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Short Communication

Wetland habitat disturbance best predicts metrics of an amphibian index of biotic integrity

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ABSTRACT

Regression and classification trees were used to identify the best predictors of the five component metrics of the Ohio Amphibian Index of Biotic Integrity (AmphIBI) in 54 wetlands in Ohio, USA. Of the 17 wetland- and surrounding landscape-scale variables considered, the best predictor for all AmphIBI metrics was habitat alteration and development within the wetland. The results were qualitatively similar to the best predictors for a wetland vegetation index of biotic integrity, suggesting that similar management practices (e.g., reducing or eliminating nutrient enrichment from agriculture, mowing, grazing, logging, and removing down woody debris) within the boundaries of the wetland can be applied to effectively increase the quality of wetland vegetation and amphibian communities.

1. Introduction

Many amphibian species in North America spend a critical part of their life in wetlands (Petranka, 1998; Pfingsten et al., 2013). Amphibians are known to reflect wetland habitat condition, due to their sensitivity to a variety of biotic and abiotic changes (e.g., U.S. EPA, 2012). This sensitivity has undoubtedly contributed to the massive decline of amphibians in recent years (e.g., Blaustein and Wake, 1990; Wyman, 1990; Wake, 1991; Alford and Richards, 1999; Houlahan et al., 2000; Alford et al., 2001; Stuart et al., 2010 and references therein). Restoring or rehabilitating amphibian populations is difficult because presence and abundance of amphibian species is associated with a combination of factors within wetlands and in the surrounding landscape (e.g., Houlahan and Findlay, 2003; Porej et al., 2004; Zanini et al., 2008). For example, terrestrial home range size and reliance on ephemeral ponds and downed woody debris vary considerably among amphibian species (e.g., Walker, 1946; Pfingsten and Downs, 1989; Petranka, 1998; Semlitsch, 1998, 2000; Harding, 2000; Pfingsten et al., 2013).

The Amphibian Index of Biotic Integrity (hereafter: AmphIBI) for Ohio, USA wetlands was developed to assess the ecological condition of amphibian habitats and communities (Micacchion, 2004). AmphIBI is calculated from five component metrics, each describing a different aspect of amphibian communities. Each metric was found to respond as expected to a wetland disturbance gradient and to wetland quality. However, the best environmental predictors of the metrics were not identified.

Suter (1993) listed numerous criticisms of multi-metric indices of biotic integrity, including a lack of predictability and continuity among the component variables in terms of their response to environmental conditions. Although Karr and Chu (1999) addressed some of these shortcomings there is still a need to determine which environmental variables best predict individual metrics of biological indices. Such information can be useful for identifying management practices that have the best chance of successfully rehabilitating or preventing degradation of biological communities. In this paper we use regression and classification trees to select the best predictors of the raw scores of the five component metrics of AmphIBI from a suite of environmental variables. Our goal is to identify patterns in the sets of best predictors and thus determine management practices that can be tailored for different components of the amphibian community, as assessed by each metric.

2. Materials and methods

2.1. Field and laboratory methods

We analyzed data from 54 forest ($n = 23$) and shrub ($n = 31$) wetlands in Ohio collected as part of previous studies conducted during 1999–2004 (Micacchion, 2004). Forest and shrub wetlands

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were combined because there was no difference between them with respect to the structure of the amphibian communities (Micacchion, 2004). A detailed description of the AmphIBI sampling protocols is found in Micacchion (2004). In brief, amphibians were captured in specially designed traps at each wetland on three dates in the same year during March–July 1999–2004. Salamanders and their larvae were identified using keys in Pfingsten and Downs (1989) and Petranka (1998). Frogs, toads, and tadpoles were identified using keys in Walker (1946) and Altig et al. (1998). Data for gray tree frog (*Hyla versicolor*) and Cope's gray tree frog (*Hyla chrysoscelis*) were combined because these species cannot be distinguished from each other by external appearance at any stage of development (USGS, 2013). Similarly, data for American toad (*Anaxyrus americanus*) and Fowler's toad (*Anaxyrus fowleri*) were combined because only larval stages were collected, during which the species cannot be distinguished from each other (Walker, 1946).

2.2. AmphIBI metrics

Procedures for calculating AmphIBI are described in detail in Micacchion (2004). In brief, AmphIBI for each wetland was calculated as the sum of five component metric scores. The five metrics were: the Amphibian Quality Assessment Index (AQAI); the relative abundance of sensitive species (% sensitive); the relative abundance of tolerant species (% tolerant); the number of species of pond breeding salamanders (PBSS); and presence of spotted salamanders (*Ambystoma maculatum*) and/or wood frogs (*Lithobates sylvaticus*) (SS/WF).

The AQAI raw score for each wetland was calculated as the average coefficient of conservatism (CC: range 1–9; Micacchion, 2004) of all the amphibians collected during the three sampling dates. Species assigned CCs ≤ 3 were considered "tolerant" because they are adapted to a greater degree of disturbance and a broader range of habitat requirements. In contrast, species assigned CCs ≥ 6 were considered to be "sensitive" to disturbance and have more specific niches. For each species, the number of individuals collected was multiplied by its CC. The products for all species were then summed, and this sum was divided by the total of all amphibians collected. The raw scores for % tolerant and % sensitive were calculated as the percent of individuals (all amphibian species combined) captured that had CCs ≤ 3 and CCs ≥ 6, respectively (Micacchion, 2004). The PBSS raw score was a count of how many unique pond-breeding salamander species were collected at each wetland. For SS/WF, the score was assigned as 10 if neither species was captured and 1 if either or both species were captured.

2.3. Predictor variables

We originally considered 17 variables as predictors of the AmphIBI metrics (Table 1). Six were metrics from the Ohio Rapid Assessment Method for wetlands (ORAM: Mack, 2001). Ten were from the Landscape Development Index (Gara and Micacchion, 2010; Brown and Vivas, 2005), quantifying the proportion of the total area for each of 10 land use categories within a 1-km radius circle from the center of the wetland, and calculated with landscape data from the National Land Cover Database (Vogelmann et al., 2001; Mack, 2004, 2006) using ArcView v. 3.2 (ESRI, 1999). A final predictor, the Vegetation Index of Biotic Integrity for Ohio wetlands (OVIBI: Mack, 2004, 2007; Stapanian et al., 2013a,b; Gara and Stapanian, 2015), was calculated from vascular plants that were assessed within a 0.1-ha sample plot (20 m × 50 m) within each wetland. Of the 17 predictor variables, six (OVIBI and ORAM 1 and ORAM 3–6) were considered "wetland-scale" because they assessed conditions within the boundary of the wetland as defined by the extent of hydrophytic vegetation, wetland hydrology, and hydric soil (U.S. ACE, 1987; Stapanian et al., 2013a). In contrast,

Table 1
Potential predictors of the five metrics of the Amphibian Index of Biotic Integrity in 54 Ohio, USA wetlands. Predictors with the prefix "LDI" are from the Landscape Development Intensity Index. The "LDI" predictors were natural log transformed for the analyses. Abbreviations: Prop. = proportion of area (radius 1 km) surrounding wetland; ORAM = Ohio Rapid Assessment Method; OVIBI = Ohio Vegetation Index of Biotic Integrity. Maximum scores for ORAM predictors and OVIBI are in parentheses.

Predictor	Description
LDI_{water}	Prop. standing water
LDI_{forest}	Prop. upland (non-hydric soils) forest
$LDI_{wetland\ forest}$	Prop. wetland (hydric soils) forest
$LDI_{wetland\ emergent}$	Prop. dominated by wetland emergent vegetation
$LDI_{pasture}$	Prop. pasture
LDI_{crop}	Prop. agricultural row-crop land
$LDI_{suburban}$	Prop. suburban residential
LDI_{rock}[a]	Prop. exposed rock substrate
$LDI_{transitional}$[a]	Prop. land being transitioned to an undefined use
LDI_{urban}	Prop. urban area
ORAM 1[a]	Wetland area, as one of seven size classes (6)
ORAM 2	Upland buffer width and intensity of land use surrounding wetland (14)
ORAM 3	Hydrology: sources, water depth, modifications to hydrologic regime (30)
ORAM 4	Habitat alteration and development, substrate disturbance (20)
ORAM 5[a]	Special wetlands (10)
ORAM 6	Plant communities, interspersion, and microtopography (20)
OVIBI	Sum of 10 measures describing wetland vegetation quality (100)

[a] Eliminated from analysis due to too few (≤ 6) unique values.

ORAM 2 and the 10 LDI predictors were considered "landscape-scale" because they assessed conditions in the area surrounding the wetland.

2.4. Statistical methods

Four predictors (ORAM 1 and ORAM 5, LDI_{rock}, and $LDI_{transitional}$) were excluded from the analysis due to too few (≤ 6) unique values. The remaining eight LDI predictors were natural log-transformed to normalize their distributions after adding 0.015 (one-half of the minimum nonzero value recorded) to each value. We used the statistical software R (R Development Core Team, 2012) and the R package rpart (Therneau et al., 2014) to develop classification (for SS/WF) and regression (for the remaining four AmphIBI metrics) trees for each response variable. The importance of each candidate predictor (Table 1) was calculated based on its contribution to all the splits in the tree (e.g., vignette of Therneau et al., 2014). Logistic regression (for the metric SS/WF) and simple linear regression (remaining four metrics) were used to determine if either of the two candidate predictors with the greatest importance was significantly related to the response. We limited the number of candidate variables in each regression model to the best two predictors, which was slightly more than Burnham and Anderson's (2002) suggested 1/10 of the number of candidate predictors (in our case, 13).

3. Results and discussion

We captured 15 amphibian taxa, with CC values ranging from 1 to 9 (Micacchion et al., 2015). AQAI scores ranged from 0 (two wetlands) to 8.80 (one wetland), with scores between 2.6–3.5 and 5.6–6.5 occurring most frequently (11 wetlands) (Fig. 1). The distributions of % tolerant and % sensitive were similar, with the "extreme" proportions (i.e., values of 0–0.1 and 0.91–1) occurring most frequently for both metrics. The number of pond breeding salamander species captured ranged from 0 at nine wetlands, to 5 at one wetland. Spotted salamanders, but not wood frogs, were