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BREEDING AND WINTERING BIRDS OF PETRIFIED FOREST NATIONAL PARK, ARIZONA

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ABSTRACT –This study provides information on the distribution, relative abundance, and habitat associations of breeding and wintering birds in the centennial year of Petrified Forest National Park, Arizona (2006). We present a summary of historical avian records, in concert with results of standardized surveys conducted during 1998 and 1999. In 1998 we established 10 transects in order to sample birds within the park. The numbers of count locations within each habitat type were established in proportion to the abundance of that habitat type within the park. Two survey methodologies (strip-transects and variable circular plots) were compared with data from 130 bird surveys during the breeding and winter seasons of 1998 and 1999. We counted a total of 2,812 birds representing 51 species. In addition, birds were captured with mist-nets in riparian habitat along the Puerco River during the 1998 breeding season; sixteen birds of 10 species were banded and breeding status confirmed for two species. Evidence of breeding was observed for 24 species, of which 13 are newly recorded as breeding in the park. This chapter also provides a monitoring protocol that will enable Petrified Forest National Park to track potential changes in bird population. The monitoring protocol will also better enable park managers to assess potential impacts of future managment activities on avian resources within Petrified Forest National Park.

Keywords: Petrified Forest, breeding birds, wintering birds, Arizona, Puerco River, national park

INTRODUCTION

PETRIFIED FOREST National Park provides several major habitat types for birds, including grassland, shrubland, pinyon-juniper and juniper woodlands, and cottonwood-dominated riparian woodland. As a national park, Petrified Forest represents a relatively stable area where management actions can be monitored and avian populations tracked over time. The park also represents one of the few ungrazed short-grass prairie locations remaining in the southwestern United States. This protected area can provide an excellent baseline reference point from which other avian studies throughout the southwest can be compared.

In the western United States, grasslands have experienced consistent and widespread avian population declines in the latter half of the past century (Peterjohn and Sauer, 1999), and because grasslands generally host few species of birds, relative to other habitat types (Wiens,1974), these declines are of even more concern to land managers. Threats to grassland habitats include but are not limited to land conversion, degradation by livestock, lack of fire, and overgrazing (West ,1984; Arnold et al., 1964; Gibson and Hurlbert, 1987). The effects of such changes on grassland avifauna are still incompletely understood. For example, grazing by livestock positively influences some nesting bird species, while others will be negatively influenced (Bock et al., 1984; Bock and Bock, 1988; Bock et al., 1992). In the Southwest there are few published studies of grassland birds, even fewer from northern Arizona (e.g., Monson, 1941; Beatty, 1978; LaRue, 1994; Rosenstock and van Riper, 2001), and no published studies on the avifauna of Petrified Forest National Park.

Riparian woodlands in the Southwest are extremely important to breeding birds; comprising less than one percent of the land area, riparian habitat supports greater than 75% of the breeding bird fauna (Johnson et al., 1977; Szaro, 1980). Destruction of riparian habitat has been identified as the leading cause of avian declines in the West (DeSante and George, 1994). Because riparian habitats are linear and limited in extent, they are susceptible to influence by outside land use practices, such as agriculture, grazing, or development (Tewksbury et al., 1998). In the Southwest, an additional conservation concern is invasion of riparian areas by non native tamarisk (i.e., salt-cedar). Tamarisk displaces native vegetation and creates expanses of monotypic vegetation, resulting in little species heterogeneity within habitats. Thus, although the riparian woodland of Petrified Forest is limited in extent, it is likely to be disproportionately valuable to birds within the park.

Petrified Forest National Park provides important avian habitats that, outside the park, are threatened by various human land-use practices. As a National Park, Petrified Forest provides an ideal location for a control site to compare results of management actions taken within and outside the park, and the relative impacts of those actions on avian communities. This study provides a baseline of information regarding the status of breeding and wintering birds 100 years after the establishment of Petrified Forest NP, and provides a

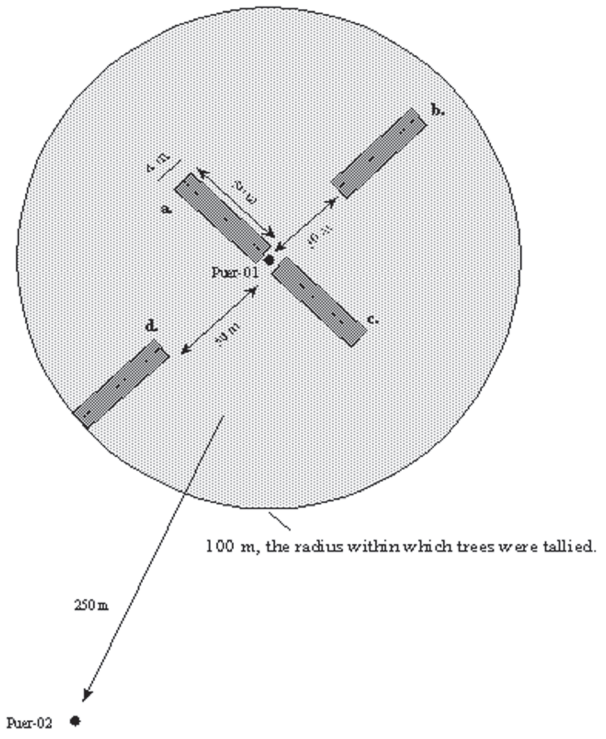

Figure *1*. Location of vegetation sampling plots relative to bird survey points along transects.

suggested future monitoring plan for bird populations within the park.

METHODS

From the Petrified Forest National Park vegetation map (Hansen and Thomas, this volume), we identified eight major vegetation habitat types within the park: 1) badland, 2) cliff edge (short shrub), 3) dune, 4) grassland, 5) juniper woodland, 6) shrubland, 7) dry wash, and 8) riparian woodland. Within the eight vegetation types we established 99 bird counting stations on 10 transects, sampling the eight habitats in proportion to their overall area of abundance within the park. Transects varied in length from 1750-3150 m, with 7-13 points located more than or about 250 m apart (Table 1). We oversampled riparian vegetation because of its significance for birds, stratifying our sampling along washes with ("riparian woodland") and without ("dry wash") cottonwood over story. Badlands were under sampled relative to their overall area because our initial observations revealed only a small number of birds utilizing this expansive habitat within the park. We sampled juniper-cliffrose woodland near Pintado Point, but did not sample the juniper-pinyon pine habitat of Chinde Mesa in the northern part of the park, because of the remoteness of the latter site.

Table *1*. Avian survey transects established in 1998 at Petrified Forest National Park, Holbrook, Arizona.

Transect Name	General transect locationa	Habitat typeb	No. survey points	Transect length (m)
BLUE	1 mi. up Blue Mesa road	grassland	10	2700
BOPI	Borrow Pit at mile 8	shrub, grassland	10	2250
DRYW	Dry Wash at mile 16.5	wash, dunes, grassland	8	1750
DUNE	West at the Teepees	dunes, badland	11	2500
FLAT	Northeast of the Flattops	grassland, tall shrub, dunes, badland	12	2750
NINE	Cliff edge above Ninemile wash	cliff-side, short-shrub	7	1850
PINT	Pintado Point	juniper woodland, badland	8	1750
PUER	Puerco River	riparian woodland	10	2400
RAIN	N of Rainbow Forest	grassland	10	2250
RT66	RT66 in the north end	shrub, grassland	13	3150

[a]Transect locations are described in more detail by Banks et al. (2003).
[b]Habitat types as designated from the 1964 Petrified Forest NP vegetation map. We refer to transects by the first habitat type listed, except for FLAT, which is termed mosaic.

Locations of all avian survey points were recorded in UTM coordinates with a PLGR Global Position System unit and exact locations of all transects were recorded (see Appendix I in Banks et al., 2003). Survey points were marked with rebar stakes and tags attached with transect name and point number. To facilitate the location of survey points for future monitoring efforts, detailed instructions for finding points along transects, using compass bearings and landmarks, as detailed in Banks et al. (2003).

We established vegetation sampling plots along all transects, to describe in more detail habitat types and to verify our *a priori* habitat delineations (Fig. 1). Two or four vegetation sampling plots were measured per bird survey point, with two plots measured if the vegetation appeared homogenous (plots a and b; Fig 1), and all four only if there was substantial vegetation variation (Table 2). We quantified percentages of different ground cover types, including bare ground, rock, grass, forbs, litter/brush, short-shrubs (less than 0.5 m in height) and shrubs. A shrub count was used to estimate shrub density, except at Puerco River, where shrub stems were counted. We measured shrub heights, sampling all shrubs in our plots that were at least 0.5 m in height, because we felt that these presented potential nest sites for bird species. At the Puerco River, we counted all trees within 100 m of our

Table *2*. Summary of vegetation characteristics in 1999, by habitat type and transect at Petrified Forest National Park, Holbrook, Arizona.

Habitat type	Transect Name	Percent ground cover				Shrubs / ha	Avg. shrub height(m)	Plots[a]
		Open	Grass	Shrub	Shortshrub			
grassland	BLUE	60	34	1	3	118	0.62	20
grassland	RAIN	52	42	1	3	274	0.69	28
shrub	RT66	42	42	4	6	526	0.79	36
shrub	BOPI	48	34	4	7	967	0.76	24
mosaic	FLAT	60	27	3	8	290	0.62	48
wash	DRYW	67	14	3	12	913	0.77	12
dunes, badland	DUNE	79	12	2	4	598	0.67	25
cliff-side, short-shrub	NINE	77	10	2	12	113	0.61	8
juniper woodland	PINT	76	2	12	10	1009	0.82	23
riparian woodland	PUER	57	10	25	1	unavailb	1.67	38

[a]Total number of vegetation plots sampled per transect.
[b]Distinct shrubs (of tamarisk and willow) were indistinguishable in riparian habitat, shrub density was very high, as indicated by shrub percentage of ground cover.

census points, according to four diameter at breast height (DBH) size classes. We then measured percent tree canopy cover, height, and species composition. At Pintado Point all shrubs (e.g., juniper, cliffrose), greater than or equal to 2 m in height were counted.

Historical Bird Records.— We compiled and analyzed all park historical records, including museum specimen records, park "Natural History Observation" cards, monthly bird observation notes, and correspondence regarding birds and bird specimens. In addition, we contacted 40 natural history museums throughout the country to locate bird specimens historically collected within Petrified Forest. We searched library databases for publications relating to birds in Petrified Forest, using the keywords: "Apache County, Arizona, aves, birds, national park, Navajo County, and Petrified Forest," in the following databases: Biological and Agricultural Index (1983-1999), Life Sciences (1982-1999), Trends in Ecology and Evolution (1939-1999), and Zoological Record (1993-1999).

Field Technique Comparisons.— We compared two bird survey methods: strip-transects and variable circular plot point-counts. Strip-transects were conducted by walking at a constant pace along the transect, recording all birds seen or heard from the transect (Emlen, 1971). Point-counts were conducted by walking to each point on a transect, and then after a one minute stationary period, counting all birds seen or heard from that point for five minutes (Reynolds et al., 1980). Paired t-tests were used to compare effectiveness of the two survey methods: each point count survey was paired with a strip transect survey conducted during the same week (1998) or on the same day (1999). We compared the number of birds and species counted per hour of survey effort.

A single observer conducted 3 sets of strip-transect surveys and 1 set of point-counts along each transect during the 1998 breeding season (2 June - 1 July; n= 40 surveys). In 1999, 3 sets of each survey type were completed by the same two observers (31 May - 26 June; n=60); each observer counted every transect. The order in which transects were counted and by whom was randomly assigned. Three sets of strip-transect surveys were conducted in winter 1998-1999 (2 December - 5 February; n=30). We tested for differences of birds counted among years and between observers, with paired tests for each transect. To account for any observer variances, we included the observer as a covariate for statistical tests of species richness or bird abundance among transects.

For all surveys, distances of birds from transect were measured with a laser range-finder. Breeding behaviors (e.g., carrying nesting material or food, feeding young) or nests found were noted during surveys. Because birds flying over a transect

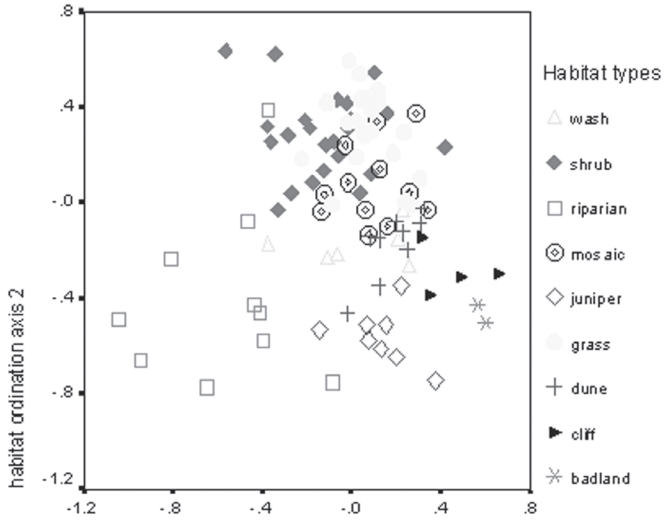

Figure 2. The vegetative characteristics of bird sampling points in Petrified Forest national Park, by habitat type. Distances amont point indicate their relative differences in terms of ground cover type and tree densities.

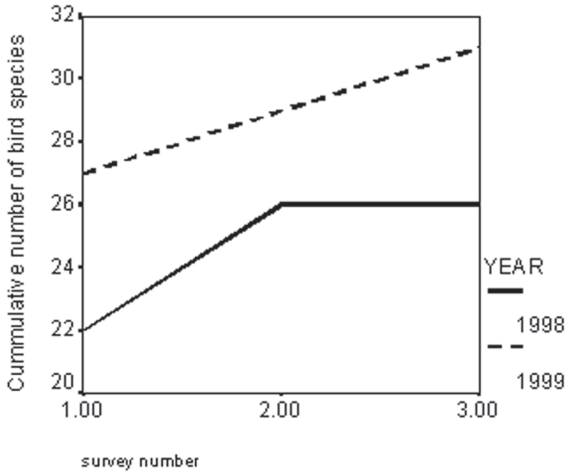

Figure 3. The number of bird species detected in the park increases with subsequent sets of surveys within a year. Data presented are from strip-transect surveys, all transects combined.

might not be associated with that specific habitat type, these birds (termed 'flyovers') were distinguished from other birds that were stationary within sight of the observer. Flyovers and birds seen at greater than 100 m from survey transects or count points were all entered into the bird check list information, but not included in the relative abundance analyses. We did not survey during periods of precipitation, or if wind speeds exceeded an average of 8 mph (5 km) or gusted at 10 mph (6 km). Wind speed and shaded temperature were taken with a digital anemometer held at arm's length in the direction of maximal wind, with average and maximal wind speeds recorded after 1-2 minutes. We found that a digital anemometer was superior to the ball-in-the-tube model, which performed erratically at speeds +/- 6 km/hr.

Table *3*. Tree tally, Puerco River and Pintado Point transects, June 1999. All trees within 100 m radius of each bird survey point were counted. Trees at Puerco were classified by diameter at breast height (cm). Trees at Pintado were considered any woody plant (i.e. shrubs at least 2 m in height). Blanks indicate that no trees of that type were present.

Point	Live Cottonwood				Dead Cottonwood[a]			Russian Olive	Juniper	Cliff Rose
	2-8	8-23	23-28	>38	8-23	23-28	>38	8-23[b]		
Puer-01			1			1				
Puer-02										
Puer-03		7	10	1	26	21	3	2		
Puer-04										
Puer-05		6	36	14	2		1			
Puer-06	5	27	8	1	2	2	3			
Puer-07	2	9	1							
Puer-08	170	15	1							
Puer-09	19	2								
Puer-10	15	17	4					1		
Pint-01										3
Pint-02										1
Pint-03										3
Pint-04										3
Pint-05									14	11
Pint-06									3	4
Pint-07									1	20
Pint-08									1	11

[a]Trees were burned in the management fire of July 1998. No trees smaller than 8 cm were burned.

[b]Russian Olive trees were only of this size class.

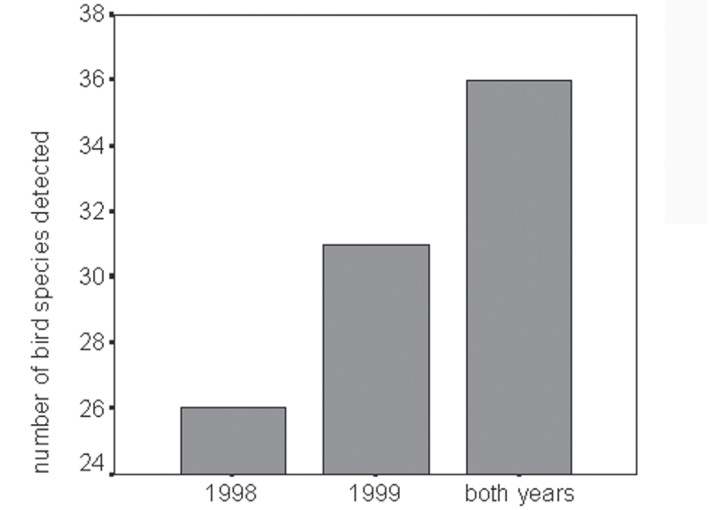

Figure 4. The total number of species detected by strip-transect surveys during the breeding season, for 1998, 1999, and the two years combined.

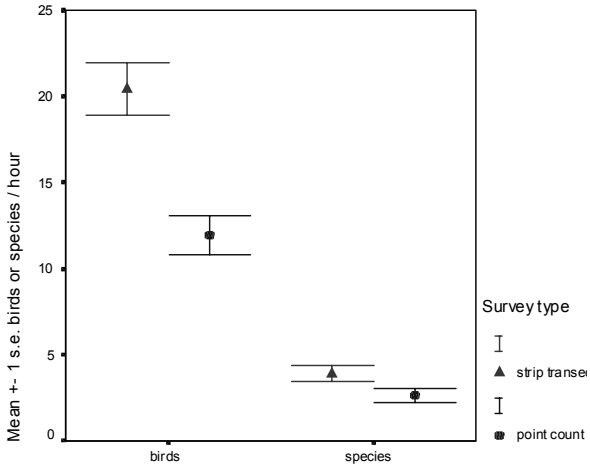

Figure 5. Numbers of birds and species detected per hour of survey effort, which includes travel time among points for point count surveys. Averages are from all transects surveyed during breeding season (n=60 for strip transects; n=40 for point counts).

To augment our strip-transect and point-count surveys in dense riparian vegetation along the Puerco River, we captured birds using mist-nets on five days in June 1998, using four to six nets per day, for a total of 137 mist-net hours. We banded birds with USFWS metal bands, took standard morphological measurements, and examined birds for evidence of breeding activity (cloacal protuberance or brood patch).

ANALYSES

To determine if birds responded uniquely to the eight vegetation habitats that we had designated *a priori* within the park, we used a multivariate ordination procedure on avian relative abundance data. Ordination reduces multiple, correlated variables (e.g., percent grass cover and percent bare ground) to a few axes, allowing one to better examine differences and similarities among sampling points. We used percent ground cover data and number of trees to ordinate survey points by vegetative characteristics using non-metric multi-dimensional scaling (MDS) program DECODA (Minchin, 1993). Following ordination, we tested whether groups of points within different habitat types were distinct with an analysis of similarities (Clarke, 1993; program ANOSIM, Minchin, 1993). ANOSIM R values will vary from 0 (no difference) to 1 (maximal difference), and herein are reported as significant at an á<.05 after sequential Bonferroni correction for multiple tests (Rice, 1989). We excluded the cliff-side transect (NINE) from vegetation analyses because this transect characterized a topographic feature rather than a true vegetation type.

Analysis of Variance (ANOVA) was used to determine if numbers of birds and species varied among habitat types; post-hoc comparisons among habitats were t-tests with Bonferroni corrections for multiple testing. Pearson correlation was utilized to determine if species abundances were correlated with specific habitat characteristics. To determine if bird community composition differed among habitat types, we ordinated all bird detections from both years of strip-transect surveys, using MDS. Then we used ANOSIM to determine if avian community composition differed among habitat types. On all analyses statistical significance was accepted when $p < 0.05$.

RESULTS

Study Areas

Vegetation measurements generally corroborated our *a priori* habitat designations (Table 2). Multivariate ordination of ground cover types and numbers of trees (Fig. 2) indicated that the two grass transects (BLUE and RAIN) were very similar to one another (ANOSIM R=.1124), as were the two shrub transects (RT66 and BOPI; R=.0435). In addition, the dry wash (DRYW), grass-dune-shrub mosaic (FLAT), and dune habitats were not distinguishable from each other or from the grass and shrub transects. An ordination based on shrub species composition yielded similar results, with only the riparian and juniper woodlands as distinct habitat types from the grass-shrub complex. Shrub

heights varied significantly among habitats (ANOVA F=18.177, p<.001), with shrubs significantly taller at the Puerco River site (Bonferroni post-hoc test p<.001); otherwise average shrub height did not vary among transects (Bonferroni post-hoc test; p>.10). At Pintado Point, we found 1 to 25 juniper or cliffrose shrubs per survey point; along Puerco River, the number of cottonwoods varied from zero to 186 per point (Table 3). In riparian habitat at Puerco River, canopy cover varied from zero to 27%, indicating a very open forest structure (Table 4). Cottonwood was the dominant canopy type at four points, tamarisk at two, and willow was co-dominant with tamarisk or cottonwood at two points. Tamarisk and willow averaged 2-3 m in height while cottonwood averaged 4-10 m tall.

Bird Surveys

Historical Bird Records.— We found no published papers regarding birds in Petrified Forest National Park. Several unpublished reports and checklists were found in the National Park Service bibliographic database. Our museum search yielded responses from 31 museums indicating only two museums with specimens collected from Petrified Forest. Six specimens are held in the Museum of Southwestern Biology at the University of New Mexico, and 131 specimens representing 68 species are contained within the Petrified Forest National Park Museum. Park "Natural History Field Observation" cards of bird sightings totaled 900 observations of 187 species (see summary in Banks et al., 2003).

Observer Differences.— We were able to combine data from both years of this study, because neither numbers of birds or species counted differed between observer or year (t=-1.584, 0.243, p=0.148, 0.813, respectively). The two observers did not differ in their average walking rates during strip transect surveys (1.67 km/hr vs. 1.79 km/hr; range= 1.07 - 2.27; ANOVA F=1.61, p =0.21). Species lists differed little between observers (30 vs. 29 species), with 14 of the 15 most abundant species shared. The numbers of birds counted did not differ between observers (t=-0.968, p=0.340), nor did estimated densities of Horned Larks from point-counts (D=.411, s.e.=.065 vs. D=.403, s.e.= .093). The only difference was that one observer counted more Horned Larks per strip-transect survey, while the other observer counted more species per point during point-count surveys (t=-2.515, p=0.033).

Field Survey Results.— In 1998 and 1999 we counted a total of 2,812 birds, representing 51 species. Horned Larks were the most frequently detected bird (49% of all detections). The next most numerous birds were Black-throated Sparrows, Rock Wrens, and Meadowlarks, comprising 9%, 7%, and 5% of all detections, respectively. Relative abundances of species among

Table *4*. Canopy and shrub measurements made in June 1999 for Riparian Woodland along the Puerco River transect, Petrified Forest National Park, Holbrook, Arizona.

Point	Shrubs						Trees		
	% shrub cover		# stems		dominant species	avg ht (m)	canopy cover %	dominant species[a]	avg canopy ht (m)[b]
	native	tamarisk	native	tamarisk					
1	71	29	112	> 250	unavail.	1.1	27	tamarisk	5 (8.5)
2	39	61	120	> 450	tamarisk	2.2	0	tamarisk	4.5
3	27	73	> 342	> 800	tamarisk	1.8	31	cottonwood	10
4	58	42	> 589	> 328	willow	1.7	0	n/a	unavail.
5	96	4	94	0	rabbitbrush	1.1	26	cottonwood	17.5
6	84	16	357	35	willow	1.1	3	cottonwood[c]	8
7	54	46	664	> 277	willow	1.6	6	tamarisk	-8
8	74	26	> 606	244	willow	2.9	4	cottonwood	4
9	79	21	> 863	> 338	willow	1.8	5	willow / tamarisk[d]	unavail.
10	41	59	> 279	> 275	willow/	1.3	23	cottonwood / willow[e]	10

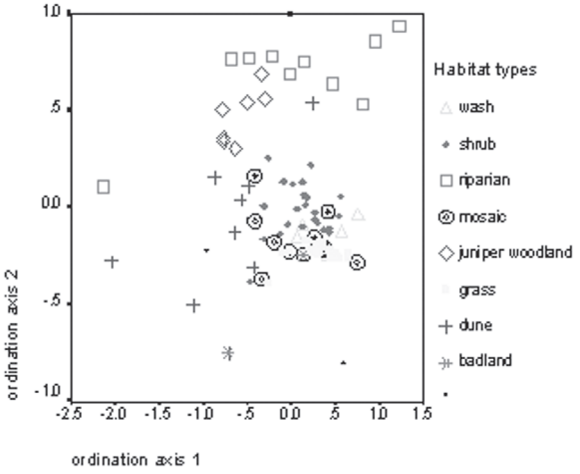

Figure 6. Bird communities according to habitat type at Petrified Forest national Park. Arizona. Points are the results of ordinating the abundances of thirty two species of birds detected during point-counts in 1995 and 1996 throughout Petrified Forest National Park. Superimposed on the plot are habitat variables that explain significant variation in the bird communities, illustrated as lines radiating from the center of the plot; the habitat mearsure increases in the direction of the arrow.

all seasons surveyed in the park are provided in Table 3. The cumulative number of detected bird species increased with each consecutive survey (Fig. 3). Some species were detected in one year and not the other, so that the total number of species seen over the 2-pooled years was substantially higher than any single year (Fig. 4).

Method Differences.— The numbers of birds and species detected between our two survey types had large differences (Fig. 5). If we consider the numbers of birds detected per hour of effort, more individuals ($t=6.381$, $p<0.001$) and more species ($t=5.80$, $p=<0.001$) were found using strip-transect surveys. However, if we consider only the time spent counting birds, (excluding time walking among points), more birds ($t=3.766$, $p=.004$) and more species ($t=-4.806$, $p<.001$) were counted per hour with point-counts.

Seasonal Differences.— Abundance and species composition of birds varied greatly between winter and breeding seasons (Table 6, Table 7). The summer season is much more important to birds at Petrified Forest NP as demonstrated by only 18 species detected in winter, in contrast to 43 during the summer breeding season. Only 12% of all bird observations were made during winter, and abundances within species were reduced during the winter surveys when compared to numbers counted during the breeding season. For instance, Horned Larks were less than half as abundant in winter when compared to summer.

The relative abundance of different bird species during breeding season (Table 6) are similar to those for both seasons combined (Table 3). During winter surveys, Horned Larks were also most abundant throughout the park, comprising 50% of detections (Table 7); however, the next most abundant species were Bushtits and Sage Sparrows, two of seven species found only in winter. Some species found in both seasons were much less abundant in winter (e.g., Meadowlarks, Rock Wren), others were about equally abundant (e.g., Red-shafted Flicker), and only the Scaled Quail showed a slight trend for higher winter abundance.

Table 5. Relative abundance of all bird species detected in Petrified Forest National Park, from all surveys during 1998 and 1999. Information is from 9 count points on 10 transects, breeding and winter seasons, presented by individual year and with the two years combined.

Species[a]	No. of Counted Individuals	Relative abundance	No. transects[b]
Horned Lark	1370	1.00	9
Black-throated Sparrow	257	0.19	8
Rock Wren	197	0.14	6
Meadowlarks[c]	142	0.10	9
Cliff Swallow	112	0.08	2
Northern Mockingbird	80	0.06	5
Says Phoebe	71	0.05	9
Bushtit	65	0.05	2
Scaled Quail	55	0.04	6
House Finch	54	0.04	3
Mourning Dove	52	0.04	5
Brown-headed Cowbird	48	0.04	9
Loggerhead Shrike	44	0.03	9
Ash-throated Flycatcher	42	0.03	4
Common Raven	34	0.02	7
Sage Sparrow	28	0.02	5
Red-shafted Flicker	19	0.01	1
Western Kingbird	19	0.01	1
Common Nighthawk	18	0.01	3
Oregon Junco	18	0.01	1
Bullock Oriole	12	0.01	1
Sage Thrasher	10	0.01	2
Western Wood-Peewee	8	0.01	2
Blue Grosbeak	8	0.01	1
American Kestrel	7	0.01	4
Lark Sparrow	7	0.01	2
Mountain Bluebird	5	0	2
Killdeer	5	0	1
European Starling	4	0	1
Long-eared Owl	4	0	1
Western Tanager	4	0	1
Brewers Sparrow	3	0	1
Blue-gray Gnatcatcher	2	0	1
Bewick's Wren	2	0	1
Lucy's Warbler	2	0	1
Prairie Falcon	2	0	1
Solitary Vireo	2	0	1

[a]An additional 14 species were detected on only one survey each, yielding a relative abundance of less than one percent: Black-headed Grosbeak, Brewer's Sparrow, Burrowing Owl, Chipping Sparrow, Cooper's Hawk, Lesser Goldfinch, Merlin, Nashville Warbler, Olive-sided Flycatcher, Red-tailed Hawk, Western Scrub-Jay, Warbling Vireo, White-crowned Sparrow, and Wilson's Warbler.

[b]Number of different transects on which this species was observed.

[c]Eastern Meadowlarks and Western Meadowlarks were combined. In 1998, the two species of Meadowlarks were not consistently distinguished; 69 were sighted on 9 transects. In 1999, greater familiarity with the species allowed us to count them separately: 18 Western Meadowlarks were observed on 4 transects, and 55 Eastern Meadowlarks were seen on 6 transects.

Table *6*. Relative abundance of bird species in Petrified Forest National Park, Holbrook, Arizona, during breeding season. Data are from all surveys, at 99 count points on 10 transects, during 1998 and 1999 combined.

Species[a]	No. of Counted Individuals	Relative abundance	No. transects[b]
Horned Lark	1208	1	9
Black-throated Sparrow	257	0.21	8
Rock Wren	193	0.16	6
Meadowlarks	139	0.12	9
Cliff Swallow	112	0.08	2
Northern Mockingbird	80	0.07	5
Say's Phoebe	70	0.06	8
House Finch	53	0.04	3
Mourning Dove	52	0.04	5
Brown-headed Cowbird	48	0.04	9
Ash-throated Flycatcher	42	0.03	4
Loggerhead Shrike	40	0.03	8
Scaled Quail	36	0.03	6
Common Raven	31	0.03	6
Western Kingbird	19	0.02	1
Common Nighthawk	18	0.01	3
Red-shafted Flicker	14	0.01	1
Bullock's Oriole	12	0.01	1
Blue Grosbeak	8	0.01	1
Sage Thrasher	8	0.01	1
Western Wood-Peewee	8	0.01	2
American Kestrel	7	0.01	4
Lark Sparrow	7	0.01	2
Killdeer	5	0	1
European Starling	4	0	1
Western Tanager	4	0	1
Brewer's Sparrow	3	0	1
Lucy's Warbler	2	0	1
Prairie Falcon	2	0	1
Solitary Vireo	2	0	1

[a]13 additional species were detected on only one survey each, yielding a relative abundance of two percent: Black-headed Grosbeak, Blue-gray Gnatcatcher, Burrowing Owl, Chipping Sparrow, Cooper's Hawk, Lesser Goldfinch, Nashville Warbler, Olive-sided Flycatcher, Red-tailed Hawk, Western Scrub-Jay, Warbling Vireo, White-crowned Sparrow, and Wilson's Warbler.

[b]Number of different transects on which this species was observed.

Habitat Differences.– The numbers of birds counted varied significantly among habitat types during the breeding season with both point counts ($F=3.64$, $p=.005$) and strip-transects ($F=3.03$; $p<.009$). The numbers of species counted also varied significantly among habitat types during the breeding season with point counts ($F=12.21$, $p<.001$) and strip-transects ($F=13.05$; $p<.001$). More species were found in riparian woodland than all other habitat types, except juniper woodland (Bonferroni post-hoc test $p<.05$). More birds were detected in grass habitats than in dune, wash or cliff (Bonferroni post-hoc test $p<.05$). During winter, habitats differed greatly in the numbers and species of birds using them. Of the 18 species detected during winter surveys, only one was detected in juniper woodland, whereas 15 were present in riparian woodland.

Our ordination results suggest that bird communities are distinct among dune, cliff-side, juniper woodland, riparian woodland, and the other grouped habitats (Fig. 6; ANOSIM $R>.268$). Bird communities in the grass, shrub, mosaic, and wash habitats were not distinguishable (ANOSIM $R<.167$). In this grass-shrub habitat group, Horned Larks were most abundant, and number of species varied from 4 to 12 per transect (Table 8). Numbers of species tended to increase with increased numbers of shrubs. In the cliff-side and dune habitats, Rock Wrens were most abundant (Table 9). It should be noted that Rock Wrens rarely used dune vegetation, but rather were abundant in the rocky canyon to the north of the

Table *7*. Relative abundance of bird species in Petrified Forest National Park, Holbrook, Arizona, during the winter non-breeding season. Data are from all surveys, at 99 count points on 10 transects, during 1998 and 1999 combined.

Species[a]	No. of Counted Individuals	Relative abundance	No. transects[b]
Horned Lark	162	1	9
Bushtit	65	0.4	2
Sage Sparrow	28	0.17	5
Scaled Quail	19	0.12	1
Oregon Junco	18	0.11	1
Mountain Bluebird	5	0.03	2
Red-shafted Flicker	5	0.03	1
Long-eared Owl	4	0.02	1
Loggerhead Shrike	4	0.02	4
Rock Wren	4	0.02	2
Common Raven	3	0.02	3
Meadowlarks	3	0.02	2
Bewick's Wren	2	0.01	1
Sage Thrasher	2	0.01	2

[a]The following four additional species were detected on only one survey each, yielding a relative abundance of one percent: Blue-gray Gnatcatcher, House Finch, Merlin, and Say's Phoebe.

[b]Number of different transects on which this species was observed.

Table *8*. Bird species relative abundances in grass-shrub habitats at Petrified Forest National Park, Holbrook, Arizona, during 1998 and 1999.

Habitat type:	Shrub		Mosaic	Wash	Grass	
Transect name:	RT66	BOPI	FLAT	DRYW	RAIN	BLUE
Horned Lark	1.0 (10)[a]	1.0 (10)	1.0 (10)	1.0 (10)	1.0 (10)	1.0 (10)
Meadowlarks	.31 (9)	.12 (6)	.08 (7)	.14 (5)	.02 (6)	.08 (8)
Brown-headed Cowbird	.11 (7)	.06 (4)	.01 (2)	.02 (2)	<.01 (1)	.01 (2)
Say's Phoebe	.04 (5)	.02 (2)	.03 (6)	.05 (3)	<.01 (1)	.01 (2)
Loggerhead Shrike	.01 (1)	.03 (3)	.00 (1)	.11 (5)	0.02 (3)	
Black-throated Sparrow	.25 (10)	.70 (10)	.14 (8)	.25 (9)		
Scaled Quail	.08 (7)	.07 (6)	.01 (2)	.08 (4)		

[a]The number of surveys (out of 10) during which the species was detected on this transect.

DUNE transect, which we sampled when walking along the crest of the dune. In juniper woodland, Black-throated Sparrows were the most abundant of 13 detected species (Table 10). In the riparian woodland along the Puerco River, we detected 37 species; Cliff Swallows were the most numerous, nesting colonially under the Puerco Bridge (Table 11).

We found that the three most abundant bird species in the park had very different breeding habitat preferences. Horned Lark abundance varied significantly among habitat types ($F=21.618$, $p<.001$), from an absence of birds in the Pintado Point juniper woodland, to an average of 79 individuals per km^2 in the Rainbow Forest grassland. Horned Larks were positively correlated with percentage of grass cover ($r=0.788$, $p=0.007$) and negatively correlated with shrub/half-shrub cover ($r=-0.747$, $p=0.013$); grass cover and shrub/half-shrub cover were inversely correlated ($r=-0.703$, $p=.023$). The second most abundant species, Black-throated Sparrows, varied among habitats ($F=6.181$, $p<0.001$) and were positively correlated with shrub density ($r=.860$, $p=.003$). More Black-throated Sparrows were found in shrub and juniper woodland habitats than in grassland or riparian woodland, where they were essentially absent ($t=s>1.46$; $p=s<.014$). The third most abundant species, Rock Wrens, varied among habitats ($F=27.025$, $p<0.001$) and was positively correlated with the amount of open ground ($r=0.663$, $p=0.037$). More Rock Wrens were present in cliff-side habitat than in any other habitat ($t=s>3.14$; $p=s<.001$).

Mist-netting.— When mist-netting in 1998, we captured 19 individuals of 11 species, including a MacGillivary's Warbler, the only one detected in the park in 1998 (Table 12). We found evidence of breeding, in the form of brood patches or cloacal protuberances, for four species, with two (Ash-throated Flycatchers and Blue Grosbeaks) not previously known to have bred in the park.

Breeding Evidence.— We found nests of 17 species and other evidence of breeding for 7 additional species (Table 13). Of the 24 species for which we detected breeding, 13 were not known to have previously bred in the park.

Table *9*. Bird species relative abundances at Petrified Forest National Park, Holbrook, Arizona, in cliff-side short-shrub and dune habitats, during 1998 and 1999 breeding seasons.

Habitat type:	Cliffside, short-shrub	Dune
Transect name:	NINE	DUNE
Rock Wren	1.0 (10)[a]	1.00 (9)
Horned Lark	0.57 (10)	0.95 (8)
Cliff Swallow	0.52 (6)	
Say's Phoebe	0.22 (7)	0.64(9)
Black-throated Sparrow	0.01 (1)	0.51 (8)
Loggerhead Shrike		0.31 (5)
Common Raven	0.05 (3)	0.10 (1)
Meadowlarks	0.03 (3)	0.05 (1)
Mourning Dove	0.08 (5)	0.05 (2)
Northern Mockingbird		0.03 (1)
Common Nighthawk	0.14 (3)	
American Kestrel	0.03 (3)	
Ash-throated Flycatcher	0.02 (1)	
Brown-headed Cowbird	0.01 (1)	
Scaled Quail	0.01 (1)	
Total no. of species:	13	9

[a]The number of surveys (out of 10) during which the species was detected on this transect.

DISCUSSION

Study Area Differences

We found that several habitats in the park differed distinctively in vegetative characteristics. Riparian woodland, as represented at our Puerco River study site, and juniper woodland, sampled near Pintado Point, were distinctively different from shrub and grass habitats throughout the rest of the park. The greater tree densities of the riparian and juniper woodlands is what primarily differentiated these transects. The

Table *10*. Bird species relative abundances at Petrified Forest National Park, Holbrook, Arizona, in juniper woodland habitat at Pintado Point, during 1998 and 1999 breeding seasons.

Species	Relative abundance	No. surveys
Black-throated Sparrow	1	10
Rock Wren	0.58	5
Northern Mockingbird	0.35	9
Ash-throated Flycatcher	0.19	5
Brown-headed Cowbird	0.15	6
Mourning Dove	0.13	4
Lark Sparrow	0.1	5
Loggerhead Shrike	0.08	4
Common Nighthawk	0.06	2
Scaled Quail	0.06	2
Prairie Falcon	0.04	1
Western Wood-Peewee	0.04	2
House Finch	0.02	1
Total no. of species:	13	

Table *11*. Bird species relative abundances at Petrified Forest National Park, Holbrook, Arizona, in riparian woodland habitat at Puerco River, during the 1998 and 1999 breeding seasons.

Species	Relative abundance	No. surveys
Cliff Swallow	1	6
Northern Mockingbird	0.85	9
House Finch	0.78	9
Mourning Dove	0.52	7
Ash-throated Flycatcher	0.46	10
Western Kingbird	0.29	6
Common Raven	0.22	6
Red-shafted Flicker	0.22	7
Bullock's Oriole	0.18	7
Brown-headed Cowbird	0.12	7
Blue Grosbeak	0.12	3
Meadowlarks	0.11	5
Western Wood-Peewee	0.09	2
Killdeer	0.08	4
Black-throated Sparrow	0.06	3
European Starling	0.06	2
Rock Wren	0.06	3
Western Tanager	0.06	2
American Kestrel	0.03	2
Common Nighthawk	0.03	1
Horned Lark	0.03	2
Lark Sparrow	0.03	2
Loggerhead Shrike	0.03	2
Lucy's Warbler	0.03	1
Solitary Vireo	0.03	2
Blue-gray Gnatcatcher	0.02	1
Black-headed Grosbeak	0.02	1
Chipping Sparrow	0.02	1
Cooper's Hawk	0.02	1
Lesser Goldfinch	0.02	1
Nashville Warbler	0.02	1
Olive-sided Flycatcher	0.02	1
Red-tailed Hawk	0.02	1
Western Scrub-Jay	0.02	1
Warbling Vireo	0.02	1
White-crowned Sparrow	0.02	1
Wilson's Warbler	0.02	1
total no. of species:	37	

remaining habitat types that we initially identified as grassland, shrubland, dry wash, and dune habitats, were not statistically distinguishable in terms of ground cover types or shrub species composition. The density of shrubs varied continuously among transects, so that while some transects were dominated more by grass and others by shrubs, there were no clear dividing points among grass or shrub habitats within the park.

Additions to our knowledge of the park's avifauna.¯ We documented 13 additional bird species that now known to breed in the park, one being the Eastern Meadowlark (*Sturnella magna*). In the general environs of Petrified Forest, Eastern Meadowlarks coexist with Western Meadowlarks (*Sturnella neglecta*), but both are similar looking species. These two species are best distinguished in the field by song, but identification can be difficult because males may sing songs that are typical of both species (Lanyon, 1994). In addition, the two species can form interspecific pairs (Lanyon, 1995). The lack of previous Eastern Meadowlark records could indicate that the species was previously present but not separately recognized, or that they have recently expanded their range into the park. Data from the Arizona Breeding Bird Atlas suggest that the latter scenario may indeed be the case, and that the species has recently increased in abundance throughout the park. In 1993 few Eastern Meadowlarks were detected relative to Westerns on survey plots bordering the park, while in 1999 Eastern were far more common than Western Meadowlarks on the same plots. Our 1998-1999 formal surveys indicate that at present, nearly three times as many Eastern- as Western Meadowlarks occur in the park. It will be informative to track relative abundances of these two species over time. In addition, the park provides an ideal site for the study of habitat partitioning and hybridization among these sibling species.

The Yellow-billed Cuckoo and the Canyon Wren have been previously recorded in the park, but we did not record either species during our study, and visual sightings have not been made in the park for the past 15 years. The historic status of the Canyon Wren in the park is not well documented, and previously observed birds may have been vagrants. However, the Yellow-billed Cuckoo bred for numerous years during the 1970s in the Puerco River riparian area, so the disappearance of this species represents a loss of a former resident bird. Yellow-billed Cuckoos have undergone a drastic reduction of range and numbers throughout the Southwest (Layman and Halterman, 1987; Rosenberg et al., 1991) and are currently receiving attention for listing as a threatened or endangered species. This is an example of how avian monitoring data collected in the park may be useful in indicating larger-scale changes in bird populations.

Survey Method Differences.¯ The strip-transect (vs. variable circle plot) survey method was the most efficient for Petrified Forest habitats, as more birds and species were detected per hour of effort. Higher numbers of bird detections enables one to better estimate bird abundances, and thus facilitates comparisons among habitats or years. Thus, we recommend continuing surveys with the strip-transect method (see Monitoring Recommendations section).

Seasonal Differences.¯ Avian abundance and diversity at Petrified Forest is substantially higher during the breeding season, than the winter. During the breeding season, Petrified Forest National Park hosts well over twice the number of species found during the winter. In addition, Petrified Forest is a popular stop-over site for spring and fall migrant birds. Indeed, the greatest diversity of species that we noted was

during the spring and fall migrations, and this is also true for the documented historical records of birds in the park. Thus, in an attempt to detect the greatest number and diversity of birds, we believe that the park should focus its monitoring and management efforts primarily toward the breeding season, and secondarily during the spring and fall migration periods.

Habitat differences. We found that several habitats in the park differed in their bird community structure. Birds found in riparian woodland, juniper woodland, cliff-side and dune habitats during breeding season were different from those found in the rest of the grass-shrub habitats. A comparison of the similarities and differences follow:

Riparian woodland hosted the greatest diversity of breeding season species in the park (37 species), three times more than in any other park habitat. In winter, riparian woodland habitat was also the most diverse, hosting 83% of the bird species present in the park. The disproportionate use of riparian woodland by birds has been found by other studies in the southwest (Carothers 1974; Szaro 1980). During migration, our incidental observations indicate that most birds were seen along the Puerco River, near the housing complexes, or on the sewage ponds. Thus, these watered habitats appear to attract migrating birds, and continued maintenance of this habitat type will significantly affect the future diversity of avian species in the park. It should be noted that we sampled two types of wash or riparian habitat in the park: one with cottonwood over story (riparian woodland at Puerco River) and one without an over story (Dry Wash). The avifauna of these two habitat types differed significantly, with Puerco River hosting twice as many birds and three times as many species as Dry Wash. The birds of Dry Wash were not distinguishable from those along other shrub and grass transects.

Table *12*. Birds captured by mist-net at Puerco River, Petrified Forest National Park, June 1998.

Species	Date	Time	Band number [a]	Age[b]	Sex	Brood patch[c]	Cloacal prot. [d]
Ash-throated Flycatcher	4-Jun-98	1055	88181083	AHY	Unknown	1	0
Ash-throated Flycatcher	12-Jun-98	810	154177532	AHY	Unknown	3	0
Ash-throated Flycatcher	29-Jun-98	1005	154177534	AHY	Female	3	0
Brown-headed Cowbird	11-Jun-98	1245	88181084	AHY	Female	0	0
Blue Grosbeak	29-Jun-98	1036	154177535	AHY	Female	1	0
Blue Grosbeak	29-Jun-98	1036	154177536	ASY	Male	0	1
Bullock's Oriole	29-Jun-98	915	88181085	SY	Male	0	0
House Finch	4-Jun-98	1045	90079607	AHY	Male	0	2
House Finch	19-Jun-98	1335	154177533	AHY	Female	2	0
MacGillivary's Warbler	11-Jun-98	1015	171046436	ASY	Female	0	0
Mourning Dove	29-Jun-98	1100	unbanded	Unkn	Female	0	0
Northern Mockingbird	11-Jun-98	735	unbanded	AHY	Unknown	3	0
Northern Mockingbird	19-Jun-98	955	85221313	AHY	Unknown	0	1
Northern Mockingbird	29-Jun-98	1035	85221314	AHY	Female	3	0
Rock Wren	19-Jun-98	805	213021076	Unkn.	Unknown	0	0
Western Flycatcher	11-Jun-98	640	213021074	AHY	Unknown	0	0
Western Flycatcher	12-Jun-98	1030	171046437	AHY	Unknown	1	0
Western Wood-Peewee	11-Jun-98	650	unbanded	Unkn.	Unknown	-	-
Western Wood-Peewee	12-Jun-98	900	213021075	AHY	Unknown	0	0

The juniper woodland also hosted a high diversity of species during the breeding season, including Lark Sparrows, Ash-throated Flycatchers, and Northern Mockingbirds, species that were only otherwise detected at the Puerco River site. This suggests that presence of higher woody vegetation, such as the cliffrose and junipers that are present in the Pintado Point area, account for much of the variation in bird use within the park (see also Rosenstock and van Riper 2001).

Cliff-side habitat was distinctive in regard to bird community composition during the breeding season. Species richness was relatively high (13 species), including nesting species such as American Kestrels, Cliff Swallows, Common Ravens, and Rock Wrens, all who built their nests in the cliff rock face. In addition, other species including Prairie Falcons and Golden Eagles are known to nest in rock faces in other locations within the park. Rock Wrens were the most abundant birds in this habitat type, and showed a strong habitat association with bare ground and rock. Wiens and Rotenberry (1981) also found a strong association between the abundance of Rock Wrens and rocky outcrops.

The dune habitat was distinctive in bird species composition, mostly due to the large numbers of Rock Wrens; however, this result is somewhat misleading, as the Rock Wrens were detected primarily in a steep arroyo to the north, rather than in the dune vegetation. This further suggests the distinctiveness of rock outcrops as important habitat for some avian species at Petrified Forest NP.

Within the grass-shrub habitats, we found that bird species richness was enhanced with increased shrub cover. In southern Utah grassland habitat Willey (1994) also found a positive association between bird species richness and vertical habitat structure, a combination of the density and number of vegetation layers. Other studies have demonstrated higher avian species diversity associated with more structurally complex habitats (e.g., Rotenberry and Wiens, 1980; Rosenstock and van Riper, 2001). While species numbers that we de-

Table *13*. Observations of bird breeding activity in Petrified Forest National Park, Holbrook, Arizona, during 1998 and 1999.

Species	location	evidence	date
American Kestrel	Cliff edge near Ninemile Wash	nest	15-Jun-99
Ash-throated Flycatcher	Puerco River	partial brood patch	4-Jun-98
Ash-throated Flycatcher	Puerco River	brood patch	29-Jun-98
Barn Swallow	Painted Desert Housing	nest with young	Jun-98
Black-throated Sparrow	Rainbow Forest	carrying food	6-May-98
Black-throated Sparrow	Puerco River	juvenile	8-Jun-98
Black-throated Sparrow	Borrow Pit	nest with young[a]	8-Jun-98
Black-throated Sparrow	Route 66	carrying food	12-Jun-98
Black-throated Sparrow	Flattops	carrying food	17-Jun-98
Black-throated Sparrow	Pintado Point	nest	19-Jun-98
Black-throated Sparrow	Pintado Point	juvenile fed by adult	28-Jun-98
Black-throated Sparrow	Pintado Point	nest	28-Jun-98
Black-throated Sparrow	Dry Wash	juvenile fed by adult	29-Jun-98
Black-throated Sparrow	Borrow Pit	nest-building	31-May-99
Black-throated Sparrow	Dry Wash	juvenile fed by adult	22-Jun-99
Black-throated Sparrow	Borrow Pit	family group	23-Jun-99
Black-throated Sparrow	Pintado Point	nest with 3 young	26-Jun-99
Blue Grosbeak	Puerco River	partial brood patch	29-Jun-98
Blue Grosbeak	Puerco River	partial cloacal	29-Jun-98
Blue Grosbeak	Puerco River	nest-building	11-Jun-99
Brewer's Sparrow	Route 66	juvenile	28-Jun-98
Bullock's Oriole	Puerco River	feeding young	27-Jun-98
Bullock's Oriole	Puerco River	nesting material	Jun-99
Cliff Swallow	Puerco River	nest	Jun-98
Cliff Swallow	Cliff edge near Ninemile Wash	nest	Jun-98
Cliff Swallow	Puerco River	nest	Jun-99
Cliff Swallow	Cliff edge near Ninemile Wash	nest	Jun-99
Cliff Swallow	Western Boundary of	brood patch	21-Jun-99
Common Nighthawk	Cliff edge near Ninemile Wash	family group	12-Jun-98
Horned Lark	various	family groups	Jun-99
House Finch	Puerco River	nest with 3 eggs[b]	8-Jun-98
House Finch	Puerco River	brood patch	19-Jun-98
House Finch	Puerco River	carrying food	31-May-99
House Sparrow	Painted Desert Housing	nest	Jun-98
Lark Sparrow	Western boundary of park	brood patch	21-Jun-99
Loggerhead Shrike	Dune transect at Teepees	family	10-Jun-98
Loggerhead Shrike	Dry Wash	nest-building	11-Jun-98
Loggerhead Shrike	Route 66	carrying food	12-Jun-98
Loggerhead Shrike	Puerco River	nest with 6 young	16-Jun-98
Loggerhead Shrike	Flattops	feeding young at	16-Jun-99
Loggerhead Shrike	Dry Wash	juvenile	22-Jun-99
Loggerhead Shrike	Flattops	family group	24-Jun-99
Mourning Dove	Puerco River	two nests with eggs	8-Jun-98
Mourning Dove	Puerco River	family group	16-Jun-98
Mourning Dove	Pintado Point	nest with 2 eggs	1-Jun-99
Northern Mockingbird	Puerco River	brood patch	11-Jun-98
Northern Mockingbird	Puerco River	nest with 3 young	16-Jun-98
Northern Mockingbird	Route 66	family group	28-Jun-98
Northern Mockingbird	Puerco River	brood patch	29-Jun-98
Northern Mockingbird	Pintado Point	nest-building	1-Jun-99
Northern Mockingbird	Pintado Point	nest with 2 eggs[c]	26-Jun-99
Prairie Falcon	Pintado Point	juveniles	Jun-98
Prairie Falcon	Pintado Point	flightless juveniles	Jun-99
Rock Wren	Cliff edge near Ninemile Wash	juvenile	5-Jun-98
Rock Wren	Flattops	juvenile	9-Jun-98
Rock Wren	near Flattops	nest with 6 eggs	20-Jun-98
Rock Wren	Flattops	family	26-Jun-98
Rock Wren	Cliff edge near Ninemile Wash	juvenile	27-Jun-98

[a]nest contained 1 Black-throated Sparrow egg and a Brown-headed Cowbird nestling.
[b]nest contained 2 House Finch eggs and 1 Brown-headed Cowbird egg.
[c]nest contained 1 Northern Mockingbird egg and 1 Brown-headed Cowbird egg.

tected was positively associated with shrub cover, increased shrub cover might not benefit all members of the grassland bird community. Black-throated Sparrows were not found in high numbers in areas of high shrub density and low grass cover, and Horned Larks were positively associated with grass cover and negatively associated with shrubs. Willey (1994) also found that Horned Larks and Black-throated Sparrows were positively associated with vertical vegetation cover and little bare ground, but he did not distinguish between grass and shrubs. Wiens and Rotenberry (1981) found that Black-throated Sparrows were positively associated with shrub cover. Our findings are consistent with those of other workers who have studied grassland habitats in the western United States, all whom have found a high degree of individuality among species in their responses to habitat characteristics. Thus, it may be difficult to generalize management objectives to the entire avian community at Petrified Forest NP, and management actions will more likely need to be made on a separate basis for each target species.

Despite the obvious importance of the woodland and cliff-providing habitats within the park, importance of the grass-shrub habitat should not be overlooked. The grass-shrub habitats actually support higher densities of birds than do the other habitats, largely due to the numbers of Horned Larks. There is reason to believe that high quality grassland habitat of Petrified Forest NP is extremely valuable in terms of conservation, in that grassland birds have been identified on a continental scale as one of the most dramatically declining avian guilds (Peterjohn and Sauer, 1999). Thus, for species reliant on grasslands, access to breeding areas that are free of excessive disturbance is important for the continued maintenance of the avian short-grass prairie guild in the park.

MONITORING RECOMENDATIONS

1) Continue monitoring avian populations, focusing primarily on the breeding season. To gain the most reliable information on breeding bird abundance in the park, strip-transect surveys should be conducted on a yearly basis. If yearly surveys are not possible, then surveys at increments of 2, 3, or 5 years could provide monitoring data, if accrued regularly over a long enough time period. Surveys should be conducted between mid-May and the end of June, with the best weeks being the last week of May through the third week of June. One-to-two weeks prior to surveying, observer(s) should locate all points on transects, marking prominent shrubs near points to facilitate rapid location during the surveys. Each transect should be surveyed three times, allowing one week between successive surveys. Flexibility to this schedule should be allowed for 'make-up surveys' due to bad weather. One or two transects may be surveyed per morning, starting at sunrise. If two counts are conducted, each transect should be surveyed first, then repeated later in the morning. Observer(s) should move as rapidly as possible between surveys to decrease the effects of rising temperature.

2) Observer(s) should be trained in bird survey techniques and familiar with species found in the park PRIOR to conducting avian censuses. One observer is preferable, but if two observers are utilized, they should be trained together. When counting, each person should count birds at least once on each transect. All observer(s) should practice with a range-finder prior to the formal count so that they feel comfortable collecting distance information. Observer(s) should follow the survey protocol described in the Methods section, being sure not to count during days with rain, or when winds exceed an average of 8 mph or gust to 10 mph. This is because aural detections make up 80% of the detections and are seriously compromised during periods of high wind and inclement weather.

3) Vegetation along bird survey transects needs to be measured in every year in which bird surveys are conducted. However, if this is not possible, other repeated monitoring increments, of 2, 5, or 10 years, would also provide worthwhile habitat monitoring data for the park. A minimum of two vegetation plots should be measured per bird survey point. It should be noted that the vegetation measurement protocol described in this report is quite simple, requires identification only of the shrub species, and is relatively time efficient. Most of the vegetation measurement could be completed by two or three observers within the several weeks of the bird survey season. Because of the high correlation between measures of shrub cover and shrubs counted in an area around the survey line, we recommend that shrubs need not be tallied, unless more specific information regarding shrub composition is desired. Likewise, we found measurements of shrub heights were fairly invariant among sites, and should be conducted only if there is specific interest in shrub heights. Because the riparian woodland at the Puerco River is so dynamic due to flooding, the presence of invasive species, and management efforts including planting of trees, continued measurements of average shrub heights, tree heights, and tree densities would be recommended for this habitat type.

4) Analysis of bird and habitat data should be reduced and analyzed each year following surveys, then collated for

comparisons among years. A large effort should be undertaken at 5-year intervals of data collection. An effective way to determine if species have changed in abundance is to compare relative abundances of species among years. This is accomplished by calculating the total number of birds counted for each species, then taking the number of the most abundant species (which will undoubtedly be the Horned Lark), and dividing that number into each of the total number counted for every other species. For example, if a total count results in 156 birds (100 Horned Larks, 30 Meadowlarks, 25 Black-throated Sparrows and one Loggerhead Shrike), the Horned Lark would have a relative index of 1.0 (100 divided by 100). Meadowlarks would have a relative index of .30 (30 divided by 100), Black-throated Sparrows .25 (25 divided by 100) and the Loggerhead Shrike a relative abundance index of .01 (1 divided by 100). Thus, by comparing among years, the park can determine if the abundance of one species is either stable, in decline or increasing, relative to the general abundances of other species. In addition, if the relative abundances of birds among habitat types vary significantly among years, comparisons should be made back to vegetation measurements to determine if vegetation changes within particular habitats might be correlated with changes in bird numbers.

5) Natural History Observation Cards should continue to be maintained as an effective part of the park's avian monitoring program. The park should continue to encourage visitors and staff to report bird sightings utilizing Observation Cards, making sure that observers provide details explaining their identification of less common species (e.g., distance at which the bird was seen, duration of observation, and how the species was distinguished from other similar species). All Observation Cards should be reviewed for Quality Control by a person familiar with birds, and if accepted should be input on a regular basis (not less than yearly), into the Avian Observation Database. This database should be made available in electronic and hard-copy form to all researchers and interested visitors through the Resource Management Office.

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REFERENCES

AOU. 1998. Check list of North American birds (7th ed.) American Ornithologists' Union, Allen Press, Lawrence, KS.

Arnold, J.F., Jameson, D. A., and E.H. Reid. 1964. The pinyon-juniper type of Arizona: Effects of fire, grazing, and tree control. USDA Forest Service Product of Research Report, 84, Washington, D.C.

Banks, A. J., van Riper III, C., and S. R. Rosenstock. 2003. Status of breeding and wintering birds in Petrified Forest National Park. USGS Southwest Biological Science Center, Colorado Plateau Field Station Open File Report. USGS/SBSC/COPL/2003/21. 83 pp.

Beatty, L. 1978. Natural resource survey and analysis of Sunset Crater and Wupatki National Monuments. Unpublished report to the Office of Natural Resource Management, NPS, Southwest Region, Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ.

Bock, C.E., and J.H. Bock. 1988. Grassland birds in southeastern Arizona: impacts of fire, grazing, and alien vegetation, p. 43-58. *In* Ecology and conservation of grassland birds. International Council for Bird Preservation Publication, 7, Cambridge, England.

Bock, C.E., Bock, J. H., Kenney, W. R., and V.M. Hawthorne. 1984. Responses of birds, rodents, and vegetation to livestock exclosure in a semidesert grassland site. Journal of Range Management, 37: 239-242.

Bock, C.E., Saab, V. A., Rich, T. D., and D.S. Dobkin. 1992. Effects of livestock grazing on neotropical migratoryl in Western North America. Pp. 296-309 in Status and Management of Neotropical Migratory Landbirds, USDA Forest Service General Technical Report RM-229, Fort Collins, Colorado.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology, 18:117-143.

Carothers, S.W. 1974. Population structure and organization of southwestern riparian birds. American Zoologist, 14:97-108.

DeSante, D.F., and T.L. George. 1994. Population trends in the landbirds of western North America. Studies in Avian Biology, 15:173-190.

Emlen, J.T. 1971. Population densities of birds derived from transect counts. Auk, 88: 323-342.

Gibson, D.J., and L.C. Hurlbert. 1987. Effects of fire, topography and year-to-year climate variation on species composition in tallgrass prairie. Vegetation, 72: 175-185.

Johnson, R.R., Haight, J. T., and J.M. Simpson. 1977. Endangered species vs. endangered habitats: a concept, p. 68-79. *In* R. Johnson and D. Jones, (eds.), Importance, preservation, and management of riparian habitats: a symposium, USDA Forest Service, General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

La Rue, C. 1994. Birds of Black Mesa, Navaho County, Arizona.

Great Basin Naturalist, 54:1-63.
Lanyon, W. E. 1994. Western Meadowlark (*Sturnella neglecta*). The birds of North America, 104 (A. Poole and F. Gills, Eds). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.
Lanyon, W. E. 1995. Eastern Meadowlark (*Sturnella neglecta*). The Birds of North America, 104 (A. Poole and F. Gills, Eds). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.
Laymon S.A., and M.D. Halterman. 1987. Can the western subspecies of the Yellow-billed Cuckoo be saved from extinction? Western Birds, 18: 19-25.
Minchin, P.R. 1993. ANOSIM (program). Louisiana State University, Louisiana.
Minchin, P.R. 1998. DECODA (program). Louisiana State University, Louisiana.
Monson, G. 1941. The effect of revegetation on the small bird population in Arizona. Journal of Wildlife Management, 5: 395-397.
Peterjohn, B.G.., and J.R. Sauer. 1999. Population status of North American grassland birds from the North American Breeding Bird Survey, 1966-1996. Studies in Avian Biology, 19:27-44.
Reynolds, R.T., Scott, J. M., and R.A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor, 82: 309-313.
Rice, W.R. 1989. Analyzing tables of statistical tests. Evolution, 43:223-225.
Rosenberg, K.V., Ohmart, R. D., Hunter, W. C., and B.W. Anderson. 1991. Birds of the Colorado River Valley. University of Arizona Press, Tucson, Arizona.
Rosenstock, S. S., and C. van Riper III. 2001. Breeding bird response to juniper woodland expansion in Northern Arizona grasslands. Journal of Range Management, 54: 226-232.
Rotenberry J.T,. and J.A. Weins. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. Ecology, 61: 1228-1250.
Szaro, R.C. 1980. Factors influencing bird populations in southwestern riparian forests, p 403-418. *In* Management of western forests and grasslands for nongame birds, USDA Forest Service General Technical Report INT-86. Intermountain Forest and Range Experiment Station, Ogden, Utah.
Tewksbury J.J.,Hejl, S. J., and T.E. Martin. 1998. Breeding productivity does not decline with increasing fragmentation in a western landscape. Ecology, 79: 2890-2903.
West, N.E. 1984. Successional patterns and productivity potentials of pinyon-juniper ecosystems, p 1301-1332. *In* Developing strategies for range management, National Academy Of Science. Westview Press, Boulder, Colorado.
Wiens, J.A. 1974. Climatic instability and the "ecological saturation" of bird communities in North American grasslands. Condor, 76: 385-400.
Wiens, J.A., and J.T. Rotenberry. 1981. Habitat associations and community structure of birds in shrubsteppe environments. Ecological Monographs, 51:21-41.
Willey, D.W. 1994. Effects of livestock grazing on grassland birds in Capitol Reef National Park, Utah. Technical Report NPS/NAUCARE/NRTR-94/05. National Park Service and Colorado Plateau Research Station, Northern Arizona University, Flagstaff, AZ.