

Londe, D. W., Fuhlendorf, S. D., Elmore, R. D. and Davis, C. A. 2019. Landscape heterogeneity influences the response of grassland birds to energy development. – Wildlife Biology 2019: wlb.00523

Appendix 1

Table A1.1. Common names and scientific name of all bird species detected during transect surveys in Osage County, Oklahoma between 2016 and 2017. Each species is summarized by the number of individuals the number of transects (in parenthesis) they were encountered on in each time since fire. Grassland obligates are bolded and are defined by Vickery et al. 1999 and Coppedge et al. 2008.

Common names	Scientific name	0–12 months	13–24 months	>24 months
		post-fire	post-fire	post-fire
American goldfinch	<i>Spinus tristis</i>	2 (1)	3 (2)	0
Barn swallow	<i>Hirundo rustica</i>	1 (1)	0	2 (1)
Bell's vireo	<i>Vireo bellii</i>	2 (2)	4 (1)	7 (6)
Brown-headed cowbird	<i>Molothrus ater</i>	5 (4)	13 (5)	7 (4)
Brown thrasher	<i>Toxostoma rufum</i>	3 (2)	2 (1)	2 (1)
Canda goose	<i>Branta canadensis</i>	6 (1)	0	0
Cliff swallow	<i>Petrochelidon pyrrhonota</i>	1 (1)	0	0
Common grackle	<i>Quiscalus quiscula</i>	7 (5)	1 (1)	1 (1)
Common nighthawk	<i>Chordeiles minor</i>	8 (7)	3 (2)	3 (4)
Common yellowthroat	<i>Geothlypis trichas</i>	4 (3)	14 (8)	10 (6)
Chuck-will's-widow	<i>Antrostomus carolinensis</i>	0	1 (1)	0
Dickcissel	<i>Spiza americana</i>	1051 (53)	1170 (43)	1101 (48)
Eastern kingbird	<i>Tyrannus tyrannus</i>	6 (3)	1 (1)	0
Eastern meadowlark	<i>Sturnella magna</i>	449 (53)	396 (43)	369 (48)
European starling	<i>Sturnus vulgaris</i>	1 (1)	0	0
Field sparrow	<i>Spizella pusilla</i>	9 (6)	3 (1)	1 (1)
Great blue heron	<i>Ardea herodias</i>	1 (1)	0	0
Greater prairie-chicken	<i>Tympanuchus cupido</i>	22 (1)	3 (1)	0
Grasshopper sparrow	<i>Ammodramus savannarum</i>	306 (50)	289 (35)	124 (32)
Henslow's sparrow	<i>Ammodramus henslowii</i>	8 (3)	302 (29)	348 (39)
Horned lark	<i>Eremophila alpestris</i>	1 (1)	0	0
Killdeer	<i>Charadrius vociferus</i>	7 (7)	1 (1)	3 (3)
Lark sparrow	<i>Chondestes grammacus</i>	1 (1)	0	0
Loggerhead shrike	<i>Lanius ludovicianus</i>	1 (1)	0	0
Mallard	<i>Anus platyrhynchos</i>	1 (1)	0	0
Mourning dove	<i>Zenaida macroura</i>	12 (9)	8 (4)	5 (4)
Northern bobwhite	<i>Colinus virginianus</i>	8 (7)	14 (12)	25 (12)
Northern mockingbird	<i>Mimus polyglottos</i>	2 (1)	0	0
Orchard oriole	<i>Icterus spurius</i>	5 (5)	2 (2)	1 (1)
Red-bellied woodpecker	<i>Melanerpes carolinus</i>	0	1 (1)	0
Red-tailed hawk	<i>Buteo jamaicensis</i>	1 (1)	0	0
Ruby-throated hummingbird	<i>Archilochus colubris</i>	1 (1)	1 (1)	0
Red-winged blackbird	<i>Agelaius phoeniceus</i>	13 (9)	24 (9)	18 (15)
Scissor-tailed flycatcher	<i>Tyrannus forficatus</i>	12 (5)	6 (5)	0
Upland sandpiper	<i>Bartramia longicauda</i>	99 (17)	11 (7)	6 (4)

Table A1.2. Model comparisons for individual grassland bird species at oil wells that were actively pumping during surveys (active), and oil wells that were temporarily turned off during the time of survey (inactive), across a gradient of times since fire in Osage County, Oklahoma in 2016 and 2017.

Time since fire	Survey type	Species	n ^a	$\Delta AICc$		
				Null	Slope	Plateau
0–12 months	inactive	dickcissel	8	1.471	0	9.381
		eastern meadowlark	8	0	4.244	12.298
		grasshopper sparrow	8	0	1.174	8.176
	active	dickcissel	18	0	3.8619	17.217
		eastern meadowlark	18	0	0.829	13.183
		grasshopper sparrow	18	0	4.799	20.239
13–24 months	inactive	dickcissel	6	0	3.783	16.838
		eastern meadowlark	6	0	3.993	16.998
		grasshopper sparrow	6	0	3.72	18.04
		Henslow's sparrow	6	0.399	0	13.828
	active	dickcissel	11	0	3.055	NA
		eastern meadowlark	11	2.585	0	NA
grasshopper sparrow		11	0	4.794	6.082	
Henslow's sparrow		11	0.087	0	13.399	
>24	inactive	dickcissel	5	0	4.178	NA
		eastern meadowlark	5	0	3.042	14.56
		grasshopper sparrow	5	3.243	0	13.551
		Henslow's sparrow	5	0	3.51	NA
	active	dickcissel	11	0	4.112	13.576
		eastern meadowlark	11	0	4.764	11.537
grasshopper sparrow		11	0	1.018	13.58	
Henslow's sparrow		11	0	4.112	13.576	

a. Number of transects

Table A1.3. Model comparisons for total bird abundances and grassland obligate bird abundances comparing three scenarios describing the response to oil wells and roads across a gradient of times since fire in Osage County, Oklahoma 2016 and 2017.

Time since fire	Survey type	Species	n	Δ AICc		
				Null	Slope	Plateau
0–12 months	control	all species	243	0	1.715	10.605
		grassland obligates	150	0	3.683	NA
	roads	all species	843	0	3.349	NA
		grassland obligates	788	0	3.369	NA
	oil wells	all species	755	0	4.254	16.295
		grassland obligates	700	0	4.183	15.563
13–24 months	control	all species	458	0	3.969	7.354
		grassland obligates	436	0	3.38	8.75
	roads	all species	701	0	4.124	16.506
		grassland obligates	666	0	4.203	NA
	oil wells	all species	880	0	3.239	NA
		grassland obligates	845	0	3.639	NA
>24 months	control	all species	312	0	2.132	NA
		grassland obligates	788	0	2.042	NA
	roads	all species	950	0	4.22	11.727
		grassland obligates	882	0	4.119	13.736
	oil wells	all species	751	0	3.027	NA
		grassland obligates	742	0	2	12.075

Table A1.4. Model selection results for the influence of Cloud cover, Windspeed (km^h), Temperature (degrees Celsius), time of day and Julian Date, for five grassland obligate species encountered in Osage County, Oklahoma between 2015–2016.

	K	AICc	Δ AICc	AICc weight	Log likelihood
Dickcissel					
Null	2	1632.14	0	0.32	-814.05
Cloud cover	3	1633.81	1.67	0.14	-813.86
Wind speed	3	1633.92	1.78	0.13	-813.92
Temperature	3	1634	1.85	0.13	-813.95
Date + Time of day	3	1634.04	1.9	0.12	-813.98
Time of day	3	1634.11	1.97	0.12	-814.01
Date	4	1636	3.86	0.05	-813.93
Eastern meadowlark					
Cloud cover	3	1235.63	0	0.98	-614.77
Time of day	3	1245.2	9.57	0.01	-619.56
Null	2	1246.1	10.46	0.01	-621.03
Date + Julian	4	1246.89	11.26	0	-619.38
Temperature	3	1247.81	12.17	0	-620.86
Date	3	1247.93	12.29	0	-620.92
Wind speed	3	1248.12	12.49	0	-621.02
Grasshopper sparrow					
Time of day	3	1084.14	0	0.73	-539.03
Date + Time of day	4	1086.17	2.03	0.26	-539.01
Wind	3	1094.77	10.63	0	-544.34
Null	2	1095.2	11.05	0	-545.58
Cloud cover	3	1095.27	11.13	0	-544.59
Temperature	3	1097.23	13.08	0	-545.57
Date	3	1097.24	13.1	0	-545.58
Henslow's sparrow					
Time of day	3	937.04	0	0.63	-465.47
Date+ Time of day	4	938.15	1.11	0.36	-465
Cloud cover	3	946.97	9.93	0	-470.44
Null	2	949.19	12.16	0	-472.57
Temperture	3	949.85	12.81	0	-471.88
Date+ Time of day	3	950.89	13.85	0	-472.4
Wind speed	3	951.19	14.16	0	-472.55
Upland sandpiper					
Wind	3	234.61	0	0.46	-114.26
Null	2	236.76	2.15	0.16	-116.36
Date	3	237.12	2.51	0.13	-115.52
Time of day	3	238.04	3.43	0.08	-115.98
Date + Time of day	4	238.67	4.05	0.06	-115.26
Temperature	3	238.8	4.19	0.06	-116.36
Cloud cover	3	238.8	4.19	0.06	-116.36

Appendix 2

Table A2.1. Model coefficients (SE) for models evaluated describing the abundance of five grassland obligate species relative to roads, oil wells and control sites across a gradient of times since fire in Osage County, Oklahoma between 2016 and 2017. Species codes: dickcissels (DICK), eastern meadowlark (EAME), grasshopper sparrow (GRSP), Henslow's sparrow (HESP), upland sandpiper (UPSA).

		Null model	Slope model		Plateau model			
		Intercept	Intercept	Slope	Intercept1	Slope	Intercept2	Breakpoint (m)
0–12 months post fire								
Control								
	All species	1.68 (0.21)	2.25 (0.42)	-0.1 (0.07)	3.72 (0.78)	1.33 (0.73)	-0.79 (0.36)	151.5 (48.5, 254.5)
	Grassland obligates	1.5 (0.15)	1.71 (0.34)	-0.04 (0.05)	NA	NA	NA	NA
	DICK	0.94 (0.09)	0.87 (0.21)	0.01 (0.03)	0.66 (0.33)	1.62 (0.81)	0.16 (0.1)	297 (0, 613)
	EAME	0.27 (0.08)	0.47 (0.16)	-0.04 (0.03)	0.4 (0.32)	0.59 (0.49)	0.04 (0.12)	24 (0, 1250.5)
	GRSP	0.28 (0.06)	0.37 (0.12)	-0.02 (0.02)	0.58 (0.22)	0.13 (0.34)	-0.12 (0.08)	203.5 (0, 451.5)
	UPSA	NA	NA	NA	NA	NA	NA	NA
Roads								
	All species	1.74 (0.06)	1.84 (0.12)	-0.02 (0.02)	NA	NA	NA	NA
	Grassland obligates	1.49 (0.06)	1.75 (0.14)	-0.02 (0.02)	NA	NA	NA	NA
	DICK	0.92 (0.04)	1.11 (0.06)	-0.04 (0.01)	1.17 (0.05)	-0.96 (0.94)	-0.02 (0.01)	449 (402, 495.5)
	EAME	0.4 (0.04)	0.38 (0.09)	0 (0.01)	0.44 (0.07)	-2.4 (1.47)	-0.32 (0.01)	450 (396.5, 503.5)
	GRSP	0.28 (0.02)	0.2 (0.03)	0.01 (0)	0.19 (0.03)	0.92 (0.53)	0.08 (0.01)	445.5 (366.5, 524.5)
	UPSA	0.08 (0.02)	0.03 (0.05)	0.01 (0.01)	0.06 (0.04)	-0.62 (0.17)	-0.08 (0.01)	415 (345, 485)
Oil wells								
	All species	1.45 (0.09)	1.47 (0.19)	-0.01 (0.03)	2.27 (0.64)	1.26 (0.31)	-0.49 (0.41)	104 (8, 200)
	Grassland obligates	1.35 (0.07)	1.3 (0.17)	0.01 (0.03)	2 (0.53)	1.08 (0.25)	-0.43 (0.33)	108 (14, 202.5)
	DICK	0.76 (0.04)	0.7 (0.09)	0.01 (0.02)	0.78 (0.13)	0.21 (0.55)	-0.08 (0.03)	340 (76.5, 603.5)
	EAME	0.34 (0.03)	0.4 (0.05)	-0.01 (0.01)	0.51 (0.11)	0.28 (0.11)	-0.06 (0.05)	199.5 (0, 475.5)
	GRSP	0.22 (0.02)	0.17 (0.05)	0.01 (0.01)	0.37 (0.16)	0.1 (0.07)	-0.11 (0.1)	115.5 (0.5, 230)
	UPSA	0.07 (0.01)	0.09 (0.02)	0 (0)	0.11 (0.03)	-0.06 (0.24)	-0.02 (0.01)	357.5 (59, 656)

13–24 months post fire**Control**

Table B1 Continued	All species	2.54 (0.12)	2.66 (0.26)	-0.02 (0.04)	2.93 (0.19)	-5.67 (3.35)	-0.98 (0.04)	439 (394.5, 484)
	Grassland obligates	2.42 (0.11)	2.61 (0.24)	-0.04 (0.04)	2.88 (0.2)	-3.83 (3.5)	-0.78 (0.04)	429.5 (363, 496.5)
	DICK	1.33 (0.08)	1.5 (0.15)	-0.03 (0.02)	1.59 (0.18)	0.31 (1.51)	-0.16 (0.03)	400 (175, 625)
	EAME	0.38 (0.07)	0.42 (0.16)	-0.01 (0.03)	0.63 (0.18)	-1.06 (1.34)	-0.24 (0.04)	358 (185, 531)
	GRSP	0.34 (0.04)	0.4 (0.09)	-0.01 (0.01)	NA	NA	NA	NA
	HESP	0.35 (0.05)	0.27 (0.1)	0.02 (0.02)	0.56 (0.14)	0.11 (0.22)	-0.16 (0.05)	209.5 (93.5, 325)
Roads	All species	2.19 (0.06)	2.15 (0.13)	0.01 (0.02)	NA	NA	NA	NA
	Grassland obligates	2.08 (0.05)	2.05 (0.12)	0 (0.02)	NA	NA	NA	NA
	DICK	1.07 (0.04)	0.95 (0.07)	0.02 (0.01)	NA	NA	NA	NA
	EAME	0.37 (0.05)	0.58 (0.08)	-0.04 (0.01)	0.52 (0.08)	1.52 (1.44)	0.12 (0.02)	404 (169, 638.5)
	GRSP	0.24 (0.02)	0.23 (0.04)	0 (0.01)	0.29 (0.09)	0.16 (0.08)	-0.03 (0.04)	199.5 (0, 549.5)
	HESP	0.38 (0.03)	0.29 (0.06)	0.02 (0.01)	0.32 (0.07)	-0.4 (1.23)	-0.87 (0.01)	418 (173, 662.5)
Oil wells	All species	2.44 (0.09)	2.6 (0.2)	-0.03 (0.03)	NA	NA	NA	NA
	Grassland obligates	2.35 (0.08)	2.47 (0.19)	-0.02 (0.03)	NA	NA	NA	NA
	DICK	1.31 (0.05)	1.32 (0.12)	0 (0.02)	NA	NA	NA	NA
	EAME	0.44 (0.03)	0.59 (0.05)	-0.03 (0.01)	0.97 (0.1)	0.49 (0.05)	-0.24 (0.06)	102.5 (72, 132.5)
	GRSP	0.34 (0.04)	0.45 (0.07)	-0.02 (0.01)	0.39 (0.12)	0.62 (0.31)	0.04 (0.04)	282 (0, 750.5)
	HESP	0.24 (0.04)	0.1 (0.06)	0.03 (0.01)	na (na)	na (na)	na (na)	#VALUE!

>24 months post fire**Control**

All species	2.23 (0.1)	2.48 (0.21)	-0.05 (0.03)	NA	NA	NA	NA
Grassland obligates	2.18 (0.09)	2.4 (0.18)	-0.04 (0.03)	NA	NA	NA	NA
DICK	1.28 (0.09)	1.58 (0.16)	-0.05 (0.26)	1.76 (0.38)	1.39 (0.36)	-0.09 (0.18)	196 (0, 751)
EAME	0.39 (0.05)	0.38 (0.12)	0 (0.02)	0.34 (0.13)	1.04 (2.66)	0.09 (0.03)	402.5 (0, 1028)
GRSP	0.2 (0.05)	0.11 (0.1)	0.02 (0.02)	-0.03 (0.3)	0.32 (0.22)	0.09 (0.19)	195 (0, 1076.5)
HESP	0.36 (0.05)	0.36 (0.11)	0 (0.02)	0.54 (0.12)	-0.31 (0.54)	-0.14 (0.03)	300.5 (128, 472.5)

Roads

All species	1.98 (0.07)	2.01 (0.17)	-0.01 (0.03)	2.17 (0.15)	-2.44 (2.67)	-0.53 (0.03)	435 (365.5, 500.5)
Grassland obligates	1.84 (0.07)	1.89 (0.16)	-0.01 (0.03)	2.03 (0.16)	-1.44 (2.82)	-0.41 (0.03)	428 (322, 533.5)

Table B1 Continued

DICK	1.13 (0.05)	1.13 (0.11)	0 (0.02)	1.23 (0.12)	-0.12 (0.93)	-0.17 (0.03)	392 (258.5, 525)
EAME	0.38 (0.03)	0.41 (0.06)	-0.01 (0.01)	0.51 (0.09)	0.17 (0.22)	-0.06 (0.03)	269.5 (55.5, 483.5)
GRSP	0.07 (0.01)	0.09 (0.03)	0 (0)	0.13 (0.06)	0.05 (0.05)	-0.02 (0.03)	178 (0, 480)
HESP	0.24 (0.03)	0.26 (0.07)	0 (0.01)	0.08 (0.15)	0.36 (0.13)	0.1 (0.07)	150 (0, 305)

Oil wells

All species	2.21 (0.09)	2.04 (0.18)	0.03 (0.03)	NA	NA	NA	NA
Grassland obligates	2.18 (0.08)	1.96 (0.17)	0.04 (0.03)	2.23 (0.26)	1.41 (0.64)	-0.16 (0.08)	252 (7, 497)
DICK	1.14 (0.05)	1.03 (0.09)	0.02 (0.02)	NA	NA	NA	NA
EAME	0.36 (0.02)	0.4 (0.05)	-0.01 (0.01)	NA	NA	NA	NA
GRSP	0.18 (0.02)	0.24 (0.04)	-0.01 (0.01)	0.34 (0.05)	0.06 (0.07)	-0.06 (0.02)	237.5 (133, 342)
HESP	0.51 (0.05)	0.3 (0.08)	0.04 (0.01)	0.11 (0.28)	0.41 (0.13)	0.1 (0.18)	149 (0, 498)

Table a2.2. Model coefficients (SE) for models evaluated describing the abundance of five grassland obligate species relative to active and inactive oil wells across a gradient of times since fire in Osage County, Oklahoma between 2016 and 2017. Species codes: dickcissels (DICK), eastern meadowlark (EAME), grasshopper sparrow (GRSP), Henslow's sparrow (HESP), upland sandpiper (UPSA).

	Null model Intercept	Slope model Intercept	Slope	Plateau model Intercept1	Slope	Intercept2	Breakpoint (m)
0–12 months post fire							
Inactive wells							
DICK	0.45 (0.01)	0.39 (0.02)	0.01 (0)	-0.06 (0.04)	0.35 (0.03)	2.25 (0.65)	112.5 (32.5,192.5)
EAME	0.29 (0.02)	0.28 (0.04)	0 (0.01)	-0.07 (0.04)	0.13 (0.08)	3.94 (1.31)	197 (37,357)
GRSP	0.18 (0.02)	0.11 (0.03)	0.01 (0.01)	0.04 (0.01)	0.45 (0.25)	7.5 (1.16)	375 (233,517)
UPSA	0.04 (0)	0.06 (0.01)	0 (0)	0.01 (0)	0.15 (0.04)	7.66 (0.79)	383 (257,509.5)
Active wells							
DICK	0.52 (0.03)	0.54 (0.06)	0 (0.01)	0.03 (0.06)	0.59 (0.14)	3.03 (3.42)	151.5 (0,571)
EAME	0.24 (0.03)	0.33 (0.05)	-0.02 (0.01)	0.05 (0.21)	0.59 (0.33)	6.05 (2.4)	302.5 (15,589.5)
GRSP	0.22 (0.04)	0.21 (0.08)	0 (0.01)	-0.2 (0.15)	0.06 (0.15)	2.36 (0.97)	118 (0,242)
13–24 months post fire							
Inactive wells							
DICK	0.66 (0.03)	0.6 (0.08)	0.01 (0.01)	0.01 (0.02)	0.15 (0.04)	7.66 (0.79)	383 (257,509)
EAME	0.03 (0.01)	0.39 (0.03)	0 (0.01)	-0.03 (0.01)	0.22 (0.12)	6 (2.04)	300 (49.5,550)
GRSP	0.27 (0.03)	0.32 (0.07)	-0.01 (0.01)	0.03 (0.02)	0.49 (0.33)	6 (4.58)	300 (0,860)
HESP	0.18 (0.03)	0.07 (0.05)	0.02 (0.01)	0.05 (0.12)	0.13 (0.09)	2.99 (3.95)	149.5 (0,632)
Active wells							
DICK	0.7 (0.03)	0.65 (0.05)	0.01 (0.01)	NA	NA	NA	NA
EAME	0.33 (0.03)	0.41 (0.06)	-0.01 (0.01)	-0.09 (0.12)	0.31 (0.1)	2.99 (2.44)	149.5 (0,448)
GRSP	0.28 (0.03)	0.33 (0.09)	-0.01 (0.01)	0.15 (0.03)	0.65 (0.13)	4.01 (0.07)	200.5 (125.5,276)
HESP	0.24 (0.03)	0.11 (0.06)	0.02 (0.01)	0.04 (0.03)	0.29 (0.26)	5.3 ()	265 (0,612)
>24 months post fire							
Inactive eells							
DICK	0.66 (0.02)	0.64 (0.06)	0 (0.01)	NA	NA	NA	NA
EAME	0.3 (0.02)	0.34 (0.04)	-0.01 (0.01)	0.06 (0.01)	0.68 (0.44)	7 (2.1)	350 (93,607.5)

GRSP	0.16 (0.02)	0.24 (0.03)	-0.01 (0)	-0.03 (0.06)	0.1 (0.04)	2.75 (2.7)	137.5 (0,450)	1
Table B2 Continued								
HESP	0.41 (0.03)	0.26 (0.06)	0.02 (0.01)	NA	NA	NA	NA	
Active wells								
DICK	0.81 (0.03)	0.78 (0.08)	0 (0.01)	NA	NA	NA	NA	
EAME	0.29 (0.04)	0.32 (0.09)	-0.01 (0.01)	-0.12 (0.05)	0.03 (0.21)	4.14 (1.21)	207 (59,355.5)	
GRSP	0.19 (0.03)	0.17 (0.08)	0 (0.01)	-0.13 (0.03)	-0.02 (14)	4.5 (0.71)	225 (137,319.5)	
HESP	0.39 (0.04)	0.26 (0.08)	0.02 (0.01)	0.11 (0.17)	0.38 (0.13)	2.92 (2.47)	146 (0,449.5)	
