Empirically Derived Indices of Biotic Integrity for Forested Wetlands, Coastal Salt Marshes and Wadable Freshwater Streams in Massachusetts

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This report is the result of several years of field data collection, analyses and IBI development, and consideration of the opportunities for wetland program and policy development in relation to IBIs and CAPS Index of Ecological Integrity (IEI). Contributors include:

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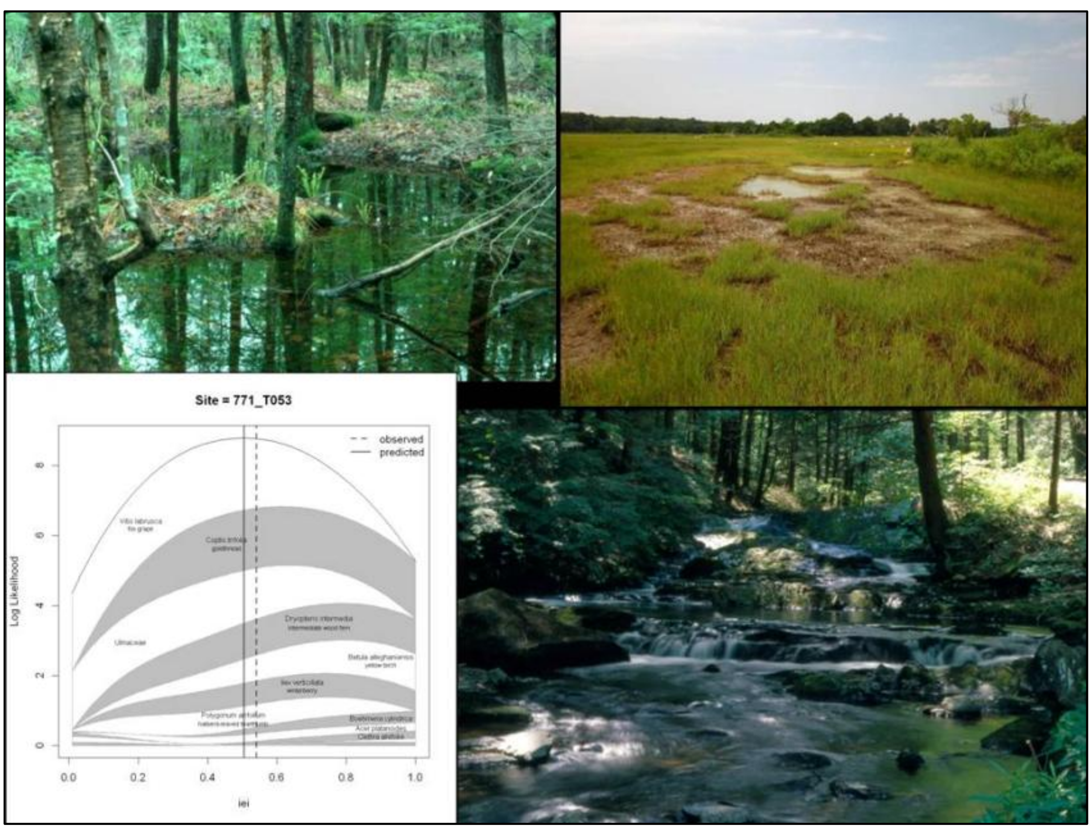

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Abstract

The purpose of this study was to develop a fully empirically-based method for developing Indices of Biotic Integrity (IBIs) that does not rely on expert opinion or the arbitrary designation of reference sites and pilot its application in forested wetlands, coastal salt marshes and wadable freshwater streams in Massachusetts. The method we developed involves: 1) using a suite of regression models to estimate the abundance of each taxon across a gradient of stressor levels, 2) using statistical calibration based on the fitted regression models and maximum likelihood methods to predict the value of the stressor metric based on the abundance of the taxon at each site, 3) selecting taxa in a forward stepwise procedure that conditionally improves the concordance between the observed stressor value and the predicted value the most and a stopping rule for selecting taxa based on a conditional alpha derived from comparison to pseudotaxa data, and 4) comparing the coefficient of concordance for the final IBI to the expected distribution derived from randomly permuted data.

Of the 164 separate IBIs we created for single taxonomic groups (and sampling methods) across stressor metrics and ecological systems (**Appendix C**), 57 were deemed statistically and ecologically reliable with cross-validated coefficient of concordance randing from 0.5 to 0.84. The IBIs for wadable stream macroinvertebrates performed exceptionally well; eight of nine IBIs had coefficients of concordance ranging from 0.59 to 0.84. The IBIs for forested wetlands also performed quite well; 48 of 120 IBIs across taxonomic groups (and sampling methods) and stressor metrics had coefficients of concordances ranging from 0.5 to 0.79, with vascular plants outperforming macroinvertbrates, diatoms, bryophytes and epiphytic macrolichens (in that order). The IBIs we created for coastal salt marshes did not perform as well; only four of 35 IBIs across taxonomic groups (and sampling methods) and stressor metrics had concordances ≥ 0.5, but the poor performance was likely due in part to the relatively low sample sizes. The strongest performing IBI was based on the wetland buffer insults metric and macroinvertebrates (0.57).

Our IBI methodology has a number of distinct advantages over conventional methods related to its completely objective procedure and the fact that it does not require reference sites. Moreover, we built in several procedures to safeguard against model overfitting, and the method is quite flexible in accomodating any taxa and stressor gradient in any ecological system and can include environmental covariates to account for natural variability among sites. Lastly, we illustrate a novel application of IBIs developed using our method to establish Continuous Aquatic Life Use (CALU) standards.

1. Introduction

Ecological indicators are often used to assess ecological condition in relation to human impacts and to monitor the status and trends of ecosystems (Cairns et al. 1993, Niemi and McDonald 2004). Despite the challenges associated with developing measures of ecological integrity (Dale and Beyeler 2003), given the expected continued increase in human population and accompanying land use intensification, state and federal agencies and conservation organizations are increasingly relying on the use of ecological indicators to inform planning, management (including regulation) and restoration at multiple scales. Indices of biotic integrity (IBIs) are ecological indicators that were introduced by James Karr and colleagues in the 1980s as a tool for quantifying changes in stream health as a result of habitat degradation or flow alteration, in addition to chronically poor chemical water quality (Karr 1981, Karr and Dudley 1981, Karr et al. 1986), but have since been extensively developed for use in a wide variety of ecosystems using a wide variety of taxa (Simon 2003).

IBIs posit an identifiable and measurable relationship between the biotic community and one or more anthropogentic stressors, and that once this relationship is established the biotic community can be used to indicate the condition of the ecoystem with respect to anthropogenic stress. However, because biota are affected by environmental conditions at multiple levels of biological organization (from genes to communities) and since different stressors can have variable effects on biota, response to changes in environmental conditions can be reflected at any of these levels and perhaps simultaneously at multiple levels (Karr 1991). Because of this complexity, it is generally deemed desirable to use a method of characterizing components of the biota that integrates and composites multiple, quantitative descriptors or metrics (Schoolmaster et al. 2012). Accordingly, Karr and colleagues (Karr 1981, Karr et al. 1986) developed the multimetric IBI approach that combined a series of metrics (biological descriptors) to characterize biological condition with fish assemblage data from streams of the Midwestern U.S.. Since then, there have been numerous adaptations of the multimetric approach using various biological assemblages data and calibrated for different geographic areas and ecosystem types, and it has been widely adopted by many federal and state agencies in water resource management and regulatory programs (e.g., Barbour et al 1999).

There are numerous challenges to the development of IBIs and consequently there have been many adaptations of the original approach to address some of these challenges (Beck and Hatch 2009). Despite substantial progress over the past three decades, there remains two inter-related, overarching challenges to the development and use of IBIs that we sought to address in this study. First, all IBIs are constructed from one or more biological descriptors or metrics. The derivation of any one metric or suite of metrics is typically based on expert knowledge of the biotic community and assumptions about how various taxa are expected to respond to anthropogenic stress. In other words, the metrics are not empirically derived, but rather are constructed as hypotheses based on expert opinion and then tested against real data (e.g., Mack 2007). Metrics that pass the empirical test are retained and incorporated into IBIs, those that are not supported by the data are discarded (Hering et al 2006). While there is nothing inherently wrong with this approach, we propose that it is unnecessarily restrictive by constraining the IBIs to a limited set of a priori hypothesized relationships and, moreover, relies too heavily on expert opinion when a fully empirical approach is possible.

The second challenge pertains to the analytical method for confronting the metrics with data to confirm and establish the stressor-response relationship. Most methods involve distinguishing a set of reference sites (i.e., minimally disturbed) from one or more classes of stressed sites and then identifying a suite of biotic metrics that effectively discrminate between or among them using statistical methods such as discriminant analysis (e.g., Davies et al. 1993). Once established, the discriminant function(s) can be used to predict the class a site belongs to based on the biotic metrics measured at the site. An alternative approach, which is used in Oregon and extensively by the U.S. Forest Service as well as in Great Britian and Australia, is based on an empirical discriminant function model that predicts the biotic attributes that would be expected to occur at a site in the absence of environmental stress and uses the deviation from expected as a measure of ecological impairment (Wright et al. 1993, Norris 1996, Hawkins et al. 2000). Importantly, both approaches require the a priori classification of training sites into discrete classes (e.g., reference versus stressed), and thus pre-supposes that the stressor-response relationship is discrete and that the sites can be placed into discrete classes prior to the statistical analysis, which typically requires some level of expert assignment. While these approaches have proven useful, we question the validity of assuming a discrete representation of the stressor-response relationship and the heavy reliance on expert opinion (e.g., assigning sites to a reference class) to inform the statistical analysis.

To address these challenges, we sought to develop a fully empirically-based method for developing IBIs that does not rely on expert opinion or the arbitrary designation of reference sites and pilot its application in forested wetlands, coastal salt marshes and wadable freshwater streams in Massachusetts.

2. Methods

2.1. Stressor metrics

As part of a broader long-term project known as the Conservation Assessment and Prioritization System (CAPS), we developed a suite of GIS-based landscape metrics to serve as indices of ecological integrity (UMassCAPS 2013). CAPS is based on a digital base map depicting various classes of developed and undeveloped land and a number of auxiliary layers representing anthropogenic alterations (such as road traffic and imperviousness) and ecological setting variables (such as wetness and growing degree days) and involves computing a variety of landscape metrics to evaluate ecological integrity for every point in the undeveloped landscape. A metric may, for example, take into account how well a point in the landscape is connected to similar points, the magnitude of natural habitat loss in the vicinity of a point, or the expected sediment or nutrient loads to a point. **Table 1** lists the suite of landscape metrics used in this study (i.e., those that we deemed relevant to the integrity of forested wetlands, coastal salt marshes and wadable freshwater streams) and a brief description of each is given in **Appendix A**. All of these metrics, hereafter referred to as "stressor metrics", measure some aspect of the adverse impact of anthropogenic activities on the integrity of ecological systems and are both intuitive (e.g.,. more pollution equals lower ecological integrity) and founded, at least in concept, on basic ecological principles and supported by scientific study. Note that while most of these metrics are positively associated with stress (i.e., higher values indicate more stress), the three resiliency metrics are negatively associated with stress. Moreover, we empirically validated many of these metrics using field-collected data. For example, the metrics pertaining to water quality impacts (i.e., Watershed Road Sediments, Road Salt, and Nutrient Enrichment) were significantly correlated with independent field data (unpublished data).

For each ecological system, we selected a suite of stressor metrics (**Table 1**) and computed their values for every 30 m cell across Massachusetts, including each of the sites in this study. In addition to the individual stressor metrics, we also computed a composite Index of Ecological Integrity (IEI) by combining the scaled stressor metrics in a weighted linear equation for each ecological system. Specifically, prior to combining the individual metrics, we rescaled each metric by percentiles for each ecological system (across the state) so that the best 10% of forested wetlands have values >0.90, for instance, and the best 25% have values >0.75, and so on. This was done to adjust for differences in units of measurement among metrics and to account for differences in the range of metric values for each ecological system. Next, expert teams assigned weights to each individual metric to reflect the relative importance of each metric for each ecological system (**Table 1**) and we then added them together to compute IEI. Note, the expert opinion used here is distinct from the use of expert opinion to create biotic metrics, which our method avoids. Also, like the three resiliency metrics, IEI has a negative relationship with stress. For the sake of parsimony, we developed IBIs for only a subset of the stressor metrics in coastal salt marshes and wadable freshwater streams (**Table 1**).

2.2. Biotic data collection

We collected or compiled biotic data in three ecological systems: 1) forested wetlands, 2) coastal salt marshes, and 3) wadable freshwater streams, using different methods at varying numbers of sites (**Table 2**, **Fig. 1**). Detailed descriptions of the standard operating procedures are on file with the Massachusetts Department of Environmental Protection (MassDEP) and a succinct description of the data collection methods are included in **Appendix A**. Briefly, between 2008-2009 we sampled vascular plants, bryophytes, epiphytic macrolichens, diatoms, and macroinvertebrates at 219 forested wetland locations (hereafter referred to as 'sites') distributed across the Chicopee River, Millers River and Concord River watersheds representing a gradient in anthropogenic stress as indexed by IEI. Similarly, between 2009-2011 we sampled vascular plants and macroinvertebrates at 130 coastal salt marsh locations. Lastly, we used data from the Masschusetts Benthic Macroinvertebrate database collected during 589 surveys at 490 wadable freshwater stream locations between 1983-2007. In all cases, we computed a tally for each taxon at each site and treated it as a Binomial response with a trial size equal to the total specimen count and/or as an unbounded Poisson response (with an offset to account for sampling effort), as appropriate, in the statistical models described below.

2.3. IBI development

Given that there is no single way to quantify anthropogenic impacts to ecological systems, and that we expect the biotic community to respond differently to different anthropogenic stressors, rather than develop a single IBI for each ecological system, we developed separate IBIs for each major taxonomic group (e.g., vascular plants, macroinvertebrates) and stressor metric in each ecological system. The development of separate IBIs for each taxonomic group reflects a practical concern over the comparative costs and benefits of collecting and identifying different taxa. Having separate IBIs for different taxonomic groups and stressor metrics also affords us great flexibility in using the observed biotic condition to indicate the nature of the stressor(s) affecting the system; in other words, determining which stressor is affecting which taxa. Given the number of IBIs we developed, it is not practical to present specific details on the development of each IBI. Instead, here we present the basic analytical method common to the development of all the IBIs and illustrate the approach with a single example.

Step 1. Taxonomic data summary

The first step involved summarizing the species abundance data at each site. For each site, we created counts of each taxon's abundance at each taxonomic level, including Species, Genus, Family, Order, Class and Phylum. This means that an individual in a sample identified to Species was counted again at the Genus level and, depending on the taxonomic group, the Family, Order, Class and Phylum levels as well. If an individual was only identified to Order, then it was only counted at the Order or higher level. We treated the abundance of each taxon at each taxonomic level as a separate dependent variable in the regression models below, and treated abundance as a Binomial response with a trial size equal to the total specimen count and/or as an unbounded Poisson response (with an offset to account for sampling effort), as appropriate. As one of several measures to safeguard against model overfitting, given the generally large number of taxa relative to the number of sites, we dropped all taxa that were observed at fewer than 10 sites.

Step 2. Regression

The second step was to fit individual responses for each taxon. Specifically, we modeled the relationship between each taxon (dependent variable) and each stressor metric (independent variable) with two functional forms and eight error models. The three-parameter logistic function (Equation 1) allowed for threshold responses of taxa to the gradient (note, the third parameter allows the upper asymptote to exceed one) while the constrained quadratic exponential (Equation 2) allowed for Gaussian and exponential responses to the gradient.

(1) $$y_i = \frac{a}{1+be^{-cx_i}} + error_i$$

(2) $$y_i = e^{(a+bx_i+cx_i^2)} + error_i$$

where y_i = the abundance of a taxon at the ith site, x_i = the value of the stressor metric at the ith site, $error_i$ = the error associated with the prediction at the ith site, and *a*,*b*, and *c* are parameters to be estimated. Note, in Equation 2 we constrained *c* to always be negative to prevent U-shaped distributions (i.e., where abudance peaks at low and high levels of the metric and is lowest in the middle), which we deemed ecologically implausible. Depending on the values of the parameters *a*, *b*, and *c*, these two functional forms can take on a wide variety of shapes, including monotonically increasing or decreasing, unimodal and sigmoidal curves, that represent plausible alternatives for how species' might respond to anthropogenic stressor gradients.

We modeled the error associated with unbounded count data with the Poisson and Negative Binomial distributions and for proportional response data (i.e., when the count observed was out of maximum possible count given by the sampling design) we used the Binomial and Beta-Binomial distributions along with the Poisson and Negative Binomial distributions. We surmised that the latter two distributions were suitable for the proportional response data because the taxa tallies remained small relative to the trial size (maximum count). In addition, we included zero-inflated versions (Zuur et al 2009) of each of these 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 four to eight suitable error models and two functional forms, we had 8-16 alternative models for each taxon. However, we dropped any model from further consideration if any of the following conditions were met: 1) the model failed to fit; 2) the delta AIC of the model was greater than 10; or 3) the fit predicted negative abundance (unrealistic) or abundance that was more than twice the maximum observed in the training data (these were often fits that behaved strangely at extreme values of the independent variable). For all retained models, we used AIC model 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 (Burnham and Anderson 2002). Note, we did not average these models at this step, but left that for the next step associated with statistical calibration, as described below.

Lastly, the Binomial and Beta-Binomial models include a parameter for trial size and thus instrinsically provide a means to account for varying sampling effort among sites, where the effort is equal to the total number of specimens counted. For example, in the wadable stream surveys, some sites were surveyed multiple times. We combined the counts across surveys and adjusted the trial size accordingly to account for the increased sampling effort. The Poisson and Negative Binomial models, on the other hand, do not contain a built-in mechanism to account for varying sampling effort. Therefore, we included an offset term in the model equal to the sampling effort so that the predicted abundance of a taxon was equal to the expected count per unit of sampling effort. For example, the macroinvertebrate pitfall samples in forested wetlands produced unbounded counts (suitable for Poisson and Negative Binomial error models), but the number of effective pitfalls varied among sites due to varying degrees of flooding during the sampling period. We included the number of unflooded pitfalls at a site as an offset in the model.

Step 3: Statistical calibration

The third step involved the procedure known as statistical calibration (Jongman et al. 1995). Calibration involves using the estimated parameters (a, b, and c) from the regression in step 2 and the observed value of the dependent variable (y_i), and estimating the value of the independent variable (x_i) -- essentially, regression in reverse. Specifically, we used the fitted models from step 2 to predict the log-likelihood of different values of the stressor metric at each site based on the abundance of taxa. The result is a log-likelihood curve that indicates the relative probability of the stressor metric being any particular value given the observed abundance of the taxon at a particular site. We generated log-likelihood curves for each site from the 8-16 different statistical models and then averaged them based on the AIC weights to make a single log-likelihood curve for each site and taxon.

As a second safegaurd against model overfitting, we performed steps 2 and 3 on 20 cross-validation groups; in each group a different 5% of the sites was omitted and thus withheld from the model fitting process in step 2. In step 3, the stressor metric value of each site was then predicted for each taxon based on the models from which the site was omitted. In this manner, no site was simultaneously used for both model fitting (in step 2) and model prediction (in step 3). Note, while we used the 20-fold cross-validation procedure to build and evaluate IBI performance, the final IBI for field application was constructed using the full dataset (i.e., without cross-validation).

Step 4: Taxa selection

The fourth step involved selecting the group of taxa that produce the most accurate predictions. Specifically, we added together the log-likelihood curves of individual taxa from step 3 to make a prediction for the site based on multiple taxa; the value of the stressor metric with the maximum log-likelihood was the predicted metric value for the site. We compared the performance of two different procedures for selecting taxa before selecting a preferred method.

Method 1.--In this method, we used a *stepwise* procedure to select the taxa, starting with the taxon that, by itself, produced the most accurate stressor metric (cross-validated) prediction based on the coefficient of concordance (Lin 1989, 2000) and then incrementally added the taxon that increased the concordance correlation coefficient of the (cross-validated) prediction the most; i.e. the conditional improvement in concordance. The concordance coefficient measures the agreement between the observed value of the stressor metric and our predicted value; a perfect concordance correlation of one occurs when the points fall on a perfect diagonal line with an intercept of zero and slope of one. Note, while the final IBI for field application was constructed using the full dataset (i.e., without cross-validation) for model fitting and calibration, the taxa were always selected based on the cross-validation procedure to avoid the erroneous selection of taxa overfit to the dataset. Unless otherwise noted, we report the cross-validated coefficient of concordance.

One of the challenges we faced was determining when to stop in the forward stepwise taxon selection process. As a third hedge against model overfitting and as a means of determining how many taxa to retain in the final IBI, we tested the significance of each taxon's fit against pseudotaxa, as follows. We created 1,000 pseudotaxa by permuting the data from the original taxa. For each pseudotaxa, we performed the same model fitting (step 2) and calibration (step 3) as the real taxas. Then during taxon selection (step 4), we compared each selected taxon's improvement in fit (i.e., concordance correlation) to the improvement in fit garnered by each of the 1,000 pseudotaxa 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 in the stepwise process up until the first taxon that didn't produce a significant increase in prediction accuracy, where significance was evaluated at both the 0.05 and 0.1 alpha levels. Lastly, for comparative purposes, we also continued the stepwise selection process until the maximum concordance was realized.

Method 2.--In this method, we used the *marginal* significance of each taxon based on the comparison to the 1,000 pseudotaxa, as described above. Specifically, for each taxon we computed the (cross-validated) coefficient of concordance and compared it to the distribution of concordances of the pseudotaxa (i.e., the distribution of expected concordances by chance alone). We computed a *p*-value for each taxon by determining the proportion of the pseudotaxa distribution of concordances greater than or equal to the observed concordance for each taxon. We included all (marginally) significant taxa in the IBI, where significance was evaluated at both the 0.05 and 0.1 alpha levels. Note, in this method we simply included all taxa with significant marginal concordances; whereas in the previous method we included taxa in a stepwise process based on their conditional improvement in concordance.

A major challenge faced with either taxa selection method is determining which taxa to include in the pool available for selection. Because we fit models to many different taxa (e.g., vascular plants and macroinvertebrates) depending on the ecological system, and at multiple taxonomic levels, we had many options. While our approach is amenable to the selection of any available taxa at any taxonomic level, for practical reasons we opted to create a limited set of IBIs as follows. First, we created separate IBIs for select combinations of stressor metrics and major taxonomic groups in each ecological system (**Tables 1-2**), for a total of 132 different IBIs. Within each major taxonomic group, we selected from taxa at all taxonomic levels from Species to Phylum. Thus, an individual Species was available for selection as a unique Species and as member of its Genus, Family, Order and Phylum, and it was possible for all five taxa to be selected in the final IBI. In addition, for macroinvertebrates, we created separate IBIs for each unique sampling method (**Table 2**), but then also created an overall macroinvertebreate IBI by selecting taxa from all available methods. Second, we created a mechanism for combining any combination of the previous individual taxa IBIs into composite multi-taxa IBIs for the corresponding stressor metrics and ecological system. In other words, based on the preferred taxa selection method (see results), we first built IBIs for each taxonomic group and stressor metric for each ecological system. Then, we combined the selected taxa from each taxonomic group into a composite, multi-taxa IBI for each stressor metric and ecological system. To illustrate this capacity, we created a composite IBI for the Index of Ecological Integrity (IEI) metric in forested wetlands by adding together the log-likelihood curves of the individual taxa that comprised the corresponding IBIs derived from vascular plants, bryophytes, epiphytic macrolichens, diatoms and macroinvertebrates to make a prediction for the site; the value of the stressor metric with the maximum log-likelihood was the predicted metric value for the site. Note, this is not the same as conducting a stepwise selection of taxa across taxonomic groups, which is an alternative but computationally more expensive process given the number of combinations of taxonomic groups, stressor metrics and ecological systems. However, for comparative purposes, we also conducted a full stepwise selection of taxa across all taxonomic groups to create an IBI for the IEI metric in forested wetlands.

Step 5: Randomization testing

The fifth step and a final hedge against model overfitting involved repeating steps 1-4 on randomly shuffled data to compute the concordance correlation coefficient expected by chance alone. Specifically, we randomly shuffled the value of the stressor metric among sites and repeated the entire modeling process to the point of calculating the concordance correlation, and did this 10 times to generate a permutation distribution of concordance correlations under the null hypothesis of no real relationship between the biota and the stressor metric. We interpreted a difference between the orginal concordance and the range of permuted concordances as evidence of real predictive ability of the IBI. Ultimately, we dropped all IBIs with observed concordances below the predicted maximum for randomly shuffled data.

Step 6: Pseudo-validation

Lastly, one of the insurmountable challanges facing the development of any IBI is the problem of circularity in the specification of both a stressor metric and one or more biotic metrics, leading to the inability to validate the IBI. Briefly, to develop an IBI we must first create a stressor metric so as to determine which species are sensitive to that measure of stress. But how can we create a stressor metric unless we already know that species are in fact sensitive to it, since if species are not sensitive to the metric we can hardly call it a stressor? In other words, a stressor metric is a pre-requisite to the development of an IBI, but an IBI is pre-requisite to the development of a biologically relevant stressor metric. This dilemma confronts all IBIs and is heretofore been given little attention in the IBI literature. A consequence of this dilemma is that it is not possible to truly validate any IBI, and our IBI approach is no exception. Indeed, our IBIs are constructed to maximally predict our constructed stressor metrics. Consequently, a strong concordance between our IBI and our stressor metric simply means that the biotic community exhibits structure in relation to the metric; it does not validate the IBI or the stressor metric. Given this dilema, we are forced to assume that our stressor metrics, as quantified, do in fact represent ecologically important stressor gradients, and to assess the merit of our stressor metrics, we are constrained to compare them to other independent published biotic metrics or IBIs, despite the circularity inherent in each of them. Our hope is that consensus among many independent biotic metrics and/or IBIs provides some assurance that our IBIs and stressor metrics are meaningful.

In an effort to pseudo-validate our IBIs and stressor metrics, we compared them to a variety of independently-derived, published biotic descriptors or metrics (hereafter referred to as "p-metrics") that are currently in use by a variety of state agencies (including Massachusetts) to assess the condition of rivers and streams. These p-metrics are typically combined to form multimetric IBIs, but the procedures for doing so involve explicit comparison between reference and stressed sites which is not consistent with our continuous perspective on the stressor-response relationship. Thus, we used the raw p-metrics themselves as the basis for comparison to our IBIs and stressor metrics. Specifically, we used data on aquatic macroinvertebrates from the wadable streams surveys to calculate 31 p-metrics (**Appendix C**). Recall that some sites were surveyed more than once. For our purposes, we calculated the p-metric for each survey separately and then averaged the scores for each site. In all cases, when numbers of taxa were part of a p-metric, we calculated for each survey the minimum number of distinct taxa guaranteed to be present based on the macroinvertebrates identified in that survey. Given that individuals were identified to different taxonomic levels, we counted every taxa present in a survey as long as there were no other taxa identified in the survey within the same taxonomic group. For example, if a survey at a site contained Hydropsychidae (Family) and *Hydropsyche morose* (a Species within the same Family) then Hydropsychidae was not included in the taxa count for that site because that Family was already represented in that survey.

We used two statistical methods to evaluate how the p-metrics related to each other and our IBIs and stressor metrics. First, we calculated simple (Pearson's product-moment) pairwise correlations among the p-metrics and our stressor metrics. For our IBIs, we calculated the correlation with each of the p-metrics. For each p-metric, we calculated the mean absolute correlation with each of the other p-metrics, the correlation with our IEI stressor metric, and the maximum correlation with any of our individual stressor metrics. Second, given the high correlations among the p-metrics, we conducted a principal components analysis (PCA) on the p-metrics and generated an ordination plot based on the first two principal component axes to show how the p-metrics related to each other and our stressor metrics.

3. Results

3.1 Taxonomic summary

The number of taxa within the major taxonomic groups in each ecological system varied widely (**Table 2**). The high taxonomic diversity in forested wetlands (842 taxa) was dominated by vascular plants (379 taxa), followed by macroinvertebrates (161 taxa), diatoms (157 taxa), bryophytes (113 taxa) and epiphytic lichens (32 taxa). Taxonomic diversity in salt marshes was much less overall (137 taxa) and was richer in macroinvertebrates (106 taxa) than vascular plants (31 taxa). Taxonomic diversity in wadable streams was intermediate (321 taxa), but it was comprised entirely of macroinvertebrates, making it exceptionally diverse in that taxonomic group.

3.2 Regression (model fitting)

All of the alternative statistical models (8-16 variations, depending on taxa) received some AIC model weight for at least some taxa and, in general, were very consistent in the fitted relationships, suggesting that the results were somewhat robust to the choice of statistical model. Nevertheless, the models receiving the greatest weights varied considerably among taxa, suggesting the importance of considering a wide range of alternative models. For example, in forested wetlands the relationship between Urticales (Order of vascular plants) abundance and IEI was best described by the constrained quadratic exponential function with beta-binomial errors (cg.3p.bb), representing 58% of the model weight, followed equally by the constrained quadratic exponential function with zero-inflated binomial errors (cg.3p.ze) and the logistic function with zero-inflated binomial errors (lg.3p.ze), each representing an additional 21% of the model weight (**Fig. 2a**). All three models indicated higher abundance at lower values of IEI (i.e., sites with low ecological integrity). In contrast, the relationship between *Trientalis borealis* (starflower) abundance and IEI was best described by the constrained quadratic exponential function with binomial errors (cg.3p.bi) and Poisson errors (cg.3p.po), representing 33% and 21% of the model weight, respectively, followed equally by the constrained quadratic exponential function with zero-inflated beta-binomial errors (cg.3p.zb) and the logistic function with zero-inflated beta-binomial erros (lg.3p.zb), each representing an additional 12% of the model weight (**Fig. 2b**). All nine models receiving some weight indicated higher abundance of the taxon at higher values of IEI. Overall, most taxa had at least three different models receiving some weight, and in many cases most of the model variants received at least some weight.

3.3 Calibration and taxon selection

Based on the fitted regression models, we were able to compute the log-likelihood of any value of each stressor metric based on the abundance of each taxon using the statistical calibration procedure. To illustrate this approach, we generated log-likelihood curves for a range of abundances for each vascular plant taxon for the IEI metric in forested wetlands. For example, for the Urticales taxon the log-likelhood curve increased with increasing IEI when abundance was 0; i.e., if Urticales was absent from a site there was an increasing log-likelihood of an increasing value of IEI, resulting in a maximum likelihood estimate of 1.0 for IEI (**Fig. 3a**). Conversely, the presence of Urticales on a site indicated that IEI was likely to be low, and the greater the abundance the more likely it was that the plot had a lower IEI value. If the abundance was 1, the maximum likelihood estimate of IEI was approximately 0.4; however, as abundance increased the maximum likelihood of IEI went to 0. Note, in this case, the difference in log-likelihoods between any particular values of IEI was ≤2.5, so the strength of evidence in favor of any single value of IEI was relatively weak. In contrast, the absence of Trientalis borealis suggested a relatively low value of IEI (although the strength of evidence was weak), and as abundance increased there was an increasingly strong suggestion of a relatively high value of IEI, peaking at 1.0 (**Fig. 3b**). In this case, the difference in log-likelihoods between any particular values of IEI was quite large, so the strength of evidence in favor of any single value of IEI was relatively strong.

Ultimately, we combined the log-likelihood calibration curves from several taxa (see below) to make a maximum likelihood prediction of the stressor metric value at each site. For example, based on the observed abundances of 44 different vascular plant species at site 771_T053, we added up the log-likelihood curves to produce an overall log-likelihood curve for the site (**Fig. 4a**). In this case, the maximum likelihood prediction of IEI (0.57) was very close to the observed value of IEI (0.55). Similarly, the maximum likelihood prediction of IEI at site M162-A010 was relatively close to the observed value (1.0 versus 0.88, respectively)(**Fig. 4b**). Across all sites we used the coefficient of concordance between the observed and predicted values of the stressor metric as a measure of IBI performance. A high concordance indicated that we were able to effectively predict the value of the stressor metric based on the taxa abundance data. For example, the maximum concordance for vascular plants and IEI was 0.79 (**Fig. 5**).

Not surprisingly, IBI performance, as judged by the (cross-validated) coefficient of concordance, varied depending on the method of taxa selection. In general, selection of taxa based on their conditional significance (in forward stepwise selection) performed better than selecting taxa based on their marginal significance. For example, the vascular plant IBI for the IEI metric in forested wetlands achieved a concordance of approximately 0.62 when it included all taxa that had a marginal significance (based on comparison to pseudotaxa) of either 0.05 or 0.1 (**Table 3**). The concordance increased to 0.76 and 0.79 based on the forward stepwise procedure that incrementally added taxa based on their conditional significance (i.e., the improvement in concordance compared to the expected improvement based on chance alone) at an alpha of 0.05 and 0.1, respectively. Note, in this case the maximum concordance possible from the stepwise procedure (0.79) was the same as stopping selection of taxa at an alpha of 0.1. We anticipated that the stepwise procedure for taxa selection would outperform the marginal selection process in terms of absolute concordance because of overfitting, and thus we speculated that the increased concordance with the stepwise procedure might actually be spurious. Consequently, we compared the observed concordances to the expected distribution of concordances from each method applied to randomized data, and interpreted the difference between observed concordance and the maximum concordance from randomized data as a more robust measure of IBI performance. In general, the increase in absolute concordance from the stepwise procedure more than offset the expected increase in concordance due to chance alone (**Table 3**), and thus we concluded that the stepwise procedure based on an alpha cutoff of 0.1 was the "best" method for generating the IBIs. Moreover, across the various IBIs, we determined that the maximum concordance to be expected by chance alone (i.e., from randomized data) was roughly 0.5, although it was generally much less. Therefore, we conservatively concluded that any IBI with an observed concordance of <0.5 was potentially spurious or too weak to be considered meaningful.

The complete stepwise process of taxa selection for the vascular plants IBI for the IEI metric in forested wetlands is shown in **figure 6a** and reveals three important points. First, concordance increased as taxa were added to the IBI, reached a peak, and then declined as more and more taxa were added to the IBI. The decrease in concordance beyond a threshold number of taxa (i.e., at maximum concordance) illustrates that adding uninformative species is detrimental to the prediction and that adding more and more species leads to overfitting. In particular, as more and more species are added to the IBI, it would seem intuitive that it should perform better and better, but in fact it becomes too well fit to the training data and as a result performs increasingly poorly when applied to the hold-out cross-validation data. Second, concordance increased rapidly at first as more species were added to the IBI, but then slowed until the maximum concordance was reached. The "shoulder" of this curve reveals the ideal number of taxa that achieves both high concordance and parsimony in the number of taxa in the IBI (**Fig. 6b**). While there are undoubtedly other methods of identifying the shoulder, we found that stopping the selection process at a conditional alpha of 0.1 achieved the goal of high concordance, parsimony in the number of taxa, and at least a partial guarantee that the final concordance was not spurious. Lastly, the final IBI for vascular plants and the IEI metric contained 25 Species, 11 Genera, 5 Families and 3 Orders, indicating the importance of considering taxa at multiple taxonomic levels.

The performance of each IBI varied markedly across taxonomic groups, stressor metrics and ecological systems (see **Appendix D** for the complete set of results). For example, concordance for the IEI metric in forested wetlands varied across major taxonomic groups from 0.57 (epiphytic macrolichens) to 0.79 (vascular plants), indicating that some taxonomic groups were better indicators of this composite stressor gradient than others (**Table 4**). However, some of the improvement in performance was explainable by increased taxonomic richness; specifically, the greater the taxonomic richness, the more likely it was to find a better performing combination of taxa (**Fig. 7**). Similarly, concordance for a single taxonomic group varied across stressor metrics within an ecological system and indicated varying sensitivity to different stressor gradients. For example, concordance for the vascular plant IBIs in forested wetlands varied across stressor metrics from 0.53 (Microclimate alterations) to 0.79 (IEI)(**Table 5**).

3.4 Multi-taxa IBIs

The multi-taxa IBI we constructed for forested wetlands based on merging the separate taxonomic group IBIs into a single composite IBI had a (cross-validated) concordance of 0.81, which was only marginally improved over the single best taxonomic group IBI concordance of 0.79 for vascular plants (**Table 4**). However, the improvement over chance was considerably greater for the multi-taxa IBI (0.71 versus 0.48), indicating that it was stastically more robust. Not surprisingly, the multi-taxa IBI based on the full stepwise selection of taxa across all taxonomic groups produced a much higher concordance (0.89; **Table 4**), but it came at the cost of a much higher expected concordance by chance alone (0.23 difference between observed and maximum random concordance), making it much less statistically reliable than the merged multi-taxa IBI. Consequently, for the final IBIs for field application, we opted to use the merge procedure for combining the separate taxonomic group IBIs into composite multi-taxa IBIs. Results of the multi-taxa IBIs for all stressor metrics based on both the merge procedure and the full stepwise procedure are included in **Appendix D**.

3.5 Pseudo-validation

All but one of the IBIs we created for macroinvertebrates in wadable streams had relatively high correlation with at least some of the published biotic metrics (p-metrics), and 15 of the 31 p-metrics had correlations >0.5 with one or more of our IBIs (**Table 6**). The three p-metrics that were most correlated to our IBIs, on average, were the Average Tolerance Value, EPT Taxa Richness, and % Sensitive Individuals. The watershed habitat loss IBI and the Average Tolerance Value metric had a correlation of 0.83, the highest correlation between any of our IBIs and the p-metrics.

The mean absolute correlation between our IEI stressor metric and the p-metrics was 0.35, although it ranged as high as 0.63, and was comparable to the mean absolute correlation among p-metrics of 0.37 (**Table 7**). The p-metrics that were most strongly correlated with IEI (>0.50) were % Sensitive Individuals, EPT Taxa Richness, Average Tolerance Value, Beck's Index, Ephemeroptera taxa richness, % Sensitive EPT Individuals, non-Chironomidae and Oligochaeta taxa richness, and Hilsenhoff's Biotic Index. P-metrics with high correlation to IEI also tended to have high average correlations with the other p-metrics, and p-metrics with low correlations to IEI also tended to have low correlations with other p-metrics. The strongest correlations between p-metrics and our stressor metrics were with IEI and Watershed Imperviousness; 25 of 31 p-metrics had their strongest correlation with our Watershed Imperviousness metric.

The first two axes of the PCA explained 41 and 16% of the variation (collectively 57%); the remaining axes each explained less than 9% of the variation. With few exceptions, p-metrics that indicate high habitat quality fell out positively on the first PCA axis and were correlated strongly with our two connectedness metrics and the IEI metric, while the p-metrics that indicate degraded habitat had negative scores on the first axis and were correlated with rest of our stressor metrics (**Fig. 8**). The two p-metrics that weighed most heavily on the negative end of the second axis (n.diptera and pct.chiromidae) both indicate poor-quality habitat while the three that scored highest on this axis all indicate good habitat quality (ept.chiro.stand, ept.chiro.ratio, and ept.chiro.abun.stand), and all five of these biotic metrics use Chironomidae as part of their calculation. However, there were other p-metrics not based on Chironomidae (n.gc, n.taxa, and pct.ept.abund) that were weakly associated with this axis. The two stressor metrics most strongly associated with the second axes were Aquatic Connectedness and Watershed Dam Intensity; both of these metrics reflect the disruption of aquatic connectivity.

4. Discussion

4.1 IBI performance

Of the 164 separate IBIs we created for single taxonomic groups (and sampling methods) across stressor metrics and ecological systems (**Appendix D**), 57 were deemed statistically and ecologically reliable based on having a (cross-validated) coefficient of concordance ≥0.5. This finding is somewhat remarkable given the inherently noisy relationships between taxa abundances and measured landscape-level stressor gradients based on GIS data. Moreover, we suspect that larger sample sizes in coastal salt marshes and forested wetlands would have allowed us to create many additional reliable IBIs. Of particular interest was the performance of the IBIs based on the composite Index of Ecological Integrity (IEI) across taxonomic groups and ecological systems. Due to its integrative nature, this multi-metric stressor index is being used by state and federal agencies and other conservation organizations in a wide variety of applications ranging from land aquistion prioritization to environmental impact assessment (UMassCAPS 2013), and thus it is useful to know how well it also performs as the basis for an IBI. The IBIs based on IEI had (cross-validated) coefficients of concordance that ranged from 0.4 for vascular plants in salt marshes to 0.79 for vascular plants in forested wetlands (**Appendix D**). In forested wetlands, IEI was the single best metric (or second best for bryophytes) among the 15 evaluated for all five major taxonomic groups, with coefficients of concordance ranging from 0.57 to 0.79. In salt marshes, IEI was the first or second best metric for the two major taxonomic groups sampled (macroinvertebrates and vascular plants, respectively), but with coefficients of concordance ≤0.53. And in wadable streams, IEI was the third best metric for the one taxonomic group sampled (macroinvertebrates), but with a relatively high coefficient of concordance of 0.78.

The IBIs we created for wadable stream macroinvertebrates performed exceptionally well. Only one of the nine IBIs we created was deemed unreliable (Watershed Dam Intensity), with a (cross-validated) coefficient of concordance of 0.42; the remaining eight IBIs had coefficients of concordance ranging from 0.59 to as high as 0.84 (Watershed Imperviousness). The strong performance of these IBIs was not too surprising given the plethora of published IBIs for stream macroinvetebrates and our relatively large sample size (n=490) and taxonomic richness (294 taxa), but it nonetheless provided strong confirmation of our methodology for creating IBIs. In addition, it was the one opportunity we had to pseudo-validate our IBIs. As noted previously, it is not possible to truly validate any IBI. However, we were able to pseudo-validate our IBIs for macroinvertebrates in wadable streams by comparing them to 31 independently developed and published biotic metrics (**Appendix C**). Overall, the published biotic metrics corroborated the validity of our stressor metrics and the IBIs we derived from them. This was evident in both the correlations in **Tables 6** and **7** and the alignment of the stressor metrics with the first principal component in the PCA (**Fig. 8**). The one stressor metric that did not align strongly with the first principal component was Watershed Dam Intensity (damint); however, it was skewed by a few extreme values; sites in which small watersheds contain relatively large dams. The weighting of each biotic metric on the first principal component almost perfectly indicates whether the metric is an indicator of good or bad habitat quality, and suggests that the first principal component is reflecting habitat quality. That our IEI and individual stressor metrics also weighed strongly on this principal component is a good indication that our metrics correspond with habitat quality as measured by the suite of independently-derived biotic metrics.

The IBIs we created for forested wetlands also performed quite well, with (cross-validated) coefficients of concordance across stressor metrics as high as 0.79. Of the 120 IBIs across taxonomic groups (and sampling methods) and stressor metrics in forested wetlands, 48 were deemed reliable with coefficients of concordance ≥0.5. Of particular interest was the finding that the strongest performing taxa across stressor metrics was vascular plants, followed closely by macroinvertebrates and diatoms (**Table 4**). Given the logistical ease of sampling and identifying vascular plants in the field compared to the other taxa, this has major implications for the practical application of bioassements in forested wetlands. The use of IBIs based on vascular plants does require a skilled botonist, but the work can be completed in the field without additional costs associated with laboratory analysis. Diatoms can be easily sampled in the field by minimally trained technicians, but the samples must be sent to a certified lab for identification at additional cost. By comparison, macroinvertebrates are difficult to sample in the field, generally requiring the use of traps and/or collection devices and multiple visits to a site, and also require having specimens identified by highly skilled taxonomists, often at considerable cost.

The IBIs we created for coastal salt marshes did not perform as well as in the other ecological systems; of the 35 IBIs across taxonomic groups (and sampling methods) and stressor metrics, only four were deemed reliable with (cross-validated) coefficient of concordances ≥0.5 (**Appendix D**). The Wetland Buffer Insults metric for macroinvertebrates had the highest concordance at 0.57, followed by the IEI metric, Similarity and Connectedness metrics for macroinvertebrates at 0.53, 0.52 and 0.50, respectively. We suspect that the poor performance was partially due to the relatively low sample sizes, but it may also reflect the complex dynamic nature of tidally influenced systems that make it more difficult to measure anthropogenic stressors.

It is worth noting that in both forested wetlands and salt marshes any single macroinvertebrate sampling method alone did not produce many usable IBIs, but the combined methods did. For example, in forested wetlands the (cross-validated) concordance for the IBI derived for the IEI metric was 0.58 for pitfall traps, 0.45 for emergence traps, and 0.36 for earthworms, but it increased to 0.71 for the combined methods, and this was despite having fewer sites (n=171) and fewer taxa (161, due to fewer sites) to select from in the combined methods than in just the pitfall traps (206 sites and 174 taxa). Among the three macroinvertebrate sampling methods, pitfall traps were considerably more productive in terms of taxonomic richness than both emergence traps and earthworm sampling, and thus not surprisingly it was the only method that by itself produced usable IBIs.

4.2 IBI methodology

In this study, we developed a new and powerful method for constructing and evaluating IBIs and demonstrated its application in three different ecological systems using a wide variety of taxonomic groups and stressor metrics. The most notable advantages of this method are that it is fully empirically-based and that there is no need to designate reference sites or 'minimally' disturbed sites. The empirical basis to our method means that there is no a priori subjectivity or expert opinion required to construct the IBI, which is a common limitation of most other methods. In our method, each taxon is given an equal opportunity to be selected for the IBI and its final selection is based entirely on its statistical performance in the context of the other taxa, not on an a priori hypothesized relationship to the stressor. In addition, most other methods require the designation of reference sites that have been 'minimally' disturbed (Stoddard et al. 2006). However, in contemporary landscapes it is impossible to find true (i.e., pristine) reference sites, and the designation of 'minimally' disturbed requires the specification of an arbitrary threshold of what constitutes 'minimal'. In reality, stressors operate as gradients, whereby sites fall out on a continuum of stressor levels. In our approach, it is not necessary, or even considered meaningful, to group sites into reference versus stressed. Rather, the stressor-biotic response relationship is treated as a continuous function.

A major concern of an empirical approach such as ours is the potential for model overfitting. In particular, given a large enough variety and number of taxa, it is relatively easy to construct a statistical model that performs exceptionally well on the dataset itself, but then fails to provide any real predictive accuracy when applied to new data. Consequently, we took several steps to safeguard against overfitting. First, we filtered the taxonomic data to eliminate taxa that occurred at <10sites, because we deemed they were insufficiently sampled and thus did not have a reliable ecological signal in the dataset. Second, we used a 20-fold cross-validation procedure during the model fitting and calibration phases, and thus the stepwise taxa selection process involved selecting taxa that offered the greatest increase in the cross-validated coefficient of concordance. This helped to ensure that species were selected that offered honest predictive value. Third, to ensure that the selected taxa did not have spurious predictive value, we evaluated each taxon during the stepwise selection process against pseudotaxa (i.e., randomly permuted species data) and stopped the selection process when the conditional improvement in concordance was insignificant (i.e., alpha >0.1). Lastly, as a final hedge against overfitting, we compared the observed coefficient of concordance of the final IBI against the expected range of concordances for randomly permuted data, and retained only IBIs with concordances greater than the maximum concordance expected for randomized data. In combination, we believe that these safeguards ensure that the final IBIs are statistically robust.

In addition to the overfitting safeguards above, our modeling approach has a number of distinctive features that make it an extremely flexible method for developing IBIs. First, we confronted the biological data with up to 16 alternative statistical models to account for model uncertainty. The constrained quadratic exponential and three-parameter logistic functions can fit a wide variety of functional forms that we deemed ecologically plausible, and the suite of error models we used (binomial, bet-binomial, Poisson, negative binomial, and the zero-inflated versions of these) are appropriate for the most common sampling designs used to inventory biota. Of course, the suite of statistical models can easily be expanded to include other forms as appropriate. Our evidence suggests that no one model form is sufficient for handling the variety of ecological relationships to be expected among diverse taxa and stressor gradients. Consequently, we used a model averaging approach based on model AIC weights to accommodate model uncertainty (Burnham and Anderson 2002).

Second, our modeling approach can be extended to include additional independent covariates to account for natural environmental variation among sites. Variation from natural environmental differences or fluctations over time can be a source of greater variation in the biotic community than that due to anthropogenic stress, causing unpredictable index responses (Wilcox et al. 2002). However, we reasoned that natural environmental variation among sites was a source of "noise" in the data rather than being confounded with the anthropogenic stressor gradient, and thus would act primarily to weaken the stressor-response signal but not lead to spurious results. Nevertheless, during preliminary analyses, in addition to the simple regression models containing a single independent variable (i.e., stressor metric), we also fit models with an additional independent covariate representing an ecological settings variable (e.g., spring hydroperiod in forested wetlands, calcium content in wadable streams). However, we later decided to omit these results due to concerns over model overfitting. In particular, given the form of the statistical models, each additional covariate involved estimating a minimum of three additional model parameters. Consequently, our taxon sufficiency filter of being present at ≥10 sites had to be doubled, which dramatically reduced the number of taxa available for constructing the IBIs given our sample sizes. We deemed the loss of taxonomic richness more important than the increase in model complexity. However, the modeling approach lends itself well to the inclusion of such environmental covariates so long as the sample size and species abundance data are sufficient to support it.

Third, our modeling approach can be used to develop IBIs in any ecological system with any single or mixed taxa at any taxonomic level. A strength of our method is its complete flexibility to work with any taxonomic data at any level in any ecological system. Of course, the greater the number and diversity of taxa, the greater the likelihood is of constructing a statistically and ecologically robust IBI (**Fig. 7**). Using our method it is possible to consider the tradeoffs between increased predictive power of the IBI (i.e., greater coefficient of concordance) and increased cost (logistical and financial) associated with sampling and identifying certain taxonomic groups. Another strength of our method is the ability to use abundance data at any taxonomic level. In the IBIs we created, higher taxonomic levels, in particular, Family and Order, were frequently selected for the final IBI. Higher-level taxonomic identification can often be done by minimally trained technicians and thus is generally much less costly than identifying specimens to the Species level.

4.3 IBI application: Continuous Aquatic Life Use standards (CALU)

Several states in the U.S., including Massachusetts, have implemented wetland and aquatic monitoring and assessment programs using a hierarchical approach as recommended by the U.S. Environmental Protection Agency (USEPA 2003 and 2006). This approach incorporates a three-tiered approach for assessing ecosystem condition: Level 1 is a landscape assessment that commonly incorporates GIS-based measures; Level 2 is a site-level assessment that commonly incorporates a rapid field assessment and relies on the use of simple field indicators; and Level 3 is an intensive site-level assessment that incorporates quantitative measures of condition and often relies on the use of IBIs. The broad suite of anthropogenic stressor metrics that we developed and evaluated in this study function as a Level 1 assessment and the IBIs we created function as a Level 3 assessment. We propose to use the stressor metrics and the corresponding IBIs together in a novel manner as described next.

Pursuant to the U.S. Clean Water Act of 1972 (33 U.S.C. 1251 et seq.) the EPA gives States and Territories the primary responsibility for implementing programs to protect and restore water quality, including monitoring and assessing the nation's waters (including wetlands) and reporting on their quality. EPA is encouraging states to describe in their water monitoring strategy their current accomplishments and strategy for wetland monitoring and assessment and to apply that strategy to help achieve the goal of increasing the quality and quantity of the Nation's wetlands. For the purpose of water quality assessment, the Biological Condition Gradient (BCG) concept was developed to provide a conceptual basis for understanding biological condition and developing numeric criteria for aquatic life use (USEPA 2005, Davies and Jackson 2006). The BCG is a comprehensive model that describes the relationship between biological condition and stressors in the surrounding environment along a disturbance gradient. EPA has suggested that states consider designating Tiers corresponding to various levels of biological condition based on the BCG model. This is referred to as the Tiered Aquatic Life Use (TALU) approach. Many IBIs are developed using reference sites and impacted sites but not the full disturbance gradient. Tiers are essentially a means for dealing with uncertainty when IBIs are not developed as dose-dependent relationships between biological condition and stressors. When IBIs are developed to correspond to a continuous stressor gradient (consistent with the BCG concept), as in our study, then it is no longer necessary to have tiered criteria tied to specific classes.

We propose an approach for the assessment of wetland and water quality condition as it pertains to aquatic life use that is consistent with TALU but eliminates the need to develop tiers. We call this approach CALU for Continuous Aquatic Life Use standards. Because both the stressor metrics and the corresponding IBIs yield scores that are continuous throughout their range and on the same scale, it is not necessary to create tiers or classes for wetlands and water bodies in order to have meaningful criteria for aquatic life use. The CALU approach is based on the relationship between the stressor metric (representing the constraints on biological condition due to the nature of the surrounding landscape) and the corresponding IBI, which represents the actual condition of a site based on biological assessments conducted in the field. The CALU relationship is expressed graphically by the concordance between the observed stressor metric and the predicted metric (which is the IBI)(**Fig. 5**). By defining an acceptable range of variability around this relationship it is possible to assess biological condition (a range of acceptable IBI scores) based on a site's particular landscape context (stressor metric score). For example, in **figure 5** we depicted an arbitrary 80-percentile range of variability about the expected IBI value. Specifically, across sites we computed the deviation in the predicted value of the stressor metric, based on the observed biological condition (or y-axis score, which is the IBI score), from the observed value of the stressor metric (x-axis score), which is also the expected value of the IBI (the diagonal line). Next, we computed the 10^{th} and 90^{th} percentiles of these deviations and plotted them as the range of acceptable variation in IBI scores (dotted lines).

The CALU approach provides a rigorous and quantitative system for assessing condition for aquatic life use that avoids the undesirable effect of cutting up a continuous environmental gradient into discrete classes or tiers. A site's biological condition (based on the IBI) relative to its landscape context (based on the stressor metric) can be assessed by noting its position relative to the diagonal on the concordance plot (**Fig. 5**). Sites between the dotted lines (i.e., within the acceptable natural range of variability) would be considered to meet standards. Sites that are above the highest dotted line (90^{th} percentile) would exceed expectations. Those falling below the lowest dotted line (10^{th} percentile) would be flagged as potentially degraded. Improvement at a site over time could be measured by documenting upward movement of a site relative to the solid diagonal line. In addition, sites could be flagged as potentially degraded based on a single IBI, for example sites falling below the 10th percential line in **figure 5**, or sites could be flagged as potentially degraded only if they fall below the 10th percential across say three or more major taxonomic groups. For example, in **figure 5** sites were assigned a point size and gray-scale intensity based on the proportion of major taxonomic group IBIs in which they fell below the acceptable natural range of variation.

The CALU approach also provides a method for identifying high-value sites that could be targeted for increased protection [Note: all sites are targeted for anti-degradation]. For example, sites that have an IEI score between say 0.6 and 1.0 and a corresponding IBI score above the acceptable natural range of variabilty have both a landscape context conducive to the maintenance of high ecological integrity and a current condition that is exemplary. The designation of "exemplary" could be assigned to sites based solely on the IBI score associated with the composite IEI metric for a single taxonomic group, as in **figure 5**. Alternatively, the designation could be based on consideration of "exemplary" scores across major taxonomic groups. For example, sites could be deemed exemplary if, and only if, they have scores above the acceptable natural range of variability for at least three of the major taxonomic groups. Certain standards could apply to these high-valued sites, such as no discharge or increased buffer zone protection. This standard would be applicable to maintaining and improving the designated use of “Fish, Other Aquatic Life and Wildlife.”

Lastly, the CALU approach also provides a mechanism for evaluating mitigation success. There is a critical need to establish measures of success for mitigation areas (i.e. replacement or restoration) and to provide monitoring and follow up to ensure success. For example, where either on-site or off-site wetland replication or restoration is proposed, an evaluation of the landscape context (e.g., IEI score) for the mitigation site could be used to establish a target for aquatic life use (IBI score) after a reasonable number of years. Annual or bi-annual monitoring of replicated or restored wetlands using the appropriate IBIs could be used to track progress toward meeting the CALU target -- an IBI score within the acceptable natural range of variation for the site's stressor metric score. In addition, where a permit is issued for work in or near a site under an assumption of no adverse impacts (e.g., groundwater withdrawal permits), monitoring using the appropriate IBIs could be used to determine whether those activities actually result in degradation of the biological integrity of the site -- moving the IBI score below the acceptable natural range of variation for the site's stressor metric score.

5. Conclusions

We developed and demonstrated a method for developing IBIs that does not rely on expert opinion or hypothesized relationships between anthropogenic stressors and biotic condition, but rather derives the stressor-response relationship empirically from the patterns in the data. In this regard, this method is unbiased and objective and makes the maximum use of the data collected to establish the stressor-response relationship. Moreover, our method does not rely on the designation of reference sites, which invariably requires a subjective and often arbitrary determination of what constitutes a reference condition. Instead, our method treats the stressor gradient as continuous and ranging from the least stressed to most stressed conditions within the landscape extent under consideration. Despite these strengths, our method is not without practical limitations. Many state agencies interested in developing IBIs do not possess the statistical modeling expertise required to implement our approach. In addition, our method requires relatively large sample sizes in order to derive IBIs that are ecologically and statistically robust. Moreover, given the empirical basis of the approach, it requires the collection of biological samples for the particular landscape extent intended for the IBI application; it is unclear whether IBIs developed in one landscape can be extrapolated to another, but it seems unlikely. Lastly, while this method was shown to be effective in our study landscape of Massachusetts, it requires replication in other landscapes to confirm its general utility.

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Table 1. Ecological integrity models for three focal ecological systems. Metrics measure the level of anthropogenic stressor to each site and are arbitrarily grouped into broad classes for organizational purposes. See **Appendix A** for a description of each metric. The Index of Ecological Integrity (IEI) for each ecological system is a weighted combination of stressor metrics selected and weighted by expert teams. Weights shown here are the percent contribution of each metric to each community (rounded to the nearest whole percent), thus columns sum to 100. The asterisk next to a weight indicates that we developed an IBI for this particular metric and ecological system.

		Ecological System		
Metric group	Metric name	Forested wetland	Salt marsh	Wadable stream
development & roads	habitat loss	9*	12*	10*
	(watershed) habitat loss	4*	0	9*
	wetland buffer insults	4*	6*	0
	road traffic	9*	5	5
	mowing & plowing	4	3	5
	microclimate alterations	4*	0	5
pollution	(watershed) road salt	4*	0	0
	(watershed) road sediment	4*	0	5*
	(watershed) nutrient enrichment	4*	0	5*
biotic alterations	domestic predators	0	5	0
	edge predators	4*	5	5
	non-native invasive plants	9*	0	0
	non-native invasive earthworms	4*	0	0
hydrological alterations	(watershed) imperviousness	0	0	10*
	(watershed) dam intensity	0	0	7*
coastal alterations	salt marsh ditching	0	15*	0
	tidal restrictions	0	18*	0
resiliency	connectedness	17*	18*	7*
	aquatic connectedness	2*	0	22*

similarity	9*	14*	0

Table 2. Number of sites (N) and number of taxa sampled by ecological system and taxonomic group between 1984-2011 in Massachustts (**Fig.** 1) for the purpose of developing Indices of Biotic Integrity (IBIs). Note, the number of taxa include the number of separate taxa across taxonomic levels from Species to Phylum that were considered in the development of the IBI.

	Ecological System					
	Forested wetland		Salt marsh		Wadable streams	
Taxonomic group	N	Taxa	N	Taxa	N	Taxa
vascular plants	214	379	130	38	--	--
bryophytes	211	113	--	--	--	--
epiphytic macrolichens	214	32	--	--	--	--
diatoms	205	157	--	--	--	--
macroinvertebrates	171	161	123	107	490	294
emergence traps	179	36	--	--	--	--
pitfall traps	206	174	--	--	--	--
earthworms	214	6	--	--	--	--
quadrats	--	--	130	37	--	--
D-net sweeps	--	--	127	42	--	--
auger	--	--	126	29	--	--
kick nets	--	--	--	--	490	294
total	219	842	130	137	490	294

Table 3. Comparison of the observed (cross-validated) coefficient of concordance (i.e., the correlation between observed and predicted stressor metric) and the minimum, mean and maximum concordances for 10 random runs, as well as the difference between the observed concordance and the maximum random concordance, for the vascular plant Index of Biotic Integrity (IBI) based on the Index of Ecological Integrity (IEI) stressor metric for forested wetlands in Massachustts. Richness is the number of taxa in the final IBI; taxa were selected using five methods: 1) forward stepwise selection until the maximum concordance (step(max)), 2) forward stepwise selection until a conditional alpha≥0.1 (step(0.1), 3) forward stepwise selection until a conditional alpha≥0.05 (step(0.05), 4) selecting all taxa with a marginal alpha≤0.1 (margin(0.1), and 5) selecting all taxa with a marginal alpha≤0.05 (margin(0.05).

			Random runs			
Method	Richness	Observed concordance	Min	Mean	Max	Difference
step(max)	76	0.79	0.28	0.39	0.48	0.32
step(0.1)	44	0.79	0.06	0.21	0.31	0.48
step(0.05)	17	0.76	0.13	0.32	0.47	0.29
margin(0.1)	240	0.62	0.13	0.18	0.23	0.39
margin(0.05)	219	0.63	0.00	0.16	0.23	0.40

Table 4. Comparison of the observed (cross-validated) coefficient of concordance (i.e., the correlation between observed and predicted stressor metric) and the minimum, mean and maximum concordances for 10 random runs, as well as the difference between the observed concordance and the maximum random concordance, for the Indices of Biotic Integrity (IBIs) for the major taxonomic groups separately and combined based on the Index of Ecological Integrity (IEI) stressor metric for forested wetlands in Massachustts. Richness is the number of taxa in the final IBI; taxa were selected based on forward stepwise selection until a conditional alpha >0.1. The "All taxa - merged" represents an IBI constructed by merging the separate taxonomic group IBIs into a single composite IBI; the "All taxa - stepwise" represents an IBI constructed by forward stepwise selection of taxa across all taxonomic groups until a conditional alpha>0.1.

			Random runs			
Taxonmic group	Richness	Observed concordance	Min	Mean	Max	Difference
vascular plants	44	0.79	0.06	0.21	0.31	0.48
macroinvertebrates	46	0.71	0.15	0.31	0.51	0.21
diatoms	17	0.68	0.21	0.29	0.36	0.32
bryophytes	11	0.61	0.19	0.24	0.33	0.28
epiphytic macrolichens	4	0.57	0.08	0.16	0.30	0.27
all taxa - merged	122	0.81	0.00	0.01	0.10	0.71
all taxa - stepwise	80	0.89	0.36	0.53	0.66	0.23

Table 5. Comparison of the observed (cross-validated) coefficient of concordance (i.e., the correlation between observed and predicted stressor metric) and the minimum, mean and maximum concordances for 10 random runs, as well as the difference between the observed concordance and the maximum random concordance, for the Indices of Biotic Integrity (IBIs) for vascular plants based on 15 different stressor metrics (see **Appendix A**) for forested wetlands in Massachustts. Richness is the number of taxa in the final IBI; taxa were selected based on forward stepwise selection until a conditional alpha>0.1.

			Random runs			
Stressor metric	Richness	Observed concordance	Min	Mean	Max	Difference
index of ecological integrity (IEI)	44	0.79	0.06	0.21	0.31	0.48
connectedness	36	0.78	0.13	0.23	0.40	0.39
(watershed) nutrient enrichment	56	0.78	0.16	0.26	0.32	0.46
(watershed) habitat loss	38	0.78	0.13	0.23	0.35	0.43
similarity	106	0.77	0.18	0.27	0.37	0.40
non-native invasive earthworms	52	0.75	0.08	0.26	0.36	0.39
(watershed) road sediment	42	0.73	0.19	0.25	0.37	0.36
non-native invasive plants	62	0.73	0.02	0.24	0.40	0.33
edge predators	80	0.70	0.19	0.26	0.38	0.31
habitat loss	42	0.69	0.18	0.30	0.38	0.31
(watershed) road salt	67	0.66	0.22	0.30	0.40	0.26
aquatic connectedness	87	0.66	0.16	0.41	0.61	0.05

road traffic	63	0.66	0.09	0.28	0.35	0.31
wetland buffer insults	93	0.54	0.21	0.32	0.40	0.13
microclimate alterations	73	0.53	0.27	0.40	0.58	-0.05

Table 6. Correlations between Indices of Biotic Integrity (IBIs) derived in this study and 31 published biotic descriptors or metrics used in IBIs (see **Appendix C** for description of published biotic metrics) applied to the Massachusetts wadable stream macroinvertebrate data. Stream macroinvertebrate IBIs from this study were developed for the stressor metrics listed in **Table 1** (and described in **Appendix B**) for wadable streams. The rows are ordered such that higher mean absolute correlations appear first.

	Stream macroinvertbrate IBI (this sudy)								
Published IBI	IEI	Habitat loss	Watershed habitat loss	Watershed road sediment	Watersehd nutrient enrichment	Watershed imperviousness	Watershed dam intensity	Connectedness	Aquatic connectedness
mean.tolval	-0.76	0.77	0.83	0.82	0.73	0.79	-0.07	-0.63	-0.29
ept	0.75	-0.66	-0.78	-0.77	-0.69	-0.74	0.12	0.56	0.56
pct.sensative.abun	0.77	-0.72	-0.68	-0.69	-0.61	-0.62	0.17	0.72	0.29
hilsenhoff.bi	-0.69	0.67	0.76	0.74	0.66	0.71	-0.1	-0.61	-0.23
becks.i	0.75	-0.69	-0.66	-0.66	-0.58	-0.59	0.17	0.73	0.2
pct.sensitive.ept.abun	0.66	-0.62	-0.71	-0.68	-0.62	-0.66	0.15	0.54	0.39
n.no.co	0.65	-0.59	-0.68	-0.68	-0.61	-0.67	0.13	0.53	0.43
ptv.0.to.5.9	0.63	-0.7	-0.74	-0.73	-0.64	-0.71	0.06	0.53	0.19
n.ephemeroptera	0.63	-0.49	-0.68	-0.67	-0.62	-0.65	0.12	0.39	0.66
pct.non.insect	-0.61	0.6	0.64	0.63	0.53	0.57	-0.07	-0.44	-0.37
dom.3.family.abun	-0.6	0.54	0.6	0.59	0.54	0.57	-0.16	-0.53	-0.34
diversity.family	0.58	-0.54	-0.6	-0.59	-0.53	-0.57	0.17	0.51	0.33
pct.ephemeroptera	0.52	-0.43	-0.63	-0.6	-0.56	-0.59	0.1	0.29	0.55
pct.shellfish	-0.56	0.5	0.58	0.56	0.5	0.49	-0.13	-0.41	-0.36
n.taxa	0.52	-0.42	-0.51	-0.52	-0.46	-0.5	0.11	0.4	0.45

n.trichoptera	0.46	-0.46	-0.55	-0.54	-0.46	-0.53	0.09	0.32	0.36
ept.chiro.stand	0.42	-0.44	-0.54	-0.52	-0.49	-0.53	0.09	0.33	0.17
n.scraper	0.35	-0.35	-0.45	-0.44	-0.4	-0.45	0.12	0.25	0.32
ept.chiro.ratio	0.41	-0.4	-0.44	-0.42	-0.39	-0.38	0.16	0.36	0.13
n.gc	0.4	-0.31	-0.37	-0.39	-0.33	-0.36	0.11	0.33	0.35
diversity.order	0.33	-0.35	-0.37	-0.4	-0.33	-0.37	0.11	0.35	0.11
pct.ept.abun	0.26	-0.23	-0.41	-0.34	-0.34	-0.38	0.03	0.15	0.15
dom.3.order.abun	-0.28	0.31	0.3	0.33	0.27	0.29	-0.06	-0.32	-0.03
pct.abun.oligochaeta	-0.28	0.28	0.33	0.33	0.27	0.31	0.06	-0.23	-0.1
pct.chironomidae	-0.15	0.19	0.25	0.24	0.26	0.29	-0.06	-0.16	0.05
n.diptera	0.25	-0.15	-0.19	-0.2	-0.16	-0.18	0.02	0.17	0.32
ept.chiro.abun.stand	0.11	-0.12	-0.27	-0.24	-0.22	-0.28	0.03	0.05	0.05
pct.tanytarsini	-0.11	0.11	0.19	0.16	0.2	0.18	-0.05	-0.11	0.03
shredders	0.19	-0.08	-0.07	-0.08	-0.09	-0.02	0.12	0.16	0.25
scraper.to.filter.collector.ratio	-0.07	0.05	0.1	0.09	0.07	0.05	-0.05	-0.03	-0.08
pct.scraper.abun	-0.01	-0.04	-0.05	-0.07	-0.05	-0.11	0	0	-0.01
column mean absolute value	0.44	0.41	0.48	0.47	0.43	0.46	0.1	0.36	0.26

Table 7. Correlations between 31 published biotic descriptors or metrics (**Appendix** C) and the Index of Ecological Integrity (IEI), among the published biotic metrics, and between published biotic metrics and the best stressor metric from this study (**Appendix B**) applied to the Massachusetts wadable stream macroinvertebrate data. Published biotic metrics are listed in order of their correlation with IEI (higher correlations first).

Published biotic metric	Association[1]	Correlation with IEI	Mean absolute correlation with other published biotic metrics	Best stressor metric[2]	Correlation with best stressor metric[1]
pct.sensative.abun	pos	0.63	0.43	iei.s	0.63
ept	pos	0.61	0.53	imperv	-0.66
becks.i	pos	0.60	0.40	iei.s	0.60
n.ephemeroptera	pos	0.53	0.46	imperv	-0.61
pct.sensitive.ept.abun	pos	0.52	0.48	imperv	-0.60
n.no.co	pos	0.52	0.52	imperv	-0.60
ptv.0.to.5.9	pos	0.49	0.49	imperv	-0.64
diversity.family	pos	0.47	0.49	imperv	-0.54
pct.ephemeroptera	pos	0.45	0.41	imperv	-0.55
n.taxa	pos	0.41	0.41	imperv	-0.46
n.trichoptera	pos	0.38	0.41	imperv	-0.47
ept.chiro.ratio	pos	0.34	0.33	whabloss	-0.36
ept.chiro.stand	pos	0.33	0.43	imperv	-0.47
n.gc	pos	0.33	0.32	imperv	-0.33
n.scraper	pos	0.30	0.33	imperv	-0.42
diversity.order	pos	0.28	0.36	imperv	-0.37
n.diptera	neg	0.20	0.28	iei.s	0.20
shredders	pos	0.16	0.15	iei.s	0.16
pct.ept.abun	pos	0.15	0.33	imperv	-0.27
ept.chiro.abun.stand	pos	0.01	0.32	imperv	-0.16

pct.scraper.abun	pos	0.00	0.14	imperv	-0.08
scraper.to.filter. collector.ratio	pos	-0.06	0.14	habloss	0.09
pct.tanytarsini	pos	-0.07	0.25	imperv	0.14
pct.chironomidae	neg	-0.13	0.33	imperv	0.22
pct.abun.oligochaeta	neg	-0.18	0.20	imperv	0.26
dom.3.order.abun	neg	-0.22	0.30	imperv	0.28
pct.shellfish	neg	-0.44	0.35	imperv	0.50
pct.non.insect	neg	-0.46	0.40	imperv	0.54
dom.3.family.abun	neg	-0.47	0.48	imperv	0.52
hilsenhoff.bi	neg	-0.51	0.50	imperv	0.61
mean.tolval	neg	-0.60	0.51	imperv	0.70
column mean absolute value	NA	0.35	0.37	NA	0.42

[1] Association refers to whether the published biotic metric has a positive (pos) or negative (neg) relationship with the Index of Ecological Integrity (IEI), and thus the converse with anthropogenic stress.

[2] The best metric is the stressor metric from this study with the highest absolute correlation with that published biotic metric.

Figure Captions

Figure 1. Sampling locations (sites) in forested wetlands (n=219), salt marshes (n=130) and wadable freshwater streams (n=490) in Massachusetts used to develop Indices of Biotic Integrity (IBIs).

Figure 2. Relationship between the observed Index of Ecological Integrity (IEI) stressor metric and the abundance of two different vascular plant taxa (a: Urticales; b: *Trientalis borealis*) in forested wetlands in Massachusetts and curves showing the fitted regression models receiving some AIC model weight (see text for details on model specifications).

Figure 3. Statistical calibration plots corresponding to the fitted regressions in **figure 2**, showing the log likelihood of IEI given varying abundances of the taxon; the peak of the curve shows the maximum likelihood estimate of IEI for a site with that taxon abundance. Note, the abundances shown here refer to the count per 100 units of effort; thus, 64 represents a count of 64 out of 100 point intercepts on a plot.

Figure 4. Statistical calibration plots showing the log likelihood of the Index of Ecological Integrity (IEI) stressor metric for sites 771_T053 (a) and M162-A010 (b) based on the observed abundances of 44 different vascular plant species in forested wetlands in Massachusetts. The log likelikhood curves for individual taxa are stacked on top of each other roughly in order of the increasing strength of evidence confered by each taxon. The vertical dashed line shows the observed value of IEI and the vertical solid line shows the maximum likelihood prediction of IEI, which occurs at the highest point on the cumulative log likelihood cuves.

Figure 5. Concordance plot showing the relationship between the observed Index of Ecological Integrity (IEI) stressor metric and the maximum likelihood prediction of IEI based on the abundances of 44 vascular plant taxa for 214 sites in forested wetlands in Massachusetts. Note, the predicted IEI is the Index of Biotic Integrity (IBI) for vascular plants and the IEI stressor metric. The solid diagonal line is the expected value for perfect concordance (i.e., coefficient of concordance=1); the dotted diagonal lines represent the 10^{th}-90^{th} percentile range of variation, which we deemed the acceptable natural range of variability in IBI score for any particular value of IEI. The point size and gray-scale intensity represents the proportion of the individual taxonomic group IBIs (vascular plants, diatoms, macroinvertebrate, bryophytes, and epiphytic macrolichens) in which a site fell below the acceptable natural range of variability in IBI score; hence, larger and darker points represent sites that had consistently "degraded" biotic condition estimates across taxonomic groups.

Figure 6. Stepwise selection of taxa for the vascular plant Index of Biotic Integrity (IBI) for the Index of Ecological Integrity (IEI) stressor metric in forested wetlands in Massachusetts. X-axis represents the steps in the sequential addition of taxa; left-side y-axis represents the coefficient of concordance between the observed IEI metric and the predicted IEI metric (which is the IBI); right-side y-axis represents the conditional alpha level (or *p*-value) for a test of the observed increase in concordance against the expected increase by chance based on randomized taxonomic abundance data (i.e., pseudotaxa) and corresponds to the red line points and line. Blue horizontal lines depict the alpha=0.05 and 0.1 significance thresholds; blue vertical lines depict the corresponding number of taxa selected using that threshold. Sub-figure a depicts the complete stepwise process involving all

379 taxa; sub-figure b depicts the stepwise process for the first 52 steps and shows the taxon selected at each step.

Figure 7. Relationship between number of taxa available for selection during the creation of an Index of Biotic Integrity (IBI) and the coefficient of concordance of the final IBI based on 156 separate IBIs created for five major taxonomic groups (and sampling methods) across 17 stressor metrics and three ecological systems (see **Tables 1-2**). Coefficient of concordance is a measure of IBI performance and represents the (cross-validated) concordance between the observed stressor metric and the predicted stressor metric based on the biotic data selected for the IBI; taxa were selected based on forward stepwise selection until a conditional alpha>0.1. The solid line is the fitted line from a simple linear regression.

Figure 8. First two axes of a principal components analysis showing how sites (black dots) relate to each other in an ordination space derived from 31 published biotic metrics applied to macroinvertebrate data collected at 490 wadable streams sites in Massachusetts. The red text indicates the orientation of the published biotic metrics in this space. Blue text and arrows show how our stressor metrics vary across the sites. The two most important things to interpret with each element in the graph are: 1) the orientation relative to the origin: similar orientation of graphical items suggests positive correlation; directly opposing orientation suggests negative correlation; orthogonal orientation suggests no correlation; and 2) the distance of each graphical item from the center: further from the origin indicates stronger relationships. The (+) and (-) after each biotic metric indicate whether that metric is expected to increase or decrease with habitat quality. The fact that most biotic metrics on the right have pluses and most on the left have minuses suggests that the first principal component axis is oriented with habitat quality.

Figure 1

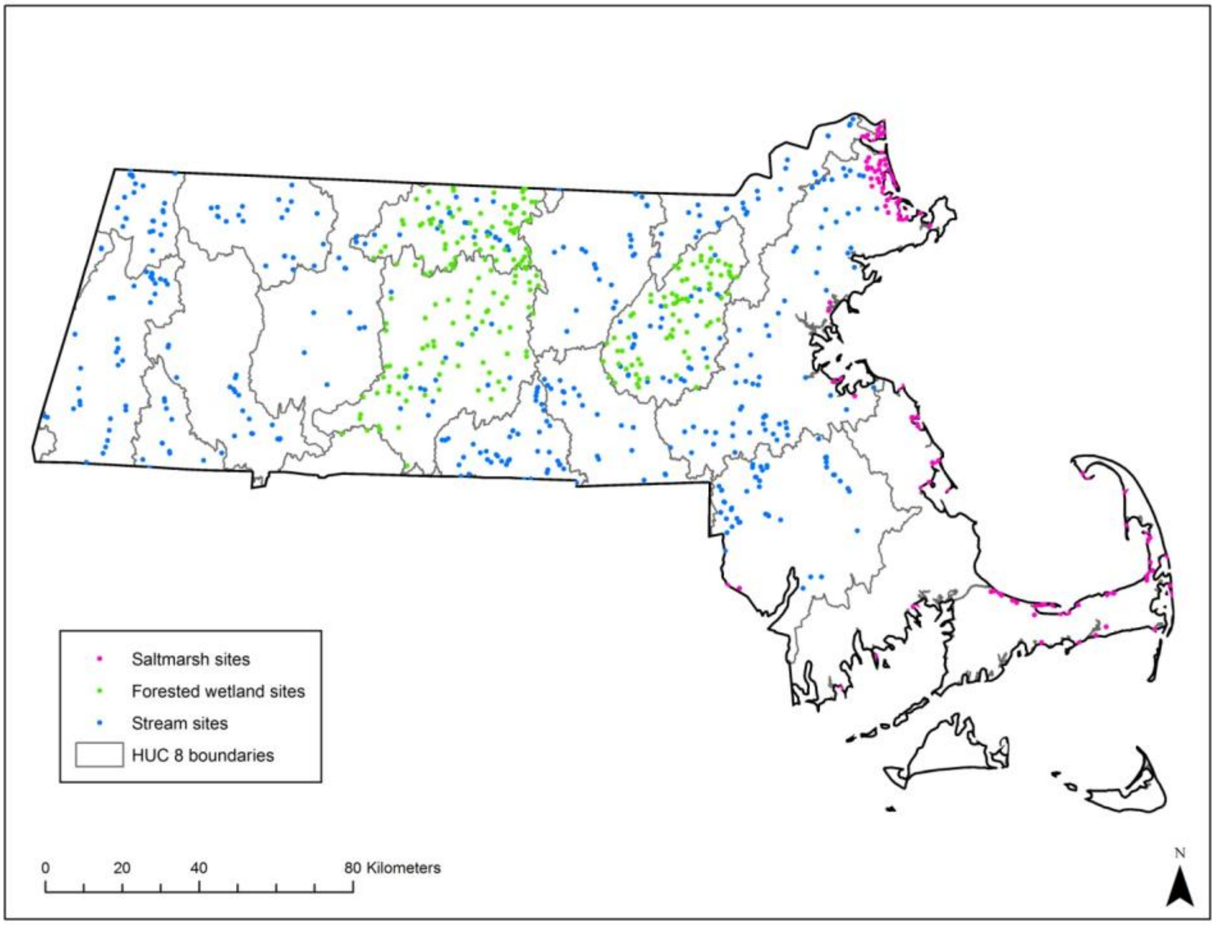

Saltmarsh sites
Forested wetland sites
Stream sites
HUC 8 boundaries
0
20
40
80 Kilometers
N

Figure 2

Figure 2a

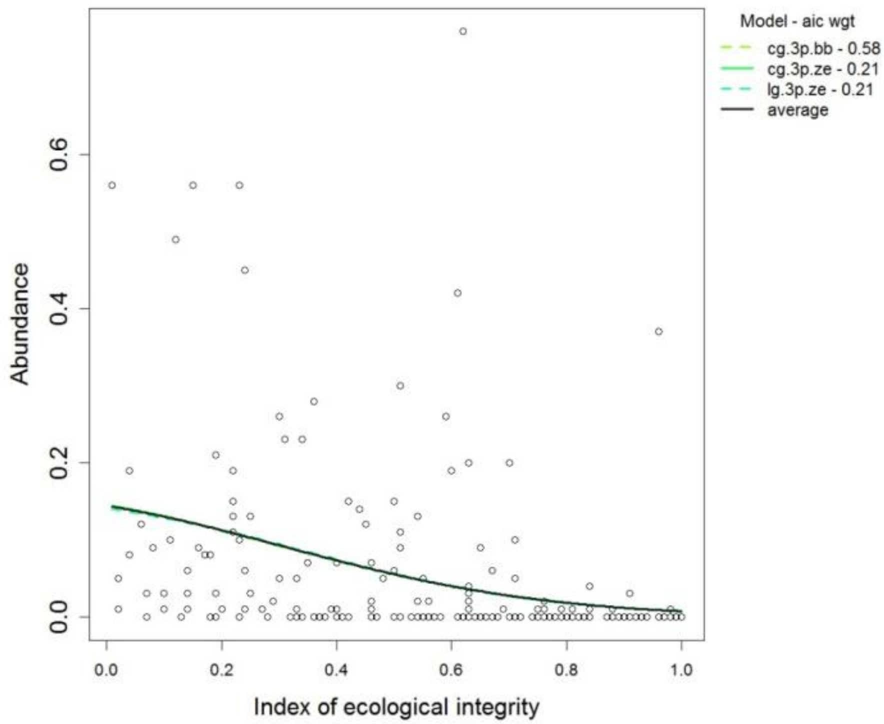


Figure 2b

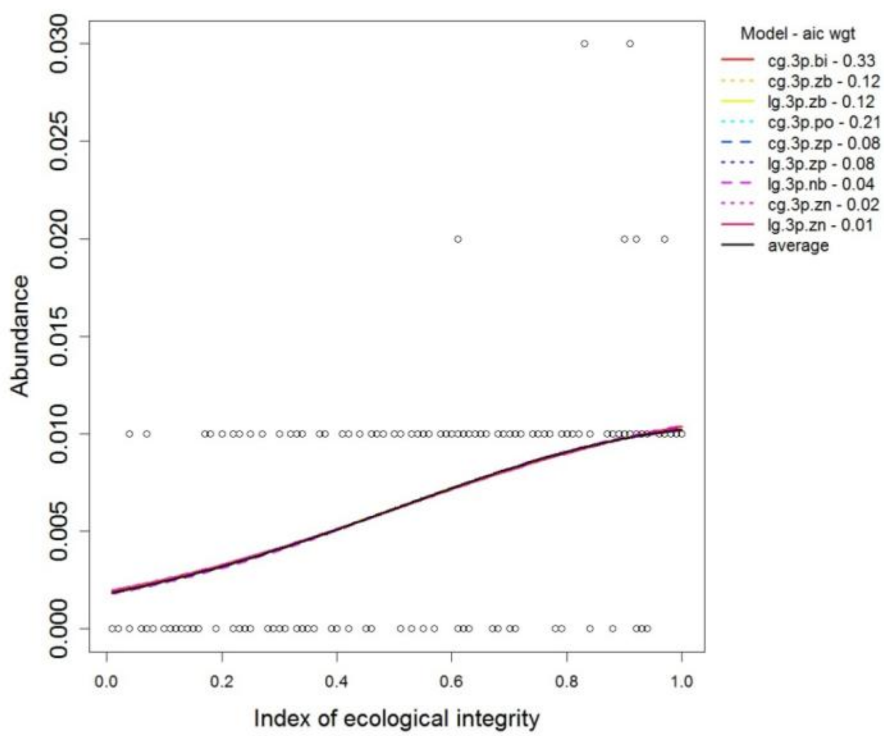


Figure 3

Figure 3a

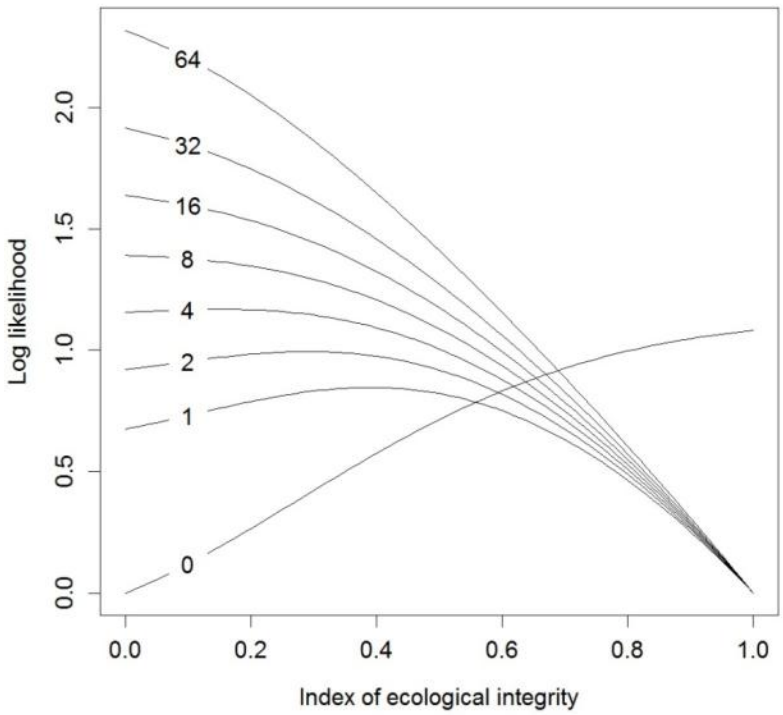


Figure 3b

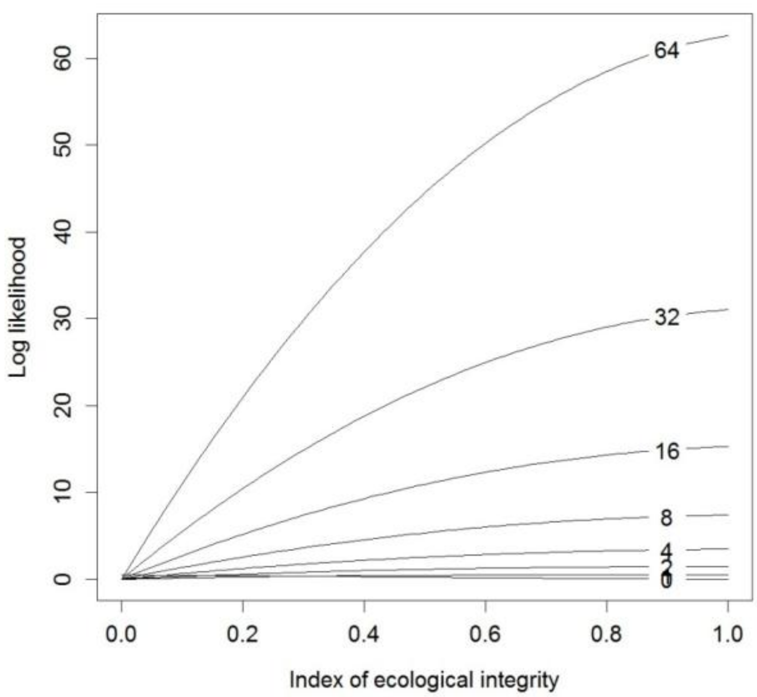


Figure 4

Figure 4a

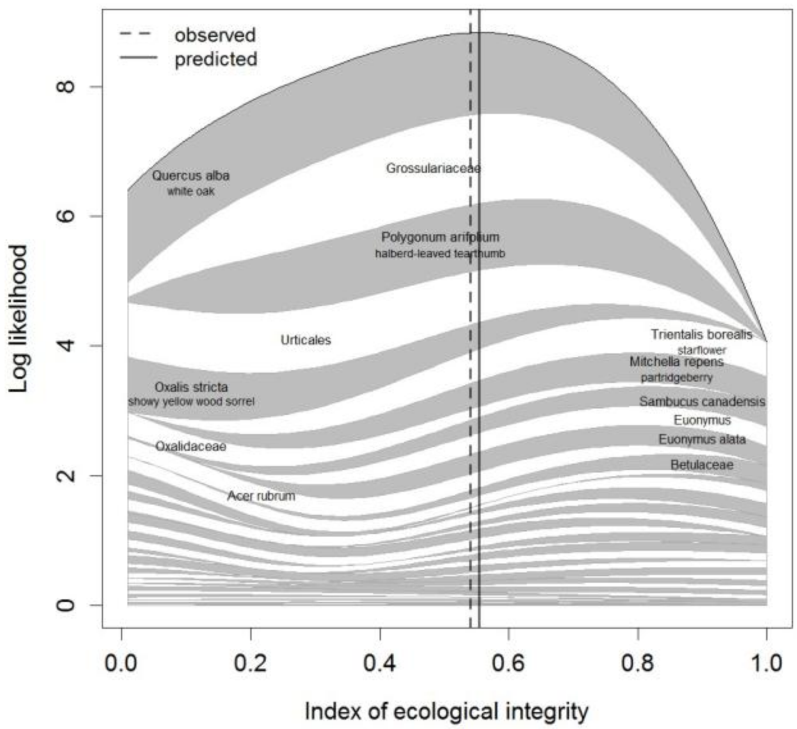


Figure 4b

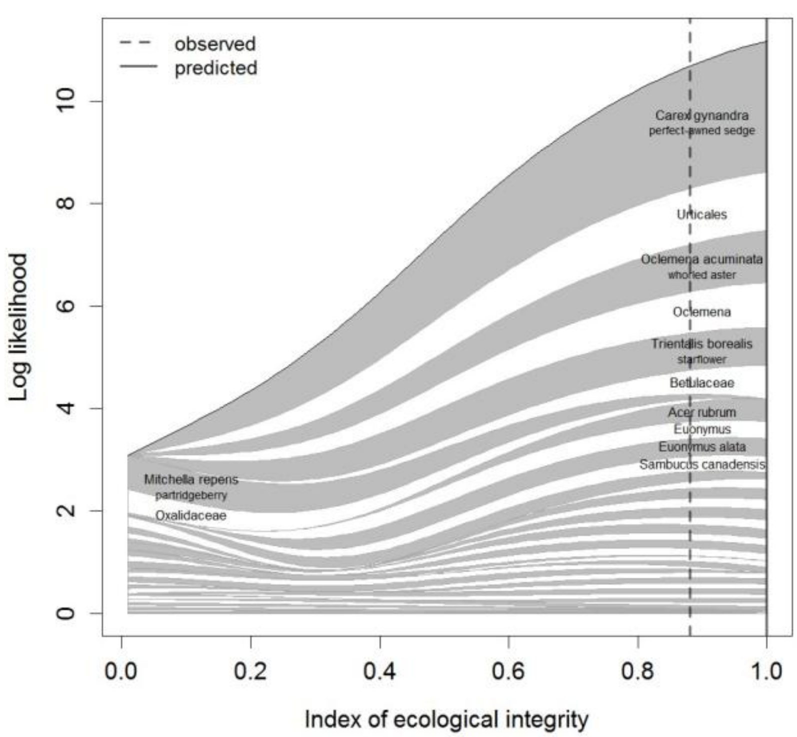


Figure 5

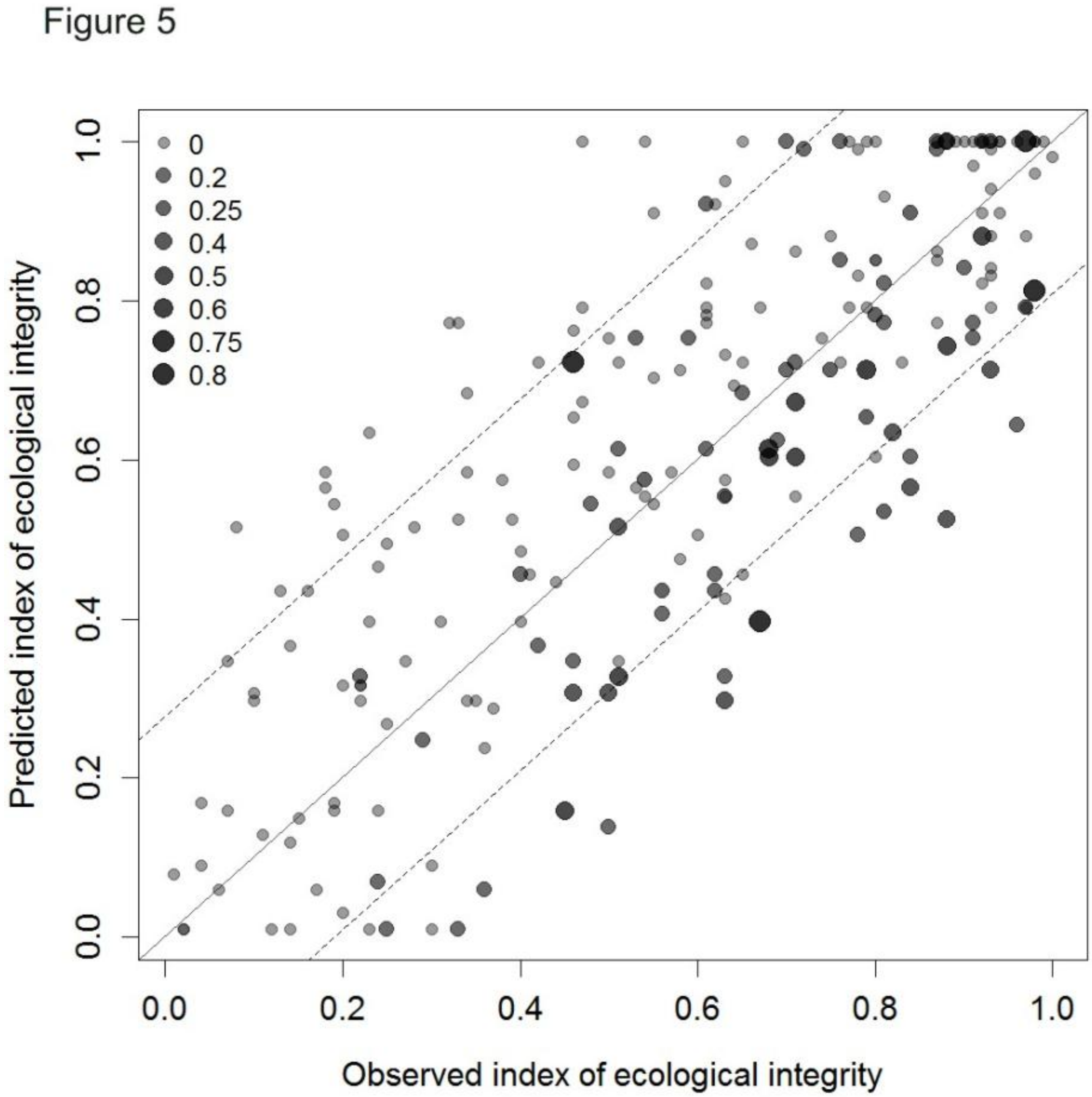


Figure 5
0
0.2
0.25
0.4
0.5
0.6
0.75
0.8
Predicted index of ecological integrity
0.0
0.2
0.4
0.6
0.8
1.0
Observed index of ecological integrity

Figure 6

Figure 6a

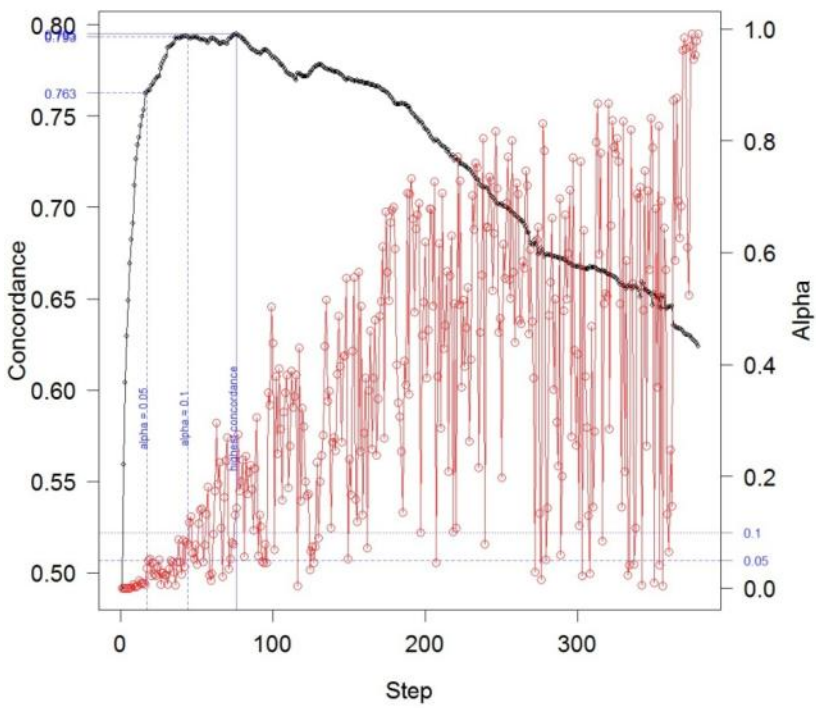


Figure 6b

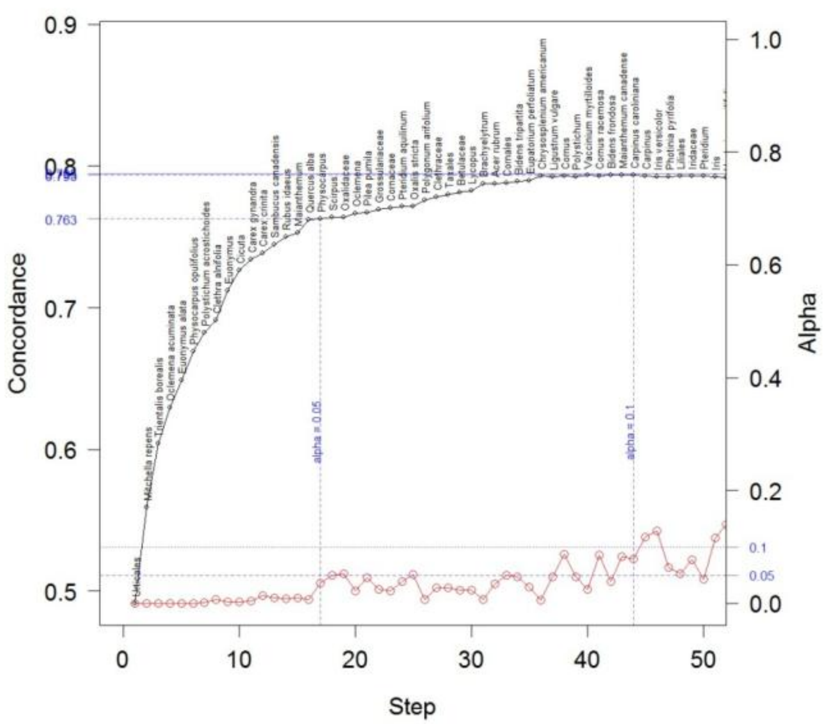


Figure 7

Figure 7

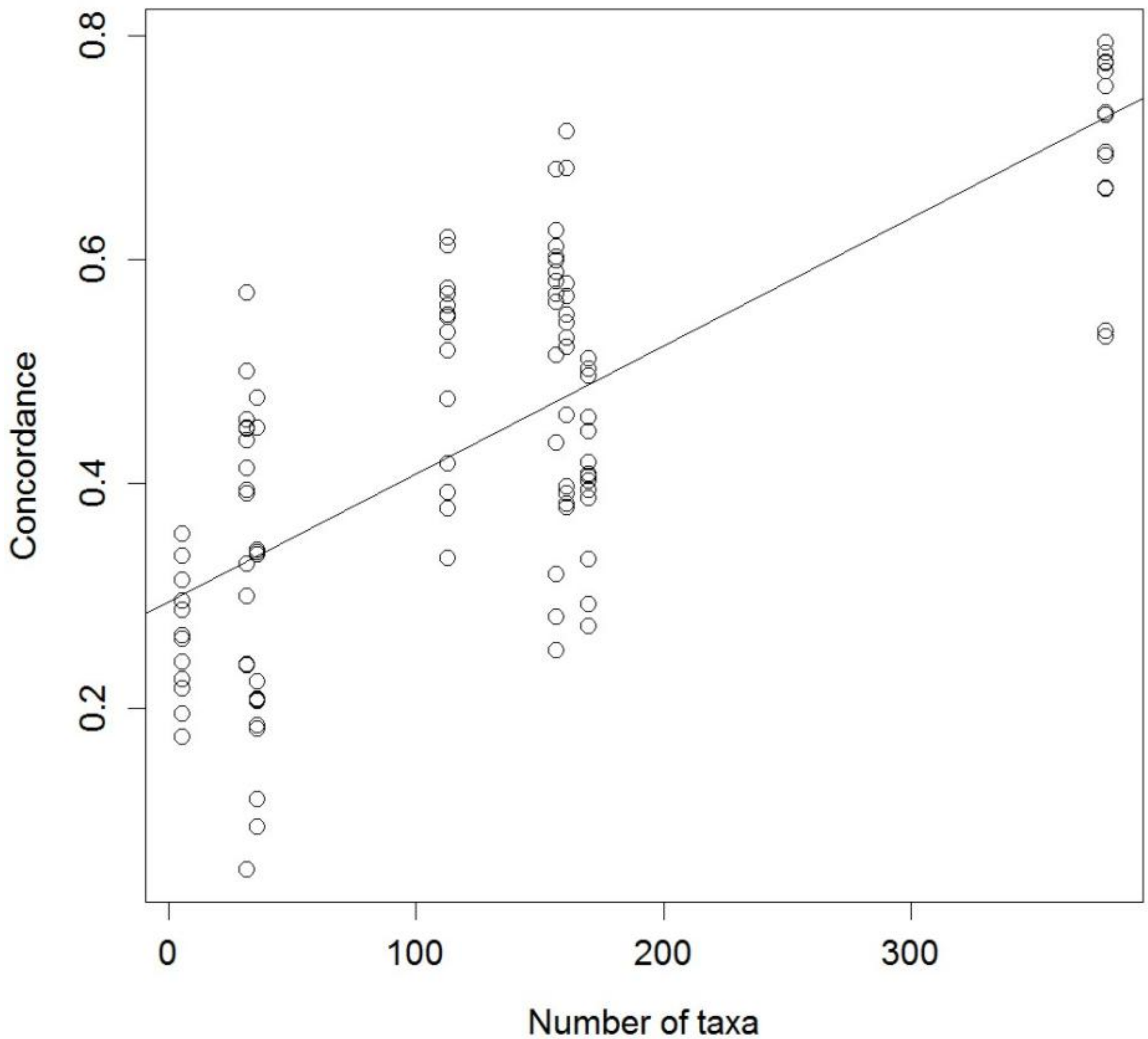
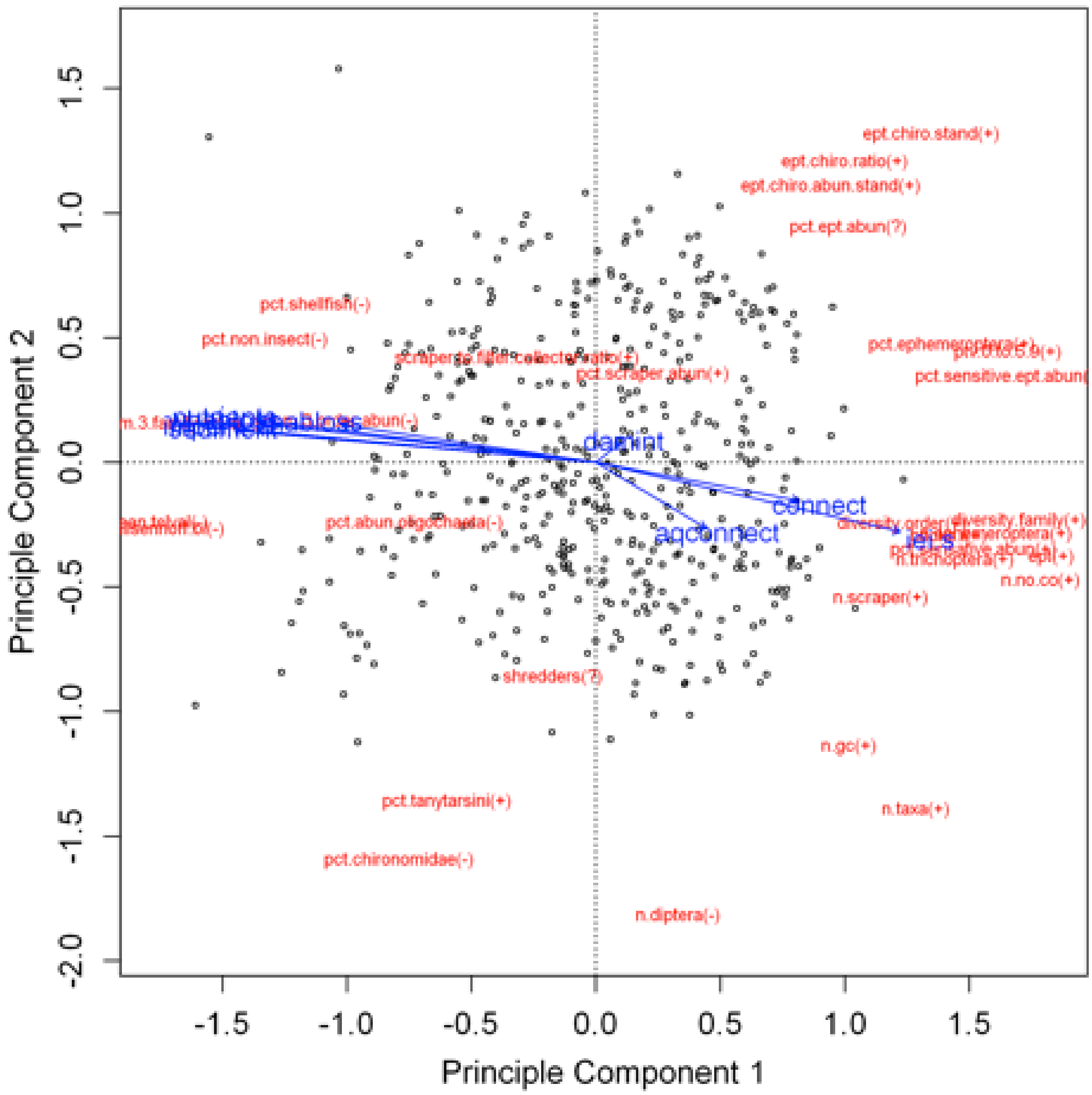


Figure 8



Principle Component 1
Principle Component 2
ept.chiro.stand(+)
ept.chiro.ratio(+)
ept.chiro.abun.stand(+)
pct.ept.abun(?)
pct.shellfish(-)
pct.non.insect(-)
pct.ephemeroptera(+)
pct.sensitive.ept.abun
pct.scraper.abun(+)
damint
connect
aqconnect
n.scraper(+)
n.no.co(+)
pct.abun.oligochaeta(-)
shredders(?)
n.gc(+)
pct.tanytarsini(+)
n.taxa(+)
pct.chironomidae(-)
n.diptera(-)

APPENDICES

This appendix includes supplemental material and is divided into five separate sections, labelled Appendix A-E, and includes detailed information on the field collection of biotic data in each of the three sampled ecological systems (Appendix A), a brief description of the anthropogenic stressor metrics used in this study (Appendix B), a brief description of 31 independently-derived, published biotic descriptors (or p-metrics) applied to the wadable freshwater stream macroinvertebrate data and used to pseudovalidate our corresponding Indices of Biotic Integrity (IBIs)(Appendix C), and complete listing of the performance of 156 IBIs we developed for five major major taxonomic groups (and sampling methods) across 17 different stressor metrics and three ecological systems (Appendix D), and a complete listing of the selected taxa in each of 57 IBIs deemed statistically and ecologically reliable that we developed for five major taxonomic groups (and sampling methods) across 17 stressor metrics and three ecological systems (Appendix E).

Appendix A. Biotic data collection methods.

We collected or compiled biotic data in three ecological systems: 1) forested wetlands, 2) coastal salt marshes, and 3) wadable freshwater streams, using different methods at varying numbers of sites. Detailed descriptions of the standard operating procedures are on file with the Massachusetts Department of Environmental Protection (MassDEP); we include only a brief description here. All biota were either identified in the field by trained experts or preserved in the field for subsequent identification in credentialed laboratories.

2.1.1. Forested wetlands

We sampled 219 forested wetland locations distributed across the Chicopee River watershed (n=73) in 2008 and the Millers River (n=72) and Concord River (n=74) watersheds, Massachusetts, in 2009. We identified all potential deciduous and mixed deciduous-conferous forested wetlands, excluding major river floodplain forests and locations near 3rd-order streams or larger and vernal pools, using the MassDEP Wetlands Mapping data (1:12,000 based on photography from 1993 and 1999). Next, we selected a stratified random sample of locations (hereafter referred to as 'sites') based on the amount of mapped impervious surface in the 100-foot buffer zone around each disjunct wetland and the composite IEI. Our goal was to obtain a representative sample of deciduous/coniferous forested wetlands that have the hydrogeomorphic classification of a 'slope' or 'flat' across a broad range of stressor levels, regognizing that it was not possible to stratify samples across each of the stressor gradients given logistical constraints on the number of sites that could be sampled. Sites were separated by at least 500 m.

We sampled vascular plants, bryophytes, epiphytic macrolichens, diatoms, and macroinvertebrates at varying numbers of sites between May 11 and September 30 within a 30-m radius plot (**Fig. A1**), as follows:

Vascular plants.--We sampled vascular plants along four 25-m long transects in the intercardinal directions from plot center using a point intercept method. We tallied each plant species that intercepted a vertical projection from forest floor to canopy every 1m along each transect (for a total of 100 points). Given uncertainty in the stochastic process describing this sampling process, we treated the tally for each taxa as both a binomial response with a trial size of 100 and as an unbounded Poisson response in the statistical models described below. Following transect sampling, we also conducted a 20-minute time-constrained survey of the entire plot and listed taxa not encountered on transects; for purposes of statistical modeling, we assigned these taxa a tally of one.

Bryophytes.--We sampled ground-dwelling mosses and liverworts in four 0.5 m-square quadrats located in representative areas along the vascular plant sampling transects. We estimated percent cover for each bryophyte species in each quadrat using the following cover classes: 0.1=<1%, 1=1-5%, 2=6-25%, 3=26-50%, 4=50-75%, 5=>75%. Given uncertainty in the stochastic process describing this sampling process and for consistency with the treatment of the other discrete response variables, we converted these percent cover estimates to an equivalent tally (based on the mid-point of each class) for each taxa and treated it as both a binomial response with a trial size of 100 and as an unbounded Poisson response in the statistical models described below. Following quadrat sampling, we also conducted a 20-minute time-constrained survey of the entire plot and listed taxa not encounted in the quadrats; for purposes of statistical modeling, we assigned these taxa a talley of one.

Epiphytic macrolichens.--We sampled epiphytic macrolichens on a sample of trees within the plot. From plot center, we used a 10- or 15-factor prism to select trees. For each tree ≥10 cm diameter at breast height (dbh), we recorded the tree species and dbh and identified and estimated percent cover for each lichen species on the trunk between ground and 2m in height using the following cover classes: 0.1=<1%, 1=1-5%, 2=6-25%, 3=26-50%, 4=50-75%, 5=>75%. For statistical modeling, we computed the surface area sampled on each tree (based on dbh) and then, based on the mid-point of each cover class, we computed the weighted average percent cover of each lichen species across trees. Finally, we converted these average percent cover estimates to an equivalent tally and then, similar to above, treated the tally for each taxa as both a binomial response with a trial size of 100 and as an unbounded Poisson response.

Diatoms.--We sampled diatoms in June before water draw down occurred at four locations closest to the midpoint of the cardinal transects. At each location, we collected samples, each 50 ml, from three microhabitats: 1) benthic leaf litter (by scraping algae from the surface of red maple leaves (or, secondarily, other deciduous leaves of similar size), 2) benthic surface sediments using a turkey baster, and 3) surface water, for a total of 12 samples per site. However, due to financial constraints we were unable to analyze the surface sediment and surface water samples. For purposes of this study, we composited the four benthic leaf litter samples into a single sample and identified to species a random sample of a maximum count of 600 valves per sample. We dropped sites with a total count of <100, which we deemed to be insufficiently sampled and then, similar to above, treated the tally for each taxa both as a binomial response with a trial size equal to the total count across taxa and as an unbounded Poisson response.

Macroinvertebrates.--We sampled macroinvertebrates using four different methods. First, targeting emerging aquatic insects, at four locations closest to the midpoint of the cardinal transects, we set emergence traps on the water surface, or on the surface of the soil in the wettest depressions in the absence of surface water, and kept them open for seven days in June. Emergence traps consisted of an inverted 107-cm long tomato cage with a 36-cm diameter attached to an inflated bicycle inner tube for floatation and encased in fiberglass screening with a collection jar at the top containing an ethanol solution. Second, targeting epigeal macroinvertebrates, we placed eight pitfall traps, two on each cardinal transect at approximately 10 and 15 m, in areas where the chance of flooding by surface water was reduced and kept them open for seven days during July-August. Pitfall traps consisted of 16 oz cups placed in the ground flush with the ground surface, filled with ~150 ml of a 50:50 propylene glycol/water solution and a drop of dishwashing soap, including a small vertebrate excluder, and overtopped with roof to prevent filling by rain. After seven days of sampling, if the pitfall trap was >half full of water we discarded it from the analyses. Lastly, we sampled earthworms using a combination of liquid extraction and midden counts. For middens, indicative of nightcrawlers (*Lumbricus terrestris*), we counted the number of middens in four 1-m^2 quadrats located 15 m from plot center along the cardinal transects. For liquid extraction, we placed an 28-cm diameter sampling frame on the soil surface in a single representative location, poured 3.8 litters of liquid mustard solution into the framed area over a period of three minutes, and collected all worms as they surfaced over a period of 10 minutes.

For purposes of this study, we composited the emergence trap samples into a single sample and the pitfall traps into a single sample and treated the taxa tallies from the composited samples separately in the analyses described below; earthworm counts and midden counts were treated separately in the analyses as well. We treated the overall tally for each taxa as an (unbounded)

Poisson response in the statistical models described below; we accounted for the occasional unequal sampling effort among sites (e.g., number of effective pitfall traps) by including an offset in the model equal to the sampling effort.

2.1.2. Coastal salt marshes

We sampled 130 coastal salt marsh locations in Massachusetts between 2009-2011. Briefly, we identified all potential salt marshes using the MassDEP Wetlands Mapping data (1:12,000 based on photography from 1993 and 1999). Next, we selected a stratified random sample of open water/low marsh/high marsh (i.e., inner marsh) sites based on a suite of stressor metrics. We excluded locations >200 m of a tidal creek or inaccessible due to physical or legal barriers. Our goal was to obtain a representative sample of inner salt marshes containing the bank of a tidal creek, bay or salt pond suitable for auger and D-net macroinvertebrate sampling (e.g., <2 m channel width; <1 m bank height) across a broad range of stressor levels, regognizing that it was not possible to stratify samples across each of the stressor gradients given logistical constraints on the number of sites that could be sampled. Sites were separated by at least 500 m.

We sampled vascular plants and macroinvertebrates between mid-July and the end of September within a 50x100 m plot (**Fig. A2**), as follows:

Vascular plants.--We sampled vascular plants along three 50-m long transects perpendicular to the tidal creek at 0, 50, and 100 m along the creek using a point intercept method. We tallied each plant species that intercepted a vertical projection from the ground to the canopy every 5 m along each transect (for a total of 33 points). We treated the tally for each taxa as both a binomial response with a trial size of 33 and an unbounded Poisson response in the statistical models described below.

Macroinvertebrates.--We sampled macroinvertebrates along the 100-m long transect parallel to the tidal creek using three different methods. First, targeting macroinvertebrates on the upper edge of the tidal creek bank, we sampled in 0.5-m square quadrats at two representative locations (~25 and ~75 m) along the transect. We identified and counted all insects to the Order level and other individuals to the Family leevel, except for barnacles which were usually too numerous to count and were instead recorded to three abundance classes. Second, targeting macroinvertebrates in the marsh creek, we used a D-frame dip net to sample at two locations (~15-21 and ~75-81 m) along the transect and aimed to collect samples from different habitat types, such as banks and vegetated margins, different substrate types, woody debris and floating alga mats, where possible. At each location we made a single dip net sweep for 6 m at the edge of the creek bank, including sweeps of vegetation, but avoiding the surface of the creek bank itself. Third, targeting benthic macroinvertebrates, we used a 6.25-cm diameter auger at two locations (~15 and 85 m) along the transect. All benthic samples were rinsed through a 0.5 mm sieve on site prior to identification or storage. For purposes of this study, we composited the samples from each method separately and treated the overall tally for each taxa from each method as an (unbounded) Poisson response in the statistical models described below; we included an offset in the model equal to the sampling effort (e.g., , number of auger samples, even though it did not vary among sites).

2.1.3. Wadable freshwater streams

We used data from the Masschusetts Benthic Macroinvertebrate database collected during 589 surveys at 490 wadable freshwater stream locations in Massachusetts between 1983-2007.

Macroinvertebrates were sampled along a 100-m long representative reach at each location away from road-stream crossings and tributaries. A composite sample was taken from individual sampling spots in the riffles and runs representing different velocities for a minimum of 2-m^2 composited area using a 1-m kick net. We limited ourselves to sites sampled with the Rapid Bioassessment Protocols (RBP) kicknet method, which were aimed at single-habitat stream reaches, in particular riffles or runs, typically with a cobble substrate, distributed across 1^{st}-5^{th} order streams. We 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. These sites were not selected a priori with regards to any of the stressor gradients we measured, but the large number and broad geographic distribution of sites we used for this study ensured adequate representation of the measured stressor gradients. Note, we accommodated multiple surveys (i.e., in different years) at the same sites by including effort level as an offset in the statistical models below.

Figure Captions

Figure A1. Sample plot layout for collecting biotic data to develop Indices of Biotic Integrity (IBIs) in for forested wetlands in Massachusetts. The four cardinal transects were sampled roughly 15 m from plot center for diatoms and macroinvertebrates. The four intercardinal transects were were sampled at 1-m increments between 5-30 m from plot center for vascular plants and roughly 15 m from plot center for bryophytes.

Figure A2. Sample plot layout for collecting biotic data to develop Indices of Biotic Integrity (IBIs) for salt marshes in Massachusetts. Transect A was a baseline transect from which Transects 1, 2, and 3 were run perpendicular at 0, 50 and 100 m to collect vascular plant data. Transect A was run along the bank of a prominent water feature such as a tidal creek, bay, or salt pond, and was used to sample macroinvertebrates.

Figure A1

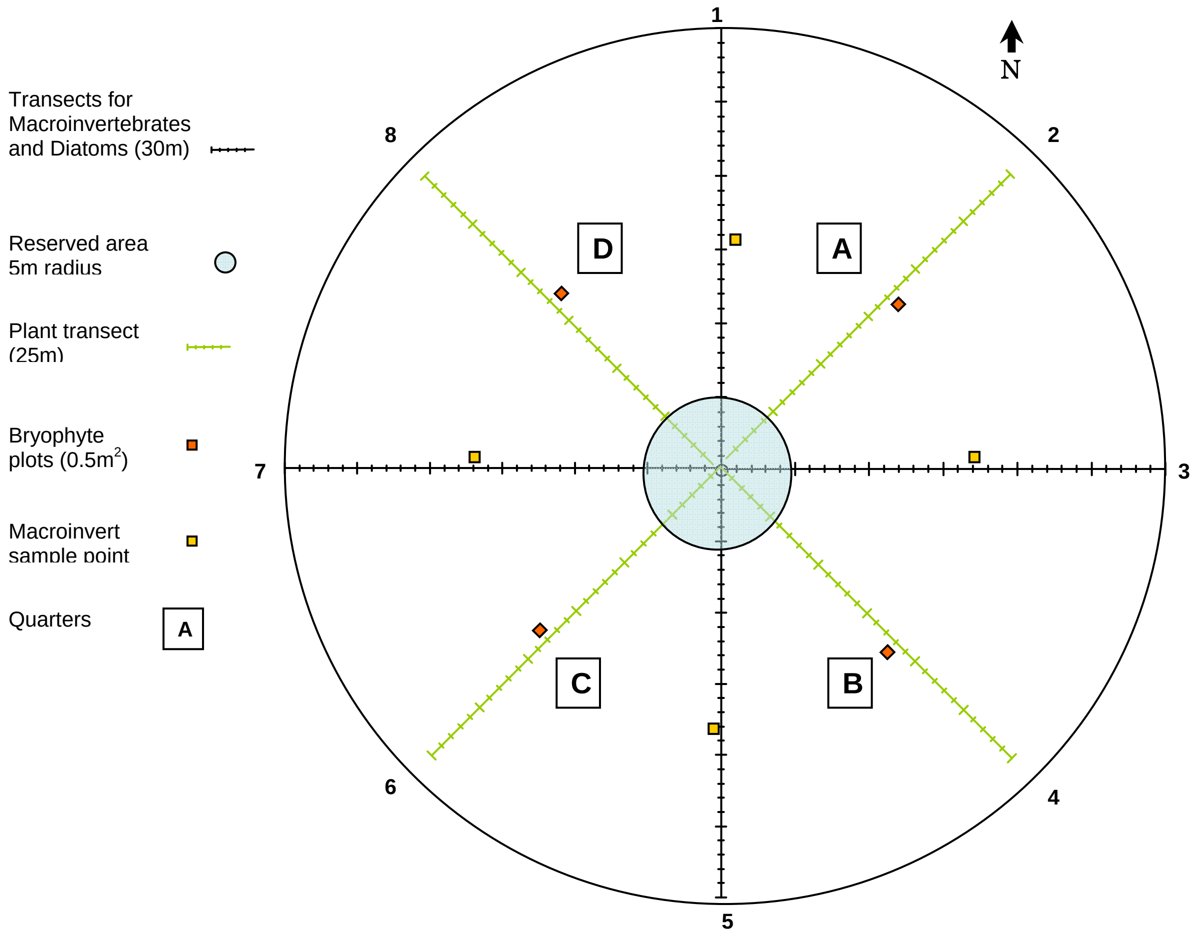
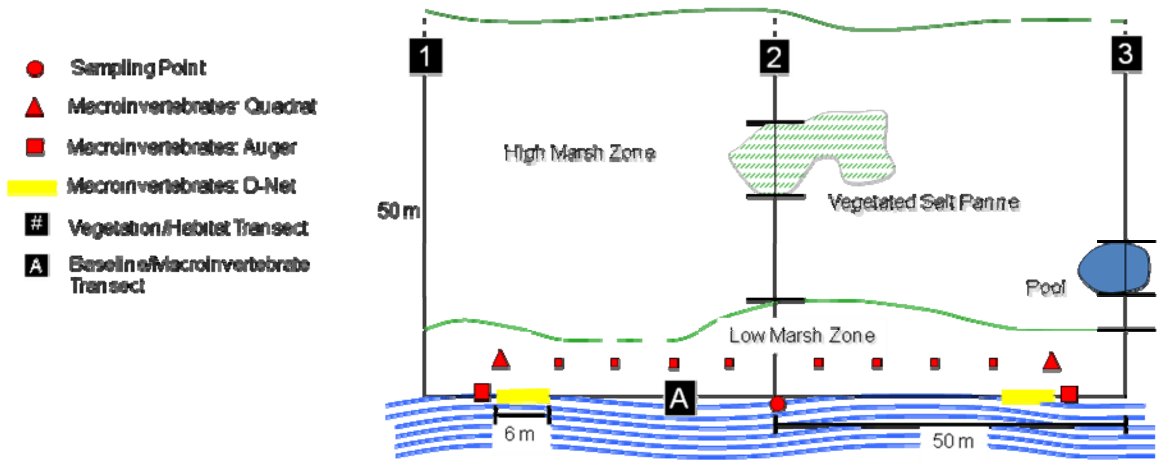

Transects for Macroinvertebrates and Diatoms (30m)
Reserved area 5m radius
Plant transect (25m)
Bryophyte plots (0.5m2)
Macroinvert sample point
Quarters
A
N
1
2
3
4
5
6
7
8
A
B
C
D

Figure A2


Sampling Point
Macroinvertebrates: Quadrat
Macroinvertebrates: Auger
Macroinvertebrates: D-Net
Vegetation/Habitat Transect
Baseline/Macroinvertebrate Transect
1
2
3
High Marsh Zone
Vegetated Salt Panne
50 m
Pool
Low Marsh Zone
A
6 m
50 m

Appendix B. Individual stressor metrics used to measure the level of anthropogenic stressor to each site. Metrics listed by name and abbreviation are arbitrarily grouped into broad classes for organizational purposes. Note, the three resiliency metrics have a negative relationship with anthropogenic stress: the value increases as stress decreases, while the rest of the metrics have a positive relationship with stress.

Metric group	**Metric name**	**Description**
development and Roads	habitat loss	measures the intensity of habitat loss caused by all forms of development in the neighborhood surrounding the focal cell, weighted by Euclidean distance using a Gaussian kernel.
	(watershed) habitat loss	measures the intensity of habitat loss caused by all forms of development in the watershed above the focal cell, weighted by flow distance from the focal cell using a time-of-flow model.
	wetland buffer insults	measures the intensity of impervious surface within a 100-ft buffer around the wetland based on 1-m spatial resolution data. This metric is an index of high-intensity development and roads in the regulated buffer around wetlands.
	road traffic	measures the intensity of road traffic (based on measured road traffic rates) in the neighborhood surrounding the focal cell, weighted by a logistic function of distance.
	mowing & plowing	measures the intensity of agriculture in the neighborhood surrounding the focal cell, weighted by a logistic function of distance. This metric is a surrogate for mowing/plowing rates (which are a direct source of animal mortality).
	microclimate alterations	measures the adverse effects of induced (human-created) edges on the microclimate integrity of patch interiors. The microclimate edge effects metric is based on the "worst" edge effect among all adverse edges in the neighborhood surrounding the focal cell, where each adverse edge is evaluated using a "depth-of-edge" function in which the "effect" is scaled using a logistic function of distance.
pollution	(watershed) road salt	measures the intensity of road salt application in the watershed above an aquatic focal cell weighted by road class and the modeled "influence value" for each cell, which is the aquatic distance from the focal cell based on a time-of-flow model. This metric is a surrogate for road salt application rates.

Metric group	Metric name	Description
	(watershed) road sediment	measures the intensity of sediment production in the watershed above an aquatic focal cell weighted by land cover class and the modeled "influence value" for each cell, which is the aquatic distance from the focal cell based on a time-of-flow model. This metric is a surrogate for road sediment production rates.
	(watershed) nutrient enrichment	measures the intensity of nutrient loading from point and non-point sources of nutrients (including fertilizers) in the neighborhood surrounding the focal cell, weighted by either on a logistic function of Euclidean distance or on the aquatic distance from the focal cell based on a time-of-flow model to development classes (primarily agriculture and residential and other developed land uses plus point-sources of nutrient, e.g., municipal discharges). This metric is a surrogate for nutrient loading rate.
biotic alterations	domestic predators	measures the intensity of development associated with sources of domestic predators (e.g., cats) in the neighborhood surrounding the focal cell, weighted by a logistic function of distance to development classes. This metric is a surrogate for domestic predator abundance measured directly in the field.
	edge predators	measures the intensity of development associated with sources of edge mesopredators (e.g., raccoons, skunks, corvids, cowbirds; i.e., human commensals) in the neighborhood surrounding the focal cell, weighted by a logistic function of distance to development classes. This metric is a surrogate for edge predator abundance measured directly in the field.
	non-native invasive plants	measures the intensity of development associated with sources of non-native invasive plants in the neighborhood surrounding the focal cell, weighted by a logistic function of distance to development classes. This metric is a surrogate for non-native invasive plant abundance measured directly in the field.
	non-native invasive earthworms	measures the intensity of development associated with sources of non-native invasive earthworms in the neighborhood surrounding the focal cell, weighted by a logistic function of distance to development classes. This metric is a surrogate for non-native invasive earthworm

Metric group	Metric name	Description
		abundance measured directly in the field.
hydrologic alterations	(watershed) imperviousness	measures the intensity of impervious surface in the watershed above the focal cell, based on imperviousness and the modeled "influence value" for each cell, which is the aquatic distance from the focal cell based on a time-of-flow model.
	(watershed) dam intensity	measures the number of dams in the watershed above an aquatic focal cell weighted by dam size and the modeled "influence value" for each cell, which is the aquatic distance from the focal cell based on a time-of-flow model.
coastal metrics	salt marsh ditching	measures the magnitude of temporal loss of open water habitat (i.e., loss of open water habitat during mid to low tides) around the focal cell due to ditching, based on a standard kernel density estimate of nearby drainage ditches.
	tidal restrictions	measures the magnitude of *hydrologic* alteration to the focal cell due to tidal restrictions, based on the estimated tidal hydroperiod (ecological setting variable) of a cell and magnitude of tidal restriction (on the upstream side of a restriction).
resiliency metrics	connectedness	measures the disruption of habitat connectivity caused by all forms of development between each focal cell and surrounding cells as well as the "resistance" of the surrounding undeveloped landscape, as well as the similarity of surroundings. A hypothetical organism in a highly connected cell can reach a large area of ecologically similar cells with minimal crossing of "hostile" cells. This metric uses a least-cost path algorithm to determine the area that can reach each focal cell, incorporating each cell's similarity to the focal cell.
	aquatic connectedness	an aquatic version of the connectedness metric, measuring connectivity along streams and rivers. Aquatic connectedness includes the resistance from culverts, bridges and dams for organisms that are primarily aquatic.

Metric group	Metric name	Description
	similarity	measures the amount of similarity between the ecological setting at the focal cell and those of neighboring cells, weighted by a logistic function of distance. Similarity is based on the ecological distance between the focal cell and each neighboring cell, where ecological distance is a multivariate distance across all ecological setting variables

Appendix C. Independently-derived, published biotic descriptors or metrics used in Indices of Biological Integrity (IBIs) in wadable freshwater streams in Massachusetts, including the biotic metric name, code (as used in tables and figures), association of the metric with habitat quality, description, and source of each metric. 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 (Species to Phyllum) unless specifically stated otherwise.

Biotic metric	Code	Association[3]	Description	Source
diversity	diversity.family diversity.order	+	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)
Ephemeroptera taxa richness	n.ephemeroptera	+	total number of mayfly taxa[1]	OHEPA (2013), Southerland et al. (2005), VTDEC (2004), RIDEM (2009), Nuzzo (2003)
Trichoptera taxa richness	n.trichoptera	+	total number of caddisfly taxa[1]	OHEPA (2013), Gerritsen and Jessup (2007)

Biotic metric	Code	Association[3]	Description	Source
Diptera taxa richness	n.deptera	-	total number of true fly taxa[1]	OHEPA (2013)
EPT taxa richness	ept	+	total number of Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa[1]	Smith et al. (2009), PADEP (2009), OHEPA (2013), 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 (2013, Southerland et al. (2005)
% Tanytarsini midges	pct. tanytarsini.abun	+	relative abundance of individuals in the tribe of the Chironomid subfamily Chironominae	OHEPA (2013)
% 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 EPT Orders; excludes all Hydropsychidae	Jessup (2007), Gerritsen and Jessup (2007)
EPT % individuals	pct.ept.abun	+	% of individuals that are in the EPT Orders	USEPA (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)

Biotic metric	Code	Association[3]	Description	Source
% Oligochaeta	pct.abun. oligochaeta	-	% of abundance in the Class Oligochaeta	VTDEC (2004)
% contribution of dominant taxa	dom.3.family. abun dom.3.order.abun	-	% 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 Orders divided[2] by the total abundance of both EPT and chironomidae	VTDEC (2004)
EPT/Chironomid ratio	ept.chiro.ratio	+	ratio[2] of total number of taxa[1] in EPT Orders 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)

Biotic metric	Code	Association[3]	Description	Source
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)
% sensitive individuals	pct.sensitive.abun	+	% of individuals with pollution tolerance values of 0 to 3	PADEP (2009)

Biotic metric	Code	Association[3]	Description	Source
PTV 0-5.9 % taxa	ptv.0.to.5.9	+	% of taxa with pollution tolerance values between 0 and 5.9	USEPA (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 biotic metrics involving ratios we set the denominator equal to one when it would otherwise have been zero. This avoided division by zero and allowed the metric to be calculated at all sites.

[3] Association with habitat quality or integrity: +, increased metric value indicated higher integrity (i.e., less stress); - , increased metric value indicated degraded habitat (i.e., more stress).

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Appendix D. Performance statistics for Indices of Biotic Integrity (IBIs) developed for five major taxonomic groups (and sampling methods) across 19 stressor metrics and three ecological systems (see **Tables 1-2**) in Massachusetts. IBIs are grouped by ecological system and major taxonomic group (and sampling method) and listed for each stressor metric in order of decreasing cross-validated coefficient of concordance. For each stressor metric, the multi-taxonomic group IBIs created by merging the individual taxonomic group IBIs (All-merged) and by conducting a full stepwise taxa selection across all taxonomic groups (All-stepwise, for forested wetlands only) are also given. Full non-cross-validated coefficient of concordance is also given (Full), along with the number of sites, number of taxa in the pool available for selection in the development of the IBI and the final number of taxa selected for the IBI. Shown in bold are IBIs with coefficient of concordance ≥0.5, which were deemed ecologically and statistically reliable based on a randomization test procedure.

Ecological system		**Concordance**				
Taxonomic group	**Stressor Metric**	**Full**	**Cross-validated**	**#Sites**	**#Taxa**	**#Taxa selected**
Forested wetlands:						
vascular plants	*index of ecological integrity (IEI)*	**0.81**	**0.79**	214	379	44
	(watershed) nutrient enrichment	**0.82**	**0.78**	214	379	56
	connectedness	**0.81**	**0.78**	214	379	36
	(watershed) habitat loss	**0.80**	**0.78**	214	379	38
	similarity	**0.80**	**0.77**	214	379	106
	non-native invasive worms	**0.75**	**0.75**	214	379	52
	(watershed) road sediment	**0.77**	**0.73**	214	379	42
	non-native invasive plants	**0.76**	**0.73**	214	379	62
	edge predators	**0.74**	**0.70**	214	379	80
	habitat loss	**0.73**	**0.69**	214	379	42
	aquatic connectedness	**0.72**	**0.66**	214	379	87

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	road traffic	**0.71**	**0.66**	214	379	63
	(watershed) road salt	**0.60**	**0.66**	214	379	67
	wetland buffer insults	**0.68**	**0.54**	214	379	93
	microclimate alterations	0.42	**0.53**	214	379	73
bryophytes	connectedness	**0.65**	**0.62**	211	113	12
	index of ecological integrity (IEI)	**0.63**	**0.61**	211	113	11
	non-native invasive worms	**0.59**	**0.57**	211	113	18
	similarity	**0.57**	**0.57**	211	113	11
	(watershed) nutrient enrichment	**0.55**	**0.56**	211	113	14
	habitat loss	**0.59**	**0.55**	211	113	11
	edge predators	**0.53**	**0.55**	211	113	13
	non-native invasive plants	**0.59**	**0.54**	211	113	17
	(watershed) habitat loss	**0.55**	**0.52**	211	113	11
	(watershed) road sediment	0.43	0.48	211	113	16
	road traffic	0.46	0.42	211	113	11
	microclimate alterations	0.43	0.42	211	113	18
	(watershed) road salt	0.42	0.39	211	113	15

Ecological system		**Concordance**				
Taxonomic group	**Stressor Metric**	**Full**	**Cross-validated**	**#Sites**	**#Taxa**	**#Taxa selected**
	wetland buffer insults	0.41	0.38	211	113	13
	aquatic connectedness	0.33	0.33	211	113	9
epiphytic macrolichens	*index of ecological integrity (IEI)*	**0.58**	**0.57**	214	32	4
	non-native invasive plants	**0.52**	**0.50**	214	32	6
	road traffic	**0.50**	0.47	214	32	9
	edge predators	0.47	0.46	214	32	5
	connectedness	0.48	0.45	214	32	3
	habitat loss	0.46	0.45	214	32	4
	non-native invasive worms	0.44	0.44	214	32	5
	similarity	0.42	0.41	214	32	4
	(watershed) road sediment	0.40	0.39	214	32	5
	(watershed) habitat loss	0.40	0.39	214	32	4
	(watershed) nutrient enrichment	0.34	0.33	214	32	4
	wetland buffer insults	0.33	0.30	214	32	7
	microclimate alterations	0.24	0.24	214	32	4
	(watershed) road salt	0.23	0.24	214	32	4
	aquatic	0.06	0.06	214	32	6

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	connectedness					
diatoms	*index of ecological integrity (IEI)*	**0.71**	**0.68**	205	157	17
	non-native invasive plants	**0.65**	**0.63**	205	157	23
	edge predators	**0.62**	**0.61**	205	157	18
	(watershed) nutrient enrichment	**0.64**	**0.60**	205	157	17
	(watershed) road sediment	**0.60**	**0.60**	205	157	23
	habitat loss	**0.60**	**0.59**	205	157	23
	(watershed) habitat loss	**0.59**	**0.58**	205	157	26
	non-native invasive worms	**0.56**	**0.57**	205	157	17
	similarity	**0.64**	**0.56**	205	157	36
	connectedness	**0.54**	**0.51**	205	157	18
	microclimate alterations	**0.57**	0.44	205	157	22
	road traffic	0.34	0.34	205	157	16
	(watershed) road salt	0.27	0.32	205	157	20
	aquatic connectedness	0.28	0.28	205	157	20
	wetland buffer insults	0.06	0.25	205	157	16
macroinvertebrates	*index of ecological integrity (IEI)*	**0.73**	**0.71**	171	161	46

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	connectedness	**0.71**	**0.68**	171	161	19
	habitat loss	**0.63**	**0.58**	171	161	38
	non-native invasive worms	**0.59**	**0.57**	171	161	23
	microclimate alterations	**0.59**	**0.55**	171	161	33
	edge predators	**0.56**	**0.55**	171	161	19
	similarity	**0.57**	**0.54**	171	161	31
	non-native invasive plants	**0.52**	**0.53**	171	161	21
	wetland buffer insults	**0.55**	**0.52**	171	161	11
	aquatic connectedness	**0.51**	0.46	171	161	37
	(watershed) habitat loss	0.39	0.40	171	161	20
	(watershed) nutrient enrichment	0.41	0.39	171	161	22
	(watershed) road salt	0.38	0.38	171	161	21
	(watershed) road sediment	0.36	0.38	171	161	21
	road traffic	0.30	0.32	171	161	23
A) emergence traps	connectedness	**0.51**	0.48	179	36	11
	index of ecological integrity (IEI)	0.44	0.45	179	36	4
	non-native invasive plants	0.34	0.34	179	36	6

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	edge predators	0.34	0.34	179	36	6
	non-native invasive worms	0.33	0.34	179	36	5
	habitat loss	0.23	0.22	179	36	8
	(watershed) habitat loss	0.25	0.21	179	36	4
	(watershed) road sediment	0.19	0.21	179	36	6
	aquatic connectedness	0.19	0.21	179	36	4
	similarity	0.18	0.18	179	36	4
	road traffic	0.19	0.17	179	36	4
	(watershed) road salt	0.18	0.18	179	36	7
	microclimate alterations	0.12	0.12	179	36	12
	(watershed) nutrient enrichment	0.11	0.09	179	36	1
	wetland buffer insults	--	--	179	36	--
B) pitfall traps	*index of ecological integrity (IEI)*	**0.57**	**0.58**	206	174	38
	connectedness	**0.52**	**0.53**	206	174	31
	non-native invasive worms	**0.52**	**0.51**	206	174	35
	habitat loss	**0.50**	0.48	206	174	13
	road traffic	0.46	0.47	206	174	31

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	wetland buffer insults	0.49	0.45	206	174	9
	(watershed) habitat loss	0.44	0.44	206	174	27
	similarity	0.41	0.44	206	174	33
	edge predators	0.49	0.43	206	174	35
	(watershed) road sediment	0.43	0.42	206	174	29
	non-native invasive plants	0.44	0.40	206	174	30
	(watershed) road salt	0.38	0.40	206	174	24
	(watershed) nutrient enrichment	0.31	0.40	206	174	25
	microclimate alterations	0.28	0.27	206	174	32
	aquatic connectedness	0.10	0.16	206	174	29
C) earthworms	*index of ecological integrity (IEI)*	0.36	0.36	214	6	1
	non-native invasive worms	0.32	0.34	214	6	3
	edge predators	0.31	0.31	214	6	2
	non-native invasive plants	0.29	0.30	214	6	2
	habitat loss	0.29	0.29	214	6	2

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	(watershed) habitat loss	0.28	0.26	214	6	2
	similarity	0.27	0.26	214	6	2
	(watershed) road sediment	0.26	0.24	214	6	2
	(watershed) road salt	0.26	0.23	214	6	2
	(watershed) nutrient enrichment	0.28	0.22	214	6	2
	microclimate alterations	0.23	0.22	214	6	3
	wetland buffer insults	0.20	0.19	214	6	2
	connectedness	0.17	0.17	214	6	1
	road traffic	0.16	0.15	214	6	2
	aquatic connectedness	--	--	214	6	--
All-merged	*index of ecological integrity (IEI)*	--	**0.81**	219	842	122
	connectedness	--	**0.81**	219	842	88
	similarity	--	**0.73**	219	842	188
	(watershed) habitat loss	--	**0.71**	219	842	99
	(watershed) nutrient enrichment	--	**0.71**	219	842	113

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	non-native invasive plants	--	**0.69**	219	842	129
	habitat loss	--	**0.69**	219	842	118
	non-native invasive worms	--	**0.69**	219	842	115
	edge predators	--	**0.65**	219	842	135
	(watershed) road sediment	--	**0.60**	219	842	107
	road traffic	--	**0.58**	219	842	122
	wetland buffer insults	--	**0.52**	219	842	140
	microclimate alterations	--	**0.51**	219	842	150
	(watershed) road salt	--	0.48	219	842	127
	aquatic connectedness	--	0.44	219	842	159
All-stepwise	connectedness	**0.91**	**0.89**	154	755	98
	non-native invasive worms	**0.92**	**0.89**	154	755	86
	index of ecological integrity (IEI)	**0.89**	**0.89**	154	755	80
	(watershed) nutrient enrichment	**0.92**	**0.87**	154	755	142
	(watershed) habitat loss	**0.84**	**0.85**	154	755	88

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	similarity	**0.86**	**0.79**	154	755	104
	(watershed) road sediment	**0.78**	**0.77**	154	755	120
	aquatic connectedness	**0.77**	**0.77**	154	755	87
	microclimate alterations	**0.72**	**0.77**	154	755	84
	(watershed) road salt	**0.81**	**0.76**	154	755	107
	edge predators	**0.72**	**0.73**	154	755	97
	road traffic	**0.80**	**0.72**	154	755	92
	wetland buffer insults	**0.77**	**0.71**	154	755	82
	habitat loss	**0.64**	**0.71**	154	755	64
	non-native invasive plants	**0.70**	**0.64**	154	755	87
Salt marsh:						
vascular plants	*index of ecological integrity (IEI)*	0.43	0.40	130	38	3
	habitat loss	0.37	0.38	130	38	11
	salt marsh ditching	0.31	0.34	130	38	3
	wetland buffer insults	0.28	0.32	130	38	4
	similarity	0.33	0.30	130	38	8

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	connectedness	0.18	0.19	130	38	1
	tidal restrictions	0.27	0.15	130	38	10
macroinvertebrates	wetland buffer insults	**0.74**	**0.57**	123	107	35
	index of ecological integrity (IEI)	**0.55**	**0.53**	123	107	33
	similarity	0.46	**0.52**	123	107	33
	connectedness	**0.54**	**0.50**	123	107	27
	habitat loss	0.43	0.48	123	107	30
	tidal restrictions	0.46	0.46	123	107	11
	salt marsh ditching	**0.50**	0.44	123	107	25
A) quadrats	connectedness	0.39	0.39	130	37	4
	index of ecological integrity (IEI)	0.35	0.35	130	37	7
	similarity	0.31	0.30	130	37	5
	salt marsh ditching	0.23	0.27	130	37	2
	habitat loss	0.15	0.16	130	37	6
	tidal restrictions	0.08	0.08	130	37	7
	wetland buffer insults	--	--	130	--	--
B) D-net sweeps	*index of ecological integrity (IEI)*	**0.51**	0.46	127	42	8
	connectedness	0.40	0.41	127	42	9
	habitat loss	0.40	0.40	127	42	5

Ecological system		Concordance				
Taxonomic group	**Stressor Metric**	**Full**	**Cross-validated**	**#Sites**	**#Taxa**	**#Taxa selected**
	wetland buffer insults	0.42	0.34	127	42	12
	similarity	0.41	0.34	127	42	8
	salt marsh ditching	0.24	0.26	127	42	18
	tidal restrictions	0.08	0.10	127	42	15
C) auger	salt marsh ditching	0.31	0.29	126	29	6
	connectedness	0.26	0.27	126	29	7
	similarity	0.26	0.27	126	29	8
	index of ecological integrity (IEI)	0.18	0.17	126	29	2
	habitat loss	0.18	0.17	126	29	5
	wetland buffer insults	0.16	0.12	126	29	8
	tidal restrictions	0.04	0.08	126	29	6
<u>Wadable streams</u>:						
macroinvertebrates	(watershed) imperviousness	**0.85**	**0.84**	490	294	80
	(watershed) habitat loss	**0.81**	**0.80**	490	294	64
	index of ecological integrity (IEI)	**0.80**	**0.78**	490	294	43
	(watershed) road sediment	**0.77**	**0.76**	490	294	35
	connectedness	**0.66**	**0.64**	490	294	48
	habitat loss	**0.66**	**0.63**	490	294	38

Ecological system		Concordance				
Taxonomic group	Stressor Metric	Full	Cross-validated	#Sites	#Taxa	#Taxa selected
	(watershed) nutrient enrichment	**0.64**	**0.60**	490	294	38
	aquatic connectedness	**0.62**	**0.59**	490	294	37
	(watershed) dam intensity	0.44	0.42	490	294	50

Appendix E. Taxa included in selected Indices of Biotic Integrity (IBIs) developed for five major taxonomic groups (and sampling methods) across 19 stressor metrics for three ecological systems (see **Tables 1-2**) in Massachusetts. IBIs are grouped by ecological system and major taxonomic group (and sampling method) and listed for each stressor metric in order of decreasing cross-validated coefficient of concordance for the 57 single-taxonomic group and 15 multi-taxonomic group IBIs with cross-validated coefficients of concordance ≥0.5 (see **Appendix D**). For each IBI, taxa are listed in order of their selection roughly corresponding to their conditional importance in the IBI. Note, multi-taxonomic group IBIs reported here are based on the full stepwise taxa selection procedure (see text) for forested wetlands only; multi-taxonomic group IBIs based on merging the single-taxonomic group IBIs are not listed here because they are constructed by simply combining the taxa from the individual single-taxonomic group IBIs listed here.

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
Forested wetlands:				
vascular plants	*index of ecological integrity (IEI)*	1	Urticales	order
		2	Mitchella repens	species
		3	Trientalis borealis	species
		4	Oclemena acuminata	species
		5	Euonymus alata	species
		6	Physocarpus opulifolius	species
		7	Polystichum acrostichoides	species
		8	Clethra alnifolia	species
		9	Euonymus	genus
		10	Cicuta	genus
		11	Carex gynandra	species
		12	Carex crinita	species
		13	Sambucus canadensis	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		14	Rubus idaeus	species
		15	Maianthemum	genus
		16	Quercus alba	species
		17	Physocarpus	genus
		18	Scirpus	genus
		19	Oxalidaceae	family
		20	Oclemena	genus
		21	Pilea pumila	species
		22	Grossulariaceae	family
		23	Cornaceae	family
		24	Pteridium aquilinum	species
		25	Oxalis stricta	species
		26	Polygonum arifolium	species
		27	Clethraceae	family
		28	Taxales	order
		29	Betulaceae	family
		30	Lycopus	genus
		31	Brachyelytrum	genus
		32	Acer rubrum	species
		33	Cornales	order
		34	Bidens tripartita	species
		35	Eupatorium	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
			perfoliatum	
		36	Chrysosplenium americanum	species
		37	Ligustrum vulgare	species
		38	Cornus	genus
		39	Polystichum	genus
		40	Vaccinium myrtilloides	species
		41	Cornus racemosa	species
		42	Bidens frondosa	species
		43	Maianthemum canadense	species
		44	Carpinus caroliniana	species
vascular plants	(watershed) nutrient enrichment	1	Celastrus orbiculatus	species
		2	Euonymus alata	species
		3	Boehmeria cylindrica	species
		4	Lonicera	genus
		5	Picea rubens	species
		6	Ranunculus recurvatus	species
		7	Viburnum dentatum	species
		8	Eupatorium maculatum	species
		9	Euonymus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		10	Sambucus canadensis	species
		11	Fraxinus nigra	species
		12	Prunus	genus
		13	Dryopteris intermedia	species
		14	Theales	order
		15	Carex gracillima	species
		16	Thelypteris palustris	species
		17	Polystichum acrostichoides	species
		18	Viburnum lantanoides	species
		19	Chrysosplenium americanum	species
		20	Gaultheria	genus
		21	Malus	genus
		22	Smilacaceae	family
		23	Carex stricta	species
		24	Liliales	order
		25	Larix laricina	species
		26	Taxales	order
		27	Larix	genus
		28	Anemone quinquefolia	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		29	Viburnum	genus
		30	Aster divaricatus	species
		31	Carpinus caroliniana	species
		32	Vaccinium myrtilloides	species
		33	Ligustrum vulgare	species
		34	Polystichum	genus
		35	Maianthemum canadense	species
		36	Carpinus	genus
		37	Fabales	order
		38	Anemone	genus
		39	Abies balsamea	species
		40	Physocarpus opulifolius	species
		41	Cornus racemosa	species
		42	Onoclea sensibilis	species
		43	Onoclea	genus
		44	Quercus alba	species
		45	Betula lenta	species
		46	Clethra alnifolia	species
		47	Vitaceae	family
		48	Sapindales	order
		49	Polygonales	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		50	Dipsacales	order
		51	Lycopus	genus
		52	Solidago rugosa	species
		53	Physocarpus	genus
		54	Taxaceae	family
		55	Bidens frondosa	species
		56	Cornus alternifolia	species
vascular plants	connectedness	1	Symplocarpus foetidus	species
		2	Betula alleghaniensis	species
		3	Coptis trifolia	species
		4	Medeola virginiana	species
		5	Clethra alnifolia	species
		6	Polygonum	genus
		7	Polypodiales	order
		8	Photinia pyrifolia	species
		9	Quercus bicolor	species
		10	Larix laricina	species
		11	Taxales	order
		12	Pteridium aquilinum	species
		13	Epilobium	genus
		14	Clethraceae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		15	Sorbus	genus
		16	Carex debilis	species
		17	Carpinus caroliniana	species
		18	Carpinus	genus
		19	Aster divaricatus	species
		20	Liliales	order
		21	Aster	genus
		22	Cornus alternifolia	species
		23	Sorbus americana	species
		24	Maianthemum	genus
		25	Physocarpus opulifolius	species
		26	Carex gynandra	species
		27	Grossulariaceae	family
		28	Cornaceae	family
		29	Geranium maculatum	species
		30	Oclemena	genus
		31	Bidens frondosa	species
		32	Aquifoliaceae	family
		33	Rosa palustris	species
		34	Alnus incana	species
		35	Fraxinus nigra	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		36	Maianthemum canadense	species
vascular plants	(watershed) habitat loss	1	Celastraceae	family
		2	Euonymus alata	species
		3	Rhamnales	order
		4	Bidens	genus
		5	Picea rubens	species
		6	Carex gynandra	species
		7	Spiraea	genus
		8	Carex gracillima	species
		9	Grossulariaceae	family
		10	Malus	genus
		11	Betula lenta	species
		12	Ligustrum vulgare	species
		13	Lycopodiophyta	division.phylum
		14	Euonymus	genus
		15	Acer rubrum	species
		16	Clethra alnifolia	species
		17	Glyceria	genus
		18	Primulales	order
		19	Dryopteris intermedia	species
		20	Dryopteris	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
			carthusiana	
		21	Carex stricta	species
		22	Thelypteridaceae	family
		23	Sambucus canadensis	species
		24	Aceraceae	family
		25	Polygonales	order
		26	Carpinus caroliniana	species
		27	Scrophulariaceae	family
		28	Carpinus	genus
		29	Cornus racemosa	species
		30	Taxales	order
		31	Viburnum lantanoides	species
		32	Quercus rubra	species
		33	Clethraceae	family
		34	Cornales	order
		35	Oclemena acuminata	species
		36	Pteridophyta	division.phylum
		37	Carex intumescens	species
		38	Ligustrum	genus
vascular plants	similarity	1	Urticales	order
		2	Malus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		3	Cornus canadensis	species
		4	Vitis labrusca	species
		5	Urticaceae	family
		6	Rhododendron prinophyllum	species
		7	Polystichum acrostichoides	species
		8	Viburnum lantanoides	species
		9	Maianthemum	genus
		10	Trillium	genus
		11	Carex lurida	species
		12	Scutellaria lateriflora	species
		13	Scirpus	genus
		14	Carpinus caroliniana	species
		15	Betula populifolia	species
		16	Clintonia borealis	species
		17	Vaccinium myrtilloides	species
		18	Scutellaria	genus
		19	Clintonia	genus
		20	Taxales	order
		21	Taxaceae	family
		22	Carpinus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		23	Celastraceae	family
		24	Polygonum	genus
		25	Iridaceae	family
		26	Asterales	order
		27	Tiarella cordifolia	species
		28	Polygonales	order
		29	Pteridium aquilinum	species
		30	Lycopus	genus
		31	Pteridium	genus
		32	Equisetum arvense	species
		33	Iris	genus
		34	Triadenum virginicum	species
		35	Malus pumila	species
		36	Carex folliculata	species
		37	Sapindales	order
		38	Medeola virginiana	species
		39	Dipsacales	order
		40	Oclemena acuminata	species
		41	Osmunda claytoniana	species
		42	Picea rubens	species
		43	Maianthemum canadense	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		44	Polystichum	genus
		45	Taxus	genus
		46	Bidens	genus
		47	Lonicera	genus
		48	Rhamnales	order
		49	Iris versicolor	species
		50	Rosa palustris	species
		51	Lindera benzoin	species
		52	Trillium undulatum	species
		53	Bidens frondosa	species
		54	Capparales	order
		55	Monotropa uniflora	species
		56	Quercus alba	species
		57	Vaccinium	genus
		58	Rubus pubescens	species
		59	Sambucus canadensis	species
		60	Magnoliopsida	class
		61	Geranium maculatum	species
		62	Monotropaceae	family
		63	Rhododendron	genus
		64	Betula lenta	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		65	Tiarella	genus
		66	Rosaceae	family
		67	Coptis trifolia	species
		68	Sambucus	genus
		69	Cornales	order
		70	Clethra alnifolia	species
		71	Rubiales	order
		72	Arales	order
		73	Clethraceae	family
		74	Boehmeria cylindrica	species
		75	Thelypteris	genus
		76	Thalictrum pubescens	species
		77	Geraniaceae	family
		78	Rubus idaeus	species
		79	Solanum dulcamara	species
		80	Eupatorium perfoliatum	species
		81	Clethra	genus
		82	Rubiaceae	family
		83	Pteridophyta	division.phylum
		84	Polypodiales	order
		85	Scrophulariaceae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		86	Caprifoliaceae	family
		87	Viburnum	genus
		88	Ilex verticillata	species
		89	Geranium	genus
		90	Symplocarpus foetidus	species
		91	Acer platanoides	species
		92	Smilax herbacea	species
		93	Thelypteris noveboracensis	species
		94	Oclemena	genus
		95	Filicopsida	class
		96	Medeola	genus
		97	Pilea pumila	species
		98	Sorbus americana	species
		99	Aquifoliaceae	family
		100	Symphyotrichum puniceum	species
		101	Dryopteris carthusiana	species
		102	Equisetophyta	division.phylum
		103	Vaccinium angustifolium	species
		104	Cornaceae	family
		105	Chrysosplenium	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
			americanum	
		106	Uvularia sessilifolia	species
vascular plants	non-native invasive worms	1	Geraniales	order
		2	Euonymus alata	species
		3	Lamiales	order
		4	Thalictrum pubescens	species
		5	Sambucus canadensis	species
		6	Solanum dulcamara	species
		7	Lamiaceae	family
		8	Smilacaceae	family
		9	Geraniaceae	family
		10	Salicales	order
		11	Frangula alnus	species
		12	Carpinus caroliniana	species
		13	Malus pumila	species
		14	Anemone quinquefolia	species
		15	Osmunda regalis	species
		16	Carex gynandra	species
		17	Sambucus	genus
		18	Oclemena acuminata	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		19	Glyceria	genus
		20	Dryopteris intermedia	species
		21	Scirpus	genus
		22	Carpinus	genus
		23	Toxicodendron vernix	species
		24	Pilea pumila	species
		25	Geranium	genus
		26	Polygonum arifolium	species
		27	Smilax	genus
		28	Iridaceae	family
		29	Dennstaedtiaceae	family
		30	Geranium maculatum	species
		31	Taxales	order
		32	Thalictrum	genus
		33	Triadenum virginicum	species
		34	Ranunculus recurvatus	species
		35	Smilax herbacea	species
		36	Equisetophyta	division.phylum
		37	Corylus	genus
		38	Rosa palustris	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		39	Populus	genus
		40	Vitis labrusca	species
		41	Ranunculus	genus
		42	Platanthera	genus
		43	Triadenum	genus
		44	Salicaceae	family
		45	Bidens frondosa	species
		46	Onoclea sensibilis	species
		47	Onoclea	genus
		48	Pteridium aquilinum	species
		49	Taxaceae	family
		50	Liliales	order
		51	Thelypteris palustris	species
		52	Dennstaedtia punctilobula	species
vascular plants	(watershed) road sediment	1	Symplocarpus foetidus	species
		2	Euonymus alata	species
		3	Boehmeria cylindrica	species
		4	Uvularia sessilifolia	species
		5	Celastrus orbiculatus	species
		6	Viburnum dentatum	species
		7	Polygonum arifolium	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		8	Carex stricta	species
		9	Clethra alnifolia	species
		10	Dryopteris	genus
		11	Onoclea sensibilis	species
		12	Polystichum acrostichoides	species
		13	Osmunda regalis	species
		14	Rhododendron prinophyllum	species
		15	Carpinus caroliniana	species
		16	Nasturtium officinale	species
		17	Carpinus	genus
		18	Fabales	order
		19	Clethraceae	family
		20	Rubus idaeus	species
		21	Rosaceae	family
		22	Carex crinita	species
		23	Geraniales	order
		24	Prunus	genus
		25	Betula lenta	species
		26	Fagaceae	family
		27	Alnus incana	species
		28	Photinia pyrifolia	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		29	Glyceria	genus
		30	Vaccinium myrtilloides	species
		31	Kalmia angustifolia	species
		32	Viburnum lantanoides	species
		33	Taxales	order
		34	Pilea pumila	species
		35	Carex gynandra	species
		36	Vitis labrusca	species
		37	Sorbus	genus
		38	Sambucus canadensis	species
		39	Smilacaceae	family
		40	Sorbus americana	species
		41	Thelypteris	genus
		42	Cicuta	genus
vascular plants	non-native invasive plants	1	Celastraceae	family
		2	Asterales	order
		3	Geraniales	order
		4	Boehmeria cylindrica	species
		5	Oclemena	genus
		6	Medeola virginiana	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		7	Betula populifolia	species
		8	Taxales	order
		9	Toxicodendron vernix	species
		10	Cicuta	genus
		11	Picea rubens	species
		12	Maianthemum	genus
		13	Chelone glabra	species
		14	Dryopteris intermedia	species
		15	Vitis labrusca	species
		16	Theales	order
		17	Malus pumila	species
		18	Polystichum acrostichoides	species
		19	Bidens frondosa	species
		20	Scirpus	genus
		21	Clethra alnifolia	species
		22	Osmundaceae	family
		23	Geraniaceae	family
		24	Corylus cornuta	species
		25	Polystichum	genus
		26	Arisaema triphyllum	species
		27	Osmunda regalis	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		28	Sambucus canadensis	species
		29	Carex gynandra	species
		30	Symphyotrichum	genus
		31	Cornus alternifolia	species
		32	Dennstaedtia punctilobula	species
		33	Geranium	genus
		34	Sambucus	genus
		35	Onoclea sensibilis	species
		36	Ranunculus recurvatus	species
		37	Polygonum arifolium	species
		38	Dennstaedtiaceae	family
		39	Thelypteris palustris	species
		40	Cornus racemosa	species
		41	Carpinus caroliniana	species
		42	Bidens	genus
		43	Carpinus	genus
		44	Symphyotrichum puniceum	species
		45	Dennstaedtia	genus
		46	Clethraceae	family
		47	Arisaema	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		48	Onoclea	genus
		49	Geranium maculatum	species
		50	Taxaceae	family
		51	Betulaceae	family
		52	Triadenum virginicum	species
		53	Rhododendron viscosum	species
		54	Clethra	genus
		55	Rosa palustris	species
		56	Vaccinium myrtilloides	species
		57	Betula papyrifera	species
		58	Acer saccharum	species
		59	Smilacaceae	family
		60	Taxus	genus
		61	Alnus	genus
		62	Viburnum lantanoides	species
vascular plants	edge predators	1	Celastraceae	family
		2	Viburnum lantanoides	species
		3	Polystichum acrostichoides	species
		4	Rosa multiflora	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		5	Celastrus orbiculatus	species
		6	Solidago gigantea	species
		7	Symphyotrichum	genus
		8	Carpinus caroliniana	species
		9	Caltha palustris	species
		10	Rosa	genus
		11	Solidago	genus
		12	Epilobium	genus
		13	Ligustrum vulgare	species
		14	Betula populifolia	species
		15	Scirpus	genus
		16	Urticaceae	family
		17	Toxicodendron vernix	species
		18	Lonicera morrowii	species
		19	Carpinus	genus
		20	Eupatorium perfoliatum	species
		21	Iridaceae	family
		22	Oxalidaceae	family
		23	Iris versicolor	species
		24	Viburnum dentatum	species
		25	Polystichum	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		26	Solidago rugosa	species
		27	Alnus	genus
		28	Grossulariaceae	family
		29	Ligustrum	genus
		30	Lysimachia ciliata	species
		31	Clematis virginiana	species
		32	Caltha	genus
		33	Symphyotrichum puniceum	species
		34	Dryopteris	genus
		35	Vaccinium myrtilloides	species
		36	Quercus alba	species
		37	Violales	order
		38	Clematis	genus
		39	Rhododendron prinophyllum	species
		40	Taxales	order
		41	Triadenum virginicum	species
		42	Taxaceae	family
		43	Eupatorium	genus
		44	Liliaceae	family
		45	Bidens tripartita	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		46	Athyrium filix-femina	species
		47	Bidens frondosa	species
		48	Rubus hispidus	species
		49	Thelypteridaceae	family
		50	Scutellaria lateriflora	species
		51	Amphicarpaea bracteata	species
		52	Glyceria	genus
		53	Lysimachia terrestris	species
		54	Maianthemum racemosum	species
		55	Polygonum	genus
		56	Solanum dulcamara	species
		57	Cornus canadensis	species
		58	Boehmeria cylindrica	species
		59	Lamiaceae	family
		60	Carex intumescens	species
		61	Sambucus canadensis	species
		62	Polygonales	order
		63	Bidens	genus
		64	Smilacaceae	family
		65	Impatiens capensis	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		66	Lysimachia	genus
		67	Picea rubens	species
		68	Maianthemum	genus
		69	Osmunda cinnamomea	species
		70	Rubiales	order
		71	Boehmeria	genus
		72	Carex crinita	species
		73	Sambucus	genus
		74	Carex gynandra	species
		75	Smilax	genus
		76	Cornus amomum	species
		77	Lycopus	genus
		78	Fabales	order
		79	Cornus racemosa	species
		80	Betula papyrifera	species
vascular plants	habitat loss	1	Urticales	order
		2	Acer platanoides	species
		3	Abies balsamea	species
		4	Euonymus alata	species
		5	Betula lenta	species
		6	Oclemena	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		7	Polystichum acrostichoides	species
		8	Laurales	order
		9	Scirpus	genus
		10	Viburnum lantanoides	species
		11	Polystichum	genus
		12	Euonymus	genus
		13	Dennstaedtia punctilobula	species
		14	Cornus canadensis	species
		15	Polygonum	genus
		16	Acer saccharum	species
		17	Geranium maculatum	species
		18	Malus	genus
		19	Triadenum virginicum	species
		20	Sapindales	order
		21	Frangula alnus	species
		22	Carpinus caroliniana	species
		23	Thelypteris palustris	species
		24	Betula populifolia	species
		25	Vaccinium myrtilloides	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		26	Malus pumila	species
		27	Solanum dulcamara	species
		28	Sambucus canadensis	species
		29	Tiarella cordifolia	species
		30	Rhododendron prinophyllum	species
		31	Carex	genus
		32	Pteridium aquilinum	species
		33	Geraniaceae	family
		34	Rhododendron	genus
		35	Carex crinita	species
		36	Carpinus	genus
		37	Scutellaria	genus
		38	Rosa palustris	species
		39	Vaccinium angustifolium	species
		40	Bidens frondosa	species
		41	Trillium	genus
		42	Triadenum	genus
vascular plants	aquatic connectedness	1	Carex crinita	species
		2	Anemone quinquefolia	species
		3	Scirpus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		4	Eupatorium maculatum	species
		5	Bidens frondosa	species
		6	Acer saccharum	species
		7	Polygonum sagittatum	species
		8	Polystichum acrostichoides	species
		9	Vaccinium myrtilloides	species
		10	Symphyotrichum	genus
		11	Carpinus caroliniana	species
		12	Carpinus	genus
		13	Ulmaceae	family
		14	Populus	genus
		15	Bidens	genus
		16	Cornus amomum	species
		17	Equisetum arvense	species
		18	Toxicodendron vernix	species
		19	Sambucus canadensis	species
		20	Geraniaceae	family
		21	Oxalis stricta	species
		22	Epilobium	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		23	Symplocarpus foetidus	species
		24	Smilax herbacea	species
		25	Lycopodium obscurum	species
		26	Sorbus americana	species
		27	Polystichum	genus
		28	Symplocarpus	genus
		29	Geranium maculatum	species
		30	Vitaceae	family
		31	Smilacaceae	family
		32	Celastraceae	family
		33	Carex lurida	species
		34	Oxalidaceae	family
		35	Oxalis	genus
		36	Acer platanoides	species
		37	Pteridium aquilinum	species
		38	Rhododendron prinophyllum	species
		39	Dryopteris cristata	species
		40	Crataegus	genus
		41	Hydrocotyle americana	species
		42	Physocarpus	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
			opulifolius	
		43	Lysimachia ciliata	species
		44	Malus pumila	species
		45	Trillium	genus
		46	Ligustrum vulgare	species
		47	Amphicarpaea bracteata	species
		48	Aquifoliaceae	family
		49	Spiraea	genus
		50	Rubus idaeus	species
		51	Betula alleghaniensis	species
		52	Carya ovata	species
		53	Ligustrum	genus
		54	Ulmus	genus
		55	Scutellaria	genus
		56	Lyonia ligustrina	species
		57	Thelypteridaceae	family
		58	Pilea pumila	species
		59	Physocarpus	genus
		60	Trillium undulatum	species
		61	Scutellaria lateriflora	species
		62	Grossulariaceae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		63	Ulmus americana	species
		64	Liliales	order
		65	Vaccinium	genus
		66	Acer rubrum	species
		67	Bidens tripartita	species
		68	Corylus cornuta	species
		69	Sapindales	order
		70	Kalmia latifolia	species
		71	Ribes	genus
		72	Rosa palustris	species
		73	Larix laricina	species
		74	Symphyotrichum puniceum	species
		75	Pteridium	genus
		76	Fraxinus americana	species
		77	Clintonia borealis	species
		78	Carex gracillima	species
		79	Carex debilis	species
		80	Sorbus	genus
		81	Aster divaricatus	species
		82	Geranium	genus
		83	Ranunculus	genus

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		84	Smilax	genus
		85	Corylus americana	species
		86	Monotropa uniflora	species
		87	Cicuta	genus
vascular plants	road traffic	1	Vitis labrusca	species
		2	Boehmeria cylindrica	species
		3	Rubiales	order
		4	Prunus virginiana	species
		5	Amphicarpaea bracteata	species
		6	Physocarpus opulifolius	species
		7	Clethra alnifolia	species
		8	Ranunculus recurvatus	species
		9	Maianthemum canadense	species
		10	Ligustrum vulgare	species
		11	Fraxinus nigra	species
		12	Physocarpus	genus
		13	Ligustrum	genus
		14	Cornus alternifolia	species
		15	Carpinus caroliniana	species
		16	Carex lurida	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		17	Carpinus	genus
		18	Photinia pyrifolia	species
		19	Poaceae	family
		20	Nyssa sylvatica	species
		21	Thelypteris palustris	species
		22	Pteridium aquilinum	species
		23	Rosa palustris	species
		24	Fragaria virginiana	species
		25	Populus	genus
		26	Cornus amomum	species
		27	Solidago rugosa	species
		28	Saxifragaceae	family
		29	Scutellaria lateriflora	species
		30	Orchidales	order
		31	Sambucus canadensis	species
		32	Carex gynandra	species
		33	Caltha palustris	species
		34	Amphicarpaea	genus
		35	Ranunculus	genus
		36	Osmunda regalis	species
		37	Betula populifolia	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		38	Anemone quinquefolia	species
		39	Fragaria	genus
		40	Fabales	order
		41	Rubus idaeus	species
		42	Osmunda claytoniana	species
		43	Triadenum virginicum	species
		44	Iris versicolor	species
		45	Abies balsamea	species
		46	Fabaceae	family
		47	Scirpus	genus
		48	Onoclea sensibilis	species
		49	Cornus racemosa	species
		50	Polystichum acrostichoides	species
		51	Onoclea	genus
		52	Aster divaricatus	species
		53	Boehmeria	genus
		54	Dryopteris carthusiana	species
		55	Alnus incana	species
		56	Thelypteris simulata	species
		57	Grossulariaceae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		58	Chrysosplenium americanum	species
		59	Carya ovata	species
		60	Smilacaceae	family
		61	Caltha	genus
		62	Carex debilis	species
		63	Bidens tripartita	species
vascular plants	(watershed) road salt	1	Euonymus alata	species
		2	Clethra alnifolia	species
		3	Solidago rugosa	species
		4	Frangula alnus	species
		5	Thalictrum pubescens	species
		6	Dalibarda repens	species
		7	Osmunda regalis	species
		8	Carex stricta	species
		9	Euonymus	genus
		10	Dryopteris intermedia	species
		11	Clematis virginiana	species
		12	Corylus cornuta	species
		13	Sambucus canadensis	species
		14	Celastrus orbiculatus	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		15	Carpinus caroliniana	species
		16	Prenanthes altissima	species
		17	Theales	order
		18	Anemone quinquefolia	species
		19	Carpinus	genus
		20	Aster divaricatus	species
		21	Ericales	order
		22	Scutellaria	genus
		23	Ligustrum vulgare	species
		24	Thelypteris palustris	species
		25	Cornus alternifolia	species
		26	Fragaria virginiana	species
		27	Celastrus	genus
		28	Sorbus	genus
		29	Clematis	genus
		30	Anemone	genus
		31	Crataegus	genus
		32	Grossulariaceae	family
		33	Malus	genus
		34	Carex gynandra	species
		35	Smilax herbacea	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		36	Vaccinium corymbosum	species
		37	Potentilla simplex	species
		38	Ribes	genus
		39	Circaea	genus
		40	Cornus racemosa	species
		41	Nasturtium officinale	species
		42	Amphicarpaea bracteata	species
		43	Lamiaceae	family
		44	Polystichum acrostichoides	species
		45	Malus pumila	species
		46	Carex gracillima	species
		47	Thelypteris noveboracensis	species
		48	Acer platanoides	species
		49	Fraxinus nigra	species
		50	Poaceae	family
		51	Fabales	order
		52	Dipsacales	order
		53	Platanthera	genus
		54	Vaccinium	genus
		55	Amphicarpaea	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		56	Fagales	order
		57	Fabaceae	family
		58	Maianthemum canadense	species
		59	Lamiales	order
		60	Fragaria	genus
		61	Caprifoliaceae	family
		62	Cornus amomum	species
		63	Vaccinium myrtilloides	species
		64	Smilacaceae	family
		65	Potentilla	genus
		66	Polystichum	genus
		67	Populus	genus
vascular plants	wetland buffer insults	1	Vitis labrusca	species
		2	Taxales	order
		3	Solidago gigantea	species
		4	Liliopsida	class
		5	Bidens tripartita	species
		6	Juglandales	order
		7	Malus	genus
		8	Ligustrum vulgare	species
		9	Vaccinium myrtilloides	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		10	Taxaceae	family
		11	Caltha palustris	species
		12	Lysimachia ciliata	species
		13	Carex lurida	species
		14	Dipsacales	order
		15	Grossulariaceae	family
		16	Taxus	genus
		17	Ribes	genus
		18	Circaea lutetiana	species
		19	Cornus racemosa	species
		20	Carex	genus
		21	Juglandaceae	family
		22	Cicuta	genus
		23	Caltha	genus
		24	Carya	genus
		25	Carpinus caroliniana	species
		26	Caprifoliaceae	family
		27	Ranunculus	genus
		28	Anemone quinquefolia	species
		29	Anemone	genus
		30	Oxalidaceae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		31	Geranium maculatum	species
		32	Acer platanoides	species
		33	Aster divaricatus	species
		34	Larix laricina	species
		35	Iris versicolor	species
		36	Abies balsamea	species
		37	Euonymus alata	species
		38	Orchidales	order
		39	Cyperaceae	family
		40	Geraniaceae	family
		41	Abies	genus
		42	Geranium	genus
		43	Thelypteris noveboracensis	species
		44	Ligustrum	genus
		45	Scutellaria lateriflora	species
		46	Euonymus	genus
		47	Ericaceae	family
		48	Hamamelis virginiana	species
		49	Carya ovata	species
		50	Vaccinium corymbosum	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		51	Photinia pyrifolia	species
		52	Clematis virginiana	species
		53	Carpinus	genus
		54	Carex crinita	species
		55	Nyssa sylvatica	species
		56	Smilacaceae	family
		57	Viburnum lantanoides	species
		58	Viburnum lentago	species
		59	Thelypteridaceae	family
		60	Arales	order
		61	Ulmaceae	family
		62	Laurales	order
		63	Osmunda cinnamomea	species
		64	Betula	genus
		65	Smilax	genus
		66	Amphicarpaea bracteata	species
		67	Thalictrum pubescens	species
		68	Acer rubrum	species
		69	Cyperales	order
		70	Equisetophyta	division.phylum

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		71	Rubus idaeus	species
		72	Quercus alba	species
		73	Polygonum sagittatum	species
		74	Carex gracillima	species
		75	Ericales	order
		76	Epilobium	genus
		77	Polystichum acrostichoides	species
		78	Cornales	order
		79	Corylus cornuta	species
		80	Maianthemum	genus
		81	Thelypteris palustris	species
		82	Lysimachia terrestris	species
		83	Pinaceae	family
		84	Pteridium aquilinum	species
		85	Rosa	genus
		86	Pilea pumila	species
		87	Rhamnaceae	family
		88	Violales	order
		89	Capparales	order
		90	Dennstaedtiaceae	family
		91	Rosa palustris	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		92	Oxalis	genus
		93	Pteridium	genus
vascular plants	microclimate alterations	1	Rhamnus cathartica	species
		2	Nasturtium officinale	species
		3	Physocarpus opulifolius	species
		4	Celastraceae	family
		5	Rhamnales	order
		6	Iridaceae	family
		7	Rhododendron prinophyllum	species
		8	Acer platanoides	species
		9	Onoclea sensibilis	species
		10	Rosaceae	family
		11	Tsuga canadensis	species
		12	Tsuga	genus
		13	Lonicera	genus
		14	Carpinus caroliniana	species
		15	Geraniales	order
		16	Onoclea	genus
		17	Rosales	order
		18	Rosa multiflora	species
		19	Carpinus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		20	Photinia pyrifolia	species
		21	Larix laricina	species
		22	Athyrium filix-femina	species
		23	Equisetum arvense	species
		24	Rubus hispidus	species
		25	Larix	genus
		26	Triadenum virginicum	species
		27	Grossulariaceae	family
		28	Rhamnus	genus
		29	Vaccinium myrtilloides	species
		30	Pteridium aquilinum	species
		31	Pteridium	genus
		32	Iris versicolor	species
		33	Lamiales	order
		34	Vitis labrusca	species
		35	Ligustrum vulgare	species
		36	Ligustrum	genus
		37	Carex gracillima	species
		38	Physocarpus	genus
		39	Athyrium	genus
		40	Rosa	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		41	Populus	genus
		42	Lycopus	genus
		43	Fagales	order
		44	Platanthera	genus
		45	Lonicera morrowii	species
		46	Impatiens capensis	species
		47	Boehmeria cylindrica	species
		48	Iris	genus
		49	Geranium maculatum	species
		50	Boehmeria	genus
		51	Balsaminaceae	family
		52	Arales	order
		53	Amphicarpaea bracteata	species
		54	Hydrocotyle americana	species
		55	Poaceae	family
		56	Cornales	order
		57	Apiaceae	family
		58	Dryopteris	genus
		59	Carex debilis	species
		60	Dipsacales	order
		61	Dryopteris cristata	species

Ecological system					
	Taxonomic group	Stressor Metric	Step	Taxon	Level
			62	Doellingeria	genus
			63	Polystichum acrostichoides	species
			64	Impatiens	genus
			65	Rubiales	order
			66	Caprifoliaceae	family
			67	Carex stricta	species
			68	Maianthemum racemosum	species
			69	Celastrales	order
			70	Cornus canadensis	species
			71	Carex intumescens	species
			72	Amphicarpaea	genus
			73	Polystichum	genus
			1	Rhamnus cathartica	species
	bryophytes	connectedness	1	Bryophyta	division.phylum
			2	Hypnum imponens	species
			3	Climacium dendroides	species
			4	Dicranales	order
			5	Metzgeriales	order
			6	Pseudobryum cinclidioides	species
			7	Climacium americanum	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		8	Sphagnum squarrosum	species
		9	Jungermanniaceae	family
		10	Polytrichum pallidisetum	species
		11	Brachythecium rivulare	species
		12	Rhizomnium	genus
bryophytes	*index of ecological integrity (IEI)*	1	Sphagnopsida	class
		2	Bazzania trilobata	species
		3	Jungermanniaceae	family
		4	Pallavicinia lyellii	species
		5	Pseudobryum cinclidioides	species
		6	Climacium americanum	species
		7	Polytrichum commune	species
		8	Hypnales	order
		9	Brachythecium rivulare	species
		10	Polytrichum pallidisetum	species
		11	Climacium dendroides	species
bryophytes	non-native invasive worms	1	Sphagnopsida	class

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		2	Bazzania trilobata	species
		3	Brachytheciaceae	family
		4	Sphagnales	order
		5	Mniaceae	family
		6	Sphagnum fimbriatum	species
		7	Pelliaceae	family
		8	Brachythecium	genus
		9	Plagiothecium denticulatum	species
		10	Climacium dendroides	species
		11	Callicladium haldanianum	species
		12	Jungermanniaceae	family
		13	Jamesoniella autumnalis	species
		14	Jamesoniella	genus
		15	Sphagnum subsecundum	species
		16	Calliergon cordifolium	species
		17	Climacium americanum	species
		18	Brachythecium salebrosum	species
bryophytes	similarity	1	Sphagnopsida	class

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		2	Bazzania trilobata	species
		3	Dicranum	genus
		4	Atrichum	genus
		5	Brachytheciaceae	family
		6	Pelliaceae	family
		7	Climacium dendroides	species
		8	Polytrichum pallidisetum	species
		9	Amblystegiaceae	family
		10	Atrichum crispulum	species
		11	Polytrichum commune	species
bryophytes	(watershed) nutrient enrichment	1	Sphagnopsida	class
		2	Polytrichum	genus
		3	Brachythecium rutabulum	species
		4	Bazzania trilobata	species
		5	Thuidium delicatulum	species
		6	Pelliaceae	family
		7	Atrichum crispulum	species
		8	Pseudobryum cinclidioides	species
		9	Herzogiella	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		10	Callicladium haldanianum	species
		11	Brachythecium	genus
		12	Aulacomnium palustre	species
		13	Callicladium	genus
		14	Polytrichum pallidisetum	species
bryophytes	habitat loss	1	Sphagnopsida	class
		2	Bazzania trilobata	species
		3	Polytrichum commune	species
		4	Atrichum crispulum	species
		5	Dicranum	genus
		6	Plagiomnium	genus
		7	Sphagnum girgensohnii	species
		8	Polytrichum pallidisetum	species
		9	Pelliaceae	family
		10	Atrichum	genus
		11	Climacium dendroides	species
bryophytes	edge predators	1	Sphagnopsida	class
		2	Bazzania trilobata	species
		3	Atrichum	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		4	Plagiothecium denticulatum	species
		5	Brachytheciaceae	family
		6	Plagiomnium ciliare	species
		7	Sphagnum subsecundum	species
		8	Jungermanniaceae	family
		9	Pelliaceae	family
		10	Plagiomnium	genus
		11	Dicranum flagellare	species
		12	Rhizomnium	genus
		13	Calypogeia fissa	species
bryophytes	non-native invasive plants	1	Sphagnopsida	class
		2	Atrichum	genus
		3	Brachytheciaceae	family
		4	Aulacomnium palustre	species
		5	Plagiomnium	genus
		6	Climacium dendroides	species
		7	Sphagnum subsecundum	species
		8	Pallavicinia lyellii	species
		9	Plagiothecium denticulatum	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		10	Calliergon	genus
		11	Jamesoniella autumnalis	species
		12	Brachythecium rutabulum	species
		13	Calypogeia fissa	species
		14	Callicladium haldanianum	species
		15	Pelliaceae	family
		16	Brachythecium salebrosum	species
		17	Atrichum altecristatum	species
bryophytes	(watershed) habitat loss	1	Sphagnopsida	class
		2	Aulacomnium palustre	species
		3	Bryhnia novae-angliae	species
		4	Hypnum	genus
		5	Thuidium delicatulum	species
		6	Pseudobryum cinclidioides	species
		7	Polytrichum	genus
		8	Sphagnum subsecundum	species
		9	Atrichum crispulum	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		10	Pelliaceae	family
		11	Brachythecium rutabulum	species
epiphytic macrolichens	*index of ecological integrity (IEI)*	1	Phaeophyscia rubropulchra	species
		2	Cetraria oakesiana	species
		3	Parmeliaceae	family
		4	Punctelia perreticulata	species
epiphytic macrolichens	non-native invasive plants	1	Parmeliaceae	family
		2	Cetraria oakesiana	species
		3	Cladonia coniocraea	species
		4	Cladoniaceae	family
		5	Physciaceae	family
		6	Phaeophyscia pusilloides	species
diatoms	*index of ecological integrity (IEI)*	1	Gomphonema parvulum	species
		2	Eunotia curvata	species
		3	Navicula minima	species
		4	Eunotia carolina	species
		5	Fragilaria vaucheriae	species
		6	Nitzschia dissipata	species
		7	Fragilariophyceae	class

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		8	Encyonema	genus
		9	Eunotia subarcuatoides	species
		10	Eunotia incisa	species
		11	Eunotia parallela	species
		12	Eunotia fallax	species
		13	Navicula festiva	species
		14	Tabellariales	order
		15	Navicula praeterita	species
		16	Neidium bisulcatum	species
		17	Tabellariaceae	family
diatoms	non-native invasive plants	1	Gomphonemataceae	family
		2	Nitzschia dissipata	species
		3	Encyonema	genus
		4	Fragilariforma	genus
		5	Eunotia elegans	species
		6	Navicula minima	species
		7	Surirellales	order
		8	Eunotia parallela	species
		9	Pinnularia viridis	species
		10	Planothidium frequentissimum	species
		11	Eunotia curvata	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		12	Bacillariales	order
		13	Pinnularia acrosphaeria	species
		14	Aulacoseira crenulata	species
		15	Eunotia serra	species
		16	Cymbella cuspidata	species
		17	Surirella	genus
		18	Pinnularia brebissonii	species
		19	Nitzschia gracilis	species
		20	Eunotia girdle	species
		21	Pinnularia girdle	species
		22	Bacillariophyta	division.phylum
		23	Navicula	genus
diatoms	edge predators	1	Gomphonema parvulum	species
		2	Nitzschia	genus
		3	Planothidium frequentissimum	species
		4	Eunotia elegans	species
		5	Sellaphoraceae	family
		6	Eunotia carolina	species
		7	Synedra acus	species
		8	Tabellaria flocculosa	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		9	Pinnularia obscura	species
		10	Pinnularia viridis	species
		11	Caloneis bacillum	species
		12	Eunotia parallela	species
		13	Navicula variostriata	species
		14	Stenopterobia	genus
		15	Eunotia girdle	species
		16	Pinnularia girdle	species
		17	Bacillariophyta	division.phylum
		18	Navicula	genus
diatoms	(watershed) nutrient enrichment	1	Gomphonema parvulum	species
		2	Navicula minima	species
		3	Eunotia implicata	species
		4	Eunotia carolina	species
		5	Caloneis bacillum	species
		6	Sellaphoraceae	family
		7	Eunotia curvata	species
		8	Frustulia krammeri	species
		9	Eunotia elegans	species
		10	Nitzschia frustulum	species
		11	Eunotia minor	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		12	Eunotia rhomboidea	species
		13	Eunotia fallax	species
		14	Luticola mutica	species
		15	Navicula praeterita	species
		16	Nitzschia dissipata	species
		17	Caloneis	genus
diatoms	(watershed) road sediment	1	Gomphonemataceae	family
		2	Fragilariforma	genus
		3	Navicula minima	species
		4	Chamaepinnularia	genus
		5	Eunotia minor	species
		6	Tabellaria	genus
		7	Nitzschia acidoclinata	species
		8	Eunotia subarcuatoides	species
		9	Pinnularia rupestris	species
		10	Navicula festiva	species
		11	Achnanthidium minutissimum	species
		12	Diadesmis contenta	species
		13	Eunotia rhomboidea	species
		14	Navicula cryptotenella	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		15	Tabellaria flocculosa	species
		16	Encyonema silesiacum	species
		17	Bacillariophyta	division.phylum
		18	Caloneis bacillum	species
		19	Eunotia girdle	species
		20	Meridion circulare	species
		21	Pinnularia girdle	species
		22	Sellaphora pupula	species
		23	Meridion	genus
diatoms	habitat loss	1	Gomphonema parvulum	species
		2	Navicula minima	species
		3	Nitzschia	genus
		4	Eunotia rhomboidea	species
		5	Eunotia minor	species
		6	Navicula praeterita	species
		7	Frustulia saxonica	species
		8	Eunotia carolina	species
		9	Eunotia elegans	species
		10	Surirella	genus
		11	Fragilariophyceae	class
		12	Staurosira	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		13	Nitzschia acidoclinata	species
		14	Chamaepinnularia soehrensis	species
		15	Navicula festiva	species
		16	Navicula tantula	species
		17	Eunotia septentrionalis	species
		18	Eunotia parallela	species
		19	Eunotia girdle	species
		20	Pinnularia girdle	species
		21	Bacillariophyta	division.phylum
		22	Caloneis	genus
		23	Navicula	genus
diatoms	(watershed) habitat loss	1	Gomphonema parvulum	species
		2	Navicula minima	species
		3	Fragilariophyceae	class
		4	Eunotia minor	species
		5	Eunotia carolina	species
		6	Tabellariales	order
		7	Eunotia rhomboidea	species
		8	Eunotia curvata	species
		9	Navicula festiva	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		10	Nitzschia acidoclinata	species
		11	Nitzschia frustulum	species
		12	Surirella	genus
		13	Chamaepinnularia	genus
		14	Aulacoseira crenulata	species
		15	Eunotia septentrionalis	species
		16	Coscinodiscophyceae	class
		17	Tabellaria flocculosa	species
		18	Caloneis bacillum	species
		19	Chamaepinnularia soehrensis	species
		20	Encyonema silesiacum	species
		21	Eunotia girdle	species
		22	Meridion circulare	species
		23	Pinnularia girdle	species
		24	Sellaphora pupula	species
		25	Bacillariophyta	division.phylum
		26	Meridion	genus
diatoms	non-native invasive worms	1	Gomphonema parvulum	species
		2	Bacillariales	order
		3	Pinnularia viridis	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		4	Tabellaria flocculosa	species
		5	Surirella	genus
		6	Planothidium frequentissimum	species
		7	Synedra acus	species
		8	Pinnularia obscura	species
		9	Nitzschia gracilis	species
		10	Eunotia parallela	species
		11	Chamaepinnularia	genus
		12	Meridion circulare	species
		13	Meridion	genus
		14	Bacillariophyta	division.phylum
		15	Eunotia girdle	species
		16	Pinnularia girdle	species
		17	Navicula	genus
diatoms	similarity	1	Gomphonema parvulum	species
		2	Navicula minima	species
		3	Planothidium	genus
		4	Nitzschia	genus
		5	Nitzschia acidoclinata	species
		6	Eunotia minor	species
		7	Eunotia parallela	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		8	Nitzschia dissipata	species
		9	Eunotia curvata	species
		10	Nitzschia gracilis	species
		11	Neidium bisulcatum	species
		12	Surirella	genus
		13	Encyonema minutum	species
		14	Eunotia carolina	species
		15	Staurosira construens	species
		16	Eunotia perpusilla	species
		17	Chamaepinnularia	genus
		18	Pinnularia hilseana	species
		19	Tabellaria flocculosa	species
		20	Navicula cryptotenella	species
		21	Pinnularia viridis	species
		22	Eunotia bilunaris	species
		23	Neidium ampliatum	species
		24	Eunotia subarcuatoides	species
		25	Pinnularia acrosphaeria	species
		26	Eunotia naegelii	species
		27	Navicula tantula	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		28	Fragilariales	order
		29	Navicula festiva	species
		30	Caloneis	genus
		31	Chamaepinnularia soehrensis	species
		32	Caloneis bacillum	species
		33	Eunotia girdle	species
		34	Pinnularia girdle	species
		35	Bacillariophyta	division.phylum
		36	Navicula	genus
diatoms	connectedness	1	Bacillariales	order
		2	Tabellaria flocculosa	species
		3	Eunotia subarcuatoides	species
		4	Eunotia glacialis	species
		5	Nupela	genus
		6	Planothidium frequentissimum	species
		7	Stenopterobia	genus
		8	Pinnularia nodosa	species
		9	Eunotia carolina	species
		10	Eunotia pectinalis	species
		11	Eunotia incisa	species
		12	Navicula minima	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		13	Navicula festiva	species
		14	Navicula tantula	species
		15	Meridion circulare	species
		16	Eunotia girdle	species
		17	Pinnularia girdle	species
		18	Navicula	genus
macro-invertebrates	*index of ecological integrity (IEI)*	1	P Hymenoptera	order
		2	Lumbricidae	family
		3	E Psychodidae	family
		4	P Parisotoma notabilis	species
		5	E Culicidae	family
		6	P Eucoilidae	family
		7	P Pheidole	genus
		8	P Pirata insularis	species
		9	P Pogonognathellus bidentatus	species
		10	P Sinella recens	species
		11	E Arachnida	class
		12	P Pseudosinella octopunctata	species
		13	E Culex	genus
		14	P Onychiuridae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		15	P Gastropoda	class
		16	E Carnidae	family
		17	E Tipulidae	family
		18	P Gryllidae	family
		19	P Mollusca	division.phylum
		20	P Staphylinidae	family
		21	P Orthoptera	order
		22	P Pulmonata	order
		23	P Pirata	genus
		24	E Empididae	family
		25	E Phoridae	family
		26	E Acari	order
		27	P Cantharidae	family
		28	P Lepidoptera	order
		29	P Pseudachorutes	genus
		30	P Hypogastrura	genus
		31	P Neoantistea magna	species
		32	P Arachnida	class
		33	P Diptera	order
		34	P Acari	order
		35	P Hemiptera	order
		36	P Coleoptera	order

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		37	P Araneae	order
		38	P Cicadellidae	family
		39	P Carabidae	family
		40	P Hahniidae	family
		41	P Sciaridae	family
		42	P Pterostichus	genus
		43	P Scaphoideus	genus
		44	P Tomocerus	genus
		45	P Trimorus	genus
		46	E Cecidomyiidae	family
macro-invertebrates	connectedness	1	P Hymenoptera	order
		2	Lumbricidae	family
		3	E Psychodidae	family
		4	P Pheidole	genus
		5	E Culicidae	family
		6	P Ceratophysella virga	species
		7	E Phoridae	family
		8	P Platygastridae	family
		9	P Eucoilidae	family
		10	P Parisotoma notabilis	species
		11	E Plecoptera	order

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		12	P Protaphorura armata	species
		13	P Agallia	genus
		14	E Insecta	class
		15	E Leuctridae	family
		16	P Isotomidae	family
		17	P Sinella recens	species
		18	E Arachnida	class
		19	P Pirata insularis	species
macro-invertebrates	habitat loss	1	Lumbricidae	family
		2	P Scelionidae	family
		3	E Psychodidae	family
		4	P Pheidole	genus
		5	Dendrobaena octaedra	species
		6	Lumbricus	genus
		7	P Eucoilidae	family
		8	E Hymenoptera	order
		9	E Plecoptera	order
		10	P Ptenothrix	genus
		11	E Hemiptera	order
		12	P Gryllidae	family
		13	P Epidapus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		14	E Scelionidae	family
		15	P Parisotoma notabilis	species
		16	P Mycetophilidae	family
		17	P Lycosidae	family
		18	P Lepidoptera	order
		19	P Mollusca	division.phylum
		20	P Neoantistea magna	species
		21	P Arachnida	class
		22	P Gastropoda	class
		23	P Hypogastrura	genus
		24	P Diptera	order
		25	P Acari	order
		26	P Hemiptera	order
		27	P Coleoptera	order
		28	P Araneae	order
		29	P Cicadellidae	family
		30	P Carabidae	family
		31	P Hahniidae	family
		32	P Sciaridae	family
		33	P Pterostichus	genus
		34	P Scaphoideus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		35	P Tomocerus	genus
		36	P Trimorus	genus
		37	E Cecidomyiidae	family
		38	middens	NA
macro-invertebrates	non-native invasive worms	1	middens	NA
		2	P Ceraphronidae	family
		3	E Hemiptera	order
		4	P Epidapus	genus
		5	P Amaurobiidae	family
		6	P Pseudachorutes	genus
		7	P Neoantistea magna	species
		8	P Arachnida	class
		9	P Diptera	order
		10	P Acari	order
		11	P Hemiptera	order
		12	P Coleoptera	order
		13	P Araneae	order
		14	P Cicadellidae	family
		15	P Carabidae	family
		16	P Hahniidae	family
		17	P Sciaridae	family

Ecological system					
	Taxonomic group	Stressor Metric	Step	Taxon	Level
			18	P Hypogastrura	genus
			19	P Pterostichus	genus
			20	P Scaphoideus	genus
			21	P Tomocerus	genus
			22	P Trimorus	genus
			23	E Cecidomyiidae	family
	macro-invertebrates	microclimate alterations	1	P Pheidole	genus
			2	Lumbricidae	family
			3	E Braconidae	family
			4	P Pseudosinella octopunctata	species
			5	P Eucoilidae	family
			6	Lumbricus	genus
			7	P Pirata insularis	species
			8	P Mymaridae	family
			9	P Myrmecina	genus
			10	E Phoridae	family
			11	P Pirata	genus
			12	P Pogonognathellus bidentatus	species
			13	P Linyphiidae	family
			14	P Neoantistea magna	species
			15	P Arachnida	class

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		16	P Diptera	order
		17	P Acari	order
		18	P Hemiptera	order
		19	P Coleoptera	order
		20	P Araneae	order
		21	P Orthoptera	order
		22	P Cicadellidae	family
		23	P Carabidae	family
		24	P Hahniidae	family
		25	P Sciaridae	family
		26	P Gryllidae	family
		27	P Neoantistea	genus
		28	P Pterostichus	genus
		29	P Scaphoideus	genus
		30	P Tomocerus	genus
		31	P Trimorus	genus
		32	E Cecidomyiidae	family
		33	middens	NA
macro-invertebrates	edge predators	1	middens	NA
		2	P Pseudachorutes	genus
		3	P Neoantistea magna	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		4	P Arachnida	class
		5	P Diptera	order
		6	P Acari	order
		7	P Hemiptera	order
		8	P Coleoptera	order
		9	P Araneae	order
		10	P Cicadellidae	family
		11	P Carabidae	family
		12	P Hahniidae	family
		13	P Sciaridae	family
		14	P Neoantistea	genus
		15	P Pterostichus	genus
		16	P Scaphoideus	genus
		17	P Tomocerus	genus
		18	P Trimorus	genus
		19	E Cecidomyiidae	family
macro-invertebrates	similarity	1	Lumbricidae	family
		2	E Psychodidae	family
		3	P Scelionidae	family
		4	P Parisotoma notabilis	species
		5	Lumbricus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		6	E Hemiptera	order
		7	P Leptothorax	genus
		8	P Neanuridae	family
		9	E Culicidae	family
		10	P Pirata insularis	species
		11	P Lycosidae	family
		12	P Orthoptera	order
		13	P Linyphiidae	family
		14	P Neoantistea magna	species
		15	P Mollusca	division.phylum
		16	P Arachnida	class
		17	P Diptera	order
		18	P Acari	order
		19	P Hemiptera	order
		20	P Coleoptera	order
		21	P Araneae	order
		22	P Cicadellidae	family
		23	P Carabidae	family
		24	P Hahniidae	family
		25	P Sciaridae	family
		26	P Neoantistea	genus
		27	P Pterostichus	genus

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		28	P Scaphoideus	genus
		29	P Tomocerus	genus
		30	P Trimorus	genus
		31	E Cecidomyiidae	family
macro-invertebrates	non-native invasive plants	1	middens	NA
		2	P Orthoptera	order
		3	P Drosophila	genus
		4	P Hypogastrura	genus
		5	P Neoantistea magna	species
		6	P Arachnida	class
		7	P Diptera	order
		8	P Acari	order
		9	P Hemiptera	order
		10	P Coleoptera	order
		11	P Araneae	order
		12	P Cicadellidae	family
		13	P Carabidae	family
		14	P Hahniidae	family
		15	P Sciaridae	family
		16	P Neoantistea	genus
		17	P Pterostichus	genus

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		18	P Scaphoideus	genus
		19	P Tomocerus	genus
		20	P Trimorus	genus
		21	E Cecidomyiidae	family
macro-invertebrates	wetland buffer insults	1	P Hymenoptera	order
		2	P Bradysia	genus
		3	E Culex	genus
		4	P Mymaridae	family
		5	P Parisotoma notabilis	species
		6	P Ichneumonidae	family
		7	Lumbricus	genus
		8	P Mycetophila	genus
		9	P Agallia	genus
		10	P Myrmecina	genus
		11	P Protaphorura armata	species
B) pitfall traps	*index of ecological integrity (IEI)*	1	P Hymenoptera	order
		2	P Bradysia	genus
		3	P Onychiurus	genus
		4	P Psychodidae	family
		5	P Pheidole	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		6	P Pseudosinella octopunctata	species
		7	P Pseudisotoma monochaeta	species
		8	P Isopoda	order
		9	P Protaphorura armata	species
		10	P Eubaeocera	genus
		11	P Parisotoma notabilis	species
		12	P Pseudisotoma	genus
		13	P Protaphorura	genus
		14	P Nitidulidae	family
		15	P Ptenothrix marmorata	species
		16	P Empididae	family
		17	P Neoantistea magna	species
		18	P Arachnida	class
		19	P Diptera	order
		20	P Acari	order
		21	P Hemiptera	order
		22	P Coleoptera	order
		23	P Araneae	order
		24	P Cicadellidae	family
		25	P Carabidae	family

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		26	P Amaurobiidae	family
		27	P Hahniidae	family
		28	P Linyphiidae	family
		29	P Dicyrtoma	genus
		30	P Hypogastrura	genus
		31	P Neoantistea	genus
		32	P Pseudachorutes	genus
		33	P Pterostichus	genus
		34	P Scaphoideus	genus
		35	P Sciara	genus
		36	P Tomocerus	genus
		37	P Trimorus	genus
		38	P Wadotes	genus
B) pitfall traps	connectedness	1	P Pheidole	genus
		2	P Dicyrtomidae	family
		3	P Leptothorax	genus
		4	P Onychiurus	genus
		5	P Isopoda	order
		6	P Ptenothrix	genus
		7	P Ptenothrix marmorata	species
		8	P Katiannidae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		9	P Myrmica	genus
		10	P Eucoilidae	family
		11	P Thysanoptera	order
		12	P Crustacea	class
		13	P Synuchus impunctatus	species
		14	P Neoantistea agilis	species
		15	P Neoantistea magna	species
		16	P Arachnida	class
		17	P Diptera	order
		18	P Acari	order
		19	P Hemiptera	order
		20	P Coleoptera	order
		21	P Araneae	order
		22	P Cicadellidae	family
		23	P Carabidae	family
		24	P Hahniidae	family
		25	P Dicyrtoma	genus
		26	P Neoantistea	genus
		27	P Pseudachorutes	genus
		28	P Pterostichus	genus
		29	P Scaphoideus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		30	P Tomocerus	genus
		31	P Trimorus	genus
B) pitfall traps	non-native invasive worms	1	P Pheidole	genus
		2	P Crustacea	class
		3	P Neanuridae	family
		4	P Lasius	genus
		5	P Dicyrtoma aurata	species
		6	P Brachystomella curvula	species
		7	P Protaphorura armata	species
		8	P Cicurina	genus
		9	P Wadotes	genus
		10	P Empididae	family
		11	P Arthropoda	division.phylum
		12	P Neoantistea agilis	species
		13	P Neoantistea magna	species
		14	P Ptenothrix marmorata	species
		15	P Arachnida	class
		16	P Diptera	order
		17	P Acari	order
		18	P Hemiptera	order

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		19	P Coleoptera	order
		20	P Araneae	order
		21	P Collembola	order
		22	P Cicadellidae	family
		23	P Carabidae	family
		24	P Amaurobiidae	family
		25	P Hahniidae	family
		26	P Linyphiidae	family
		27	P Dicyrtoma	genus
		28	P Hypogastrura	genus
		29	P Neoantistea	genus
		30	P Pseudachorutes	genus
		31	P Ptenothrix	genus
		32	P Pterostichus	genus
		33	P Scaphoideus	genus
		34	P Tomocerus	genus
		35	P Trimorus	genus
All-stepwise	connectedness	1	Coptis trifolia	species
		2	Hypnum	genus
		3	Oclemena acuminata	species
		4	Nitzschia palustris	species
		5	Dicranum flagellare	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		6	Bacillariophyceae	class
		7	Rosa multiflora	species
		8	Clethra alnifolia	species
		9	Prunus	genus
		10	P Tomoceridae	family
		11	Rubiales	order
		12	Sellaphora pupula	species
		13	Navicula minima	species
		14	Dryopteris intermedia	species
		15	P Arthropoda	division.phylum
		16	Vaccinium myrtilloides	species
		17	Polytrichales	order
		18	Euonymus alata	species
		19	Eunotia flexuosa	species
		20	Physocarpus opulifolius	species
		21	Eunotia glacialis	species
		22	Aster	genus
		23	Pellia epiphylla	species
		24	Fragilariophyceae	class
		25	Phaeophyscia pusilloides	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		26	Lycopus	genus
		27	P Mymaridae	family
		28	E Muscidae	family
		29	Aster divaricatus	species
		30	P Onychiuridae	family
		31	Maianthemum canadense	species
		32	P Bourletielliidae	family
		33	Eunotia steineckei	species
		34	Cicuta	genus
		35	Climacium dendroides	species
		36	P Pirata	genus
		37	E Hemiptera	order
		38	Chamaepinnularia	genus
		39	Gomphonema parvulum	species
		40	P Neoantistea	genus
		41	P Arachnida	class
		42	P Diptera	order
		43	P Acari	order
		44	P Hemiptera	order
		45	P Coleoptera	order
		46	P Araneae	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		47	P Cicadellidae	family
		48	P Carabidae	family
		49	P Sciaridae	family
		50	P Pterostichus	genus
		51	P Tomocerus	genus
		52	P Trimorus	genus
		53	middens	NA
		54	Encyonema silesiacum	species
		55	P Scaphoideus	genus
		56	Eunotia elegans	species
		57	Meridion circulare	species
		58	Navicula variostriata	species
		59	Pinnularia girdle	species
		60	Pinnularia obscura	species
		61	Bacillariophyta	division.phylum
		62	Fragilariales	order
		63	Meridion	genus
		64	Navicula	genus
		65	P Orthoptera	order
		66	P Neoantistea magna	species
		67	E Cecidomyiidae	family

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		68	Eunotia rhomboidea	species
		69	Luticola	genus
		70	P Nitidulidae	family
		71	Pinnularia brebissonii	species
		72	Fragilariaceae	family
		73	Pinnularia borealis	species
		74	P Agonum fidele	species
		75	P Agonum	genus
		76	P Pallodes pallidus	species
		77	P Pallodes	genus
		78	Neidium bisulcatum	species
		79	Eunotia girdle	species
		80	P Gryllidae	family
		81	P Linyphiidae	family
		82	Dendrobaena octaedra	species
		83	Pinnularia rupestris	species
		84	Brachyelytrum septentrionale	species
		85	Maianthemum	genus
		86	Eunotia tenella	species
		87	Cornus alternifolia	species
		88	Pinnularia viridis	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		89	Naviculaceae	family
		90	Polytrichaceae	family
		91	Pinnularia nodosa	species
		92	Fragilariforma	genus
		93	Luticola mutica	species
		94	Dendrobaena	genus
		95	Pinnularia termitina	species
		96	P Hahniidae	family
		97	Gomphonema gracile	species
		98	Eunotia paludosa	species
All-stepwise	non-native invasive worms	1	Urticales	order
		2	Achnanthidium minutissimum	species
		3	Sphagnum subsecundum	species
		4	Cladonia coniocraea	species
		5	Rubus	genus
		6	E Ceraphronidae	family
		7	Leucobryum glaucum	species
		8	E Psychodidae	family
		9	Pinnularia maior	species
		10	Stauroneis anceps	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		11	Planothidium frequentissimum	species
		12	P Ceraphronidae	family
		13	P Sinella recens	species
		14	P Parisotoma notabilis	species
		15	Cetraria oakesiana	species
		16	P Bourletielliidae	family
		17	Jungermanniaceae	family
		18	Amblystegiaceae	family
		19	Betulaceae	family
		20	Vaccinium angustifolium	species
		21	Sambucus canadensis	species
		22	Fagales	order
		23	Bacillariophyceae	class
		24	E Hemiptera	order
		25	P Dicyrtoma aurata	species
		26	Polytrichum commune	species
		27	Cymbella	genus
		28	Eunotia serra	species
		29	Nitzschia acidoclinata	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		30	Celastrales	order
		31	Calliergon	genus
		32	Gomphonema parvulum	species
		33	Navicula festiva	species
		34	P Myrmecina	genus
		35	Amelanchier	genus
		36	Clematis virginiana	species
		37	Quercus bicolor	species
		38	P Pseudobourletiella spinata	species
		39	Fragilariophyceae	class
		40	P Julida	order
		41	P Parisotoma	genus
		42	P Orthoptera	order
		43	Meridion circulare	species
		44	P Agonum fidele	species
		45	P Neoantistea magna	species
		46	P Mollusca	division.phylum
		47	P Arachnida	class
		48	P Diptera	order
		49	P Acari	order
		50	P Hemiptera	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		51	P Coleoptera	order
		52	P Araneae	order
		53	P Cicadellidae	family
		54	P Carabidae	family
		55	P Hahniidae	family
		56	P Sciaridae	family
		57	P Pterostichus	genus
		58	P Scaphoideus	genus
		59	P Tomocerus	genus
		60	E Cecidomyiidae	family
		61	Sellaphora pupula	species
		62	Tabellaria quadrisepta	species
		63	Pinnularia girdle	species
		64	Pinnularia obscura	species
		65	Bacillariophyta	division.phylum
		66	Naviculaceae	family
		67	Meridion	genus
		68	Navicula	genus
		69	P Staphylinidae	family
		70	Eunotia elegans	species
		71	Pinnularia brebissonii	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		72	P Gastropoda	class
		73	P Agonum	genus
		74	Fragilariales	order
		75	Fragilariaceae	family
		76	P Pulmonata	order
		77	P Linyphiidae	family
		78	P Neoantistea	genus
		79	P Platydracus viridianus	species
		80	P Platydracus	genus
		81	Pinnularia termitina	species
		82	P Hypogastrura	genus
		83	P Phoridae	family
		84	P Amaurobiidae	family
		85	P Trimorus	genus
		86	P Lycosidae	family
All-stepwise	*index of ecological integrity (IEI)*	1	Urticales	order
		2	Cetraria oakesiana	species
		3	Bryophyta	division.phylum
		4	Planothidium frequentissimum	species
		5	E Psychodidae	family
		6	Oclemena	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		7	Navicula cryptocephala	species
		8	P Lepidoptera	order
		9	Pelliaceae	family
		10	Lumbricus	genus
		11	Eunotia implicata	species
		12	Euonymus alata	species
		13	Jamesoniella autumnalis	species
		14	Equisetophyta	division.phylum
		15	Betula lenta	species
		16	Navicula festiva	species
		17	Tabellaria flocculosa	species
		18	Fagales	order
		19	Dryopteris intermedia	species
		20	Parmeliaceae	family
		21	Thalictrum pubescens	species
		22	Sphagnum subsecundum	species
		23	Fagus grandifolia	species
		24	Eunotia praerupta	species
		25	P Ceraphronidae	family
		26	Bacillariophyceae	class

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		27	Dendrobaena octaedra	species
		28	P Sinella recens	species
		29	Fragilariophyceae	class
		30	P Platygastridae	family
		31	Dendrobaena	genus
		32	Tabellariales	order
		33	Chamaepinnularia	genus
		34	P Ptenothrix marmorata	species
		35	P Ceratophysella	genus
		36	Thuidium delicatulum	species
		37	Orchidales	order
		38	Surirellales	order
		39	Luticola	genus
		40	P Cantharidae	family
		41	Diatoma anceps	species
		42	Eunotia girdle	species
		43	Encyonema silesiacum	species
		44	P Orthoptera	order
		45	P Agonum fidele	species
		46	P Arachnida	class

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		47	P Diptera	order
		48	P Acari	order
		49	P Hemiptera	order
		50	P Coleoptera	order
		51	P Araneae	order
		52	P Cicadellidae	family
		53	P Carabidae	family
		54	P Neoantistea	genus
		55	P Pterostichus	genus
		56	P Scaphoideus	genus
		57	P Tomocerus	genus
		58	P Trimorus	genus
		59	Pinnularia girdle	species
		60	Pinnularia obscura	species
		61	Eunotia elegans	species
		62	E Cecidomyiidae	family
		63	Bacillariophyta	division.phylum
		64	Meridion	genus
		65	Navicula	genus
		66	middens	NA
		67	P Neoantistea magna	species
		68	P Hahniidae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		69	Fragilariales	order
		70	Fragilariaceae	family
		71	E Mycetophilidae	family
		72	Fragilariforma virescens	species
		73	Surirellaceae	family
		74	Tabellariaceae	family
		75	Gomphonema gracile	species
		76	P Platydracus viridianus	species
		77	Eunotia naegelii	species
		78	Pinnularia acrosphaeria	species
		79	P Pterostichus coracinus	species
		80	Meridion circulare	species
All-stepwise	(watershed) nutrient enrichment	1	P Hymenoptera	order
		2	Navicula praeterita	species
		3	Boehmeria cylindrica	species
		4	Achnanthales	order
		5	Eunotia rhomboidea	species
		6	Celastrus orbiculatus	species
		7	P Platydracus viridianus	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		8	Celastrus	genus
		9	P Platygastridae	family
		10	Encyonema silesiacum	species
		11	Pinnularia hilseana	species
		12	Eunotia elegans	species
		13	P Platydracus	genus
		14	Navicula variostriata	species
		15	P Orthoptera	order
		16	P Arachnida	class
		17	P Diptera	order
		18	P Acari	order
		19	P Hemiptera	order
		20	P Coleoptera	order
		21	P Carabidae	family
		22	P Sciaridae	family
		23	P Pterostichus	genus
		24	P Tomocerus	genus
		25	P Trimorus	genus
		26	E Cecidomyiidae	family
		27	middens	NA
		28	Meridion circulare	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		29	Pinnularia girdle	species
		30	Pinnularia obscura	species
		31	Sellaphora pupula	species
		32	Bacillariophyta	division.phylum
		33	Fragilariales	order
		34	Fragilariaceae	family
		35	Meridion	genus
		36	Gomphonema parvulum	species
		37	P Cicadellidae	family
		38	P Agonum fidele	species
		39	Luticola mutica	species
		40	P Neoantistea magna	species
		41	Gomphonema angustatum	species
		42	Dicranum polysetum	species
		43	Naviculales	order
		44	Celastraceae	family
		45	Bacillariophyceae	class
		46	Pinnularia brebissonii	species
		47	Navicula tantula	species
		48	Cymbellales	order
		49	Caloneis	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		50	P Hahniidae	family
		51	Pinnularia termitina	species
		52	P Pseudachorutes	genus
		53	P Gryllidae	family
		54	Eunotia naegelii	species
		55	Betula papyrifera	species
		56	Nitzschia acidoclinata	species
		57	Carex lurida	species
		58	Boehmeria	genus
		59	Nitzschia gracilis	species
		60	Rhizomnium appalachianum	species
		61	Encyonema minutum	species
		62	Dicranum scoparium	species
		63	Planothidium lanceolatum	species
		64	Sphagnum fallax	species
		65	Eunotia bilunaris	species
		66	P Lepidoptera	order
		67	Sphagnum squarrosum	species
		68	Placoneis	genus
		69	E Hemiptera	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		70	Thelypteris palustris	species
		71	Coscinodiscophyceae	class
		72	Chamaepinnularia	genus
		73	P Neoantistea	genus
		74	Eunotia girdle	species
		75	P Pterostichus coracinus	species
		76	Planothidium	genus
		77	Picea rubens	species
		78	Oclemena acuminata	species
		79	Eunotia minor	species
		80	Placoneis elginensis	species
		81	P Onychiuridae	family
		82	Cetraria oakesiana	species
		83	Rhamnaceae	family
		84	Cornus alternifolia	species
		85	Eunotia implicata	species
		86	Nitzschia dissipata	species
		87	E Dolichopodidae	family
		88	Eunotia steineckei	species
		89	P Pseudosinella octopunctata	species
		90	Doellingeria umbellata	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		91	Polytrichum pallidisetum	species
		92	Orchidales	order
		93	Aporrectodea	genus
		94	Physcia millegrana	species
		95	Dicranaceae	family
		96	Polytrichum ohioense	species
		97	Pellia epiphylla	species
		98	Thuidium delicatulum	species
		99	Picea	genus
		100	Onoclea sensibilis	species
		101	Mnium hornum	species
		102	P Bradysia	genus
		103	P Pirata insularis	species
		104	Doellingeria	genus
		105	E Sciaridae	family
		106	Osmunda cinnamomea	species
		107	Pinnularia abaujensis	species
		108	Ascomycota	division.phylum
		109	P Camponotus	genus
		110	Punctelia	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		111	Ascomycetes	class
		112	Fragilariforma virescens	species
		113	Pinnularia viridis	species
		114	Oclemena	genus
		115	Polygonales	order
		116	Sphagnum fimbriatum	species
		117	Ilex verticillata	species
		118	Polytrichum	genus
		119	Lecanorales	order
		120	Bidens	genus
		121	Cymbella aspera	species
		122	Lysimachia	genus
		123	P Protaphorura armata	species
		124	Punctelia rudecta	species
		125	P Brachystomellidae	family
		126	P Myrmecina	genus
		127	Physcia	genus
		128	Physocarpus opulifolius	species
		129	Sphagnum subsecundum	species
		130	P Braconidae	family

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		131	Pelliaceae	family
		132	P Brachystomella	genus
		133	Cladoniaceae	family
		134	E Braconidae	family
		135	Polygonaceae	family
		136	Ranunculus	genus
		137	Hydrocotyle americana	species
		138	P Protaphorura	genus
		139	P Amaurobiidae	family
		140	Calypogeia fissa	species
		141	P Ichneumonidae	family
		142	Pinnularia acrosphaeria	species
All-stepwise	(watershed) habitat loss	1	Primulales	order
		2	Metzgeriales	order
		3	Cetraria oakesiana	species
		4	P Onychiuridae	family
		5	Nitzschia	genus
		6	Oclemena	genus
		7	P Formicidae	family
		8	E Psychodidae	family
		9	Polygonales	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		10	P Lepidoptera	order
		11	Cymbella aspera	species
		12	Dryopteris	genus
		13	Anemone quinquefolia	species
		14	Cymbella cuspidata	species
		15	Pinnularia hilseana	species
		16	Eunotia implicata	species
		17	Pinnularia abaujensis	species
		18	Diadesmis	genus
		19	P Myrmecina	genus
		20	P Brachystomellidae	family
		21	Eunotia soleirolii	species
		22	E Hemiptera	order
		23	Chamaepinnularia	genus
		24	Navicula praeterita	species
		25	P Araneae	order
		26	Gomphonema angustatum	species
		27	Diatoma anceps	species
		28	Brachyelytrum septentrionale	species
		29	Achnanthidiaceae	family
		30	Melanelixia	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
			subaurifera	
		31	Eunotia naegelii	species
		32	P Agonum fidele	species
		33	P Arachnida	class
		34	P Diptera	order
		35	P Acari	order
		36	P Hemiptera	order
		37	P Coleoptera	order
		38	P Cicadellidae	family
		39	P Carabidae	family
		40	P Sciaridae	family
		41	P Pterostichus	genus
		42	P Tomocerus	genus
		43	P Trimorus	genus
		44	E Cecidomyiidae	family
		45	middens	NA
		46	Encyonema silesiacum	species
		47	Meridion circulare	species
		48	Navicula variostriata	species
		49	Pinnularia girdle	species
		50	Pinnularia obscura	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		51	Sellaphora pupula	species
		52	Bacillariophyta	division.phylum
		53	Fragilariales	order
		54	Fragilariaceae	family
		55	Meridion	genus
		56	Gomphonema parvulum	species
		57	Luticola mutica	species
		58	Melanelixia	genus
		59	Pinnularia brebissonii	species
		60	Navicula	genus
		61	Cymbellales	order
		62	Maianthemum canadense	species
		63	P Sinella recens	species
		64	P Protaphorura armata	species
		65	Eunotia subarcuatoides	species
		66	Nitzschia palea	species
		67	Dryopteris intermedia	species
		68	E Braconidae	family
		69	P Protaphorura	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		70	Eunotia tenella	species
		71	Eunotia flexuosa	species
		72	Amblystegiaceae	family
		73	Punctelia	genus
		74	P Ptenothrix	genus
		75	P Amaurobiidae	family
		76	Fragilariforma virescens	species
		77	P Gryllidae	family
		78	Aster	genus
		79	Eunotia elegans	species
		80	P Neoantistea magna	species
		81	P Wadotes	genus
		82	Scrophulariaceae	family
		83	Encyonema minutum	species
		84	P Platydracus viridianus	species
		85	P Epidapus	genus
		86	Caloneis	genus
		87	Eunotia girdle	species
		88	Tabellaria quadrisepta	species
All-stepwise	similarity	1	Urticales	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		2	Juglandales	order
		3	Cornus canadensis	species
		4	Rosa multiflora	species
		5	Oclemena	genus
		6	P Myrmecina	genus
		7	Lumbricus	genus
		8	Cymbella	genus
		9	Hypnaceae	family
		10	Staurosira	genus
		11	Viburnum lantanoides	species
		12	Pinnularia nodosa	species
		13	Medeola virginiana	species
		14	Eunotia implicata	species
		15	Monotropa uniflora	species
		16	Eunotia rhomboidea	species
		17	Navicula praeterita	species
		18	Bacillariophyceae	class
		19	Eunotia naegelii	species
		20	Carex debilis	species
		21	Encyonema minutum	species
		22	Sellaphora pupula	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		23	Planothidium frequentissimum	species
		24	Sphagnum girgensohnii	species
		25	E Psychodidae	family
		26	Pinnularia hilseana	species
		27	E Hemiptera	order
		28	Stauroforma exiguiformis	species
		29	Nitzschia gracilis	species
		30	Meridion circulare	species
		31	P Mollusca	division.phylum
		32	P Arachnida	class
		33	P Diptera	order
		34	P Acari	order
		35	P Hemiptera	order
		36	P Coleoptera	order
		37	P Araneae	order
		38	P Cicadellidae	family
		39	P Carabidae	family
		40	P Hahniidae	family
		41	P Sciaridae	family
		42	P Pterostichus	genus
		43	P Scaphoideus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		44	P Tomocerus	genus
		45	P Trimorus	genus
		46	middens	NA
		47	Pinnularia girdle	species
		48	Pinnularia obscura	species
		49	Bacillariophyta	division.phylum
		50	Navicula	genus
		51	Pinnularia brebissonii	species
		52	P Gastropoda	class
		53	E Cecidomyiidae	family
		54	Diatoma	genus
		55	Luticola mutica	species
		56	Navicula variostriata	species
		57	Fragilariophyceae	class
		58	P Epidapus	genus
		59	P Platydracus viridianus	species
		60	P Julida	order
		61	P Hypogastrura	genus
		62	P Platydracus	genus
		63	Gomphonema parvulum	species
		64	Fragilariales	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		65	P Orthoptera	order
		66	P Agonum fidele	species
		67	Eunotia elegans	species
		68	Caloneis	genus
		69	Meridion	genus
		70	Fragilariaceae	family
		71	Pinnularia borealis	species
		72	P Neoantistea magna	species
		73	Encyonema silesiacum	species
		74	P Agonum	genus
		75	P Linyphiidae	family
		76	Planothidium	genus
		77	P Dicyrtoma	genus
		78	P Pirata	genus
		79	Monotropaceae	family
		80	Thelypteridaceae	family
		81	P Staphylinidae	family
		82	Nitzschia acidoclinata	species
		83	P Pulmonata	order
		84	Celastrales	order
		85	Tabellariales	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		86	E Muscidae	family
		87	Naviculaceae	family
		88	Eunotia flexuosa	species
		89	P Gryllidae	family
		90	P Pterostichus coracinus	species
		91	Eunotia girdle	species
		92	Neidium bisulcatum	species
		93	Navicula tantula	species
		94	Stauroforma	genus
		95	Gomphonema angustatum	species
		96	Jungermanniaceae	family
		97	Sambucus canadensis	species
		98	Cetraria oakesiana	species
		99	Pallavicinia lyellii	species
		100	Euonymus alata	species
		101	E Empididae	family
		102	P Dicyrtomidae	family
		103	Punctelia rudecta	species
		104	P Wadotes	genus
All-stepwise	(watershed) road sediment	1	Symplocarpus foetidus	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		2	Pseudobryum cinclidioides	species
		3	Gaultheria	genus
		4	Carex lurida	species
		5	Cetraria oakesiana	species
		6	Stauroneis phoenicentron	species
		7	Luticola mutica	species
		8	Nitzschia acidoclinata	species
		9	Quercus alba	species
		10	Eunotia tenella	species
		11	P Thysanoptera	order
		12	Orchidales	order
		13	Eunotia septentrionalis	species
		14	Pinnularia acrosphaeria	species
		15	Achnanthales	order
		16	Corylus cornuta	species
		17	Malus pumila	species
		18	Sambucus canadensis	species
		19	Sellaphora pupula	species
		20	Oclemena acuminata	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		21	Betula papyrifera	species
		22	Placoneis	genus
		23	Neidium bisulcatum	species
		24	E Hemiptera	order
		25	Achnanthidium minutissimum	species
		26	E Plecoptera	order
		27	Euonymus alata	species
		28	Pleurozium schreberi	species
		29	P Mymaridae	family
		30	Anemone quinquefolia	species
		31	Clematis virginiana	species
		32	Aulacoseira crenulata	species
		33	Cymbella cuspidata	species
		34	Fabales	order
		35	Staurosira	genus
		36	Melanelixia subaurifera	species
		37	Gomphonemataceae	family
		38	Gomphonema	genus
		39	Gomphonema angustatum	species
		40	Eunotia naegelii	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		41	Fabaceae	family
		42	Gaultheria procumbens	species
		43	Nitzschia frustulum	species
		44	P Neoantistea	genus
		45	P Arachnida	class
		46	P Diptera	order
		47	P Acari	order
		48	P Hemiptera	order
		49	P Coleoptera	order
		50	P Cicadellidae	family
		51	P Carabidae	family
		52	P Sciaridae	family
		53	P Isotoma	genus
		54	P Pterostichus	genus
		55	P Tomocerus	genus
		56	P Trimorus	genus
		57	E Cecidomyiidae	family
		58	middens	NA
		59	Eunotia elegans	species
		60	Gomphonema parvulum	species
		61	Meridion circulare	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		62	Navicula variostriata	species
		63	Pinnularia girdle	species
		64	Pinnularia obscura	species
		65	Bacillariophyta	division.phylum
		66	Fragilariales	order
		67	Fragilariaceae	family
		68	Meridion	genus
		69	Navicula	genus
		70	Eunotia girdle	species
		71	Encyonema silesiacum	species
		72	P Hahniidae	family
		73	Pinnularia brebissonii	species
		74	Betula lenta	species
		75	Eunotia soleirolii	species
		76	Solanales	order
		77	P Onychiuridae	family
		78	Orchidaceae	family
		79	Surirellales	order
		80	Diatoma	genus
		81	Chamaepinnularia	genus
		82	Eunotia flexuosa	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		83	Caloneis	genus
		84	Cymbellales	order
		85	Staurosira construens	species
		86	Achnanthidiaceae	family
		87	Eunotia exigua	species
		88	P Pirata insularis	species
		89	P Lepidoptera	order
		90	Eunotia tautoniensis	species
		91	Hypnaceae	family
		92	P Pseudachorutes	genus
		93	P Amaurobiidae	family
		94	Diatoma anceps	species
		95	Navicula praeterita	species
		96	Dalibarda repens	species
		97	Calypogeiaceae	family
		98	Sphagnum subsecundum	species
		99	Navicula cryptocephala	species
		100	Eunotia minor	species
		101	Malus	genus
		102	P Braconidae	family
		103	Naviculaceae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		104	Melanelixia	genus
		105	Maianthemum	genus
		106	P Neoantistea magna	species
		107	P Platydracus viridianus	species
		108	Thelypteris palustris	species
		109	P Diplopoda	class
		110	Fagales	order
		111	Sphagnum flexuosum	species
		112	Phaeophyscia pusilloides	species
		113	P Bradysia	genus
		114	P Wadotes	genus
		115	Eunotia praerupta	species
		116	P Platygastridae	family
		117	P Platydracus	genus
		118	P Julida	order
		119	Gomphonema gracile	species
		120	P Cantharidae	family
All-stepwise	aquatic connectedness	1	Clethra alnifolia	species
		2	Carex stricta	species
		3	Aulacoseira crenulata	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		4	Betulaceae	family
		5	Prunus virginiana	species
		6	Hydrocotyle americana	species
		7	Sphagnum flexuosum	species
		8	Eunotia tenella	species
		9	Rubus idaeus	species
		10	Sphagnum fallax	species
		11	E Muscidae	family
		12	E Sciaridae	family
		13	Achnanthidium reimeria	species
		14	Amblystegiaceae	family
		15	Dryopteris carthusiana	species
		16	Lycopodium	genus
		17	P Ceratophysella virga	species
		18	Geraniaceae	family
		19	Pinnularia hilseana	species
		20	Encyonema silesiacum	species
		21	E Mycetophilidae	family
		22	Frustulia vulgaris	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		23	Cornales	order
		24	Parmelia sulcata	species
		25	Naviculales	order
		26	P Mymaridae	family
		27	Thelypteris palustris	species
		28	Surirellales	order
		29	Potentilla	genus
		30	Theales	order
		31	Dryopteris	genus
		32	Pinnulariaceae	family
		33	P Hypogastruridae	family
		34	Hydrocotyle	genus
		35	Nitzschia frustulum	species
		36	Eunotia flexuosa	species
		37	Polytrichum pallidisetum	species
		38	Lyonia ligustrina	species
		39	Symphyotrichum puniceum	species
		40	Eunotia girdle	species
		41	Navicula	genus
		42	Nitzschia acidoclinata	species
		43	P Drosophila	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		44	P Arachnida	class
		45	P Diptera	order
		46	P Coleoptera	order
		47	P Tomocerus	genus
		48	E Cecidomyiidae	family
		49	middens	NA
		50	Eunotia elegans	species
		51	Gomphonema parvulum	species
		52	Meridion circulare	species
		53	Navicula variostriata	species
		54	Pinnularia girdle	species
		55	Pinnularia obscura	species
		56	Bacillariophyta	division.phylum
		57	Fragilariales	order
		58	Bacillariales	order
		59	Fragilariaceae	family
		60	Bacillariaceae	family
		61	Caloneis	genus
		62	Meridion	genus
		63	Nitzschia	genus
		64	Navicula festiva	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		65	P Chironomidae	family
		66	Cymbellales	order
		67	Naviculaceae	family
		68	Malus pumila	species
		69	Calypogeiaceae	family
		70	Solidago gigantea	species
		71	Lonicera morrowii	species
		72	Synedra rumpens	species
		73	Pleurozium schreberi	species
		74	Pinnularia abaujensis	species
		75	Placoneis elginensis	species
		76	Melanelixia subaurifera	species
		77	Gomphonemataceae	family
		78	Cymbella	genus
		79	Gomphonema	genus
		80	Stauroneis phoenicentron	species
		81	Eunotia naegelii	species
		82	P Sciaridae	family
		83	Navicula praeterita	species
		84	Fragilariforma virescens	species
		85	Pinnularia borealis	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		86	Stauroneis kriegeri	species
		87	Pinnularia termitina	species
All-stepwise	microclimate alterations	1	Maianthemum racemosum	species
		2	Anacardiaceae	family
		3	Rubus	genus
		4	P Mymaridae	family
		5	Pinnularia termitina	species
		6	Navicula variostriata	species
		7	Cymbellales	order
		8	Achnanthidium reimeria	species
		9	Bryales	order
		10	P Hymenoptera	order
		11	Malus pumila	species
		12	P Ceratophysella virga	species
		13	Fagus grandifolia	species
		14	Surirellales	order
		15	Berberis thunbergii	species
		16	Lindera benzoin	species
		17	Fragilariforma virescens	species
		18	Pellia epiphylla	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		19	P Myrmecina	genus
		20	P Wadotes	genus
		21	Stauroneis phoenicentron	species
		22	Encyonema silesiacum	species
		23	Luticola mutica	species
		24	P Neoantistea magna	species
		25	P Platydracus viridianus	species
		26	P Linyphiidae	family
		27	P Arachnida	class
		28	P Diptera	order
		29	P Acari	order
		30	P Hemiptera	order
		31	P Coleoptera	order
		32	P Araneae	order
		33	P Orthoptera	order
		34	P Staphylinidae	family
		35	P Cicadellidae	family
		36	P Carabidae	family
		37	P Hahniidae	family
		38	P Sciaridae	family
		39	P Gryllidae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		40	P Pterostichus	genus
		41	P Scaphoideus	genus
		42	P Tomocerus	genus
		43	P Trimorus	genus
		44	middens	NA
		45	Eunotia elegans	species
		46	Gomphonema parvulum	species
		47	Meridion circulare	species
		48	Pinnularia brebissonii	species
		49	Pinnularia girdle	species
		50	Pinnularia rupestris	species
		51	Bacillariophyta	division.phylum
		52	Fragilariales	order
		53	Fragilariaceae	family
		54	Meridion	genus
		55	Navicula	genus
		56	E Cecidomyiidae	family
		57	P Neoantistea	genus
		58	Stauroneis kriegeri	species
		59	Neidium bisulcatum	species
		60	P Cantharidae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		61	Pinnularia nodosa	species
		62	E Plecoptera	order
		63	Neidiaceae	family
		64	Pinnularia obscura	species
		65	Neidium	genus
		66	P Hypogastrura	genus
		67	P Agonum fidele	species
		68	Pleurozium schreberi	species
		69	Navicula tantula	species
		70	Pleurozium	genus
		71	P Agonum	genus
		72	P Amaurobiidae	family
		73	E Leuctridae	family
		74	Eunotia girdle	species
		75	E Hemiptera	order
		76	Navicula cryptocephala	species
		77	P Platydracus	genus
		78	Navicula festiva	species
		79	Plagiomnium cuspidatum	species
		80	Stauroneidaceae	family
		81	Caloneis	genus

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		82	P Drosophilidae	family
		83	Navicula praeterita	species
		84	Eunotia naegelii	species
All-stepwise	(watershed) road salt	1	Bidens	genus
		2	P Pseudosinella octopunctata	species
		3	E Psychodidae	family
		4	Stauroneidaceae	family
		5	Navicula cryptocephala	species
		6	Physcia millegrana	species
		7	Eunotia minor	species
		8	Clethra alnifolia	species
		9	Diadesmis	genus
		10	Brachythecium rivulare	species
		11	Oxalidaceae	family
		12	Staurosira	genus
		13	Jamesoniella autumnalis	species
		14	Eunotia implicata	species
		15	Carex stricta	species
		16	P Sinella recens	species
		17	P Camponotus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		18	Onoclea sensibilis	species
		19	Pleurozium schreberi	species
		20	Chamaepinnularia	genus
		21	Osmunda claytoniana	species
		22	Orchidales	order
		23	Myelochroa aurulenta	species
		24	Orchidaceae	family
		25	Diatoma anceps	species
		26	Vaccinium myrtilloides	species
		27	Eunotia exigua	species
		28	Pleurozium	genus
		29	E Hemiptera	order
		30	Phaeophyscia pusilloides	species
		31	Hydrocotyle americana	species
		32	Anemone quinquefolia	species
		33	P Neoantistea magna	species
		34	P Hahniidae	family
		35	P Arachnida	class
		36	P Diptera	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		37	P Acari	order
		38	P Coleoptera	order
		39	P Araneae	order
		40	P Cicadellidae	family
		41	P Carabidae	family
		42	P Sciaridae	family
		43	P Pterostichus	genus
		44	P Tomocerus	genus
		45	P Trimorus	genus
		46	middens	NA
		47	Gomphonema parvulum	species
		48	Meridion circulare	species
		49	Navicula variostriata	species
		50	Pinnularia brebissonii	species
		51	Encyonema silesiacum	species
		52	Eunotia elegans	species
		53	Pinnularia girdle	species
		54	Pinnularia obscura	species
		55	Bacillariophyta	division.phylum
		56	Fragilariales	order
		57	Fragilariaceae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		58	Caloneis	genus
		59	Meridion	genus
		60	Navicula	genus
		61	Anemone	genus
		62	Eunotia naegelii	species
		63	P Linyphiidae	family
		64	P Pseudachorutes	genus
		65	E Cecidomyiidae	family
		66	Gomphonema angustatum	species
		67	P Neoantistea	genus
		68	P Staphylinidae	family
		69	Sphagnum squarrosum	species
		70	P Hemiptera	order
		71	P Scaphoideus	genus
		72	Melanelixia subaurifera	species
		73	P Ceraphronidae	family
		74	Dalibarda repens	species
		75	Achnanthidium minutissimum	species
		76	Cymbellales	order
		77	Polytrichum pallidisetum	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		78	Eunotia tenella	species
		79	Hydrocotyle	genus
		80	P Braconidae	family
		81	Clematis virginiana	species
		82	Carex lurida	species
		83	Eunotia tautoniensis	species
		84	Gomphonema gracile	species
		85	Nitzschia acidoclinata	species
		86	Pinnularia viridis	species
		87	Gomphonemataceae	family
		88	Navicula festiva	species
		89	Pinnularia termitina	species
		90	Gomphonema	genus
		91	Neidium bisulcatum	species
		92	Climacium dendroides	species
		93	Staurosira construens	species
		94	Surirellales	order
		95	Eunotia soleirolii	species
		96	Pelliaceae	family
		97	P Ptenothrix	genus

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		98	E Ceratopogonidae	family
		99	Stauroneis phoenicentron	species
		100	Sphagnum subsecundum	species
		101	Aster	genus
		102	Pinnularia acrosphaeria	species
		103	P Onychiuridae	family
		104	Stauroforma exiguiformis	species
		105	Stauroforma	genus
		106	Eunotia serra	species
		107	Achnanthales	order
All-stepwise	edge predators	1	middens	NA
		2	Sellaphora pupula	species
		3	Rubus hispidus	species
		4	Gomphonema gracile	species
		5	P Agonum fidele	species
		6	Fragilariales	order
		7	Fragilariaceae	family
		8	P Arachnida	class
		9	P Diptera	order
		10	P Acari	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		11	P Hemiptera	order
		12	P Coleoptera	order
		13	P Araneae	order
		14	P Orthoptera	order
		15	P Cicadellidae	family
		16	P Carabidae	family
		17	P Pterostichus	genus
		18	P Scaphoideus	genus
		19	P Tomocerus	genus
		20	P Trimorus	genus
		21	E Cecidomyiidae	family
		22	Pinnularia girdle	species
		23	Pinnularia obscura	species
		24	Bacillariophyta	division.phylum
		25	Naviculaceae	family
		26	Navicula	genus
		27	P Gastropoda	class
		28	P Phoridae	family
		29	Eunotia girdle	species
		30	P Drosophila	genus
		31	P Hahniidae	family
		32	P Pulmonata	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		33	Pinnularia brebissonii	species
		34	Meridion	genus
		35	Neidium bisulcatum	species
		36	P Agonum	genus
		37	Gomphonema parvulum	species
		38	P Drosophilidae	family
		39	P Dohrniphora	genus
		40	Eunotia elegans	species
		41	P Neoantistea magna	species
		42	P Neoantistea	genus
		43	P Hypogastrura	genus
		44	P Lepidocyrtus	genus
		45	Navicula festiva	species
		46	E Tipulidae	family
		47	Chamaepinnularia	genus
		48	P Sciaridae	family
		49	P Linyphiidae	family
		50	P Mollusca	division.phylum
		51	Meridion circulare	species
		52	Toxicodendron vernix	species
		53	Frustulia vulgaris	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		54	P Protaphorura armata	species
		55	P Isotoma	genus
		56	P Pirata	genus
		57	Surirellales	order
		58	Galium	genus
		59	P Amaurobiidae	family
		60	Gomphonema angustatum	species
		61	Staurosira	genus
		62	P Staphylinidae	family
		63	Surirellaceae	family
		64	P Pirata insularis	species
		65	Malus pumila	species
		66	Eunotia curvata	species
		67	P Chironomidae	family
		68	P Platydracus viridianus	species
		69	Planothidium	genus
		70	P Wadotes	genus
		71	P Platydracus	genus
		72	Fragilariforma virescens	species
		73	P Pseudachorutes	genus

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		74	Navicula variostriata	species
		75	Fragilariforma	genus
		76	P Pterostichus coracinus	species
		77	P Dicyrtoma	genus
		78	Tabellaria quadrisepta	species
		79	P Julida	order
		80	P Psocoptera	order
		81	Pinnularia termitina	species
		82	Maianthemum	genus
		83	Clethra alnifolia	species
		84	P Orchesella	genus
		85	Bacillariophyceae	class
		86	E Hemiptera	order
		87	P Gryllidae	family
		88	Liliaceae	family
		89	Dendrobaena octaedra	species
		90	Frangula alnus	species
		91	Maianthemum canadense	species
		92	Pinnularia viridis	species
		93	P Dicyrtoma aurata	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		94	P Thysanoptera	order
		95	P Katiannidae	family
		96	P Diplopoda	class
		97	Eunotia exigua	species
All-stepwise	road traffic	1	Physciaceae	family
		2	Nitzschia	genus
		3	Maianthemum canadense	species
		4	Prunus virginiana	species
		5	Urticales	order
		6	Luticola mutica	species
		7	Achnanthales	order
		8	E Culicidae	family
		9	E Phoridae	family
		10	Betula lenta	species
		11	E Hemiptera	order
		12	Rubus hispidus	species
		13	P Epidapus	genus
		14	P Mollusca	division.phylum
		15	P Mymaridae	family
		16	Pinnularia viridis	species
		17	Pinnularia borealis	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		18	P Gryllidae	family
		19	Eunotia flexuosa	species
		20	Eunotia implicata	species
		21	Navicula festiva	species
		22	Pinnularia obscura	species
		23	Maianthemum	genus
		24	P Myrmecina	genus
		25	Achnanthidium reimeria	species
		26	Climacium dendroides	species
		27	Eunotia septentrionalis	species
		28	P Katiannidae	family
		29	P Collembola	order
		30	E Cecidomyiidae	family
		31	Neidiaceae	family
		32	P Orthoptera	order
		33	P Neoantistea magna	species
		34	P Arachnida	class
		35	P Diptera	order
		36	P Acari	order
		37	P Hemiptera	order
		38	P Coleoptera	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		39	P Cicadellidae	family
		40	P Carabidae	family
		41	P Hahniidae	family
		42	P Sciaridae	family
		43	P Neoantistea	genus
		44	P Pterostichus	genus
		45	P Scaphoideus	genus
		46	P Tomocerus	genus
		47	P Trimorus	genus
		48	middens	NA
		49	Eunotia elegans	species
		50	Gomphonema parvulum	species
		51	Meridion circulare	species
		52	Navicula tantula	species
		53	Navicula variostriata	species
		54	Neidium bisulcatum	species
		55	Pinnularia brebissonii	species
		56	Pinnularia girdle	species
		57	Bacillariophyta	division.phylum
		58	Fragilariales	order
		59	Fragilariaceae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		60	Naviculaceae	family
		61	Meridion	genus
		62	Navicula	genus
		63	P Platydracus viridianus	species
		64	P Platydracus	genus
		65	Cymbellaceae	family
		66	Achnanthidium	genus
		67	P Ceratophysella virga	species
		68	Eunotia paludosa	species
		69	E Muscidae	family
		70	Pinnularia nodosa	species
		71	Neidium	genus
		72	Nitzschia gracilis	species
		73	P Insecta	class
		74	P Gastropoda	class
		75	Eunotiales	order
		76	Nitzschia acidoclinata	species
		77	P Pseudachorutes	genus
		78	Encyonema silesiacum	species
		79	Surirellales	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		80	Melanelixia subaurifera	species
		81	Surirellaceae	family
		82	Leucobryum glaucum	species
		83	Bacillariophyceae	class
		84	Orchidales	order
		85	Cymbella	genus
		86	Fragilariforma virescens	species
		87	Rhizomnium	genus
		88	Lycopus	genus
		89	Planothidium	genus
		90	Pinnularia abaujensis	species
		91	Scutellaria lateriflora	species
		92	Fragilariophyceae	class
All-stepwise	wetland buffer insults	1	P Hymenoptera	order
		2	Hypogymnia physodes	species
		3	Lumbricus	genus
		4	P Parisotoma notabilis	species
		5	Geum	genus
		6	P Bradysia	genus
		7	Eunotia tautoniensis	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		8	P Katiannidae	family
		9	Carex intumescens	species
		10	Maianthemum canadense	species
		11	Navicula cryptocephala	species
		12	Carex debilis	species
		13	Navicula variostriata	species
		14	Ericales	order
		15	Solanales	order
		16	Pelliaceae	family
		17	Potentilla simplex	species
		18	Synedra	genus
		19	Photinia pyrifolia	species
		20	Pinnularia acrosphaeria	species
		21	Diatoma	genus
		22	P Epidapus	genus
		23	Eunotia girdle	species
		24	Pinnularia obscura	species
		25	Dicranum polysetum	species
		26	Naviculales	order
		27	P Arachnida	class
		28	P Acari	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		29	P Hemiptera	order
		30	P Coleoptera	order
		31	P Araneae	order
		32	P Cicadellidae	family
		33	P Carabidae	family
		34	P Sciaridae	family
		35	P Pterostichus	genus
		36	P Scaphoideus	genus
		37	P Tomocerus	genus
		38	P Trimorus	genus
		39	middens	NA
		40	Gomphonema parvulum	species
		41	Meridion circulare	species
		42	Pinnularia girdle	species
		43	Bacillariophyta	division.phylum
		44	Fragilariales	order
		45	Fragilariaceae	family
		46	Meridion	genus
		47	Encyonema silesiacum	species
		48	E Cecidomyiidae	family
		49	Fragilariforma virescens	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		50	Eunotia elegans	species
		51	P Hahniidae	family
		52	P Agonum	genus
		53	Nitzschia	genus
		54	Navicula	genus
		55	P Agonum fidele	species
		56	P Orthoptera	order
		57	Bidens tripartita	species
		58	Nitzschia acidoclinata	species
		59	P Staphylinidae	family
		60	Neidium bisulcatum	species
		61	P Neoantistea magna	species
		62	Stauroneidaceae	family
		63	P Platydracus viridianus	species
		64	Pinnularia appendiculata	species
		65	Pteridium aquilinum	species
		66	Thelypteris	genus
		67	Eunotia naegelii	species
		68	Pinnularia termitina	species
		69	Nitzschia gracilis	species
		70	P Neoantistea	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		71	P Phoridae	family
		72	P Gryllidae	family
		73	Eunotia rhomboidea	species
		74	Luticola mutica	species
		75	Stauroneis kriegeri	species
		76	Pinnularia nodosa	species
		77	P Diptera	order
		78	Stauroneis	genus
		79	Achnanthidium	genus
		80	P Platydracus	genus
		81	Pinnularia microstauron	species
		82	Cymbellaceae	family
All-stepwise	habitat loss	1	Ulmus americana	species
		2	P Gryllidae	family
		3	Bacillariophyceae	class
		4	Nitzschia gracilis	species
		5	Eunotia rhomboidea	species
		6	Smilax herbacea	species
		7	Viburnum lantanoides	species
		8	Gomphonema gracile	species
		9	Euonymus alata	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		10	Stauroneis phoenicentron	species
		11	Parmeliaceae	family
		12	P Platydracus viridianus	species
		13	Euonymus	genus
		14	Dendrobaena octaedra	species
		15	Dendrobaena	genus
		16	Staurosira construens	species
		17	E Hemiptera	order
		18	Diatoma	genus
		19	P Orthoptera	order
		20	Eunotia elegans	species
		21	P Agonum fidele	species
		22	P Platydracus	genus
		23	P Staphylinidae	family
		24	Pinnularia borealis	species
		25	P Arachnida	class
		26	P Diptera	order
		27	P Acari	order
		28	P Hemiptera	order
		29	P Coleoptera	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		30	P Araneae	order
		31	P Cicadellidae	family
		32	P Carabidae	family
		33	P Pterostichus	genus
		34	P Tomocerus	genus
		35	P Trimorus	genus
		36	middens	NA
		37	Pinnularia girdle	species
		38	Pinnularia obscura	species
		39	Naviculaceae	family
		40	Meridion	genus
		41	Navicula	genus
		42	P Sciaridae	family
		43	Bacillariophyta	division.phylum
		44	Meridion circulare	species
		45	Caloneis	genus
		46	Fragilariales	order
		47	Pinnularia brebissonii	species
		48	P Myrmecina	genus
		49	P Nitidulidae	family
		50	P Neoantistea magna	species

Ecological system					
	Taxonomic group	Stressor Metric	Step	Taxon	Level
			51	P Neoantistea	genus
			52	Fragilariaceae	family
			53	Pinnularia acrosphaeria	species
			54	Gomphonema parvulum	species
			55	Eunotia bilunaris	species
			56	Navicula festiva	species
			57	P Agonum	genus
			58	Luticola mutica	species
			59	P Pirata	genus
			60	P Pseudachorutes	genus
			61	E Cecidomyiidae	family
			62	Navicula variostriata	species
			63	Eunotia naegelii	species
			64	P Dicyrtoma	genus
	All-stepwise	non-native invasive plants	1	middens	NA
			2	Rubus hispidus	species
			3	E Hemiptera	order
			4	Jungermanniaceae	family
			5	Planothidium	genus
			6	Encyonema silesiacum	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		7	Fragilaria vaucheriae	species
		8	Stauroneis anceps	species
		9	Gomphonema gracile	species
		10	Achnanthidium minutissimum	species
		11	Stauroforma exiguiformis	species
		12	Navicula festiva	species
		13	Navicula praeterita	species
		14	Eunotia elegans	species
		15	P Hypogastrura	genus
		16	P Phoridae	family
		17	P Pseudachorutes	genus
		18	P Platydracus viridianus	species
		19	P Amaurobiidae	family
		20	Fragilariales	order
		21	P Neoantistea magna	species
		22	P Arachnida	class
		23	P Diptera	order
		24	P Acari	order
		25	P Hemiptera	order
		26	P Coleoptera	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		27	P Araneae	order
		28	P Cicadellidae	family
		29	P Carabidae	family
		30	P Hahniidae	family
		31	P Sciaridae	family
		32	P Pterostichus	genus
		33	P Scaphoideus	genus
		34	P Tomocerus	genus
		35	P Trimorus	genus
		36	Pinnularia girdle	species
		37	Pinnularia obscura	species
		38	Sellaphora pupula	species
		39	Bacillariophyta	division.phylum
		40	Naviculaceae	family
		41	Navicula	genus
		42	P Neoantistea	genus
		43	Eunotia girdle	species
		44	P Staphylinidae	family
		45	P Orthoptera	order
		46	Nitzschia gracilis	species
		47	P Mollusca	division.phylum
		48	Gomphonema	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
			parvulum	
		49	P Linyphiidae	family
		50	Eunotia rhomboidea	species
		51	P Drosophila	genus
		52	Meridion	genus
		53	P Platydracus	genus
		54	Pinnularia brebissonii	species
		55	Meridion circulare	species
		56	E Cecidomyiidae	family
		57	P Agonum	genus
		58	Fragilariaceae	family
		59	Navicula variostriata	species
		60	P Chironomidae	family
		61	Neidium bisulcatum	species
		62	P Gastropoda	class
		63	P Pulmonata	order
		64	P Dohrniphora	genus
		65	P Drosophilidae	family
		66	P Wadotes	genus
		67	P Pterostichus coracinus	species
		68	Stauroforma	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		69	P Psocoptera	order
		70	P Lepidocyrtus	genus
		71	P Isotoma	genus
		72	P Julida	order
		73	Jamesoniella autumnalis	species
		74	Pinnularia acrosphaeria	species
		75	Dendrobaena octaedra	species
		76	Chamaepinnularia	genus
		77	P Orchesella	genus
		78	Eunotiales	order
		79	P Protaphorura armata	species
		80	Hypnaceae	family
		81	P Pirata insularis	species
		82	Toxicodendron vernix	species
		83	P Agonum fidele	species
		84	Rhamnales	order
		85	Eunotia curvata	species
		86	P Katiannidae	family
		87	P Lycosidae	family

Salt marsh:

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
macro-invertebrates	connectedness	1	Q Coleoptera	order
		2	D Palaemonidae	family
		3	D Littorina	genus
		4	A Crustacea	class
		5	A Talitridae	family
		6	D Acari	order
		7	Q Miridae	family
		8	D Insecta	class
		9	A Terebellida	order
		10	A Ampharetidae	family
		11	A Hydrobiidae	family
		12	D Hemiptera	order
		13	D Orthoptera	order
		14	D Chironomidae	family
		15	Q Gastropoda	class
		16	D Hydrobiidae	family
		17	A Mesogastropoda	order
		18	A Littorinimorpha	order
		19	A Isopoda	order
		20	Q Hymenoptera	order
		21	A Arachnida	class

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		22	A Littorinidae	family
		23	A Littorina	genus
		24	A Tanaidacea	order
		25	D Bivalvia	class
		26	D Palaemonetes pugio	species
		27	A Spionida	order
macro-invertebrates	*index of ecological integrity (IEI)*	1	D Palaemonidae	family
		2	A Crustacea	class
		3	A Ampharetidae	family
		4	D Collembola	order
		5	D Hydrobiidae	family
		6	A Talitridae	family
		7	A Maldanidae	family
		8	A Hydrobiidae	family
		9	A Isopoda	order
		10	D Palaemonetes pugio	species
		11	D Trichoptera	order
		12	Q Delphacidae	family
		13	D Orthoptera	order
		14	D Culicidae	family
		15	Q Miridae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		16	Q Formicidae	family
		17	A Capitellida	order
		18	Q Orthoptera	order
		19	D Acari	order
		20	D Bivalvia	class
		21	Q Aphididae	family
		22	Q Hymenoptera	order
		23	D Nereididae	family
		24	A Tanaidacea	order
		25	A Diptera	order
		26	A Mollusca	division.phylum
		27	A Insecta	class
		28	A Mesogastropoda	order
		29	Q Talitridae	family
		30	A Gastropoda	class
		31	A Phyllodocidae	family
		32	D Chironomidae	family
		33	Q Amphipoda	order
macro-invertebrates	similarity	1	D Palaemonidae	family
		2	Q Formicidae	family
		3	Q Miridae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		4	D Palaemonetes pugio	species
		5	D Culicidae	family
		6	Q Orthoptera	order
		7	Q Diptera	order
		8	D Chironomidae	family
		9	A Maldanidae	family
		10	A Isopoda	order
		11	A Terebellida	order
		12	Q Collembola	order
		13	D Collembola	order
		14	D Palaemonetes	genus
		15	A Talitridae	family
		16	A Littorinimorpha	order
		17	D Decapoda	order
		18	D Bivalvia	class
		19	A Hydrobiidae	family
		20	D Acari	order
		21	Q Carcinus maenas	species
		22	A Littorinidae	family
		23	A Ampharetidae	family
		24	A Littorina	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		25	A Capitellida	order
		26	Q Aphididae	family
		27	Q Cicadellidae	family
		28	Q Arthropoda	division.phylum
		29	D Miridae	family
		30	Q Delphacidae	family
		31	A Spionida	order
		32	D Orthoptera	order
		33	D Nereididae	family
macro-invertebrates	connectedness	1	Q Coleoptera	order
		2	D Palaemonidae	family
		3	D Littorina	genus
		4	A Crustacea	class
		5	A Talitridae	family
		6	D Acari	order
		7	Q Miridae	family
		8	D Insecta	class
		9	A Terebellida	order
		10	A Ampharetidae	family
		11	A Hydrobiidae	family
		12	D Hemiptera	order

Ecological system Taxonomic group	Stressor Metric	Step	Taxon	Level
		13	D Orthoptera	order
		14	D Chironomidae	family
		15	Q Gastropoda	class
		16	D Hydrobiidae	family
		17	A Mesogastropoda	order
		18	A Littorinimorpha	order
		19	A Isopoda	order
		20	Q Hymenoptera	order
		21	A Arachnida	class
		22	A Littorinidae	family
		23	A Littorina	genus
		24	A Tanaidacea	order
		25	D Bivalvia	class
		26	D Palaemonetes pugio	species
		27	A Spionida	order
Wadable streams:				
macro-invertebrates	(watershed) imperviousness	1	Ephemeroptera	order
		2	Gammaridae	family
		3	Cheumatopsyche	genus
		4	Rhithrogena	genus
		5	Hydropsyche morosa	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		6	Trichoptera	order
		7	Hydropsyche betteni	species
		8	Hydropsychidae	family
		9	Chimarra	genus
		10	Hydropsyche	genus
		11	Stenelmis	genus
		12	Mollusca	division.phylum
		13	Maccaffertium modestum	species
		14	Chironomidae	family
		15	Pristinella osborni	species
		16	Rheocricotopus robacki	species
		17	Tubificidae	family
		18	Odontoceridae	family
		19	Simulium vittatum	species
		20	Plecoptera	order
		21	Amphipoda	order
		22	Hydroptilidae	family
		23	Polypedilum scalaenum	species
		24	Leptophlebiidae	family
		25	Tipula	genus
		26	Gammarus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		27	Zavrelia	genus
		28	Clinocera	genus
		29	Empididae	family
		30	Isopoda	order
		31	Atherix	genus
		32	Synorthocladius	genus
		33	Helicopsyche borealis	species
		34	Chloroperlidae	family
		35	Dolophilodes distinctus	species
		36	Hyalella azteca	species
		37	Hyalella	genus
		38	Acentrella turbida	species
		39	Sialis	genus
		40	Parachaetocladius	genus
		41	Potthastia gaedii	species
		42	Neoperla	genus
		43	Tallaperla maria	species
		44	Simulium	genus
		45	Cladotanytarsus	genus
		46	Eukiefferiella brehmi	species
		47	Chironomus	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		48	Dicrotendipes	genus
		49	Lumbriculus variegatus	species
		50	Lepidoptera	order
		51	Cryptochironomus	genus
		52	Pristina	genus
		53	Chimarra obscura	species
		54	Isonychiidae	family
		55	Amnicola	genus
		56	Meropelopia	genus
		57	Phaenopsectra	genus
		58	Stenochironomus	genus
		59	Cricotopus trifascia	species
		60	Argia	genus
		61	Epeorus	genus
		62	Stenelmis crenata	species
		63	Cricotopus bicinctus	species
		64	Diplectrona	genus
		65	Cricotopus annulator	species
		66	Rhyacophila fuscula	species
		67	Pteronarcyidae	family
		68	Polycentropus	genus

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		69	Cardiocladius	genus
		70	Enchytraeidae	family
		71	Pagastia	genus
		72	Apatania	genus
		73	Brillia	genus
		74	Rhyacophilidae	family
		75	Stempellinella	genus
		76	Neureclipsis	genus
		77	Micropsectra dives	species
		78	Serratella	genus
		79	Pteronarcys	genus
		80	Baetis intercalaris	species
macro-invertebrates	(watershed) habitat loss	1	Crustacea	class
		2	Tubificida	order
		3	Chloroperlidae	family
		4	Odontoceridae	family
		5	Chironomus	genus
		6	Dolophilodes	genus
		7	Eukiefferiella brehmi	species
		8	Polypedilum tritum	species
		9	Polypedilum fallax	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		10	Enchytraeidae	family
		11	Ephemerellidae	family
		12	Parachaetocladius	genus
		13	Isonychiidae	family
		14	Amphipoda	order
		15	Eukiefferiella claripennis	species
		16	Stempellinella	genus
		17	Clinocera	genus
		18	Stenelmis crenata	species
		19	Leuctra	genus
		20	Tipula	genus
		21	Empididae	family
		22	Conchapelopia	genus
		23	Rhynchobdellida	order
		24	Tvetenia paucunca	species
		25	Diplectrona	genus
		26	Diptera	order
		27	Tallaperla	genus
		28	Apataniidae	family
		29	Coenagrionidae	family
		30	Simulium tuberosum	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		31	Gyraulus	genus
		32	Polypedilum scalaenum	species
		33	Amnicola	genus
		34	Gomphidae	family
		35	Helicopsyche borealis	species
		36	Atherix	genus
		37	Diamesa	genus
		38	Cricotopus vierriensis	species
		39	Cricotopus trifascia	species
		40	Cricotopus annulator	species
		41	Pteronarcys	genus
		42	Leptophlebiidae	family
		43	Hyalellidae	family
		44	Plauditus	genus
		45	Hyalella azteca	species
		46	Lumbriculus variegatus	species
		47	Hyalella	genus
		48	Polypedilum aviceps	species
		49	Baetis intercalaris	species
		50	Nigronia serricornis	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		51	Calopterygidae	family
		52	Neoperla	genus
		53	Pristinella osborni	species
		54	Stenochironomus	genus
		55	Peltoperlidae	family
		56	Hydropsyche morosa	species
		57	Tallaperla maria	species
		58	Hydropsyche betteni	species
		59	Maccaffertium modestum	species
		60	Trichoptera	order
		61	Hydropsychidae	family
		62	Chimarra	genus
		63	Hydropsyche	genus
		64	Stenelmis	genus
macro-invertebrates	*Index of ecological integrity*	1	Plecoptera	order
		2	Chloroperlidae	family
		3	Ephemerellidae	family
		4	Amphipoda	order
		5	Heptageniidae	family
		6	Clitellata	class
		7	Pteronarcyidae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		8	Diamesa	genus
		9	Rheotanytarsus distinctissimus	species
		10	Nigronia serricornis	species
		11	Tricorythodes	genus
		12	Tallaperla	genus
		13	Nais	genus
		14	Arachnida	class
		15	Diptera	order
		16	Pharyngobdellida	order
		17	Uenoidae	family
		18	Agnetina	genus
		19	Cricotopus trifascia	species
		20	Nanocladius	genus
		21	Physa	genus
		22	Brachycentrus	genus
		23	Macrostemum zebratum	species
		24	Psychomyia	genus
		25	Rheocricotopus robacki	species
		26	Eukiefferiella brehmi	species
		27	Pseudocloeon	genus
		28	Rhynchobdellida	order

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		29	Probezzia	genus
		30	Chelifera	genus
		31	Lumbriculus variegatus	species
		32	Psilotreta	genus
		33	Simulium vittatum	species
		34	Planorbidae	family
		35	Paratanytarsus	genus
		36	Coleoptera	order
		37	Tvetenia paucunca	species
		38	Elmidae	family
		39	Nais variabilis	species
		40	Sublettea coffmani	species
		41	Stenelmis crenata	species
		42	Ceraclea	genus
		43	Glossiphoniidae	family
macro-invertebrates	(watershed) road sediment	1	Crustacea	class
		2	Leptophlebiidae	family
		3	Enchytraeidae	family
		4	Ephemerellidae	family
		5	Chloroperlidae	family
		6	Isonychiidae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		7	Odontoceridae	family
		8	Stenelmis crenata	species
		9	Simulium tuberosum	species
		10	Cricotopus trifascia	species
		11	Eukiefferiella brehmi	species
		12	Amnicola	genus
		13	Apataniidae	family
		14	Stempellinella	genus
		15	Atherix	genus
		16	Neoperla	genus
		17	Helicopsyche borealis	species
		18	Leuctridae	family
		19	Empididae	family
		20	Clinocera	genus
		21	Paragnetina immarginata	species
		22	Maccaffertium modestum	species
		23	Potthastia longimana	species
		24	Pentaneura	genus
		25	Stenochironomus	genus
		26	Polycentropus	genus
		27	Lumbriculus	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
			variegatus	
		28	Insecta	class
		29	Cheumatopsyche	genus
		30	Hydropsyche betteni	species
		31	Trichoptera	order
		32	Hydropsychidae	family
		33	Chimarra	genus
		34	Hydropsyche	genus
		35	Stenelmis	genus
macro-invertebrates	connectedness	1	Chloroperlidae	family
		2	Leuctridae	family
		3	Elmidae	family
		4	Gammaridae	family
		5	Lumbriculida	order
		6	Perlodidae	family
		7	Eukiefferiella pseudomontana	species
		8	Eukiefferiella brehmi	species
		9	Psilotreta	genus
		10	Hydroptila	genus
		11	Eurylophella	genus
		12	Rheotanytarsus distinctissimus	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		13	Micropsectra dives	species
		14	Clitellata	class
		15	Clinocera	genus
		16	Dicrotendipes	genus
		17	Potthastia gaedii	species
		18	Rheocricotopus	genus
		19	Nais	genus
		20	Atherix	genus
		21	Stempellinella	genus
		22	Diamesa	genus
		23	Baetidae	family
		24	Corydalidae	family
		25	Probezzia	genus
		26	Naididae	family
		27	Argia	genus
		28	Cryptochironomus	genus
		29	Insecta	class
		30	Simulium vittatum	species
		31	Hydropsyche betteni	species
		32	Hydropsyche morosa	species
		33	Trichoptera	order

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		34	Hydropsychidae	family
		35	Chimarra	genus
		36	Hydropsyche	genus
		37	Stenelmis	genus
		38	Meropelopia	genus
		39	Pseudocloeon	genus
		40	Rheocricotopus robacki	species
		41	Caenidae	family
		42	Pristinella osborni	species
		43	Maccaffertium modestum	species
		44	Pentaneura	genus
		45	Chimarra aterrima	species
		46	Acroneuria abnormis	species
		47	Drunella	genus
		48	Chimarra obscura	species
macro-invertebrates	habitat loss	1	Plecoptera	order
		2	Physidae	family
		3	Gomphidae	family
		4	Nais variabilis	species
		5	Brachycentridae	family
		6	Odontoceridae	family

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		7	Nigronia serricornis	species
		8	Crangonyctidae	family
		9	Pteronarcyidae	family
		10	Cricotopus annulator	species
		11	Pharyngobdellida	order
		12	Caenidae	family
		13	Rhyacophilidae	family
		14	Eurylophella	genus
		15	Stenochironomus	genus
		16	Ferrissia	genus
		17	Antocha	genus
		18	Coenagrionidae	family
		19	Dolophilodes distinctus	species
		20	Caenis	genus
		21	Gyraulus	genus
		22	Rheocricotopus robacki	species
		23	Psilotreta	genus
		24	Macronychus glabratus	species
		25	Isonychia bicolor	species
		26	Mesogastropoda	order
		27	Cardiocladius	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
			obscurus	
		28	Pteronarcys	genus
		29	Sublettea coffmani	species
		30	Tallaperla maria	species
		31	Baetis intercalaris	species
		32	Hydropsyche betteni	species
		33	Hydropsyche morosa	species
		34	Trichoptera	order
		35	Hydropsychidae	family
		36	Chimarra	genus
		37	Hydropsyche	genus
		38	Stenelmis	genus
macro-invertebrates	nutrients	1	Crustacea	class
		2	Chironomus	genus
		3	Pteronarcys	genus
		4	Diplectrona	genus
		5	Cheumatopsyche	genus
		6	Chimarra aterrima	species
		7	Tallaperla maria	species
		8	Baetis intercalaris	species
		9	Micropsectra dives	species

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		10	Chimarra obscura	species
		11	Maccaffertium modestum	species
		12	Hydropsyche betteni	species
		13	Ephemeroptera	order
		14	Trichoptera	order
		15	Hydropsychidae	family
		16	Chimarra	genus
		17	Hydropsyche	genus
		18	Stenelmis	genus
		19	Hydropsyche morosa	species
		20	Paragnetina immarginata	species
		21	Polypedilum fallax	species
		22	Attenella	genus
		23	Amnicola limosa	species
		24	Rheocricotopus robacki	species
		25	Insecta	class
		26	Chelifera	genus
		27	Sperchon	genus
		28	Polypedilum flavum	species
		29	Simulium tuberosum	species

Ecological system				
Taxonomic group	**Stressor Metric**	**Step**	**Taxon**	**Level**
		30	Eukiefferiella pseudomontana	species
		31	Cardiocladius albiplumus	species
		32	Polypedilum illinoense	species
		33	Baetis tricaudatus	species
		34	Eurylophella	genus
		35	Simulium vittatum	species
		36	Odontoceridae	family
macro-invertebrates	aquatic connectedness	1	Baetidae	family
		2	Helicopsychidae	family
		3	Potthastia gaedii	species
		4	Orthocladius	genus
		5	Helicopsyche borealis	species
		6	Psychomyia	genus
		7	Isonychiidae	family
		8	Pteronarcys	genus
		9	Rheotanytarsus pellucidus	species
		10	Sperchon	genus
		11	Cricotopus bicinctus	species
		12	Tricorythodes	genus

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		13	Polypedilum	genus
		14	Aeschnidae	family
		15	Tipula	genus
		16	Cricotopus vierriensis	species
		17	Amnicola	genus
		18	Optioservus trivittatus	species
		19	Erpobdella	genus
		20	Nigronia	genus
		21	Lepidostoma	genus
		22	Oulimnius latiusculus	species
		23	Enchytraeidae	family
		24	Hyalellidae	family
		25	Gammaridae	family
		26	Oulimnius	genus
		27	Heterocloeon	genus
		28	Coenagrionidae	family
		29	Diplectrona	genus
		30	Simulium vittatum	species
		31	Parametriocnemus	genus
		32	Chimarra aterrima	species
		33	Lumbriculida	order

Ecological system				
Taxonomic group	Stressor Metric	Step	Taxon	Level
		34	Synorthocladius	genus
		35	Psychomyiidae	family
		36	Polypedilum illinoense	species
		37	Rheocricotopus robacki	species