AN INDEX OF RIPARIAN INTEGRITY FOR THE AUSTIN AREA

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ABSTRACT

A GIS based assessment tool is presented that uses aerial photography and land use data to measure stream corridor integrity. This method combines 10 metrics, taken from vegetative distribution and development patterns within multiple scales of stream buffer analysis (immediate vicinity of study site, 10m, 30m, 50m and 100m corridors along streams). Development of the index is presented along with results of its comparison to 80 Austin area stream biological data sets.

INTRODUCTION

In recent years, riparian condition has become an integral part of any comprehensive environmental monitoring program (Barbour et al 1999, Wissmar and Bechta 1998). The effect riparian zones have on aquatic systems is well documented (Correll 1999). Measuring riparian quantity and quality is a less developed area of study with a wide range of practices depending on study goals and resource availability. Methods to evaluate riparian systems generally fall into two categories: small area, high intensity field assessments and large area assessments using satellite imagery. Field studies provide detailed, species-level community analysis and require large labor investments per unit area. Assessments of riparian areas using satellite imagery tend to aggregate plant communities and look at large-scale (full river system) patterns with minimal investment of labor per unit area. Both methods require manual adjustment of geographic data based on best professional judgment and are difficult to reproduce for comparison purposes.

The City of Austin uses the Environmental Integrity Index (EII) to assess stream health for all watersheds in our jurisdiction (COA 1997). This approach provides detailed biological, physical and chemical data from specific locations, usually 3-6 sites per watershed, and uses these points as representatives for the drainage area above them. This approach is appropriate and practical for water quality measures (biological, chemical) since watershed effects theoretically aggregate at a downstream point in a fluvial system (Wetzel 2001, Hynes 1970). However, riparian condition at a single point does not necessarily represent that condition upstream. There is a high degree of variability in riparian condition depending on development patterns, topography, geology and management practices. A method to fully assess riparian condition throughout an entire stream corridor would greatly improve our understanding of the effect of riparian quality on stream health.

A comprehensive index of riparian condition based on manually interpreting aerial photography was used to evaluate riparian effect on stream biotic condition in the Pacific Northwest (Horner and May 1999, May and Horner 2000). During the development and implementation of this index in the Austin area for a grant from the WMI, the method was retrofitted to work within a Geographic Information System, using classified high-resolution aerial images instead of manual interpretation of satellite imagery. The resulting method is presented in this paper, including modifications and improvements made following further review and analysis with a larger City of Austin biological data set.

METHODS

In general, several types of data are used in this index as individual metrics, or statistics, which when combined, provide a comprehensive and diverse measure of overall riparian integrity. These metrics can be calculated and combined to automatically generate index scores for any stream corridor with sufficient source data. A review of the data types is presented below, followed by the selection of metrics and index development.

Aerial Photography/Land Cover

The city of Austin acquired 2-foot resolution color infra-red photography in year 2000 and 2003 that covers all the watersheds in our jurisdiction (WPDRD city-wide masterplan areas). All initial analysis and development of the index was done using the 2000 photography, which was flown before leaf drop in October 2000. It is anticipated that this same type of data (Leaf-on, Color Infra-Red) will be collected on a three year rotation for the immediate future.

This relatively high-resolution imagery provides good infra-red spectral signatures for many vegetation classes. Photosynthetic plants radiate energy in the infra-red spectrum which ranges from a muddy dark red for minimally active plants to bright pink for highly active or “hot” plants. This photosynthetic signature is what is used to separate plant types or groups (Fig. 1).

Figure 1. Example of Color Infra Red photography. Riparian zone of walnut Creek upstream of US I35.

A supervised classification was completed in all study watersheds based on the following vegetative classes shown in Figure 2.

- Evergreen/Ashe Juniper
- Deciduous trees and Live Oak
- Tall grass meadow
- Short grass meadow
- Concrete/Asphalt/Impervious cover
- Lawn/turf/hot vegetation

The selection of these classes was based on *a priori* ecological grouping as well as the resolution of the available photography. For example, Live Oak could not be separated from other deciduous trees. Field verification was performed on all classes and accuracies were above 80% for each class.

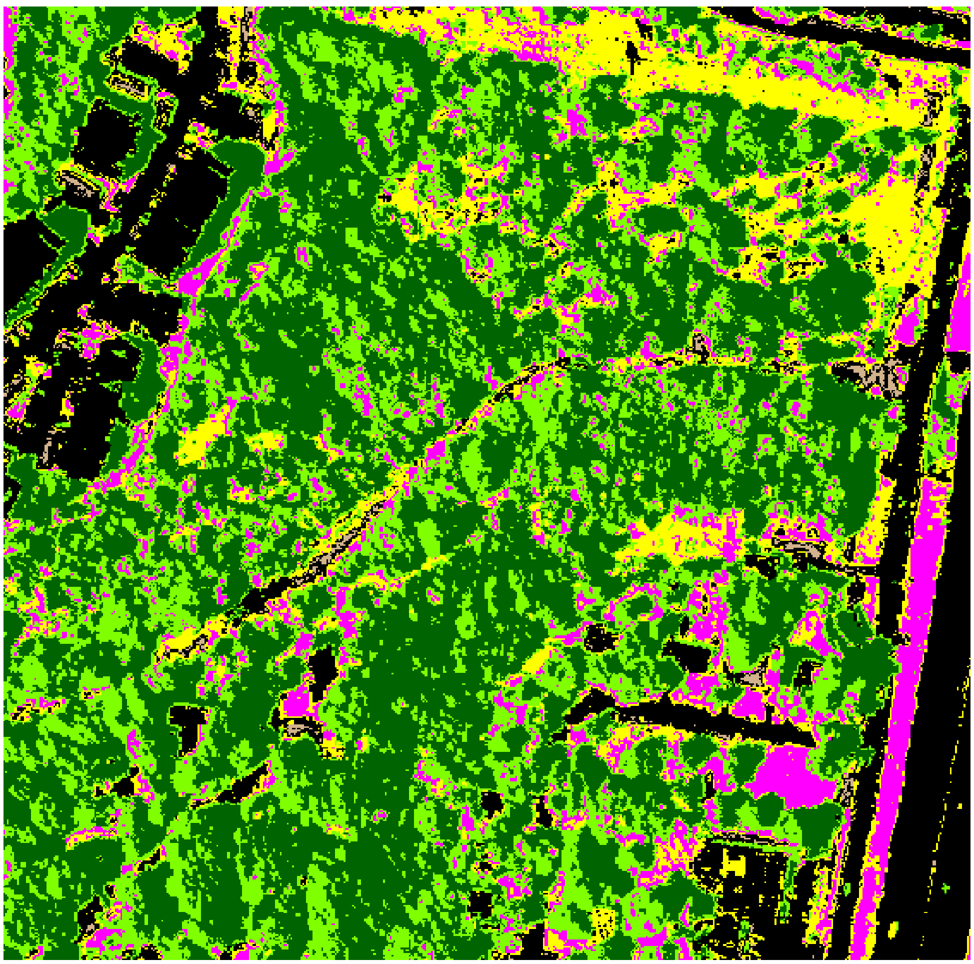

Figure 2. Example of a classified image: Dark green=Evergreen, Light green= Deciduous, Yellow=Short Grass meadow, Black=Impervious cover, Pink=Lawn/hot vegetation. Riparian zone of Walnut Creek upstream of I35.

Land Use Data

The City of Austin maintains a detailed coverage of land use based on the Anderson Land Use classification scheme (Anderson 1976) and developed using planimetric data and aerial photography. The basic categories which represent the land uses are:

- Single Family - Residential
- Multi-family - Residential
- Commercial
- Office
- Industrial
- Civic/Educational
- Open Space/Parks
- Transportation
- Undeveloped/Rural

This system is maintained in a GIS coverage in which polygons are used to describe single land use categories. The City of Austin land use data is updated periodically (approximately every 5 years) and the data used in this analysis was updated in the year 2000. Land use in the analysis was used primarily to describe how development encroaches on a riparian area where aerial photography would not be as accurate, usually due to canopy cover (Fig. 2).

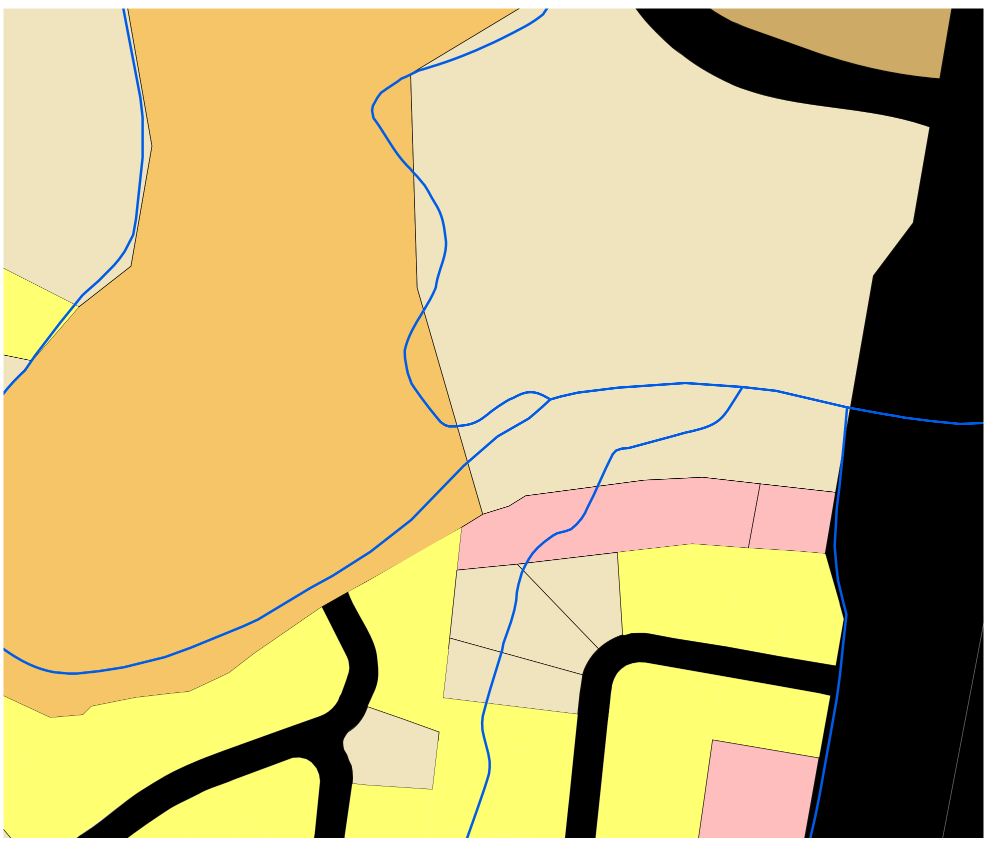

Figure 3. Example of Land use polygons along riparian zone of Walnut Creek at US I35. Yellow=residential, pink=commercial, orange=multi-family, black=transportation and tan=undeveloped.

Hydrology
A line file of all Austin area streams is used as the basic hydrology layer which defines the stream centerline and which establishes the basis line from which buffers/riparian zones are offset. The file used for this analysis is the ASI Stream network (ASI/Ellen Wadsworth, 2001), which is the most accurate and comprehensive to date. However, due to the extensive network of tributaries, and the time required to establish buffers for each one, only the mainstem branch and major tributaries are utilized for riparian analysis in this study.

Metric selection
A list of approximately 50 different metrics were evaluated from literature research and compilations by WMI (Horner and Mays (1999, 2000). The metrics represented land cover and land use (10 measures) within multiple buffer areas (10m, 30m, 50m, 100m and local/immediate vicinity). In order to test these metrics in the Austin area, 80 biological sites were selected where all major data types were available. Riparian buffer data were classified and compiled in order to compare to site biological scores. Initially, the long list of riparian metrics was reduced by removing variables that were strongly correlated ($r>0.80$). From this list, metrics were placed into four general categories (Horner and Mays 2000); Extent, Continuity, Quality and Local effect. Extent utilizes a large, 100 meter buffer on either side of the stream center line. Any encroachment in this area limits the functionality of the larger-scale processes that riparian zones provide. Continuity measures any complete break in the riparian buffer and uses road crossings and encroachments beyond the 10-meter buffer as indicators of degradation. Quality measures of riparian buffers utilize the 30 and 50 meter buffer areas and generally look for dominance of healthy riparian plant communities such as deciduous trees and tall grasses. Local effect looks at the impacts of different land use and land cover practices in the immediate vicinity of a site (100m radius). The combination of these different scales and ecological services provides a comprehensive and robust measure of overall riparian integrity.

The metrics within each of the above groups were correlated to the biological scores at all sites and reduced to a manageable number by selecting those with the best relationship (highest correlation coefficients) with the benthic macroinvertebrate community measures. The final list was reduced to 10 metrics, two each in the Extent and Quality categories and three each in the Continuity and Local Effect category (Table 1).

Table 1. Categories and final metrics included in Index of Riparian Integrity.

Category		**Metrics**
Extent	1	% Development in 100m buffer (from aerial photos)
	2	% Developed in 100m buffer (from land use)
Continuity	3	# of Road Crossings per km
	4	% Concrete/Asphalt in 10m Buffer (from aerial photos)
	5	% impervious cover in 10m (from land use)
Quality	6	% Deciduous trees in 30m buffer
	7	% Tall grass in 50m buffer
Local Effect	8	% Lawn/turf at local buffer (100m)
	9	%Short Grass at local buffer
	10	% Development in local buffer (from aerial photos)

Index development
Once the core metrics were selected (Table 1), an indexing methods was used to distill raw statistics from the metrics (i.e. % Tall grass in 50m buffer) into unit-less percentiles that can be compared to each other. The most important step in this process is establishing what the natural ranges of these statistics are

among Austin area data. For example, the range of the "number of road crossings per km" in the Austin data set was a minimum of 0 and a maximum of 4. The 5th and 95th percentiles of that range are used to exclude outliers. Depending on the ecological significance of each metric, the "optimum" of any given metric can be either the 5th or 95th percentile. For example, "number of road crossings" is better the fewer roads, so the 5th percentile is used as the optimum. The "percent development in the 100m buffer" is better the lower the percent is, so the 5th percentile is the optimum. Once ranges and optimums are set for each metric, the indexed metric is calculated for a given riparian zone using the following formula:

IRI metric score = 100 * ((Truncated raw metric score – 5th percentile)/(95th percentile – 5th percentile)).

This procedure is followed for each of the 10 metrics, which provides a 0-100 point scale for each metric based on its natural range. Each of these "raw" indexed metric scores is then averaged to get an overall site index score. Finally, this raw site score is divided by the best scoring reference site (catchment area with least disturbed land cover and minimal to no development) for that data period (tied to the date of the source spatial data), which results in a locally and temporally relevant normalized index score for each riparian zone evaluated. This is the IRI score discussed in the following results.

RESULTS

To evaluate how well the IRI could predict biological condition, a series of regressions and multiple regressions were performed. Overall, the IRI performed fairly well against biological Index scores (an index of 9 benthic macroinvertebrate metrics), with a significant regression, r=0.58 and R^2 of 0.33 (Fig. 4). As riparian integrity increases with the IRI, biological scores generally increase with it.

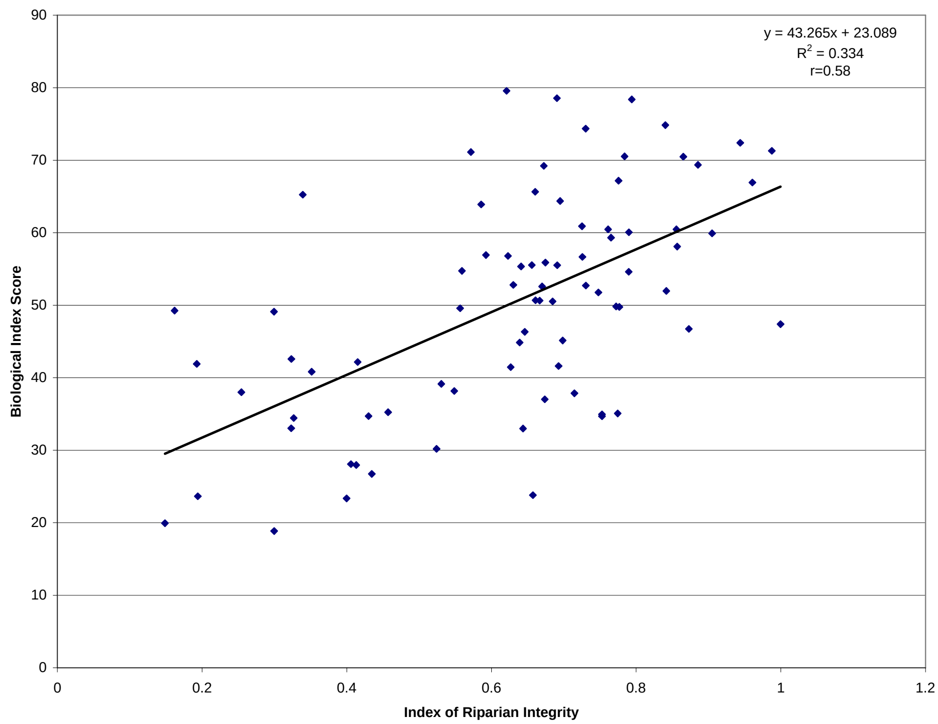

Figure 4. Scatterplot of IRI vs. biological index score, 80 City of Austin sites.

Individual metrics within the IRI were also evaluated as to their strength in the index. Ridge multiple regressions were performed of each of the 10 IRI metrics (independent variables) vs. the biological variables (the 9 dependent biological metrics and the overall biological index score). The Ridge technique compensates for correlation among independent variables within the IRI. The results showed that among the IRI metrics, the most powerful predictors of the biological index score were % Lawn/turf at the local scale, % Development from Land Use at the 100m buffer, and Impervious Cover from Land Use within the 10m buffer (Table 2). Looking at individual regressions (10 dependent biological variables), two of the IRI metrics were significant in almost every one. These two metrics were % Lawn/turf at the local scale and % Development from Land Use at the 100m buffer. Several other metrics were also significant in these regressions, but these two were the most common and best predictors of biological condition. Among the individual biological metrics, the ability of the IRI to predict them ranged from an R^2 of 0.12 for the Number of Taxa metric to an R^2 of 0.29 for the % Dominant Metric. The combined Biological Index score was better predicted (R^2 of 0.33) than any of the individual metrics.

Table 2. Results from forward-stepwise Ridge multiple regression. Metrics column has individual biological metrics that are used to calculate Index Score. Variables 1-3 are those significant variables ($P<0.05$) that best predicted (highest Beta value) with the biological metrics in the multiple regressions. R^2 values are the coefficient of determination for each of the regressions. Yellow and blue shading highlights the two most important independent variables.

Metrics	**R2**	**Variable 1**	**Variable 2**	**Variable 3**
HBI	0.16	xing/km	local_lawn/turf	30_decid/liveoak
#Ephem	0.25	100_%dev_lu	local_shortgrass	
#EPT	0.25	10_impcov_lu	local_lawn/turf	
#Intol	0.19	100_%dev_lc	10_impcov_lu	
#Taxa	0.12	local_lawn/turf	10_impcov_lu	
%Dom	0.29	100_%dev_lc	local_lawn/turf	
%Chir	0.21	50_tallgrass	30_decid	100_%dev_lu
%EPT	0.25	100_%dev_lu	local_lawn/turf	
%Pred	0.23	100_%dev_lu	xing/km	50_tallgrass
Site Score	**0.33**	**local_lawn/turf**	**100_%dev_lu**	**10_ic_lu**

DISCUSSION

The Index of Riparian Integrity utilizes both aerial photography and traditional planimetric land use data to evaluate stream corridor health. Based on the analysis presented in this paper, there is a significant and fairly strong relationship between this method of assessing riparian integrity and biological condition, as measured by the macroinvertebrate community. The addition of classified aerial imagery to the traditional land use measures of development appears to significantly increase our ability to predict stream condition. Vegetative measures of land cover accounted for 12 out of 21 significant variables in the regressions performed (Land use accounted for 9). This finding should aid efforts to understand the high level of variability observed in the biological health of Austin's streams.

The primary advantage to including aerial photography in riparian analysis is to reduce staff field time. Although no quantitative comparison was attempted to traditional field method of riparian assessment, the difference in resources and staff time appear to be large. As noted previously, most field methods do some level of sub-sampling or representative sampling so that the entire watershed is not walked and evaluated. Even under these simplified methods, assessing the riparian zone in a single small watershed would take 3-4 days of field time and a day of data preparation and analysis. The proposed IRI method would take less than one day and would assess every linear foot of stream channel. However, it should be noted that the resolution of this method is wholly dependent on the classification data obtained (photography) and should be used primarily as a watershed-scale assessment tool, followed by field assessment in areas of concern. Another advantage of this method is that it is more objective and reproducible. All assessment values obtained from IRI can be compared across and within watersheds as long as the source data is the same.

One of the IRI variables that merits close attention is the lawn/turf or hot vegetation at the local scale (100m radius around study site). This vegetative group includes irrigated and "managed/maintained" turf as well as very active growing vegetation, probably in areas of recent disturbance. This metric was the single best predictor of biological condition among the IRI variables, and always with a negative relationship with the biological metrics (as this variable increases in value, biological health decreases). This may be a surrogate for a particular chemical or physical effect, but since this variable was stronger than other measures of development within this local area, it is likely that managed turf is causing more degradation than other forms of development in the riparian area. This result clearly has management implications regarding both quantity of managed turf allowed in riparian areas and what practices are appropriate to manage this turf (irrigation, fertilizers, herbicides, pesticides, etc).

References:

Anderson J.R, E.E. Hardy, J.T. Roach and R. E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. USGS professional paper 964; U.S. Government Printing Office, Washington D.C.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for use in streams and wadeable rivers, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Correll, Dave, Vegetated Stream Riparian Zones: Their Effects on Stream Nutrients, Sediments, and Toxic Substances: An Annotated and Indexed Bibliography of the world literature including buffer strips, and interactions with hyporheic zones and floodplains.Smithsonian Environmental Research Center Edgewater, Maryland, USA .Eighth Edition, April 1999

Gordon, N.D., T.A. McMahon and B.L. Finlayson, 1992. Stream Hydrology: An Introduction for Ecologists. John Wiley & Sons, N.Y., N.Y.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41:540-551

Horner, R.R. and C.W. May. 1999. Regional Study Supports Natural Land Cover Protection as Leading best Management Practice for Maintaining Stream Ecological Integrity. Proceedings of The Comprehensive Stormwater and Aquatic Ecosystem Management Conference. Auckland, NZ

May, C.W and R.R. Horner. 2000. The Cumulative Impacts of Watershed Urbanization on Stream-Riparian Ecosystems. AWRA Riparian Ecology and Management in multiland use watersheds Conference. Portland OR August 28-31, 2000.

Meyer, Judy L. Ph.D. Where Rivers are Born: The Scientific Imperative for Defending Small Streams and Wetlands. Sierra Club and American Rivers, September 2003.

Peterson, B.J., W.M. Woheim, P.L. Mulholland, J.R. Webster, J.L. Meyer, J.L. Tank, E. Marti, W.B. Bowden, W.M. Valett, A.E. Hershey, W.H. McDowell, W.K. Dodds, S.K. Hamilton. S.Gregory, and

D.D. Morrall. 2001. Control of Nitrogen Export from Watersheds by Headwater Streams.*Science*292:86-90.

Richards, C. and G. Host. 1994. Examining land use influences on stream habitats and macroinvertebrates: a GIS approach. Water Resources Bulletin 30(4): 729-738.

Schueler, Tom. 1995. The architecture of urban stream buffers. Watershed protection techniques. Vol. 1, No. 4. Pp. 155-163.

Wissmar, R.C and R.L. Bechta. 1998. Restoration and management of riparian ecosystems: a catchment perspective. Freshwater Biology 40: 571-585.