Effects of Gas-Well-Compressor Noise on the Ability to Detect Birds during Surveys in Northwest New Mexico

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CHAPTER 7

EFFECTS OF GAS-WELL-COMPRESSOR NOISE ON THE ABILITY TO DETECT BIRDS DURING SURVEYS IN NORTHWEST NEW MEXICO

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Abstract.—We used three site types to address whether noise from gas well compressors interfered with our ability to detect birds in the Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico: (1) gas wells without compressors (control), (2) gas wells with compressors turned off only during surveys (T-off), and (3) gas wells with compressors running during the surveys (T-on). We conducted 571 bird surveys at 294 point-count locations, which were 50–150 m from gas well pads. We measured sound pressure levels (SPLs) at point locations: control mean = 38.6 ± 3.0 (SD) dB(A); T-off mean = 55.0 ± 5.2 dB(A), measured with compressors on; and T-on mean = 52.7 ± 4.5 dB(A). We observed significant differences in species richness, individual abundance, and bird diversity among site types; the differences existed between control and T-on sites and between T-off and T-on sites, but not between control and T-off sites. Species richness, individual abundance, and species diversity were all significantly and negatively influenced by SPL values. A significantly higher proportion of birds were detected on T-off sites compared with T-on sites for 13 species; this compares with only one species that was detected more at T-on sites than at T-off sites. Our results strongly suggest that noise emitted from gas well compressors significantly impaired our ability to detect birds. We determined that the detection threshold is ~45 dB(A), beyond which noise impairs human ability to detect birds within 60 m. These results are relevant to bird surveys in areas where natural and anthropogenic noise may negatively bias detections.

Key words: bird surveys, compressor noise, detection, gas wells, New Mexico.

Efectos de los Compresores de Pozos de Gas Natural en la Habilidad de Detectar Aves durante Censos en el Noreste de Nuevo México

Resumen.—Usamos tres tipos de localidad para determinar si el ruido de los compresores de pozos de gas natural interfiere con nuestra habilidad de detectar aves en el Área de Administración del Hábitat de Rattlesnake Canyon, condado de San Juan, Nuevo México: (1) pozos de gas sin compresores (control), (2) pozos de gas con compresores apagados sólo durante los censos (T-off), y (3) pozos de gas con compresores encendidos durante los censos (T-on). Hicimos 571 censos de aves en 294 localidades de puntos de conteo, que se ubicaron entre 50 y 150 m de las plataformas de pozos de gas. Medimos los niveles de presión del sonido (NPSs) en los puntos de conteo: media del control = 38.6 ± 3.0 (DE) dB(A); media de T-off = 55.0 ± 5.2 dB(A), medida con los compresores encendidos; media de T-on = 52.7 ± 4.5 dB(A). Observamos

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diferencias significativas en riqueza de especies, abundancia individual y diversidad de aves entre los tipos de localidad; las diferencias existieron entre el control y los titios T-on, y entre los sitios T-off y T-on, pero no entre el control y los sitios T-off. La riqueza de especies, la abundancia individual y la diversidad de especies estuvieron significativa y negativamente influenciadas por los valores de NPS. Una proporción significativamente mayor de aves de 13 especies fue detectada en los sitios T-off que en los sitios T-on; esto se compara con que sólo una especie fue más detectada en los sitios T-on que en los T-off. Nuestros resultados sugieren fuertemente que el ruido emitido por los compresores de pozos de gas natural afecta significativamente nuestra habilidad para detectar aves. Determinamos que el umbral de detección es cercano a 45 dB(A), por encima del cual el ruido afecta la habilidad humana para detectar aves dentro de un radio de 60 m. Estos resultados son relevantes para los censos de aves en sitios donde el ruido natural y antropogénico podrían sesgar negativamente la detección de los individuos.

Bird surveys are conducted for numerous reasons, including investigation of bird–habitat relationships (Griffis-Kyle and Beier 2005, Shirley 2005, Riffell et al. 2006), effects of habitat disturbance or changes in land-use patterns (Yamaura et al. 2007), and response to land treatments (Barbaro et al. 2005), and to monitor populations over time (Holmes and Sherry 2001, Knutson et al. 2006). Results from bird surveys are used widely for making management decisions (Madden et al. 2000), even though it is generally recognized that abundance does not necessarily indicate the overall quality of a habitat (Johnson and Temple 1986, Madden et al. 2000). Surveys are also almost always incomplete and subject to biases, which can result in overestimation or underestimation of populations (Thompson 2002).

Over the past couple decades, numerous methods have been used instead of, or in addition to, the more classic approach of circular or variable circular point counts (Reynolds et al. 1980). The more recent methods are promoted for their ability to determine detection probabilities: double sampling (Cochran 1977), double-observer sampling (Cook and Jacobson 1979, Nichols et al. 2000), distance sampling (Burnham et al. 1980, Buckland et al. 1993, Rosenstock et al. 2002), and occupancy (Royle and Nichols 2003, MacKenzie and Royle 2005). Although these methods are not "perfect," detection probabilities allow for adjustments to be made to density, occupancy, or other population estimates.

Additional challenges to bird surveys include interference with our ability to detect individuals due to environmental factors, such as habitat or topographic features, fragmentation, developments, outdoor pets, foot and road traffic, aircraft, and anthropogenic noise (hereafter "noise"). The effects of the latter on ecological communities have been particularly difficult to gauge. It is often challenging, if not impossible, to isolate noise as a single testable variable because noise, itself, is usually confounded by other variables that are associated with noise. For example, studies on the effect of human noise (talking, laughing, etc.) are confounded with disturbance caused by physical presence of people (Burger and Gochfeld 1998) and with foraging opportunities provided by people (Fernández-Juricic 2001). Similarly, studies on the effects of road or highway noise (Brotons and Herrando 2001) are often confounded with effects of habitat fragmentation caused by the roads themselves, and by the visual disturbance of moving vehicles.

To our knowledge, all previous studies that involved isolation of noise as a single variable have experimentally added noise through loudspeakers (Simons et al. 2007, Pacifici et al. 2008) to the environment rather than turning off noise that is regularly present. Simons et al. (2007) and Pacifici et al. (2008) found that detection probabilities varied greatly in survey experiments that used recorded birdsongs with and without added background noise. Simons et al. (2007) found that detection probabilities decreased with increased noise, and they cited another researcher's finding that detection increased with age and experience of the observer before dropping off after the age of 65. In Pacifici et al.'s (2008) study, within 100 m, detection probabilities ranged from zero to 1, depending on species, habitat, and observer as well as noise.

Noise is considered a form of pollution and has been increasing over this and the previous century (for a detailed review, see Ortega 2012). Although noise pollution is a difficult problem to study, there is an urgent need to increase our understanding of its effects on wildlife and other aspects of the environment, including how noise may influence bird surveys and other field methods. Compared with noise from other sources, noise from gas well compressors offers a unique opportunity to study the effects of noise without other complications, for several reasons: (1) compressors can be turned off and on; (2) ecological communities that surround gas wells with compressors can be compared with those that surround gas wells that do not have compressors; and (3) habitats that surround gas wells with and without compressors are often unconfounded by other variables, such as potential differences in well pad size, vegetative structure, and various other disturbances (Francis et al. 2009).

Here, we address whether noise from gas well compressors interfered with our ability to detect birds in terms of species richness, diversity, and abundance. We conducted bird surveys with the standard distance-sampling protocol (Thomas et al. 2006) at gas wells without compressors, gas wells with compressors turned off only during surveys, and gas wells with compressors running during surveys. Specifically, we tested the null hypothesis that there would be no significant differences in abundance, diversity, or density of birds among the three site types.

Study Area and Methods

The study was conducted in the Rattlesnake Canyon Habitat Management Area (RCHMA), San Juan County, New Mexico. The RCHMA consists of 44,580 ha and is part of the San Juan Basin, one of the most extensively developed energy-producing regions in the contiguous United States with ~18,000 active oil and gas wells (Bureau of Land Management [BLM] 2003). The RCHMA is managed by the BLM and is dominated by piñon–juniper (*Pinus edulis–Juniperus osteosperma*) forests and open Big Sagebrush (*Artemisia tridentata*) grasslands.

From 21 May through 4 July 2007, we conducted bird surveys at 18 sites consisting of three site types: (1) gas wells without compressors (control; $n = 8$ sites), (2) gas wells with compressors that were turned off during our surveys (T-off; $n = 5$ sites), and (3) gas wells with compressors that were not turned off during our surveys (T-on; $n = 5$ sites). Other than the compressors being shut off during our surveys and for occasional maintenance, they were in operation 24 h day^{-1}, 7 days week^{-1}. Between two concentric circles around each well pad (one 50 m and one 150 m from the compressor exhaust pipe for T-off and T-on sites and from the well head for control sites), we selected 294 random points, using the random point generator in a geographic information system (GIS). The numbers of random points on most sites were 16 or 17. We chose 50 m to avoid the well pads and 150 m to retain the effects of high-amplitude compressor noise.

Each point served as a point-count location, and most were visited twice during the study. At each point-count location, we conducted a 7-min bird survey; all surveys were completed before noon. We identified to species each bird seen or heard, and for each bird we recorded (1) distance with a range finder from the point-count location when first detected; (2) distance from the point-count location if the bird came closer to the point-count location than where first detected; (3) compass bearing from the point-count location; (4) type of detection (aural or visual); and (5) sex, when possible. Additionally, we collected the following data for each point-count location: start time and date for each survey, and sound pressure level (SPL; described below).

We took SPL measurements at most point-count locations, measured with both A- and C-weighting–scale with a Casella convertible sound dosimeter–sound pressure level meter (model CEL 320 and CEL 1002 converter; measures 30–140 dB). The SPL meters were certified with National Institute for Standards and Technology traceable certification. We used 95-mm acoustic windscreens, and we measured SPL only when wind conditions were below category 3 ($\approx$ 13–18 km h^{-1}) on the Beaufort Wind Scale. Here, we focus on the A scale, because it weights frequencies according to human hearing ability. We provide the SPLs for the site types on the C scale only for reference, and we do not consider the C scale in other analyses. In order to compare SPL at T-off sites with both the control and T-on sites, all point-count locations on T-off sites were measured for sound with compressors running on a separate day from point-count surveys.

Although data were collected in the field, using the sampling protocol in DISTANCE, version 5.0 (Thomas et al. 2006), the methods also allow for analysis using index sampling (or a fixed radius) by truncating all observations beyond a selected distance. We selected 60 m as a fixed radius because the habitat was relatively open, and we were confident that most birds were detected within this distance. Therefore, for determining species richness, abundance, and species diversity, we truncated all observations at 60 m from the point-count location, using the closest distance from which each individual was detected. We used the Shannon-Weiner Index to determine bird diversity, rescaled to be proportional to species richness (e^H; Ricklefs 1979). For species with adequate sample size of detections (≥40 detections), we used DISTANCE to determine density, using the first distance each bird was observed from. In DISTANCE, we truncated observation distances where necessary to obtain half normal distributions. We compared density among and between sites with the program CONTRAST (see Acknowledgments). We used chi-squared goodness-of-fit tests for contingency tables. To test for differences in mean SPL values and observed abundance, richness, and diversity (e^H) among treatment types (control, T-off, T-on), we used linear mixed-effect models (LMERs) with the nlme package and Tukey's post hoc tests in the program R (R Core Development Team 2009). We modeled each response variable with treatment type as a fixed effect and gas well site as a random effect. To determine how background noise conditions during surveys influenced detections, we used LMERs to model each response variable with point-count location SPL treated as a fixed effect and gas well site as a random effect, using data only from point-count locations on control and T-on sites because compressors were turned off during surveys on T-off sites. We considered $P < 0.05$ significant. Means are presented ± SD and all parameter estimates are presented ± SE. Scientific names of species are given in the Appendix.

Results

Mean SPL values were significantly influenced by site type on both the A and C scales. The SPL values were significantly lower at control-site point-count locations than at T-on or T-off point-count locations when compressors were on, but SPL values at point-count locations on T-on and T-off (when compressors were on) did not differ significantly (Table 1 and Fig. 1).

Results from our linear mixed-effect models suggested that species richness, individual

Table 1. Mean (± SD) and range of sound pressure levels (dB on the A scale and C scale) at bird survey locations 50–150 m from gas wells without compressors (control sites), gas wells with compressors turned off during surveys (T-off), and gas wells with compressors running during surveys (T-on), at Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico, 2007. Sound pressure level (SPL) measurements at T-off sites were taken with or without compressors running.

Site type	Mean ± SD	Range	*P*	χ^2 [a]
(A) Survey results				
SPL (dB[A] scale)				
Control (n = 128)	38.6 ± 2.7	33.1–46.6	<0.001	52.371
T-off with compressors on (n = 80)	55.0 ± 5.2	43.4–65.5		
T-on (n = 80)	52.7 ± 4.5	44.0–62.3		
SPL (dB[C] scale)				
Control (n = 128)	55.6 ± 3.0	48.7–69.2	<0.001	50.981
T-off with compressors on (n = 80)	75.0 ± 4.7	63.4–86.2		
T-on (n = 80)	71.3 ± 4.6	62.6–84.9		
	P			
(B) Post hoc Tukey test results				
SPL (dB[A] scale)				
Control vs. T-off with compressors on	<0.001			
Control vs. T-on	<0.001			
T-off with compressors on vs. T-on	0.207			
SPL (dB[C] scale)				
Control vs. T-off with compressors on	<0.001			
Control vs. T-on	<0.001			
T-off with compressors on vs. T-on	0.062			

[a] Likelihood ratio test (df = 2).

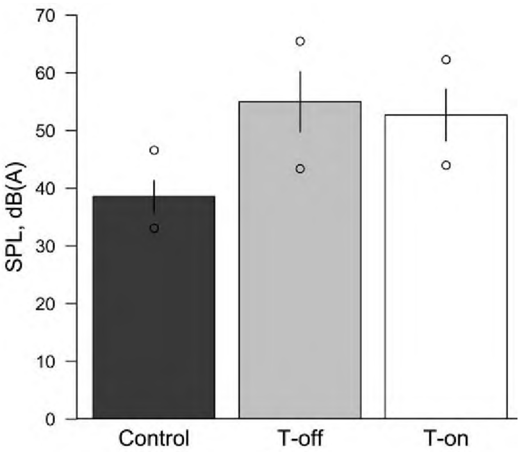

FIG. 1. Means (± SD) and ranges of sound pressure levels (SPL; A-weighted decibels) at sites without compressors (control), at sites with compressors turned off during surveys but with SPL measurements taken while compressors were running (T-off), and at sites with compressors running during surveys and SPL measurements (T-on), at Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico, 2007. Open circles denote the minimum and maximum SPL values measured at point-count locations for each site type.

abundance, and species diversity differed among site types (Table 2). Specifically, differences existed between control and T-on sites and between T-off and T-on sites, but not between control and T-off sites (Table 2). This strongly suggests that the noise generated by compressors significantly interfered with our ability to detect birds. We also noted differences among site types regarding how we detected birds; 15.3% and 17.1% of detections on control and T-off sites, respectively, were visual only (as opposed to aural and aural plus visual), whereas 34.6% of detections on T-on sites were visual only ($\chi^2 = 125.562$, df = 2, $P < 0.001$).

Excluding T-off survey locations to exclude those data where SPL values were not representative of acoustic conditions during surveys, mean individual abundance, species richness, and species diversity were significantly and negatively influenced by SPL (abundance, $\beta_{SPL} = -0.19 \pm 0.03$, $t = -5.68$, $P < 0.001$, $n = 208$; species richness, $\beta_{SPL} = -0.12 \pm 0.02$, $t = -5.83$, $P < 0.001$, $n = 208$; diversity, $\beta_{SPL} = -0.10 \pm 0.02$, $t = -5.80$, $P < 0.001$, $n = 208$; Fig. 2).

Upon examining these trends over smaller ranges of SPL values, we found no relationship between SPL and mean individual abundance ($\beta_{SPL} = 0.05 \pm 0.09$, $t = 0.60$, $P = 0.552$, $n = 128$), species richness ($\beta_{SPL} = 0.02 \pm 0.05$, $t = 0.42$, $P = 0.673$, $n = 128$), and diversity ($\beta_{SPL} = 0.00 \pm 0.04$, $t = 0.05$, $P = 0.960$, $n = 128$) below or at 45 dB(A). Yet above 45 dB(A), mean individual abundance ($\beta_{SPL} = -0.21 \pm 0.05$, $t = -3.82$, $P < 0.001$, $n = 80$), species richness ($\beta_{SPL} = -0.13 \pm 0.03$, $t = -3.65$, $P < 0.001$, $n = 80$), and diversity ($\beta_{SPL} = -0.10 \pm 0.03$, $t = -3.27$, $P = 0.002$, $n = 80$) all declined with increases in SPL. When data from point-count locations were binned within ranges of 5 dB(A) above and below 45 dB(A) (40.1 ≤ 45 and 45.1 ≤ 50 dB[A]), there was an apparent difference in mean species richness ($\beta_{<45} = 1.86 \pm 0.39$, $t = 4.73$, $P < 0.001$, $n = 63$), abundance ($\beta_{<45} = 3.56 \pm 0.71$, $t = 4.99$, $P < 0.001$, $n = 63$), and diversity ($\beta_{<45} = 1.30 \pm 0.36$, $t = 3.57$, $P < 0.001$, $n = 63$; Fig. 3). On the basis of these relationships over smaller SPL ranges and the difference in mean species richness, individual abundance, and diversity above and below 45 dB(A), we determined that the detection threshold is ~45 dB(A), where SPLs above this impair human ability to hear birds within 60 m (Fig. 3).

Distance analysis revealed some differences in bird densities among sites (Table 3). Violet-green Swallows required truncation at 80 m on the control sites in order to obtain a half normal distribution; distances for all other species were not truncated. Violet-green Swallows were detected at significantly higher density on T-on sites than on control sites ($\chi^2 = 5.149$, df = 1, $P = 0.023$; CONTRAST). Chipping Sparrows were detected at significantly higher density on T-on sites than on control sites and T-off sites ($\chi^2 = 5.478$, df = 1, $P = 0.019$ and $\chi^2 = 10.050$, df = 1, $P = 0.002$, respectively; CONTRAST). House Finches were detected at significantly lower density on control sites than on T-off sites ($\chi^2 = 4.204$, df = 1, $P = 0.040$) and T-on sites ($\chi^2 = 8.407$, df = 1, $P = 0.004$; CONTRAST). Spotted Towhees were detected at significantly higher density on the control and T-off sites than on the T-on sites ($\chi^2 = 12.590$, df = 1, $P = 0.000$ and $\chi^2 = 6.675$, df = 1, $P = 0.010$, respectively; CONTRAST). Ash-throated Flycatchers were detected at a marginally significant higher density on T-off sites than on T-on sites ($\chi^2 = 3.572$, $P = 0.059$).

At all site types, more Chipping Sparrows were heard only than seen only, but at the T-on sites 55% (70/128) of detections were aural only, whereas on the control and T-off sites 73% (169/231) and 82% (115/140) of the detections were aural only, respectively. Correcting for survey sample size (see Appendix), we observed no

TABLE 2. Mean (± SD) species richness, individual abundance, and species diversity within 60 m of point-count locations among three site types—controls, treatments with compressors turned off during surveys (T-off), and treatments with compressors running during surveys (T-on)—at Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico, 2007.

Site type	Mean ± SD	Range	*P*	$\chi^{2\,a}$
(A) Survey results				
Species richness				
Control (266 surveys, 128 plots)	5.4 ± 1.4	2.5–9.0	<0.001	28.595
T-off (152 surveys, 80 plots)	5.5 ± 1.5	1.7–9.0		
T-on (153 surveys, 80 plots)	2.9 ± 1.4	0–6.0		
Abundance				
Control (266 surveys, 128 plots)	7.8 ± 2.6	2.5–16	<0.001	28.407
T-off (152 surveys, 80 plots)	7.6 ± 2.3	3.0–13.0		
T-on (153 surveys, 80 plots)	4.0 ± 2.2	0–12.0		
Diversity (e^H)				
Control (266 surveys, 128 plots)	4.9 ± 1.3	2.5–8.5	<0.001	27.698
T-off (152 surveys, 80 plots)	5.1 ± 1.4	1.9–8.5		
T-on (153 surveys, 80 plots)	2.8 ± 1.2	0–6.0		
	P			
(B) Post hoc Tukey test results				
Site type				
Species richness				
Control vs. T-off	0.928			
Control vs. T-on	<0.001			
T-off vs. T-on	<0.001			
Abundance				
Control vs. T-off	0.896			
Control vs. T-on	<0.001			
T-off vs. T-on	<0.001			
Diversity (e^H)				
Control vs. T-off	0.789			
Control vs. T-on	<0.001			
T-off vs. T-on	<0.001			

[a]Likelihood ratio test (df = 2).

difference in the proportion of aural-only detections of Chipping Sparrows between control and T-off sites, but a significantly lower proportion of Chipping Sparrows were detected aurally only at T-off sites than at T-on sites ($\chi^2 = 11.243$, $P < 0.005$). The majority of Violet-green Swallow detections (not truncated for distance) on all site types were visual only, and we found no difference among site types (77% at T-on sites, $n = 57$ detections; 62% at control sites, $n = 55$ detections; 62% on T-off sites, $n = 64$ detections).

A significantly higher proportion of birds were detected on T-off sites than on T-on sites for 13 species (Appendix). Only Lark Sparrows were detected at a significantly higher proportion on T-on sites than on T-off sites (Appendix).

DISCUSSION

C-weighted SPL measurements were consistently higher than those on the A scale. This suggests that much of the noise was low-frequency noise (Ortega 2012), yet the frequency composition of the noise on treatment sites had considerable energy extending to and above 5.0 kHz (see Francis et al. 2009: fig. S2). This frequency range is well within the range of human hearing (Dooling and Popper 2007) and overlaps considerably with the frequency range used by many birds (Patricelli and Blickley 2006, Slabbekoorn and Ripmeester 2008). High amplitudes of compressor noise within this frequency range significantly impaired our ability to detect birds on T-on sites.

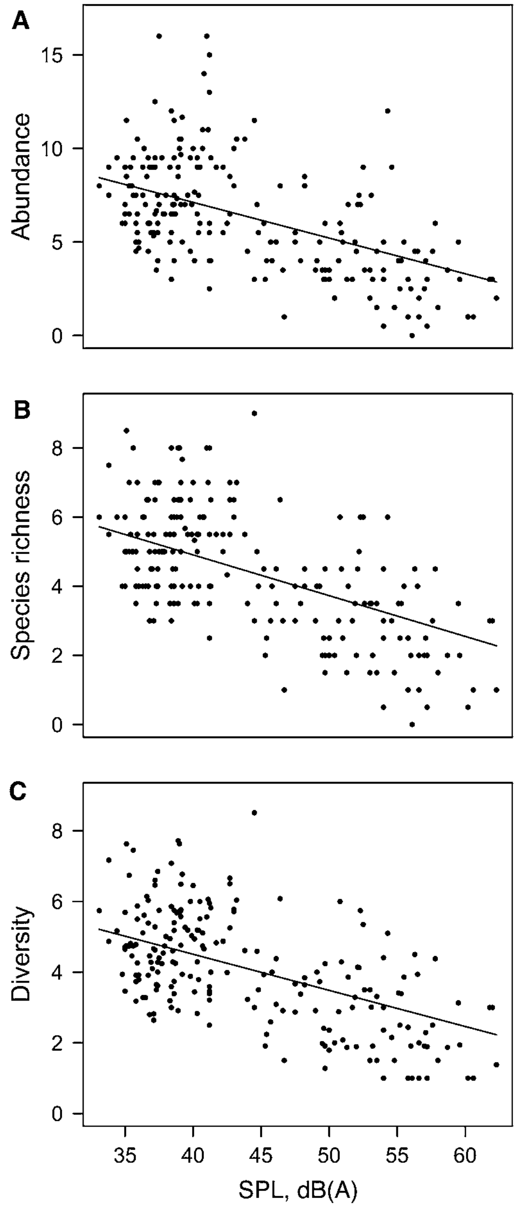

FIG. 2. (A) Mean individual abundance, (B) species richness, and (C) diversity within 60 m of point-count locations for all control sites and treatment sites with compressors turned on during surveys at Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico, 2007. Point-count locations were 50–150 m from gas wells, plotted with sound pressure levels (SPL; A-weighted decibels). Trend lines reflect estimates from linear mixed-effect models with SPL as a fixed factor and gas well site as a random factor.

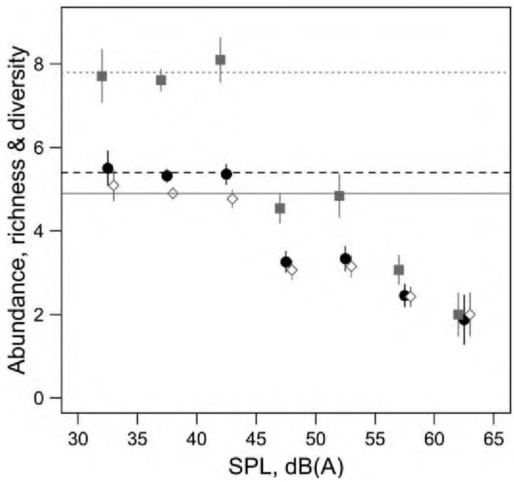

FIG. 3. Mean avian individual abundance, species richness, and diversity within 5 dB sound-pressure-level bins (e.g., 30.1 ≤ 35, 35.1 ≤ 40) at control and treatment site types, Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico, 2007. Gray squares denote abundance, black circles represent species richness, and white diamonds denote species diversity (e^H). Error bars represent standard error of the mean. The horizontal lines represent mean species richness (black long-dashed line), individual abundance (gray short-dashed line), and species diversity (gray solid line) at control sites (see Table 2).

In a previous nesting study (Francis et al. 2009), we noted differences in bird community composition in terms of nests between control sites and treatment sites (both T-off and T-on), and these differences must also be considered in the interpretation of detection differences during surveys. Mourning Dove nests were significantly more abundant on control sites, whereas Black-chinned Hummingbird and House Finch nests were significantly more common on sites with compressors (Francis et al. 2009). In the present study, we found a significantly lower density of House Finches on control sites, which supports our previous findings. Also supporting our previous findings in the nest study, we found a higher proportion of Mourning Doves and a lower proportion of Black-chinned Hummingbirds on control sites than on T-off sites.

Violet-green Swallows were detected at 31% (47/152) of T-off sites and 31% (48/153) of T-on sites (Appendix). However, we found Violet-green Swallows and Chipping Sparrows at higher densities at

TABLE 3. Densities of birds (individuals ha^{-1} ± SE; n = number of detections) on three site types—gas wells without compressors (controls; 266 surveys), treatments with compressors turned off during surveys (T-off; 152 surveys), and treatments with compressors running during surveys (T-on; 153 surveys)—at Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico, 2007. See Appendix for scientific names of species.

Species	Control	T-off	T-on
Gray Flycatcher	0.084 ± 0.015, n = 170	0.060 ± 0.018, n = 103	n =41 [a]
Ash-throated Flycatcher	0.036 ± 0.005, n = 212	0.053 ± 0.013, n = 126	0.022 ± 0.010, n = 42
Gray Vireo	0.021 ± 0.004, n = 142	0.026 ± 0.006, n = 110	n = 21 [b]
Violet-green Swallow	0.020 ± 0.010, n = 49	0.031 ± 0.014, n = 61	0.079 ± 0.024, n = 57
Juniper Titmouse	0.060 ± 0.015, n = 102	0.041 ± 0.017, n = 76	0.033 ± 0.012, n = 36
Bewick's Wren	0.018 ± 0.003, n = 155	0.016 ± 0.003, n = 119	n = 51 [a]
Spotted Towhee	0.099 ± 0.015, n = 467	0.079 ± 0.014, n = 256	0.033 ± 0.011, n = 58
Chipping Sparrow	0.122 ± 0.020, n = 245	0.084 ± 0.019, n = 140	0.233 ± 0.043, n = 129
House Finch	0.017 ± 0.004, n = 100	0.041 ± 0.011, n = 113	0.075 ± 0.019, n = 83

[a] Could not fit to half normal distribution.
[b] Sample size too low for DISTANCE analysis.

T-on sites. Neither species differed significantly in the proportion detected between T-off and T-on sites (see Appendix). Violet-green Swallows were most easily detected visually at all sites; therefore, aural cues may not have been as important.

Chipping Sparrows were detected during 81% (215/266) of surveys on control sites, 78% (119/152) of surveys on T-off sites, and 81% (124/153) of surveys on T-on sites (Appendix). With the same effort put into nest searching at both site types during the nest study, we found no significant difference between the numbers of Chipping Sparrow nests on control (n = 42 nests, 59.2%) and treatment sites (n = 29 nests, 40.8%, C. P. Ortega unpubl. data). The proportion of Chipping Sparrows detected during surveys at all three site types was equivalent (Appendix), yet Chipping Sparrows were detected at higher densities on T-on sites than on control and T-off sites. We do not know why we observed a higher density of Chipping Sparrows in the presence of noise, but perhaps the compressor noise may have masked our sounds to their ears, making them less wary, and perhaps our ability to detect their high trills and sharp chips (Middleton 1998) was unimpaired by the compressors.

In the nest study at the same sites, we found no significant difference between the numbers of Spotted Towhee nests on control (n = 15 nests, 45.5%) and on treatment sites (n = 18 nests, 54.5%; C. P. Ortega unpubl. data). However, Spotted Towhees nested significantly farther from gas well pads with compressors than from gas well pads without compressors (Francis et al. 2009). In the present study, we found the highest proportion of Spotted Towhees on control sites and the lowest proportion on T-on sites. Although Spotted Towhees were most abundant on control sites, we detected fewer of them on T-on sites than on T-off sites, which suggests that our ability to detect them was impaired by compressor noise. A total of 13 species followed this same pattern (see Appendix).

We considered the possibility that when compressors were turned off, birds may have moved closer to the well pad, increasing the density of birds on the T-off sites. We do not believe this occurred, because (1) our surveys occurred during the breeding season, when most birds have established home ranges and territories based on their selection during usual conditions; and (2) the birds detected on T-off sites followed the same pattern as would be predicted from the nest study at the same sites.

The results of the present study have implications for many studies using bird surveys. Noise exceeding ~45 dB(A) impaired our ability to detect many birds, and it is likely that other studies at sites reaching or exceeding this SPL underestimate individual numbers as well as number of species. To put 45 dB(A) in perspective, a typical library has a background noise level of ~50 dB(A), and normal conversation speech is ~60 dB(A) (Timerson 1999). However, it appears that a lower background noise level is required to hear and confidently identify many species of birds by vocalization.

In some studies, comparisons are made between or among landscape-use patterns that differ in noise conditions, such as effects of fragmentation associated with roads or other noisy land uses (Cornelius et al. 2000, Forman and Deblinger 2000, Brotons and Herrando 2001, Gutzwiller and Barrow 2003), urban sprawl (DeGraaf et al. 1991, Rottenborn 1999, Hennings and Edge 2003, Slabbekoorn and Peet 2003, Wood and Yezerinac 2006), military activities (Doresky et al. 2001), and energy development (Bayne et al. 2008, Francis et al. 2009). In other studies, natural noise, such as from waterfalls or streams, likely impaired the ability to detect birds (Simons et al. 2006).

Riparian areas are particularly important for birds, as exemplified by ≥77% of all birds in the arid southwest United States relying on riparian areas for at least part of the year (Johnson and Temple 1986). Therefore, many bird surveys are conducted along streams (Rottenborn 1999, Whitaker and Montevecchi 1999, Bryce et al 2002, Hennings and Edge 2003, Lussier et al. 2006), yet the noise of streams likely limits observer abilities to detect birds. This may be particularly pronounced with narrow streams on steep gradients with large boulders and woody debris that dissipate the energy of water with noise amplitudes reaching or exceeding 45 dB(A).

The Breeding Bird Survey (BBS) is another well-cited and important long-term survey effort that is conducted throughout the United States and parts of Canada and Mexico along roads that have varying levels of traffic noise. The sound pressure levels along many BBS routes, measured in North Carolina, are above the 45 dB(A) threshold level that we found (see Simons et al. 2009: fig. 6). When Simons et al. (2009) experimentally increased noise in a simulated study from 40 dB(A) to 50 dB(A), the average detection rates dropped by 42% for six species common to North Carolina. The observed population declines of many North American species survey-wide since the establishment of BBS in 1966 may be confounded by traffic noise, which has undoubtedly increased along many survey routes since 1966.

Usually, there is little that researchers can do to reduce noise in the environment or to address the confounding variables that accompany most noise sources. Some techniques for analyzing survey data, such as double-observer sampling (Cook and Jacobson 1979, Nichols et al. 2000), distance sampling (Burnham et al. 1980, Buckland et al. 1993, Rosenstock et al. 2002), and occupancy (Royle and Nichols 2003, MacKenzie and Royle 2005), may be useful for comparing detection probabilities between or among site types, but even these methods do not correct for the problem of a species being present but undetected during all survey efforts.

There are, however, other methods to address the shortcomings of bird surveys in noisy areas. It may take a combination of nest studies, netting, and banding (Ralph and Dunn 2004), in addition to point-count or transect surveys, to obtain a more accurate account of bird communities in noisy areas. By using a combination of surveys and nest studies, species-specific differences may be revealed and further investigated. For example, in Alberta, Canada, Habib et al. (2007) found that male Ovenbirds (*Seiurus aurocapilla*) near gas-well-compressor stations experienced significantly reduced pairing success, and inexperienced individuals were more abundant at these noisier sites than at gas wells without compressors. A similar pattern of reduced pairing success in noisy areas was found for Reed Buntings (*Emberiza schoeniclus*; Gross et al. 2010). If a survey that controls for the influence of noise on detections reveals no differences between sites that vary in noise levels, yet a nest study at the same sites (and also controlling for the influence of noise on nest detections) demonstrates significantly fewer nests in noisier areas, it could be that noise masks the songs of territorial males, resulting in unsuccessful pairing attempts (i.e., fewer nests).

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APPENDIX. Number of detections within 60 m of point-count locations for each species on three site types—gas wells without compressors (controls), treatments with compressors turned off during surveys (T-off), and treatments with compressors running during surveys (T-on)—at Rattlesnake Canyon Habitat Management Area, San Juan County, New Mexico, 2007 (n = number of surveys).

	Control	T-off	T-on	Control vs. T-off [a]		T-off vs. T-on [b]	
Species	(n = 266)	(n = 152)	(n = 153)	P	χ^2	P	χ^2
Wild Turkey (*Meleagris gallopavo*)	7	0	0				
Gambel's Quail (*Callipepla gambelii*)	0	1	0				
Turkey Vulture (*Cathartes aura*)	6	5	0				
Red-tailed Hawk (*Buteo jamaicensis*)	0	1	2				
Mourning Dove (*Zenaida macroura*)	63	14	11	<0.001	11.000		
Great Horned Owl (*Bubo virginianus*)	2	1	0				
Common Nighthawk (*Chordeiles minor*)	1	0	0				
Common Poorwill (*Phalaenoptilus nuttallii*)	1	0	0				
White-throated Swift (*Aeronautes saxatalis*)	0	1	0				
Black-chinned Hummingbird (*Archilochus alexandri*)	16	26	21	<0.001	11.840		
Broad-tailed Hummingbird (*Selasphorus platycercus*)	8	0	1				
Hairy Woodpecker (*Picoides villosus*)	24	7	1				
Northern Flicker (*Colaptes auratus*)	3	0	0				
Western Wood-Pewee (*Contopus sordidulus*)	0	2	0				
Gray Flycatcher (*Empidonax wrightii*)	156	96	40			<0.001	23.430
Ash-throated Flycatcher (*Myiarchus cinerascens*)	146	71	28			<0.001	18.960
Cassin's Kingbird (*Tyrannus vociferans*)	7	2	8				
Gray Vireo (*Vireo vicinior*)	97	73	14			<0.001	40.400
Plumbeous Vireo (*V. plumbeus*)	39	8	0	<0.01	7.599		
Western Scrub-Jay (*Aphelocoma californica*)	28	8	4				
Pinyon Jay (*Gymnorhinus cyanocephalus*)	16	0	0	<0.005	9.143		
Common Raven (*Corvus corax*)	3	5	7				
Violet-green Swallow (*Tachycineta thalassina*)	43	47	48	<0.005	9.781		
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	0	3	1				
Mountain Chickadee (*Poecile gambeli*)	25	11	1			<0.005	8.399
Juniper Titmouse (*Baeolophus ridgwayi*)	96	56	35			<0.05	4.985
Bushtit (*Psaltriparus minimus*)	85	53	42				
White-breasted Nuthatch (*Sitta carolinensis*)	25	11	3			<0.05	4.624
Pygmy Nuthatch (*S. pygmaea*)	1	0	0				
Rock Wren (*Salpinctes obsoletus*)	3	1	1				
Canyon Wren (*Catherpes mexicanus*)	8	0	1				
Bewick's Wren (*Thryomanes bewickii*)	86	54	32			<0.025	5.773
Blue-gray Gnatcatcher (*Polioptila caerulea*)	50	7	1	<0.001	14.286		
Western Bluebird (*Sialia mexicana*)	25	15	5			<0.025	5.066
Mountain Bluebird (*S. currucoides*)	24	17	10				
American Robin (*Turdus migratorius*)	2	0	0				
Virginia's Warbler (*Oreothlypis virginiae*)	5	1	0				
Yellow-rumped Warbler (*Setophaga coronata*)	1	1	0				
Black-throated Gray Warbler (*S. nigrescens*)	56	41	6			<0.001	26.290
Western Tanager (*Piranga ludoviciana*)	9	7	0				
Green-tailed Towhee (*Pipilo chlorurus*)	3	0	1				

(continued)

Appendix. Continued.

Species	Control (n = 266)	T-off (n = 152)	T-on (n = 153)	Control vs. T-off [a] P	Control vs. T-off [a] χ^2	T-off vs. T-on [b] P	T-off vs. T-on [b] χ^2
Spotted Towhee (*P. maculatus*)	382	188	58			<0.001	69.560
Chipping Sparrow (*Spizella passerina*)	215	119	124				
Lark Sparrow (*Chondestes grammacus*)	0	1	9			<0.025	6.348
Sage Sparrow (*Amphispiza belli*)	0	2	1				
Black-headed Grosbeak (*Pheucticus melanocephalus*)	47	15	4	<0.05	3.968	<0.025	6.441
Brown-headed Cowbird (*Molothrus ater*)	102	31	2	<0.005	9.796	<0.001	25.680
House Finch (*Carpodacus mexicanus*)	76	89	72	<0.001	22.026		
Pine Siskin (*Spinus pinus*)	4	0	2				
Lesser Goldfinch (*S. psaltria*)	67	34	12			<0.005	10.670

[a] Chi-square goodness-of-fit tests comparing detection numbers on control sites and T-off sites, df = 1.

[b] Chi-square goodness-of-fit tests comparing detection numbers on T-on and T-off sites, df = 1.