction sites*

**Field Data Collection**

Sampling occurred during spring tide cycles between June 22 and August 31, 2009. CZM and
MassDEP staff remotely assessed each site using a set of criteria using local knowledge and GIS
resources, including but not limited to aerial photography (oblique and orthophotography), DEP
Wetlands, and MassGIS Open Space data. Sites are assessed for sampling based on the
following criteria:

- Physical access (including safety considerations)

- Legal access

- Potential for restriction

- Lack of control structures (e.g. flapper, electric sluice, or self-regulating tide gates)

Sites that met these criteria are prioritized for sampling based on the total acreage of salt marsh upstream (as depicted in MassDEP Wetlands mapping data; 1:12,000 based on photography from 1990-1993), with emphasis placed on those with greater acreage. A total of 50 potential tidal restrictions were evaluated.

Tide gauges were constructed by field personnel according to CZM modifications to specifications by Delta Laboratories' (Rochester, NY) Adopt-A-Stream program (http://www.adopt-a-stream.org/pdf/monitoring_tools/combination_staff_gauge.pdf). A prototype was built by CZM staff. Field personnel built an additional eight sets (pairs) of tide gauges to deploy at sites simultaneously.

Tide gauges are installed on both sides of a potential tidal restriction: downstream (seaward) and upstream (towardss headwaters). The high water levels measured downstream and upstream of a restriction are used to calculate the difference in relative tide elevations.

**Photo-interpretation**

The source imagery for characterizing potential restrictions was the MassGIS 2005 and 2008 color orthophotos (technical specifications and metadata available at MassGIS), and the MassDEP Wetlands Data layer (technical specifications and metadata available at MassGIS). Oblique images from Bing.com and Google Earth were used to assist in identifying the presence of a culvert or bridge.

All photointerpretation occurred at a nominal scale of 1:1200. Only features that were visible at this scale on the source imagery were used to characterize potential restrictions. Photointerpreters did not zoom in to more accurately characterize potential restrictions, nor did they zoom out to increase the work rate.

Photointerpreters used ArcGIS 9.2 and 14 inch LCD screens to identify potential restrictions. All data were recorded in the attribute table of the potential restriction point layer. The scenario number was recorded in the attribute table for abruptness of change in wetland salinity. A ratio was recorded in the attribute table for the difference in channel width, relative width of impounded water/scour pool, and fill.

## Characterization of Potential Tidal Restrictions

Because we are only concerned with tidal restrictions affecting salt marsh, potential restrictions were only evaluated if the wetland directly down-gradient was classified by DEP Wetlands as salt marsh.

Resources that were used to characterized potential tidal restrictions included:

- Orthophotos from 2005 and 2008 downloaded from MassGIS,
- Oblique images from Bing.com,
- Aerial images from Google Earth,
- DEP wetland layer,
- CAPS roads and land cover grid,
- USGS topo maps, and
- USGS Scour assessment

Potential tidal restrictions were characterized using the following five variables.

- Abruptness of change in wetland salinity
- Difference in channel width up-gradient vs. down-gradient of the potential restriction
- Relative width of impounded water/ scour pool up-gradient of the potential restriction
- Relative width of impounded water/ scour pool down-gradient of the potential restriction
- Amount of fill associated with a potential restriction
- Culvert or bridge

## Organization of Data

Each of the characterization variables were listed as a column heading within the attribute table of the tidal restriction point layer. Data were recorded as either nominal, ordinal scale (0-3), or continuous data. The attribute table also included; presence of culvert or bridge, the name of the researcher that defined the characterization for the potential restriction, the name of the researcher that reviewed the characterization, the data that were used to make the assessment, the date of the data used, the source of the data used, if there is another potential restriction up and/or down-gradient from the focal potential restriction, the date of characterization, and the restriction road type.

## Variables for Use in Assessing Potential Tidal Restrictions

It was expected that the ultimate classification of potential tidal restrictions would be based on the five variables listed below. Ulimately, these variables were not used for assessing tidal restrictions. However, they are still available for other potential uses. The five variables were assessed in the following manner.

*Abruptness of Change in Wetland Salinity*

This variable was based on the degree to which DEP wetland types (freshwater vs. salt water)
were different down-gradient vs. up-gradient of the potential restriction and the presence of
plants that could indicate the influence of fresh water. The most abrupt change possible was
represented by salt marsh below a potential restriction and a freshwater wetland without
indicators of brackish conditions above.

Phragmites was used as an indicator of brackish water and shrubs (except where they occur
near the upland border of a salt marsh) were used as indicators of freshwater. The rubric
assumed a change in water salinity based on the DEP wetlands classification and on the percent
cover of Phragmites and shrubs within a 100m arc up-gradient and down-gradient from a
potential restriction.

Scenario number (Table 2.1) was recorded for each potential tidal restriction. Scenarios 1-5
assumed relatively pure salt marsh down-gradient of a potential restriction without indicators
of fresh or brackish water (no Phragmites; no shrubs). Scenarios 6-10 are for salt marshes
down-gradient of a potential restriction with indicators of freshwater influence (presence of
Phragmites and/or shrubs).

*Table 2.1: Rubric for characterizing abruptness in change between wetland resource types*

| Scenario | DOWN-GRADIENT | | | | UP-GRADIENT | | | |
|---|---|---|---|---|---|---|---|---|
| | Salinity* | Phragmites | | Shrubs | Salinity* | Phragmites | | Shrubs |
| 1 | Salt | None** | And | None | Fresh | None | | |
| 2 | Salt | None | And | None | Fresh | 5% - 50% | | |
| 3 | Salt | None | And | None | Fresh | 50% - 100% | | |
| 4 | Salt | None | And | None | Salt | None | And | None |
| 5 | Salt | None | And | None | Salt | 5% - 50% | And/Or | 5% - 50% |
| 6 | Salt | 5% - 50% | And/Or | 5% - 50% | Fresh | None | | |
| 7 | Salt | 5% - 50% | And/Or | 5% - 50% | Fresh | 5% - 50% | | |
| 8 | Salt | 5% - 50% | And/Or | 5% - 50% | Fresh | 50% - 100% | | |
| 9 | Salt | 5% - 50% | And/Or | 5% - 50% | Salt | None | And | None |
| 10 | Salt | 5% - 50% | And/Or | 5% - 50% | Salt | 5% - 50% | And/Or | 5% - 50% |

*Based on DEP Wetlands data layer
**None is < 5%

*Difference in channel width up-gradient vs. down-gradient of the potential restriction*

This variable compared the width of the channel above to the width of the channel below the potential restriction. The natural stream width was determined by measuring the stream width every 50 meters away from the potential restriction up to 200 meters away or until another water body was encountered (e.g. confluence with another creek or river), including the width immediately at the restriction at 0m. The mean was then taken of the five natural stream width measurements to give the average natural stream width for each side of the restriction. A ratio was recorded by dividing the down-gradient width by the up-gradient width. A result greater than 1 indicated that the down-gradient side of the potential restriction was wider than the up-gradient side.

*Relative width of impounded water/ scour pool (two variables: one up-gradient and one down-gradient of the potential restriction)*

This assessed the ratio between the width of the impounded water or scour pool compared to the width of the natural channel on each side of the potential restriction. Impoundments and scour pools were treated together because it was not clear that we would be able to readily distinguish from aerial photographs scour pools from small impoundments. This was treated as two variables and represented as separate columns for up-gradient and down-gradient in the attribute table.

If there was a visible impoundment or scour pool just up-gradient or down-gradient of the potential restriction, the width of the impoundment/scour pool was compared to the <u>natural channel width</u> on the same side (up-gradient or down-gradient) of the potential restriction. The natural stream width was determined by measuring the stream width every 50 meters past the end of the impoundment/scour pool up to 200 meters away. The mean was then taken of the four natural stream width measurements to give the average natural stream width. The <u>impoundment/scour pool width</u> was measured by taking one measurement at the widest part of the impoundment/scour pool. The impoundment/scour pool width was then divided by the natural stream width to calculate the difference expressed as a ratio.

*Amount of fill associated with a potential restriction*

The type of fill that was assessed included only areas where a road, railroad or other linear anthropogenic feature crossed through a salt marsh preventing flow of water through the marsh outside of the natural confines of the channel. It was assumed that such fill had the potential to disrupt salt marsh hydrology during high spring tides but that the affect on salt marsh ecology was substantially less than restrictions affecting channels. This was measured as a ratio. The ratio was based on the distance of the marsh the fill crossed in relation to the width of the marsh. Expressed another way it was the length of road, railroad or other linear feature crossing a marsh (crossing length) minus the opening for water movement (culvert or bridge), divided by the width of the marsh at the crossing (crossing length). Fill created by the digging or maintenance of ditches through the marsh was not included in this evaluation.

Additional Information

One additional variable was included in the attribute table and assessed to the extent possible but was not intended to be included in the final assessment of severity for potential tidal restrictions.

*Culvert or Bridge*

For our purposes a "bridge" had no bottom leaving the natural streambed intact. A culvert was a crossing structure that had a bottom, even if that bottom was embedded. A culvert was identified by the presence of a headwall or by direct visual identification from source imagery. A bridge crossed over the channel allowing free flow of water beneath. Bridges often threw shadows in aerial photographs while culverts did not. The MassDEP wetlands data layer was also used as a source to help differentiate between the presence of a culvert or bridge. DEP identified a bridge by passing the wetland delineation line "through" the road, thereby mapping the wetland under the road. They identified a culvert by stopping the wetland delineation line at the road and depicted the culvert as a hydrologic connection. This is not 100% accurate; however, it did give insight as to what other photo-interpreters thought.

**Data Analysis/Development of Tidal Restriction Metric**

Initially we expected to develop and parameterize the tidal restriction metric for CAPS based on available field data on tidal restrictions and statistical analyses of the five variables derived from aerial photo-interpretation. Unfortunately, we were unable to construct any model using photo-interpreted data that would accurately predict the severity of tidal restrictions when compared to field data. Therefore, we abandoned the use of photo-interpreted data and developed a new approach for characterizing restriction severity that then served as the basis for development of a tidal restriction metric.

The tidal restrictions metric is one of the more complex metrics in CAPS. It depends upon the tidal regime settings variable, and uses a similar approach. The entire process is described in three steps below.

1.  Estimate tidal regime to build the tidal regime settings variable. Input GIS data were interpolated from mean tidal range (m) from 120 NOAA tide stations off the coast of Massachusetts, New Hampshire, and Rhode Island (figure 2.4), the 5 m DEM from MassGIS, and DEP wetlands. We placed 2500 random points in each of uplands and salt marshes (based on DEP wetlands). A logistic regression model was built to predict salt marshes vs. uplands. The best model included the DEM, tide range, and a dummy variable that differentiated areas north and south of the Cape (this was needed to achieve a spatially random error distribution; we presume that it's accounting for a bias in either the DEM or tide station data). The model was significant ($P < 0.001$), with a correct classification rate of 91% (Table 2.2).
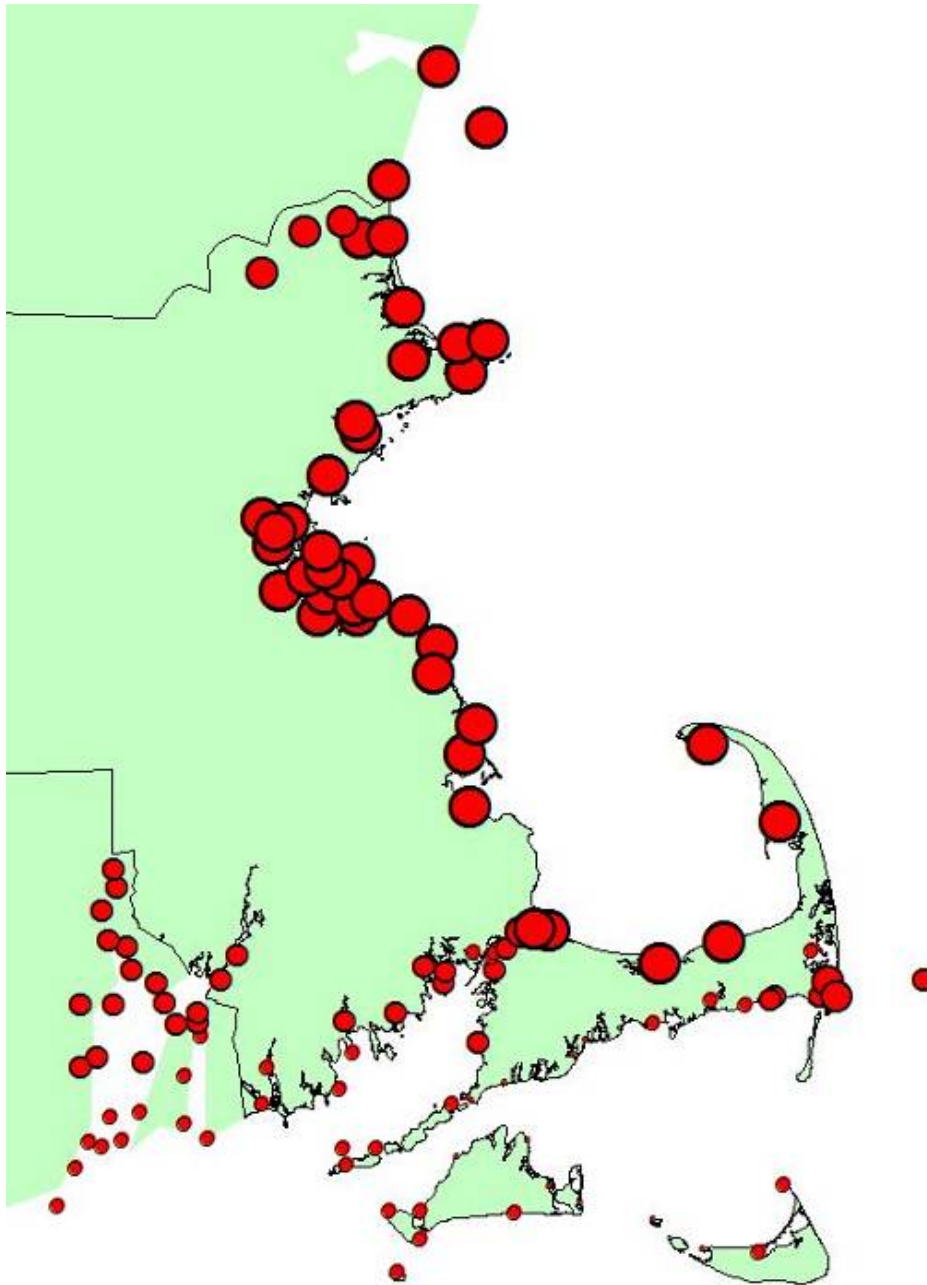
*Figure 2.4. Location of NOAA tide stations used to develop the tidal regime settings variable*

*Table 2.2. Confusion matrix for salt marsh vs. upland logistic regression, n = 5000*

|  |  | predicted | |
|---|---|---|---|
|  |  | marsh | upland |
| obs. | marsh | 2259 | 296 |
|  | upland | 149 | 2406 |

Interestingly, several of the areas where the logistic regression made errors of commission are freshwater wetlands above tide gates—apparently these represent former salt marshes that have been degraded into freshwater wetlands by tidal restrictions.

The P(salt marsh) from this logistic regression is our tidal regime settings variable. Values near 0 represent areas that are likely to be uplands or freshwater wetlands, and values near 1 represent areas that are likely to be salt marshes, and thus have a regular tidal influence.

2. Estimate severity of tidal restrictions. We did this by calculating the ratio of the area of tidal regime = salt marsh (tides setting variable from step 1 > 0.5) above each potential restriction to the area of salt marshes (from DEP wetlands) above the restriction. This ratio is the proportion of salt marsh that hasn't been lost. We assume that tidal restrictions are driving much of the loss. We then used linear regression to predict the restriction height of the field-measured restrictions (from CZM and 2009 CZM/DEP field season, n = 67) from this ratio (P < 0.001, r2 = 0.364). The relationship is noisy but strong (figure 2.5). This allowed us to assign a restriction height to all potential tidal restrictions in the coastal zone. These heights are obviously not precise, but they give an index of the severity of each restriction.
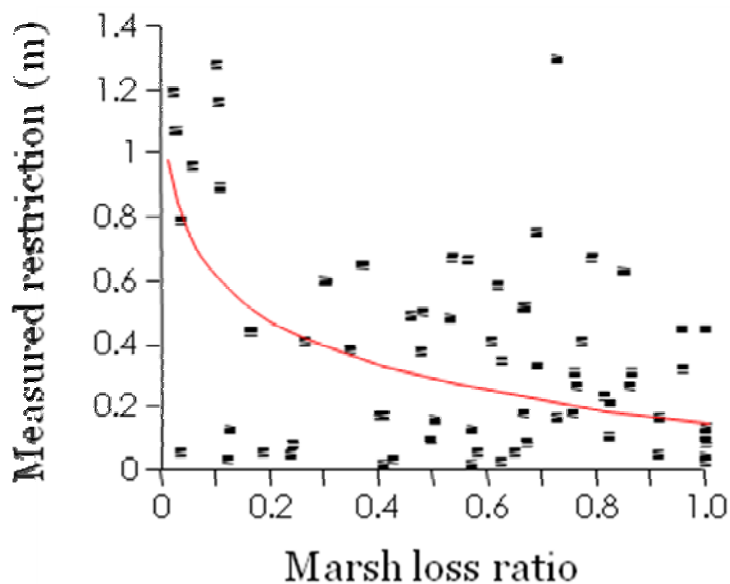


*Figure 2.5. Relationship between the height of field-based measured tidal restrictions and calculated ratio of salt marsh loss*

3. The actual tidal restriction metric is simple: we follow each watershed up from the mouth, tracking the most severe restriction crossed while moving up the watershed. Then, for each cell in the entire watershed, subtract the restriction heights at that point from the tidal range, and recalculate the tidal regime settings variable. This gives us both our original tidal settings variable (for a world without tidal restrictions), and a new tidal variable that takes tidal restrictions into account. The tidal restrictions metric is simply the difference between

the two. This metric will be used to assess the effects of tidal restrictions on what is
currently salt marsh but it can also be used in ecological integrity models for freshwater
wetlands that used to be salt marsh (figure 2.6).
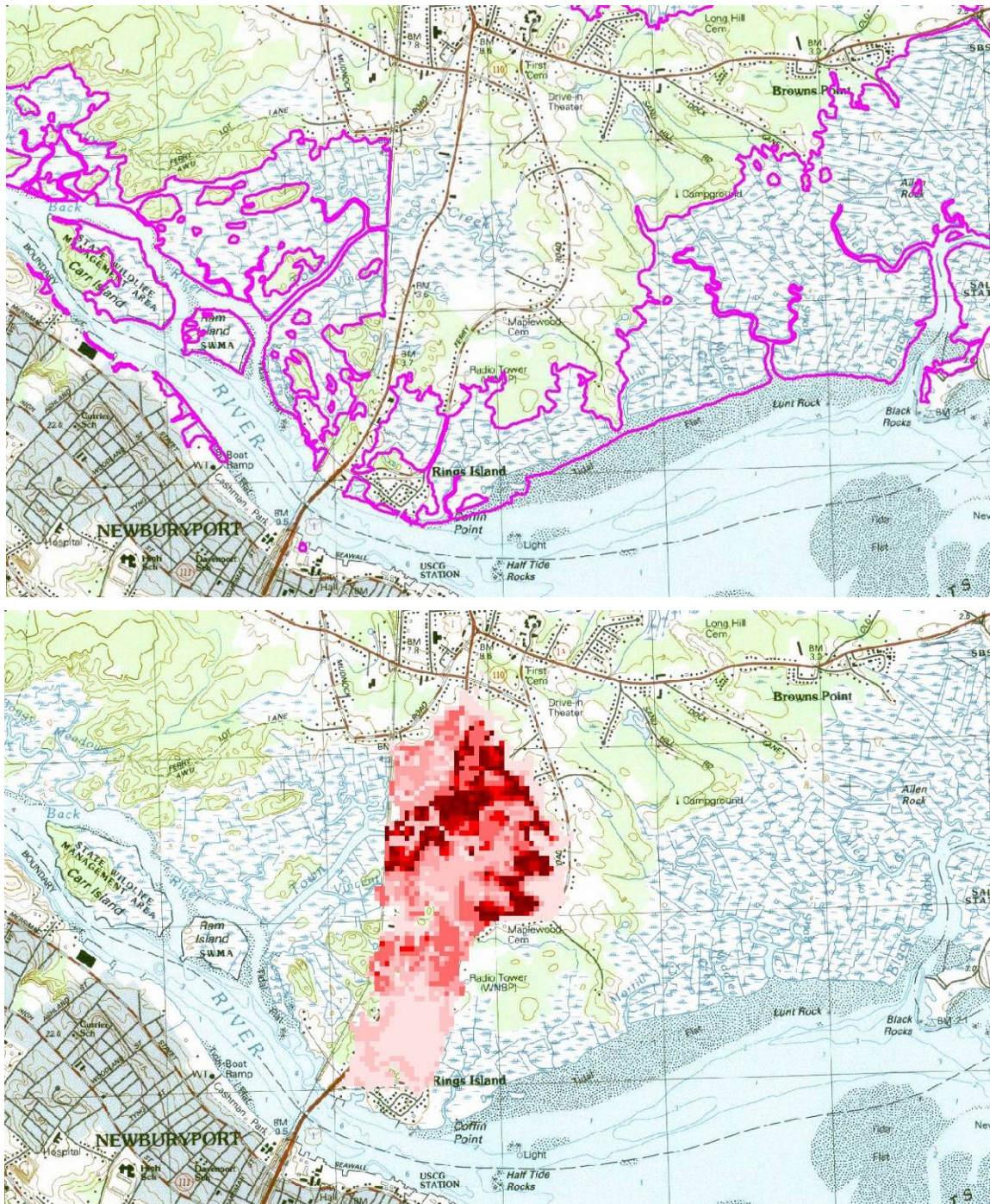


*Figure 2.6. Application of the CAPS tidal restriction metric to salt marsh polygons (top) in the
vicinity of Newburyport, MA. The darker the color the more adverse the effects from tidal
restrictions (bottom).*

# Chapter 3

# Development of Invertebrate and Algae IBIs for Forested Wetlands: Sample Identification

Over the course of two field seasons a large collection of algae and invertebrates have been sampled in forested wetlands. As part of this grant, we sorted and identified selected algae (diatoms) and invertebrates sampled in the 2008 and 2009 field seasons. These data will be used to develop indices of biological integrity for use in evaluating wetland condition and calibrating landscape-based models (CAPS) for assessing ecological integrity in wetland and aquatic ecosystems.

STATUS OF INVERTEBRATE SAMPLE DATA FROM 2009

Identification of specimens collected in the 2009 field season focused on sorting and initial identification to the Order level of emergence trap (Table 3.1) and pit trap (Table 3.2) invertebrate samples.

**Emergence Trap Samples 2009 - Concord and Millers River Watersheds**

All samples (497 samples from 145 sites) have been sorted to Order (Table 2).

*Table 3.1. 2009 Taxa (Emergence Trap Samples)*

| Taxa | Total | # Sites Obs. | Max Obs. |
|------|-------|--------------|----------|
| Diptera | 7858 | 145 | 940 |
| Collembola | 165 | 81 | 16 |
| Acari | 103 | 62 | 4 |
| Hymenoptera | 74 | 54 | 5 |
| Hemiptera | 69 | 53 | 5 |
| Nematoda | 62 | 1 | 62 |
| Coleoptera | 53 | 38 | 4 |
| Araneae | 53 | 45 | 3 |
| Plecoptera | 36 | 8 | 28 |
| Psocoptera | 35 | 32 | 2 |
| Trichoptera | 25 | 15 | 5 |
| Thysanoptera | 11 | 11 | 1 |
| Lepidoptera | 9 | 8 | 2 |
| Opiliones | 9 | 7 | 2 |
| Ephemeroptera | 2 | 1 | 2 |

| | | | |
|---|---|---|---|
| Pulmonata | 2 | 1 | 2 |
| Neuroptera | 2 | 2 | 1 |
| Unidentified | 1 | 1 | 1 |
| Gastropoda | 1 | 1 | 1 |
| Odonata | 1 | 1 | 1 |
| Orthoptera | 1 | 1 | 1 |
| Mecoptera | 1 | 1 | 1 |
| Isopoda | 1 | 1 | 1 |

**Pitfall Trap Samples 2009 - Concord and Millers River Watersheds**

Sample identification to the order level is in progress (1099 samples). 452 samples have been
sorted and 32,282 specimens identified to date (Table 3.2).

*Table 3.2. 2009 Taxa (Pitfall Trap Samples)*

| Taxa | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|
| Collembola | 12605 | 443 | 396 |
| Acari | 3579 | 374 | 131 |
| Coleoptera | 3521 | 379 | 97 |
| Diptera (adult) | 2699 | 392 | 95 |
| Araneae | 2586 | 406 | 90 |
| Hymenoptera | 2436 | 376 | 102 |
| Gastropoda | 2337 | 149 | 162 |
| Hemiptera | 715 | 273 | 36 |
| Diptera (larva) | 558 | 176 | 56 |
| Isopoda | 453 | 85 | 38 |
| Julida | 279 | 90 | 37 |
| Unknown | 93 | 60 | 5 |
| Orthoptera | 79 | 59 | 3 |
| Polydesmida | 66 | 38 | 6 |
| Lepidoptera | 47 | 45 | 2 |
| Opiliones | 43 | 34 | 8 |
| Pseudoscorpiones | 34 | 16 | 13 |
| Annelida | 28 | 23 | 4 |
| Bivalvia | 25 | 10 | 8 |
| Thysanoptera | 19 | 14 | 4 |
| Psocoptera | 19 | 19 | 1 |
| Neuroptera | 16 | 13 | 2 |
| Polyzoniida | 15 | 9 | 4 |
| Lithobiomorpha | 8 | 4 | 3 |
| Trichoptera | 6 | 5 | 2 |

| | | | |
|---|---|---|---|
| Amphipoda | 5 | 3 | 3 |
| Nematode | 5 | 4 | 2 |
| Scutigeromorpha | 2 | 2 | 1 |
| Mecoptera | 1 | 1 | 1 |
| Plecoptera | 1 | 1 | 1 |
| Chordeumatida | 1 | 1 | 1 |
| Siphonaptera | 1 | 1 | 1 |

**STATUS OF DIATOM AND INVERTEBRATE SAMPLE DATA FROM 2008**

Analysis of 2008 samples focused on identification of specimens for select taxa of algae and invertebrates that had been previously sorted to the Order level. Table 3.3 provides a summary of the taxonomic resolution achieved for those specimens that have been identified to date.

*Table 3.3. Taxonomic resolution of identifications to date for taxa that were selected for analysis*

| Taxa Group | | Order | Family | Genus | Species | Total |
|---|---|---|---|---|---|---|
| Diatoms - Water samples | Total | 0 | 0 | 629 | 14887 | 15516 |
| | % | 0 | 0 | 4 | 96 | |
| Diatoms - Leaf Litter samples | Total | 0 | 0 | 1576 | 38202 | 39778 |
| | % | 0 | 0 | 4 | 96 | |
| Araneae - Pitfall Trap Samples | Total | 191 | 345 | 316 | 1113 | 1965 |
| | % | 10 | 18 | 16 | 57 | |
| Coleoptera - Pitfall Trap Samples | Total | 0 | 0 | 3 | 1317 | 1320 |
| | % | 0 | 0 | 0 | 100 | |
| Hemiptera - Pitfall Trap Samples | Total | 0 | 68 | 1392 | 50 | 1510 |
| | % | 0 | 5 | 92 | 3 | |
| Hemiptera - Emergence Trap Samples | Total | 3 | 4 | 15 | 3 | 25 |
| | % | 12 | 8 | 60 | 12 | |
| Hymenoptera - Pitfall Trap Samples | Total | 1 | 132 | 1269 | 155 | 1557 |
| | % | 0 | 8 | 82 | 10 | |
| Hymenoptera - Emergence Trap Samples | Total | 0 | 17 | 9 | 0 | 26 |
| | % | 0 | 65 | 35 | 0 | |
| Orthoptera - Pitfall Trap Samples | Total | 0 | 21 | 47 | 2 | 70 |
| | % | 0 | 30 | 67 | 3 | |

**Diatoms 2008**

Leaf litter and water samples collected from forested wetlands within the Chicopee Watershed have been analyzed for diatom community composition. Rex R. Lowe analyzed the samples using a 600-valve count.

Leaf Litter Samples (n=71)

Taxonomic richness: 23 Families, 48 genera, ~238 species. 4% of the valves identified could not be classified beyond genera (Table 3.3). Common taxa: *Eunotia sp., Pinnularia sp., Eunotia exigua (Breb. Ex Kütz.) Rabenh., Eunotia curvata f. bergii Woodhead & Tweed, Eunotia pectinalis (O.F. Müller) Rabenhorst, Fragilariaforma virescens (Ralfs) Williams & Round, Eunotia paludosa v. paludosa Grun., Meridion circulare (Greville) Agardh, Tabellaria floculosa (Roth) Kütz, Gomphonema sp., Eunotia septentrionalis Østrup, Gomphonema parvulum (Kütz.) Kütz.* (Table 3.4).

Water Samples (n=28)

Taxonomic richness: 19 Families, 37 genera, 158 species. 4% of the valves identified could not be classified beyond genera (Table 3.3). Common taxa: *Pinnularia, Eunotia, Eunotia paludosa v. paludosa* Grun., *Eunotia exigua* (Beb. Ex Kutz.) Rabenh. (Table 3.5).

**Invertebrates 2008**

The following Orders were selected for finer taxonomic identification: Araneae, Coleoptera, Collembola, Diptera, Hemiptera, Hymenoptera, and Orthoptera. Diptera specimens were sent to John Tipping at Lotic Inc. Sean Werle is identifying the Collembola specimens. Don Chandler identified Coleoptera specimens and Eric Eaton identified Hemiptera, Hymenoptera, Orthoptera, and Araneae specimens.

Emergence Trap Samples 2008-Chicopee Watershed

Hemiptera: Observed at 16 sites. 4 Families, 7 genera, 3 species. 12% were identified to species, 60% to genus, 8% to family, and 12% were left at the order level (Table 3.3). Common genus: *Scaphoideus* (Table 3.6).

Hymenoptera: Observed at 16 sites. 5 Families and 4 genera. 35% of the specimens were identified to genus and 65% were left at the family level (Table 3.3). Common family*: Diapriidae, Formicidae* (Table 3.7).

Pitfall Trap Samples 2008-Chicopee Watershed

Araneae: Observed at 62 sites. 17 Families, 51 genera, identified 59 species. 57% were identified to species, 16% to genus, 18% to family, and 9.7% were left at the order level (Table 3.3). Common taxa include *Neoantistea magna*, Linyphilidae, *Wadotes*, and Lycosidae (Table 3.8).

Coleoptera: Observed at 61 sites. 32 Families, 108 Genus, 163 Species (95 morphospecies). 100% of the specimens were identified to species/morpho-species (Table 3.3). Common

species/morphospecies: *Pterostichus coracinus, Agonum fidele, Platydracus viridianus, Pallodes
pallidus, Synuchus impunctatus, Carpelimus #1, Agonum gratiosum* (Table 3.9).

Collembola: 50% of the samples (44/64 sites) have been identified. Identifications were not
made beyond the genus level. Common genera: *Tomocerus, Dicyrtoma, Sinella, Hypogastrura,
Pseudachorutes* (Table 3.10).

Hemiptera: Observed at 60 sites. 20 Families, 25 genera, identified 10 species. 3% were
identified to species, 92% to genera, and 5% were left at the family level (Table 3.3). Common
genera and species: *Scaphoideus, Ceratocombus vegans* (Table 3.11).

Hymenoptera: Observed at 62 sites. Identified 18 Families, 14 genera, and 6 species. 10% were
identified to species, 82% to genus, and 8% were left at the family level (Table 3.3). Common
genera and families: *Trimorus, Aphaenogaster, and Ceraphronidae* (Table 3.12).

Orthoptera: Observed at 30 sites. 2 Families, 4 genera, identified 2 species. 3% were identified
to species, 67% to genus, 30% to family and 3% were left at the order level (Table 3.3).
Common genus: *Gryllus* (Table 3.13).

The following tables contain summaries of samples identified to date, including those
specimens identified as part of this grant project and in earlier phases of the work.

*Table 3.4. 2008 Diatom Taxa (Leaf Litter). Total is the cumulative taxon abundance for all samples, # of
sites obs. is the total number of sites that taxon was oserved, and max obs. is the maximum number of
specimens identified at one site. *cf before a species name indicates "resembles".*

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Achnanthes* | *biasolettiana Grunow* | ACHNBIAS | 2 | 1 | 2 |
| *Achnanthes* | *cf. chlidanos Hohn & Hellerman* | ACHNcf.CHLI | 4 | 1 | 4 |
| *Achnanthes* | *hauckiana var. rostrata* | ACHNHAUC | 1 | 1 | 1 |
| *Achnanthes* | *nodosa Cleve_Euler* | ACHNNODO | 6 | 2 | 4 |
| *Achnanthes* | *cf. rosenstockii Lange_Bertalot* | ACHNcf.ROSE | 198 | 4 | 147 |
| *Achnanthidium* | *exiguum (Grunow) D.B. Czarnecki* | ACHNEXIG | 3 | 1 | 3 |
| *Achnanthidium* | *minutissimum (Kützing) Czarnecki* | ACHNMINU | 776 | 21 | 274 |
| *Achnanthidium* | *minutissimum var. microcephala Hust.* | ACHNMINUmi | 128 | 3 | 93 |
| *Achnanthidium* | *Achnanthidium sp.* | ACHNsp. | 24 | 9 | 6 |
| *Aulacoseira* | *crenulata (Ehrenberg) Thwaites* | AULACREN | 494 | 8 | 345 |
| *Aulacoseira* | *lacustris (Grunow) Krammer* | AULALACU | 22 | 1 | 22 |
| *Aulacoseira* | *nygaardii (Camburn) Camburn & Charles* | AULANYGA | 336 | 3 | 333 |
| *Aulacoseira* | *perglabra (Østrup) E.Y. Haw.* | AULAPERG | 2 | 2 | 1 |
| *Aulacoseira* | *Aulacoseira sp.* | AULAsp. | 6 | 2 | 3 |
| *Brachysira* | *brebissonii R. Ross* | BRACBREB | 2 | 2 | 1 |
| *Brachysira* | *microcephala (Grunow) Compère* | BRACMICRO | 4 | 2 | 2 |
| *Caloneis* | *bacillum (Grunow) P.T.Cleve* | CALOBACI | 12 | 5 | 4 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Caloneis* | *ventricosa (Ehrenb.) Meist.* | CALOVENT | 2 | 1 | 2 |
| *Caloneis* | *Caloneis sp.* | CALOsp. | 4 | 2 | 2 |
| *Chamaepinnularia* | *hassiaca (Krasske) Cantonati & Lange_Bertalot* | CHAMHASS | 2 | 1 | 2 |
| *Chamaepinnularia* | *soehrensis ( Krasske) Lange_Bert.* | CHAMSOEH | 11 | 5 | 4 |
| *Chamaepinnularia* | *Chamaepinnularia sp.* | CHAMsp. | 71 | 10 | 33 |
| *Cocconeis* | *pediculus Ehr.* | COCCPEDI | 1 | 1 | 1 |
| *Cocconeis* | *neodiminuta Krammer* | COCCNEOD | 1 | 1 | 1 |
| *Cocconeis* | *placentula Ehr.* | COCCPLAC | 5 | 4 | 2 |
| *Cocconeis* | *Cocconeis sp.* | COCCsp. | 1 | 1 | 1 |
| *Cyclotella* | *ocellata Pant.* | CYCLOCEL | 18 | 1 | 18 |
| *Cyclotella* | *Cyclotella sp.* | CYCLsp. | 2 | 1 | 2 |
| *Cymbella* | *affinis Kütz* | CYMBAFFI | 1 | 1 | 1 |
| *Cymbella* | *aspera (Ehrenb.) H. Perag.* | CYMBASPE | 5 | 4 | 2 |
| *Cymbella* | *cuspidata Kützing* | CYMBCUSP | 2 | 1 | 2 |
| *Cymbella* | *hauckii Van Heurck* | CYMBHAUC | 8 | 2 | 7 |
| *Cymbella* | *cf. hebridica Grunow ex Cleve* | CYMBcf.HEBR | 2 | 1 | 2 |
| *Cymbella* | *naviculaformis Auersw. ex Heribaud* | CYMBNAVI | 49 | 4 | 39 |
| *Cymbella* | *tumidula Grun.* | CYMBTUMI | 2 | 1 | 2 |
| *Decussata* | *placenta (Ehrenberg) Lange_Bertalot & Mezeltin* | DECUPLAC | 89 | 21 | 15 |
| *Denticula* | *kuetzingii Grunow* | DENTKUET | 2 | 1 | 2 |
| *Diadesmis* | *biceps Arnott ex Grunow* | DIADBICE | 2 | 1 | 2 |
| *Diadesmis* | *contenta (Grunow) D.G. Mann* | DIADCONT | 11 | 4 | 4 |
| *Diadesmis* | *paracontenta Lange_Bertalot and Werum* | DIADPARA | 3 | 3 | 1 |
| *Diadesmis* | *perpusilla (Kützing) D.G. Mann* | DIADPERP | 6 | 3 | 3 |
| *Diatoma* | *anceps (Ehrenberg) Kirchner* | DIATANCE | 237 | 17 | 117 |
| *Diatoma* | *anceps var. linearis M.Perag.* | DIATANCEli | 57 | 1 | 57 |
| *Diatoma* | *mesodon (Ehrenberg) Kützing* | DIATMESO | 4 | 2 | 2 |
| *Diploneis* | *elliptica (Kützing) P.T. Cleve* | DIPLOELLI | 4 | 4 | 1 |
| *Encyonema* | *silesiacum (Bleisch in Rabenhorst) D.G. Mann* | ENCYSILE | 11 | 6 | 3 |
| *Encyonema* | *minutum (Hilse in Rabenhorst) D.G. Mann* | ENCYMINU | 49 | 14 | 12 |
| *Encyonema* | *norvegica (Grunow in A. Schmidt) Bukhtiyarova* | ENCYNORV | 2 | 1 | 2 |
| *Encyonema* | *norvegica var. lapponica (A. Cleve) EY Haw. & MG Kelly* | ENCYNORVla | 4 | 2 | 2 |
| *Encyonema* | *ventricosum v. angustatum Krammer* | ENCYVENTan | 1 | 1 | 1 |
| *Encyonemopsis* | *cf. subminuta Krammer & Reichardt* | ENCYcf.SUBM | 2 | 1 | 2 |
| *Eunotia* | *arculus (Grun.) Lange_Bertalot & Norpel* | EUNOARCU | 2 | 1 | 2 |
| *Eunotia* | *bigibba Kütz.* | EUNOBIGI | 10 | 4 | 5 |
| *Eunotia* | *bilunaris Ehr. Mills.* | EUNOBILU | 517 | 27 | 175 |
| *Eunotia* | *carolina Patrick* | EUNOCARO | 225 | 8 | 111 |
| *Eunotia* | *crista_gallii P.T. Cl.* | EUNOCRIS | 2 | 1 | 2 |
| *Eunotia* | *curvata (Kütz.) Lagerst* | EUNOCURV | 47 | 4 | 18 |
| *Eunotia* | *curvata v. subarcuata Woodhead & Tweed* | EUNOCURVsu | 11 | 2 | 9 |
| *Eunotia* | *curvata f. bergii Woodhead & Tweed* | EUNOCURVfb | 1909 | 48 | 226 |
| *Eunotia* | *denticulata (Bréb. ex Kütz.) Rabenh.* | EUNODENT | 4 | 2 | 2 |
| *Eunotia* | *elegans Østrup* | EUNOELEG | 188 | 7 | 82 |
| *Eunotia* | *exigua (Breb. Ex Kütz.) Rabenh.* | EUNOEXIG | 2120 | 53 | 393 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Eunotia* | *fallax A. Cleve* | EUNOFALL | 192 | 16 | 84 |
| *Eunotia* | *flexuosa Bréb. ex Kütz.* | EUNOFLEX | 126 | 9 | 39 |
| *Eunotia* | *cf. glacialis F. Meister.* | EUNOcf.GLAC | 4 | 1 | 4 |
| *Eunotia* | *girdle view 12_23 µm* | EUNOgirdlS | 3276 | 58 | 300 |
| *Eunotia* | *girdle view 30_45 µm* | EUNOgirdl | 264 | 18 | 93 |
| *Eunotia* | *incisa W. Sm. ex Greg,* | EUNOINCI | 34 | 3 | 20 |
| *Eunotia* | *meisteri Boyer* | EUNOMEIS | 23 | 3 | 20 |
| *Eunotia* | *microcephala Migula* | EUNOMICR | 7 | 3 | 3 |
| *Eunotia* | *naegeli Migula* | EUNONAEG | 605 | 12 | 310 |
| *Eunotia* | *monodon Ehr.* | EUNOMONO | 10 | 4 | 5 |
| *Eunotia* | *nymanniana Grun.* | EUNONYMA | 2 | 1 | 2 |
| *Eunotia* | *paludosa v. paludosa Grun.* | EUNOPALUpa | 2061 | 37 | 580 |
| *Eunotia* | *paludosa v. trinacria (Krasske) Norpel* | EUNOPALUtr | 1316 | 23 | 545 |
| *Eunotia* | *paralella Ehr.* | EUNOPARA | 55 | 10 | 19 |
| *Eunotia* | *pectinalis (O.F. Müller) Rabenhorst* | EUNOPECT | 1580 | 45 | 288 |
| *Eunotia* | *perpusilla Grun.* | EUNOPERP | 97 | 12 | 42 |
| *Eunotia* | *praerupta Ehr.* | EUNOPRAE | 263 | 11 | 99 |
| *Eunotia* | *cf. praerupta Her.* | EUNOcf.PRAE | 1 | 1 | 1 |
| *Eunotia* | *rhomboidea Hust.* | EUNORHOM | 197 | 16 | 59 |
| *Eunotia* | *septentrionalis Østrup* | EUNOSEPT | 1116 | 31 | 256 |
| *Eunotia* | *serra (Ralfs) Ehr.* | EUNOSERR | 29 | 5 | 14 |
| *Eunotia* | *siolii Hust. Ehr.* | EUNOSIOL | 2 | 2 | 1 |
| *Eunotia* | *soleirolii Boyer* | EUNOSOLE | 316 | 11 | 150 |
| *Eunotia* | *steineckii Peters.* | EUNOSTEI | 14 | 4 | 9 |
| *Eunotia* | *subarcuatoides Alles, Norpel & Lange_Bertalot* | EUNOSUBA | 27 | 9 | 9 |
| *Eunotia* | *sudetica O.F. Muller* | EUNOSUDE | 21 | 7 | 9 |
| *Eunotia* | *GSMNP sp. 1* | EUNOSP.1 | 5 | 2 | 3 |
| *Eunotia* | *GSMNP sp. 17* | EUNOSP.17 | 1 | 1 | 1 |
| *Eunotia* | *tautoniensis Hust. Ex Patrick* | EUNOTAUT | 582 | 19 | 141 |
| *Eunotia* | *tenella (Grunow) Hustedt* | EUNOTENE | 102 | 7 | 51 |
| *Fragilaria* | *cf. acidobiontica Camburn & Charles* | FRAGcf.ACID | 240 | 3 | 155 |
| *Fragilaria* | *neoproducta Lange_Bertalot* | FRAGNEOP | 2 | 1 | 2 |
| *Fragilaria* | *vaucheria (Kütz.) Peters.* | FRAGVAUC | 345 | 9 | 300 |
| *Fragilariaforma* | *virescens (Ralfs) Williams & Round* | FRAIVIRE | 4984 | 41 | 561 |
| *Fragilariaforma* | *Fragilariaforma sp.* | FRAIFRAG | 1 | 1 | 1 |
| *Frustulia* | *crassinervia Lange_Bertalot & Krammer* | FRUSCRAS | 4 | 2 | 2 |
| *Frustulia* | *krammeri Lange_Bertalot & Metzeltin* | FRUSKRAM | 13 | 6 | 8 |
| *Frustulia* | *pseudomagaliesmontana Camburn & Charles* | FRUSPSEU | 1 | 1 | 1 |
| *Frustulia* | *saxonica Rabh* | FRUSSAXO | 529 | 25 | 133 |
| *Frustulia* | *vulgaris (Thwaites) DeToni* | FRUSVULG | 40 | 12 | 13 |
| *Frustulia* | *Frustulia sp.* | FRUSsp. | 6 | 1 | 6 |
| *Gomphonema* | *affine Kützing* | GOMPAFFI | 5 | 1 | 5 |
| *Gomphonema* | *angustatum (Kütz.) Rabenh.* | GOMPANGU | 248 | 28 | 42 |
| *Gomphonema* | *gracile Ehr.* | GOMPGRAC | 80 | 17 | 12 |
| *Gomphonema* | *parvulum (Kütz.) Kütz.* | GOMPPARV | 937 | 30 | 177 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|-------|---------|------|-------|--------------|----------|
| *Gomphonema* | *subclavatum (Grunow) Grunow* | GOMPSUBC | 10 | 5 | 2 |
| *Gomphonema* | *truncatum Ehrenb.* | GOMPTRUN | 2 | 1 | 2 |
| *Gomphonema* | *Gomphonema sp. (girdle views)* | GOMPsp. | 512 | 34 | 66 |
| *Hantzschia* | *amphioxys (Ehr.) Grunow* | HANTAMPH | 9 | 2 | 5 |
| *Hantzschia* | *vivax (W. Smith) Tempère* | HANTVIVA | 1 | 1 | 1 |
| *Hantzschia* | *Hantzschia sp.* | HANTsp. | 1 | 1 | 1 |
| *Hippodonta* | *capitata (Ehrenb.) Lange_Bert., Metzeltin & Witkowski* | HIPPCAPI | 1 | 1 | 1 |
| *Karayeva* | *clevei ( Hustedt) Round & Bukhtiyarova* | KARACLEV | 2 | 1 | 2 |
| *Kobayasiella* | *Kobayasiella sp.* | KOBAsp. | 2 | 1 | 2 |
| *Luticola* | *cohnii (Hilse) D.G. Mann* | LUTICOHN | 4 | 1 | 4 |
| *Luticola* | *mutica (Kütz.) DG Mann* | LUTIMUTI | 7 | 5 | 2 |
| *Luticola* | *undulata (Hilse) Mann* | LUTIUNDU | 1 | 1 | 1 |
| *Luticola* | *Luticola sp.* | LUTIsp. | 5 | 1 | 5 |
| *Meridion* | *allensmithii Brandt* | MERIALLE | 46 | 9 | 25 |
| *Meridion* | *circulare (Greville) Agardh* | MERICIRC | 2635 | 35 | 291 |
| *Meridion* | *Meridion sp.* | MERIsp. | 122 | 4 | 63 |
| *Microcostatus* | *krasskei (Hustedt) Johansen & Sray* | MIRCKRAS | 165 | 3 | 162 |
| *Navicula* | *angusta Grun.* | NAVIANGU | 14 | 3 | 6 |
| *Navicula* | *asellus Weinhold ex Hustedt* | NAVIASEL | 1 | 1 | 1 |
| *Navicula* | *bacillum Ehrenb.* | NAVIBACI | 5 | 2 | 3 |
| *Navicula* | *bryophila Petersen* | NAVIBRYO | 10 | 5 | 3 |
| *Navicula* | *cocconeiformis Greg. ex Greville* | NAVICOCC | 10 | 3 | 5 |
| *Navicula* | *cryptocephala Kütz* | NAVICRYP | 372 | 15 | 177 |
| *Navicula* | *cryptotenella Lange_Bertalot* | NAVICRYT | 10 | 3 | 4 |
| *Navicula* | *exigua (W. Gregory) O. Müller* | NAVIEXIG | 2 | 1 | 2 |
| *Navicula* | *festiva Krasske* | NAVIFEST | 5 | 1 | 5 |
| *Navicula* | *gregaria Donkin* | NAVIGREG | 8 | 3 | 4 |
| *Navicula* | *hambergii Hust.* | NAVIHAMB | 9 | 5 | 2 |
| *Navicula* | *cf. hustedtii Krasske* | NAVIcf.HUST | 2 | 1 | 2 |
| *Navicula* | *keelii Patr.* | NAVIKEEL | 1 | 1 | 1 |
| *Navicula* | *cf. lanceolata (C. Agardh) Kütz.* | NAVIcf.LANC | 56 | 5 | 46 |
| *Navicula* | *cf. lenzii Hust.* | NAVIcf.LENZ | 2 | 1 | 2 |
| *Navicula* | *cf. leptostriata E. Jorgensen* | NAVIcf.LEPT | 16 | 5 | 4 |
| *Navicula* | *libonensis Schumann* | NAVILIBO | 2 | 1 | 2 |
| *Navicula* | *minima Grunow in Van Heurck* | NAVIMINI | 2 | 1 | 2 |
| *Navicula* | *notha Wallace* | NAVINOTH | 11 | 4 | 6 |
| *Navicula* | *cf. perminuta Grunow* | NAVIcf.PERM | 2 | 1 | 2 |
| *Navicula* | *protracta (Grun.) Cl.* | NAVIPROT | 3 | 1 | 3 |
| *Navicula* | *pseudolanceolata Lange_Bertalot* | NAVIPSEU | 3 | 2 | 2 |
| *Navicula* | *pseudoventralis Hustedt* | NAVIPSVE | 2 | 1 | 2 |
| *Navicula* | *rhynchocephala Kütz* | NAVIRHYN | 2 | 1 | 2 |
| *Navicula* | *scuteloides W. Smith* | NAVISCUT | 1 | 1 | 1 |
| *Navicula* | *submuralis Hust.* | NAVISUBM | 13 | 4 | 5 |
| *Navicula* | *cf. tantula Hust.* | NAVIcf.TANT | 25 | 8 | 8 |
| *Navicula* | *tenelloides Hust.* | NAVITENE | 2 | 1 | 2 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Navicula* | *tenuicephala Hust.* | NAVITENU | 2 | 1 | 2 |
| *Navicula* | *variostriata Krasske* | NAVIVARI | 40 | 7 | 18 |
| *Navicula* | *Navicula sp.* | NAVIsp. | 389 | 22 | 72 |
| *Neidium* | *affine v. amphirynchus* | NEIDAFFIam | 2 | 1 | 2 |
| *Neidium* | *affine v. undulatum (Grunow) Cleve* | NEIDAFFIun | 6 | 2 | 4 |
| *Neidium* | *alpinum Hust.* | NEIDALPI | 2 | 1 | 2 |
| *Neidium* | *ampliatum (Ehr.) Krammer* | NEIDAMPL | 64 | 7 | 43 |
| *Neidium* | *bisucatum (Lagerst.) Cl.* | NEIDBISU | 80 | 20 | 23 |
| *Neidium* | *Neidium sp.* | NEIDsp. | 6 | 4 | 2 |
| *Nitzschia* | *acidoclinata Lange_Bertalot Hust.* | NITZACID | 548 | 23 | 90 |
| *Nitzschia* | *amphibia Grunow* | NITZAMPH | 7 | 1 | 7 |
| *Nitzschia* | *clausii Hantzsch* | NITZCLAU | 4 | 1 | 4 |
| *Nitzschia* | *dissipata (Kütz.) Grun.* | NITZDISS | 5 | 4 | 2 |
| *Nitzschia* | *dissipata var. media (Hantzsch) Grunow* | NITZDISSme | 9 | 5 | 2 |
| *Nitzschia* | *filiformis (W.Sm.) Van Heurck* | NITZFILI | 10 | 2 | 8 |
| *Nitzschia* | *cf. flexa Schumann* | NITZcf.FLEX | 1 | 1 | 1 |
| *Nitzschia* | *frustulum (Kütz.) Grun* | NITZFRUS | 40 | 5 | 12 |
| *Nitzschia* | *gracilis Hantzsch* | NITZGRAC | 55 | 5 | 39 |
| *Nitzschia* | *cf. nana Grun.* | NITZcf.NANA | 64 | 9 | 32 |
| *Nitzschia* | *cf. normanii Grun.* | NITZcf.NORM | 2 | 1 | 2 |
| *Nitzschia* | *palea (Kütz.) W. Smith* | NITZPALE | 37 | 7 | 15 |
| *Nitzschia* | *cf. paleacea Grunow* | NITZcf.PALA | 4 | 2 | 2 |
| *Nitzschia* | *cf. palustris Hust.* | NITZcf.PALU | 141 | 17 | 32 |
| *Nitzschia* | *cf. recta Hantz.* | NITZcf.RECT | 18 | 1 | 18 |
| *Nitzschia* | *cf. vermicularis (Kütz.) Hantz.* | NITZcf.VERM | 2 | 1 | 2 |
| *Nitzschia* | *Nitzschia sp.* | NITZsp. | 233 | 24 | 62 |
| *Nupela* | *neglecta Ponader, Lowe & Potapova* | NUPENEGL | 9 | 4 | 3 |
| *Nupela* | *Nupela sp.* | NUPEsp. | 8 | 4 | 4 |
| *Nupela* | *wellneri (Lange_bertalot) Lange_bertalot* | NUPEWELL | 4 | 1 | 4 |
| *Pinnularia* | *abaujensis v. lacustris Camburn & Charles* | PINNABAUla | 42 | 11 | 14 |
| *Pinnularia* | *abaujensis v. linearis (Hust.) Patr.* | PINNABAUli | 31 | 7 | 10 |
| *Pinnularia* | *abaujensis v. rostrata Patr.* | PINNABAUro | 8 | 1 | 8 |
| *Pinnularia* | *abaujensis v. subundulata (Mayer) Patrick* | PINNABAUsu | 13 | 2 | 12 |
| *Pinnularia* | *acrosphaeria Rabh.* | PINNACRO | 9 | 4 | 4 |
| *Pinnularia* | *acuminata v. interrupta (Boyer) Patr.* | PINNACUM | 4 | 1 | 4 |
| *Pinnularia* | *biceps W. Greg.* | PINNBICE | 3 | 2 | 2 |
| *Pinnularia* | *borealis (Ehrenberg) Rabenhorst* | PINNBORE | 5 | 4 | 2 |
| *Pinnularia* | *brebissonii (Kütz.) Rabh.* | PINNBREB | 43 | 9 | 22 |
| *Pinnularia* | *brebissonii var. minuta* | PINNBREBmi | 2 | 1 | 2 |
| *Pinnularia* | *burkii Patr.* | PINNBURK | 9 | 5 | 2 |
| *Pinnularia* | *cf. Kwacksii Camb. & Charles* | PINNcf.KWAC | 2 | 1 | 2 |
| *Pinnularia* | *cf. dactylus Ehrenberg* | PINNcf.DACT | 2 | 1 | 2 |
| *Pinnularia* | *divergens W. Smith* | PINNDIVE | 14 | 3 | 6 |
| *Pinnularia* | *divergentissima var. subrostrata* | PINNDIVRsu | 3 | 1 | 3 |
| *Pinnularia* | *flexuosa A. Cleve_Euler* | PINNFLEX | 2 | 1 | 2 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Pinnularia* | *gentilis (Donkin) Cleve* | PINNGENT | 4 | 1 | 4 |
| *Pinnularia* | *gibbiformis Krammer* | PINNGIBB | 2 | 1 | 2 |
| *Pinnularia* | *girdle view* | PINNgirdle | 1113 | 55 | 163 |
| *Pinnularia* | *hilseana Janisch ex Rabh.* | PINNHILS | 286 | 11 | 74 |
| *Pinnularia* | *legumen (Ehr.) Ehr.* | PINNLEGU | 9 | 3 | 4 |
| *Pinnularia* | *maior (Kütz.) Cleve* | PINNMAIO | 18 | 6 | 7 |
| *Pinnularia* | *cf. mesogonglya Ehr.* | PINNcf.MESO | 6 | 2 | 4 |
| *Pinnularia* | *microstauron (Ehr.) Cl.* | PINNMICR | 2 | 1 | 2 |
| *Pinnularia* | *microstauron v. adarondakensis Camburn & Charles* | PINNMICRad | 104 | 15 | 45 |
| *Pinnularia* | *nodosa (Ehr.) W. Sm.* | PINNNODO | 25 | 6 | 9 |
| *Pinnularia* | *obscura Krasske* | PINNOBSC | 18 | 7 | 9 |
| *Pinnularia* | *rupestris Hantzsch* | PINNRUPE | 137 | 19 | 54 |
| *Pinnularia* | *cf. ruttneri Hust.* | PINNcf.RUTT | 1 | 1 | 1 |
| *Pinnularia* | *stomatophora Grun.* | PINNSTOM | 4 | 3 | 2 |
| *Pinnularia* | *streptoraphe Cleve* | PINNSTRE | 28 | 2 | 27 |
| *Pinnularia* | *subcapitata Greg.* | PINNSUBC | 104 | 22 | 17 |
| *Pinnularia* | *subcapitata var. paucistriata (Grun.) Cl.* | PINNSUBCpa | 16 | 8 | 3 |
| *Pinnularia* | *substomatophora Hust.* | PINNSUBS | 1 | 1 | 1 |
| *Pinnularia* | *termitina (Ehr.) Patr.* | PINNTERM | 928 | 21 | 251 |
| *Pinnularia* | *viridiformis Krammer* | PINNVIRI | 81 | 1 | 81 |
| *Pinnularia* | *viridis (Nitzsch) Ehrenberg* | PINNVIRD | 14 | 5 | 7 |
| *Pinnularia* | *viridis var. minor Cleve* | PINNVIRDmi | 9 | 5 | 4 |
| *Pinnularia* | *wisconsinensis Camburn & Charles* | PINNWISC | 2 | 1 | 2 |
| *Pinnularia* | *Pinnularia sp.* | PINNsp. | 3 | 2 | 2 |
| *Placoneis* | *elginensis (Greg.) E. J. Cox* | PLACELGI | 46 | 14 | 13 |
| *Placoneis* | *abiskoensis (Hustedt). Lange_Bertalot & Metzeltin* | PLACABIS | 5 | 4 | 2 |
| *Placoneis* | *neglecta (Krasske) Lowe* | PLACNEGL | 2 | 1 | 2 |
| *Planothidium* | *dubium (Grunow) Round et Bukhtiyarova* | PLANDUBI | 4 | 1 | 4 |
| *Planothidium* | *frequentissimum (Lange_Bert.) Round et L.Bukhtiyarova* | PLANFREQ | 66 | 7 | 47 |
| *Planothidium* | *lanceolatum (Bréb. ex (Kütz.) Round & Bukhtiyarova* | PLANLANC | 994 | 16 | 268 |
| *Planothidium* | *Planothidium sp.* | PLANsp. | 8 | 3 | 4 |
| *Pseudostaurosira* | *brevistriata (Grunow) Williams & Round* | PSEUBREV | 3 | 2 | 2 |
| *Rhopalodia* | *gibba (Ehrenb.) O. Müll.* | RHOPGIBB | 1 | 1 | 1 |
| *Rhopalodia* | *gibberula (Ehrenb.) O. Müll.* | RHOPGIBE | 2 | 1 | 2 |
| *Sellaphora* | *pupula (Kütz.) Mereschk.* | SELLPUPU | 41 | 9 | 21 |
| *Sellaphora* | *cf. seminulum (Grunow) D.G. Mann* | SELLcf.SEMI | 17 | 4 | 8 |
| *Stauroneis* | *anceps Ehr.* | STAUANCE | 88 | 15 | 53 |
| *Stauroneis* | *anceps f. linearis (Ehrenberg) Cleve* | STAUANCP | 42 | 3 | 24 |
| *Stauroneis* | *cf. kriegeri Patr.* | STAUcf.KRIE | 86 | 17 | 18 |
| *Stauroneis* | *phoenicentron (Nitz.) Ehr.* | STAUPHOE | 29 | 10 | 8 |
| *Stauroneis* | *smithii var. incisa* | STAUSMIT | 2 | 1 | 2 |
| *Staurosira* | *construens Ehr.* | STAUCONS | 9 | 2 | 8 |
| *Staurosira* | *construens v. venter (Ehr.) Hamilton* | STAUCONSve | 32 | 6 | 14 |
| *Staurosirella* | *leptostauron (Ehr.) D.M.Williams et Round* | STAULEPT | 6 | 3 | 2 |
| *Staurosirella* | *pinnata (Ehrenberg) Williams & Round* | STAUPINN | 3 | 2 | 2 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Stenopterobia* | *delicatissima ( Lewis) Breb. ex VH* | STENDELI | 9 | 2 | 7 |
| *Stenopterobia* | *Stenopterobia sp.* | STENsp. | 3 | 2 | 2 |
| *Stephanodiscus* | *Stephanodiscus sp.* | STEPsp. | 2 | 1 | 2 |
| *Surirella* | *angustata Kütz.* | SURIANGU | 4 | 2 | 2 |
| *Surirella* | *Surirella sp.* | SURIsp. | 2 | 1 | 2 |
| *Synedra* | *acus Kütz.* | SYNEACUS | 83 | 2 | 62 |
| *Synedra* | *acus var. radians (Kütz.) Hust.* | SYNEACUSra | 37 | 7 | 13 |
| *Synedra* | *amphicephala v. austriaca Grunow* | SYNEAMPH | 4 | 1 | 4 |
| *Synedra* | *rumpens Kütz.* | SYNERUMP | 42 | 6 | 18 |
| *Synedra* | *rumpens v. fragilarioides Grun.* | SYNERUMPfr | 104 | 2 | 103 |
| *Synedra* | *Synedra sp.* | SYNEsp. | 126 | 10 | 62 |
| *Tabellaria* | *binalis (Ehr.) Grun.* | TABEBINA | 1 | 1 | 1 |
| *Tabellaria* | *fenestrata (Lyngb.) Kütz.* | TABEFENE | 2 | 1 | 2 |
| *Tabellaria* | *floculosa (Roth) Kütz* | TABEFLOC | 1310 | 35 | 194 |
| *Tabellaria* | *quadricepta* | TABEQUAD | 5 | 4 | 2 |
| *Tetracyclus* | *rupestris (Braun) Grun.* | TETRRUPE | 2 | 1 | 2 |
| *Tryblionella* | *debilis (Arn.) Grunow* | TRYBDEBI | 1 | 1 | 1 |
| *Tryblionella* | *marginulata (Grunow) DG Mann* | TRYBMARG | 1 | 1 | 1 |
| *Ulnaria* | *ulna (Nitz.) Compere* | ULNAULNA | 41 | 5 | 34 |
| *Uknown* | *Unknown genus* | UNKNOWN | 9 | 2 | 8 |

Table 3.5. 2008 Diatom Taxa (Water Samples). Total is the cumulative taxon abundance for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs. is the maximum number of specimens identified at one site. *cf before a species name indicates "resembles".

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Achnanthes* | *cf. rosenstockii Lange_Bertalot* | ACHNcf.ROSE | 13 | 1 | 13 |
| *Achnanthes* | *cf. pseudoswazi J.R. Carter* | ACHNcf.PSEO | 43 | 1 | 43 |
| *Achnanthidium* | *minutissimum (Kützing) Czarnecki* | ACHNMINU | 29 | 4 | 16 |
| *Achnanthidium* | *minutissimum var. microcephala Hust.* | ACHNMINUmi | 3 | 1 | 3 |
| *Achnanthidium* | | ACHNsp. | 21 | 3 | 15 |
| *Asterionella* | *formosa* | ASTEFORM | 12 | 2 | 10 |
| *Aulacoseira* | *crenulata (Ehrenberg) Thwaites* | AULACREN | 566 | 5 | 379 |
| *Aulacoseira* | | AULAsp. | 2 | 1 | 2 |
| *Caloneis* | *bacillum (Grunow) P.T.Cleve* | CALOBACI | 3 | 1 | 3 |
| *Caloneis* | *hyalina* | CALOHYAL | 3 | 1 | 3 |
| *Caloneis* | *ventricosa (Ehrenb.) Meist.* | CALOVENT | 2 | 1 | 2 |
| *Caloneis* | | CALOsp. | 4 | 2 | 2 |
| *Chamaepinnularia* | *soehrensis ( Krasske) Lange_Bert.* | CHAMSOEH | 3 | 1 | 3 |
| *Chamaepinnularia* | | CHAMsp. | 41 | 6 | 17 |
| *Cymbella* | *cuspidata Kützing* | CYMBCUSP | 31 | 1 | 31 |
| *Cymbella* | *hauckii Van Heurck* | CYMBHAUC | 1 | 1 | 1 |
| *Cymbella* | | CYMBsp. | 1 | 1 | 1 |
| *Decussata* | *placenta (Ehrenberg) Lange_Bertalot & Mezeltin* | DECUPLAC | 20 | 7 | 9 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Diadesmis* | *biceps Arnott ex Grunow* | DIADBICE | 2 | 1 | 2 |
| *Diadesmis* | *contenta (Grunow) D.G. Mann* | DIADCONT | 1 | 1 | 1 |
| *Diadesmis* | *perpusilla (Kützing) D.G. Mann* | DIADPERP | 1 | 1 | 1 |
| *Diatoma* | *anceps (Ehrenberg) Kirchner* | DIATANCE | 1 | 1 | 1 |
| *Diatoma* | *anceps var. linearis M.Perag.* | DIATANCEli | 12 | 1 | 12 |
| *Diploneis* | *elliptica (Kützing) P.T. Cleve* | DIPLOELLI | 3 | 1 | 3 |
| *Encyonema* | *silesiacum (Bleisch in Rabenhorst) D.G. Mann* | ENCYSILE | 5 | 2 | 3 |
| *Encyonema* | *minutum (Hilse in Rabenhorst) D.G. Mann* | ENCYMINU | 62 | 11 | 15 |
| *Eunotia* | *bigibba Kütz.* | EUNOBIGI | 5 | 2 | 3 |
| *Eunotia* | *bilunaris Ehr. Mills.* | EUNOBILU | 81 | 6 | 28 |
| *Eunotia* | *carolina Patrick* | EUNOCARO | 31 | 4 | 21 |
| *Eunotia* | *crista_gallii P.T. Cl.* | EUNOCRIS | 9 | 1 | 9 |
| *Eunotia* | *curvata (Kütz.) Lagerst* | EUNOCURV | 113 | 11 | 35 |
| *Eunotia* | *curvata v. subarcuata Woodhead & Tweed* | EUNOCURVsu | 248 | 2 | 235 |
| *Eunotia* | *curvata f. bergii Woodhead & Tweed* | EUNOCURVfb | 373 | 16 | 126 |
| *Eunotia* | *diodon* | EUNODIOD | 24 | 2 | 22 |
| *Eunotia* | *elegans Østrup* | EUNOELEG | 11 | 2 | 7 |
| *Eunotia* | *exigua (Breb. Ex Kütz.) Rabenh.* | EUNOEXIG | 827 | 21 | 176 |
| *Eunotia* | *fallax A. Cleve* | EUNOFALL | 35 | 4 | 17 |
| *Eunotia* | *flexuosa Bréb. ex Kütz.* | EUNOFLEX | 22 | 2 | 19 |
| *Eunotia* | *formica Ehr.* | EUNOFORM | 3 | 2 | 2 |
| *Eunotia* | *cf. glacialis F. Meister* | EUNOcfGLAC | 9 | 3 | 4 |
| *Eunotia* | *girdle view 12_23 μm* | EUNOgirdlS | 2320 | 26 | 360 |
| *Eunotia* | *girdle view 30_45 μm* | EUNOgirdl | 27 | 2 | 20 |
| *Eunotia* | *incisa W. Sm. ex Greg,* | EUNOINCI | 1 | 1 | 1 |
| *Eunotia* | *major* | EUNOMAJO | 7 | 1 | 7 |
| *Eunotia* | *microcephala Migula* | EUNOMICR | 14 | 4 | 7 |
| *Eunotia* | *naegeli Migula* | EUNONAEG | 331 | 8 | 160 |
| *Eunotia* | *nymanniana Grun.* | EUNONYMA | 5 | 3 | 3 |
| *Eunotia* | *paludosa v. paludosa Grun.* | EUNOPALUpa | 1281 | 20 | 156 |
| *Eunotia* | *paludosa v. trinacria (Krasske) Norpel* | EUNOPALUtr | 149 | 13 | 35 |
| *Eunotia* | *paralella Ehr.* | EUNOPARA | 1 | 1 | 1 |
| *Eunotia* | *pectinalis (O.F. Müller) Rabenhorst* | EUNOPECT | 303 | 17 | 125 |
| *Eunotia* | *perpusilla Grun.* | EUNOPERP | 32 | 1 | 32 |
| *Eunotia* | *praerupta Ehr.* | EUNOPRAE | 36 | 6 | 10 |
| *Eunotia* | *praerupta v. monodon f. polaris (Berg.) Symoens* | EUNOPRAEmo | 14 | 1 | 14 |
| *Eunotia* | *rhomboidea Hust.* | EUNORHOM | 71 | 10 | 19 |
| *Eunotia* | *septentrionalis Østrup* | EUNOSEPT | 509 | 15 | 214 |
| *Eunotia* | *serra (Ralfs) Ehr.* | EUNOSERR | 15 | 4 | 7 |
| *Eunotia* | *soleirolii Boyer* | EUNOSOLE | 119 | 5 | 87 |
| *Eunotia* | *steineckii Peters.* | EUNOSTEI | 7 | 4 | 3 |
| *Eunotia* | *sudetica O.F. Muller* | EUNOSUDE | 74 | 4 | 27 |
| *Eunotia* | *tautoniensis Hust. Ex Patrick* | EUNOTAUT | 216 | 7 | 78 |
| *Eunotia* | *tenella (Grunow) Hustedt* | EUNOTENE | 55 | 6 | 37 |
| *Fragilaria* | *cf. acidobiontica Camburn & Charles* | FRAGcf.ACID | 2 | 1 | 2 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Fragilaria* | *cf. tenera* | FRAGcfTENE | 134 | 1 | 134 |
| *Fragilaria* | *vaucheria (Kütz.) Peters.* | FRAGVAUC | 25 | 2 | 21 |
| *Fragilariaforma* | *virescens (Ralfs) Williams & Round* | FRAIVIRE | 1594 | 12 | 463 |
| *Frustulia* | *crassinervia Lange_Bertalot & Krammer* | FRUSCRAS | 15 | 2 | 10 |
| *Frustulia* | *krammeri Lange_Bertalot & Metzeltin* | FRUSKRAM | 5 | 2 | 3 |
| *Frustulia* | *pseudomagaliesmontana Camburn & Charles* | FRUSPSEU | 1 | 1 | 1 |
| *Frustulia* | *saxonica Rabh* | FRUSSAXO | 210 | 10 | 67 |
| *Frustulia* | *vulgaris (Thwaites) DeToni* | FRUSVULG | 15 | 3 | 7 |
| *Gomphonema* | *acuminatum Ehr.* | GOMPACUM | 1 | 1 | 1 |
| *Gomphonema* | *angustatum (Kütz.) Rabenh.* | GOMPANGU | 19 | 5 | 6 |
| *Gomphonema* | *gracile Ehr.* | GOMPGRAC | 55 | 7 | 21 |
| *Gomphonema* | *cf minutum Agardh.* | GOMPcfMINU | 17 | 2 | 16 |
| *Gomphonema* | *parvulum (Kütz.) Kütz.* | GOMPPARV | 320 | 10 | 136 |
| *Gomphonema* | *subclavatum (Grunow) Grunow* | GOMPSUBC | 9 | 2 | 5 |
| *Gomphonema* | *variostriatum Camburn & Charles* | GOMPVARI | 5 | 2 | 4 |
| *Gomphonema* | | GOMPsp. | 172 | 9 | 60 |
| *Lemnicola* | *hungarica (Grun.) Round* | LEMNHUNG | 4 | 1 | 4 |
| *Luticola* | *mutica (Kütz.) DG Mann* | LUTIMUTI | 2 | 1 | 2 |
| *Meridion* | *allensmithii Brandt* | MERIALLE | 2 | 1 | 2 |
| *Meridion* | *circulare (Greville) Agardh* | MERICIRC | 714 | 13 | 150 |
| *Navicula* | *angusta Grun.* | NAVIANGU | 3 | 1 | 3 |
| *Navicula* | *asellus Weinhold ex Hustedt* | NAVIASEL | 2 | 1 | 2 |
| *Navicula* | *cryptocephala Kütz* | NAVICRYP | 190 | 5 | 172 |
| *Navicula* | *cryptotenella Lange_Bertalot* | NAVICRYT | 3 | 1 | 3 |
| *Navicula* | *gregaria Donkin* | NAVIGREG | 1 | 1 | 1 |
| *Navicula* | *cf lanceolata (C. Agardh) Kütz.* | NAVICcfLANC | 3 | 1 | 3 |
| *Navicula* | *minima Grunow in Van Heurck* | NAVIMINI | 6 | 2 | 3 |
| *Navicula* | *cf obsoleta Hust.* | NAVIcfOBSO | 3 | 1 | 3 |
| *Navicula* | *phyllepta Kutz.* | NAVIPHYL | 7 | 1 | 7 |
| *Navicula* | *subrotundata Hust.* | NAVISUBR | 18 | 1 | 18 |
| *Navicula* | *cf. tantula Hust.* | NAVIcfTANT | 31 | 6 | 17 |
| *Navicula* | *tenelloides Hust.* | NAVITENE | 1 | 1 | 1 |
| *Navicula* | *tenuicephala Hust.* | NAVITENU | 8 | 1 | 8 |
| *Navicula* | *variostriata Krasske* | NAVIVARI | 20 | 4 | 8 |
| *Navicula* | *ventralis* | NAVIVENT | 17 | 3 | 13 |
| *Navicula* | | NAVIsp. | 185 | 11 | 36 |
| *Neidium* | *affine v. amphirynchus* | NEIDAFFIam | 10 | 1 | 10 |
| *Neidium* | *ampliatum (Ehr.) Krammer* | NEIDAMPL | 41 | 8 | 17 |
| *Neidium* | *bisucaltum (Lagerst.) Cl.* | NEIDBISU | 63 | 7 | 21 |
| *Neidium* | | NEIDIRID | 1 | 1 | 1 |
| *Neidium* | | NEIDsp. | 2 | 1 | 2 |
| *Nitzschia* | *acicularis* | NITZACIC | 8 | 1 | 8 |
| *Nitzschia* | *acidoclinata Lange_Bertalot Hust.* | NITZACID | 9 | 1 | 9 |
| *Nitzschia* | *amphibia Grunow* | NITZAMPH | 10 | 2 | 7 |
| *Nitzschia* | *dissipata (Kütz.) Grun.* | NITZDISS | 11 | 3 | 5 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Nitzschia* | *frustulum (Kütz.) Grun* | NITZFRUS | 24 | 5 | 9 |
| *Nitzschia* | *gracilis Hantzsch* | NITZGRAC | 99 | 4 | 73 |
| *Nitzschia* | *linearis* | NITZLINE | 4 | 1 | 4 |
| *Nitzschia* | *cf. nana Grun.* | NITZcf.NANA | 50 | 4 | 28 |
| *Nitzschia* | *palea (Kütz.) W. Smith* | NITZPALE | 29 | 4 | 14 |
| *Nitzschia* | *cf. paleacea Grunow* | NITZcf.PALA | 43 | 4 | 21 |
| *Nitzschia* | *cf. palustris Hust.* | NITZcf.PALU | 31 | 6 | 11 |
| *Nitzschia* | | NITZsp. | 142 | 8 | 68 |
| *Nupela* | *neglecta Ponader, Lowe & Potapova* | NUPENEGL | 1 | 1 | 1 |
| *Nupela* | | NUPEsp. | 15 | 3 | 9 |
| *Pinnularia* | *abaujensis v. abujensis (Pant.) Ross* | PINNABAUab | 6 | 3 | 3 |
| *Pinnularia* | *abaujensis v. lacustris Camburn & Charles* | PINNABAUla | 35 | 9 | 10 |
| *Pinnularia* | *abaujensis v. linearis (Hust.) Patr.* | PINNABAUli | 14 | 4 | 4 |
| *Pinnularia* | *abaujensis v. subundulata (Mayer) Patrick* | PINNABAUsu | 1 | 1 | 1 |
| *Pinnularia* | *acrosphaeria Rabh.* | PINNACRO | 12 | 3 | 7 |
| *Pinnularia* | *biceps W. Greg.* | PINNBICE | 1 | 1 | 1 |
| *Pinnularia* | *biceps v. pusilla Camburn and Charles* | PINNBICE.1 | 14 | 1 | 14 |
| *Pinnularia* | *brebissonii (Kütz.) Rabh.* | PINNBREB | 7 | 4 | 3 |
| *Pinnularia* | *brebissonii var. minuta* | PINNBREBmi | 1 | 1 | 1 |
| *Pinnularia* | *burkii Patr.* | PINNBURK | 40 | 4 | 20 |
| *Pinnularia* | *gibbiformis Krammer* | PINNGIBB | 11 | 1 | 11 |
| *Pinnularia* | *girdle view* | PINNgirdle | 506 | 26 | 64 |
| *Pinnularia* | *hilseana Janisch ex Rabh.* | PINNHILS | 1 | 1 | 1 |
| *Pinnularia* | *cf intermedia* | PINNcfINTE | 3 | 1 | 3 |
| *Pinnularia* | *legumen (Ehr.) Ehr.* | PINNLEGU | 3 | 1 | 3 |
| *Pinnularia* | *maior (Kütz.) Cleve* | PINNMAIO | 15 | 2 | 13 |
| *Pinnularia* | *cf. mesogonglya Ehr.* | PINNcf.MESO | 3 | 1 | 3 |
| *Pinnularia* | *mesolepta* | PINNMESL | 6 | 1 | 6 |
| *Pinnularia* | *microstauron (Ehr.) Cl.* | PINNMICR | 6 | 3 | 3 |
| *Pinnularia* | *microstauron v. adarondakensis Camburn & Charles* | PINNMICRad | 34 | 6 | 13 |
| *Pinnularia* | *nodosa (Ehr.) W. Sm.* | PINNNODO | 14 | 4 | 6 |
| *Pinnularia* | *nodosa var. constricta f. truncata Fusey* | PINNNODOco | 3 | 1 | 3 |
| *Pinnularia* | *obscura Krasske* | PINNOBSC | 5 | 2 | 3 |
| *Pinnularia* | *rupestris Hantzsch* | PINNRUPE | 100 | 13 | 25 |
| *Pinnularia* | *cf. ruttneri Hust.* | PINNcf.RUTT | 20 | 2 | 17 |
| *Pinnularia* | *subcapitata Greg.* | PINNSUBC | 92 | 7 | 28 |
| *Pinnularia* | *subcapitata var. paucistriata (Grun.) Cl.* | PINNSUBCpa | 17 | 2 | 10 |
| *Pinnularia* | *termitina (Ehr.) Patr.* | PINNTERM | 674 | 13 | 195 |
| *Pinnularia* | *viridis (Nitzsch) Ehrenberg* | PINNVIRD | 50 | 5 | 39 |
| *Pinnularia* | | PINNsp. | 16 | 6 | 8 |
| *Placoneis* | *elginensis (Greg.) E. J. Cox* | PLACELGI | 24 | 5 | 8 |
| *Placoneis* | | PLACsp. | 3 | 1 | 3 |
| *Planothidium* | *dubium (Grunow) Round et Bukhtiyarova* | PLANDUBI | 2 | 1 | 2 |
| *Planothidium* | *frequentissimum (Lange_Bert.) Round et L.Bukhtiyarova* | PLANFREQ | 8 | 2 | 7 |
| *Planothidium* | *lanceolatum (Bréb. ex (Kütz.) Round & Bukhtiyarova* | PLANLANC | 104 | 5 | 81 |

| Genus | Species | Code | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| *Psammothidium* | *subatomoides (Hust.) Bukhtiyarova & Round* | PSAMSUBA | 5 | 1 | 5 |
| *Pseudostaurosira* | *parasitica* | PSEUPARA | 5 | 1 | 5 |
| *Pseudostaurosira* | *brevistriata (Grunow) Williams & Round* | PSEUBREV | 1 | 1 | 1 |
| *Rhopalodia* | *gibba (Ehrenb.) O. Müll.* | RHOPGIBB | 3 | 1 | 3 |
| *Sellaphora* | *pupula (Kütz.) Mereschk.* | SELLPUPU | 17 | 3 | 12 |
| *Sellaphora* | *cf. seminulum (Grunow) D.G. Mann* | SELLcf.SEMI | 8 | 2 | 5 |
| *Stauroneis* | *anceps Ehr.* | STAUANCE | 125 | 5 | 110 |
| *Stauroneis* | *anceps f. linearis (Ehrenberg) Cleve* | STAUANCP | 13 | 2 | 11 |
| *Stauroneis* | *cf. kriegeri Patr.* | STAUcf.KRIE | 46 | 7 | 19 |
| *Stauroneis* | *phoenicentron (Nitz.) Ehr.* | STAUPHOE | 4 | 2 | 3 |
| *Stauroneis* | *smithii var. incisa* | STAUSMIT | 3 | 1 | 3 |
| *Stauroneis* | | STAUsp. | 3 | 2 | 2 |
| *Staurosira* | *construens v. venter (Ehr.) Hamilton* | STAUCONSve | 38 | 1 | 38 |
| *Stenopterobia* | *curvula (W. Smith) Krammer* | STENCURV | 1 | 1 | 1 |
| *Stenopterobia* | *delicatissima (Lewis) Breb. ex VH* | STENDELI | 13 | 3 | 5 |
| *Surirella* | *angustata Kütz.* | SURIANGU | 1 | 1 | 1 |
| *Surirella* | | SURIsp. | 8 | 2 | 7 |
| *Synedra* | *acus var. radians (Kütz.) Hust.* | SYNEACUSra | 22 | 1 | 22 |
| *Synedra* | *rumpens Kütz.* | SYNERUMP | 209 | 2 | 208 |
| *Synedra* | | SYNEsp. | 1 | 1 | 1 |
| *Tabellaria* | *fenestrata (Lyngb.) Kütz.* | TABEFENE | 6 | 1 | 6 |
| *Tabellaria* | *flocculosa (Roth) Kütz* | TABEFLOC | 456 | 16 | 114 |
| *Tabellaria* | *quadricepta* | TABEQUAD | 1 | 1 | 1 |
| *Ulnaria* | *ulna (Nitz.) Compere* | ULNAULNA | 1 | 1 | 1 |
| | | UNKNOWN | 6 | 3 | 3 |

*Table 3.6. 2008 Hemiptera collected in emergence traps. Total is the cumulative taxon abundance for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs. is the maximum number of specimens identified at one site.*

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|---|
| Hemiptera | Aphididae | | | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Agallia* | *quadripunctata* | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Coelidia* | *olitoria* | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Dikraneura* | | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Erythroneura* | | 3 | 3 | 1 |
| Hemiptera | Cicadellidae | *Eupteryx* | *flavoscuta* | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Scaphoideus* | | 10 | 6 | 2 |
| Hemiptera | Cicadellidae | | | 1 | 1 | 1 |
| Hemiptera | Miridae | *Neolygus* | | 1 | 1 | 1 |
| Hemiptera | Miridae | | | 1 | 1 | 1 |
| Hemiptera | Nabidae | | | 1 | 1 | 1 |
| Hemiptera | | | | 3 | 3 | 1 |

*Table 3.7. 2008 Hymenoptera collected in emergence traps. Total is the cumulative taxon abundance for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs. is the maximum number of specimens identified at one site.*

| Order | Family | Genus | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|
| Hymenoptera | Ceraphronidae | | 1 | 1 | 1 |
| Hymenoptera | Diapriidae | | 13 | 9 | 3 |
| Hymenoptera | Formicidae | *Camponotus* | 5 | 4 | 2 |
| Hymenoptera | Formicidae | *Formica* | 2 | 1 | 2 |
| Hymenoptera | Formicidae | *Temnothorax* | 1 | 1 | 1 |
| Hymenoptera | Ichneumonidae | | 1 | 1 | 1 |
| Hymenoptera | Scelionidae | | 2 | 2 | 1 |
| Hymenoptera | Scelionidae | *Trimorus* | 1 | 1 | 1 |

*Table 3.8. 2008 Araneae collected in pitfall traps. Total is the cumulative taxon abundance for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs. is the maximum number of specimens identified at one site.*

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|---|
| Araneae | Agelenidae | *Agelenopsis* | | 7 | 7 | 1 |
| Araneae | Agelenidae | *Tegenaria* | | 1 | 1 | 1 |
| Araneae | Agelenidae | | | 1 | 1 | 1 |
| Araneae | Amaurobiidae | *Amaurobius* | *borealis* | 1 | 1 | 1 |
| Araneae | Amaurobiidae | *Amaurobius* | | 1 | 1 | 1 |
| Araneae | Amaurobiidae | *Callobius* | | 1 | 1 | 1 |
| Araneae | Amaurobiidae | *Coras* | | 3 | 3 | 1 |
| Araneae | Amaurobiidae | *Wadotes* | *calcaratus* | 2 | 2 | 1 |
| Araneae | Amaurobiidae | *Wadotes* | *hybridus* | 16 | 7 | 4 |
| Araneae | Amaurobiidae | *Wadotes* | | 85 | 35 | 5 |
| Araneae | Amaurobiidae | | | 3 | 3 | 1 |
| Araneae | Araneidae | *Mangora* | | 1 | 1 | 1 |
| Araneae | Clubionidae | *Clubiona* | *spiralis* | 1 | 1 | 1 |
| Araneae | Clubionidae | *Clubiona* | | 2 | 2 | 1 |
| Araneae | Clubionidae | | | 3 | 2 | 2 |
| Araneae | Corinnidae | *Castianeira* | *cingulata* | 6 | 4 | 3 |
| Araneae | Corinnidae | *Castianeira* | | 1 | 1 | 1 |
| Araneae | Corinnidae | *Phrurotimpus* | *alarius* | 22 | 12 | 4 |
| Araneae | Corinnidae | *Phrurotimpus* | *borealis* | 6 | 5 | 2 |
| Araneae | Corinnidae | *Phrurotimpus* | | 15 | 10 | 4 |
| Araneae | Dictynidae | *Cicurina* | *brevis* | 1 | 1 | 1 |
| Araneae | Dictynidae | *Cicurina* | *robusta* | 5 | 5 | 1 |
| Araneae | Dictynidae | *Cicurina* | | 13 | 10 | 2 |
| Araneae | Dictynidae | | | 1 | 1 | 1 |
| Araneae | Gnaphosidae | *Haplodrassus* | | 1 | 1 | 1 |
| Araneae | Gnaphosidae | *Herpyllus* | *ecclesiasticus* | 2 | 2 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Araneae | Gnaphosidae | *Sergiolus* | *capulatus* | 1 | 1 | 1 |
| Araneae | Gnaphosidae | *Zelotes* | *duplex* | 1 | 1 | 1 |
| Araneae | Gnaphosidae | *Zelotes* | *subterraneus* | 3 | 3 | 1 |
| Araneae | Gnaphosidae | *Zelotes* | | 4 | 3 | 2 |
| Araneae | Gnaphosidae | *Zeloteshentzi* | | 1 | 1 | 1 |
| Araneae | Gnaphosidae | | | 2 | 2 | 1 |
| Araneae | Hahniidae | *Antistea* | *brunnea* | 19 | 9 | 7 |
| Araneae | Hahniidae | *Antistea* | | 1 | 1 | 1 |
| Araneae | Hahniidae | *Cryphoeca* | *montana* | 1 | 1 | 1 |
| Araneae | Hahniidae | *Hahnia* | | 2 | 2 | 1 |
| Araneae | Hahniidae | *Hahnia* | *cinerea* | 1 | 1 | 1 |
| Araneae | Hahniidae | *Neoantistea* | *agilis* | 46 | 20 | 5 |
| Araneae | Hahniidae | *Neoantistea* | *magna* | 426 | 54 | 30 |
| Araneae | Hahniidae | *Neoantistea* | *radula* | 1 | 1 | 1 |
| Araneae | Hahniidae | *Neoantistea* | | 23 | 12 | 5 |
| Araneae | Hahniidae | | | 4 | 4 | 1 |
| Araneae | Linyphiidae | *Bathyphantes* | *pallida* | 7 | 3 | 5 |
| Araneae | Linyphiidae | *Bathyphantes* | | 8 | 7 | 2 |
| Araneae | Linyphiidae | *Centromerus* | *cornupalpis* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Ceraticelus* | *fissiceps* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Ceraticelus* | *minutus* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Ceraticelus* | | 3 | 3 | 1 |
| Araneae | Linyphiidae | *Ceratinops* | | 6 | 1 | 6 |
| Araneae | Linyphiidae | *Dicymbium* | *elongatum* | 2 | 2 | 1 |
| Araneae | Linyphiidae | *Diplocephalus* | *subrostratus* | 2 | 2 | 1 |
| Araneae | Linyphiidae | *Diplocephalus* | | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Eperigone* | *entomologica* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Eperigone* | *tridentata* | 6 | 2 | 5 |
| Araneae | Linyphiidae | *Eperigone* | *trilobata* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Erigone* | | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Gnathonaroides* | *pedalis* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Idionella* | | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Lepthyphantes* | *zebra* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Lepthyphantes* | | 2 | 1 | 2 |
| Araneae | Linyphiidae | *Oedothorax* | *trilobatus* | 20 | 6 | 7 |
| Araneae | Linyphiidae | *Pityohyphantes* | | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Pocadicnemis* | *americana* | 4 | 3 | 2 |
| Araneae | Linyphiidae | *Pocadicnemis* | *pumila* | 6 | 6 | 1 |
| Araneae | Linyphiidae | *Sisicottus* | | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Walckenaeria* | *castenea* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Walckenaeria* | *communis* | 4 | 4 | 1 |
| Araneae | Linyphiidae | *Walckenaeria* | *directa* | 3 | 3 | 1 |
| Araneae | Linyphiidae | *Walckenaeria* | *indirecta* | 4 | 3 | 2 |
| Araneae | Linyphiidae | *Walckenaeria* | *minuta* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Walckenaeria* | *vigilax* | 1 | 1 | 1 |
| Araneae | Linyphiidae | *Walckenaeria* | | 24 | 13 | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Araneae | Linyphiidae | | | 119 | 42 | 11 |
| Araneae | Liocranidae | *Agroeca* | *minuta* | 2 | 1 | 2 |
| Araneae | Liocranidae | *Agroeca* | *ornata* | 8 | 8 | 1 |
| Araneae | Lycosidae | *Pirata* | *montanus* | 53 | 3 | 49 |
| Araneae | Lycosidae | *Pirata* | *piratica* | 1 | 1 | 1 |
| Araneae | Lycosidae | *Pirata* | | 72 | 18 | 41 |
| Araneae | Lycosidae | *Piratainsularis* | | 260 | 25 | 57 |
| Araneae | Lycosidae | *Schizocosa* | *crassipes* | 2 | 2 | 1 |
| Araneae | Lycosidae | *Schizocosa* | | 3 | 2 | 2 |
| Araneae | Lycosidae | *Trebacosa* | *marxi* | 134 | 20 | 56 |
| Araneae | Lycosidae | *Trebacosa* | | 3 | 2 | 2 |
| Araneae | Lycosidae | *Trochosa* | *terricola* | 2 | 1 | 2 |
| Araneae | Lycosidae | *Trochosa* | | 12 | 10 | 2 |
| Araneae | Lycosidae | | | 191 | 37 | 60 |
| Araneae | Lyvosidae | *Pirata* | *insularis* | 1 | 1 | 1 |
| Araneae | Philodromidae | *Philodromus* | *rufus* | 2 | 2 | 1 |
| Araneae | Salticidae | *Chinattus* | *parvulus* | 2 | 2 | 1 |
| Araneae | Salticidae | *Habrocestoides* | *parvulum* | 1 | 1 | 1 |
| Araneae | Salticidae | *Marpissa* | *lineata* | 3 | 1 | 3 |
| Araneae | Salticidae | | | 5 | 5 | 1 |
| Araneae | Tetragnathidae | *Pachygnatha* | *brevis* | 3 | 1 | 3 |
| Araneae | Tetragnathidae | *Pachygnatha* | | 10 | 5 | 4 |
| Araneae | Tetragnathidae | | | 6 | 2 | 3 |
| Araneae | Theridiidae | *Robertus* | *riparius* | 3 | 3 | 1 |
| Araneae | Theridiidae | | | 1 | 1 | 1 |
| Araneae | Thomisidae | *Ozyptila* | *americana* | 1 | 1 | 1 |
| Araneae | Thomisidae | *Ozyptila* | *distans* | 1 | 1 | 1 |
| Araneae | Thomisidae | *Ozyptila* | | 3 | 3 | 1 |
| Araneae | Thomisidae | *Xysticus* | | 3 | 3 | 1 |
| Araneae | Thomisidae | | | 1 | 1 | 1 |
| Araneae | Zoridae | | | 1 | 1 | 1 |
| Araneae | | | | 190 | 51 | 13 |

*Table 3.9. 2008 Coleoptera collected in pitfall traps. Total is the cumulative taxon abundance for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs. is the maximum number of specimens identified at one site.*

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|---|
| Coleoptera | Anthribidae | *anthribid* | *anthribid #1* | 1 | 1 | 1 |
| Coleoptera | Apionidae | *Apion* | *finitimus* | 1 | 1 | 1 |
| Coleoptera | Cantharidae | *cantharid_larva* | *cantharid_larva #1* | 4 | 4 | 1 |
| Coleoptera | Cantharidae | *cantharid_larva* | *cantharid_larva #2* | 2 | 2 | 1 |
| Coleoptera | Cantharidae | *Rhagonycha* | *Rhagonycha #1* | 17 | 14 | 3 |
| Coleoptera | Cantharidae | *Rhagonycha* | *Rhagonycha #2* | 1 | 1 | 1 |

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|---|
| Coleoptera | Carabidae | *Agonum* | *affine* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Agonum* | *fidele* | 41 | 26 | 6 |
| Coleoptera | Carabidae | *Agonum* | *gratiosum* | 31 | 20 | 4 |
| Coleoptera | Carabidae | *Agonum* | *melanarium* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Agonum* | *mutatum* | 18 | 7 | 5 |
| Coleoptera | Carabidae | *Agonum* | *palustre* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Agonum* | *retractum* | 7 | 4 | 4 |
| Coleoptera | Carabidae | *Agonum* | *thoreyi* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Amphasia* | *interstitialis* | 3 | 3 | 1 |
| Coleoptera | Carabidae | *Bembidion* | *Bembidion #1* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Bembidion* | *concretum* | 12 | 7 | 5 |
| Coleoptera | Carabidae | *carabid* | *carabid #1* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *carabid_larva* | *carabid_larva #1* | 3 | 3 | 1 |
| Coleoptera | Carabidae | *carabid_larva* | *carabid_larva #2* | 10 | 9 | 2 |
| Coleoptera | Carabidae | *carabid_larva* | *carabid_larva #3* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *carabid_larva* | *carabid_larva #4* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Cymindis* | *limbata* | 3 | 3 | 1 |
| Coleoptera | Carabidae | *Dicaelus* | *Dicaelus #1* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Elaphrus* | *americanus* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Loricera* | *pilicornis* | 4 | 2 | 3 |
| Coleoptera | Carabidae | *Notiophilus* | *aeneus* | 2 | 2 | 1 |
| Coleoptera | Carabidae | *Olisthopus* | *micans* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Oodes* | *fluvialis* | 6 | 5 | 2 |
| Coleoptera | Carabidae | *Oxypselaphus* | *pusillus* | 3 | 3 | 1 |
| Coleoptera | Carabidae | *Patrobus* | *longicornis* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Platynus* | *decentis* | 6 | 6 | 1 |
| Coleoptera | Carabidae | *Poecilus* | *lucublandus* | 4 | 1 | 4 |
| Coleoptera | Carabidae | *Pterostichus* | *adoxus* | 3 | 2 | 2 |
| Coleoptera | Carabidae | *Pterostichus* | *caudicalis* | 1 | 1 | 1 |
| Coleoptera | Carabidae | *Pterostichus* | *commutabilis* | 13 | 11 | 2 |
| Coleoptera | Carabidae | *Pterostichus* | *coracinus* | 42 | 31 | 3 |
| Coleoptera | Carabidae | *Pterostichus* | *corvinus* | 10 | 7 | 2 |
| Coleoptera | Carabidae | *Pterostichus* | *diligendus* | 2 | 2 | 1 |
| Coleoptera | Carabidae | *Pterostichus* | *luctuosus* | 31 | 15 | 6 |
| Coleoptera | Carabidae | *Pterostichus* | *mutus* | 2 | 2 | 1 |
| Coleoptera | Carabidae | *Pterostichus* | *patruelis* | 2 | 2 | 1 |
| Coleoptera | Carabidae | *Pterostichus* | *pennsylvanicus* | 11 | 8 | 3 |
| Coleoptera | Carabidae | *Pterostichus* | *rostratus* | 4 | 3 | 2 |
| Coleoptera | Carabidae | *Pterostichus* | *tenuis* | 2 | 2 | 1 |
| Coleoptera | Carabidae | *Pterostichus* | *tristis* | 25 | 13 | 6 |
| Coleoptera | Carabidae | *Sphaeroderus* | *canadensis* | 5 | 5 | 1 |
| Coleoptera | Carabidae | *Sphaeroderus* | *stenostomus* | 6 | 6 | 1 |
| Coleoptera | Carabidae | *Synuchus* | *impunctatus* | 32 | 23 | 3 |

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|---|
| Coleoptera | Carabidae | *Trichiotichnus* | *autumnalis* | 1 | 1 | 1 |
| Coleoptera | Carabidae | | | 1 | 1 | 1 |
| Coleoptera | Cercopidae | *Clastoptera* | *Clastoptera #1* | 1 | 1 | 1 |
| Coleoptera | Chrysomelidae | *Altica* | *Altica #1* | 1 | 1 | 1 |
| Coleoptera | Chrysomelidae | *Capraita* | *subvittata* | 1 | 1 | 1 |
| Coleoptera | Chrysomelidae | *chrysomelid_larva* | *chrysomelid_larva #1* | 5 | 5 | 1 |
| Coleoptera | Cryptophagidae | *Caenoscelis* | *Caenoscelis #1* | 2 | 2 | 1 |
| Coleoptera | Curculionidae | *Anthonomus* | *Anthonomus #1* | 2 | 1 | 2 |
| Coleoptera | Curculionidae | *Barypeithes* | *pellucidus* | 2 | 2 | 1 |
| Coleoptera | Curculionidae | *Conotrachelus* | *posticatus* | 4 | 3 | 2 |
| Coleoptera | Curculionidae | *Dryophthorus* | *americanus* | 1 | 1 | 1 |
| Coleoptera | Curculionidae | *Sphenophorus* | *Sphenophorus #1* | 1 | 1 | 1 |
| Coleoptera | Curculionidae | *Trachyphloeus* | *bifoveolatus* | 1 | 1 | 1 |
| Coleoptera | Curculionidae | *Xylosandrus* | *germanus* | 2 | 2 | 1 |
| Coleoptera | Dytiscidae | *Agabus* | *Agabus #1* | 1 | 1 | 1 |
| Coleoptera | Dytiscidae | *Agabus* | *Agabus #2* | 1 | 1 | 1 |
| Coleoptera | Dytiscidae | *Agabus* | *Agabus #3* | 1 | 1 | 1 |
| Coleoptera | Dytiscidae | *dytiscid_larva* | *dytiscid_larva #1* | 1 | 1 | 1 |
| Coleoptera | Dytiscidae | *dytiscid_larva* | *dytiscid_larva #2* | 3 | 1 | 3 |
| Coleoptera | Dytiscidae | *Hydaticus* | *aruspex* | 2 | 2 | 1 |
| Coleoptera | Elateridae | *Dalopius* | *Dalopius #1* | 1 | 1 | 1 |
| Coleoptera | Elateridae | *Dalopius_larva* | *Dalopius_larva #1* | 4 | 4 | 1 |
| Coleoptera | Elateridae | *elaterid* | *elaterid #1* | 1 | 1 | 1 |
| Coleoptera | Elateridae | *elaterid_larva* | *elaterid_larva #1* | 1 | 1 | 1 |
| Coleoptera | Elateridae | *elaterid_larva* | *elaterid_larva #2* | 1 | 1 | 1 |
| Coleoptera | Formicidae | *Camponotus* | | 1 | 1 | 1 |
| Coleoptera | Geotrupidae | *Geotrupes* | *balyi* | 1 | 1 | 1 |
| Coleoptera | Hydraenidae | *Hydraena* | *Hydraena #1* | 4 | 4 | 1 |
| Coleoptera | Hydrophilidae | *Anacaena* | *limbata* | 4 | 4 | 1 |
| Coleoptera | Hydrophilidae | *Cercyon* | *connivens* | 3 | 3 | 1 |
| Coleoptera | Hydrophilidae | *Cryptopleurum* | *Cryptopleurum #2* | 1 | 1 | 1 |
| Coleoptera | Hydrophilidae | *Cymbiodyta* | *vindicata* | 1 | 1 | 1 |
| Coleoptera | Hydrophilidae | *hydrophilid_larva* | *hydrophilid_larva #1* | 1 | 1 | 1 |
| Coleoptera | Lampyridae | *lampyrid* | *lampyrid #1* | 1 | 1 | 1 |
| Coleoptera | Lampyridae | *lampyrid_larva* | *lampyrid_larva #3* | 5 | 5 | 1 |
| Coleoptera | Lampyridae | *lampyrid_larva* | *lampyrid_larva #4* | 11 | 10 | 2 |
| Coleoptera | Lampyridae | *lampyrid_larva* | *lampyrid_larva #5* | 1 | 1 | 1 |
| Coleoptera | Lampyridae | *lampyrid_larva* | *lampyrid_larva #6* | 1 | 1 | 1 |
| Coleoptera | Lampyridae | *lampyrid_larva* | *lampyrid_larva #8* | 2 | 2 | 1 |
| Coleoptera | Lampyridae | *Photinus* | *Photinus #1* | 3 | 1 | 3 |
| Coleoptera | Lampyridae | *Pyractomena* | *Pyractomena #1* | 3 | 3 | 1 |
| Coleoptera | Lampyridae | *Pyropyga* | *decipiens* | 3 | 3 | 1 |
| Coleoptera | Leiodidae | *Agathidium* | *oniscoides* | 2 | 2 | 1 |

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|-------|--------|-------|---------|-------|--------------|----------|
| Coleoptera | Leiodidae | *Catops* | *hornianus* | 2 | 1 | 2 |
| Coleoptera | Leiodidae | *Leiodes* | *Leiodes #1* | 1 | 1 | 1 |
| Coleoptera | Lycidae | *Plateros* | *Plateros #1* | 1 | 1 | 1 |
| Coleoptera | Lycidae | *Plateros* | *Plateros #2* | 1 | 1 | 1 |
| Coleoptera | Melandryidae | *Dicerea* | *literata* | 1 | 1 | 1 |
| Coleoptera | Melandryidae | *melandryid_larva* | *melandryid_larva #1* | 1 | 1 | 1 |
| Coleoptera | Nitidulidae | *Pallodes* | *pallidus* | 38 | 24 | 8 |
| Coleoptera | Nitidulidae | *Stelidota* | *geminata* | 1 | 1 | 1 |
| Coleoptera | Nitidulidae | *Stelidota* | *octomaculata* | 2 | 1 | 2 |
| Coleoptera | Ptiliidae | *Acrotrichus* | *Acrotrichus #1* | 8 | 5 | 3 |
| Coleoptera | Ptiliidae | *Nephanes* | *Nephanes #1* | 5 | 4 | 2 |
| Coleoptera | Ptiliidae | *Nossidium* | *Nossidium #1* | 1 | 1 | 1 |
| Coleoptera | Ptiliidae | *Ptenidium* | *Ptenidium #1* | 3 | 3 | 1 |
| Coleoptera | Ptiliidae | *ptiliid_larva* | *ptiliid_larva #1* | 1 | 1 | 1 |
| Coleoptera | Scarabaeidae | *Dialytes* | *striatulus* | 1 | 1 | 1 |
| Coleoptera | Scarabaeidae | *Serica* | *Serica #1* | 1 | 1 | 1 |
| Coleoptera | Scirtidae | *Cyphon* | *Cyphon #1* | 13 | 12 | 2 |
| Coleoptera | Scirtidae | *Cyphon* | *Cyphon #2* | 4 | 4 | 1 |
| Coleoptera | Scirtidae | *Cyphon* | *Cyphon #3* | 2 | 2 | 1 |
| Coleoptera | Scirtidae | *Cyphon* | *Cyphon #4* | 1 | 1 | 1 |
| Coleoptera | Scirtidae | *Cyphon_larva* | *Cyphon_larva #1* | 22 | 4 | 19 |
| Coleoptera | Scydmaenidae | *Euconnus* | *Euconnus #1* | 1 | 1 | 1 |
| Coleoptera | Scydmaenidae | *Euconnus* | *Euconnus #2* | 1 | 1 | 1 |
| Coleoptera | Scydmaenidae | *Euconnus* | *Euconnus #3* | 4 | 4 | 1 |
| Coleoptera | Scydmaenidae | *Parascydmus* | *Parascydmus #1* | 13 | 9 | 3 |
| Coleoptera | Scydmaenidae | *scydmaenid_larva* | *scydmaenid_larva #1* | 3 | 2 | 2 |
| Coleoptera | Scydmaenidae | *scydmaenid_larva* | *scydmaenid_larva #2* | 1 | 1 | 1 |
| Coleoptera | Silphidae | *Nicrophorus* | *defodiens* | 3 | 1 | 3 |
| Coleoptera | Sphindidae | *Eurysphindus* | *hirtus* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Acylophorus* | *caseyi* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Aleocharinae* | | 2 | 2 | 1 |
| Coleoptera | Staphylinidae | *Aleocharinae* | *Aleocharinae #2* | 19 | 12 | 3 |
| Coleoptera | Staphylinidae | *Aleocharinae* | *Aleocharinae #4* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Aleocharinae* | *Aleocharinae #5* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Aleocharinae* | *Aleocharinae #6* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Aleocharinae* | *Aleocharinae #7* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Aleocharinae* | *Aleocharinae #8* | 2 | 2 | 1 |
| Coleoptera | Staphylinidae | *Aleocharinae* | *Aleocharinae #9* | 13 | 9 | 3 |
| Coleoptera | Staphylinidae | *Aleocharinae_larva* | *Aleocharinae_larva #1* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Bibloplectus* | *ruficeps* | 2 | 2 | 1 |
| Coleoptera | Staphylinidae | *Bryoporus* | *rufescens* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Carpelimus* | *Carpelimus #1* | 43 | 21 | 9 |
| Coleoptera | Staphylinidae | *Cordalia* | *Cordalia #1* | 2 | 2 | 1 |

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|-------|--------|-------|---------|-------|--------------|----------|
| Coleoptera | Staphylinidae | *Euaesthetus* | *Euaesthetus #1* | 11 | 9 | 2 |
| Coleoptera | Staphylinidae | *Eubaeocera* | *Eubaeocera #1* | 6 | 5 | 2 |
| Coleoptera | Staphylinidae | *Eubaeocera* | *Eubaeocera #2* | 16 | 15 | 2 |
| Coleoptera | Staphylinidae | *Eubaeocera* | *Eubaeocera #3* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Eubaeocera* | *Eubaeocera #5* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Gabrius* | *Gabrius #1* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Gyrophaena* | *Gyrophaena #1* | 4 | 3 | 2 |
| Coleoptera | Staphylinidae | *Gyrophaena* | *Gyrophaena #2* | 2 | 2 | 1 |
| Coleoptera | Staphylinidae | *Ischnosoma* | *pictum* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Laetulonthus* | *laetulus* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Lathrobium* | *Lathrobium #1* | 4 | 4 | 1 |
| Coleoptera | Staphylinidae | *Lithocharis* | *Lithocharis #1* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Lordithon* | *Lordithon #1* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Philonthus* | *caeruleipennis* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Philonthus* | *Philonthus #1* | 3 | 3 | 1 |
| Coleoptera | Staphylinidae | *Platydracus* | *viridianus* | 55 | 25 | 7 |
| Coleoptera | Staphylinidae | *Proteinus* | *Proteinus #1* | 4 | 4 | 1 |
| Coleoptera | Staphylinidae | *Quedius* | *Quedius #1* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Rybaxis* | *Rybaxis #1* | 2 | 1 | 2 |
| Coleoptera | Staphylinidae | *Sepedophilus* | *Sepedophilus #1* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *staph_larva* | *staph_larva #1* | 4 | 3 | 2 |
| Coleoptera | Staphylinidae | *staph_larva* | *staph_larva #2* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *staph_larva* | *staph_larva #3* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Stenus* | *Stenus #1* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Tachinus* | *fumipennis* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Tachinus* | *scrutator* | 1 | 1 | 1 |
| Coleoptera | Staphylinidae | *Tasgius* | *Tasgius #1* | 1 | 1 | 1 |
| Coleoptera | Staphylinoidea | *larva* | *larva #1* | 1 | 1 | 1 |
| Coleoptera | Tenebrionidae | *Anaedus* | *brunneus* | 1 | 1 | 1 |
| Coleoptera | Tenthredinidae | *tenthredinid_larva* | *tenthredinid_larva #1* | 2 | 2 | 1 |
| Coleoptera | Tetratomidae | *Orchesia* | *ovata* | 2 | 2 | 1 |
| Coleoptera | Thripidae | *Thripidae* | *Thripidae #1* | 2 | 1 | 2 |
| Coleoptera | Throscidae | *Aulonothroscus* | *constrictor* | 1 | 1 | 1 |

*Table 3.10. 2008 Collembola collected in pitfall traps. Total is the cumulative taxon abundance
for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs.
is the maximum number of specimens identified at one site.*

| Order | Family | *Genus* | Total | # Sites Obs. | Max obs. |
|-------|--------|---------|-------|--------------|----------|
| Collembola | Entomobryidae | *Entomobrya* | 13 | 7 | 3 |
| Collembola | Entomobryidae | *Heteromurus* | 1 | 1 | 1 |
| Collembola | Entomobryidae | *Lepidocyrtus* | 67 | 26 | 14 |
| Collembola | Entomobryidae | *Orchesella* | 103 | 29 | 18 |

| Order | Family | *Genus* | Total | # Sites Obs. | Max obs. |
|---|---|---|---|---|---|
| Collembola | Entomobryidae | *Sinella* | 239 | 40 | 27 |
| Collembola | Entomobryidae | *Tomocerus* | 226 | 42 | 24 |
| Collembola | Entomobryidae | | 9 | 5 | 4 |
| Collembola | Hypogastruridae | *Hypogastrura* | 729 | 39 | 207 |
| Collembola | Hypogastruridae | *Microgastrura* | 4 | 4 | 1 |
| Collembola | Hypogastruridae | *Neanura* | 2 | 2 | 1 |
| Collembola | Hypogastruridae | *Odontella* | 9 | 6 | 3 |
| Collembola | Hypogastruridae | *Paranura* | 2 | 2 | 1 |
| Collembola | Hypogastruridae | *Pseudachorutes* | 116 | 39 | 17 |
| Collembola | Hypogastruridae | *Willemia* | 2 | 1 | 2 |
| Collembola | Hypogastruridae | | 1 | 1 | 1 |
| Collembola | Isotomidae | *Dagamaea* | 1 | 1 | 1 |
| Collembola | Isotomidae | *Folsomia* | 2 | 1 | 2 |
| Collembola | Isotomidae | *Isotoma* | 72 | 26 | 14 |
| Collembola | Isotomidae | *Isotomurus* | 9 | 1 | 9 |
| Collembola | Isotomidae | *Proisotoma* | 2 | 2 | 1 |
| Collembola | Onychiuridae | *Onychiurus* | 12 | 8 | 2 |
| Collembola | Poduridae | *Podura* | 1 | 1 | 1 |
| Collembola | Sminthuridae | *Arrhopalites* | 2 | 2 | 1 |
| Collembola | Sminthuridae | *Dicyrtoma* | 331 | 41 | 61 |
| Collembola | Sminthuridae | *Neosminthurus* | 2 | 2 | 1 |
| Collembola | Sminthuridae | *Sminthurides* | 2 | 2 | 1 |
| Collembola | Sminthuridae | *Sminthurus* | 1 | 1 | 1 |
| Collembola | | | 34 | 2 | 33 |

*Table 3.11. 2008 Hemiptera collected in pitfall traps. Total is the cumulative taxon abundance for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs. is the maximum number of specimens identified at one site.*

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|---|---|---|---|---|---|---|
| Hemiptera | Achilidae | *Epiptera* | | 1 | 1 | 1 |
| Hemiptera | Achilidae | | | 10 | 9 | 2 |
| Hemiptera | Aleyrodidae | | | 2 | 2 | 1 |
| Hemiptera | Anthocoridae | *Orius* | | 1 | 1 | 1 |
| Hemiptera | Aphididae | | | 23 | 12 | 8 |
| Hemiptera | Ceratocombidae | *Ceratocombus* | *vagans* | 26 | 20 | 3 |
| Hemiptera | Cercopidae | *aphrophora* | *cribrata* | 1 | 1 | 1 |
| Hemiptera | Cercopidae | | | 2 | 2 | 1 |
| Hemiptera | Cicadellidae | *Agallia* | *constricta* | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Agallia* | *quadripunctata* | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Agallia* | | 21 | 17 | 3 |
| Hemiptera | Cicadellidae | *Agalliopsis* | | 2 | 2 | 1 |
| Hemiptera | Cicadellidae | *Alebra* | | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Coelidia* | *olitoria* | 1 | 1 | 1 |

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|-------|--------|-------|---------|-------|-------------|----------|
| Hemiptera | Cicadellidae | *Erythroneura* | | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Ponana* | | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | *Scaphoideus* | | 303 | 58 | 34 |
| Hemiptera | Cicadellidae | *Typhlocyba* | | 1 | 1 | 1 |
| Hemiptera | Cicadellidae | | | 4 | 4 | 1 |
| Hemiptera | Cixiidae | *Cixius* | *meridionalis* | 1 | 1 | 1 |
| Hemiptera | Delphacidae | *Nothodelphax* | | 1 | 1 | 1 |
| Hemiptera | Delphacidae | *Pissonotus* | | 3 | 2 | 2 |
| Hemiptera | Delphacidae | | | 3 | 2 | 2 |
| Hemiptera | Derbidae | *Cedusa* | | 1 | 1 | 1 |
| Hemiptera | Flatidae | *Metcalfa* | *pruinosa* | 1 | 1 | 1 |
| Hemiptera | Heteroptera | | | 1 | 1 | 1 |
| Hemiptera | Miridae | *Fulvius* | *slateri* | 1 | 1 | 1 |
| Hemiptera | Miridae | *Phytocoris* | | 1 | 1 | 1 |
| Hemiptera | Miridae | | | 7 | 7 | 1 |
| Hemiptera | Nabidae | *Hoplistoscelis* | *sordidus* | 1 | 1 | 1 |
| Hemiptera | Nabidae | *Lasiomerus* | *annulatus* | 1 | 1 | 1 |
| Hemiptera | Nabidae | | | 6 | 5 | 2 |
| Hemiptera | Ortheziidae | | | 2 | 2 | 1 |
| Hemiptera | Psyllidae | | | 2 | 2 | 1 |
| Hemiptera | Reduviidae | *Barce* | | 2 | 2 | 1 |
| Hemiptera | Rhyparochromidae | *Rhyparochromus* | | 1 | 1 | 1 |
| Hemiptera | Saldidae | *Saldula* | | 10 | 7 | 4 |
| Hemiptera | Veliidae | *Microvelia* | | 7 | 4 | 3 |

*Table 3.12. 2008 Hymenoptera collected in pitfall traps. Total is the cumulative taxon abundance for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs. is the maximum number of specimens identified at one site.*

| Order | Family | Genus | Species | Total | # Sites Obs. | Max obs. |
|-------|--------|-------|---------|-------|-------------|----------|
| Hymenoptera | Aphelinidae | | | 1 | 1 | 1 |
| Hymenoptera | Braconidae | | | 5 | 5 | 1 |
| Hymenoptera | Ceraphronidae | | | 24 | 21 | 2 |
| Hymenoptera | Chalcidoidea | | | 1 | 1 | 1 |
| Hymenoptera | Cynipidae | | | 1 | 1 | 1 |
| Hymenoptera | Diapriidae | | | 17 | 15 | 2 |
| Hymenoptera | Dryinidae | | | 9 | 6 | 4 |
| Hymenoptera | Encyrtidae | | | 5 | 5 | 1 |
| Hymenoptera | Eulophidae | | | 4 | 4 | 1 |
| Hymenoptera | Figitidae | | | 4 | 4 | 1 |
| Hymenoptera | Formicidae | *Aphaenogaster* | | 55 | 33 | 4 |
| Hymenoptera | Formicidae | *Camponotus* | | 26 | 19 | 4 |
| Hymenoptera | Formicidae | *Formica* | | 9 | 1 | 9 |
| Hymenoptera | Formicidae | *Lasius* | *flavus* | 25 | 4 | 12 |

| Order | Family | Genus | Species | Total | # Sites Obs. | Max obs. |
|-------|--------|-------|---------|-------|--------------|----------|
| Hymenoptera | Formicidae | *Lasius* | *niger* | 17 | 15 | 2 |
| Hymenoptera | Formicidae | *Lasius* | *umbratus* | 78 | 4 | 39 |
| Hymenoptera | Formicidae | *Lasius* | | 16 | 6 | 10 |
| Hymenoptera | Formicidae | *Myrmecina* | *americana* | 11 | 6 | 4 |
| Hymenoptera | Formicidae | *Myrmica* | *rubra* | 1 | 1 | 1 |
| Hymenoptera | Formicidae | *Myrmica* | | 28 | 17 | 3 |
| Hymenoptera | Formicidae | *Ponera* | *pennsylvanica* | 2 | 2 | 1 |
| Hymenoptera | Formicidae | *Stenamma* | | 4 | 3 | 2 |
| Hymenoptera | Formicidae | *Tapinoma* | | 1 | 1 | 1 |
| Hymenoptera | Formicidae | *Temnothorax* | | 26 | 11 | 12 |
| Hymenoptera | Formicidae | | | 3 | 3 | 1 |
| Hymenoptera | Halictidae | | | 1 | 1 | 1 |
| Hymenoptera | Ichneumonidae | | | 6 | 6 | 1 |
| Hymenoptera | Megaspilidae | | | 1 | 1 | 1 |
| Hymenoptera | Mymaridae | | | 6 | 6 | 1 |
| Hymenoptera | Platygastridae | | | 4 | 4 | 1 |
| Hymenoptera | Pompilidae | *Anoplius* | | 1 | 1 | 1 |
| Hymenoptera | Pteromalidae | | | 1 | 1 | 1 |
| Hymenoptera | Scelionidae | *Baeus* | | 7 | 7 | 1 |
| Hymenoptera | Scelionidae | *Trimorus* | | 253 | 58 | 32 |
| Hymenoptera | Scelionidae | | | 19 | 15 | 3 |
| Hymenoptera | Tenthredinidae | *Macrophya* | | 1 | 1 | 1 |
| Hymenoptera | | | | 1 | 1 | 1 |

*Table 3.13. 2008 Orthoptera collected in pitfall traps. Total is the cumulative taxon abundance
for all samples, # of sites obs. is the total number of sites that taxon was oserved, and max obs.
is the maximum number of specimens identified at one site.*

| Order | Family | Genus | Species | Total | # Sites Obs. | Max Obs. |
|-------|--------|-------|---------|-------|--------------|----------|
| Orthoptera | Gryllidae | *Gryllus* | | 33 | 22 | 5 |
| Orthoptera | Gryllidae | *Neoxabea* | *bipunctata* | 1 | 1 | 1 |
| Orthoptera | Gryllidae | *Oecanthus* | *fultoni* | 1 | 1 | 1 |
| Orthoptera | Gryllidae | *Oecanthus* | | 1 | 1 | 1 |
| Orthoptera | Gryllidae | | | 21 | 10 | 5 |
| Orthoptera | Rhaphidophoridae | *Ceuthophilus* | | 13 | 12 | 2 |

# Appendix A
# Relationships between individual taxa and IEI

Each of these plots shows the relationship between the relative abundance of a taxa and IEI. All models that received AIC weights are shown (colored lines) as well as the model average (black line). Abbreviations used in the plots to describe error models are: bi – binomial, bb – beta binomial, po – Poisson, nb – negative binomial, zb – zero inflated binomial, ze – zero inflated beta binomial, zp – zero inflated Poisson, zn – zero inflated negative binomial. The functional forms are abbreviated as: lg.3p - three parameter logistic, cg.3p – constrained exponential quadratic.

There are many more sites with low IEI than high IEI and these plots tend to highlight occurrences because all the zeros overlap. One consequence of this is that if a taxon was equally likely to occur everywhere there would still be more at sites with lower IEIs. The models take this into account but your eye may be thrown off.
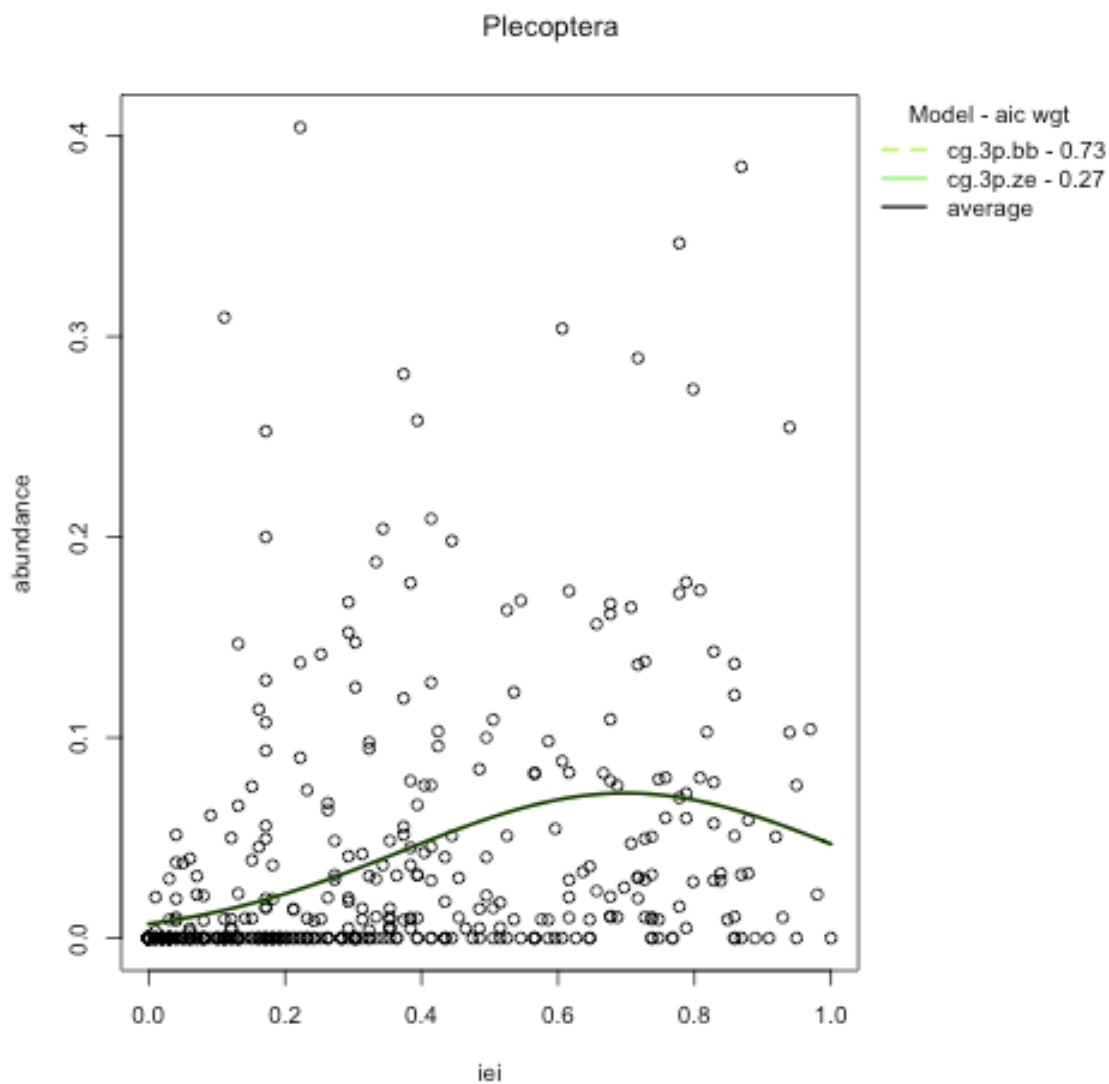
*Figure A.1. Plecoptera abundance was modeled as a bell curve that peaks at a relatively high IEI.*
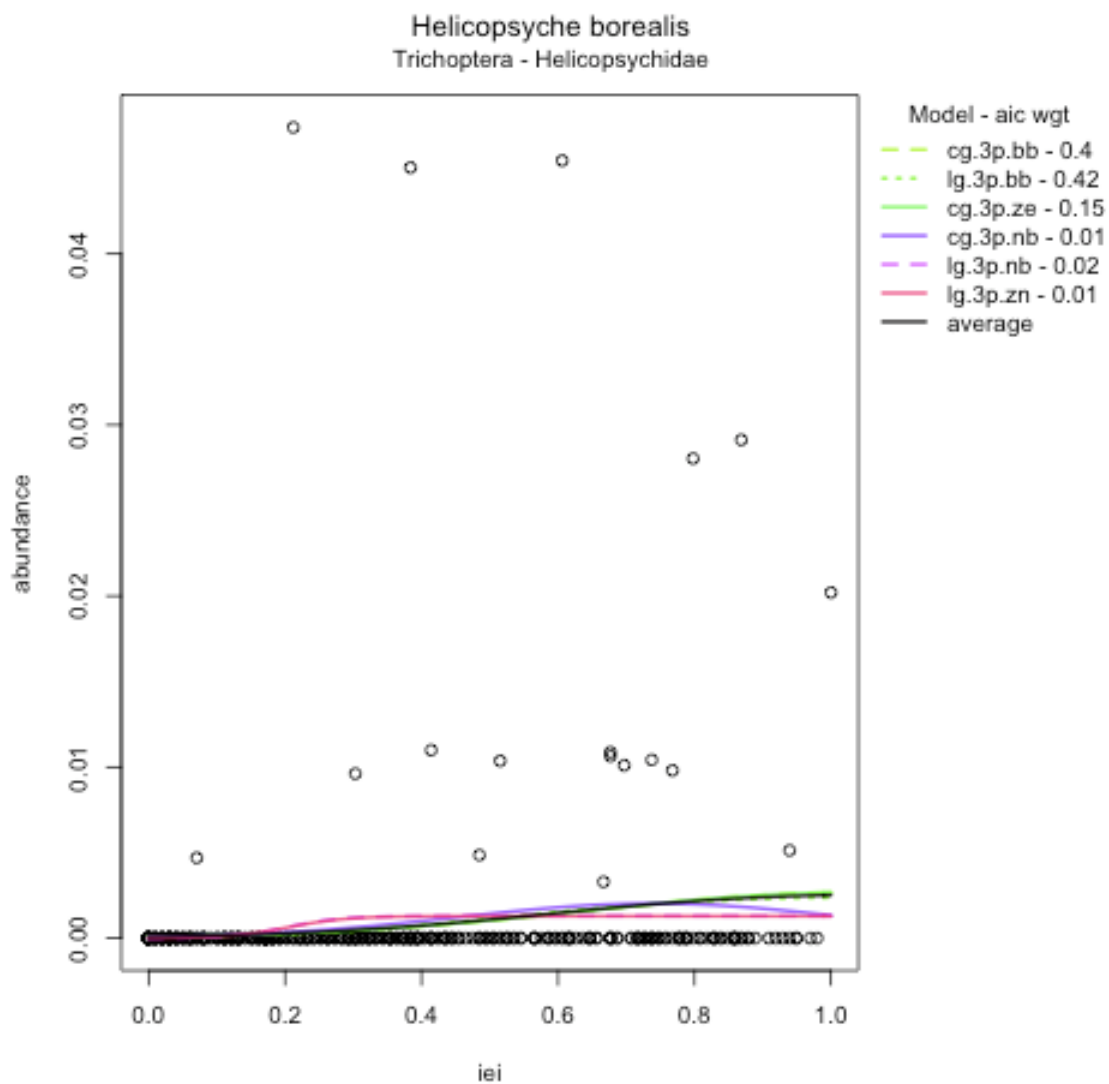
*Figure A.2.* Helicopsyche borealis *(Trichoptera, Helicopsychidae) abundance increases with IEI.*
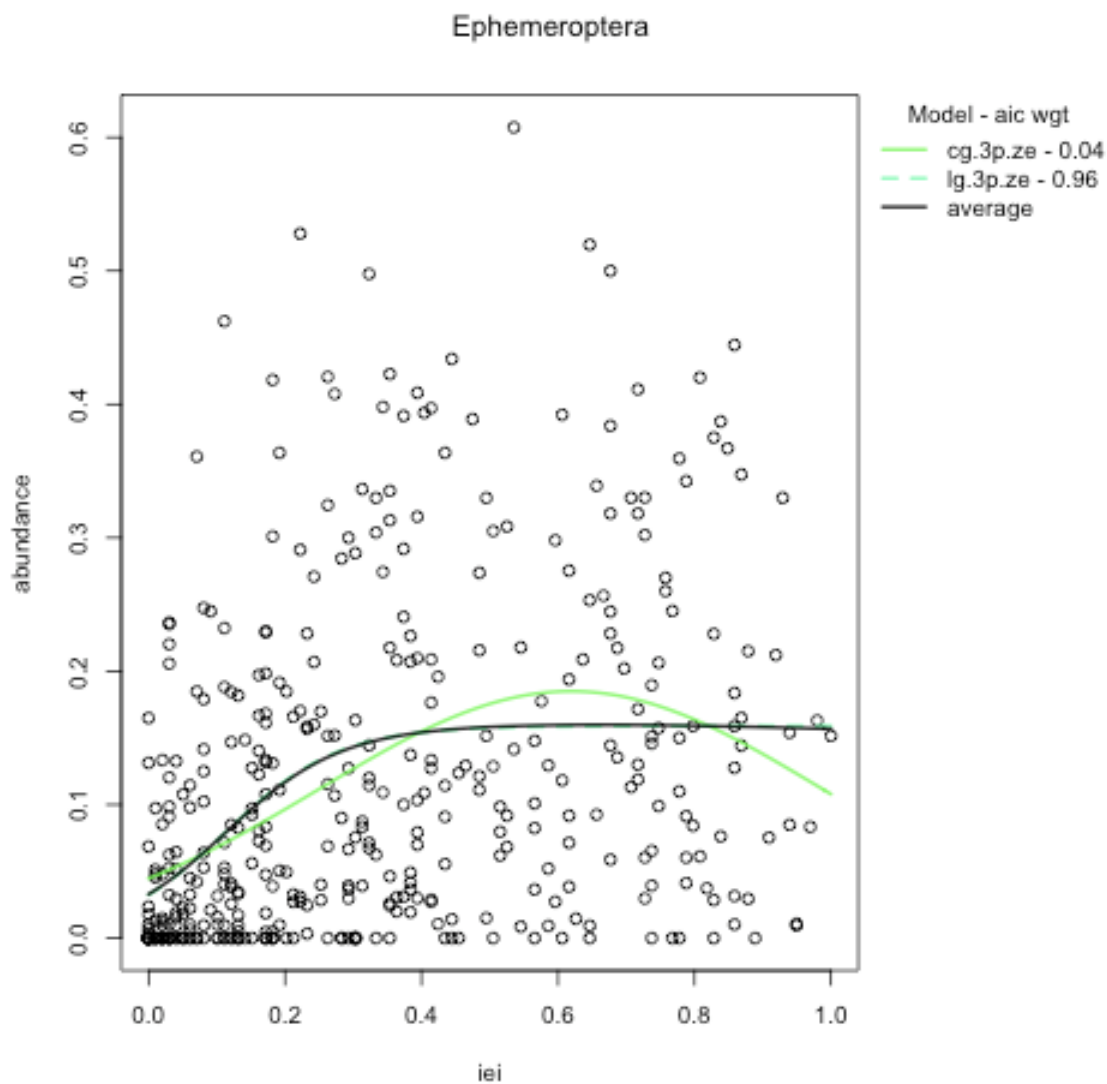
*Figure A.3. Emphemeroptera abundance exhibits somewhat of a threshold response to IEI with
abundance lower at the lowest IEI.*
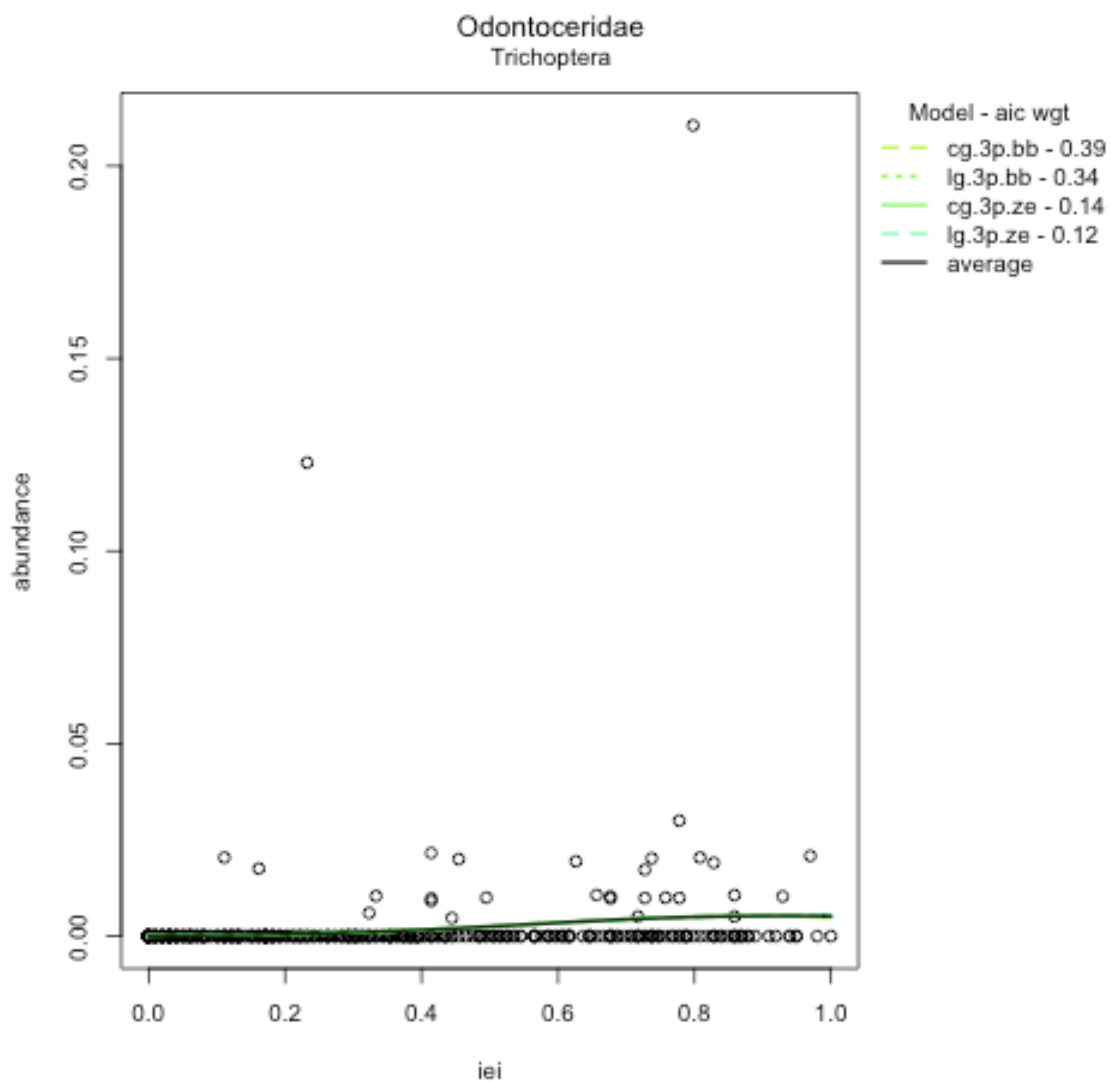
*Figure A.4. Odontoceridae (Trichoptera) abundance is slightly higher at higher IEIs.*
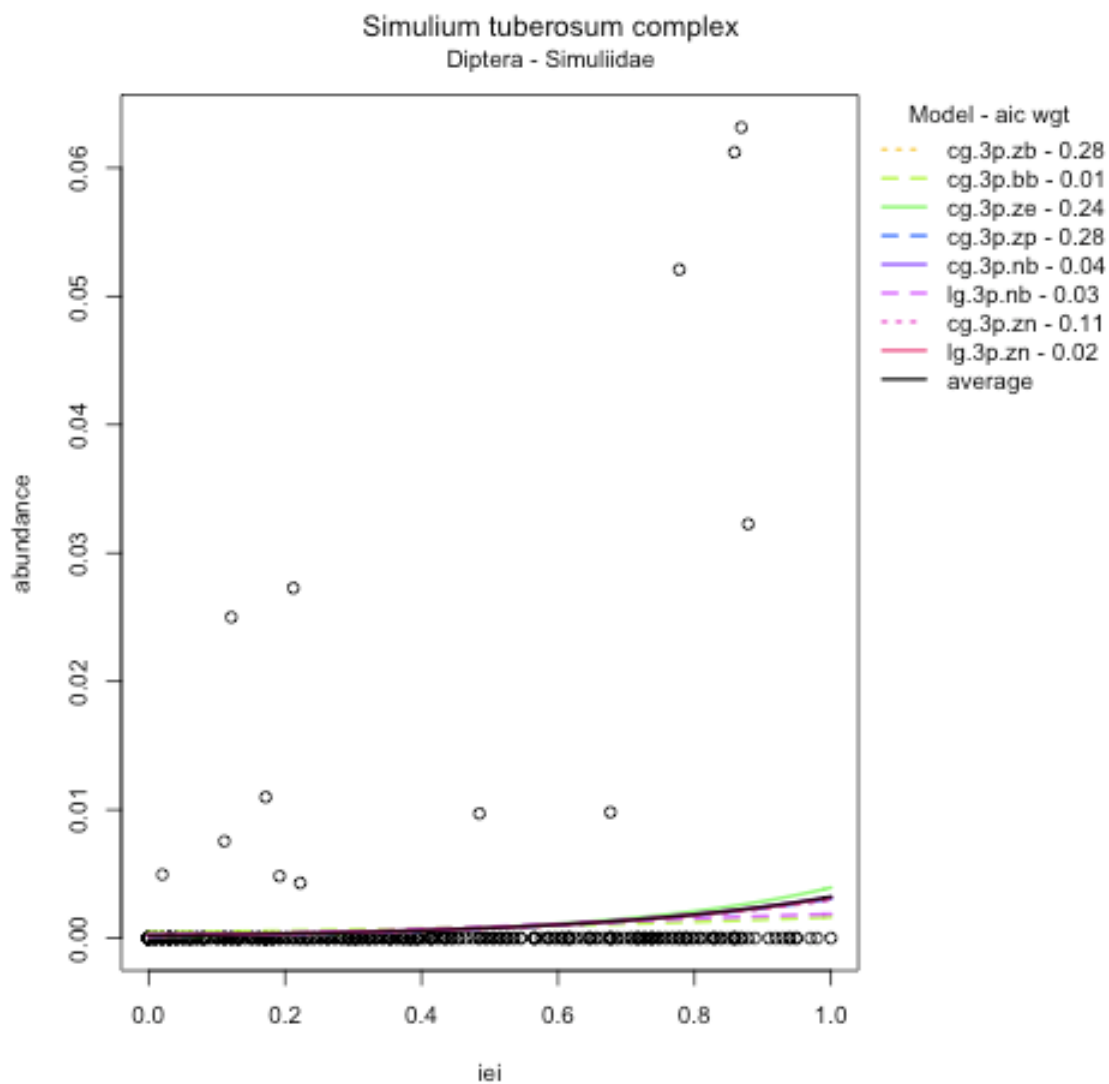
*Figure A.6.* Simulium tuberosum *(Diptera, Simuliidae)*
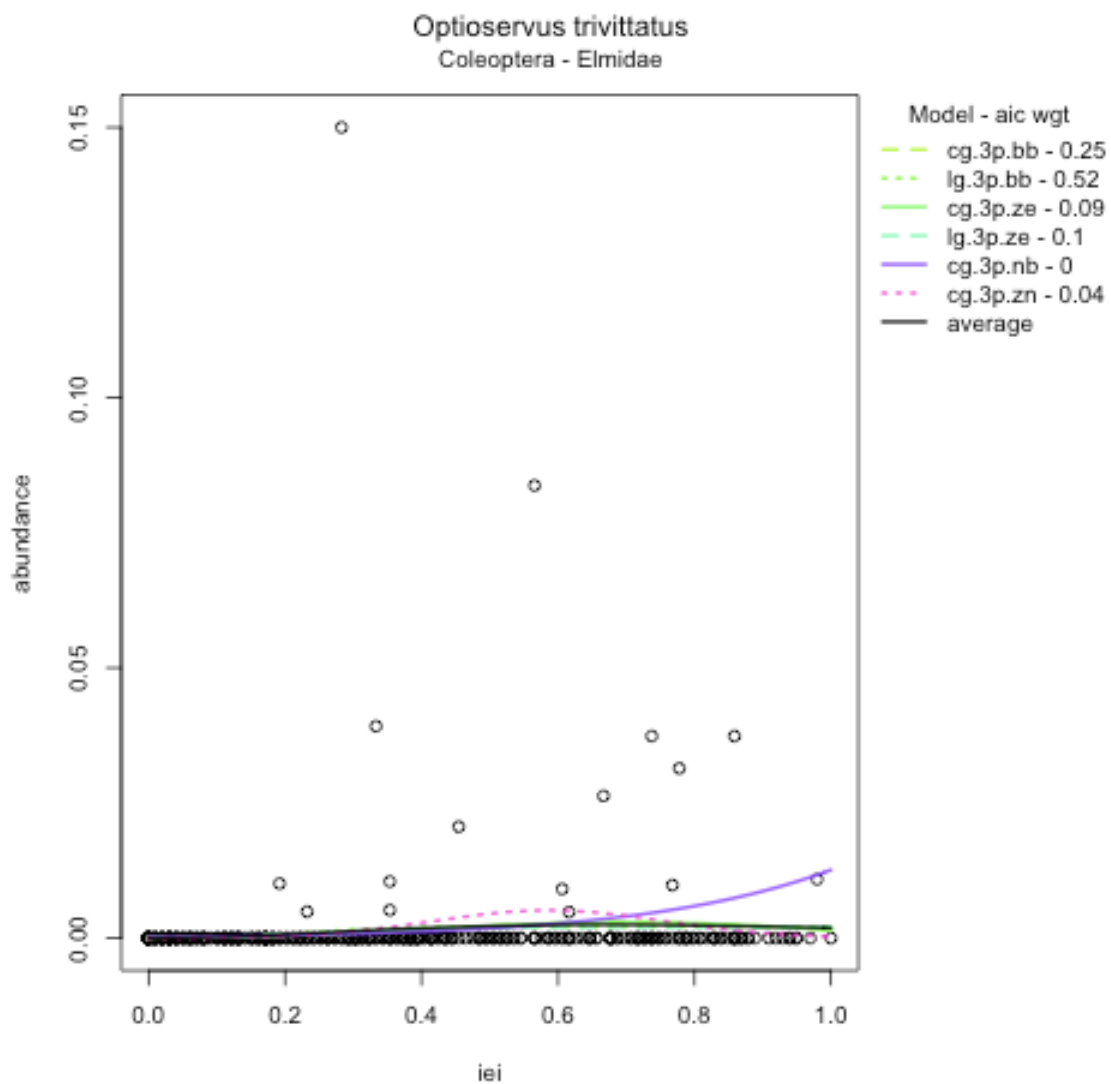
*Figure A.7.* Optioservus trivattatus *(Coleoptera, Elmidae) abundance is highest at moderate IEIs.*
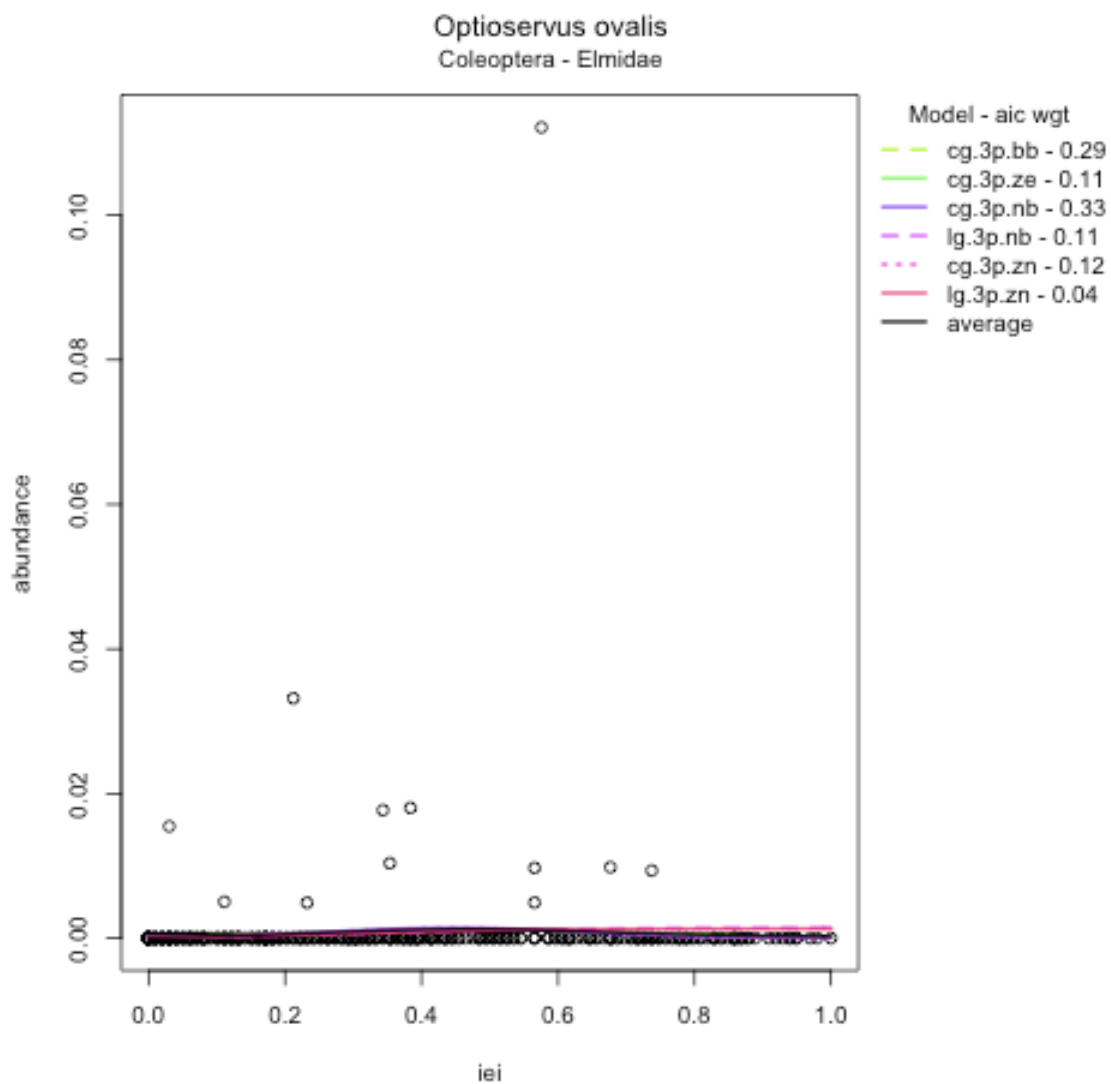
*Figure A.8.*Optioservus ovalis *(Coleoptera, Elmidae)*
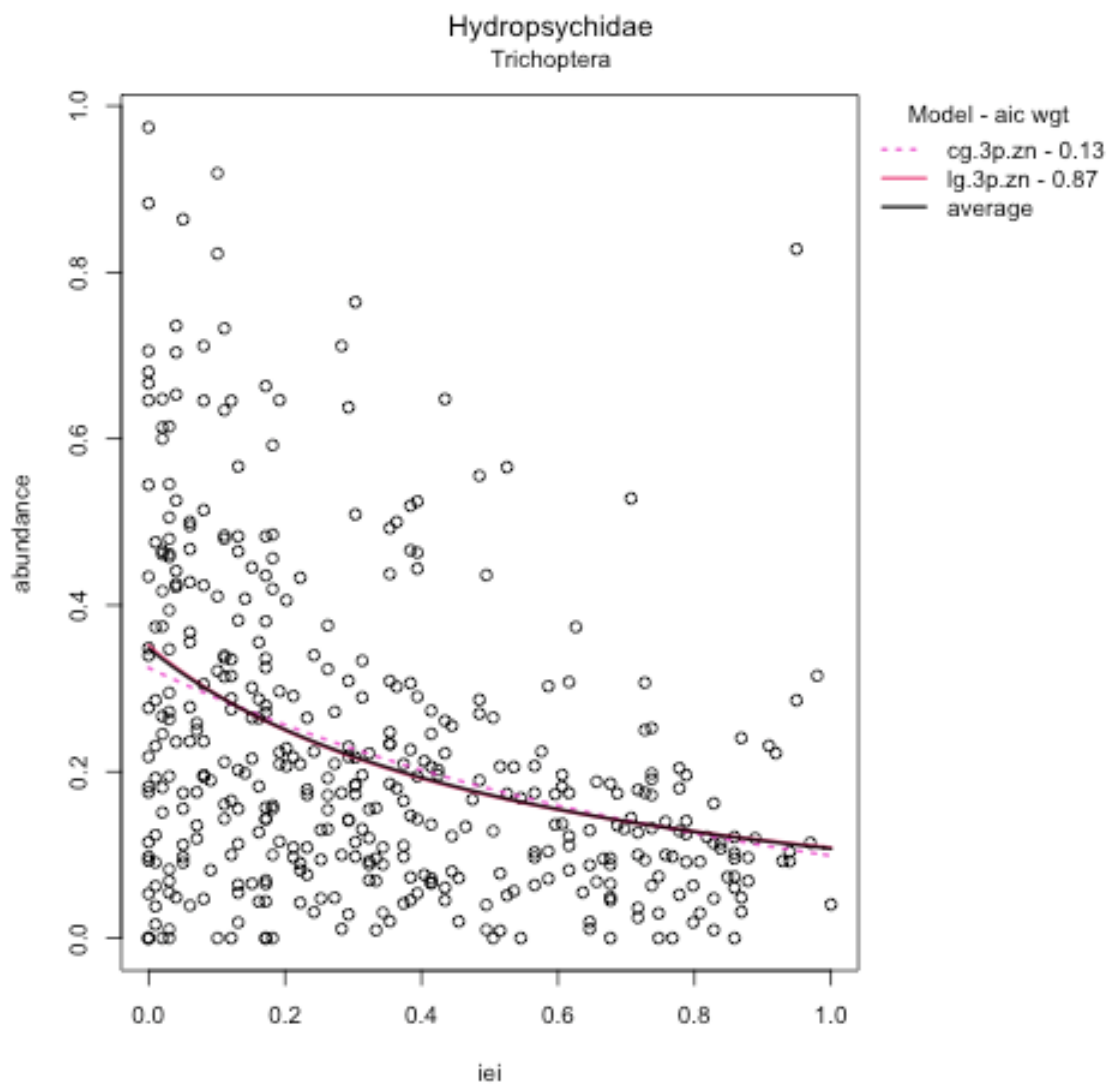
*Figure A.9. Relative Hydrophychidae (Trichoptera) abundance decreases with increasing IEI.*
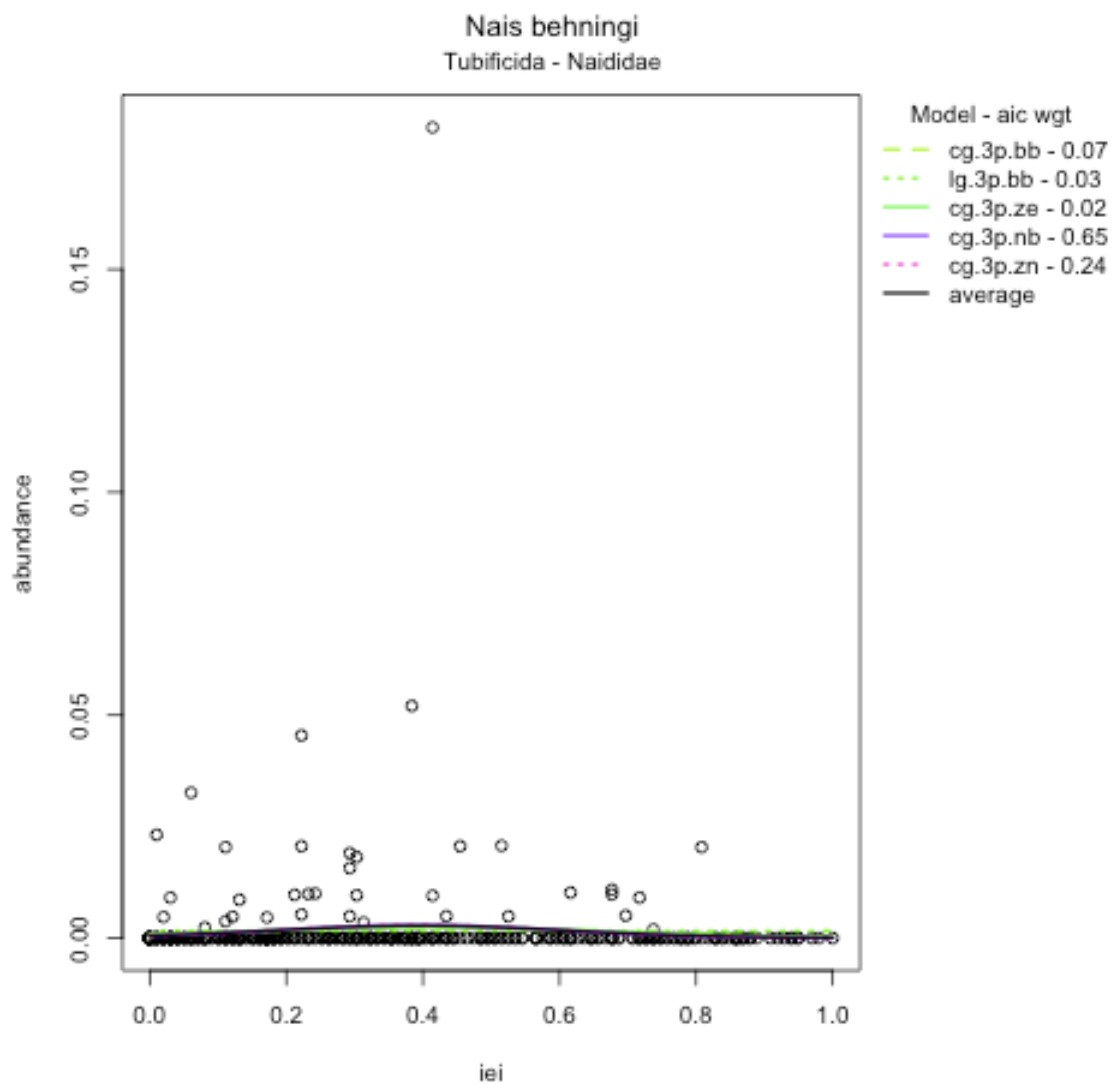
*Figure A.10.* Nais behningi *(Tubificida, Naididae) is more abundant at moderate and low IEI sites.*
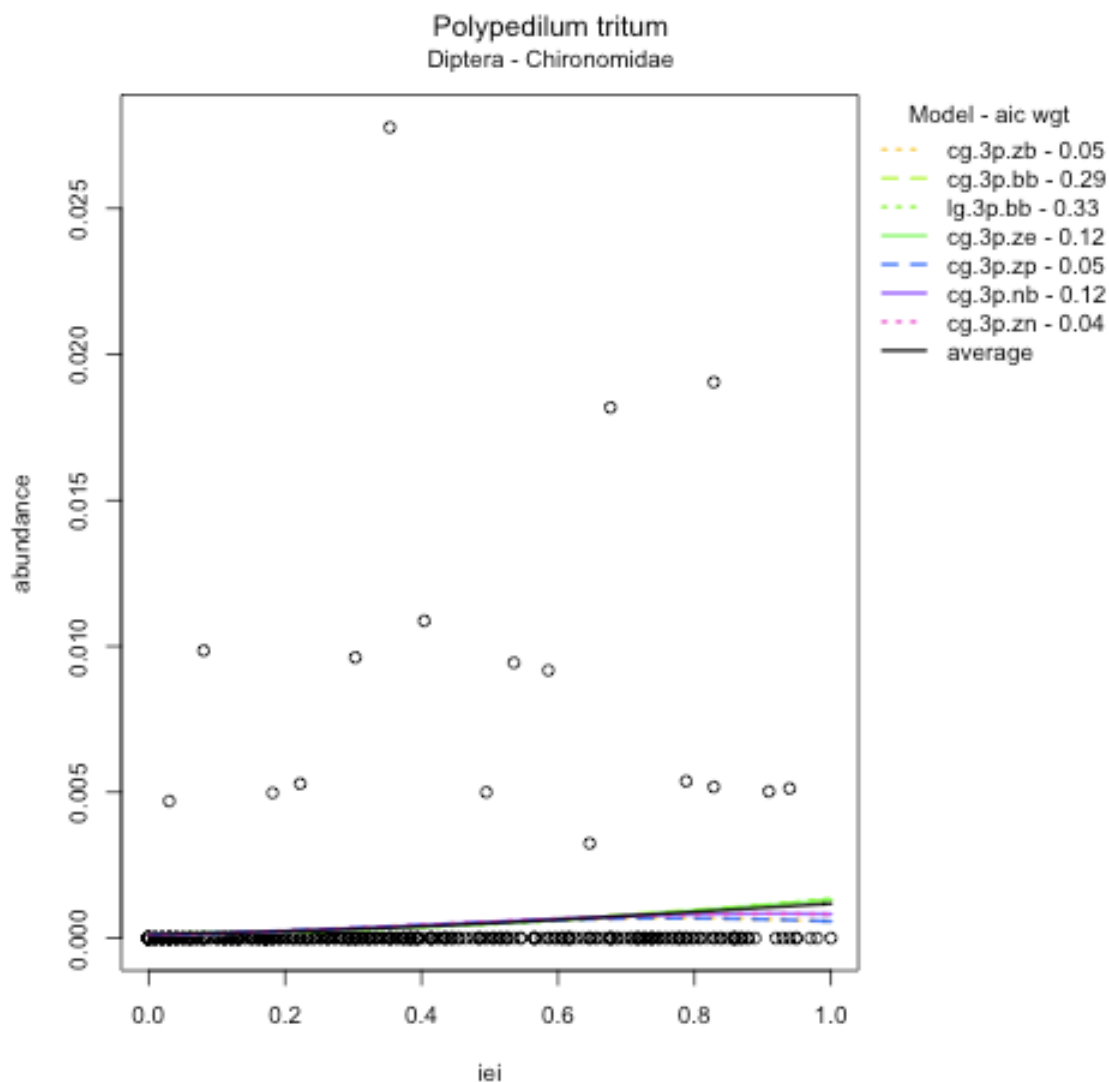
*Figure A.11.* Polypedium tritum *(Diptera, Chironomidae) abundance occurs more frequently at higher
IEIs.*
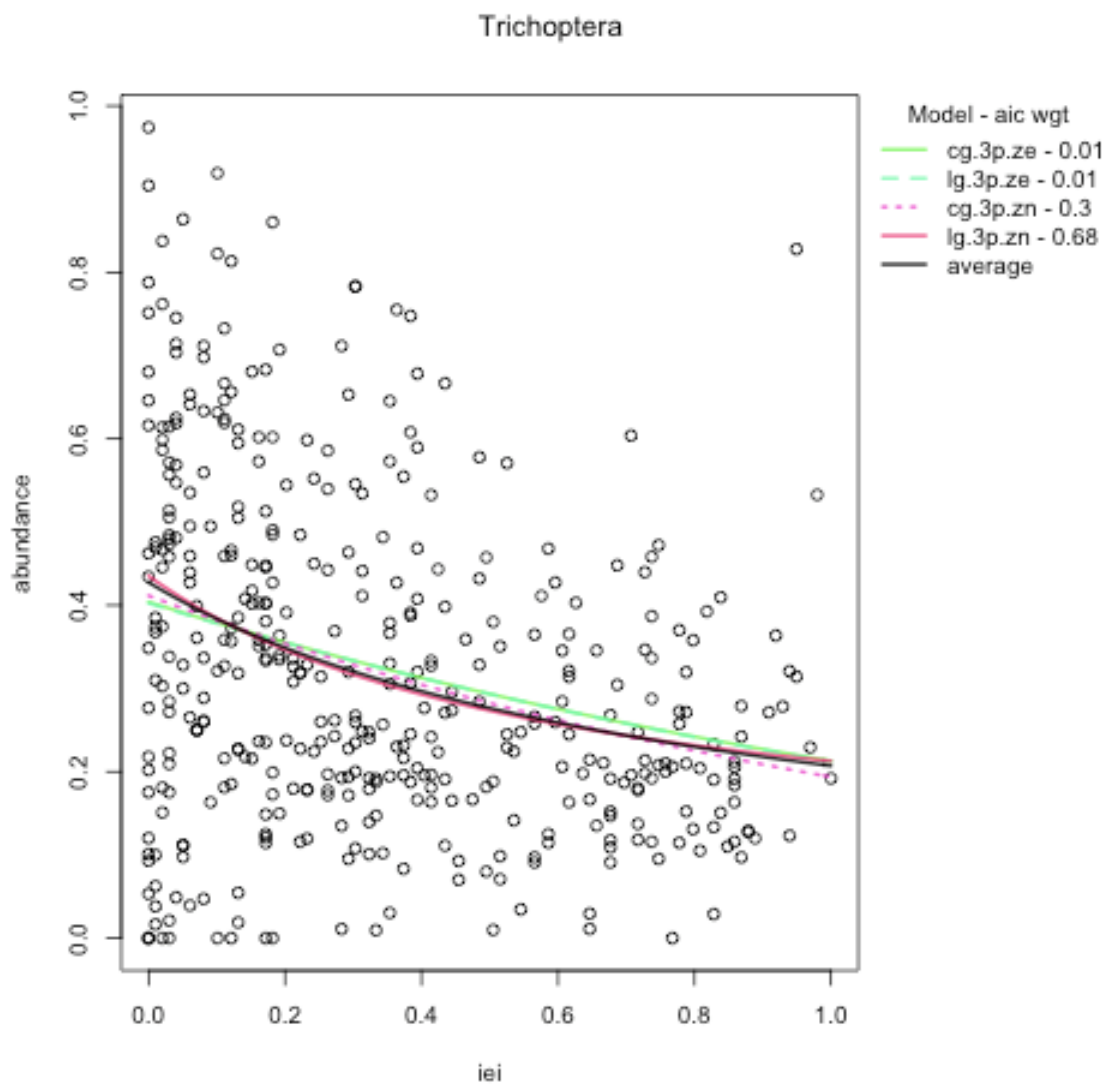
*Figure A.12. Trichoptera relative abundance declines with increasing IEI.*
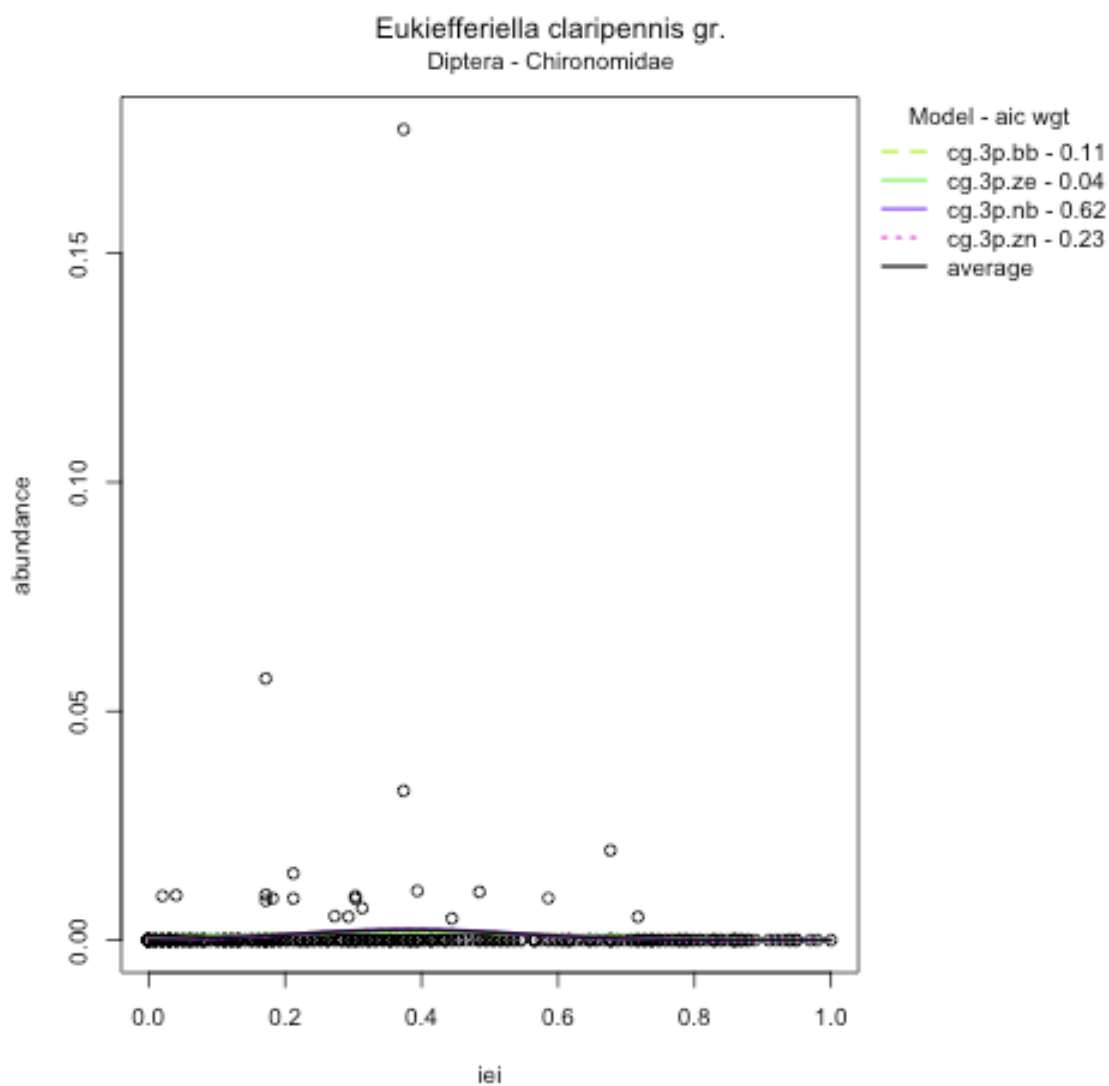
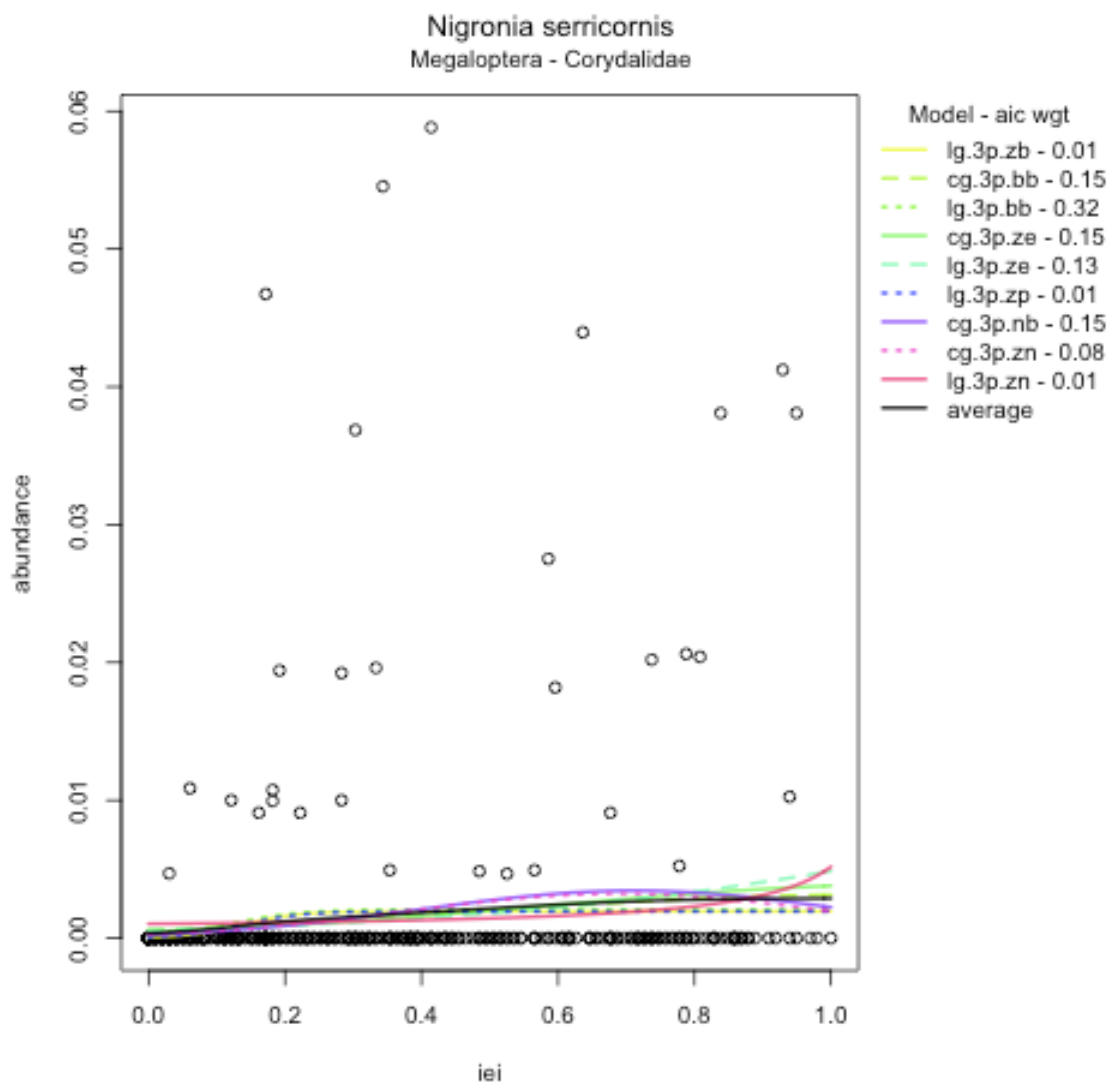*Figure A.13.* Eukiefferfiella claripennuis *gr. (Diptera, Chironomidae)*

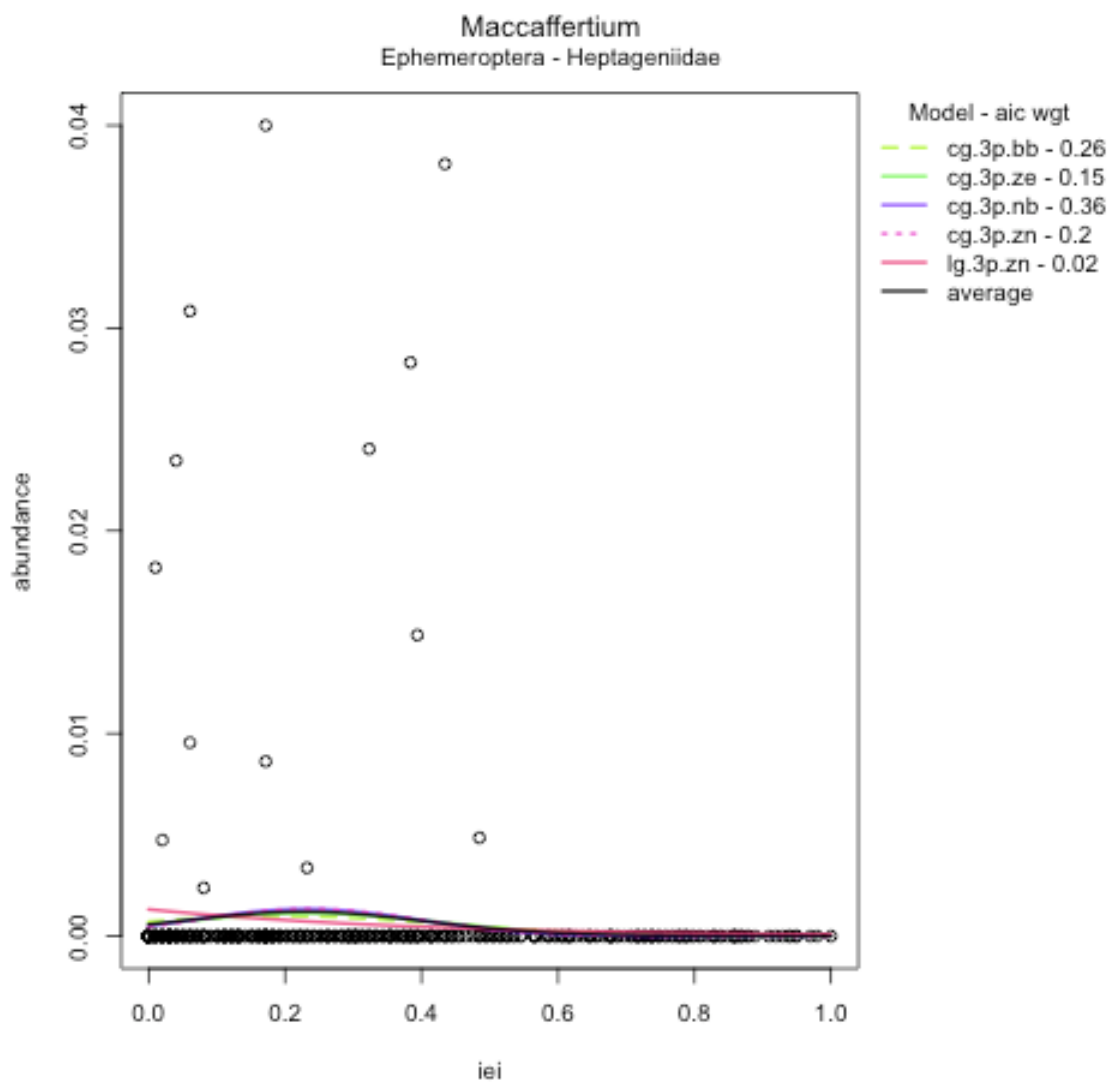*Figure A.14.* Nigronia serricornis *(Megaloptera, Corydalidae)*

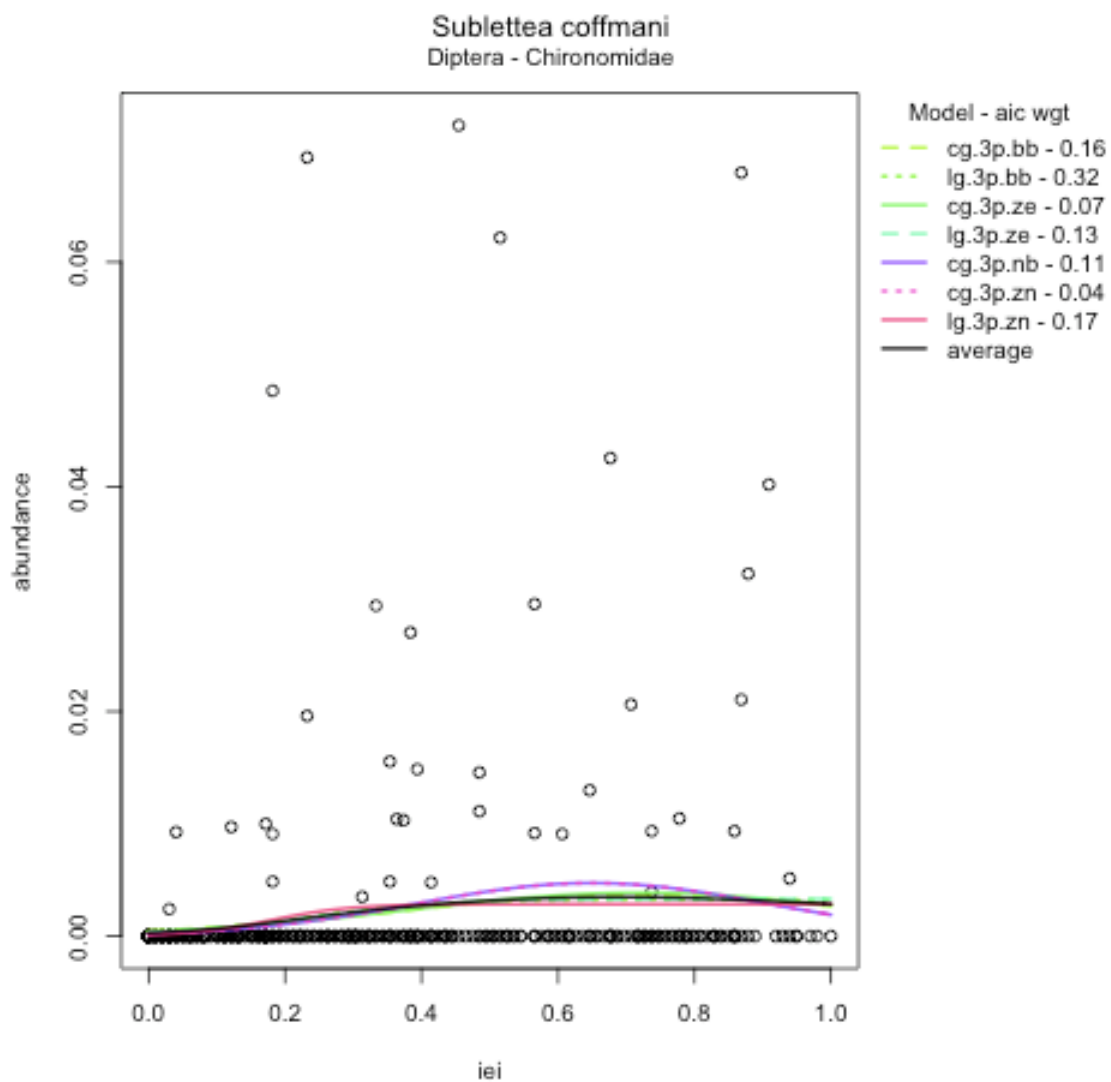*Figure A.15. Maccaffertium (Ephemeroptera, Heptageniidae)*

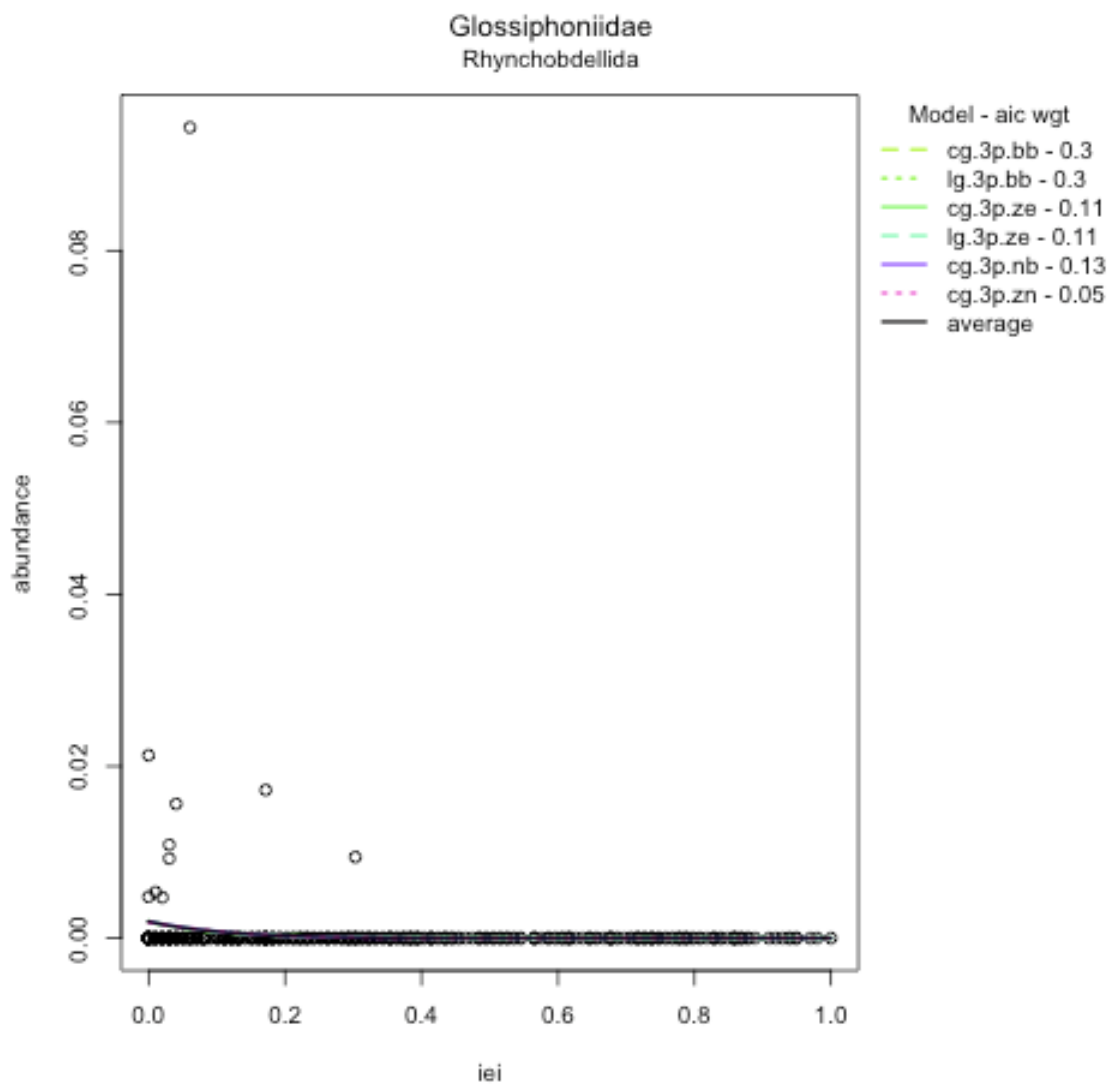*Figure A.16.* Sublettea Coffmani *(Diptera, Chironomidae)*

*Figure A.17. Glossiphoniidae (Rhynchobdellida)*

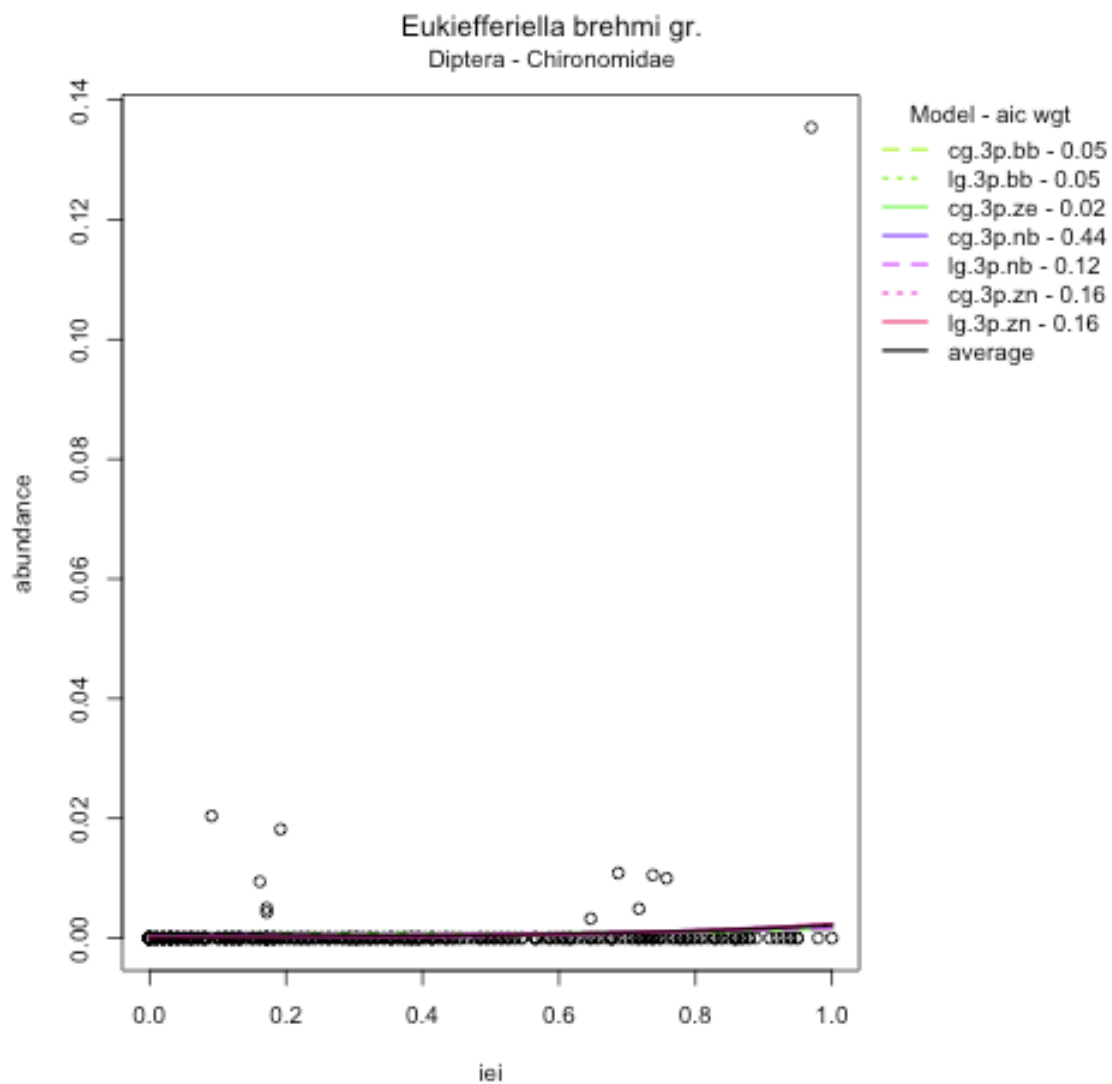*Figure A.18.* Eukiefferiella brehmi *gr. (Diptera, Chironomidae)*

# Appendix B
# Indices of Biological Integrity (IBIs) Tested Against CAPS IEI and Selected Metrics

*Table B.1. IBI, IBI codes (used in table 2 and figure 1), association of the metric with habitat quality, description and source of each IBI. In some cases we calculated metrics slightly different than in the references in particular when we counted taxa we did so across all taxonomic levels unless specifically stated otherwise.*

| IBI | Code | Association[3] | Description | Source |
|---|---|---|---|---|
| Diversity | diversity.g (genus) diversity.f (family) | + | Shannon-Weiner Diversity $$H \ = \ - \sum_i P_i \ln(P_i)$$ where $P_i$ is the proportional abundance of species i . | Smith et al. (2009), Coles et al. (2010) |
| Total Taxa Richness | n.taxa | + | Total number of taxa[1] at site. | Smith et al. (2009), PADEP (2009), OHEPA (1988, rev. 2008), Jessup (2007), Coles et al. (2010), Southerland et al. (2005), VTDEC (2004), RIDEM (2009), Nuzzo (2003)) |
| Non-Chironomidae and Oligochaeta Taxa Richness | n.no.co | + | Total number of taxa[1] outside the Chironomidae and Oligochaeta. | Smith et al. (2009) |

| IBI | Code | Association[3] | Description | Source |
|-----|------|----------------|-------------|--------|
| Ephemeroptera Taxa Richness | n.ephemeroptera | + | Total number of mayfly taxa[1]. | OHEPA (1988, rev. 2008), Southerland et al. (2005), VTDEC (2004), RIDEM (2009), Nuzzo (2003) |
| Trichoptera Taxa Richness | n.trichoptera | + | Total number of caddisfly taxa[1]. | OHEPA (1988, rev. 2008), Gerritsen and Jessup (2007) |
| Diptera Taxa Richness | n.deptera | - | Total number of true fly taxa[1]. | OHEPA (1988, rev. 2008) |
| EPT Taxa Richness | ept | + | Total number of Ephemeroptera, Plecoptera, and Tricoptera taxa[1]. | Smith et al. (2009), PADEP (2009), OHEPA (1988, rev. 2008), Coles et al. (2010), Southerland et al. (2005), VTDEC (2004), RIDEM (2009), Jessup (2007), Nuzzo (2003) |
| % Ephemeroptera | pct.ephemeroptera | + | Percent of taxa[1] in the order Ephemeroptera. | OHEPA (1988, rev. 2008), Southerland et al. (2005) |

| IBI | Code | Association[3] | Description | Source |
|---|---|---|---|---|
| % Tanytarsini midges | pct.tanytarsini.abun | + | Relative abundance of individual in the tribe of the Chironomid subfamily Chironominae | OHEPA (1998, rev. 2008) |
| % Richness non-insect | pct.non.insect | - | % of taxa that are non-insect | Jesup (2007), Coles et al. (2010) |
| % Sensitive EPT Individuals | pct.sensitive.ept.abun | + | Relative abundance of individuals in the Orders EPT. This excludes all Hydropsychidae. | Jessup (2007), Gerritsen and Jessup (2007) |
| EPT % Individuals | pct.ept.abun | + | % of individuals that are in the orders EPT. | WSA(2006), Jesup (2007) |
| % Richness of mollusks and crustaceans | pct.shellfish | - | % of taxa[1] (total richness) that are mollusks and crustaceans | Coles et al. (2010) |
| % Chironomidae | pct.chironomidae | - | % of taxa[1] that are midge larvae | Southerland et al. (2005) |
| % Oligochaeta | pct.abun.oligochaeta | - | % of abundance in the Class Oligochaeta. | VTDEC (2004) |
| % Contribution of Dominant Taxa | dom.3.f.abun (family) dom.3.o.abun (order) | - | % contribution of the most abundant 3 taxa at either the family or order level. Species and genus were not used because many samples were not identified to those levels. | Smith et al. (2009), Coles et al. (2010), Gerristen and Jessup (2007), RIDEM (2009), Nuzzo (2003) |
| EPT/(EPT + Chironomidae) (Taxa) | ept.chiro.stand | + | ept/(ept+n.chironomidae) The ratio[2] of ept taxa[1] to ept and chironomidae taxa[1]. | VTDEC (2004) |
| EPT/(EPT + Chironomidae) (Abundance) | ept.chiro.abun.stand | + | ept.abun/(ept.abun+chironomidae.abun) Total abundance of ept divided[2] by the total abundance of both ept and chironomidae. | VTDEC (2004) |

| IBI | Code | Association[3] | Description | Source |
|---|---|---|---|---|
| EPT/Chironomid Ratio | ept.chiro.ratio | + | Ratio[2] of total number of taxa[1] in orders E.P.T. and the total number of Chironomidae. | |
| Richness of gather-collector taxa | n.gc | + | Total richness of taxa classified as 'gatherers' and 'collectors' | Coles et al. (2010) |
| Scraper Richness | n.scraper | + | Number of taxa classified in the feeding group 'scrapers'. (Not adjusted for catchment size.) | Jessup (2007), WSA (2006), Southerland et al. (2005), Gerritsen and Jessup (2007) |
| % Scrapers | pct.scraper.abun | + | Relative abundance of individuals in the feeding group 'scrapers' | Southerland et al. (2005) |
| Ratio of scrapers/filtering collectors | scraper.to.filter.collector.ratio | + | Ratio[2] of the feeding guilds "scrapers" to "filtering-collectors" (calculated on abundance not number of taxa) | RIDEM(2009), Nuzzo (2003) |
| Shredder Ratio (individuals) | shredders | | Ratio of shredder abundance to total abundance | RIDEM(2009) |
| Hilsenhoff's Biotic Index | hilsenhoff.bi | - | Multiply the number of individuals of each species by its tolerance value. Sum the products and divide by the total number of individuals. | Smith et al. (2009), PADEP (2009), Jessup (2007), VTDEC (2004), RIDEM (2009), Nuzzo (2003) |
| Beck's Index (Version 3) | becks.i | + | Weighted count of the number of taxa (not individuals) with PTV's of 0, 1, or 2. $=3*N_0+ 2*N_1+1*N_2$ Where $N_i$= Count of individuals with tolerance value i | PADEP (2009) RIDEM (2009) |

| IBI | Code | Association[3] | Description | Source |
|-----|------|---------------|-------------|--------|
| % Sensitive individuals | pct.sensitive.abun | + | % of individuals with pollution tolerance values of 0 to 3. | PADEP (2009) |
| PTV 0-5.9 % Taxa | ptv.0.to.5.9 | + | % of taxa with a Pollution Tolerance Values between 0 and 5.9 | WSA (2006) |
| Average taxa tolerance | mean.tolval | - | Average taxa pollution tolerance value | Coles et al. (2010) |

[1] To calculate unique taxa within a sample all taxa were included so long as no other taxon was identified in the sample within the same group. For example if a specimen is identified only to order that order would be counted in the taxa count as long as no other specimens in the sample were from that order.

[2] In IBIs involving ratios we set the denominator equal to one when it would otherwise have been zero. This avoided division by zero and allowed the IBIs to be calculated at all sites.

[3] Association with habitat quality or integrity: +, the IBI indicated high integrity; - , the IBI indicates degraded habitat.