

Herpetofauna as Indicator Species in the Health of Riparian Buffer Zones

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Abstract

How do you tell how healthy an ecosystem is? There are different scientific methods to address this question, one of which is to look at the reptiles and amphibians which are present at a given site. Reptiles and Amphibians are good indicators of a healthy ecosystem since their lifestyle is dependent on water and the quality of their habitat to thrive. During my study I studied the health of two riparian buffer locations along the Guest River, in Wise County Virginia, using amphibian and reptile communities as a study system. Amphibians are especially susceptible to the degradation of an ecosystem due to their affinity to water. The locations used were a heavily-disturbed buffer zone in Norton, Virginia, and an undisturbed reference buffer zone at the Guest River Gorge in Coeburn, Virginia. At each site we placed coverboards and frog pipes in order to attract herpetofauna. We went to each site weekly, at different times, during the summer of 2012 in order to get a good sample size. At the Norton site, we found species that are known to be found in disturbed habitats, but few of the species known to be strong habitat specialists. From the differences of species found at each site, we determined that fewer disturbances in a riparian buffer zone will prove to be beneficial to herpetofaunal populations. Destroying the habitat in a riparian zone is harmful to many different species, even if it is not easily seen. The use of herpetofauna as indicator species is not commonly done in riparian buffer zones, but this study shows that it can be a good determinant for evaluating ecosystem health.

Keywords: Herpetofauna, riparian buffer, indicator species

1. Introduction

The definition of a riparian buffer zone varies between different agencies and sources. The generally accepted definition of a riparian buffer zone is the lands adjacent to streams where vegetation is strongly influenced by the presence of water¹⁷. A more detailed definition states that riparian buffer zones are vegetated areas along both sides of water bodies that generally consist of trees, shrubs and grasses and are transitional boundaries between land and water environments. Riparian zones act as buffers to protect surface waters from contamination and are habitats for a large variety of animals and birds⁹. These habitats are important for an ecosystem for various reasons, including preventing erosion, sedimentation or water pollution. These qualities make riparian habitats vital to conserve or restore.

Knowing the importance of a certain type of habitat is the first step in understanding proper restoration or management techniques. The other important information to know about the habitat is a measure of health or ecological status. One method of determining the habitat health is using an indicator species to gage the overall health of the habitat being studied. As defined by Rolstad et. al. (1988) and others, an indicator species is a species that is used to mirror environmental conditions or biological phenomena that are too difficult, inconvenient or expensive to measure directly. By monitoring the condition and behavior of an indicator species, scientists can determine how changes in the environment are likely to affect other species that are more difficult to study²⁰. As other research has stated, reptiles and amphibians are good species to use as indicators for the health of a habitat^{1, 10, 14}. Due to the dependency of water for amphibians and habitat specialization present for many reptiles, these taxa make good candidates for being indicator species³.

The southern Appalachian Mountains represent one ecoregion that contains a high level of biodiversity – particularly for amphibians – and has experienced a large degree of habitat modification over the preceding century due to natural resource extraction. Much of the western Appalachian front, in particular, has experienced overwhelming anthropogenic modification due to the extraction and transport of mineral resources, most typically anthracite (coal)^{26, 24, 15}. As a result, the vegetation and successional dynamics of many mixed hardwood forests have been altered following mineral extraction, and many areas have experienced substantial change in local topography and hydrology due to mining activities or modifications to riparian corridors for mineral transport^{12, 4}. In addition, waterways throughout this region have experienced indirect impacts from acid mine drainage (AMD) as a result of the oxidation of pyritic rocks exposed during habitat alteration^{11, 16}.

Reptiles and amphibians are known to be good indicators of habitat health for various reasons. These reasons are why this study chose to use them as focal taxa. Many reptiles and amphibians are highly philopatric and long-lived, and they exist in relatively stable populations. Amphibians are defined as needing water to survive and reproduce, which streams or riparian buffer zones are good at providing. Due to these attributes, it makes them more tractable and reliable indicators of potential biotic diversity than anadromous fish or macroinvertebrates, and their relative abundance can be a useful indicator of stream condition¹⁰.

For this study we chose reptiles and amphibians, herpetofauna, because of the proximity to water at both sites and the importance they hold in our region. The sites chosen for this study were along the same river reach with similar habitats. One site was disturbed through clearcutting about two years before the study for a sewer pipeline cut while the other was located in undisturbed habitat in the Jefferson National Forest. Both sites were roughly equal in land

area. The data collected from both sites were compared to each other to gauge the ability for herpetofauna to track riparian habitat condition.

2. Methodology

2.1 study area

The site used in this study was a one kilometer riparian buffer along the Guest River in Wise County, Virginia (36.936995, -82.6062) that was used previously in an all-inclusive biodiversity study. The land is located just on the outskirts of the City of Norton, and the landowner gave permission for the study to take place at the site. It is bordered by active Norfolk Southern railroads. The Norton site was clear cut beside the Guest River about two years before the study took place. A control site was located on USDA National Forest land about 14.5 km downstream of the Norton site at a recreational corridor in the Guest River Gorge (36.91919,-82.450355). The Guest River Gorge recreation trail is an old railroad bed that has been converted to biking/hiking trail. The riparian buffer zone at the Guest River Gorge has been untouched since the 1940s and is home to an intact, mixed Appalachian hardwood forest and various wildlife such as herons, salamanders, butterflies, and many wildflowers²⁵.

Each study site was sectioned off into approximate 1 hectare replicate sampling blocks in order to quantify the relative abundance of herpetofauna in each section. The Norton site had seven total blocks: five of them were in disturbed habitat, and two of them were on the opposite side of the river that was untouched by previous deforestation. At the Guest River Gorge site there were five blocks total, all within the first mile of the gorge in order to keep the two sites similar in distance covered along the river. The Guest River Gorge blocks were chosen in accordance with their similarity to the undisturbed portion of the riparian buffer at the Norton site. Management restrictions prevented an equal number of replicate blocks from being defined at both sites; however, replication was maximized at each site within these restrictions.

2.2 materials

We used coverboards, PVC frog pipes, and visual encounter surveys to sample herpetofauna. Drift fence arrays could not be used for this study due to the status of the Guest River Gorge as an active recreational corridor and accompanying concerns over watershed impacts and user safety. Previous studies from the Appalachian region showed that wooden coverboards were the best option for the habitat used in this study²¹. The boards were cut to be roughly 2x4' sections of oriented strand board (OSB). There were seven boards placed randomly on each block at each site. Untreated OSB board was used in order to prevent potential harm to amphibians or avoidance of the boards. The frog pipes were made from one inch diameter PVC piping that had a cap at one end with a hole drilled through just above the cap to prevent filling completely with water, based on the recommendations of Borg, et. al.⁶. There were roughly five of the frog pipes placed at each block at each site, depending on availability of suitable hardwood trees at each block.

2.3 survey methods

Data collection was completed at each site weekly during the summer through mid-fall of 2012. At each block, a visual encounter survey was completed that searched all available cover, natural and artificial, within 30 minutes or less, if all available cover was searched. To prevent getting an uneven spread of sampling times (and thus different periods of activity for various species) the site visits were scheduled in a pattern of three different times: an early morning visit (approximately 0600-0800 hours), a midafternoon visit (1600-2000 hours), and a late night visit (1900-2200 hours).

When a reptile or amphibian was found we would record the following data: block number, species name, where it was located (cover type, actively foraging, etc.), snout to vent length (SVL), weight, and sex, when possible. To prevent capturing the same organisms repeated times and to get a better idea of the abundance of a species at each site, visual implant elastomer was used as a mark and recapture method. Elastomer was only used on amphibians that were able to be marked using a hypodermic insulin needle⁸.

2.4 habitat data collection

Several habitat variables were also measured within each sampling block to investigate potential mechanisms for differences in herpetofaunal diversity between sites. The key characteristics that herpetofauna rely on are leaf litter depth, canopy cover, coarse woody debris, soil moisture, rock cover, stem density and the presence of water. The above variables and collection methods discussed below were based off of previous research performed by Semlitsch et. al²³.

For measuring the habitat evenly across both sites each block had habitat data collected from six randomly placed one meter quadrats. Each habitat variable was broken down into categories. The top layer of leaf litter was measured in each quadrat with a dial caliper to estimate litter depth. The canopy cover was measured using a GRS densitometer as the percentage of canopy cover present at each block. Coarse woody debris (CWD) had three categories based on diameter: less than thirty centimeters, between thirty and sixty centimeters, or between sixty and ninety centimeters. Soil moisture was measured using a soil corer to collect the top ten centimeters of soil that were then placed in Ziploc bags. Each bag of soil was weighed and recorded. The bags of soil were then placed in an incubator with the tops open for three days at thirty-seven degrees Celsius. The bags were then weighed again to provide an estimate of soil moisture in each block. The rocks were measured using five different categories based on maximum rock width: less than twenty centimeters, between twenty and forty centimeters, between forty and sixty centimeters, between sixty and eighty centimeters, and greater than eighty centimeters. Stem sizes were measured as well, but virtually all were less than ten centimeters. Size categories were therefore not used for this habitat variable. If there was a permanent or semipermanent source of water, separate from the main channel of the river, at each block then that was also noted. Each of these characteristics was averaged per block at each site.

2.5 data analysis

Herpetofaunal species richness (S) and Shannon diversity (H') were compared between replicate habitat blocks at the disturbed (Norton) and reference (Guest River Gorge) sites in order to obtain a coarse assessment of differences in herpetofaunal communities between the sites. These comparisons were performed as a Student's *t* Test for Shannon diversity and a Mann-Whitney *U*

Test for species richness. A nonparametric test was used for the latter comparison due to a lack of normally-distributed data that could not be transformed to meet the assumptions of a parametric test. These statistical comparisons were performed in Minitab v.16, with a significance level of $\alpha = 0.05$ used for both comparisons.

Following these coarse comparisons, *a priori* general linear models were constructed to examine the potential causal influences of local habitat features (canopy cover, stem density, rock cover, coarse woody debris, soil moisture, and presence of aquatic habitat) in shaping differences in herpetofaunal community structure between these two sites. Models were constructed in Program SAM v.4.0 and evaluated using Akaike's Information Criterion (AIC)^{7, 19}. Collinearity among habitat variables was reduced prior to model construction using a Principal Components Analysis (PCA) in Program SAM. When evaluating models, a corrected version of AIC scores (AIC_c) was used to account for small sample sizes in our dataset, with resulting models of $\Delta AIC_c < 2.0$ considered strongly competitive⁷. Model selection uncertainty was presented with Akaike weights (w_i), which represent the likelihood of the model given the available data and thus depend on the set of tested models.

3. Data

3.1 herpetofauna data analysis

We collected a total of 145 individuals from thirty species encountered across both sites from 128 person-hours of active searching. At the Norton site, there were fifty-two individuals found and thirteen species found overall. At the Guest River Gorge site, there were a total of ninety-three individuals found and twenty-one species. There were a number of species that were only found at the Guest River Gorge site but not at the Norton site. Most of those species are species known to be habitat specialists. These species include *Lithobates sylvaticus* (wood frog), *Pseudotriton ruber* (red salamander), *Pseudotriton montanus* (mud salamander), *Desmognathus monticola* (seal salamander), *Carphophis amoenus* (worm snake) and *Aneides aeneus* (green salamander).

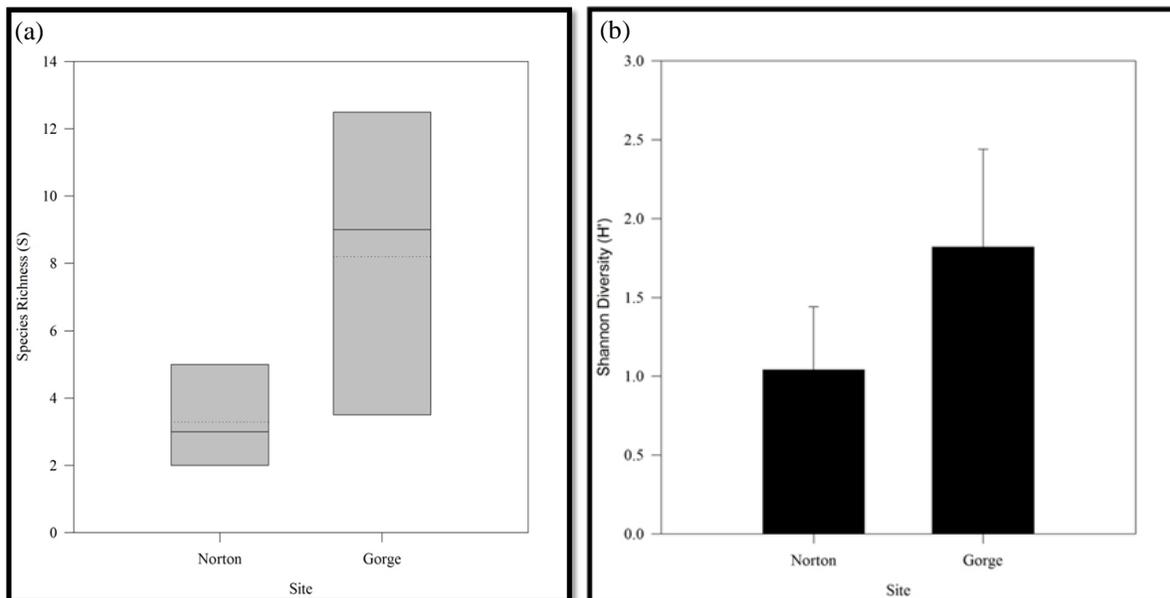


Figure 1. (a) Species Richness between the Norton site and the Guest River Gorge site. (b) Shannon Diversity (H') (mean \pm 1SD) between the Norton site and the Guest River Gorge site.

Both Shannon diversity ($t = -2.516$, $df = 9$, $p = 0.033$) and species richness ($T = 44.5$, $n = 7$, $p = 0.048$) showed significant differences between disturbed and reference sites, with both variables significantly higher at the Guest River Gorge reference site (Figure 1). A PCA of habitat variables indicated strong collinearity among habitat variables related to forest cover (Table 1); these variables were therefore condensed into a principal component representing forest complexity, with this variable and remaining, noncollinear variables (rock density 20-40cm, coarse woody debris 60-90 cm, and presence of aquatic habitat) entered into subsequent general linear models. Three classes for rock cover (40-60cm, 60-80cm, and >80cm) were excluded from all analyses due to a lack of observations for these variables in our overall habitat dataset.

A single model was considered strongly competitive in explaining variation in Shannon Diversity (Table 2). This model included the variables “forest complexity” and “presence of water;” Akaike weight for this model was notably high ($w_i = 0.887$). Shannon diversity was specifically higher in habitat blocks characterized by higher amounts of canopy cover, coarse woody debris and soil moisture, as well as the presence of ephemeral aquatic habitat. A similar model was considered strongly competitive for species richness (Table 3). This model was accompanied by an additional model containing the single variable “presence of water.” Support for this model, however, was relatively low ($w_i = 0.248$). Again, richness was higher in habitat blocks characterized by higher amounts of canopy cover, coarse woody debris, soil moisture, and the presence of ephemeral aquatic habitat.

Habitat variable	PC1 (“Forest complexity”)
Litter Depth (mm)	0.971
Soil moisture (%)	0.912
Canopy Cover (%)	0.819
Stem density (<10cm)	-0.905
CWD (<30cm)	0.738
CWD (30-60cm)	0.694
CWD (60-90cm)	
Rock cover (<20cm)	-0.816
Rock cover (20-40cm)	
Presence of ephemeral aquatic habitat	

Table 1 Principal component of forest complexity within riparian habitat blocks along the Guest River in Wise County, Virginia, as determined by a PCA (based on the correlation matrix) of 13 habitat variables. Only those loadings with values $> |0.500|$ are included in the table and interpreted in results.

Model	Variables	r^2	AICc	Δ AICc	w_i	p-value
Forest complexity, presence of water	2	0.876	11.548	0	0.887	<0.001

Table 2 Competing models constructed using a suite of four riparian habitat characteristics as independent variables and herpetofaunal diversity (Shannon diversity) as a dependent variable along the Guest River in Wise County, Virginia. Only strongly-competitive models (Δ AICc < 2) are listed.

Model	Variables	r^2	AIC _c	ΔAIC _c	w_i	p-value
Forest complexity, presence of water	2	0.794	57.305	0	0.604	0.002
Presence of water	1	0.609	59.084	1.778	0.248	0.005

Table 3 Competing models constructed using a suite of four riparian habitat characteristics as independent variables and herpetofaunal species richness as a dependent variable along the Guest River in Wise County, Virginia. Only strongly-competitive models ($\Delta AIC_c < 2$) are listed.

4. Discussion

There was a significant difference in both species richness and herpetofaunal diversity between the Norton Site and the site at the Guest River Gorge. Before the study the general thought was that the Guest River Gorge would have higher richness and diversity than the Norton site, due to a longer time since last disturbance at the Guest River Gorge. These primary differences in community structure, combined with the role of habitat features in driving these differences, suggest that herpetofauna can be used as an indicator species of a riparian buffer zone. This information will help local managers with the City of Norton to know the features that would be beneficial for proposed restoration efforts at the Norton Site, as well as regional managers charged with restoring riparian habitat along the western Appalachian front.

The habitat data indicated that the presence of isolated aquatic habitat and increased forest complexity are important benchmarks for increased herpetofaunal richness and diversity. Previous studies have shown that herpetofauna, amphibians especially, are directly correlated with an aquatic habitat presence as well as the complexity of forest habitats^{22, 13}. The amount of CWD and suitable rocks as cover objects are key features for herpetofaunal diversity in combination with the proximity to water. Comparisons of individual habitat variables related to forest complexity with herpetofaunal diversity in our system suggest that specifics for keeping the habitat optimal for herpetofauna specifically are having less rock cover and fewer herbaceous stems, such as grasses associated with an open forest canopy. Conversely, higher canopy cover, increased soil moisture, and higher amounts of coarse woody debris were associated with increased richness and diversity. Looking at the ecosystem scale, if the habitat is modified to be in better condition for herpetofauna, then there will likely be corresponding benefits to macroinvertebrate populations that are primary prey items for herpetofauna and are well-established as indicators of riparian health. Increased forest complexity, for example, has previously been shown to increase macroinvertebrate diversity in and along Appalachian streams in ways similar to that highlighted for herpetofauna in this study^{5, 18}. Conversely, an increased population of herpetofauna will likely attract large mammals and birds that feed on herpetofauna as prey items.

Our data further indicated that individual herpetofaunal species may be indicative of habitat condition as focal indicator species within the larger faunal community. Wood Frogs (*Lithobates sylvaticus*), for example, were abundant in isolated aquatic habitat at the Guest River Gorge yet absent from multiple aquatic habitats at the Norton site that were similar in wetland character to the Guest River Gorge. Previous research on this species has found that Wood Frogs prefer forested wetlands and survive dry periods by using moisture-retaining material in intact forests (moss mats, leaf litter) as refugia². Although our study did not explicitly test the quality of breeding and non-breeding habitats for this and other anuran species, our data indicate that the

degree of habitat disturbance present at Norton may have eliminated these habitat features and thus prevented Wood Frog presence. Future research may wish to more explicitly address the role of this and other species as focal indicators within Appalachian riparian herpetofaunal communities.

In the future, more comparative research should be completed to have a better understanding of the different habitat types present in the region in accordance with a list of the species that should be found in the area. This would be useful for managers that are looking to restore forest ecosystems in the area. Another avenue for future studies would be to look at the macroinvertebrate and herpetofaunal communities concurrently to examine if and how trophic relationships may be altered along various trajectories of forest restoration. These studies would be especially important, given the parallel relationships between increased diversity and forest complexity shown in this study and previous macroinvertebrate research. Macroinvertebrates are another good indicator species that can help increase populations of various other organisms, including herpetofauna, birds, and small mammals. Having a better overall understanding of the interconnectivity of an ecosystem may help to pinpoint signatures of ecological disturbance and therefore introduce mitigation and restoration measures before ecosystem integrity is compromised.

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