The Ecological Outcomes of Land System Architecture (LSA) Change:

A Case Study of Riverfront Redevelopment in Tempe, Arizona

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ABSTRACT

Improving the sustainability of urban areas can have a dramatic impact on improving global sustainability. Land use/land cover is both a driver and a potential solution to global environmental change, therefore land system architecture (LSA)—which focuses on the role of size, shape, distribution, and connectivity of land units in relation to the system's social-environmental dynamics—is an important tool for working towards urban sustainability. Research on the interactions between LSA and urban ecosystems is in an early stage, with most work evaluating separate ecological outcomes such as the urban heat island, surface water run-off, or biota. Here, we use long-term data from CAP LTER along with satellite imagery for an integrated comparison of surface urban heat island, vegetation, and bird biota in a redeveloped region along the Rio Salado. The riverfront of the Rio Salado in Tempe, Arizona experienced significant redevelopment as part of the Tempe Town Lake development between the early 1990s and 2000. We examined how the LSA of the riverfront changed during this period; what the ecological outcomes were in terms of land surface temperature, vegetation presence/health, and bird biota; and which LSA changes relate to ecological outcomes. The relationship between LSA and ecological outcomes have implications for modifying or preserving the LSA of a landscape. Of the LSA components examined at the Rio Salado and comparison site, shape complexity and distribution have a stronger relationship with temperature and vegetation presence/health than size and connectivity. For the Rio Salado, we find that interspersed and complex open space as well as a permanent source of water supports waterbird species in the urban landscape mosaic.

STUDY AREA

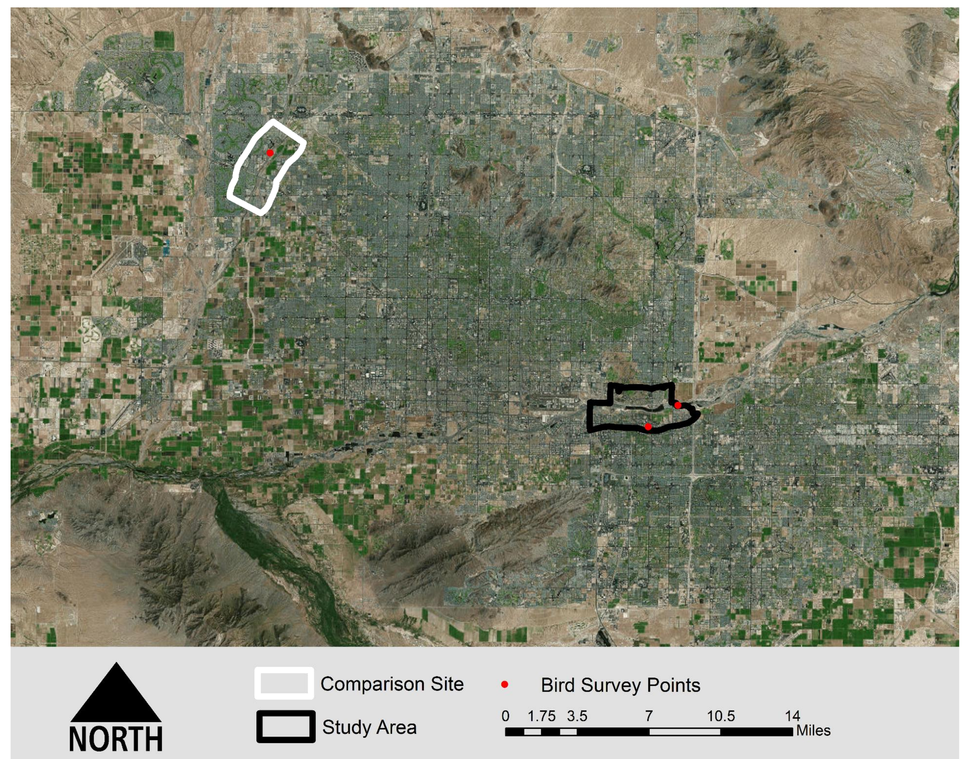

Figure 1. Study areas and location of CAP LTER bird survey sites within each study area.

Our study area is one mile on either side of the Rio Salado in Tempe, Arizona, USA (Figure 1). The Tempe segment of the Rio Salado has seen more development than most of the Rio Salado riverfront. Beginning in the 1990s, the city of Tempe started planning and construction along the Rio Salado to the north of its downtown; channelizing it in 1999 and calling this segment Tempe Town Lake. Subsequent development around the lake includes Tempe Beach Park, a riverfront trail, and mixed-use development. The comparison site is a riparian area that also experienced urbanization during this period.

RESEARCH QUESTIONS

1. How does the landscape change in terms of size, shape, distribution, and connectivity as a result of the Tempe Town Lake development?
2. How do the environmental variables respond?

DATA & METHODS

Satellite imagery and several long-term datasets from CAP-LTER were used to determine landscape change and the ecological response:

VARIABLE	DATASET
Land Use/Land Cover (LULC)	CAP LTER LULC Classification (Zhang and Li 2017)
Bird Community Metrics (abundance, richness, and turnover)	CAP LTER Bird Community Census (Bateman et al., 2017)
Normalized Difference Vegetation Index (NDVI)	Landsat 5 and 8
Land Surface Temperature (LST)	Landsat 5 and 8

The four components of land system architecture (LSA)—size, shape, distribution, and connectivity—are measured using FRAGSTATS (McGarigal and Marks 1995) metrics:

LSA	METRIC	DEFINITION
Size	Percent of Landscape	Percentage of the landscape that is covered by a given class
Shape	Median Shape Index	Measure of median compactness, 1 = patch is completely square. < 1 as the patch shape becomes less compact
Distribution/ Isolation	Median Euclidean Nearest Neighbor	Median distance between the center of a patch and the nearest neighboring patch of the same class
Connectivity	Interspersion and Juxtaposition Index	Measure of interspersion, higher the value the greater the interspersion. 0 = patch is adjacent to one other patch type

LSA CHANGE

Figure 2. Changes in the component of LSA (as measured by FRAGSTAT metrics) for the Rio Salado and comparison site. The grey vertical bars mark the period in which construction on the Rio Salado began. *Note: Due to the minimal presence of crop cover in the Rio Salado site, the crop connectivity values were high and variable, two years were removed to improve visualization.*

ECOLOGICAL CHANGE

The three ecological variables measured at each site were the quantity/health of vegetation according to NDVI (Figure 3a), land surface temperature (Figure 3b), as well as abundance, richness and turnover of the bird community (Figure 4).

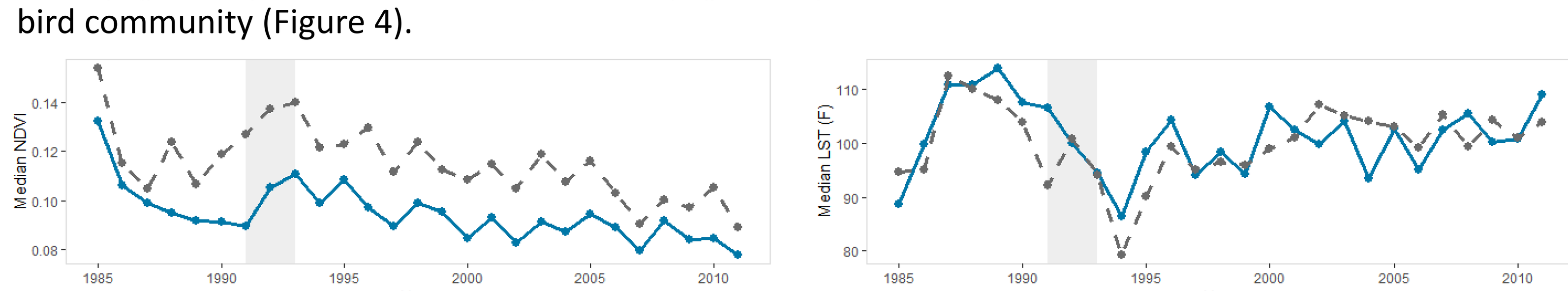

Figure 3. Median Normalized Difference Vegetation Index – NDVI (left) and Land Surface Temperature – LST (right) for the Rio Salado and comparison site. The grey vertical bars mark the period in which construction on the Rio Salado began.

The construction period corresponds to a change in the long term trend of NDVI and LST. Bird community abundance and richness decline at both sites but more dramatically for the Rio Salado. The turnover is variable, but generally higher at comparison site.

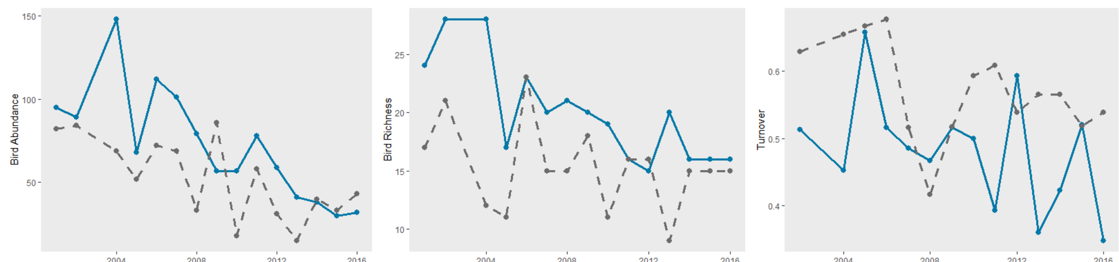

Figure 4. Bird Community Metrics. Left to right: abundance, richness, and turnover.

RESULTS

Table 1 is the repeated measures correlation results for a given class' LSA, LST, and NDVI values. Shape and distribution have a stronger relationship with NDVI and LST than size and connectivity. Figure 5 is the non-metric multidimensional scaling visualization of the temporal and spatial relationship between bird species and the LSA components.

Table 1. Repeated Measures Correlation results. Values with * are statistically significant (p = 0.05 or less) level

	NDVI			LST	
	Rio Salado	Comparison Site		Rio Salado	Comparison Site
Size	0.20	-0.12	**Size**	-0.31	-0.15
Shape	0.14	-0.47*	**Shape**	-0.41*	0.44*
Connectivity	-0.20	0.07	**Connectivity**	0.26	-0.03
Distribution	0.44*	0	**Distribution**	-0.76*	-0.08

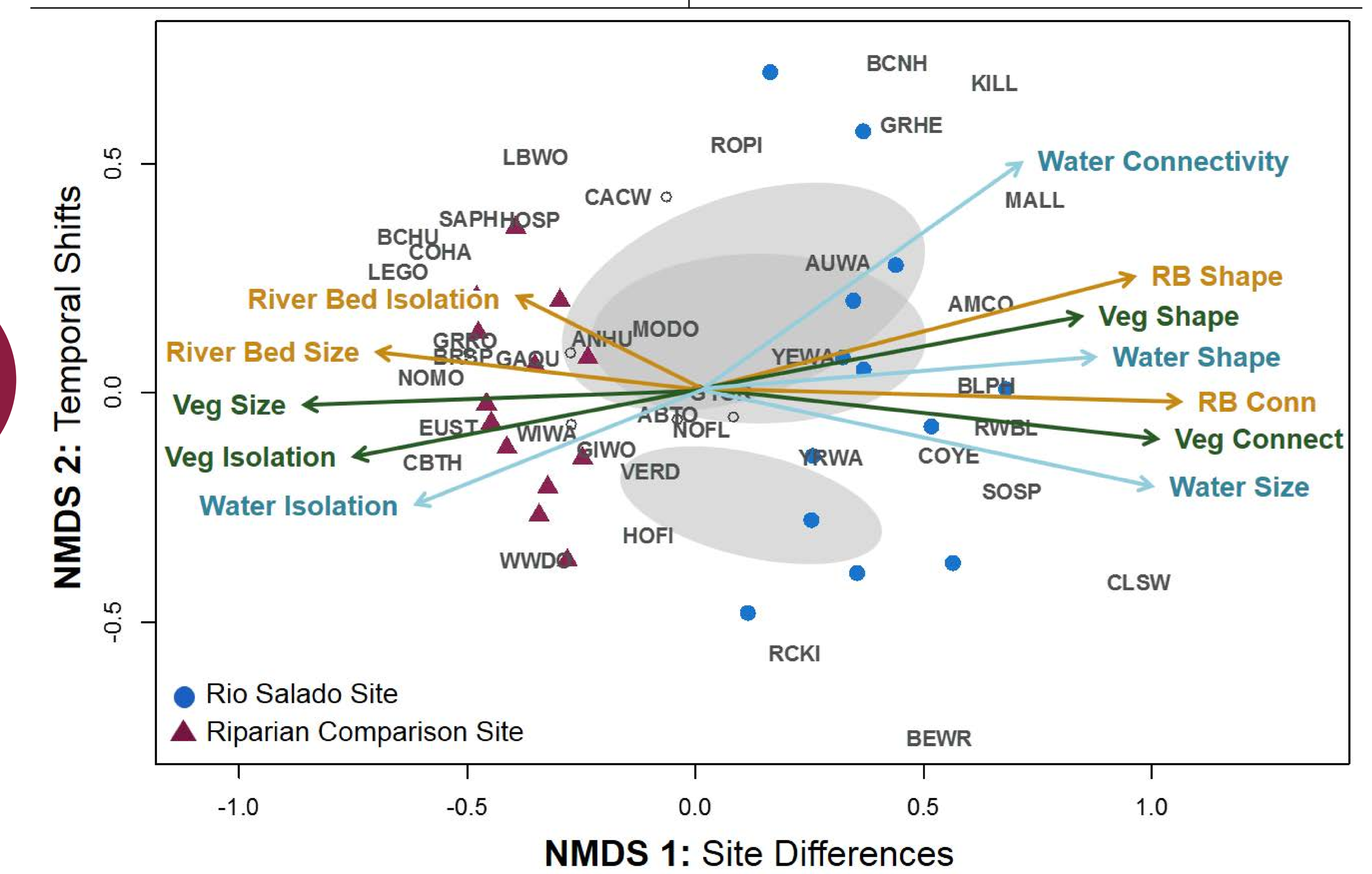

Figure 5. Non-metric multidimensional scaling (NMDS) visualizing the temporal and spatial relationship between bird species and LSA components of size, shape, connectivity, and distribution/isolation. Grey ellipses represent centroids for the three time periods (2000, 2005, and 2010) along the y axis. Site differences are reflected by the x axis. Vectors reflect the strength and direction of the LSA components.

DISCUSSION

Differences in the association between LSA components and the bird community are greater between sites than temporally. This suggests that the riverfront interventions in Tempe affected the bird community beyond the metropolitan region's ongoing urbanization.

We find that greater patch isolation and open space (river bed and vegetation) patch size are related to terrestrial bird species in the ephemeral comparison site. Comparatively, the perennial Rio Salado site is characterized by more interspersed, complex open space associated with waterbird species. The LSA of each site affects the relationship with LST and NDVI as well. At the comparison site, patches that are more compact are cooler with greater vegetation presence/health. While at the Rio Salado, patches that are more isolated are cooler with greater vegetation presence/health.

CITATIONS

Bateman, H.L., Childers, D.L., Katti, M., Shochat, E., Warren, P.S., 2017. Point-count bird censusing: long-term monitoring of bird abundance and diversity in central Arizona-Phoenix, ongoing since 2000. Environ. Data Initiat. https://doi.org/10.6073/pasta/201add557165740926aab6e056db6988

McGarigal, K., Marks, B.J., 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure.

Turner, B.L.I., Janetos, A.C., Verburg, P.H., Murray, A.T., 2013. Land system architecture: Using land systems to adapt and mitigate global environmental change. Glob. Environ. Change 23, 395–397. doi.org/10.1016/j.gloenvcha.2012.12.009

Zhang, Y., Li, X., 2017. Land cover classification of the CAP LTER study area at five-year intervals from 1985 to 2010 using Landsat imagery. Environ. Data Initiat. https://doi.org/10.6073/pasta/dab4db27974f6c8d5b91a91d30c7781d

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