Landscape and Urban Planning 159 (2017) 48–61

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Decadal declines in bird abundance and diversity in urban riparian zones

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HIGHLIGHTS

- Migratory bird community composition differs between two seasons in central Arizona.
- Decade-long bird abundance has decreased >50% in some Phoenix riparian areas.
- Proportion of urban invader species has increased in the riparian bird community.
- Specialists are associated with dense, tall vegetation, and less impervious surface.
- Riparian areas with perennial flows attract greatest abundance and species of birds.

ARTICLE INFO

Article history:
Received 18 November 2015
Received in revised form 22 August 2016
Accepted 5 September 2016

Keywords:
Avian community ecology
Biodiversity conservation
Long-term data
Migratory birds
Riparian habitat
Urbanization

ABSTRACT

Urbanization is frequently cited as a major driver of species losses worldwide; however, most studies in urban areas use a space-for-time substitution approach to document effects of urbanization through time. Ultimately, understanding the effects of urbanization on biodiversity requires long-term datasets. We examined long-term changes in bird assemblages at 12 riparian sites in the greater Phoenix metropolitan area and nearby Sonoran Desert region, featuring a range of human modifications and levels of water flow. Riparian areas in arid cities represent a key habitat type that is sensitive to human modification and supports high levels of species diversity. We used long-term data to: (1) explore variation in bird communities as a function of water permanence and degree of human-modification; (2) identify which environmental variables best describe differences found across riparian site types; and (3) assess how riparian bird communities, abundance, and species richness have changed through time. Engineered riparian sites supported more broadly distributed generalists; whereas, natural riparian sites supported more specialists. Sites with perennial flows had more vegetation and water compared to ephemeral sites and engineered sites had more impervious surface compared to natural sites. In nearly all comparisons, bird species richness, diversity, and abundance declined across riparian types during the period of study, even for common species. Bird communities in natural settings have changed more than communities at engineered sites. Overall, the riparian bird community is shifting toward urban dwelling, resident species that are characteristic of riparian sites with less water and more impervious surface.

1. Introduction

Worldwide, urban areas are expanding and are among the most rapidly changing landscapes. Urban areas modify wildlife habitat by replacing native vegetation cover with structures, roads, and other impervious surfaces (Czech et al., 2000Czech, Krausman, & Devers, 2000) among many other effects (Pickett et al., 2011). Bird species density (the number of species/area) in cities is reduced relative to surrounding regions, and appears to be highly sensitive to changes in land cover (Aronson et al., 2014). However, most urbanization studies use a space-for-time substitution approach to document effects of urbanization through time (Pickett et al., 2011). Understanding effects of urbanization on biodiversity requires long-term datasets, which document temporal changes in species composi-

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http://dx.doi.org/10.1016/j.landurbplan.2016.09.026

tion and species gains or losses (Magurran et al., 2010; Strohbach, Hrycyna, & Warren, 2014).

Although cities are designed primarily for the benefit of humans, many species of wildlife persist and thrive in urban environments (Aronson et al., 2014; Marzluff, 2001; McKinney, 2002; Pickett et al., 2011). Many large cities occur along waterways, and can alter stream hydrology and watershed infiltration because of impervious surfaces (Paul & Meyer, 2001). However, a more basic challenge in arid ecosystems is to provide sufficient water to maintain riparian ecosystems. In arid cities, perennial water from novel urban sources, such as storm drains, can support riparian areas with diverse plant and bird communities (Bateman et al., 2015). Compared to other ecosystems, riparian areas support some of the highest bird diversities (Knopf & Samson, 1994), but can also be habitats that are highly sensitive to modification (Naiman, Decamps, & Pollock, 1993). Therefore, there is a growing need to identify sustainable mechanisms to restore and maintain urban riparian ecosystems and the services, such as habitat, they provide (Bernhardt & Palmer, 2007).

During the last century, the greater Phoenix metropolitan area in central Arizona has had one of the fastest growing populations in the United States (Hobbs & Stoops, 2002). In this region, a system of channels and canals transport water from reservoirs on the Verde, Salt, and Colorado Rivers (Gober, Wentz, Lant, Tschudi, & Kirkwood, 2011) to support a large urban population of 4 million in Maricopa County (U.S. Census Bureau, 2015). Employing datasets available from the Central Arizona–Phoenix Long-Term Ecological Research program (https://caplter.asu.edu), we examined the effects of urbanization on riparian habitats and bird communities in Phoenix and the surrounding Sonoran Desert region. The aims of our study were to: (1) explore variation in bird species richness, abundance, and community composition as a function of water permanence and degree of human-modification; (2) identify which environmental variables measured at different scales (site- and landscape-level) best describe differences in habitat characteristics found across riparian site types; and (3) examine the temporal patterns of avian abundance, species richness, and diversity across riparian site types.

2. Methods

2.1. Study area

Our research was conducted within the study area of the Central Arizona–Phoenix Long-Term Ecological Research program (hereafter CAP LTER), which encompasses the greater Phoenix metropolitan area and surrounding Sonoran Desert (hereafter Phoenix; Fig. 1). CAP LTER established two to four study sites in each of four riparian habitat types: (1) ephemeral-engineered (n = 4); (2) ephemeral-natural (n = 2); (3) perennial-engineered (n = 3); and (4) perennial-natural (n = 3). CAP LTER defined types as ephemeral versus perennial based on the permanence of water. Types were also classified as engineered or natural defined by the degree of human-modification, which is more of a continuum rather than a dichotomy. Specifically, the ephemeral-engineered sites included a 200-m square retention basin surrounded by neighborhoods, two unlined earthen flood control channels surrounded by neighborhoods and golf courses, and one artificial water catchment surrounded by desert. The ephemeral-natural sites were along intermittent rivers surrounded by desert and some low density residential areas. The perennial-engineered sites included a landscaped riparian preserve, a constructed wetland, and a water retention area along the Salt River. These sites were surrounded by urban or agricultural areas. The perennial-natural sites were located along perennial river reaches and were surrounded by desert. Sites ranged between 295 and 683 m in elevation.

2.2. Bird surveys

Following Bibby, Burgess, Hill, and Mustoe (2000), CAP LTER used point count surveys with a 40-m fixed-radius where a trained observer recorded all birds seen and heard. At each point, the observer remained quiet for five minutes, then recorded birds for 15 min. Observers identified species based on Sibley (2000), and classified species according to Pyle and DeSante (2013). Birds detected beyond the 40-m truncation distance or that flew over the point were not counted, except for wide-ranging and foraging species (i.e. waterfowl, shorebirds, birds of prey, nighthawks, Greater Roadrunner, *Geococcyx californianus;* Belted Kingfisher, *Megaceryle alcyon;* and Loggerhead Shrike, *Lanius ludovicianus*). Surveys were conducted under similar environmental conditions and were completed within four hours of sunrise. From 2001 to 2013 (surveys were not conducted in 2003), three observers visited each point twice annually, once during winter (end of December to mid-February) and once during spring (end of March to mid-May).

2.3. Vegetation and environmental variables

We collected eight site-level (within a 40-m radius around the point) and four landscape-level (within a 1-km radius around the point) environmental variables during spring 2013. Site-level variables included percent cover for marsh, water, impervious surface (i.e., pavement, structures, etc.), and bare ground. We used slightly modified Daubenmire (1959) cover classes (i.e., cover classes: none, 0–1%, 1–5%, 5–25%, 25–50%, 50–75%, 75–95%, >95%) to estimate percent cover for each category within a 40-m radius. We quantified vegetation at the site-level by selecting 10 random points stratified to represent all vegetation types present (i.e., riparian, Sonoran Desert, marsh, etc.). Points were at least 10 m apart and none of the points were located in open water bodies or on roads. We recorded the proportion of random points where vegetation was present at three height classes (low, below 0.6 m; medium, 0.6–1.5 m; and high, above 1.5 m). We recorded percent canopy cover in four cardinal directions using a concave densiometer, averaged the four readings per point, then averaged over the 10 points. At the landscape level, we used ArcGIS 10.2 to quantify four land cover categories (i.e., impervious surface, bare ground, water, and vegetation) around each sampling site (1-km radius). Land cover categories were included in a land-cover classification dataset provided by CAP LTER, which was generated from 2010 National Agriculture Imagery Program (NAIP) imagery using methods detailed by Li, Myint, Zhang, Galletti, Zhang et al. (2014).

2.4. Data analyses

To compare bird abundance and species richness across riparian habitat types through time, we used Bayesian modeling since we had an unbalanced design. We generated two Bayesian models (one for abundance and one for species richness) with Markov Chain Monte Carlo (MCMC) using package rjags (Plummer, 2014) for program R stats version 3.2.1 (R Core Team, 2013). The models followed a Poisson distribution (since data are univariate discrete numbers) with a log link function. As input, we used data from all three observers for each year and season. We used time as a covariate, and included a random effect for sites. We also included a novice observer effect to our models, since observers tend to have lower than expected count in the first year of conducting bird surveys (Kendall, Peterjohn, & Sauer, 1996). To compare how riparian type and season differ, we allowed parameters to vary by riparian type and season. We assigned non-informative pri-