

Discontinuities in body mass distributions of bird communities does not capture a large-scale and long-term woody plant encroachment in Kansas, United States

Introduction

Body size influences the frequency and intensity of inter- and intraspecific competition for resources, territory, and mates, thereby dictating the spatial and temporal scales at which a species of a distinct body size operates [peters1983effect; silva1995allometric; allen2006patterns]. The scaling structure of terrestrial communities have been found to have ‘lumpy’ distributions — that is, they are not well-described using parametric statistical descriptions. If the scaling structure of a community manifests in the body mass distribution of the community, it is considered reflective of the discontinuous and heterogeneous nature of resource use. Specifically, holling1992cross suggests that the body mass distribution of a community or group of species reflects the discontinuous nature of environmental structures and processes. Quantitative analyses of animal body sizes [allen2006patterns; nash2014habitat] and other similar distributions has revealed the ubiquity of the discontinuous nature of distributions of animal body masses [skillen2008ecological; havlicek2001pelagic], plant biomass [spanbauer2016body], city population sizes [garmestani2005time], and animal home range sizes [restrepo2008discontinuities].

Given the ubiquity of discontinuities in body mass distributions of fauna and social systems [allen2009discontinuities], the ecological significance of these patterns may prove useful in understanding ecosystem structure and functioning [angeler2016management]. Various hypotheses are given for drivers of the discontinuous structure of animal body mass distributions including those related to resource use (the Energetic and Textural Discontinuity hypotheses), community interactions, biogeography, and evolution/phylogenetics [allen2006discontinuities; holling1992cross; blackburn1994animal; allen2006patterns], and these hypotheses consecutively represent the spatial and temporal scales at which the system components operate.

Discontinuities in body mass distributions been quantified using various methods (e.g., multivariate time series models, regression trees, and gap rarity index) which are collectively referred to as ‘discontinuity analyses’ [nash2014discontinuities; barichev2018method; stow2007evaluating; allen2009discontinuities]. Using various methods, the discontinuous nature of body masses of ecological communities is well-documented, having been observed in various taxa of both terrestrial [allen2006patterns] and aquatic [spanbauer2016body] communities. While identifying discontinuities in body mass aggregations and other systems is ubiquitous, much work is needed to sift through the hypotheses for drivers of these patterns [allen2006patterns].

The goal of this Chapter is to determine if, under the assumption there exists a northward-shifting spatial regime in the Central Great Plains from 1970 to 2015 (Roberts et al. in prep), local bird communities exhibited shifts in the scaling structure, and whether vulnerable species were impacted by this shift. I use discontinuity analyses to determine whether large-scale shifts in the vegetative structure impact scale-specific structure (as manifested in body mass distributions) of local bird communities. As an extension of allen1999body I test competing hypotheses for drivers of discontinuous body mass distributions by examining the location of vulnerable (declining) bird species within individual body mass aggregations. I found no evidence to support hypotheses for top-down influence of landscape-scale changes in vegetative structure on body mass distributions in my study area. I discuss the negative results and the potential limitations of this study and approach.

Methods

The Central Great Plains has undergone a large-scale and relatively rapid spread of a native invasive woody plant, the Eastern Redcedar [*Juniperus virginianus*; van2009causes; twidwell2016plant; donovan2018social], influencing habitat and resource availability for bird communities across multiple spatial scales [chapman2004tree]. A recent decadal analysis (C.P. Roberts et al. in prep) of avian body mass distributions suggests the avian communities within this study area underwent significant structural ‘regime’ shifts as a consequence of large-scale drivers including woody plant encroachment, and a climate

change. Based on observed changes in the body mass distribution structure of avian communities the authors suggest a spatial regime boundary moved from approximately over a 30-year period. Here, I use determine the influence of their proposed moving spatial regime on local bird communities in a region of Kansas, U.S that is suggested to have undergone a regime shift. I achieve this by first identifying the scaling structure of the body mass distributions of local bird communities using discontinuity analysis. If the proposed regime shifts occurred at the larger spatial scales, then we should expect local-scale shifts to have occurred within the same time frame. I further examine the effect of the large-scale woody plant encroachment on the local avifauna by examining if and how vulnerable species (i.e. grassland obligates and other declining species) are impacted. Using the body mass distributions built from the entire local communities, I calculate the distance of these species-of-interest to the nearest ‘edge’ of a body mass aggregation.

Study area and avian community data

I constructed body mass distributions using route-level data from the North American Breeding Bird Survey hereafter [NABBS; @bbsData]. The NABBS uses citizen scientist volunteers to annually collect data using a standardized roadside, single observer, 3-minute point count protocol and has organized data collection annually across North America (Figure @ref(fig:bbsPoints)) since 1966. Each roadside survey consists of 50, 3-minute point counts (data collected using sight and sound) along ~ 24.5 mile stretch of road. Due to strict reliance on volunteers, some routes are not covered every year. I retained only the NABBS routes falling within the state boundaries of Kansas and Nebraska, further restricting analyses to routes with at least 3 years’ worth of data during the years 1970, 1985, 2000, and 2015.

Although NABBS volunteers attempt identify all species in the point-count area, biases exist in data collection. For this reason, I removed some species from the analyses (see Methods section in Chapter @ref(fisherSpatial) for a discussion). I removed all

I examined a subset of the area analyzed in C.P. Roberts et al. (in prep) which is proposed to have underwent a large-scale regime shift, as exhibited by changes in the scaling structure of the avian body mass distributions. Roberts et al. (in prep) hypothesize that a spatial regime boundary exists in the Central Great Plains and suggests it has exhibited a Northward shift at a rate of $\sim \frac{0.05^\circ \text{ latitude}}{\text{year}}$. The authors used discontinuity analysis to identify these ‘spatial regimes’, using the body massess of breeding bird communities. Their hypothesized spatial regime boundary occurs at 39° latitude in year 1970, 39.5° latitude in year 1985, 40° latitude in year 2000, and 40.5° latitude in year 2015 (see Figure @ref(fig:routesWithSpatRegimes)). I used the same latitudinal boundary to classify

Assuming the location and timing of these spatial regime boundaries, I restricted analyses to

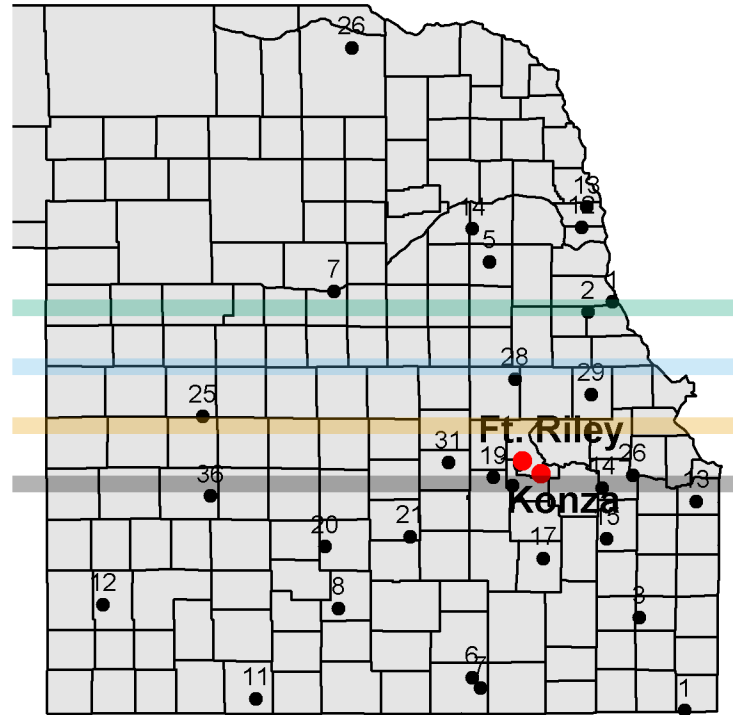
Identifying community scaling structure using body mass distributions

Distance to edge

@allen2006body propose alternative hypotheses for the relative locations of species within the body mass aggregation distributions as a function of ‘distance to edge’, a measure indicating the distance (in log-mass units) of each species to the edge of a body mass aggregation. This distance to edge measure is zero when the species is an ‘edge species’, and increases as it approaches the center of a single body mass aggregation.

If the spatial regime shift occurred in the bird community, it should manifest in the local community scaling structure through one or both of species turnover and a shift in the number of body mass aggregations.

```
temp <- getTab(fn="nRtesPerRegimePerYear") %>%
  rename(`# BBS routes` = nLoc,
         Year = year, Regime = regime)
kableExtra::kable(temp, "latex", booktabs=TRUE)
```



spatial regime location per Roberts et. al 1970 1985 2000 2015

Figure 1: North American Breeding Bird Survey routes (points) surrounding the (latitudinal) locations (horizontal bars) of the spatial regimes as proposed in Roberts et al. (in prep) in Nebraska and Kansas, United States. Routes with less than 3 years of data (among years 1970, 1985, 2000, 2015) are not displayed. Numbers indicate the route numbers assigned by the Breeding Bird Survey, and Kansas and Nebraska state numbers of 38 and 54, respectively (not shown). Fort Riley military base and Konza prairie are shown geographical reference.

Year	Regime	# BBS routes
1970	North	14
1970	South	24
1985	North	12
1985	South	25
2000	North	13
2000	South	24
2015	North	16
2015	South	25

English Common Name	Grassland Obligate
\textcolor{red}{American Crow}	
\textcolor{red}{American Kestrel}	
\textcolor{red}{Barn Swallow}	
\textcolor{red}{Black-capped Chickadee}	
\textcolor{black}{Bobolink}	yes
\textcolor{red}{Brown-headed Cowbird}	
\textcolor{red}{Brown Thrasher}	
\textcolor{black}{Chestnut-collared Longspur}	yes
\textcolor{red}{Chimney Swift}	
\textcolor{black}{Chipping Sparrow}	yes
\textcolor{red}{Common Grackle}	
\textcolor{red}{Common Yellowthroat}	
\textcolor{black}{Dickcissel}	yes
\textcolor{red}{Eastern Kingbird}	
\textcolor{red}{Eastern Meadowlark}	yes
\textcolor{black}{Field Sparrow}	yes
\textcolor{red}{Grasshopper Sparrow}	yes
\textcolor{black}{Henslow's Sparrow}	yes
\textcolor{red}{House Sparrow}	
\textcolor{black}{Lark Bunting}	yes
\textcolor{black}{Lark Sparrow}	yes
\textcolor{black}{LeConte's Sparrow}	yes
\textcolor{red}{Loggerhead Shrike}	
\textcolor{black}{McCown's Longspur}	yes
\textcolor{red}{Northern Bobwhite}	
\textcolor{red}{Northern Rough-winged Swallow}	
\textcolor{red}{Nothorn Flicker}	
\textcolor{red}{Red-headed Woodpecker}	
\textcolor{red}{Red-winged Blackbird}	
\textcolor{black}{Savannah Sparrow}	yes
\textcolor{black}{Sprague's Pipit}	yes
\textcolor{red}{Swainson's Hawk}	
\textcolor{red}{Upland Sandpiper}	yes
\textcolor{black}{Vesper Sparrow}	yes
\textcolor{red}{Western Kingbird}	
\textcolor{red}{Western Meadowlark}	yes
\textcolor{black}{Yellow-headed Blackbird}	yes

I first identify the discontinuous structure of the bird community before and after woody encroachment

occurring at the landscape-scale. Next, I

on a local bird community

use the body mass distributions of bird communities in the Central Great Plains before and after a large-scale shift in vegetative structure to

bird test the Biotic Interaction Hypothesis, which suggests that the biotic interactions within a community operates at the local scale over a relatively short time scale, thus shaping the body mass distribution of the community.

For example, a recent comparison of body mass distributions in streams of varying quality revealed discontinuous body mass distributions, but no difference in the number of aggregations in the presence of disturbances [bibbi2019body].

extinction @wardwell2009variability - population variability

invasion @allen1999body

regime shifts @spanbauer2016body, suggested in @angeler2016management

@nash2014discontinuities -

as manifested in animal body masses is well-documented, however, the ecological significance of such discontinuous structure remains unknown.

The interactions among species in a single aggregation presumably experience a higher frequency and intensity of interspecific interactions with each other as opposed to those in different aggregations (Peterson and others 1998).

Methods

@dunning2007crc

I used discontinuity analysis to identify the cross-scale structure of the avian communities across space-time [barichievy2018method].

Given the extent and resolution of our data, we are able to only test the biotic interaction and textural discontinuity hypotheses [allen2006patterns]. “If scale dependent resource variability is introduced into the model, then a single mode can separate into multiple modes (Marquet et al. 1995), indicating an interaction between the distribution of resources in the landscape and body mass aggregations.” from allen2006patterns

##Bibliography: grassland birds in NA @vickery2001recent – grassland birds experienced widespread declines, in part spurring the beginning of the NABBS program. BBS trend estimates estimated at least 15 species declining over the period of 1966-1996, (Peterjohn and Sauer 1999). Compared to other functional groups or species guilds, grassland obligates seemed to have fared worst. These declines are primarily attributed to habitat loss and degradation. And it is no secret that native grasslands are among the most endangered biomes on the planet (Referece).

The CRP program (beginning in the mid1980s) appears to have benefitted some species, however. Bobolink, Sedge Wrens, Dickcissels, Le Conte’s sparrows, Henslow’s sparrows.

Species not positively influenced have been the Grasshopper Sparrow, Eastern and Western Meadowlarks (Sauer et al. 1999), despite these species utilizing CRP habitat and for resources cribbed. . . (Johnson and Schwartz 1993, Best et al. 1997).

@brennan2005north – prairie vegetation loss, intensifying agricultural efficiency and practices, lack of fire, and habitat loss all contribute to the ongoing “crisis” with the loss of grassland and grass-shrub avifauna.

@correll2019quantifying –

Discussion

Study limitations

1. Cross-taxa interactions – bm dists assumes that the bird comm is not competing for resources with other taxa...
2. Annual BBS surveys may not represent true census of the area (aggregating the pres/abs data over multiple years...)
- 3.