Development of an Index of Biotic Integrity for Macroinvertebrates in Freshwater Low Gradient Wadeable Streams in Southeast New England

FINAL REPORT

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Executive Summary

Under the Clean Water Act, state environmental agencies are charged with monitoring and assessment of streams and rivers. Currently, the Massachusetts Department of Environmental Protection (MassDEP) and the Rhode Island Department of Environmental Management (RIDEM) collect water chemistry data and sample biological communities to characterize the condition of streams. Where available, these data are compared against water quality standards and biological criteria that have been developed to quantify water quality conditions. Along the coast of southeast New England, non-tidal, low gradient, slow-moving streams that either lack or have infrequent riffle habitat are fairly prevalent. Yet, until recently, stream assessment efforts in New England have largely focused on moderate to high gradient, rocky-bottom streams with riffle habitats.

MassDEP and RI DEM have collected macroinvertebrate samples from riffle habitats for many years and have developed riffle habitat multimetric indices to assess the effects of anthropogenic stress on macroinvertebrate assemblages (Jessup et al. 2012, Jessup and Stamp 2020). Multimetric indices (also referred to as Indices of Biotic Integrity (IBIs)) are numeric representations of biological condition based on the combined signals of several different assemblage measurements (Karr 1981). The raw measurements are recalculated or standardized as biological metrics, or numerical expressions of attributes of the biological assemblage (based on sample data) that respond to human disturbance in a predictable fashion. The index scores provide a measure of how far conditions at a site have deviated from the expected state of the macroinvertebrate community, which is based on comparisons with reference sites.

Because there are natural differences in the structure and function of macroinvertebrate assemblages in low gradient versus faster-moving, rocky-bottom streams, the collection methods and riffle habitat multimetric indices that MassDEP and RI DEM have developed cannot be effectively applied in the low gradient, slow-moving streams that occur along the coast of southeast New England. To address this, MassDEP developed a low gradient, multihabitat collection method for macroinvertebrates in 2013. The multihabitat method allowed for effective sampling of snags, root wads, leaf packs, aquatic macrophytes, undercut banks, overhanging vegetation, fine sediments, and hard substrates. In 2019, with funding from the U.S. Environmental Protection Agency (U.S. EPA) Southern New England Program (SNEP), the multihabitat collection method was used to sample over 50 sites in low gradient, non-tidal, wadeable streams in MA and RI. The sites were located in the SNEP region, which consists of coastal watersheds in Cape Cod, Narragansett Bay, Buzzards Bay, and the Islands. The intent of collecting these data was to obtain a dataset that could be used to calibrate a low gradient IBI for macroinvertebrate assemblages in the SNEP region. The Low-Gradient Coastal Index of Biotic Integrity (IBI) for Wadeable Waters in Southern New England project is supported by the Southeast New England Program (SNEP) Watershed Grants. SNEP Watershed Grants are funded by the U.S. Environmental Protection Agency (EPA) through a collaboration with Restore America's Estuaries (RAE) and awarded to the NEIWPCC. For more on SNEP Watershed Grants, see www.snepgrants.org.

In this report, we describe the development of a low gradient multihabitat IBI for the SNEP region. The IBI calibration dataset included data from 109 sites in Massachusetts (MA) and Rhode Island (RI). This work was done concurrently with the development of a statewide low gradient IBI for Massachusetts, which utilized data from an additional 69 low gradient sites located outside the SNEP region. There was overlap across the MassDEP and SNEP datasets and several staff members from MassDEP participated in both projects. Thus, the two projects were not completely independent and often were informing one another.

When developing the IBI, steps included compiling and preparing data, defining site disturbance categories and criteria, performing classification analyses, scoring and selecting metrics, compiling index alternatives, evaluating performance, and selecting and validating the final IBI. The top candidate IBIs had high discrimination efficiency (minimal error when discriminating between reference and stressed sites) and metrics that were familiar to the workgroup members, ecologically meaningful, and diverse in response mechanisms. The workgroup also wanted an IBI that performed well with different subsample sizes (300-, 200-, and 100-organism samples) to simplify application across the region.

The input metrics for the final IBI are listed in Table ES-1. The IBI had low error in the separation of index values in least-disturbed reference and most disturbed stressed sites (Index DE: 97.6%; higher discrimination efficiency indicates that a greater percentage of stressed index values are outside of the reference inter-quartile range) (Figure ES-1). As an alternate measure of performance, the relationship between IBI scores and four measures of disturbance (overall watershed condition at local and total watershed-scales, percent urban, and percent agriculture) were also evaluated. Associations with all but the percent agriculture metric were fairly strong (Spearman correlation coefficients ≥ |0.53|) and in keeping with the expected direction of response. Most sites had low percent agriculture, which likely accounts for the weak correlation between the IBI and percent agriculture.

To validate the IBI, relationships between IBI scores and stressor indicators that were not used in defining the IBI calibration stressor gradient were evaluated. The independent stressor variables included habitat scores, dissolved oxygen (DO), conductivity, and percent forest cover in the watershed. Some natural (non-stressor) variables were also compared, including acidity (pH), substrate, and temperature. Results confirmed that the IBI was indeed responsive along the stressor gradient.

As a final step, exploratory analyses were performed to inform potential numeric thresholds for four biological condition categories (Exceptional Condition, Satisfactory Condition, Moderately Degraded, and Severely Degraded). The thresholds proposed in this report are preliminary and subject to further review, refinement, and approval by MassDEP and RI DEM before they are applicable in biological assessment programs. The new low gradient IBI and preliminary thresholds improve the ability of MassDEP and RI DEM to identify degradation in biological integrity and water quality and will be re-evaluated in coming years as they obtain and analyze more low gradient samples.

Table ES-1. Metrics included in the low gradient IBI.

Metric (abbrev)	Response to increasing stress	Scoring formula
% Plecoptera, Odonata, Ephemeroptera, and Trichoptera (POET) taxa (pt_POET)	Decrease	100*(metric)/40
% Predator taxa (pt_ffg_pred)	Decrease	100*(metric)/32
% Non-insect taxa (pt_NonIns)	Increase	100*(46-metric)/42
% Odonata, Ephemeroptera, and Trichoptera (OET) individuals (pi_OET)	Decrease	100*(metric)/49
% Tolerant taxa (pt_tv_toler)	Increase	100*(36-metric)/33
% Semivoltine taxa (pt_volt_semi)	Decrease	100*(metric)/12

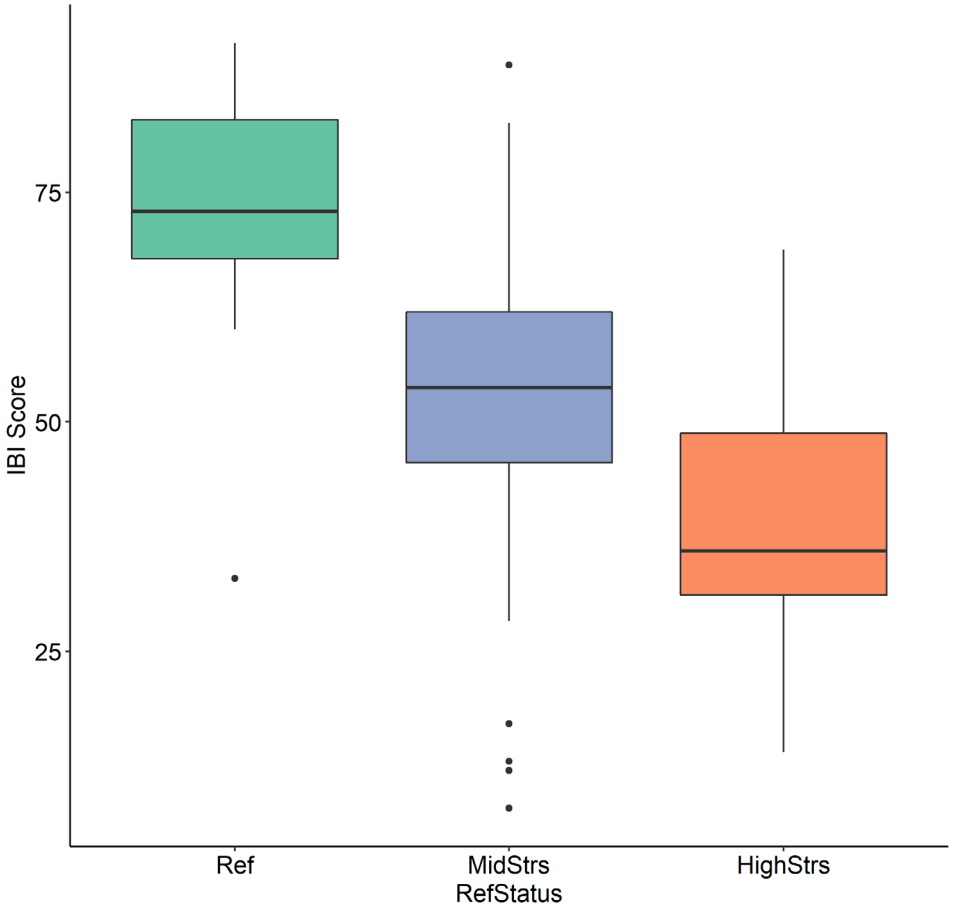

Figure ES-1. Distributions of low gradient IBI values in reference (Ref), intermediate (MidStrs), and stressed (HighStrs) sites.

Acknowledgments

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Project authors and analysts included Ben Jessup, Ben Block, and Jen Stamp of Tetra Tech. An appropriate citation for this report is as follows:

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