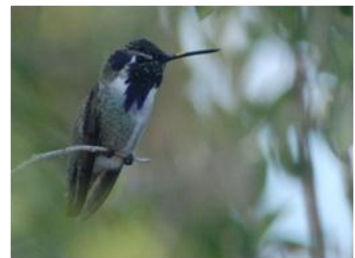
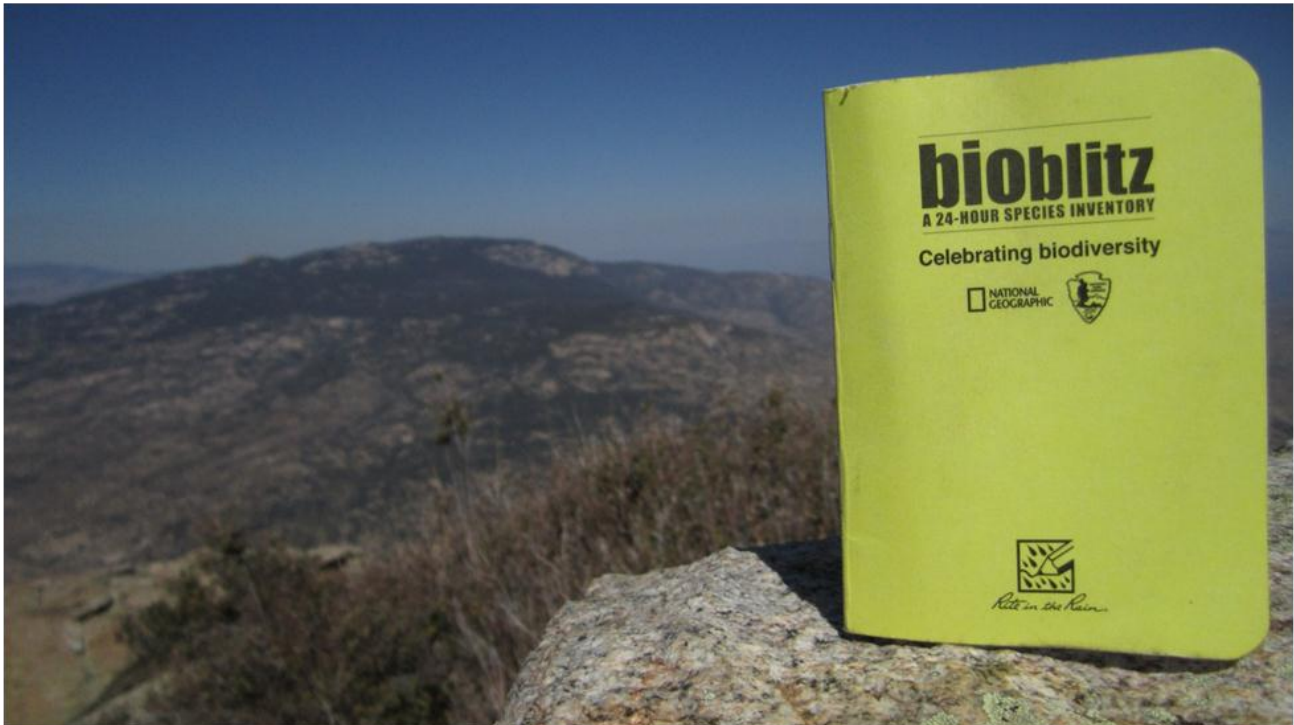




Using BioBlitz data to assess bird populations across ecological gradients of Saguaro National Park: Foundations for future studies of climate change impacts



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# Assessing bird populations across ecological gradients of Saguaro National Park: Foundations for future studies of climate change impacts

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## INTRODUCTION

Interannual variation and changes in climate can have significant short- and long-term effects on the spatiotemporal distribution of organisms (Parmesan 2006, Walther et al. 2002).

Understanding the range, capacity, and plasticity of species' responses to climatic variation will be critical for accurate predictive models of species responses and ecological cascades of climate change effects (Malcolm et al. 2002) that may guide future management and conservation decisions.

Birds can provide a useful indicator of ecological responses to climatic variation and change (Coppack & Both 2002, Cotton 2003), especially small-bodied songbirds (<20g) which experience significant physiological demands throughout their annual cycle (Berthold 1975).

Like many other taxa (Parmesan 2006), a diversity of responses to climate change has been observed in birds globally (Both et al. 2006, Møller et al. 2008). Understanding the effects of climatic conditions on bird populations is particularly complex due to differential effects across latitudes (Fontaine et al. 2009) and elevations.

Adaptive responses to short-term climatic variation and long-term climate change will partly depend on species' current levels of phenotypic plasticity (Bradshaw & Holsapfel 2006, Charmantier 2008). Species may exhibit phenological shifts in the timing of key life cycle

phases such as migration or nesting (Gordo 2007), distributional shifts (Sutherland 1998), or ecological shifts in habitat use or niche space (Kellermann *In Review*). The extent of this flexibility can be related to factors such as species' functional traits, or habitat breadth. These responses are poorly understood (Faaborg et al. 2010), particularly in arid regions (Skagen et al. 1997) which may experience drastic changes in response to climate (Scheffer et al. 2001) and where the magnitude of its effects on bird habitats may be incongruent with more temperate areas at higher latitudes (Fontaine et al. 2009) or ecologically equivalent higher elevations.

Ecologists have recognized for more than 50 years that vegetation communities partially drive the diversity, structure, distribution and abundance of bird communities (MacArthur and MacArthur 1961) as proximate factors, through habitat selection and likely as ultimate factors, through food availability, nest habitat, and predator protection (Rottenbury and Weins 1980). Long-term research in the Santa Rosa Mountains of southern California has shown and upslope change in the distribution of vegetation communities by ~65m in just 30 years (Kelly and Goulden 2008). In the nearby Colorado Desert and Peninsular Mountains, Black-throated Sparrow (*Amphispiza bilineata*) populations at low elevations have been experiencing complete nest failure in dry years while those at higher, moister elevation sites are having relatively successful breeding seasons, which could lead to elevational range shifts over time (Hargrove and Rottenbury 2011). However these shifts have not occurred over a 26 year survey period, suggesting that the range limits of some arid land species may already be determined by their physiological tolerances (Hargrove and Rotenberry 2011). While lower elevation bird species may be able to shift their distributions up slope, although possibly constrained by physiological and habitat tolerances, those species already inhabiting the highest elevation areas may be at

greatest risk (Sekercioglu et al. 2007), which has already occurred with extirpation of some isolated populations of Pika (*Ochotona princeps*) in the Great Basin (Beever et al. 2003). Despite these concerns, elevational distributions, seasonal movements, phenology and ecological tolerances remain poorly understood for many species, particularly in the mountains and deserts of America's arid southwest.

Southwest of the Colorado Plateau the land is dominated by arid ecosystems including the Sonoran and Chihuahuan Deserts, large relatively lowland regions interspersed with rugged mountains that can reach more than 3000m elevation. These mountains represent oases of vegetation communities similar to those of more temperate regions including oak woodlands and mixed-conifer forests. The deserts, grasslands, woodlands, and forests of the Madrean Archipelago of southeast Arizona, southwest New Mexico, and northern Mexico represent an ecological "crossroads" and a hotspot of biodiversity critical for conservation (Spector 2002); however, development and landuse change, altered disturbance regimes, along with climate change are affecting these unique ecosystems. Saguaro National Park in southeast Arizona encompasses 37,005 ha (91,442 acres) of Sonoran Desert, Madrean woodlands, and montane conifer forests and with adjoining the Rincon Mountain Wilderness managed by the Coronado National Forest, protect nearly all of the Rincon mountains, a large roadless area critical to conservation of regional biodiversity.

In 2007, The National Geographic Society began the Bioblitz campaign, a series of annual 24 hour events " in which teams of volunteer scientists, families, students, teachers, and other community members work together to find and identify as many species of plants, animals,

microbes, fungi, and other organisms as possible" (National Geographic 2012) within the boundaries of focal National Park. The 2011 Bioblitz took place at Saguaro National Park outside Tucson, Arizona during 21-22 October. As part of this program, National Geographic and the National Park Service provide support to graduate students to participate in the event. Recent research has shown the importance of long-term data sets in detecting distributional changes (Kelley and Goulden 2008, Hargrove and Rotenberry 2011). My goal was to use the data collected on birds during Bioblitz at Saguaro National Park to examine elevational ranges of bird species within the park and provide a baseline for future comparisons in studies of the impacts of climate change on bird populations in the park and in the Madrean Archipelago.

## **BIOBLITZ PARTICIPATION**

At least 65 people, plus a number of school and university groups, contributed bird observations during the Saguaro National Park Bioblitz during 21-22 October, 2011.

Participants who contributed to the avian component of the Bioblitz included professional scientists from state, federal, and academic institutions, undergraduate and graduate students from multiple universities, citizen scientists, and other members of the community across from a wide range of socioeconomic backgrounds and ages. Bioblitz participants recorded observed birds at more than 35 distinct locations throughout both the Rincon Mountain (Figure 1) and Tucson Mountain Districts (Figure 2) of the national park and across the large elevational range of vegetation communities and bird habitats that exist in the park.



**Figure 1. Locations where birds were recorded by participants in the Rincon Mountain district of Saguaro National Park, Arizona during the 2011 National Geographic Bioblitz, 21-22 October.**



**Figure 2. Locations where birds were recorded by participants in the Tucson Mountain district of Saguaro National Park, Arizona during the 2011 National Geographic Bioblitz, 21-22 October.**

## **METHODS**

Participants employed a range of observation methods to detect and record birds including transects, area searches, incidental observations, and audio playback of bird recordings.

Observers explored and utilized trails, washes, ridges, parking lots, and picnic areas and crossed open trail-less terrain to observe and document birds at over 35 distinct areas within the park (Figure 1). Observation locations ranged from lowland Sonoran Desert habitats of the Tucson Mountain District at less than 700 meters elevation (2296ft) to mixed conifer and ponderosa pine forests of the Saguaro Wilderness Area peaks in the Rincon Mountains District at more than 2500m (8200ft). Mean elevation across all observation locations was 1136m (3726ft).

I used Google Earth (2012) to plot all observation locations and derive coordinates and elevation. When participants observed birds over a large expanse such as using trails and roads to perform transect or area search surveys I used either the mid-way point or the center of the area as the representative location and elevation for those bird detections. Observers did not record the location of each individual bird detected.

## **RESULTS**

We detected 105 total bird species comprising 9 taxonomic orders (Table 1), across both park districts and the entire elevational gradient of habitats in Saguaro National Park. Some species were only detected in particular vegetation communities that occur within limited elevational bands, while others occurred across a wide range of habitats (Table 1). There were also distinct differences in the bird communities reported from the two park districts.

**Table 1. Bird species recorded within Saguaro National Park, Arizona 21-22 October, 2011 during the National Geographic Bioblitz. Mean, maximum, and minimum elevation, and elevation range (meters) are based on either the elevation of individual survey points or the center point of area searches or transects.**

| <b>Species</b>              | <b>Mean Elevation</b> | <b>Maximum elevation</b> | <b>Minimum elevation</b> | <b>Elevation range</b> |
|-----------------------------|-----------------------|--------------------------|--------------------------|------------------------|
| Acorn Woodpecker            | 2243                  | 2585                     | 1900                     | 685                    |
| American Goldfinch          | 940                   | 940                      | 940                      | 0                      |
| American Kestrel            | 798                   | 970                      | 686                      | 284                    |
| American Robin              | 2585                  | 2585                     | 2585                     | 0                      |
| Ana's Hummingbird           | 877                   | 1000                     | 792                      | 208                    |
| Arizona Woodpecker          | 2585                  | 2585                     | 2585                     | 0                      |
| Ash-throated Flycatcher     | 878                   | 970                      | 737                      | 233                    |
| Audubon's Warbler           | 1900                  | 1900                     | 1900                     | 0                      |
| Barn Owl                    | 2585                  | 2585                     | 2585                     | 0                      |
| Bewick's Wren               | 1243                  | 2585                     | 746                      | 1839                   |
| Black-chinned Hummingbird   | 785                   | 785                      | 785                      | 0                      |
| Black-chinned Sparrow       | 1030                  | 1030                     | 1030                     | 0                      |
| Black-Tailed Gnatcatcher    | 900                   | 1030                     | 737                      | 293                    |
| Black-throated Gray Warbler | 742                   | 746                      | 737                      | 9                      |
| Black-throated Sparrow      | 858                   | 1030                     | 686                      | 344                    |
| Black Phoebe                | 987                   | 1030                     | 944                      | 86                     |
| Blue-gray Gnatcatcher       | 935                   | 1030                     | 699                      | 331                    |
| Brewer's Sparrow            | 997                   | 1480                     | 699                      | 781                    |
| Bridled Titmouse            | 2048                  | 2585                     | 1480                     | 1105                   |
| Broad-billed Hummingbird    | 1000                  | 1000                     | 1000                     | 0                      |
| Brown-crested Flycatcher    | 1000                  | 1000                     | 1000                     | 0                      |
| Bushtit                     | 1850                  | 2585                     | 737                      | 1848                   |
| Cactus Wren                 | 846                   | 1030                     | 686                      | 344                    |
| Canyon Towhee               | 1103                  | 2585                     | 746                      | 1839                   |
| Canyon Wren                 | 1289                  | 1900                     | 746                      | 1154                   |
| Chipping Sparrow            | 1948                  | 2585                     | 1030                     | 1555                   |
| Common Raven                | 1080                  | 2585                     | 699                      | 1886                   |
| Cooper's Hawk               | 1224                  | 2585                     | 686                      | 1899                   |
| Curve-billed Thrasher       | 863                   | 1030                     | 686                      | 344                    |
| Dark-eyed Junco             | 2098                  | 2585                     | 1480                     | 1105                   |
| Dickcissel                  | 1000                  | 1000                     | 1000                     | 0                      |
| Elf Owl                     | 787                   | 787                      | 787                      | 0                      |
| Empidonax flycatcher        | 884                   | 1030                     | 737                      | 293                    |
| Eurasian Collared-Dove      | 737                   | 737                      | 737                      | 0                      |

| Species                  | Mean<br>Elevation | Maximum<br>elevation | Minimum<br>elevation | Elevation<br>range |
|--------------------------|-------------------|----------------------|----------------------|--------------------|
| Gambel's Quail           | 864               | 1000                 | 737                  | 263                |
| Gila Woodpecker          | 856               | 1030                 | 686                  | 344                |
| Gilded Flicker           | 868               | 1024                 | 714                  | 310                |
| Great-horned Owl         | 1193              | 2585                 | 714                  | 1871               |
| Greater Roadrunner       | 878               | 944                  | 746                  | 198                |
| Green-tailed Towhee      | 1000              | 1480                 | 833                  | 647                |
| Hairy Woodpecker         | 2238              | 2585                 | 1900                 | 685                |
| Hammond's Flycatcher     | 2585              | 2585                 | 2585                 | 0                  |
| Harris's Hawk            | 803               | 803                  | 803                  | 0                  |
| Hepatic Tanager          | 1900              | 1900                 | 1900                 | 0                  |
| Hermit Thrush            | 1228              | 1900                 | 746                  | 1154               |
| House Finch              | 1007              | 2585                 | 686                  | 1899               |
| House Wren               | 2585              | 2585                 | 2585                 | 0                  |
| Hutton's Vireo           | 2098              | 2585                 | 1480                 | 1105               |
| Inca Dove                | 699               | 699                  | 699                  | 0                  |
| Indigo Bunting           | 1030              | 1030                 | 1030                 | 0                  |
| Ladder-backed Woodpecker | 1297              | 2585                 | 803                  | 1782               |
| Lark Sparrow             | 926               | 1030                 | 803                  | 227                |
| Lazuli Bunting           | 970               | 970                  | 970                  | 0                  |
| Lesser Goldfinch         | 1137              | 2585                 | 844                  | 1741               |
| Lesser Nighthawk         | 803               | 803                  | 803                  | 0                  |
| Lincoln's Sparrow        | 1030              | 1030                 | 1030                 | 0                  |
| Loggerhead Shrike        | 963               | 1000                 | 944                  | 56                 |
| Mexican Jay              | 2048              | 2585                 | 1480                 | 1105               |
| Mountain Chickadee       | 2238              | 2585                 | 1900                 | 685                |
| Mourning Dove            | 1008              | 2585                 | 686                  | 1899               |
| Northern Cardinal        | 861               | 1030                 | 686                  | 344                |
| Northern Flicker         | 1089              | 2585                 | 686                  | 1899               |
| Northern Goshawk         | 2585              | 2585                 | 2585                 | 0                  |
| Northern Mockingbird     | 868               | 1030                 | 699                  | 331                |
| Northern Pygmy-Owl       | 2585              | 2585                 | 2585                 | 0                  |
| Olive Warbler            | 2064              | 2228                 | 1900                 | 328                |
| Orange-crowned Warbler   | 1000              | 1000                 | 1000                 | 0                  |
| Painted Redstart         | 1030              | 1030                 | 1030                 | 0                  |
| Phainopepla              | 884               | 1612                 | 686                  | 926                |
| Pine Siskin              | 2243              | 2585                 | 1900                 | 685                |
| Plumbeous Vireo          | 1900              | 1900                 | 1900                 | 0                  |
| Pygmy Nuthatch           | 2238              | 2585                 | 1900                 | 685                |

| Species                 | Mean Elevation | Maximum elevation | Minimum elevation | Elevation range |
|-------------------------|----------------|-------------------|-------------------|-----------------|
| Pyrrhuloxia             | 874            | 1030              | 737               | 293             |
| Red-breasted Nuthatch   | 2585           | 2585              | 2585              | 0               |
| Red-naped Sapsucker     | 2585           | 2585              | 2585              | 0               |
| Red-shafted Flicker     | 1869           | 2228              | 1480              | 748             |
| Red-Tailed Hawk         | 946            | 1612              | 686               | 926             |
| Rock Wren               | 981            | 2585              | 686               | 1899            |
| Ruby-crowned Kinglet    | 1487           | 2585              | 746               | 1839            |
| Rufous-crowned Sparrow  | 2585           | 2585              | 2585              | 0               |
| Rufous-winged Sparrow   | 930            | 1030              | 833               | 197             |
| Sage Thrasher           | 844            | 844               | 844               | 0               |
| Says Phoebe             | 848            | 1030              | 699               | 331             |
| Sharp-shinned Hawk      | 1793           | 2585              | 1000              | 1585            |
| Song Sparrow            | 1030           | 1030              | 1030              | 0               |
| Spotted Towhee          | 1646           | 2585              | 970               | 1615            |
| Stellar's Jay           | 2407           | 2585              | 2228              | 357             |
| Townsend's Solitaire    | 1900           | 1900              | 1900              | 0               |
| Townsend's Warbler      | 980            | 989               | 970               | 19              |
| Verdin                  | 841            | 1030              | 686               | 344             |
| Vesper Sparrow          | 940            | 940               | 940               | 0               |
| Western Flycatcher      | 970            | 970               | 970               | 0               |
| Western Bluebird        | 2238           | 2585              | 1900              | 685             |
| Western Flycatcher      | 1465           | 1900              | 1030              | 870             |
| Western Kingbird        | 905            | 905               | 905               | 0               |
| Western Meadowlark      | 737            | 737               | 737               | 0               |
| Western Screech-Owl     | 1200           | 1612              | 787               | 825             |
| Western Scrub-Jay       | 1778           | 2585              | 970               | 1615            |
| Whiskered Screech-Owl   | 2407           | 2585              | 2228              | 357             |
| White-breasted Nuthatch | 1845           | 2585              | 1030              | 1555            |
| White-crowned Sparrow   | 1191           | 2585              | 833               | 1752            |
| White-throated Swift    | 1696           | 2585              | 970               | 1615            |
| White-winged Dove       | 1030           | 1030              | 1030              | 0               |
| Yellow-eyed Junco       | 2238           | 2585              | 1900              | 685             |
| Yellow-rumped Warbler   | 1357           | 2585              | 746               | 1839            |

## Rincon Mountain District

Bioblitz participants recorded 95 bird species in the Rincon Mountain district, over 72% more than in the Tucson Mountain District. The Rincon Mountain district lies east of the city of Tucson, AZ and protects a large portion of the Rincon Mountains, one of the "Sky Island Mountains" of the Madrean Archipelago. The highest point in the Rincon District is Mica Mountain with an elevation of 2641m (8666ft); the far greater height of the mountains and subsequent diversity of bird habitats in this district, is undoubtedly the reason for the drastic difference in diversity between the two districts. Vegetation communities in the Rincon Mountain district include Sonoran Desert (Figure 3), grasslands, mesquite, oak, and pinyon-juniper woodlands (Figure 4), and pine-oak and mixed montane conifer forests (Figure 5). The most commonly reported species in the Rincon district were Rock Wren (*Salpinctes obsoletus*), Common Raven (*Corvus corax*), Curve-billed Thrasher (*Toxostoma curvirostrae*), Black-throated Sparrow (*Amphispiza bilineata*), and House Finch (*Carpodacus mexicanus*, Table 2).

## Tucson Mountain District

The Tucson Mountain district lies west of Tucson and includes a rugged area of low mountains primarily dominated by Sonoran Desert communities (Figure 3). The highest point in the Tucson district is Wasson Peak at an elevation of 1428m (4687ft). Bioblitz participants reported 55 bird species from this district with the most common species including Curve-billed Thrasher, Gila Woodpecker (*Melanerpes uropygialis*), Cactus Wren (*Campylorhynchus brunneicapillus*), Verdin (*Auriparus flaviceps*), and Rock Wren (Table 2). The lower diversity in this district compared to the Rincon Mountain District is primarily due to the differences in elevation and associated vegetation communities and bird habitats. However, the Tucson

Mountain district has also been surrounded by suburban development over the past 50 years and is rapidly losing connectivity with other large areas of native, undeveloped parts of the landscape. Future research should consider regional development, wildlife corridors, and buffer zones in conservation planning for this district.

**Table 2. Bird species reported from the Rincon Mountain and Tucson Mountain Districts of Saguaro National Park during the 2011 National Geographic Bioblitz.**

| Rincon Mountain District    | Tucson Mountain District    |
|-----------------------------|-----------------------------|
| Acorn Woodpecker            | American Kestrel            |
| American Goldfinch          | Ana's Hummingbird           |
| American Robin              | Ash-throated Flycatcher     |
| Ana's Hummingbird           | Bewick's Wren               |
| Arizona Woodpecker          | Black-chinned Hummingbird   |
| Ash-throated Flycatcher     | Black-Tailed Gnatcatcher    |
| Audubon's Warbler           | Black-throated Gray Warbler |
| Barn Owl                    | Black-throated Sparrow      |
| Bewick's Wren               | Blue-gray Gnatcatcher       |
| Black Phoebe                | Brewer's Sparrow            |
| Black-chinned Sparrow       | Bushtit                     |
| Black-Tailed Gnatcatcher    | Cactus Wren                 |
| Black-throated Sparrow      | Canyon Towhee               |
| Blue-gray Gnatcatcher       | Canyon Wren                 |
| Brewer's Sparrow            | Common Raven                |
| Bridled Titmouse            | Cooper's Hawk               |
| Broad-billed Hummingbird    | Curve-billed Thrasher       |
| Brown-crested Flycatcher    | Elf Owl                     |
| Bushtit                     | <i>Empidonax</i> flycatcher |
| Cactus Wren                 | Eurasian Collared-Dove      |
| Canyon Towhee               | Gambel's Quail              |
| Canyon Wren                 | Gila Woodpecker             |
| Chipping Sparrow            | Gilded Flicker              |
| Common Raven                | Greater Roadrunner          |
| Cooper's Hawk               | Great-horned Owl            |
| Curve-billed Thrasher       | Hermit Thrush               |
| Dark-eyed Junco             | House Finch                 |
| Dickcissel                  | Inca Dove                   |
| <i>Empidonax</i> flycatcher | Ladder-backed Woodpecker    |

| Rincon Mountain District | Tucson Mountain District |
|--------------------------|--------------------------|
| Gambel's Quail           | Lazuli Bunting           |
| Gila Woodpecker          | Lesser Goldfinch         |
| Gilded Flicker           | Mourning Dove            |
| Greater Roadrunner       | Northern Cardinal        |
| Great-horned Owl         | Northern Flicker         |
| Green-tailed Towhee      | Northern Mockingbird     |
| Hairy Woodpecker         | Phainopepla              |
| Hammond's Flycatcher     | Pyrrhuloxia              |
| Harris's Hawk            | Red-Tailed Hawk          |
| Hepatic Tanager          | Rock Wren                |
| Hermit Thrush            | Ruby-crowned Kinglet     |
| House Finch              | Rufous-winged Sparrow    |
| House Wren               | Says Phoebe              |
| Hutton's Vireo           | Spotted Towhee           |
| Indigo Bunting           | Townsend's Warbler       |
| Ladder-backed Woodpecker | Verdin                   |
| Lark Sparrow             | Western Flycatcher       |
| Lesser Goldfinch         | Western Kingbird         |
| Lesser Nighthawk         | Western Meadowlark       |
| Lincoln's Sparrow        | Western Screech-Owl      |
| Loggerhead Shrike        | White-crowned Sparrow    |
| Mexican Jay              | White-throated Swift     |
| Mountain Chickadee       | Yellow-rumped Warbler    |
| Mourning Dove            |                          |
| Northern Cardinal        |                          |
| Northern Flicker         |                          |
| Northern Goshawk         |                          |
| Northern Mockingbird     |                          |
| Northern Pygmy-Owl       |                          |
| Olive Warbler            |                          |
| Orange-crowned Warbler   |                          |
| Painted Redstart         |                          |
| Phainopepla              |                          |
| Pine Siskin              |                          |
| Plumbeous Vireo          |                          |
| Pygmy Nuthatch           |                          |
| Pyrrhuloxia              |                          |
| Red-breasted Nuthatch    |                          |
| Red-naped Sapsucker      |                          |

| Rincon Mountain District | Tucson Mountain District |
|--------------------------|--------------------------|
| Red-shafted Flicker      |                          |
| Red-Tailed Hawk          |                          |
| Rock Wren                |                          |
| Ruby-crowned Kinglet     |                          |
| Rufous-crowned Sparrow   |                          |
| Rufous-winged Sparrow    |                          |
| Sage Thrasher            |                          |
| Says Phoebe              |                          |
| Sharp-shinned Hawk       |                          |
| Song Sparrow             |                          |
| Spotted Towhee           |                          |
| Stellar's Jay            |                          |
| Townsend's Solitaire     |                          |
| Verdin                   |                          |
| Vesper Sparrow           |                          |
| Western Bluebird         |                          |
| Western Flycatcher       |                          |
| Western Screech-Owl      |                          |
| Western Scrub-Jay        |                          |
| Whiskered Screech-Owl    |                          |
| White-breasted Nuthatch  |                          |
| White-crowned Sparrow    |                          |
| White-throated Swift     |                          |
| White-winged Dove        |                          |
| Yellow-eyed Junco        |                          |
| Yellow-rumped Warbler    |                          |

## Sonoran Desert

Sonoran Desert habitats are characterized by a diversity of cactus and agave species, including the iconic saguaro (*Carnegiea gigantea*) as well as shrubs and small trees including jojoba (*Simmondsia chinensis*), mesquite (*Prosopis spp.*), and Palo Verde (*Parkinsonia spp.*, Figure 3). Bird species commonly reported by Bioblitz participants which are indicative of these habitats

include the Black-throated Sparrow, Curve-billed Thrasher, Cactus Wren, Gila Woodpecker, Gilded Flicker (*Colaptes chrysoides*), and Elf Owl (*Microthene whitneyi*).

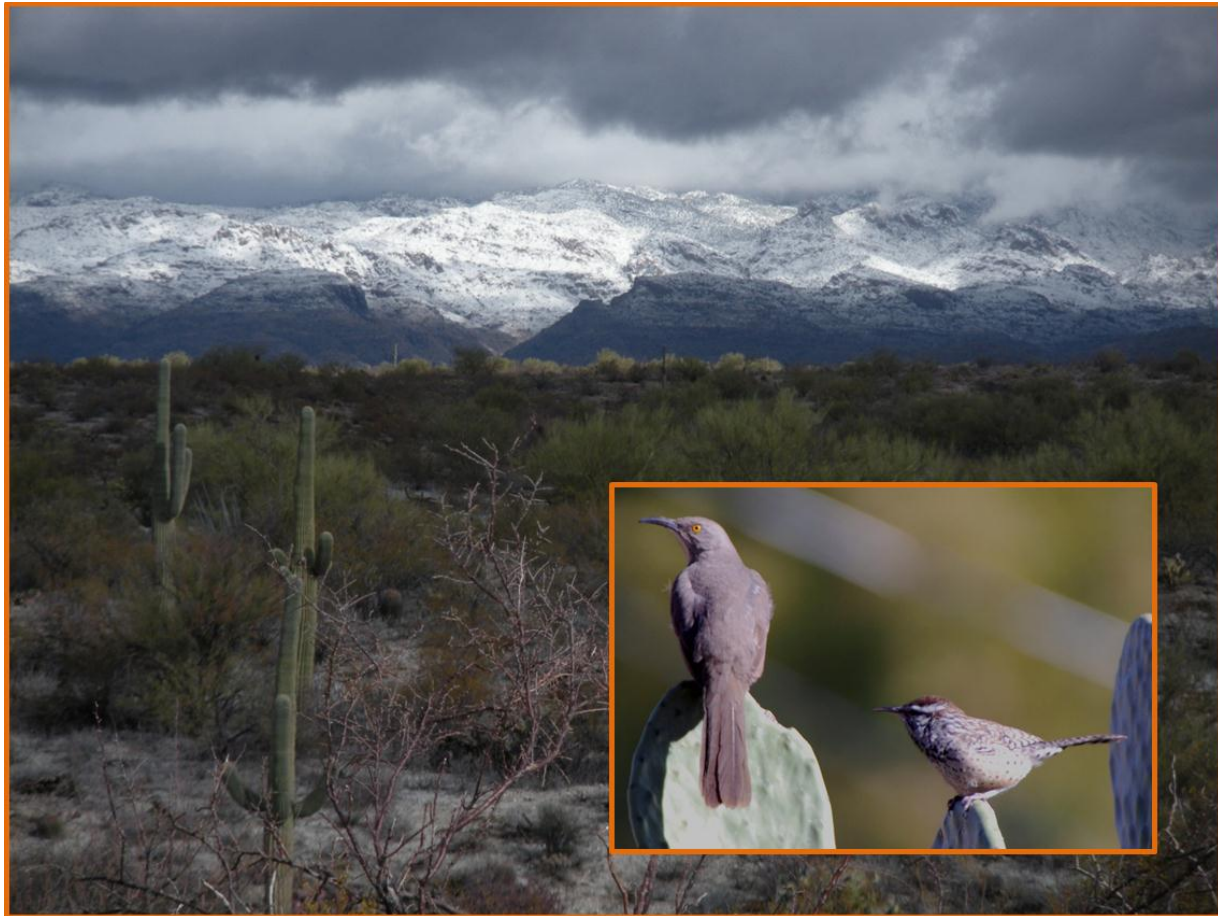


**Figure 3. Sonoran Desert vegetation communities dominate the lower elevations of Saguaro National Park. Common bird species reported from these habitats during the 2011 National Geographic Bioblitz included Curve-billed Thrasher and Cactus Wren (inset). Photos © Jherime L. Kellermann**

### **Mixed Grasslands, Mesquite, Oak, and Pinyon - Juniper Woodlands**

Intermediate elevations of Saguaro National Park between roughly 1000-1700m are comprised of a mixture of grasslands with, often encroaching, mesquite and shrubs at lower elevations graduating into evergreen oak woodlands (e.g. *Quercus arizonica* and *Q. emoryi*) with increasing amounts of pinyon pine (e.g. *Pinus cembroides*) and juniper species (primarily

*Juniperus deppeana*) with increasing elevation (Figure 4). Grasslands and mesquite and oak savannas can contain high sparrow diversity and a number of species were reported during the Bioblitz including Brewer's Sparrow (*Spizella breweri*), Chipping Sparrow (*Spizella passerine*), Lark Sparrow (*Chondestes grammacus*), White-crowned Sparrow (*Zonotrichia leucophrys*), Green-tailed Towhee (*Pipilo chlorurus*), Rufous-crowned Sparrow (*Aimophila ruficeps*), and Rufous-winged Sparrow (*Aimophila carpalis*). All but the last two of these sparrow species do not breed on southeast Arizona. Therefore these individuals, detected during the Bioblitz in late-October are either migrating south or are wintering in the area. Grasslands in this region are severely threatened by invasive species such as buffelgrass (*Pennisetum ciliare*), mesquite and shrubland encroachment, over grazing, and altered natural disturbance regimes, particularly wildfire.

Oak, pinyon, and juniper woodlands are only present in the Rincon Mountain District of Saguaro National Park and have several distinct species that were reported during the Bioblitz including Acorn (*Melanerpes formicivorus*) and Arizona (*Picoides arizonae*) Woodpeckers, Bridled Titmouse (*Baeolophus wollweberi*), White-breasted Nuthatch (*Sitta carolinensis*) and Black-throated Gray Warbler (*Setophaga nigrescens*).



**Figure 4.** Intermediate elevations in Saguaro National Park contain mixtures of grasslands, mesquite and shrub communities, and oak and pinyon-juniper savannahs and woodlands. This photo shows a gradient of these communities along the Miller Creek trail on the eastern slope of the Rincon Mountains. Breeding bird species indicative of these habitats that were reported during the Bioblitz include Black-throated Gray Warbler and Acorn Woodpecker (inset). *Photos © Jherime L. Kellermann*

## Montane Conifer

Pine-oak and mixed montane conifer forests only occur at the highest elevations of Saguaro National Park and the Madrean Sky Island Mountains (Figure 5). These forests are the only areas in the region that receive significant snowfall in the winter months of December-March. Some of the species indicative of these habitats that were reported during the 2011 Bioblitz include Hairy Woodpecker (*picoides villosus*), Stellar's (*Cyanocitta stelleri*) and Mexican (*Aphelocoma ultramarine*) Jays, Mountain Chickadee (*Poecile gambeli*), Painted Redstart

(*Myioborus pictus*), Olive Warbler (*Peucedramus taeniatus*), and Yellow-eyed Junco (*Junco phaeonotus*).



**Figure 5. Pine-oak and mixed montane conifer woodlands at Happy Valley and Rincon Peak (distance) in the Rincon Mountain District of Saguaro National Park. Bird species indicative of these habitats that were detected during the 2011 National Geographic Bioblitz include Painted Redstart and Mexican Jay (insets). Photos © Jherime L. Kellermann**

## **Range breadth**

While many species were restricted to the vegetation communities associated with particular elevational ranges described in the above sections, other species occurred across a wide range of elevations and habitats. Species with the largest elevational ranges included House Finch, Rock Wren, Cooper's Hawk (*Accipiter cooperii*), Great-horned Owl, and Mourning Dove (*Zenaida macroura*, Table 1). These species also have large geographic ranges which span much of North

America and therefore may have the greatest adaptive capacity for responding to the future climatic and ecological impacts associated with climate change.

## **Species residency**

We detected several Neotropical migratory species that do not breed in southern Arizona but only pass through as they travel between their more temperate northern breeding grounds and their wintering grounds in Mexico and Central and South America. These individuals were migrating late or over-wintering in the region and included Yellow-rumped Warbler (*Setophaga coronate*), Orange-crowned Warbler (*Oreothlypis celata*), Hammond's Flycatcher (*Empidonax hammondi*) and Ruby -crowned Kinglet (*Regulus calendula*). Two other Neotropical migratory species were detected that would be considered "vagrants" in our area and are rarely seen: Dickcissel (*Spiza americana*) and Indigo Bunting (*Passerina cyanea*).

The Rincon Mountains are within the breeding range of many Neotropical migratory bird species that winter in Latin America and have typically departed by late October. However, we did detect individuals of a few of these species, including Olive Warbler (*Peucedramus taeniatus*), Hepatic Tanager (*Piranga flava*), and Painted Redstart (*Myioborus pictus*). These species, especially Olive Warbler and Painted Redstart are associated with upper elevation habitats especially mixed conifer and pine-oak forests respectively.

Many year-round resident species are elevational migrants. Spotted Towhee (*Pipilo maculatus*), House Wren (*Troglodytes aedon*), and Bushtit (*Psaltiriparus minimus*) may all track food availability across adverse gradient throughout the year and avoiding cold winter temperatures at high elevations and hot summer conditions in the desert.

As unique as many bird species are to the Sonoran desert, many species are only encountered at highest elevations (typically >2000m) in Arizona and many of these were detected including Stellar's Jay (*Cyanocitta stelleri*), Mountain Chickadee (*Poecile gambeli*), and Red-breasted Nuthatch (*Sitta canadensis*). These species are common above the Colorado plateau and in the Rocky and Sierra Nevada Mountains.

## CONCLUSIONS

Saguaro National Park, the Tucson and Rincon Mountains, and the Madrean Archipelago are a hotspot of avian diversity. This diversity, in part, is due to the complex topography of the region and the resultant complexity of vegetation communities and thus bird habitats that exist over more than 2000m of elevation. Each distinct landcover type within Saguaro National Park, including Sonoran Desert, grassland, shrubland, oak and pinyon-juniper woodland, and pine-oak and mixed-conifer forest have distinct bird communities that are somewhat restricted to the elevational constraints of those habitats. There is also an assortment of bird species that are present in all of these habitats throughout the year, or migrate elevationally to exploit resources as they become seasonally available or as conditions exceed their physiological tolerances. The park also provides habitat for species which are year-round residents, wintering migrants that breed further north, Neotropical migrants that breed in the park and winter in Latin America, and *en route* migrants that select stopover habitats within the park as they migrate between southern wintering grounds and northern breeding areas.

In ways, all species are susceptible to the ecological impacts associated with climate change in the arid southwest, especially increasingly hotter and drier conditions (Seager et al. 2007).

However, those with the greatest range of flexibility may be least at risk as they have the greatest capacity to alter change in synchrony with environmental conditions. The species with the broadest elevational and ecological ranges such as House Finch, Bewick's Wren, and Mourning Dove may be the least at risk.

Meanwhile, those species that are specialists on unique components of Sonoran Desert habitats and those restricted to the isolated highest elevation montane conifer forest habitats, may experience the greatest ecological constraints. Although species such as Cactus Wren, Curve-billed Thrasher, Gilded Flicker, Elf Owl, and Black-throated Sparrow (Hargrove and Rotenberry 2011) already withstand hot and arid summer temperatures, they may be dependent on microclimates that are provided by the diverse ecological communities endemic to the Sonoran Desert. Increased temperatures and declining precipitation could bring catastrophic droughts to this region, resulting in major losses of structural and biological diversity through massive range contraction and local extirpations of vegetation, insects, herptofauna, mammals, and birds alike.

Likewise, there are many species in Saguaro National Park that are constrained to the highest elevation forests and many of these are further restricted in their geographic ranges in the United States to just southeast Arizona and southwest New Mexico. Species such as Olive Warbler, Hepatic Tanager (*Piranga flava*), Painted Redstart, Bridled Titmouse, Mexican Jay and Yellow-eyed Junco are limited to the upper elevation forests of the Rincon Mountains and other "Sky Islands" of the Madrean Archipelago. Like Pika in similar isolated high peaks of the Great Basin (Beever et al. 2003), already at the upper elevational limits available in the region and

constrained by physiological tolerances and habitat requirements associated with these montane forests, they may be unable to colonize new areas when these areas are lost and become locally extirpated. Although common in other parts of the US, species such as Stellar's Jay, Mountain Chickadee, Red-breasted Nuthatch, Hairy Woodpecker, and Pine Siskin, which can only be found at the tops of the tallest Sky Islands may also be lost from the region.

Migratory species with biogeographically expansive annual ranges may be particularly susceptible (Robinson et al. 2008), particularly those that span broad latitudinal gradients across which climate change impacts may not be consistent (Fontaine et al. 2009). Migratory birds may provide a useful indicator of ecological responses to climatic variation and change (Coppack & Both 2002, Cotton 2003), especially small-bodied songbirds (<20g) which the physiological demands of migrating long distances, often hundreds to thousands of kilometers, requires them to stop along the way to rest and feed (Berthold 1975). Like many other taxa (Parmesan 2006), a diversity of responses has been observed in migratory birds globally (Both et al. 2006, Møller et al. 2008). Understanding the effects of climatic conditions on migratory bird populations is particularly complex due to differential effects between breeding areas, wintering grounds (Gordo et al. 2005) and at stopover sites during migration (Marra et al. 2005, Barlein & Hüppop 2004). Because migration is a significant source of annual mortality in migratory songbirds (Sillett & Holmes 2005), environmental conditions at stopover sites can affect arrival time on breeding grounds (Elwood et al. 2010, Marra et al. 2005, Balbontin et al. 2009) and breeding success (Norris et al. 2004, Both et al. 2005), and spatiotemporal and ecological patterns of migratory bird movements are poorly understood for many regions and bird species, research at stopover sites during migration is a priority for avian conservation

(Moore et al. 1995, Donovan et al. 2002) and research (Faaborg et al. 2010). Species may exhibit phenological shifts in migration timing (Gordo 2007), distributional shifts in migration routes (Sutherland 1998), or ecological shifts in habitat use, or niche space (Kellermann *In Review*). The extent of this flexibility can be related to factors such as species' functional traits, habitat breadth, or migration distance (Moussus et al 2010). These responses are poorly understood (Faaborg et al. 2010), particularly in arid regions (Skagen et al. 1997) which may experience drastic changes in response to climate (Scheffer et al. 2001) and where the magnitude of its effects on stopover habitats may be incongruent with northern temperate breeding grounds (Fontaine et al. 2009) accentuating phenological mismatches. Therefore, migratory species already constrained by selection of limited habitat threatened by climate change such as Elf Owl, Olive Warbler, and Painted Redstart may be of the greatest conservation concern.

Birds supply a vast range of ecosystem services to natural as well as human communities (Wenny et al. 2011), therefore, not only would the loss of these species critically reduce biodiversity in one of the most biologically rich areas of North America, with cascading effects throughout the ecosystems, it would have significant effects on local humans as well. In addition to the thousands of people that live in the Sky Island region that take great joy and inspirations from songs, calls, and displays of local bird species, bird watching is a significance source of tourism worth millions of dollars a year (Sekercioglu 2002) to local businesses from hotels and restaurants, to bird guides and nature shops, to local nature reserves and parks

If climate change is sufficiently rapid, as had occurred in other regions (Allen and Breshears 1998 , Kelly and Goulden 2008, Hargrove and Rotenberry 2011), all member of vegetation communities may not be able to discover or reach suitable habitats resulting in reduced biodiversity and impoverished novel ecosystems. As scientists, concerned community members, and land managers developing adaptive strategies for the future ecological cascades of climate change impacts, informed by data collection will be critical for maintaining biodiversity in critical conservation regions such as Saguaro National Park and the Madrean Archipelago.

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