Response of Vegetation and Breeding Birds to the Removal of Cattle on the San Pedro River, Arizona (U.S.A.)

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Abstract: *In late 1987 cattle were removed from the San Pedro Riparian National Conservation Area (NCA) in southeastern Arizona (U.S.A.). We monitored vegetation density and abundance of birds during the breeding season during 1986–1990 in riparian, mesquite grassland, and Chihuahuan desert-scrub communities in the NCA. The density of herbaceous vegetation increased four- to six-fold in riparian and mesquite grassland communities. Little change occurred in herbaceous vegetation in desert scrub, or in the density of shrubs or trees in any of the communities. Of 61 bird species for which sufficient data were collected, mean detections per kilometer increased for 42 species, 26 significantly, and decreased for 19 species, 8 significantly. The number of individuals of all avian species detected on surveys increased each year from 103/kilometer in 1986 to 221/kilometer in 1991, an average annual increase of 23% ($p < 0.001$). The largest increases occurred in riparian species, open-cup nesters, Neotropical migrants, and insectivores. Species of the Chihuahuan desert-scrub, in which vegetation changed the least, showed the smallest increases. Only a few of the species showed increasing regional trends for the same period, as demonstrated by the North American Breeding Bird Survey; thus, increases on the San Pedro Riparian NCA were likely caused by the change in local conditions, not by regional effects. Our results suggest that removing cattle from riparian areas in the southwestern United States can have profound benefits for breeding birds.*

Respuesta de la Vegetación y las Aves en Reproducción a la Remoción de Ganado en el Río San Pedro, Arizona (U.S.A.)

Resumen: *A finales de 1987 el ganado fue removido del Área de Conservación Nacional Riparia del Río San Pedro (NCA) ubicada en el sureste de Arizona (USA). Monitoreamos la densidad de la vegetación y la abundancia de aves durante la estación reproductiva entre 1986 y 1990 en comunidades riparias, pastizales de mesquite y de maleza del desierto chihuahueño en la NCA. La densidad de la vegetación herbácea incrementó de cuatro a seis veces en la comunidad riparia y en el pastizal de mesquite. Pocos cambios ocurrieron en la vegetación herbácea de maleza del desierto y en la densidad de arbustos o árboles en cualquiera de estas comunidades. De las 61 especies de aves con suficientes datos recolectados, el promedio de detecciones por kilómetro para 42 especies aumentó, 26 de ellas significativamente, y disminuyó para 19 especies, 8 de ellas significativamente. El número de individuos para todas las especies de aves detectadas en todos los muestreos aumentó de un año al otro 103 por kilómetro en 1986 a 221 por kilómetro en 1991, en promedio, el incremento anual fue del 23% ($p < 0.001$). Los incrementos mayores ocurrieron en especies riparias, especies que anidan en copas abiertas, migrantes neotropicales e insectívoros. Las especies de la maleza del desierto chihuahueño, en el cual la vegetación cambió menos, mostraron los incrementos más pequeños. Solo unas cuantas especies tienen tendencias regionales en incremento para el mismo período, esto lo demuestran los*

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muestreos de Aves Reproductoras de Norteamérica; asi pues, es probable que los incrementos en la NCA Riparia de San Pedro fueron causados por los cambios en las condiciones locales y no por efectos regionales. Nuestros resultados sugieren que la remoción de ganado de áreas riparias en el suroeste de los Estados Unidos puede tener profundos beneficios para las aves en reproducción.

Introduction

Riparian areas are critically important to wildlife in the southwestern United States for their water and lush vegetation, which are missing from the dry, less productive environments that typically cover the adjacent landscape (Chaney et al. 1990). This habitat supports a disproportionate number and diversity of aquatic and terrestrial wildlife. At least 80% of the vertebrates occurring regularly in Arizona and New Mexico use riparian areas at some stage of their lives, and more than half are riparian obligates (Chaney et al. 1990; Krueper 1996). Riparian areas support a higher breeding diversity of birds than all other western habitats combined (Anderson & Ohmart 1977; Johnson et al. 1977; Johnson & Haight 1985; Rosenberg et al. 1991; Skagen et al. 1998). Western riparian habitats also harbor some of the highest noncolonial avian breeding densities in North America (Johnson et al. 1977; Skagen et al. 1998).

The extent of southwestern riparian ecosystems in Arizona has declined substantially during the past 300 years, from approximately 5% of the state landmass to <1% (Ohmart 1994, 1996). Arguably, the single land-use activity that has most affected western riparian systems and has led to the greatest change within western ecosystems in general has been livestock grazing (Bahre 1991; Fleischner 1994; Wuerthner 1994). Livestock grazing can change vegetative communities in many ways, including reducing plant density, changing species composition, decreasing plant vigor, decreasing seed and insect production, and eliminating vegetative recruitment (Ryder 1980; Platts 1991; Horning 1994; Ohmart 1996; Belsky et al. 1999). Additionally, trampling of soils by livestock may increase wind and water erosion, compact soils, and prevent seedling establishment.

Depending on the magnitude of livestock use, these impacts can decrease avian reproductive success, lower food availability, increase predation on nests and adults, lower avian density and species diversity, and cause shifts in foraging techniques, distribution, and habitat use (Buttery & Shields 1975; Sedgwick & Knopf 1987; Knopf et al. 1988). Understory bird species are particularly affected by grazing. A small number of species that prefer open habitats or lower vegetative density may benefit from a shift in vegetative structure and composition brought on by grazing (Taylor 1986; Saab et al. 1995).

Moderate to heavy grazing by domestic livestock has occurred in southern Arizona for at least 300 years (Allen 1989; Krueper 1996). In 1694, approximately 100,000 cattle were present within the headwaters of the San Pedro River Valley (Allen 1989). By the late 1880s, up to 1.5 million cattle were estimated to be using the grasslands of southern Arizona annually, primarily south of the Gila River (Dobyns 1981; Bahre 1991; Ohmart 1996).

Overstocking of the range during the 1880s severely degraded grasslands in the Upper San Pedro River Valley and throughout the Southwest (Hastings & Turner 1965; Bahre 1991; Donahue 1999). Overgrazing within the San Pedro River Valley caused erosion and increased siltation and entrenchment (Stromberg et al. 1996). Also, the vast freshwater cienagas maintained by beavers (*Castor canadensis*) were drained and replaced by mesquite (*Prosopis velutina*), Fremont cottonwood (*Populus fremontii*), Gooding willow (*Salix goodingii*), and seepwillow (*Baccharis glutinosa*).

Riparian vegetation can recover rapidly following the removal of livestock grazing (Fleischner 1994; Ohmart 1996), but research on riparian recovery and regeneration on a large scale has been limited in the arid Southwest. Most studies have concentrated on determining the short-term effects of changing grazing systems on vegetation in mid- to high-elevation habitats, or within small-scale livestock grazing exclosures. Fleischner (1994) suggested that exclosure studies do not accurately reflect the ecological potential of ecosystems. Exclosures are usually of small size, have been in place only a short time, and typically have been grazed prior to exclosure. Thus, there exist few large-scale or long-term studies that measure ecosystem recovery. Even fewer studies have measured change of riparian vegetation and the resultant change of avian populations after the removal of livestock grazing in arid lowland riparian ecosystems. Our objectives were to determine (1) how quickly and to what extent vegetation and avian communities would respond following cattle exclusion and (2) what ecological attributes would best characterize avian species showing the strongest and weakest responses.

Study Area

The study was conducted within the San Pedro Riparian National Conservation Area (NCA) of Cochise County,

Arizona (Fig. 1). The San Pedro River is 310 km long and is the only permanently undammed river in the southwestern United States. The NCA is 3–8 km wide, 69 km long, and nearly 23,000 ha in size; it varies in elevation from 1295 m at the international boundary to 1113 m at the northernmost boundary. Within the NCA, the San Pedro River is perennial for 35 km and ephemeral elsewhere. Cattle removal from the study area began in late 1987 after the vegetative growing season and avian breeding season. On 1 January 1988, a 15-year grazing moratorium was initiated, which eliminated the season-long, cow-calf regime of 6,500–13,000 head that had been characteristic for the study area in previous years.

A total of 355 species of birds has been recorded within the NCA (Krueper 2000). Of the 108 breeding species, 63 are migrants and 45 are permanent residents. Between 5 and 10 million migratory songbirds use the San Pedro River annually for migration and breeding (Rojo et al. 1998).

Vegetation in the NCA was divided into 21 communities (Brown et al. 1979). We combined these categories to obtain three broad communities: riparian, mesquite grassland, and Chihuahuan desert-scrub. In 1987 the riparian community covered approximately 1000 ha of the NCA and was dominated by Fremont cottonwood, Gooding willow, seepwillow, forbs, and perennial grasses such as side-oats grama (*Bouteloua curtipendula*) and tobosa (*Hilaria mutica*). The mesquite grassland community covered approximately 5000 ha and was dominated by mesquite, whitethorn acacia (*Acacia neovernicosa*), and sacaton grass (*Sporobolus wrightii*). The Chihuahuan desert-scrub community covered 12,000 ha and was dominated by whitethorn acacia, creosote (*Larrea divaricata*), inkweed (*Suaeda torreyana*), zinnia (*Zinnia acerosa*), dogweed (*Dyssodea acerosa*), and native and non-native grasses.

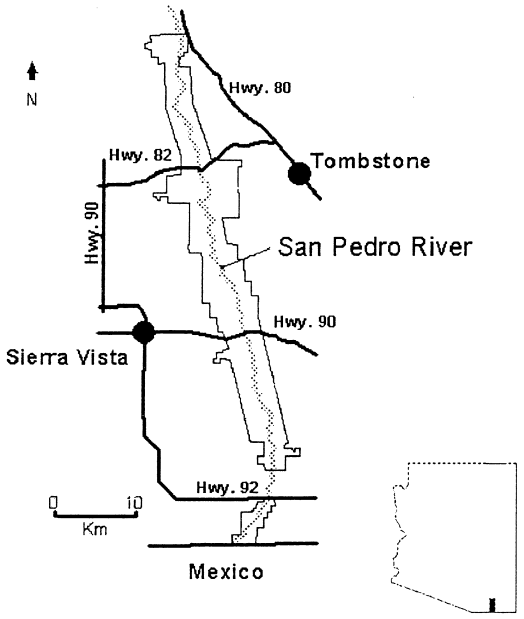

Figure 1. Location of the San Pedro Riparian National Conservation Area.

Methods

We established 15 transects in riparian (6 transects), mesquite (7 transects), and desert-scrub (2 transects) communities. Transect length varied from 0.8 km to 1.6 km within each community type. Avian surveys were conducted at regular intervals three times per month every month for 5 years (1986–1990). Vegetation was sampled at the peak of summer growth (September or October) in 1986, 1989, and 1992 and on three transects again in 1998.

We used the technique developed by MacArthur and MacArthur (1961) and modified by Anderson and Ohmart (1984) to determine foliage density. Vegetation was measured every 50 m along transects at 12 heights (0.15–21.3 m). At each height, the perpendicular distance to the nearest patch of live vegetation that covered >50% of a clipboard-sized area (approximately 22.5 cm × 40 cm) was recorded on each side of the transect. We calculated foliage-density indices from these data for herbs, shrubs, short trees, and tall trees by selecting heights and horizontal distances and recording the proportion of measurements in which the vegetation of each type was recorded within the selected distance. Thus, denser vegetation resulted in higher index values. We used transects as primary sampling units. For shrubs, for example, the height was 1.5 m and the perpendicular distance was 4.6 m. The proportion of the measurements at 1.5 m in which shrubs were recorded at distances of <4.6 m was determined for each transect. The foliage-density index was the mean of the transect-specific values. The vegetation types, heights, and distances were (1) herbaceous layer, for which height was 0.15 m, 0.6 m, and 1.5 m and distance was 0.3 m; (2) shrub layer, for which height was 1.5 m and distance was 4.6 m; (3) short trees, for which height was 4.6 m and distance was 10.7 m; and (4) tall trees, for which height was 15 m and distance was 15 m. We selected distances so that vegetation other than the focal type (e.g., shrubs) was seldom recorded. We evaluated the significance of differences in the density index between years with a paired t test with df = $n - 1$, where n is the number of transects.

We sampled birds using fixed-width transects as described by Anderson and Ohmart (1984), with the survey area extending 124 m on each side of the transect. A walking pace of 30 m/minute was maintained.

We used data collected during the breeding season (May–July) on all species with ≥100 detections and that occurred on ≥3 transects. We calculated means for each transect and year, and we used linear regression on the

grand means/year, averaged across all transects, to estimate the trend during 1986–1990. We determined the significance of trends by calculating transect-specific slopes, with linear regression and testing whether their mean was significantly different from 0.0 using a one-sample t test and df = $n - 1$, where n is the number of transects. An equivalent annual rate of change was calculated as the fourth root of the change in the trend line (value in 1990/value in 1986).

We estimated trends for groups of species and for single species. Species were assigned to one or more of our three plant communities (riparian, mesquite, desert scrub) and to one or more vertical strata (0–1.4, 1.5–4.6, >4.6 m) based on a subjective determination of where they were commonly detected during the study. Each species was also assigned to one foraging guild (insectivore, granivore, omnivore, or other) and one nest type (open cup vs. cavity) based on the methods of Ehrlich et al. (1988). Permanent residents were distinguished from Neotropical migrants based on the Partners in Flight criteria (Gauthreaux 1992). In the analysis of groups, we combined all detections and calculated a new trend without regard to species.

To determine whether population trends in the study area were similar to regional trends, and thus might be caused by events outside the study area, we examined North American Breeding Bird Survey (BBS) trends with "high credibility scores" (Sauer et al. 2000) during 1980–1999 for Arizona, the Mexican Highlands physiographic area, U.S. Fish and Wildlife Service (FWS) Region 2, and the western BBS region (Sauer et al. 2000).

Results

Vegetation

The density of herbaceous vegetation increased substantially ($p < 0.01$) in riparian and mesquite communities (Table 1; Fig. 2). The density indices at 0.15 m and 0.6 m roughly doubled during 1986–1989, and additional increases occurred during 1989–1992. The overall increase was two- to threefold at the height of 0.15 m and four- to fivefold at the height of 0.6 m. The density index at 1.5 m was 0.0 in 1986 and 1989 but increased to 0.06 on the riparian transects and 0.15 on the mesquite transects by 1992.

Herbaceous vegetation did not show a significant change in the desert-scrub community (Table 1), and shrubs, short trees, and tall trees did not show significant changes in any of the three communities (Table 1). No significant changes during 1992–1998 were evident from the three transects measured in 1998.

Birds

Sixty-one bird species met the requirements for inclusion in the analysis (Table 2). Mean detections/kilometer increased for 42 species, 26 significantly, and decreased for 19 species, 8 significantly. The mean number of detections of all species increased significantly ($p < 0.001$), from 103/km in 1986 to 221/km in 1990 (Table 3). The equivalent average rate of increase was 23%/year. The numbers detected also increased significantly ($p < 0.05$) in all 13 groups of species (Table 3). The biggest increases occurred among open-cup nesters, Neotropical migrants, riparian species, and insectivores. The smallest increases occurred among birds of the Chihuahuan desert-scrub.

Detections of open-cup nesters increased significantly faster than cavity nesters, insectivores increased faster than omnivores, and Neotropical migrants increased faster than residents ($p < 0.05$ with a two-sample t test). Differences among the three plant community groups (riparian, mesquite, desert-scrub) and among the vertical strata groups were not tested because some species were assigned to more than one category within the group.

The highest ratio of increasing species to decreasing species occurred in insectivores, granivores, midstory species, upperstory species, and riparian species (Table 3).

Table 1. Average foliage-density index for herbs in 1986, 1989, and 1992 on the San Pedro Riparian National Conservation Area, Arizona.[a]

Community	*No. of transects*	*Species*	*Height (m)*	*1986*	*1989[b]*	*1992[b]*	*Species*	*1986*	*1989*	*1992*
Riparian	6	herbs	0.15	0.36	0.74**	0.75	shrubs	0.25	0.25	0.31
			0.61	0.14	0.36*	0.58**	low trees	0.64	0.58	0.72
			1.53	0.00	0.00	0.06	tall trees	0.49	0.59	0.68
Mesquite	7	herbs	0.15	0.25	0.59**	0.94*	shrubs	0.10	0.06	0.08
			0.61	0.16	0.26	0.89**	low trees	0.26	0.38	0.42
			1.53	0.00	0.00	0.15*	tall trees	0.00	0.00	0.00
Desert-scrub	2	herbs	0.15	0.50	0.54	0.25	shrubs	0.35	0.31	0.50
			0.61	0.02	0.03	0.09	low trees	0.01	0.01	0.01
			1.53	0.00	0.00	0.00	tall trees	0.00	0.00	0.00

[a] *Cattle were removed in late 1987.*
[b] *Asterisks indicate significant differences between the means in 1986 and 1989 or between 1989 and 1992 based on a paired* t *test;* *$p < 0.05$; **$p < 0.01$.

Figure 2. Photographs taken from the same locations on the San Pedro Riparian National Conservation Area before (June 1987) and 4 years after (June 1991) cattle removal (top two sets), and one set of photographs from 1984 and 1997 (10 years after cattle removal).

Granivores had the highest percentage of increasing species, followed by insectivores, upperstory species, Neotropical migrants, and riparian species, in decreasing order. The lowest ratios of increasing species to decreasing species occurred among omnivores, residents, Chihuahuan desert-scrub species, and cavity nesters. The same groups had the highest percentage of decreasing species.

Few of the species that changed significantly in abundance on the San Pedro NCA exhibited similar regional BBS trends. Among the 26 species showing significant annual increases in this study, only the Common Raven (for all scientific names, see Table 2) showed consistent and significant regional annual increases (Arizona, +6.1%; FWS Region 2, +5.1%; west, +2.8%). Among the 8 species showing significant decreases in this study, 3 species also showed significant regional BBS annual declines: House Sparrow (FWS Region 2, −2.9%), Eastern Meadowlark (west, −4.0%), and Black-throated Sparrow (Arizona, −4.2%; Mexican Highlands, −5.1%; west, −1.6%).

Table 2. Species with increasing and decreasing trends during the breeding season on the San Pedro Riparian National Conservation Area, Arizona, before and after removal of cattle in late 1987, sorted by significance level of the trend.

	Detections/km							
	1986	*1987*	*1988*	*1989*	*1990*	*Annual change**	*SE*	p
Increasing species								
Cassin's Sparrow (*Aimophila cassinii*)	0.06	0.92	5.19	5.15	2.15	2.42	0.00	0.000
Dusky-capped Flycatcher (*Myiarchus tuberculifer*)	0.03	0.07	0.09	0.32	0.31	1.93	0.00	0.000
N. Beardless-Tyrannulet (*Camptostoma imberbe*)	0.06	0.04	0.17	0.25	0.46	1.82	0.00	0.000
Yellow Warbler (*Dendroica petechia*)	3.21	6.05	8.77	17.68	16.71	1.55	0.00	0.000
Western Wood-Pewee (*Contopus sordidulus*)	1.51	1.62	2.18	3.23	4.17	1.31	0.00	0.000
Summer Tanager (*Piranga rubra*)	3.73	5.91	5.81	10.61	10.13	1.29	0.00	0.000
Abert's Towhee (*Pipilo aberti*)	6.14	7.28	8.63	13.11	15.43	1.28	0.03	0.000
Great Blue Heron (*Ardea herodias*)	0.24	0.65	0.42	0.43	0.97	1.27	0.00	0.000
Mallard (*Anas platyrhynchos*)	0.80	0.61	1.07	0.92	1.81	1.23	0.00	0.000
Blue Grosbeak (*Passerina caerulea*)	2.92	5.20	4.46	6.19	7.22	1.22	0.00	0.000
Ash-throated Flycatcher (*Myiarchus cinerascens*)	1.81	2.36	2.41	3.66	3.74	1.21	0.01	0.000
Cassin's Kingbird (*Tyrannus vociferans*)	3.46	3.93	3.06	6.07	5.54	1.15	0.00	0.000
Common Yellowthroat (*Geothlypis trichas*)	1.27	3.24	5.36	12.95	14.71	1.87	0.10	0.001
Brown-headed Cowbird (*Molothrus ater*)	3.47	5.03	5.58	6.21	8.11	1.21	0.03	0.001
Vermilion Flycatcher (*Pyrocephalus rubinus*)	2.35	3.22	3.40	5.40	7.30	1.32	0.05	0.003
White-winged Dove (*Zenaida asiatica*)	1.93	2.69	3.37	7.54	10.78	1.56	0.10	0.005
Bewick's Wren (*Thryomanes bewickii*)	10.87	10.85	9.82	14.34	14.97	1.10	0.02	0.005
Yellow-breasted Chat (*Icteria virens*)	5.35	6.60	7.94	17.17	20.58	1.44	0.08	0.006
Lesser Goldfinch (*Carduelis psaltria*)	5.08	5.17	3.73	7.00	6.13	1.07	0.01	0.006
Gray Hawk (*Asturina nitida*)	0.57	0.92	0.54	0.84	1.15	1.14	0.03	0.014
Hooded Oriole (*Icterus cucullatus*)	0.00	0.17	0.21	0.20	0.41	1.86	0.21	0.015
Brown-crested Flycatcher (*Myiarchus tyrannulus*)	2.07	2.32	2.43	3.34	3.54	1.16	0.04	0.016
Mourning Dove (*Zenaida macroura*)	1.05	1.41	1.80	5.30	4.09	1.50	0.13	0.020
Common Raven (*Corvus corax*)	0.02	0.01	0.17	0.13	0.24	2.18	0.38	0.038
House Finch (*Carpodacus mexicanus*)	2.17	1.39	1.71	2.80	3.12	1.15	0.06	0.051
N. Rough-winged Swallow (*Stelgidopteryx serripennis*)	0.08	0.38	0.35	0.64	0.53	1.55	0.21	0.054
Black Phoebe (*Sayornis nigricans*)	0.27	0.15	0.10	0.51	0.92	1.44	0.17	0.058
Black-chinned Hummingbird (*Archilochus alexandri*)	0.57	0.57	0.50	0.71	1.63	1.26	0.10	0.069
Indigo Bunting (*Passerina cyanea*)	0.02	0.02	0.27	0.54	0.58	2.73	0.79	0.095
Lucy's Warbler (*Vermivora luciae*)	13.80	14.68	13.76	16.03	20.81	1.10	0.04	0.101
Bell's Vireo (*Vireo bellii*)	0.91	1.50	1.22	1.89	2.69	1.27	0.13	0.102
Phainopepla (*Phainopepla nitens*)	0.11	0.10	0.78	0.16	0.64	1.47	0.23	0.113
Yellow-billed Cuckoo (*Coccyzus americanus*)	0.43	0.63	0.78	0.96	1.19	1.28	0.15	0.132
Common Ground-Dove (*Columbina passerina*)	0.08	0.18	0.07	0.54	0.41	1.57	0.31	0.145
Red-winged Blackbird (*Agelaius phoeniceus*)	0.08	0.01	0.16	0.12	0.31	1.71	0.40	0.153
Song Sparrow (*Melospiza melodia*)	1.09	0.80	1.39	3.00	4.18	1.49	0.33	0.209
Turkey Vulture (*Cathartes aura*)	0.51	0.00	3.68	1.37	0.85	1.40	0.31	0.262
Ladder-backed Woodpecker (*Picoides scalaris*)	1.52	1.67	1.62	1.59	2.10	1.06	0.05	0.317
Gila Woodpecker (*Melanerpes uropygialis*)	2.63	2.41	2.47	3.07	2.79	1.04	0.04	0.391
Bullock's Oriole (*Icterus bullockii*)	1.55	1.67	1.56	2.21	1.69	1.05	0.07	0.524
Botteri's Sparrow (*Aimophila botterii*)	1.83	2.61	1.47	4.21	2.40	1.11	0.16	0.539
White-breasted Nuthatch (*Sitta carolinensis*)	1.24	1.72	1.30	1.66	1.50	1.03	0.07	0.669
Decreasing species								
Great Horned Owl (*Bubo virginianus*)	0.43	0.42	0.21	0.47	0.33	0.96	0.00	0.000
Northern Cardinal (*Cardinalis cardinalis*)	0.46	0.20	0.25	0.43	0.25	0.95	0.00	0.000
Killdeer (*Charadrius vociferus*)	1.43	0.67	0.57	0.56	0.50	0.80	0.00	0.000
European Starling (*Sturnus vulgaris*)	0.64	0.72	0.70	0.55	0.21	0.78	0.00	0.000
House Sparrow (*Passer domesticus*)	0.34	0.49	0.38	0.09	0.00	0.51	0.09	0.005
Greater Roadrunner (*Geococcyx californianus*)	0.72	0.43	0.33	0.21	0.26	0.76	0.06	0.013
Eastern Meadowlark (*Sturnella magna*)	1.43	1.52	1.00	1.71	0.80	0.90	0.03	0.028
Black-throated Sparrow (*Amphispiza bilineata*)	1.86	0.91	0.89	0.64	0.76	0.81	0.07	0.048
Verdin (*Auriparus flaviceps*)	0.69	0.79	0.33	0.10	0.34	0.71	0.14	0.110
Red-tailed Hawk (*Buteo jamaicensis*)	0.22	0.17	0.16	0.20	0.09	0.84	0.08	0.124
Cactus Wren (*Campylorhynchus brunneicapillus*)	0.53	0.55	0.40	0.39	0.18	0.78	0.17	0.263
Crissal Thrasher (*Toxostoma crissale*)	0.93	0.44	0.60	0.68	0.44	0.90	0.11	0.403
Cooper's Hawk (*Accipiter cooperii*)	0.26	0.10	0.07	0.16	0.14	0.92	0.09	0.423
Bushtit (*Psaltriparus minimus*)	2.16	1.23	1.85	1.89	1.31	0.94	0.06	0.437
Gambel's Quail (*Callipepla gambelii*)	3.12	2.52	1.28	2.64	1.79	0.90	0.12	0.456
Northern Mockingbird (*Mimus polyglottos*)	1.72	1.34	1.28	1.17	1.05	0.89	0.14	0.488
Western Kingbird (*Tyrannus verticalis*)	2.08	1.52	1.56	1.61	1.70	0.97	0.06	0.571
Northern Flicker (*Colaptes auratus*)	1.83	1.85	1.45	1.77	1.66	0.98	0.06	0.729
Canyon Towhee (*Pipilo fuscus*)	0.52	0.39	0.37	0.51	0.36	0.96	0.13	0.762

**Annual rate of change that produces the observed proportional change in trend lines during 1986–1990.*

Table 3. Bird population trends by species group during the breeding season on the San Pedro Riparian National Conservation Area, Arizona.[a]

		Mean deductions/m								*Number of species that*	
Species group	n	*1986*	*1987*	*1988*	*1989*	*1990*	*Annual change[b]*	*SE*	p	*increased significantly*	*decreased significantly*
All species	61	103	123	133	206	221	1.23	0.02	0.000	26	8
Riparian species	47	81	102	107	175	195	1.26	0.02	0.000	24	3
Mesquite species	38	70	81	85	122	130	1.18	0.02	0.001	13	4
Chihuahuan desert-scrub	21	34	33	37	46	46	1.10	0.03	0.019	6	5
Open-cup nesters	46	73	90	103	169	181	1.28	0.02	0.000	22	6
Cavity nesters	10	25	28	27	32	37	1.09	0.03	0.037	3	2
Understory species	43	65	74	83	129	138	1.23	0.02	0.001	16	7
Midstory species	39	75	92	92	139	152	1.20	0.02	0.001	18	2
Upperstory species	29	55	68	70	108	115	1.21	0.02	0.001	16	2
Insectivores	23	55	69	73	121	134	1.26	0.02	0.000	13	0
Granivores	5	12	13	12	25	26	1.24	0.07	0.031	4	0
Omnivores	24	31	36	41	54	54	1.16	0.02	0.001	6	6
Residents	34	53	52	53	81	84	1.15	0.02	0.001	9	8
Neotropical migrants	38	66	88	99	159	171	1.28	0.02	0.000	20	3

[a] *Cattle were removed in late 1987.*
[b] *Annual rate of change that produces the observed proportional change in trend lines during 1986–1990.*

Discussion

Vegetation

Herbaceous vegetation in riparian and mesquite communities increased greatly (Fig. 2) following removal of cattle. Others have reported similar results from riparian areas (Platts 1991; Fleischner 1994; Ohmart 1994, 1996) and desert grasslands (Gardner 1950; Bock et al. 1984; Brady et al. 1989). However, the responses in our study were both quicker and larger than expected, particularly in the mesquite grassland sites. Responses were quickest and most pronounced in the lower vegetation layers, as would be expected based on their accessibility to grazing cattle. The Chihuahuan desert-scrub sites showed no significant increase in vegetation during the study period, although increases may eventually occur (Blydenstein et al. 1957; Webb & Stielstra 1979).

Birds

Birds are affected by habitat structure, floristics, and vegetation volume (Willson 1974; James & Wamer 1982; Anderson et al. 1983; Cody 1985; Mills et al. 1991) and are known to respond to changes in habitat quality and quantity (Furness & Greenwood 1993). Thus, it was not surprising that populations in our study increased rapidly following the removal of cattle.

Recently, Saab et al. (1995) and Tewksbury et al. (2002) reviewed the effects of cattle on birds in western North America. Among 68 species of Neotropical migrants, 46% decreased in abundance with cattle grazing, 29% increased, and 25% showed no clear response (Saab et al. 1995). In our study, the corresponding values for significant population trends among all species were 53%, 8%, and 39%. Of the species that occurred along the major riparian systems reviewed by Tewksbury et al. (2002), 63% were less abundant in grazed locations and none were less abundant in ungrazed locations. Saab et al. (1995) and Tewksbury et al. (2002) found that open-nesting species are more affected by cattle than are cavity nesters, similar to what occurred in our study. Although cavity nesters also increased significantly in our study, it is unlikely that sufficient time had elapsed to allow an increase in the abundance of cavities. Thus, the increase in cavity nesters suggests that cavities are not strictly limiting the abundance of cavity-nesting species, and that food, cover, or both are also important and increased after removal of cattle.

Saab et al. (1995) found that ground-nesting species are most affected by cattle grazing, followed by shrub-nesting and canopy-nesting species. Tewksbury et al. (2002) also found that species nesting below 2.5 m are less abundant in grazed than ungrazed sites. Species nesting above 5 m showed a nonsignificant trend toward being less abundant in grazed sites. In our study, understory, midstory, and upperstory groups (classified on the basis of foraging height rather than nest height) increased at significant and similar rates. The increase by canopy species was somewhat unexpected. We suspect that removal of cattle led to increased food abundance in the lower vegetation layers and that canopy species foraged at these lower levels often enough to benefit substantially. Mobile prey, dependent on the lower vegetation, also may have moved up into the higher vegetative layers.

Saab et al. (1995) analyzed differences for seven foraging guilds and found a significant difference only for ground insectivores, which were more abundant on the grazed sites. We found that insectivores, granivores, and omnivores all increased at significant rates following the

removal of cattle, with insectivores showing the strongest response. Saab et al. (1995) and Tewksbury et al. (2002) reported that long-distance migrants appeared more susceptible to the effects of cattle grazing than did short-distance migrants. This is consistent with our finding that Neotropical migrants increased at a greater rate than residents. Resident species, however, also showed a highly significant increase in our study.

Among the 43 species whose abundance Saab et al. (1995) compared on grazed and ungrazed sites, 14 occurred in our study. Species that Saab et al. (1995) found to be more abundant on ungrazed sites and that also occurred in our study included the Western Wood-Pewee, Common Yellowthroat, Song Sparrow, Red-winged Blackbird, Northern Oriole (Bullock's Oriole), and Northern Flicker. In our study, the first two of these increased significantly, the next three did not increase significantly, and the last showed a nonsignificant decrease following the removal of cattle. Thus, our results are largely consistent with those of Saab et al. (1995).

Hunter et al. (1987) documented changes in riparian bird densities following an extreme flooding episode that severely reduced foliage density in all vertical vegetative layers. These changes may be similar to the effects of intense cattle grazing. Breeding species in Hunter et al. (1987) that decreased significantly were the Yellow-billed Cuckoo, Gila Woodpecker, Summer Tanager, Ladder-backed Woodpecker, Northern Flicker, Abert's Towhee, Northern (Bullock's) Oriole, Mourning Dove, and Verdin. Our results are consistent with those of Hunter et al. (1987) for all species except the Northern Flicker and Verdin, which decreased, but not significantly, with the removal of cattle.

Management Implications

Our general finding was that removal of cattle was followed by increases in all groups of birds we analyzed. The increasing species included several species of special concern in the region. Hunter et al. (1987) identified 17 southwestern riparian birds that have declined or have been extirpated from major river systems since 1900. Eleven of these occurred frequently enough in this study to allow analysis of population trends. Six species (Brown-crested Flycatcher, Vermilion Flycatcher, Yellow Warbler, Summer Tanager, Hooded Oriole, and Yellow-breasted Chat) increased significantly following the removal of cattle, and three others (Yellow-billed Cuckoo, Gila Woodpecker, and Bell's Vireo) showed nonsignificant increases.

Four species (Abert's Towhee, Cassin's Kingbird, Hooded Oriole, and Northern Beardless-Tyrannulet) of concern to Partners in Flight in the Sierra Madre Occidental region (Latta et al. 1999) increased significantly. Six other species of concern (Bell's Vireo, Black-chinned Hummingbird, Botteri's Sparrow, Gila Woodpecker, Lucy's Warbler, and Phainopepla) showed increases that were not significant.

The removal of cattle from the San Pedro River NCA thus led to rapid and substantial recovery of riparian and mesquite vegetation and bird populations, including several species of high conservation concern. The speed, magnitude, and extent of the recovery was surprising and suggests that even severely degraded systems can recover quickly, in at least some cases, after cattle removal. We suggest that removal of cattle from riparian habitats might be of similar value in conserving biodiversity and species of special concern in many locations of the arid southwest.

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