EFFECTS OF WIND POWER ON THE DEMOGRAPHY AND POPULATION GENETICS OF THE GREATER PRAIRIE-CHICKEN

QUARTERLY REPORT

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Quarterly Report
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EXECUTIVE SUMMARY

Field.— Wind power development has not occurred at the impact areas of Unit 1 and 2, and is not likely to be completed during the study period. Construction of the Meridian Way project is ongoing at the Unit 3 impact area at the time of this report. Effort this quarter was focused on monitoring females to quantify habitat selection and space use. As of 15 October, more than 8,000 locations of radio-marked females have been acquired by triangulation and by approaching radio-marked birds on foot, resulting in an average of 22 locations per bird. Radio-transmitters were fitted to 101 new females in the spring of 2008 and 35 females with active radio-transmitters from 2007 were monitored in 2008. In 2008, 119 nests were located and added to our sample for the entire pre-construction sample. Overall, we have located 231 nests in total. Seasonal fecundity (female offspring per female) was lower at Unit 1 (0.08 $\pm$ 0.04SE) than units 2 (0.11 $\pm$ 0.06) and 3 (0.21 $\pm$ 0.06). However, annual survival ($\pm$SE) was highest at Unit 1 (0.68 $\pm$ 0.07) and lowest at Units 2 (0.37 $\pm$ 0.08) and 3 (0.15 $\pm$ 0.06). Prairie-chicken populations are not viable given our observed demographic rates, and a majority of losses of nests and adults were caused by predation.

Laboratory.— Efforts this quarter have been focused on completing genotyping for birds sampled in 2008 samples with our 11-marker microsatellite array. We have extracted DNA and completed molecular analysis for all adult individual prairie-chickens captured during the 2008 season (n =258). With the addition of the 2008 samples, the total number of individual prairie-chickens for which we have constructed multi-locus genetic profiles for over the course of this project is 589 individuals (Table 1).

To ensure genotyping accuracy we routinely re-analyze all homozygous loci within individuals and a randomly chosen 10% of the heterozygous loci within individuals. For the 2008 samples, we have completed the re-analysis of all homozygotes (n = 138 individuals) and the random subset of 10% of the heterozygotes (n = 30 individuals). Based on analyzes of these data we have an allelic dropout rate of 0.6% for birds genotyped in 2008. When combining 2008 data with 2006 and 2007 estimates of allelic dropout we have a low overall allelic dropout rate across all three years of this project of 0.49%.

Measurements of genetic diversity (H_O H_E and AR) and effective population size N_e have been calculated for each research unit independently and also across the entire Flint Hills Prairie-chicken distribution (Table 1). In addition, we have also estimated inbreeding within units with F_{IT} values and exchange among units with F_{ST} values (Fig. 1).

FIELD BASED HYPOTHESES

Hypothesis I) Lek Attendance: ***Lek attendance on impact sites is not affected by wind-power development.***

Accomplishments Since Last Quarter

The lekking season occurs from March – May. No data were collected during this quarter to address this hypothesis.

Goals For Next Quarter

The lekking season occurs from March – May. No effort will be made to address this hypothesis in the upcoming quarter.

Hypothesis II) Avoidance of anthropogenic structures: ***Prairie-chickens do not avoid wind-towers and/or other anthropogenic features on impact sites.***

Accomplishments Since Last Quarter

Wind power development has not occurred at Unit 1 and 2 impact areas, and is not likely to be completed during the study period. Construction of the Meridian Way project is ongoing at the Unit 3 impact area at the time of this report. Effort this quarter was focused on monitoring females to quantify habitat selection and space use. Radio-marked prairie-chickens were located $\geq$3 times/week from project trucks, an ATV, or on foot using portable radio receivers and handheld 3-element Yagi antennas. Bird locations are estimated from $\geq$2 triangulation bearings using a maximum-likelihood estimator in program LOCATE III or flush locations were recorded with a GPS. Aerial searches were conducted using fixed-wing aircraft when birds were unable to be located by ground-based telemetry.

As of 15 October, more than 8,000 locations of radio-marked females have been acquired by triangulation and by approaching radio-marked birds on foot, resulting in an average of 22 locations per bird. Estimation of home range size and space use from the movement data has not been completed, but we are on track to collect the 30-50 locations per individual per season that are required for estimation of home range size using kernel methods for fitting surfaces to movement data.

We continue to document the location of anthropogenic structures at all three research units. Study areas are being mapped from the ground and the locations of anthropogenic structures has been collected using a handheld GPS unit. Locations are used to develop GIS layers on property land cover maps. Mapping will allow us to assess the impacts of all anthropogenic structures on the demography and space use of prairie-chickens in areas with and without wind power development.

Goals For Next Quarter

Breeding season space use by females will be evaluated at all study sites by incorporating the estimated locations into ArcMap 9.3. Home ranges of hens will be estimated for the breeding period by calculating 95% fixed-kernel utilization distribution for each radio-marked animal using the Animal Movements extension in ArcMap 9.3. We will proceed to model breeding season space use in 4 steps: 1) estimate the relative frequency of use for sampled habitat units for each radio-marked prairie-chicken for each breeding season period; 2) use the relative frequency as the response variable in a multiple regression analysis of probability of use as a function of habitat predictor variables (including landscape metrics and proximity to human structures) for each animal; 3) use coefficients from individual models to calculate coefficient values for habitat variables for the population, and 4) create probability of use prediction maps for each year using the best supported functions for resource selection.

Hypothesis III) Impacts on Fecundity Rates: ***Wind development will not reduce nest success or chick survival.***

Accomplishments Since Last Quarter

Radio-transmitters were fitted to 101 females in the spring of 2008 (see previous quarterly report). In addition, 35 females captured in 2007 were still alive with active radio-transmitters and were monitored in 2008. Radio-marked hens were located by triangulation or homing ≥3 times/week from project trucks, an ATV, or on foot. When females localized in an area and their estimated location did not change for 3 successive days, we used portable radio receivers and handheld Yagi antennas to locate and flush the female so that the eggs could be counted and nest location recorded with a GPS unit. If the nest was first found during egg-laying, nest sites were visited again in <2 weeks to determine final clutch size and nest status. During the first visit during incubation, eggs were removed and carried >200 m from the nest and floated in a small container of luke-warm water to assess stage of incubation, estimate hatch date, and estimate the date of clutch initiation by backdating. Nest sites were not visited again until it was determined that the female had departed the nest and was located away from the nest for ≥2 consecutive days). Once the female departed the nest, we returned to the nest site and classified nest fate as successful (≥1 chick hatched and left the nest), failed (e.g., hail damage, trampled by livestock), depredated, or abandoned. For successful nests, hatchability was calculated as the percentage of eggs that hatched and produced chicks.

Within 3 days of hatching, chicks were captured off of the nests, counted, measured and fitted with uniquely marked patagial tags. After processing, chicks were immediately released at the capture site. Pre-fledging brood survival was estimated by conducting flush counts within 2 days of the 14th day post hatch (the average day of fledge) at dawn or dusk to determine the number of surviving chicks in the brood. For counts of 0 chicks, the brood hen was flushed again the following day to be certain no chicks remained in the brood.

In 2008, 119 nests were located and added to our sample for the entire pre-construction sample. Overall, we have located 231 nests in total. The apparent nest initiation rate and renesting probability (±SE) of our total sample averaged 0.82 (0.07) and 0.61 (0.09), respectively. Mean clutch sizes were 12.4 (0.2) and 10.5 (0.2) for first nests and renests, respectively. Of 167 first nests, 25 nests successfully hatched chicks. Nineteen of 64 renesting attempts successfully hatched. Apparent nest success for all nests combined was 19%. Third nesting attempts were documented for 2 females; one of the third nests was successful. Hatchability of eggs in successful nests that survived incubation was high at 0.82 (0.03) chicks per egg.

Fourteen of 43 broods successfully produced fledglings for an apparent brood survival rate to fledge of 33% (samples pooled for all years). Within successful broods, 56 ± 3% of chicks survived from hatching until fledging. We combined our estimates of demographic parameters to calculate seasonal fecundity as the number of female offspring produced per breeding female. Seasonal fecundity was low across all research sites (0.15 ± 0.06 female offspring per breeding female). We estimate that only 1 female prairie-chicken fledgling was produced for every 6.7 breeding females on our study sites. Moreover, fecundity was depressed at Unit 1 (0.08 + 0.04) as compared to units 2 and 3 (0.11 ± 0.06 and 0.21 ± 0.06, respectively), although 95% confidence intervals overlapped in all cases.

Goals For Next Quarter

We will use the nest survival model in Program MARK to generate maximum likelihood estimates of daily nest survival. Multiple model selection and inference will be used to evaluate the importance of multiple sources of variation on daily nest survival prior to wind power development. Explanatory variables will include: nest age, nest attempt (first or renest), hen age, VOR (dm), COVER, and distances to anthropogenic features. We will calculate the expected nest survival probability by raising the daily nest survival estimate to an exponent equal to the mean incubation interval for prairie-chickens on the study site. The duration of laying and incubation periods will be determined from direct observations of successful nests discovered during laying, or from published values in the literature if necessary. Confidence intervals will be estimated with the delta method.

Systematic flush counts were used to estimate survival during the pre-fledging (0-14 days) and post-fledging periods (14-60 days).   Because broods were not observed daily, we will use the nest survival model type in Program MARK to evaluate daily brood survival probabilities. Covariates will include hen age, a forb:grass cover index, VOR, and average home range distance to closest anthropogenic feature. Daily brood survival probabilities will be calculated using maximum likelihood estimates.

Hypothesis IV) Impacts on Breeding Habitat: ***Placement of wind-towers and related structures does not impact the habitat use of breeding greater prairie-chickens.***

Accomplishments Since Last Quarter

Radio-marked prairie-chickens were located $\geq$3 times/week from project trucks and ATV's, or on foot using portable radio receivers and handheld 3-element Yagi antennas. Bird locations are estimated from $\geq$2 triangulation bearings using a maximum-likelihood estimator in program LOCATE III or flush locations were recorded with a GPS. Vegetation structure was quantified at each nest site within 3 days of hatching or failure. We recorded visual obstruction readings (VOR in dm) and non-overlapping vegetation cover (% grass, forbs, and shrub) at nests, paired random points within 200 m of the nest, and random points across the study sites as described above to assess pre-construction habitat availability at two spatial scales.

During 2008, vegetation characteristics (i.e., local habitat conditions) were measured at 117 nest sites and 116 paired random points within 200 m of the nest site. Vegetation was also quantified at 51 brood locations and 51 random paired brood points. To quantify the availability of nesting habitat on the study areas, the same data were collected at 224 random points across all 3 research units.

Goals For Next Quarter

The nesting and brood rearing period occurs during May – July. Therefore no data will be collected to address this hypothesis in the next quarter. An analysis of variance (ANOVA) will be used to compare mean VORs, grass heights, forb heights, and percent coverage among nest locations, random points within 200 m of the location, and random points from across the entire study site for 2008. Percent data will be angular transformed and all other variables were log transformed if necessary to meet the assumptions of normality. The variables % forb cover, % grass, % bare ground, and % shrub cover may be correlated. Similarly, VOR, grass height, and forb height may be correlated. Principal components analysis or other multivariate statistics will be used to summarize these parameters, before these covariates are used to model nest and brood site selection.

Hypothesis V) Impacts on Survival: ***Wind-power development does not increase mortality rates of greater prairie-chickens.***

Accomplishments Since Last Quarter

During 3 March - 10 May, 2008, 101 female greater prairie-chickens were fitted with radio-transmitters and 152 newly captured males were fitted with unique bands. In addition, 35 females originally radio-marked in 2007 were monitored in 2007. Radio-marked prairie-chickens were located ≥4 times/week during the spring and summer and ≥1 time/week during the winter from project trucks, an ATV, or on foot using portable radio receivers and handheld 3-element Yagi antennas. When a mortality signal was heard, the transmitter was located and retrieved. Probable causes of death were determined by field investigation and necropsies when carcasses are retrievable. However, scavenging often confounds the determination of mortality causes. Mortality events were classified as (1) predation, (2) hunter, (3) collision, or (4) unknown. Unknown causes included mortalities with conflicting or confounding signs of mortality (e.g., raptor flushed from carcass with mammalian chew marks).

We estimated female survival using nest survival procedure, a general model for known-fate data in program MARK 4.3. Weekly probability of survival was modeled as a function of week since marking (t), linear (lin) and quadratic (quad) trends, research unit, female age, and additive combinations of these factors. Multiple model selection and inference was used to evaluate the importance of these sources of variation on weekly survival prior to wind power development. We calculated the overall annual survival probability of females from March 2007 to March 2008 by calculating the product of weekly survival probabilities across the study period.

Results.— Overall, annual female survival at all sites was 0.43 (95% C.I. = 0.32-0.54). Annual survival (±SE) was higher at Unit 1 (0.68 ± 0.07) than at Units 2 (0.37 ± 0.08) and 3 (0.15 ± 0.06; Fig. 1). An effect of age-class (yearling vs. adult) was not supported by the data. Both trend models (linear and quadratic) indicated that survival increased across the period.

Fifty-two mortality events were investigated in the field during 2008 and 132 total for the entire study. The majority of mortality events (89%) were the result of predation. Four birds died due to collisions with power lines or fences. Two hens were killed by hay mowing equipment, and one hen was killed in a hail storm. We have not documented any cases of hunting mortality in radio-marked females, and have received no reports of bands recovered from hunter-killed birds. We continue to track 45 birds at the time of this report. If appropriate, surviving birds that are recaptured in Spring 2009 will be equipped with new transmitters and their survival status updated to alive from censored.

Goals For Next Quarter

We will begin trapping prairie-chickens in March 2009. Each remaining research units will be staffed with 3 technicians. Our goal will be to capture and equip $\geq$25 hens per site (50 hens/unit; 100 hens total) with radio-transmitters and band >80% of the males on each lek trapped. Recaptures of marked birds will be recorded to estimate annual apparent survival via mark-recapture statistics. Target goals may be revised pending discussions of changes to our study plan.

LABORATORY BASED HYPOTHESES

Hypothesis I) Affects on breeding behavior: ***There will be no change detected in the Ne/N.***

Accomplishments Since Last Quarter

We have completed DNA extraction and genotyping for all Flint Hills Greater Prairie-chicken samples captured during the 2008 trapping season (n=258). Following genotyping and accuracy assessment we calculated the effective population size for each deme and for all demes combined (Table 1).

Goals for Next Quarter

Calculate confidence intervals for N_e estimates. Our goal is to calculate the ratio of effective population size and census population size (N_e/N). We are developing more robust estimates of population census size based on mark-recapture modeling that will be taken from the demographic component of this research.

Hypothesis II) Influence on Natal Dispersal: ***There will be no differences detected in the dispersal patterns of prairie chickens pre and post wind-power development.***

Accomplishments Since Last Quarter

We assessed the probability of identity (PI) and the probability of identity between sibs (PI_{sibs}) within each study unit (Table 1). Low values of PI and PI_{sibs} are desirable and can be considered an estimate of the power of our genetic analysis to unambiguously assign molecular identity to individuals within a unit. No other major analysis was conducted on this hypothesis over the last quarter.

Goals for Next Quarter

Our goals for next quarter include completion of genotyping of all chicks, extraction of embryonic chick DNA from depredated eggs, relatedness analysis between all mother-offspring family groups, and paternity investigations of potential fathers from our molecular sampling of males captured at lek sites in 2007-08 within each study unit as the potential fathers of nearby broods. We will also begin to investigate recruitment within study units, by comparing the genotype of yearling prairie chickens captured in 2007 and 2008 that have a high probability of being assigned as either the maternal or paternal descendant of individuals captured at leks with their study unit during previous trapping effort in the pre-construction sampling period.

Table 1. Results of molecular analysis for the Flint Hills Greater Prairie-chicken population and each of the three study units within the population from 2006-2008. N sample size, H_O observed heterozygosity, H_E expected heterozygosity, AR allelic richness, N_e effective population size, PI probability of identity, and PI_{sibs} probability of identity between siblings.

Deme	N	H_O	H_E	AR	N_e	F_{IS}	PI	PI_{sibs}
Unit 1	138	0.69	0.77	7.0	228.1	0.098	$7.1x10^{-15}$	$2.3x10^{-5}$
Unit 2	230	0.72	0.79	8.4	336.2	0.108	$3.9x10^{-16}$	$1.3x10^{-6}$
Unit 3	221	0.72	0.79	7.9	284.8	0.096	$9.5x10^{-16}$	$1.5x10^{-6}$
Flint Hills Population	589	0.71	0.79	7.7	829.3	-	$2.1x10^{-16}$	$7.0x10^{-5}$

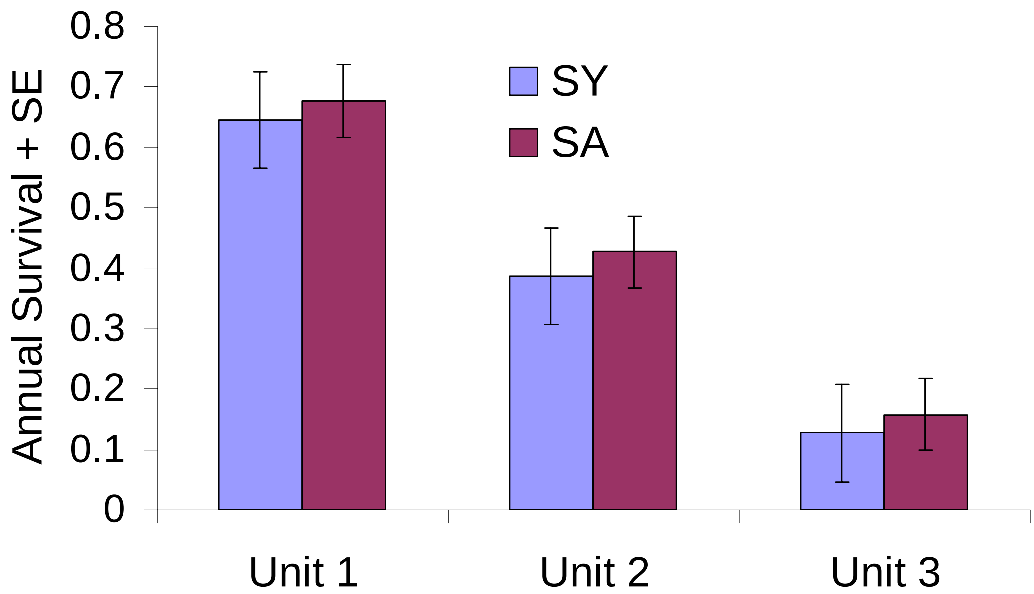

Figure 1. Annual survival of yearling and adult female greater prairie-chickens at three research areas in Kansas, March 2007 – March 2008 (S_Y = yearling survival, S_A = adult survival).

Figure 2. Map of the genetic structure among Greater Prairie-chickens within the Flint Hills study area. Each of the three research units are identified, along with estimates of inbreeding within units and the degree of genetic isolation between pairs of units. Low F_{ST} values between units indicate greater gene flow and consequently less genetic isolation. Larger F_{IS} values within units indicate greater potential for inbreeding among individuals within a unit. Both F_{ST} and F_{IS} values are retrospective analyses of gene flow and inbreeding; therefore they are estimates of historical gene flow or isolation and may not be indicative of contemporary disturbance or other isolating mechanisms on the landscape.