Development of a nationally consistent benthic macro-invertebrate indicator of **lake biological condition**

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The assessment of lake condition has traditionally focused on chemical parameters and less so on the biological assessment of lake communities. As part of the National Aquatic Resource Surveys (NARS), the National Lakes Assessment (NLA) provides a comprehensive assessment of the physical, chemical and biological condition of lakes within the contiguous United States (US EPA 2024). To assess the biological condition of the nation's lakes, NLA developed both a zooplankton and benthic macroinvertebrate multi-metric index (MMI) of biotic integrity (Mitchell et al. 2025). MMIs have been widely used for assessing biological condition in stream for well over 40 years, with stream benthic macroinvertebrates being the assemblage used for most MMIs. The use of benthic macroinvertebrates for MMIs in lentic systems, however, has been much more limited.

Benthic macroinvertebrates used in the development of the NLA MMI were collected by kick/sweep netting from ten littoral zone plots spaced around the lake and composited into a single lake sample. Data from the 2007 and 2012 NLA surveys were used to develop the MMI. A standardized exact count of 300 organisms was used to calculate community metrics for all analyses. Organisms were typically identified to genus; however, some taxa were keyed to higher taxonomic levels (e.g., Family, Order). A total of 126 metrics based on taxa richness, percent of individuals, and percent of taxa, were developed using taxonomic composition measures and autecology information. Autecology based metrics included information on habitat use, feeding behavior and pollution tolerance. Defining a gradient of human disturbance condition is essential to develop and evaluate the usefulness of an MMI.

Identification of NLA least-disturbed reference and most disturbed sites was accomplished by screening NLA data using five chemical factors (total phosphorus, total nitrogen, chloride, sulfate, turbidity), three physical habitat indices based on riparian habitat disturbance, and three indices derived from a field stressor checklist (Mitchell et al. 2025). Screening thresholds and the MMI scoring were set separately for each of five aggregate NLA ecoregions (Figure 1).

When developing the NLA MMI, one best preforming metric was selected from each of the six following metric categories: composition, diversity, richness, feeding group, habit, and tolerance. Metrics were standardized to a 0-10 scale, summed together, and multiplied by 100/60 so that the final MMI ranged from 0-100. MMIs were developed separately for five aggregate NLA ecoregions (Figure 1). Metric and MMI performance were evaluated using signal:noise ratios, a range test, and responsiveness to the human disturbance gradient. An all-subsets procedure was used to evaluate all possible combination of metrics to find the optimal combination of the six metrics that were included in the MMI (Table 1).

In addition to being used for evaluating metric and MMI responsiveness, reference sites were used for setting condition category (good/fair/poor) benchmarks. MMI benchmarks were set at the 5th and 25th percentile of the reference site distribution for each of the five assessment regions (Table 2).

Results from the 2022 NLA survey showed that at the national level 44 percent of the lake target population was in good condition for littoral benthic macroinvertebrates, with 26 percent in fair and 27 percent in poor condition. Three percent of the target lake population was not assessed due to missing benthic macroinvertebrate data for a subset of sampled lakes. Within the five assessment
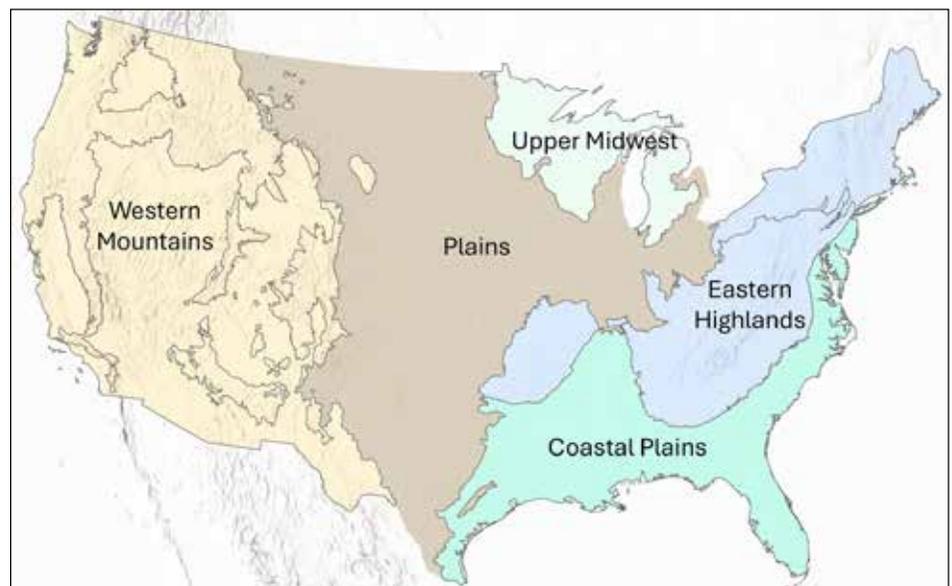

Figure 1. Five aggregate ecoregions used for multi-metric index development.

Table 1. Benthic macroinvertebrate metrics used in each of the five NLA biological ecoregions MMIs.

Ecoregion	Composition	Diversity	Feeding Group	Habit	Richness	Tolerance
Coastal Plains	percent Non-Insect Taxa (-)	percent Individuals in Top 3 Chironomid Taxa (-)	Predator Richness (+)	Sprawler Richness (+)	EPT[a] Taxa Richness (+)	percent Individuals with PTV[b] < 6 (+)
Eastern Highlands	percent Non-Insect Taxa (-)	percent Individuals in Top 3 Chironomid Taxa (-)	Collector-Gatherer Richness (+)	Clinger Richness (+)	EPOT[c] Richness (+)	Taxa Richness with PTV ≥2.0 and <4.0 (+)
Plains	percent Diptera Taxa (-)	Shannon Diversity Index (+)	Predator Richness (+)	percent Climber Taxa (+)	EPOT Richness (+)	percent Individuals with PTV ≥2.0 and <4.0 (+)
Upper Midwest	percent Non-Insect Individuals (-)	percent Individuals in Top 3 Chironomid Taxa (-)	percent Shredder Individuals (-)	Clinger Richness (+)	Crustacean Richness (-)	percent Taxa with PTV ≥2.0 and <4.0 (+)
Western Mountains	percent Odonata Individuals (-)	percent Individuals in Top 5 Chironomid Taxa (+)	Scraper Richness (-)	Clinger Richness (+)	Trichoptera Richness (+)	percent Taxa with PTV ≥2.0 and <4.0 (+)

[a] Ephemeroptera, Plecoptera, Trichoptera; [b] Pollutant Tolerance Value; [c] Ephemeroptera, Plecoptera, Odonata, Trichoptera; (+/-) Positive or Negative relationship to disturbance

Table 2. Macroinvertebrate MMI condition class benchmarks calculated as the 25th percentile (good) or 5th percentile (poor) from the reference lake distribution in NLA 2007-2017 lakes.

Ecoregion	# of Ref Lakes	MMI Good Condition Benchmark (25th of reference lakes)	MMI Poor Condition Benchmark (5th of reference lakes)
Coastal Plains	29	≥ 51.8	< 40.4
Eastern Highlands	105	≥ 44.5	< 31.4
Plains	84	≥ 39.5	< 26.6
Upper Midwest	76	≥ 51.4	< 37.2
Western Mountains	122	≥ 47.6	< 32.6

regions (Figure 2), the percentage of lakes in good condition ranges from a high of 56.5 percent in the Plains to a low of 25.5 percent in the Eastern Highlands. When developing multiple metric indices at a large geographic scale (national/continental) it is important to consider both the natural variation and human disturbance gradients across the landscape. The process by which multiple general stressor gradients were identified across various regions of the United States has allowed the NLA program to develop regionally relevant benthic macroinvertebrate MMIs for assessing the biological condition of the nation's lakes. The responsiveness to disturbance and good repeatability of these MMIs across the first four NLA surveys (2007 through 2022) will allow the NLA program to provide consistent biological condition estimates for future surveys and capture changes due to human influence over time.

References

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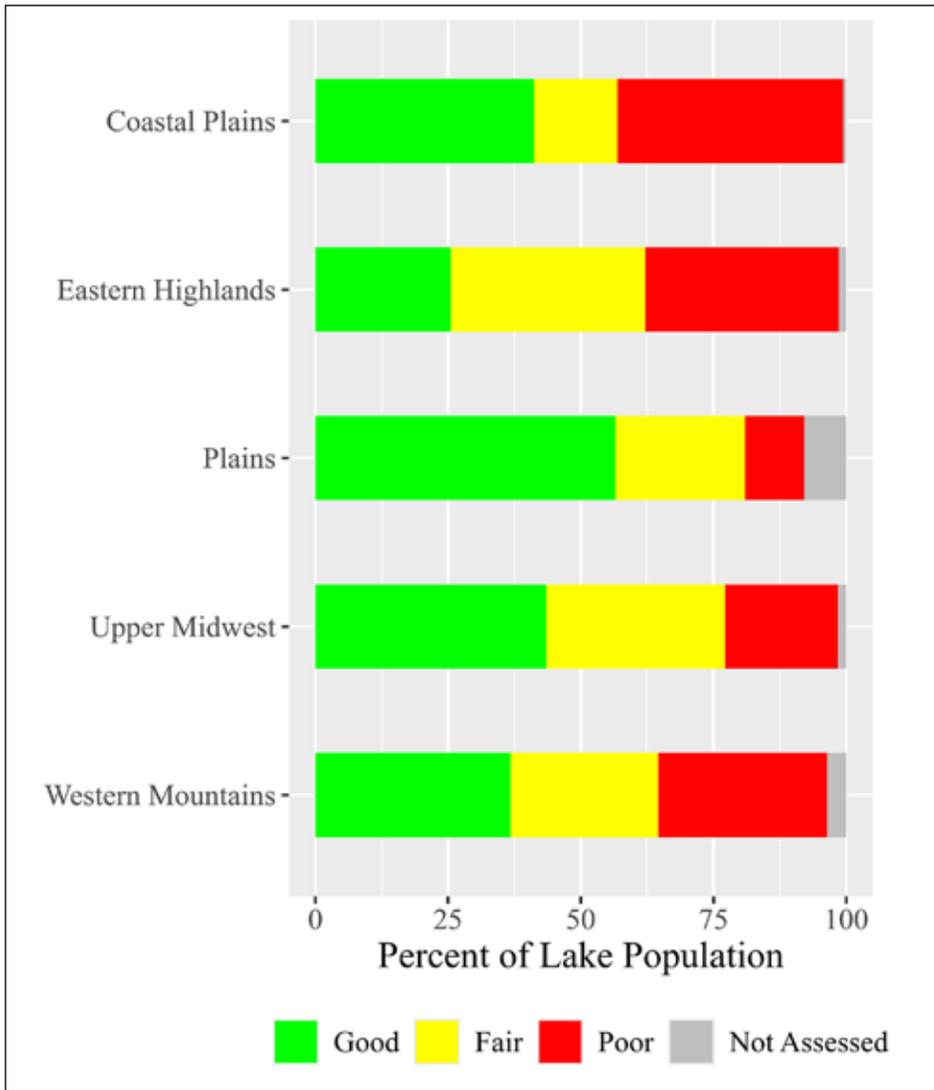
Figure 2. Proportion of U.S. lakes in good, fair, and poor benthic macroinvertebrate condition with respect to assessment ecoregions.

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