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Research paper

Waterbird community composition, abundance, and diversity along an urban gradient

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ABSTRACT

Urban riparian corridors have the capacity to maintain high levels of bird abundance and biodiversity. How riparian corridors in cities are used by waterbirds has received relatively little focus in urban bird studies. The principal objective of our study was to determine how habitat and landscape elements affect waterbird biodiversity in an arid city. We surveyed 36 transects stratified across a gradient of urbanization and water availability along the Salt River, a riparian corridor that is monitored as part of the Central Arizona-Phoenix Long-Term Ecological Research study system located in Phoenix, Arizona, USA. Habitat and landscape variables were reduced via Principal Component Analysis to be used in a constrained ordination that identified waterbird community composition patterns, and then used to model the responses of guild abundance and diversity. Habitat and landscape components from the constrained ordination explained 39% of the variation in the waterbird community. Land use components were related to the suite of species at each site, but had a weaker relationship to guild abundance or diversity. Habitat-level components (water physiognomy, shoreline composition, and terrestrial vegetation cover) were more important in predicting both guild abundance and diversity. We found that water physiognomy was the strongest driver shaping waterbird community parameters. The implications of our study are relevant to urban planning in arid cities, offering the opportunity to design and improve wildlife habitat while providing other important public amenities.

1. Introduction

Globally, urban land area increased by 58,000 km^2 between 1970 and 2000 (Seto, Fragkias, Güneralp, & Reilly, 2011). Cities continue to expand outward, urban and exurban settlement covers four to five times the area it did in 1950 (Brown, Johnson, Loveland, & Theobald, 2005) and urban land area is expected to triple by 2030 (Seto, Güneralp, & Hutyra, 2012). Twenty-nine of the world's ecoregions, which house 3056 species and 213 endemic species, have at least a third of their total area urbanized (Mcdonald, Kareiva, & Forman, 2008). Rapidly expanding urban areas necessitate a better understanding of how biodiversity in urban environments is influenced by human decisions that affect habitat characteristics (Hostetler and Knowles-Yanez, 2003).

Urban research has highlighted key biodiversity trends that span numerous taxa and geographical locations. Generally, cities have a higher abundance of commensal and generalist species, but lower biological diversity than non-urban landscapes (McKinney, 2008). In dense urban areas, bird abundance is often high and richness is low, whereas avian richness often peaks in areas of intermediate urban density (e.g., Blair, 1996; Melles, Glenn, & Martin, 2003). Land use, available habitat, and socioeconomic factors can all affect biodiversity patterns within the urban matrix (Melles, 2005; Lerman & Warren, 2011). The numerous studies of urban bird biodiversity often focus on terrestrial species, but there has been less focus on how waterbirds respond to urbanization. Waterbird communities may respond differently to urbanization than terrestrial species because of their unique habitat and foraging requirements.

Waterbirds are a diverse group of species closely associated with freshwater and marine habitats, and are important as both indicators of ecosystem health (Ogden et al., 2014) and as a source of recreational revenue (Carver, 2009). Regardless of their importance, global waterbird populations are declining (Wetlands International, 2012). One main cause of the decline is the increase in anthropogenic land-uses, reducing habitat availability at stopover and wintering sites (Page & Gill, 1994). In arid regions, water is a highly variable resource and aquatic habitat is especially important for waterbirds, making habitat loss an important issue (Kingsford, Roshier, & Porter, 2010). Despite their limited extent, mesic strips of riparian habitat in desert regions

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stand in a stark contrast to an otherwise arid landscape, providing wintering and stopover sites (Patten, 1998; Flannery et al., 2004; Villaseñor-Gómez, 2008). Urbanization reduces or modifies aquatic habitats for waterbirds by diverting water for municipal purposes, creating habitat from built infrastructure, or modifying existing streams, floodplains, and wetlands (Grimm, Faeth, Golubiewski, Redman, Wu, & Briggs, 2008). However, in arid regions, the loss of existing aquatic and semi-aquatic habitat due to development can be paralleled by a net increase in overall water availability through built habitat such as artificial lakes or constructed wetlands (Larson & Grimm, 2012).

Findings from Rosa et al. (2003) suggest that waterbird species richness in arid environments decreases only when disturbance encroaches on the wetland, narrowing the width or changing the structure. Another urban study in the non-arid state of Florida found that waterbird guilds have a significantly higher than expected richness along developed shorelines compared to undeveloped habitat (Traut & Hostetler, 2004). In this study, our goal is to further investigate if waterbirds take advantage of non-traditional aquatic habitat along an urban riparian corridor and, if so, what biophysical features of the habitat are most important in supporting a diverse community. Specifically, our research objectives are to: (1) identify how waterbird diversity shifts along a gradient of urbanization and water availability, and (2) determine the relationship between habitat and landscape elements with waterbird community parameters (guild abundance, community composition, and diversity).

2. Methods

2.1. Study area

The Phoenix Metropolitan Area is one of the fastest growing cities in the United States, with an estimated population of over 4.4 million as of April 2014 and a growth rate of 4% per year in the last 40 years (US Census, 2015). The Salt River is a river that is diverted by the Granite Reef Diversion Dam into canals as part of the Salt River Project to provide drinking and irrigation water to Phoenix. The majority of the riverbed that passes through Phoenix is dry, with the exceptions of patchy ephemeral and perennial water sources. The result is a highly heterogeneous riparian corridor with patchy habitat characteristics spread throughout the extent of the river. The surrounding matrix is equally variable, comprising desert, urban, and agricultural land use and cover. Our study focused on a 75-kilometer segment of the Salt River that spans the Phoenix metropolitan area (Fig. 1), starting at Saguaro Lake (33.5656, −111.5361) and ending at the Gila River confluence (33.3811, −112.3131).

2.2. Avifauna

The waterbird community was surveyed during the winters of 2015 and 2016 (December-February) at 18 transects 225 m in length per winter, for a total of n = 36 transects (Fig. 1). Transects were randomly placed parallel to the water's edge, stratified along gradients of water availability (dry, ephemeral, perennial) and level of urbanization (urban, intermediate, and desert). The sampling scheme resulted in transects that were at least 700 m apart, which meets the recommendations that transects be at least 200 m apart in dense environments and at least 500 m apart in open environments to produce independent samples and reduce spatial autocorrelation for bird studies (Sutherland, 2006). Surveys were conducted in the winter when most waterbirds migrate through the region. We used the line transect method (Bibby, Burgess, Hill & Mustoe, 2000) to conduct community surveys, recording waterbirds within 150 m of the transect center (sensu, DeLuca, Studds, King, & Marra, 2008; Rathod & Padate, 2007; Roy, Goswami, Aich, & Mukhopadhyay, 2011). Trained observers slowly walked along the edge of the stream bed to flush cryptic or hidden species and recorded any birds seen or heard within the truncation distance. Counts occurred within 4 h of sunrise, with wind below 20 km per hour and precipitation no heavier than a light drizzle. Surveys were completed three times per winter season (Conway, 2011). On repeat visits, the site order and direction that the observer walked (up or downstream) were rotated to reduce bias.

Community measurements of guild abundance and diversity were derived from bird surveys pooled over two years of sampling because there was no significant difference in guild abundance or richness between the two years, and year-effects were not the focus of our study. Birds were classified into six guilds (dabbling ducks, diving ducks, fish-eating birds, rails, shorebirds, and wading birds) primarily based on bird foraging strategies and functional traits (Elphick & Dunning, 2001; Appendix I). Prior to analysis, species abundance for each site was standardized by the area of water so that abundance data were interpreted as usage per available habitat, or the relative abundance. Guild abundance was calculated as the sum of total individuals per guild averaged over the three visits and log-transformed to normalize the data. We calculated species richness by summing total species detected on any one the surveys at each transect. We determined waterbird diversity by calculating the Shannon Diversity Index at each site (Hill, 1973).

We visualized the Renyi diversity profiles of sites grouped according to their position within level of urbanization and water availability (Hill, 1973). The Renyi diversity profile shows biodiversity across multiple indices. The horizontal axis (H-alpha) represents a range of indices that emphasize richness and evenness (low x-axis values) to those that emphasize abundance (high x-axis values). The 12 sites with highest levels of urbanization were assigned to 'urban', followed by the next 12 being placed into 'intermediate' and the final 12 with the lowest levels of urbanization along the gradient were considered 'desert'. This was repeated for the four levels of water availability.

2.3. Land cover classification of study area

We performed a supervised land cover classification with ERDAS Image software (2006) based on the Landsat 8 Satellite imagery (11 bands and a 30 m resolution), acquired in February 2015. In supervised classification the analyst selects representative samples for each land cover class, known as 'training sites.' The spectral signatures of training sites are then used to determine the land cover class for each raster cell by pattern matching using maximum-likelihood classification. The land cover classification included seven categories: urban/developed (residential, industrial, and commercial land use), cultivated vegetation (agriculture, irrigated grass, golf courses, and mesic yards), riparian vegetation, impervious surface, water, river gravel, and undeveloped (desert, desert shrub, urban desert remnant parks). The supervised classification results were confirmed in the field at the sampling locations. The land cover classes were then reclassified into separate rasters in order to derive habitat and landscape variables. The water classification raster was converted to polygons and combined with a shapefile mapping artificial lakes in Phoenix (Larson & Grimm, 2012) to ensure that all water was mapped as accurately as possible and to capture any cells that may have been misclassified in the supervised classification.

2.4. Environmental variables

For each transect, we quantified 20 environmental variables categorized as habitat or landscape scale (Table 1). Variable measurements were made from the land cover classification or directly from the Landsat 8 satellite data. Analyses were performed in ArcMap 10.1 geographic information system (ESRI 2006) and measurements were verified in the field for each transect.

We used the land cover classification and unclassified imagery to measure 12 habitat variables (Table 1) within 150 m of either side of the transect, encompassing a total area of 225 m × 300 m. Similar to