INVERTEBRATE STATUS INDEX

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The Invertebrate Status Index is a multimetric index that was derived for the NAWQA Program to provide a simple national characterization of benthic invertebrate communities. This index—referred to here as the National Invertebrate Community Ranking Index (NICRI)—provides a simple method of placing community conditions within the context of all sites sampled by the NAWQA Program. The multimetric index approach is the most commonly used method of characterizing biological conditions within the U.S. (Barbour and others, 1999). Using this approach, communities may be compared by considering how individual metrics vary among sites or by combining individual metrics into a single composite (i.e., multimetric) index and examining how this single index varies among sites. Combining metrics into a single multimetric index simplifies the presentation of results (Barbour and others, 1999) and minimizes weaknesses that may be associated with individual metrics (Ohio EPA, 1987a,b).

The NICRI is a multimetric index that combines 11 metrics (RICH, EPTR, CG_R, PR_R, EPTRP, CHRP, V2DOMP, EPATOLR, EPATOLA, DIVSHAN, and EVEN; Table 1) into a single, nationally consistent, composite index. The NICRI was used to rank 140 sites of the FY94 group of study units, with median values used for sites where data were available for multiple reaches and(or) multiple years.

The metrics that form this index have been shown to differentiate undeveloped (≈ reference) sites from other land uses at a national level. These metrics were selected from among 107 candidate community metrics (see Derivation and Calculation of the NICRI below) for description of the selection process). These 107 metrics were calculated for data from all 1,026 Richest Targeted-Habitat (RTH) samples released by the USGS National Water-Quality Laboratory's Biological Group as of December 10, 1999. The richest targeted habitat is the instream habitat type that supports the faunistically richest community of benthic invertebrates, usually a fast-flowing, coarse-grained riffle (Cuffney and others, 1993).

The NICRI is, essentially, an average of standardized metrics. Percent rankings, calculated using the Excel function PERCENTRANK, were used to standardize the individual metrics across all samples or sites. This function evaluates the relative standing of a value within a data set by calculating the percentage of sites or samples ranked below the value. Therefore, a percent rank of 0.8 indicates that 80% of the values in the data set are less than the value being examined and 20% of the values are equal to or greater than the value being examined. Percent ranking not only standardizes values within a range of from 0 to 1, but also reduces the influence of outliers in the data set.

Nine of the metrics used to calculate the NICRI are directly related to water quality, that is, they increase in value as water quality increases. Two metrics (CHRP and V2DOMP) respond in the opposite fashion. To compensate for this behavior, standardized scores (percent ranks) for these metrics were subtracted from 1 prior to calculating the average metric score. Average metric scores were then rescaled using the PERCENTRANK function and multiplied by 100 to produce a final NICRI score that ranged from 0 (low ranking relative to other NAWQA Program sites and presumably diminished community conditions) to 100 (high ranking relative to other NAWQA Program sites and presumably excellent community conditions).

A composite index is thought to be better at differentiating water-quality effects than single metrics (Gibson, 1996) because it provides a more complete picture of biological condition by combining responses at species, community, and ecosystem levels (Karr, 1991; Karr and others, 1986; Plafkin and others, 1989). This was the case with the NICRI, which showed better differentiation of undeveloped sites from agriculture, mining, and urban land uses.

Derivation and Calculation of the NICRI

The National Invertebrate Community Ranking Index (NICRI) is a multimetric index that is, essentially, an average of 11 standardized metrics that have been shown to differentiate undeveloped (≈ reference) sites from other land uses at a national level. These metrics were selected from among 107 candidate community metrics and combined into a national index as described below.

1. Data sources

Data used for calculating and evaluating the candidate methods included all 1,026 Richest Targeted-Habitat (RTH) samples released by the USGS National Water-Quality Laboratory's Biological Group (BG) as of December 10, 1999. These samples were collected from 601 sites, in 38 study units. Taxonomy for all samples was updated to the current BG standards using taxonomic name change mapping provided by BG. National percent ranks were based on 140 Richest Targeted-Habitat (RTH) samples collected at fixed sites of the FY94 group of Study Units.

2. Ambiguous taxa

Ambiguous taxa (i.e., taxa for which specimens from different samples were identified to different taxonomic levels—such as, family, genus, or species) were removed by distributing 'parent' abundances among 'children' in accordance with the relative abundances of the children. For example, if a sample contained 100 individuals identified only to Hydropsychidae – plus 5 genera of Hydropsychidae represented by 10, 20, 30, 60, and 80 individuals – then the resolved data set would have no individuals identified to Hydropsychidae and the abundance for the 5 genera would now be 15, 30, 45, 90, and 120 respectively. This method of resolving ambiguous taxa gives a truer estimate of taxa richness by eliminating redundancy and preserves overall abundance within the sample. When multiple related ambiguities were present (e.g., abundances reported for Hydropsychidae, several genera of Hydropsychidae, and several species of Hydropsychidae), ambiguities were resolved starting at the lowest taxonomic level (e.g., Genus) and proceeding up the taxonomic hierarchy (e.g., Hydropsychidae) until all ambiguities are resolved.

3. <u>Calculation of metrics</u>

A metric is an enumeration representing a community characteristic or combination of characteristics that change in a predictable way as human influence increases (Fausch and others, 1990; Gibson, 1996). A total of 107 candidate metrics were considered during the development of the Summary Report. These metrics are a compilation of metrics used by various State and Federal agencies for the development of multimetric community condition indices (Barbour and others, 1999; Shackleford, 1988; Plafkin and others, 1989; Barbour and others, 1992; 1995; 1996; 1999; Smith and Voshell, 1997; Fore and others, 1996; Kerans and Karr, 1994; DeShon, 1995). These metrics are considered to be ecologically relevant and to respond to a wide range of anthropogenic disturbances. The predicted responses to increasing perturbation for many of these metrics have been compiled and published by the USEPA (Barbour and others, 1999, Chapter 7, Tables 7-1 and 7-2), as has information on tolerance and functional groups (Barbour and others, 1999, Appendix B).

Most of these metrics are simple aggregations of taxonomic, functional, or trophic groups that have been used or proposed for use in the development of biocriteria. However, two metrics, EPATOLR and EPATOLA, were derived specifically for use in NAWQA Summary Reports. These metrics take advantage of information on organism tolerances complied by the USEPA (Barbour and others, 1999, Appendix B, Part III) and are used in place of Family-level tolerance metrics such as the Hilsenhoff Biotic Index (HBI). EPATOLR and EPATOLA are thought to have advantages over the HBI because they are based on tolerance information at finer levels of taxonomic resolution (e.g., Genus and Species). Two assumptions were made in the development of the EPATOLR and EPATOLA metrics:

a. If multiple regional tolerance values were listed for a taxon, an average tolerance value was calculated and used in constructing the metric. This was necessary since the regional tolerances reported in the manual did not provide a complete national coverage nor was there a clear correspondence between the regions represented by the tolerance values and the location of NAWQA sampling sites.
b. If a tolerance value was reported at a higher taxonomic level (e.g., Family), that tolerance was applied to lower taxonomic levels (e.g., Genus and Species) when tolerance information for the lower levels was not

available. This assumption maximized the proportion of each sample's richness (average of 97.2 %) and abundance (average of 96.7 %) that was assigned to a tolerance value.

EPATOLR (richness-weighted EPA tolerance) is the average tolerance of all taxa at a site:

$$EPATOLR = \frac{\sum_{i-1}^{S} T_i}{S}$$

where: *Ti* is the tolerance value of taxon *i*
S is the number of taxa in the sample

EPATOLA (abundance-weighted EPA tolerance) is the average tolerance of all taxa at a site weighted by the abundance of each taxon:

$$EPATOLA = \frac{\sum_{i-1}^{S} T_i A_i}{\sum_{i-1}^{S} A_i}$$

where: *Ti* is the tolerance value of taxon *i*
A_i is the abundance of taxon *i* in the sample
S is the number of taxa in the sample

The distinction between these two metrics is that each taxon included in the EPATOLR metric has an equal influence on the value of the metric, whereas the more abundant taxa have greater influence on the value of EPATOLA than do less abundant taxa.

Diversity (Shannon-Wiener) and Evenness were calculated using the MSVP software package (Kovach, 1998). Other metrics were calculated using MS Access and Excel 2000. Statistical analyses (descriptive statistics, box plots, and correlations) were calculated using SYSTAT 9 (SPSS, 1999).

4. <u>Selecting metrics for National consideration</u>

The 140 sites that comprise the national set of fixed sites for the set of study units that began in FY94 represent a complex mixture of anthropogenic (land use) and natural (elevation, stream size, ecoregion) factors that are known to influence the distribution of biological communities. Metrics for national comparisons should be able to distinguish land-use effects over broad areas while being relatively insensitive to changes in natural features. Desirable characteristics for a community metric are (1) relevance to the community being studied, (2) sensitivity to stressors, (3) high signal to noise ratio (i.e., low natural variability but large response to stressors), (4) minimal disturbance to the environment, and (5) cost effectiveness (Barbour and others, 1995, Fore and others, 1996, Karr and Chu, 1999). The development of biocriteria by State and Federal agencies (Shackleford, 1988; Plafkin and others, 1989; Barbour and others, 1992, 1995, 1996; Smith and Voshell, 1997; Fore and others, 1996; Kerans and Karr, 1994; DeShon, 1995) has resulted in the compilation of a large number of candidate metrics.

Evaluation of national metrics can only approximate the level of detail employed by many State biomonitoring programs (DeShon, 1995) in the development of metrics and community condition indices. The NAWQA Program lacks sufficient reference sites, *a priori* knowledge of site conditions, and replication of environmental settings to provide the equivalent of community conditions indices such as the Invertebrate Community Index (ICI; Ohio EPA, 1987a,b). Consequently, although it is possible to use the NAWQA Program data to produce meaningful comparisons of the values of metrics and indices across the country, it is not possible to provide information on whether these metrics indicate excellent, good, fair, or poor water quality. Such assessments must be made within the context of local water-quality perceptions and expectations.

National metrics were evaluated on the basis of four characteristics:

1. relevance — was the metric relevant at a majority of the sites examined?
2. variability (noise) -- how much variability is there in the measurement of the metric?
3. responsiveness (signal) — how much does the metric change over a range of conditions?
4. sensitivity to stressors (land use) — does the metric change in response to land-use changes?

Multiple-year and multiple-reach samples were used to assess the variability of each metric. Eighty-three multiple-year and 49 multiple-reach sites were identified among NAWQA sites sampled from 1993 to 1998. The primary determinant for acceptable variability was the coefficient of variation (CV) associated with multiple reaches (table 2). Variability was deemed to be acceptable if the average coefficient of variation for multiple reach sites was $\leq$ 25 %. Multiple-year variability was relegated to a supporting role because it was anticipated that multiple-year variability would exceed multiple-reach variability (Resh, 1995). This was true for 96 of the 107 metrics examined, though there was a strong correspondence between these two estimators of variance (fig. 1.). Nineteen of the 107 candidate metrics had acceptable levels of variability (shaded values, table 2).

Responsiveness of each metric was assessed based on a consideration of the range of values observed in the data set (table 2). This evaluation assumes that the 1,026 samples in the combined FY 91 and 94 data encompassed conditions that vary from severely impacted to relatively pristine. A useful metric should exhibit a wide range of values as it responds to the large underlying changes in water-quality conditions. Taxa richness (RICH) displayed a large range of response across the data set (2-73) and would be characterized as a responsive metric and further evaluated for use as a national metric. In contrast, the richness of piercing insects (PI_R), exhibited little change in value over the data set (0-1); this metric holds little promise of detecting changes and was not considered as a national metric.

Relevance was assessed by considering the percentage of samples for which the metric value was greater than zero (table 2). Metrics that are calculable at only a small number of sites are of limited utility for national comparisons, though they may be very important locally or regionally. For example, pteronarcyid stonefly richness (PTERYR) is relevant only in a small number of samples (13.8 %) across the country. This reflects the relatively restricted distribution of these long-lived shredders that prefer cool, high-gradient streams, with closed canopies and lots of coarse leafy detritus. In contrast, the number of shredding insect taxa (SH_R) is a more relevant metric because it is applicable to 96.8% of the samples collected by the NAWQA Program.

Nineteen metrics (RICH, EPTR, DIPR, CHR, CG_R, PR_R, EPTRP, EPEMRP, DIPRP, CHRP, GC_FCP, V2DOMP, V3DOMP, V4DOMP, V5DOMP, EPATOLR, EPATOLA, DIVSHAN, AND EVEN) met the criteria for relevance, responsiveness, and variability. The sensitivities of these metrics to stressors were assessed based on their ability to differentiate undeveloped sites from other land-use categorizations (i.e., agriculture, mining, urban, and mixed). This assessment was based on the 140 FY94 fixed sites for which basin-scale land-use data were available. Box plots of each metric were grouped by major land-use categories. A metric was considered to be sufficiently sensitive if the median value associated with undeveloped sites was substantially different from the median for other land-use categories and if there was relatively little overlap between the the median for undeveloped sites and the interquartile ranges for other land-use categories. Two of the six richness metrics (DIPR and CHR, fig. 2.) exhibited large overlaps (percentiles and medians) and were dropped from consideration. Three (EPEMRP, DIPRP, GC_FCP, fig. 3.) of the 9 community composition indices were dropped because they didn’t adequately differentiate the undeveloped sites. The tolerance, diversity, and evenness metrics (fig. 4.) met the sensitivity criteria and were retained. Three of the dominance metrics (V3DOMP, V4DOMP, and V5DOMP) were dropped from consideration because they were deemed to be redundant with V2DOMP.

The remaining eleven metrics (RICH, EPTR,CG_R, PR_R, EPTRP, CHRP, V2DOMP, EPATOLA, EPATOLR, DIVSHAN, and EVEN) met all criteria (relevance, variability, responsiveness, and sensitivity) for consideration as metrics for the national comparisons of NAWQA Program sites.

RICH (taxa richness) measures the overall variety of the macroinvertebrate assemblage (Resh and others, 1995) present in a sample. This metric is probably the most commonly used community metric (Bode and Novak, 1995) in biomonitoring. Increasing richness is thought to indicate increasing health of the assemblage (Resh and Grodhaus, 1983; Weber, 1973) and suggests that niche space, habitat, and food resources are adequate for the survival and reproduction of many species. Subsets of total richness (EPTR, CG_R, and PR_R) accentuate key indicator groupings.

EPTR (richness of mayflies, stoneflies, and caddisflies) and EPTRP (percentage of taxa richness composed of mayflies stoneflies, and caddisflies) combine richness measures for three orders that are generally considered to be intolerant of poor water quality (Lenat, 1987, 1988). As with total richness, assemblage health is considered to be directly related to EPT richness.

An increase in the percentage of total richness composed of chironomid larvae (CH_RP) is thought to be indicative of increasing perturbation and declining assemblage health (Barbour and others, 1996b; Hayslip, 1993). Midge larvae tend to be generalists and an increase in generalists is typically associated with declining community condition.

Functional feeding groups provide information on the balance of feeding strategies in the benthic assemblage. These metrics are considered to be surrogates for complex ecological processes involving trophic interactions, production, and food resource availability (Karr and others, 1986, Cummins and others, 1989, Plafkin and others, 1989). Generalists, such as collector gatherers (CG_R) have a broader range of acceptable food materials than specialists (Cummins and Klug, 1979) so an increase in the number of collector-gatherer generalists is thought to indicate a degradation of assemblage health. Conversely, the number of predators (PR_R) would be associated with a decline in the abundance and diversity of prey and indicative of a decrease in the health of the assemblage (Karr and Chu, 1997; Kearns and Karr, 1994). However, the utility of functional feeding groups in water-quality assessment has not been well demonstrated. There are considerable difficulties and ambiguities in the assignment of organisms to functional feeding groups and this contributes to problems with the calculation and application of these metrics (Karr and Chu, 1997).

Dominance is the percent of total abundance represented by the most numerous species in the sample. It is used as a simple measure of community balance (Bode and Novak, 1995). An increase in dominance is considered to be indicative of a decrease in the health of the assemblage, as abundance becomes concentrated in a few taxa. V2DOMP corresponds to the dominance of the two most abundant taxa in the sample.

Diversity (DIVSHAN) and evenness (EVEN) are measures of information content that attempt to characterize both the number of taxa and the distribution of abundance among taxa. These metrics have been widely used in water-quality studies (Resh and McElravy, 1993) and are touted as indicators of important ecological properties (diversity/stability hypothesis [Goodman, 1975] or competitive interactions [Hurlbert, 1971]) that are of importance to water quality assessment. However, the relationship between these metrics and ecological properties remains inconclusive (Washington, 1984). Diversity and evenness have a tendency to be redundant with taxa richness and percent dominance (Barbour and others, 1996b) and, like richness and dominance, are thought to decrease as water quality decreases (Norris and Georges, 1993). Diversity indices can be affected by a variety of factors that are not related to changes in water quality (sampling methods, time of year sampled, and taxonomic levels used for identifications; Hughes, 1978). The standardized sample collection (Cuffney and others, 1993) and processing (Moulton and others, 2000) procedures used in the NAWQA Program minimize most of these interferences. However, great care should be exercised in the comparison of NAWQA Program metrics with those of other State or Federal programs.

Tolerance metrics (EPATOLR and EPATOLA) are computationally and conceptually similar to the Hilsenhoff Biotic Index (Hillsenhoff, 1988). EPATOLR and EPATOLA use the USEPA's (Barbour, 1999) compilation of numeric tolerance scores, which range from 0 (intolerant) to 10 (very tolerant). Consequently, low metric scores indicate the presence of an assemblage that is more intolerant of perturbation and, presumably, a healthier assemblage. USEPA's tolerance scores represent responses to a wide range of perturbations and are compiled for a variety of taxa that are identified at a range of taxonomic levels (Species to Class). This is in contrast with the Hilsenhoff Biotic Index (HBI), which was originally developed to measure responses to organic pollution using tolerances compiled at the Family level.

5. <u>National Invertebrate Community Ranking Index (NICRI)</u>

The NICRI is a multimetric index that combines into a single, nationally consistent, composite index the 11 metrics that met the criteria for relevance, responsiveness, variability, and sensitivity, as described above. The metrics that form this index (RICH, EPTR, CG_R, PR_R, EPTRP, CHRP, V2DOMP, EPATOLR, EPATOLA, DIVSHAN, and EVEN) have been shown to differentiate undeveloped (≈ reference) sites from other land uses at a national level. The NICRI is, essentially, an average of standardized metrics. Percent rankings, calculated using the Excel function PERCENTRANK, were used to standardize the individual metrics across all samples (1,026 RTH samples from FY91 and FY94 study units) or sites (140 fixed sites in FY94 study units; median values were derived from all available data [multiple year and multiple reach] for a site). This function evaluates the relative standing of a value within a data set by calculating the percentage of sites or samples ranked below the value. Therefore, a percent rank of 0.8 indicates that 80% of the values in the data set are less than the value being examined and 20 % of the values are equal to or greater than the value being examined. Percent rankings not only standardizes values within a range of from 0 to1, but also reduces the influence of outliers in the data set.

Nine of the metrics used to calculate the NICRI are directly related to water quality, that is, they increase in value as water quality increases. Two metrics (CHRP and V2DOMP) respond in the opposite fashion. To compensate for this behavior, standardized scores (percent ranks) for these metrics were subtracted from 1 prior to calculating the average metric score. Average metric scores were then rescaled using the PERCENTRANK function and multiplied by 100 to produce a final NICRI score that ranged from 0 (low ranking relative to other NAWQA Program sites and presumably diminished community conditions) to 100 (high ranking relative to other NAWQA Program sites and presumably excellent community conditions).

A composite index is thought to be better at differentiating water-quality affects than single metrics (Gibson, 1996) because it provides a more complete picture of biological condition by combining responses at species, community, and ecosystem levels (Karr, 1991; Karr et al., 1986; Plafkin et al., 1989). This was the case with the NICRI, which showed better differentiation of undeveloped sites from agriculture, mining, and urban land uses (fig. 5.).

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Table 1. Invertebrate community metrics considered in the national data summarization. Metrics selected for the National Invertebrate Community Ranking Index are shown in RED.

Richness metrics:

RICH	**Total richness (number of non-ambiguous taxa)**
EPTR	**Number of mayfly, stonefly, and caddisfly taxa**
EPEMR	Number of mayfly taxa
PLECOR	Number of stonefly taxa
TRICHR	Number of caddisfly taxa
PTERYR	Number of Pteronarcidae taxa
COLEOPR	Number of Coleoptera taxa
DIPR	Number of Diptera taxa
CHR	Number of midge taxa
ORTHOR	Number of Orthocladinae midge taxa
TANYR	Number of Tanytarsanii midge taxa
MOLCRUR	Total richness (number of non-ambiguous taxa)
NONINSR	Number of non-insect taxa
ODONOR	Number of Odonata taxa
GASTROR	Number of Gastropoda taxa
BIVALVR	Number of Bivalvia taxa
CORBICR	Number of Cobriculidae taxa
AMPHIR	Number of Amphipoda taxa
ISOPODR	Number of Isopoda taxa
OLIGOR	Number of Oligochaeta taxa
FC_R	Number of filtering-collector taxa
SC_R	Number of scraper taxa
SH_R	Number of shredder taxa
PI_R	Number of piercer taxa
CG_R	**Number of collector-gatherer taxa**
OM_R	Number of omnivore taxa
PR_R	**Number of predator taxa**
PA_R	Number of parasite taxa

Percentage of taxa richness metrics

EPTRp	**Percentage of total richness composed of mayflies, stoneflies, and caddisflies**
EPEMRp	Percentage of total richness composed of mayflies
PLECORp	Percentage of total richness composed of stoneflies
TRICHRp	Percentage of total richness composed of caddisflies
PTERYRp	Percentage of total richness composed of Pteronarcidae
COLEOPRp	Percentage of total richness composed of Coleoptera
DIPRp	Percentage of total richness composed of Diptera
CHRp	**Percentage of total richness composed of midges**
ORTHORp	Percentage of total richness composed of Orthocladinae midges
TANYRp	Percentage of total richness composed of Tanytarsanii midges
MOLCRUrp	Percentage of total richness composed of molluscs and crustaceans

Abundance metrics:

ABUND	Total number of organisms in the sample
EPT	Abundance of EPT
EPEM	Abundance of mayflies
PLECO	Abundance of stoneflies
TRICH	Abundance of caddisflies
PTERY	Abundance of Pteronarcidae
COLEOP	Abundance of Coleoptera
DIP	Abundance of Diptera
CH	Abundance of midges
NCHDIP	Abundance of non-midge Diptera
ORTHO	Abundance of Orthocladinae midges
TANY	Abundance of Tanytarsanii midges
MOLCRU	Abundance of Mollusca and Crustacea
NONINS	Abundance of non-insects
ODONO	Abundance of Odonata
GASTRO	Abundance of Gastropoda
BIVALV	Abundance of Bivalvia
CORBIC	Abundance of Corbiculidae
AMPHI	Abundance of Amphipoda

ISOPOD	Abundance of Isopoda
OLIGO	Abundance of Oligochaeta
FC	Abundance of filtering-collectors
SC	Abundance of scrapers
SH	Abundance of shredders
PI	Abundance of piercers
CG	Abundance of collector-gatherers
OM	Abundance of omnivores
PR	Abundance of predators
PA	Abundance of parasites

Percentage abundance (compostion) metrics:

EPT_CHp	Ratio of EPT to midge abundance
EPTp	Percentage of total abundance composed of mayflies, stoneflies, and caddisflies
EPEMp	Percentage of total abundance composed of mayflies
PLECOp	Percentage of total abundance composed of stoneflies
THRICp	Percentage of total abundance composed of caddisflies
ODONOp	Percentage of total abundance composed of odonates
COLEOPp	Percentage of total abundance composed of Coleoptera
DIPp	Percentage of total abundance composed of Diptera
CHp	Percentage of total abundance composed of midges
ORTHO_CH	Ratio of orthoclad midges to total midge abundance
TANY_CH	Ratio of Tanytarsini to total midge abundance
TANYp	Percentage of total abundance composed of Tanytarsini midges
ODIPNIp	Percentage of total abundance composed of non-midge dipterans and non-insects
MOLCRUp	Percentage of total abundance composed of molluscs and crustaceans
GASTROp	Percentage of total abundance composed of gastropods
BIVALp	Percentage of total abundance composed of bivalves
CORBICp	Percentage of total abundance composed of Corbiculidae
AMPHIp	Percentage of total abundance composed of Amphipoda

ISOPp	Percentage of total abundance composed of Isopoda
OLIGOp	Percentage of total abundance composed of Oligochaeta

Tolerance/dominance metrics:

EPATOLR	**Average EPA tolerance for based on richness**
EPATOLA	**Abundance-weighted EPA tolerance**
V1DOMp	Percentage of total abundance represented by the most abundant taxon
V2DOMp	**Percentage of total abundance represented by the two most abundant taxon**
V3DOMp	Percentage of total abundance represented by the three most abundant taxon
V4DOMp	Percentage of total abundance represented by the four most abundant taxon
V5DOMp	Percentage of total abundance represented by the five most abundant taxon

Functional-feeding group metrics:

SCPIr	Number of scraper and piercer taxa
OM_SCp	Percentage of total abundance represented by omnivores and scavengers
GC_FCp	Percentage of total abundance represented by gatherers and filterers
GCp	Percentage of total abundance represented by gatherers
FCp	Percentage of total abundance represented by filterers
PRp	Percentage of total abundance represented by predators
SCp	Percentage of total abundance represented by scrapers
SC_FC	Ratio of scrapers to filterers
SHp	Percentage of total abundance represented by shredders

Diversity/Evenness metrics

DivShan	**Shannon-Wiener diversity index**
Even	**Evenness (Shannon-Wiener diversity/maximum diversity)**

Multimetric index

NICRI	National invertebrate community ranking index

Table 2. Summary of metric variability and responsiveness. Multiple-year and multiple-reach variability were assessed as the average coefficient of variation (CV). Responsiveness is indicated by the minimum, maximum, and percent occurrence of each metric for the 1,026 samples that constituted the FY 91 and 94 data sets.

	Variability		Variability		Responsiveness		
	Multiple reach		Multiple year				Percent
Metric	CV (%)	N	CV (%)	N	Minimum	Maximum	occurrence
RICH	**14.5**	49	**21.4**	83	2	73	100.0%
EPTR	**21.9**	49	29.9	83	0	37	97.6%
CG_R	**24.1**	49	27.8	83	1	27	100.0%
PR_R	**23.5**	49	37.8	83	0	19	99.2%
EPTRP	**14.7**	49	**21.9**	83	0	67	97.6%
CHRP	**18.6**	49	**19.7**	83	4	76	100.0%
EPATOLR	**4.3**	49	**5.8**	83	2	8	100.0%
EPATOLA	**9.6**	49	**9.1**	83	1	10	100.0%
V2DOMP	**23.6**	49	**21.2**	83	18	100	100.0%
DivShan	**10.2**	49	**13**	83	0	4	100.0%
Even	**7.8**	49	**10.3**	83	21	93	100.0%

Figure 1. Correspondence between estimates of variability compiled from multiple reach and multiple year data. The straight line indicates a 1:1 correspondence between the two estimators of variability.

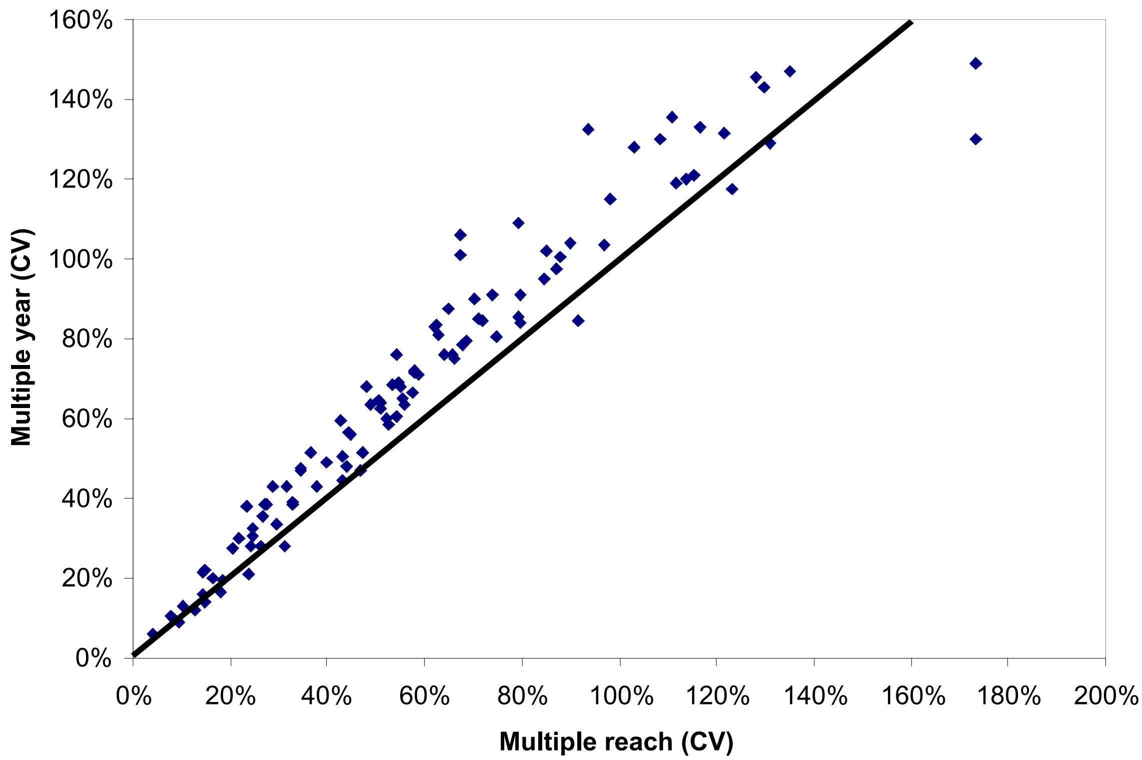

Figure 2. Invertebrate community richness metrics summarized by land-use classification.

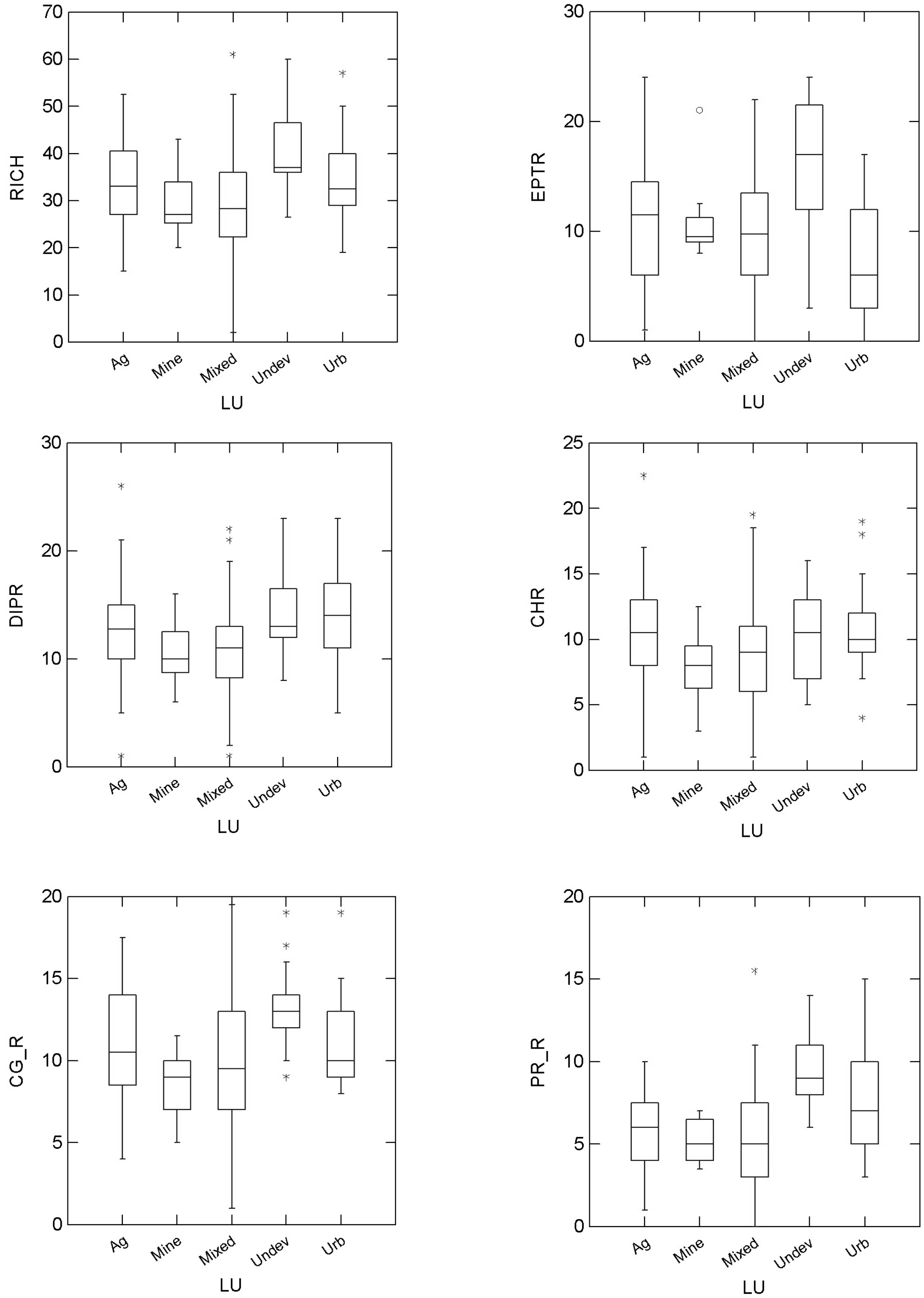

Figure 3. Invertebrate community composition (relative abundance) metrics summarized by land-use classification.

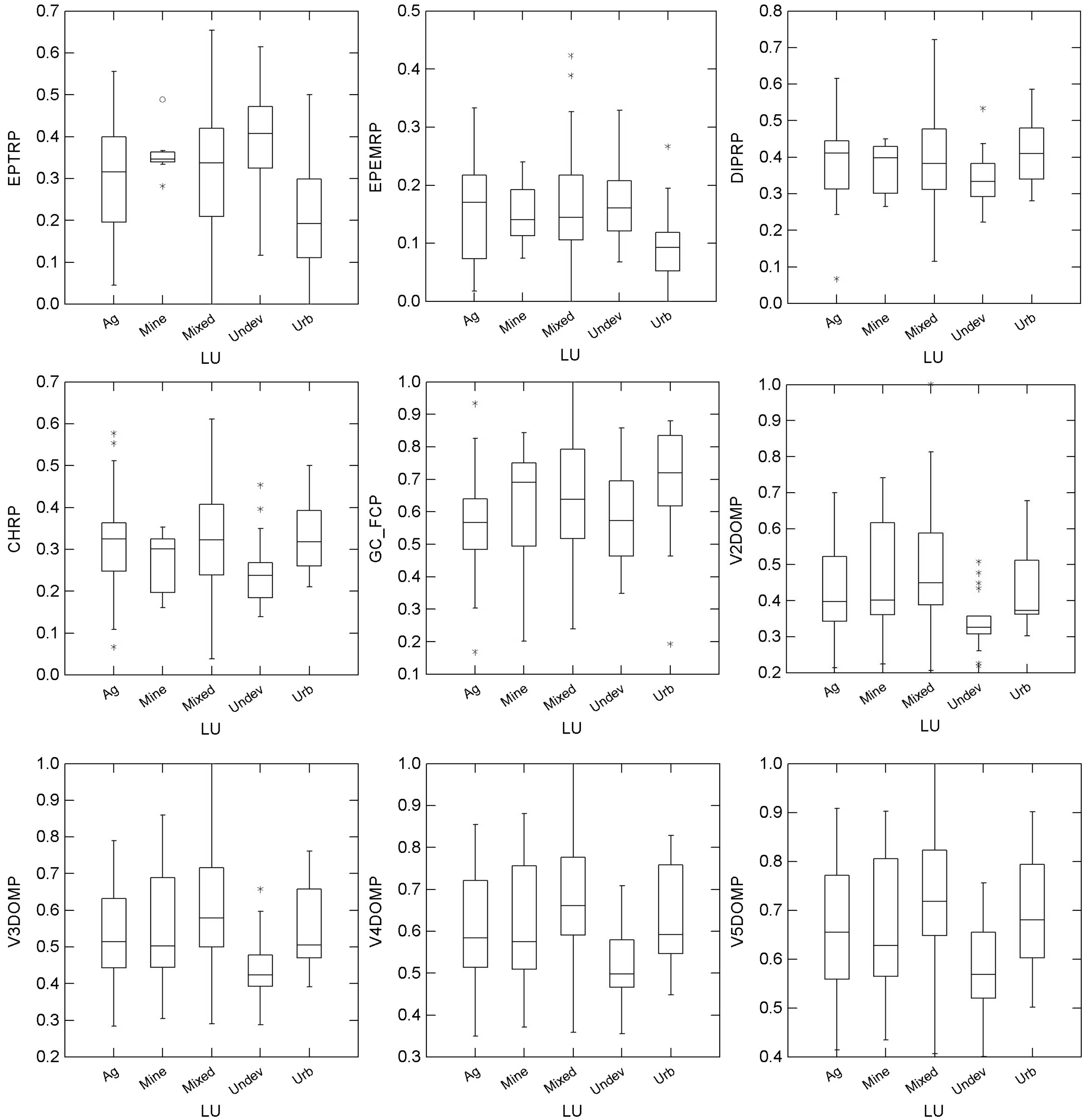

Figure 4. Invertebrate community tolerance, diversity, and evenness metrics summarized by land-use classification.

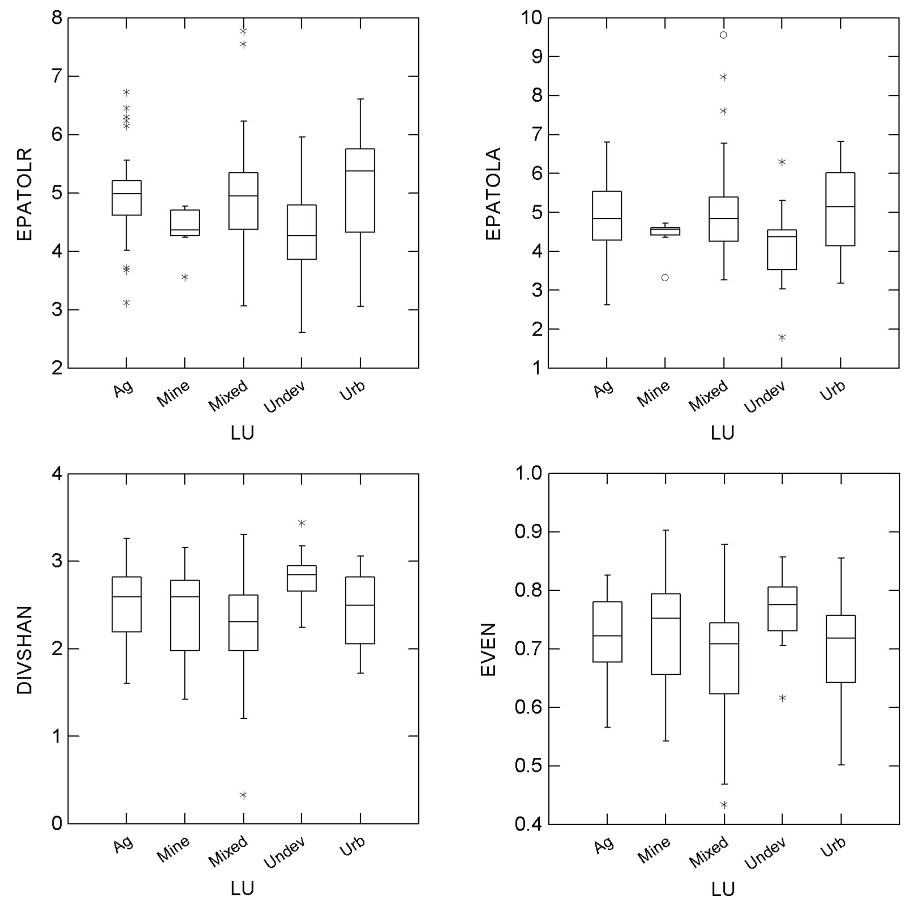

Figure 5. National invertebrate community ranking index (NICRI) summarized by land-use classification.