Developing a Bird Integrity Index (BII) for Use as an Indicator of Stream Condition in the Northern Adirondack Park

by Jesse Rock

Mentor: Dr. Michale Glennon

Adirondack Watershed Institute

Paul Smith's College

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Abstract

The primary goal of this research was to create a Bird Integrity Index (BII) to be used for the ecological integrity analysis of streams and their related riparian zones in the northern Adirondack Park based on frameworks provided by previous research in Oregon. Fifty-eight metrics were tested from avian survey (point count) data along fifteen stream reaches of 0.5km in length. These metrics represented aspects of avian taxonomic richness, dietary preferences, foraging techniques, tolerance or intolerance to human disturbance, and nesting strategies. To evaluate the responsiveness of each metric, they were plotted against an index of stream condition based on sampling of benthic macroinvertebrates according to the outline provided by the stream biomonitoring research unit of the New York State Department of Environmental Conservation. Five of the fifty-eight candidate metrics remained after removing metrics that had an R^2 value of less than .2 or were highly correlated. Individual avian metric scores ranged from 0-10 and BII scores were set on a scale of 0-100. While the BII presented here was successful in responding to varying conditions based on disturbance levels (R^2= .64), due to multiple unexpected relationships between avian metrics and stream condition, it is proposed that more in-depth and comparative research be completed before an Adirondack specific BII is presented for field usage.

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Table of Contents

List of Tables and Figures

Introduction

The use of certain taxonomic groups as biological indicators in the study of streams and stream restoration is an important tool for understanding the potential level of human impacts and the success of restoration efforts in streams (Dybala et al., 2018; Lund et al., 2013; Pander and Geist, 2013). Biological indicators show measurable response to their environmental conditions (Bryce, 2006). In the monitoring and research of streams, benthic macroinvertebrates have been the primary biological indicator of stream conditions across the world. (Purcell et al., 2009; Rosenberg and Resh, 1993; Resh, 2008). They are so commonly used because they are excellent for determining the impacts of collective stressors and can provide insight into not only current conditions, but the past as well. Benthic macroinvertebrates are also relatively universal in all streams and are a cost-effective means of stream condition monitoring (Purcell et al., 2009). Even though benthic macroinvertebrates may hold a dominance in stream research, other methods using different taxonomic groups have been proven effective as well (Bryce et al., 2002).

Next to benthic macroinvertebrates, fish assemblages are highly relied upon in stream research as indicators of ecological condition. Primary indicators like fishes and benthic macroinvertebrates are often chosen because they are directly impacted by water column and substrate conditions (Bryce et al., 2002). This direct connection would seemingly give them an advantage over terrestrial sources in the accuracy of in-stream condition assessment. However, due to the link between aquatic streams and riparian zones, which are critical components of stream ecosystems, riparian zone fauna species assemblages could be indicative of stream conditions as well (Bryce et al., 2002). With this knowledge, there has been new research into the use of bird assemblages as stream condition indicators based on their link to the health of riparian conditions and therefore, to streams. Previous research has indicated that birds are a valuable addition as indicators for stream ecosystem bioassessments (Bryce et al, 2002; Bryce, 2006). These findings suggest that not limiting research to directly aquatic habitats and using more than just one taxonomic group for stream assessments and research is essential to thorough and inclusive science.

Since birds respond rapidly to change, are sensitive to environmental impact and fragmentation, respond to disturbances at multiple trophic levels, can be found in abundance in multiple ecoregions and habitats, and present themselves as a readily available subject for monitoring, they are an excellent indicator and resource for ecological condition assessment across multiple habitat types (DeLuca et al., 2004; Glennon and Porter, 2005). In relation to stream assessment and monitoring, it is important to note that many of the issues that lead to stream impairment begin in the terrestrial environment along streams and not within the stream itself, and therefore, the inclusion of riparian condition assessments is essential to the assessment and management of streams (Bryce, 2006). As riparian areas represent an interface between aquatic and terrestrial systems, they often hold high species diversity compared to the surrounding areas (Bub, et al, 2004). Among these riparian species, birds can be one of the best species groups for responsiveness and economic ease to sample. Birds and bird assemblages are sensitive to both watershed and riparian zone disturbances. This is an improvement over strictly aquatic indicators from which riparian forest conditions can only be indirectly inferred (Bryce, 2006).

The use of birds as community-based indicators of ecological integrity is an established process working at watershed to ecoregion scale (O'Connell et al., 2007). To assess human impact on the land, the establishment of bird indicator assemblages and the placing of birds into Indices of Biologic Integrity (IBI's) created tools for furthering ecological impact assessment and risk management. By placing birds into guilds categories based on species traits, or classes of birds that use the same type of environmental resources to a certain function (ie. cavity nesting, bark gleaning), the bird-based IBI methodology can be more effective than simple species richness alone (Glennon & Porter, 2005). The IBI takes the assemblage structure of a regional fauna at a particular site, in this case birds, and translates that into a numeric score which can be used as a measure of ecological condition. In most cases, this score is the sum of a number of individual metrics from measures of taxa-richness or species-proportionate abundance data (Bryce, 2006). As these indices are often multi-metric, when combined with other indicators they can provide a way to assess ecological conditions over a broad scale. They also allow ranking of different ecoregions in regards to priorities of conservation and restoration (O'Connell et al., 2007).

A bird specific index of stream and riparian health, the Bird Integrity Index (BII) was created and tested in Oregon with the goal of making a management and monitoring tool for assessing the integrity of stream riparian zones. Initial research tested 62 candidate metrics which represented elements of bird taxonomic richness, tolerance/ intolerance to human disturbance, foraging techniques, dietary preferences, and nesting strategies in how they are affected by human activities in agricultural regions (Bryce et al., 2002). Later BII research changed focus from agricultural streams to forested stream reaches looking at 81 candidate bird metrics (Bryce, 2006). Of the metrics tested in the two studies, 13 were successful in representing stream and riparian health in agricultural streams when plotted against a disturbance index (Native Species Richness, Number of Neotropical Migrant Species, % Warbler Species, %Omni/Granivore Species, % Insectivore Species, %Ground Gleaning Species, Number Woodland Ground nest Ind., Number Native Cavity Nest Species, Number of Nest Sensitive Individuals, %Tolerant Species, Number Intolerant Individuals, Number Foliage Gleaning Species, % Bark Gleaning Species) and 9 metrics showed success in forested reaches (% Tolerant Species, % intolerant Species, % Interior Species, % Foliage Gleaning Ind., % Ground Gleaning Ind., % Omni-Granivore Species, % Insectivore Ind, % Nest Parasite Ind., % Nest Sensitive Species) (Bryce, 2006; Bryce et al., 2002). In the research conducted by Bryce, (2006) and Bryce et al, (2002), the BII undoubtedly reflects the impacts that agriculture and urbanization have on riparian bird assemblages along with less obvious impacts observed in forested streams. It was proposed that the BII could aid in guiding management of riparian zones and suggest priorities for restoration or mitigation of stream riparian zone disturbances in the specific climatic and ecoregion conditions of Oregon (Bryce, 2006). This raises the possibility that the Oregon BII can be applied with adaptations to other ecoregions with similar bird assemblages.

The primary goal of this research was to create a BII (Bird Integrity Index) to be used for the ecological integrity analysis of streams and their related riparian zones in the northern Adirondack Park based on frameworks provided by Bryce, (2006) and Bryce et al., (2002). The existence of an Adirondack BII could hold the potential to provide a new and very efficient means of monitoring the condition of streams and riparian habitats in a cost effective and publicly inclusive manner. The utility of an ADK BII could help to dictate the future of stream assessment and restoration work in the Adirondack Park along with areas of similar ecological and climatic condition.

Methods

Study Area

The Adirondack park encompasses an area of 19,700 km^2 in the northern part of New York State. Elevations within the park range from 30m to 1600m above sea level and the land itself exhibits a mixture of several ecotones being dominated by a deciduous-mixed coniferous forest with species like maple-birch-beech (*Acer spp., Betula spp*., *Fagus Grandifolia*) and spruce-hemlock-fir (*Picea spp., Tsuga canadensis, Abies balsamea*). The definitions of these ecotones are based on elements of natural and social factors that create four generalized regions of the Adirondacks (Central Adirondacks, Eastern Foothills, Western Foothills, High Peaks Region; Glennon and Porter, 2005). The region where this field study took place is in the northern-most portion of the park and holds close similarity to the Central Adirondacks ecotone containing hills and rounded mountains with a spruce, fir, and northern hardwood dominated forest. White pine is also found in this region even though it is normally associated with the Eastern foothills ecotype (Glennon & Porter, 2005).

Site Selection

All research was conducted within a 20km radius of Paul Smith's College between 44°15 and 44°30 Longitude and 74°00' and 74°30' Latitude. Elevation for this area is, on average, 500m above sea level. Forested riparian zones in the Adirondacks have gone through dramatic change over the 300 years since European settlement. Old growth forests, especially in riparian zones, have become a rarity and have been replaced by young to mature forests, 50-100 years of age (Keeton et al., 2007). Within the study area, completely untouched reference stream conditions were not prevalent enough for data collection as all reaches were expected to exhibit some element of past human impact (logging, mining, agriculture). The primary differentiation between reaches regarding stream condition in these areas has been influenced by the legacy age of disturbance and what condition the stream currently represents. In total, 15 avian stream reaches were chosen for sampling in 9 individual streams (Figure 1). These reaches were chosen on streams that appeared as blue lines on a USGS 1:100,000 scale topographic map and are considered 2nd to 4th order wadable streams. The spectrum of impact conditions due to legacy effects and current impacts was determined on preserved (state owned) park wilderness, and private lands through assessment of macroinvertebrates as per Bode et al., (2004).

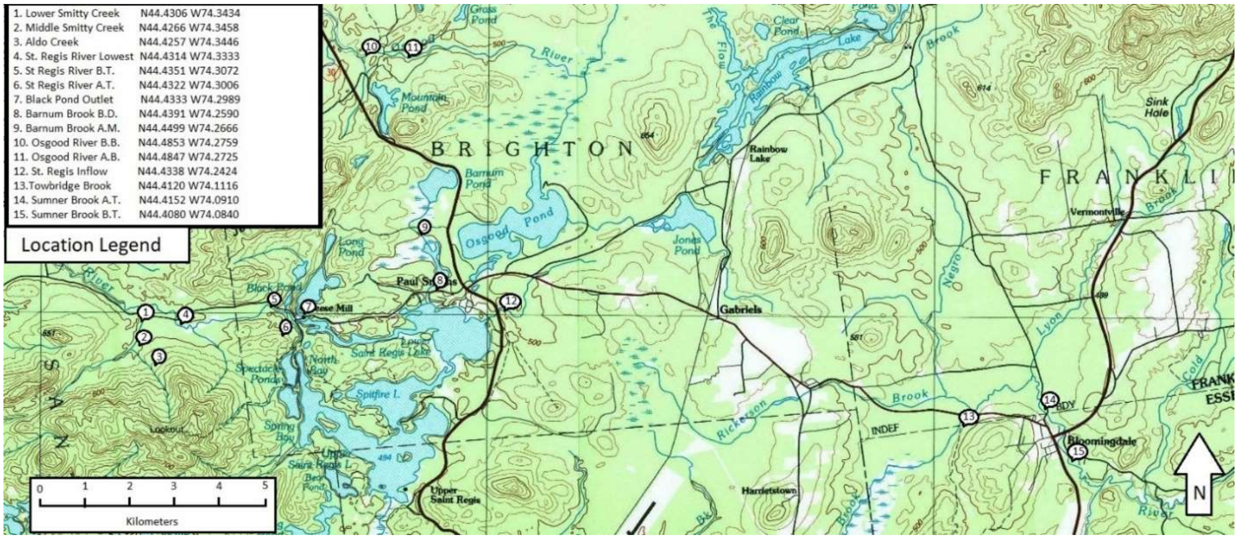

Figure 1. Map of 15 reaches tested within 20km radius of Paul Smiths, NY.

Avian Field Methods

Data on avian assemblages was collected over a six-week period (throughout the summer of 2019 starting the last week of May and ending the second week of July) during the first four hours after sunrise to optimize breeding bird exposure. Data collection followed a point count methodology along transects at the set stream reaches. Avian reach transects were defined as a 500-meter stretch of stream following the sinuosity of the stream. Transects were chosen to represent areas of similar habitat and structure with easy accessibility for the researcher. At every 100m, the researcher stopped for ten minutes to record all species and number of individuals of said species heard or seen within the time frame. Five stops were completed per transect with the data from each of the stops being pooled together to represent the avian reach as a whole. The data collector followed a route that traveled within 25 meters of the stream bank to allow maneuverability through difficult portions of the reach and combat the noise produced by running water when it interfered with the ability to collect data while still remaining in the riparian zone. There was no set radius of detection in which to record observed birds at point counts as the objective was not to determine avian population densities but to illustrate bird species composition per reach of stream. Therefore, every bird heard or seen at a sampling point was recorded in order to maximize the number of observations collected. However, all attempts were made to prevent the double counting of individuals from the previous point count location.

Prior to data collection, the researcher was tested on local bird species identification to ensure at least 90% accuracy on identifying species that were most likely to be observed.

Benthic Macroinvertebrate Field Methods

Benthic macroinvertebrate data were collected at a sub-reach within the defined 500-meter avian transect at each of the fifteen locations. Macroinvertebrate collection sites were chosen based on guidelines provided in Appendix 1 of the "30 Year Trends in Water Quality of Rivers and Streams in New York State" by Bode et al., (2004) of the stream biomonitoring research unit of the New York State Department of Environmental Conservation. Macroinvertebrate sampling methodologies also followed protocols defined in Bode et al., (2004) using a D-net with a 5-meter kick sampling methodology within stream riffle formations. Organisms collected were stored in a 95% Ethyl alcohol solution for later laboratory analysis.

Defining Stream Impact

Sampling of benthic macroinvertebrates established a gradient of stream condition to which the avian related metrics could be compared. In order to ensure an accurate and confirmed methodology for gauging stream condition, protocols developed and tested by the stream biomonitoring unit research of the New York State Department of Environmental Conservation (Bode et al, 2004) was used as an unchanging baseline. To determine overall stream water quality, three macroinvertebrate metrics were originally chosen to be used: (1) Species Richness, the total number of species taxa found within a sample, (2) EPT value, total number of species as Ephemeroptera (mayflies) Plecoptera (stoneflies) and Trichoptera (caddisfly), of a 100-organism subsample, and (3) Percent Model Affinity, a measure of similarity to a model non-impacted community based on the percent abundance of seven major groups of macroinvertebrates (Lenat, 1987; Bode et al., 1996; Hilsenhoff, 1987; Novak and Bode, 1992; Bode et al., 2004). All organisms were identified to morphs by order under a dissecting microscope to the best of the researcher's ability. For the purpose of this study, each different visually identifiable morph was considered a separate species.

Candidate Avian Metrics

The metrics chosen for evaluating avian assemblages were guided through research conducted by Bryce, (2006) and ongoing research being conducted by Dr. Michale Glennon as these metrics used proved to be successful in a geospatial area containing similar species composition to the Adirondack Park. As a guide for the creation of an Adirondack BII, these metrics represented aspects of avian taxonomic richness and abundance, tolerance or intolerance to disturbance, dietary/foraging preferences, migrant status, family association, and nesting strategies.

Taxonomic richness and abundance were represented by more simplistic metrics looking at species richness and total number of individuals. Certain family associations like warblers were expected to decrease in abundance and species composition with increased disturbance or lower macroinvertebrate-based stream condition. Since species of neotropical migrants are considered sensitive species, their response to decreasing stream condition was hypothesized to be evident at an observable detail (Bryce et al, 2002; Bryce, 2006; Terborgh, 1989; Wilcove and Terborgh, 1984).

Tolerance to human disturbance was represented by metrics looking at species labeled as tolerant and intolerant yet distinguished from ubiquitous species (exhibit a broad range in both disturbed and undisturbed habitat) and generalists (easily adaptable to a variety of habitats) based on literature review (Bryce, 2006; Bryce et al., 2002; Poole and Gill, 1999). Tolerant and intolerant species were determined by bird responses to human degradation of established habitat. For example, tolerant species were hypothesized to benefit by the impact of logging or urbanization (where PMA values are expected to be lower) where intolerant species would not. With tolerance, habitat preference was also assessed looking at forest interior vs non-forest interior species.

Foraging and dietary guilds were used to classify birds via feeding strategies and food preference during the breeding season (Bryce, 2006; Bryce et al., 2002; Terres, 1980; Ehrlich et al, 1988; DeGraaf et al, 1991). Discrepancies between references were settled in relation to New York specific bird assemblage information and previous local research (as per Dr. Michale Glennon). Guilds used for metric development were foliage gleaners, bark gleaners, and ground gleaners (under foraging strategies), granivores/omnivores, and insectivores, (under dietary guilds).

Nesting Strategies were classified as ground, cavity, and cup/platform. Ground nesters and cavity nesters were expected to show the most direct correlation between stream habitat condition and abundance as impacted areas may be susceptible to human disturbance with a lack of old snags and dead hollows for nesting habitat in comparison to more natural streams (Bryce, 2006; Table 1).

Table 1. List of observed species with metric guilds and classifications.

Avian code	Species Name	Neotropical Migrant	Native Species	Warbler	Omnivore/Granivore	Insectivore	Foraging Type	Tollerance	Conifer Species	Forest Interior	Nesting Type
ALFL	Alder Flycatcher	Y	Y	N	N	Y	NA	I	N	N	C/P
AMCR	American Crow	N	Y	N	Y	N	GG	U	N	N	C/P
AMRE	American Redstart	Y	Y	Y	N	Y	NA	I	N	N	C/P
AMRO	American Robin	N	Y	N	Y	N	GG	U	N	N	C/P
BARS	Barn Swallow	Y	Y	N	N	Y	NA	T	N	N	C/P
BEKI	Belted Kingfisher	N	Y	N	N	N	NA	G	N	N	NA
BCCH	Black Capped Chickadee	N	Y	N	Y	N	FG	G	N	N	C
BLBW	Blackburnian Warbler	Y	Y	Y	N	Y	FG	I	Y	Y	C/P
BTBW	Black-throated Blue Warbler	Y	Y	Y	N	Y	FG	I	N	Y	C/P
BTNW	Black-throated Green Warbler	Y	Y	Y	N	Y	FG	I	N	Y	C/P
BLJA	Blue Jay	N	Y	N	Y	N	GG	T	N	N	C/P
BHVI	Blue-headed vireo	N	Y	N	N	Y	FG	I	N	Y	C/P
CEDW	Ceder Waxwing	N	Y	N	Y	N	FG	G	N	N	C/P
CHSP	Chipping sparrow	Y	Y	N	Y	N	GG	I	N	N	C/P
COGR	Common Grackle	N	Y	N	Y	N	GG	G	N	N	C/P
COLO	Common Loon	N	Y	N	N	N	NA	NA	N	N	G
CORA	Common Raven	N	Y	N	Y	N	GG	U	N	N	C/P
COYE	Common Yellowthroat	Y	Y	Y	N	Y	FG	T	N	N	G
DEJU	Dark-eyed Junko	N	Y	N	Y	N	GG	U	Y	N	G
DOWO	Downy woodpecker	N	Y	N	N	Y	BG	U	N	N	C
GCKI	Golden Crowned Kinglet	N	Y	N	Y	N	FG	I	Y	N	C/P
GWWA	Golden-winged Warbler	Y	Y	Y	N	Y	FG	I	UN	UN	UN
GRCA	Grey Catbird	Y	Y	N	Y	N	GG	G	N	N	C/P
HAWO	Hairy Woodpecker	N	Y	N	N	Y	BG	I	N	N	C
HETH	Hermit Thrush	N	Y	N	N	Y	GG	I	N	N	G
HOSP	House Sparrow	N	Y	N	Y	N	GG	T	N	N	C
LEFL	Least flycatcher	Y	Y	N	N	Y	NA	G	N	N	C/P
MALL	Mallard	N	Y	N	N	N	NA	G	N	N	G
MODO	Mourning Dove	N	Y	N	Y	N	GG	T	N	N	C/P
NOFL	Northern Flicker	N	Y	N	N	Y	GG	U	N	N	C
NOPA	Northern Parula	Y	Y	Y	N	Y	FG	I	N	N	C/P
NOWA	Northern Waterthrush	Y	Y	N	N	Y	GG	I	N	N	G
OVEN	Ovenbird	Y	Y	Y	N	Y	GG	I	N	N	G
PIWO	Pileated Woodpecker	N	Y	N	N	Y	BG	I	N	N	C
RBNU	Red-breasted nuthatch	N	Y	N	Y	N	BG	I	N	N	C
REVI	Red-eyed Vireo	Y	Y	N	N	Y	FG	I	N	N	C/P
RWBB	Red-winged blackbird	N	Y	N	Y	N	GG	G	N	N	C/P
SOSP	Song Sparrow	N	Y	N	Y	N	GG	U	N	N	G
SWSP	Swamp Sparrow	N	Y	N	Y	N	GG	U	N	N	G
WAVI	Warbling verio	Y	Y	N	N	Y	FG	I	N	N	C/P
WTSP	White-throated sparrow	N	Y	N	Y	N	GG	G	N	N	G
WIWR	Winter Wren	N	Y	N	N	Y	GG	I	N	N	C
WODU	Wood Duck	N	Y	N	N	N	GG	NA	N	N	G
YEWA	Yellow warbler	Y	Y	Y	N	Y	FG	I	N	N	C/P
YRWA	Yellow-rumped warbler	N	Y	Y	N	Y	FG	I	Y	N	C/P

Y= yes, N= no, NA= not available, GG= ground gleaner, FG= foliage gleaner, BG= bark gleaner, T = tollerant, G= generalist, U= ubiquitous, UN= nnknown, C/P= cup/platform, C= cavity, G= ground

Results

Stream Condition Analysis

The three metrics chosen for analysis (Species Richness, EPT Value, and Percent Model Affinity) have been shown to be related to stream condition as defined by Bode et al., (2004). Upon final data screening, it was determined that PMA value was the best metric for defining a gradient of stream condition as Species Richness and EPT richness had too much repetition of values and little variability across sites of the same condition categorization. When ranked by PMA, streams were categorized as 8 being severely impacted, 5 moderately impacted, and 2 slightly impacted as per Appendix V of Bode et al., (2004). No streams could be categorized as non-impacted by PMA ranking. It should be noted that no streams could be categorized as non-impacted by Species richness or EPT ranking either. Once stream conditions were ranked by PMA value, this gradient of condition was used as the standard to be plotted against the avian metrics of condition.

Avian Metric Screening

Avian metric categories were summarized in four ways: (1) number of species, (2) number of individuals, (3) percent species, (4) percent individuals. Each of these metrics were examined to find the most responsive, repeatable, and precise metrics based on R^2 value. This was accomplished by plotting avian metrics against the stream condition ranking (determined by PMA macroinvertebrate analysis). For a metric to be considered for the Adirondack BII, it was required to show a positive or negative relationship with an R^2 value of determinable correlation at a minimum of 0.2.

Point Count Results Overview

Overall avian richness varies from 9 to 19 species and 17-36 individuals across the 15 stream reaches. All stream reaches were dominated by native avian species with only 1 non-native species (house sparrow) being present only at Sumner Brook Below Town. The most abundant species present at 13 of the 15 reaches was the red-breasted nuthatch followed by the hermit thrush, red-eyed vireo, and northern parula being present at 12 reaches each. The reaches with the greatest species and number of individuals were found in more open stream corridors near larger bodies of water or in lower gradient, meandering streams (Black Pond Outlet, St.

Regis Inflow, Barnum Below Town, Lower Reach Smitty Creek). The reaches with the lowest species and individual abundance were faster moving streams in higher gradient corridors through heavily forested areas (Aldo Creek, Osgood Below Bridge, St. Regis River Lowest). The only exception to this was Sumner Brook Below Town which for the first 100m bordered human habitation before becoming heavily wooded along its banks.

Avian Metric Results

In total, 58 metrics of avian stream condition were analyzed and compared against stream condition classification via PMA. Of these 58 metrics, 10 had an R^2 value greater than .2 with the greatest being an R^2 of .51. Ranked in order from greatest R^2 to least, these were # Native Species, # Ground Gleaning Individuals, # Species, # Native Individuals, # Individuals, # Ground Gleaning Species, # Insectivore Individuals, % Foliage Gleaning Individuals, # Neotropical Individuals, # Omnivore/Granivore Species. Of these ten metrics, only % Foliage Gleaning Individuals showed a positive correlation with PMA value (Figure 2).

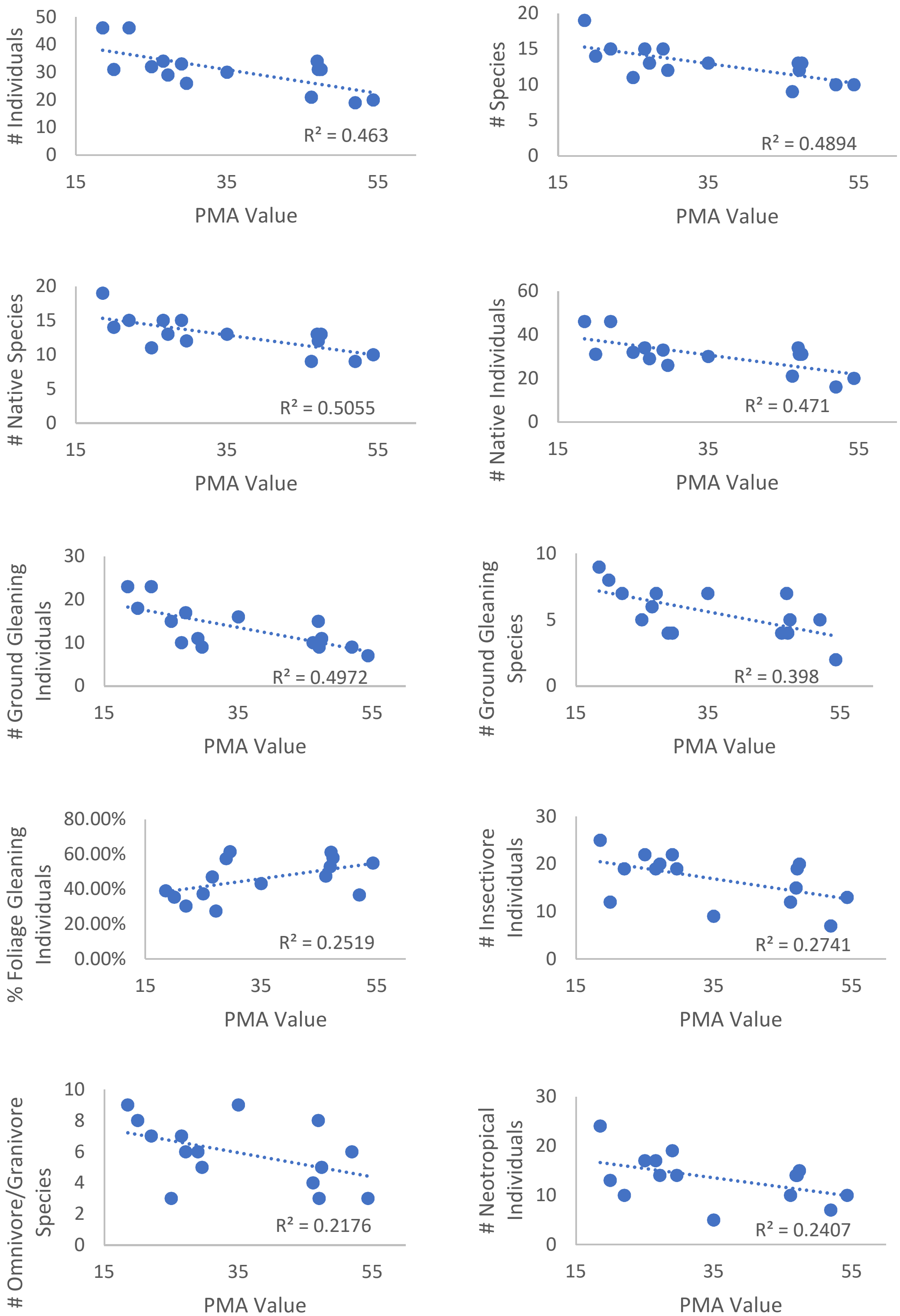

Figure 2. Top ten avian metrics with R^2 values of greater than 0.2 for tested stream reaches.

Final Index and Site Score Distribution

The ten metrics that showed a consistent increase or decline across the range of PMA defined stream condition with an $R^2 \geq 0.2$ were considered responsive for index creation (Figure 2). Of these metrics, two of the 10 were from the same metric category (number of ground gleaning species and individuals). In this case, the one with the highest correlation to disturbance was chosen (# ground gleaning individuals). The remaining 9 metrics were then tested for statistical redundancy via a 10x10 correlation matrix (9 metrics plus PMA condition gradient). This test revealed that five of the nine metrics were highly correlated with the other four metrics and/or each other (Pearson $R > 0.85$). In each of the five cases where high correlation was observed, the metric with the greater R^2 value was chosen and the redundant metric discarded. This resulted in the final analysis for BII creation containing five metrics (# Native Species, # Ground Gleaning Species, # Insectivore Individuals, % Foliage Gleaning Individuals, and # Omnivore/Granivore Species).

Based on previous research (Bryce et al., 2002), the range for index creation was based on a 0-100 scale. The first step of this process was to use a linear interpolation methodology to place individual raw metric values on a scale of 0 to 10. Metric scores were calculated by dividing the raw metric value by its range (determined as the lowest possible value [0] to the highest value observed for each metric) and multiplying by 10. In cases where the observed avian metric decreased with greater PMA value, the scoring range was reversed from 10-0. In conclusion, the final index scores for each site were calculated as the sum of the metric scores (by site) multiplied by 10 and divided by the number of metrics (5) to keep them on a 0-to-100 scale. The BII scores for the 15 stream reaches ranged from 12.72 to 64.20 with an average of 42.99 (Figure 3). When the BII values are plotted against PMA values for the streams, the BII shows a stronger relationship (R2=.64) than any individual metric (R^2=.22 to R^2=.51). This would indicate that 64% of a stream's predicted PMA value (and therefore predicted condition) could be explained by a value determined through the BII.

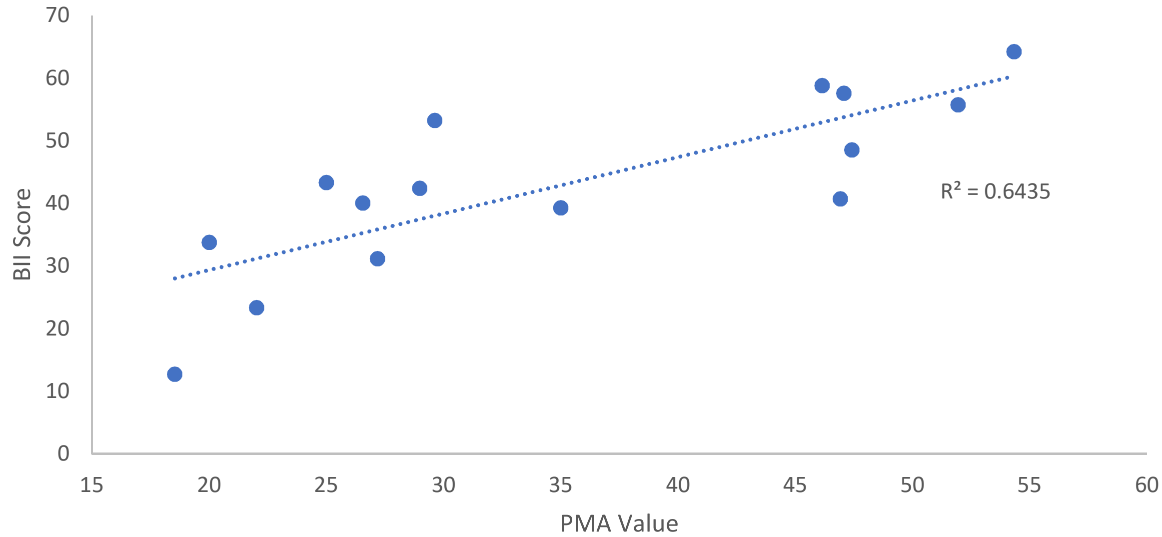

Figure 3. BII scores of the 15 stream reaches plotted against PMA valued stream condition.

Discussion and Conclusion

The original goal of this research was to see if the development of a bird specific index of biotic integrity for Adirondack streams was possible based on research being conducted on stream corridors in Oregon. While the final Adirondack BII was statistically successful in establishing a means of condition determination, I feel that a broader more intensive study would need to be completed over several years to establish a usable BII based on stream condition analysis through benthic macroinvertebrates and PMA analysis. The main reason I call for a more intensive study is due to my research showing negative relationships between site condition and specific metrics in direct contrast to those observed in Bryce et al., (2002) and Bryce (2006). It should be of note that while previous research by Bryce et al. (2002) an Bryce (2006) showed negative relationships with their measure of site condition for Ground Gleaning and Omnivore/Granivore related metrics, negative relationships between site condition and avian metric condition related to Species, Individuals, Natives, Insectivores and Neotropicals was not observed.

While there could be multiple potential reasons for the negative correlations observed in my study that are outside of what would be expected, three can be argued as most likely. Firstly, the definition of stream condition in my research varied from the research conducted by Bryce et al. (2002) and Bryce (2006). In the Oregon studies, stream condition was determined by analysis of human activity along stream corridors through site history and condition with a disturbance index through a Geographical Information System (GIS). Instead of using this methodology, I used a one-time direct analysis of benthic macroinvertebrate communities in my tested streams based on NY State stream condition determination protocols as per Bode et al., (2004). The potential variability between these two methodologies of determining condition could account for the difference in metric relationship to defined stream condition. In future testing, a comprehensive comparison of benthic macroinvertebrate analysis for Adirondack streams to disturbance index methodologies used by Bryce et al, (2002) and Bryce (2006) would need to be accomplished. In this analysis, it would be beneficial to collect benthic macroinvertebrate data from multiple sub-reaches per site and identify them to the true species level (identifying to species name) instead of visual difference in morphs for families. With this, data would need to be collected for studied Adirondack streams over multiple years regarding benthic macroinvertebrates and avian assemblages to establish a stronger database for stream condition assessment.

Second, the physical variability present amongst my stream reaches might have been too great for a comparative analysis. While all streams were defined as 2nd to 4th order wadable streams, this classification still allows for a lot of variability in shape, form, substrate, and flow patterns. For example, while most of my streams had natural sand and gravel substrates, Sumner Brook had portions that were cement bottom and filled with riprap which differed from all other streams tested. In streams showing the greatest species richness and individual abundance, the physical attributes at these streams were similar to one another but differed highly from the rest of the data set regarding flow rate, width, and sinuosity. Potentially, results similar to Bryce et al. (2002) and Bryce (2006) might be seen if all testing was restricted to streams of closer similarity by physical conditions and traits. In future studies, it is advised that a more thorough analysis of stream physical attributes be completed first to find a data pool of streams that vary in ecological condition but not in physical traits.

While my first two hypotheses address the potential errors that could have resulted in the negative relationships observed, the last addresses the possibility of those negative relationships being a correct representation of the study area. First, it must be recognized that by themselves, # Species and # Individuals showed a negative correlation to PMA. Since all avian metrics tested in this study were based on a classification of species and individuals, my metrics could have been a representation of this initial negative relationship. While it has been generally accepted that higher species and individual richness represents higher condition of habitat, there are instances where this is not the case. One of these is related to the Intermediate Disturbance Hypothesis where species diversity and individual richness can increase with intermediate levels of impact. In this case, it is possible that as human habitation and development influences the conditions along a stream, novel ecosystems can be created which can boost observed richness and diversity before a point is reached where too much human modification to an ecosystem eventually results in a drop of diversity and richness (Bryce, 2006).

In further support of the negative relationship I observed between species richness and ecological condition, in their avian-based index of biotic integrity, Glennon and Porter (2005) showed the same negative relationship between species richness and general ecological condition for the Adirondack Park. While not stream condition focused, their results present a solid argument that a negative relationship between avian species richness and ecological condition may be an area specific trait related to the lack of severe land alterations, or typical impacts of urbanization seen outside of the Adirondack Park (Glennon and Porter, 2005). Even though stream condition determined by my PMA analysis showed streams with highly impacted conditions in my study area, there is a potential that these classifications are flawed. While I am confident in the established benthic macroinvertebrate gradient of conditions, the individual classification of each stream's level of impact may have inaccuracies due to morph level identification and single sample testing. It is likely that overall condition of streams within the study area is less impacted than my PMA value indicates as the majority of reaches tested were trout streams and there was no heavy logging, farming, or mass land alteration along any stream reach.

Based on the research conducted by Glennon and Porter (2005), there is a high probability that the levels of impact deemed high enough to trigger a downturn in observed avian species richness may not be present within the study area due to legal protections on the land and waterways within the Adirondack Park. While this is a positive trait for the integrity of the land within the park's border, it makes establishing definable levels of reference conditions within the study area difficult. To combat the lack of a broad gradient of conditions within the Adirondack Park, it is advised that future research establish reference streams based on multiple condition determination methodologies (benthic macroinvertebrates, physical trait analysis, fish species analysis) for each potential condition gradient inside and (when necessary) outside of the boarders of the park to ensure the full spectrum of potential impact conditions is observed.

While the results of my research may not be enough to establish a confidently usable Adirondack BII, they still support the use of birds as a monitor of ecological condition. Even though my results regarding certain metrics' correlation to defined condition contradicts those of previous research, they may not necessarily be wrong as there is potential that these negative correlations are a factor of area specific interactions. Regardless of their accuracy, these metric relationships present new questions that are an opportunity to further the development of avian indexes of biotic integrity in the Adirondack Park and surrounding areas. In conclusion, the use of avian assemblages as determinates of stream corridor condition shows great promise in the future of ecological monitoring.

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