Lesser prairie-chicken habitat changes since court delisting

Satellite and government data show extensive habitat loss

Center for Conservation Innovation

The conservation status of the lesser prairie-chicken (*Tympanuchus pallidicintus*) is being assessed by the U.S. Fish and Wildlife Services as part of the Species Status Assessment process, which will be used to make a listing determination for the species under the Endangered Species Act. To contribute to the assessment, we used satellite imagery, habitat change detection algorithms, and U.S. Government data to estimate the amount of the species' habitat that has been lost since its court-ordered delisting. The data show that ~78 km2 of prairie-chicken habitat have been converted to new development such as oil and gas infrastructure; considering the 200m buffer used by the Service in analyzing effects on the species, an estimated 924 km2 have been impacted by this growth. Further, data indicate that over 1,300 km2 of the species' habitat have been converted to new agricultural uses since 2016. Taken together, these results highlight that ongoing habitat loss is a serious threat to the species.

Background

The lesser prairie-chicken (*Tympanuchus pallidicintus*, hereafter 'LPC') is a grouse species native to regions of Colorado, Kansas, Oklahoma, Texas, and New Mexico (Figure 1). Throughout its range, the species requires a mix of sagebrush, native grass prairie and shrublands. Much of this habitat has been lost to agricultural conversion, and LPC populations have declined from historical levels across its range. Energy development has also eliminated and degraded LPC habitat because the species avoids tall structures, a possible adaptation to avoid aerial predators. The U.S. Fish & Wildlife Service (FWS) listed the LPC as threatened under the Endangered Species Act (ESA) in April 2014 because of these threats.

Prior to ESA listing, the Western Association of Fish and Wildlife Agencies (WAFWA) developed the Lesser Prairie-Chicken Range-wide Conservation Plan (RWP) in 2013. Under the RWP, many landowners could meet the protections required under the ESA for the LPC by enrolling in the RWP and adopting conservation measures to minimize and mitigate the effects of land use activities detrimental to the species. On September 1, 2015, a court overturned the listing decision, concluding that FWS had not adequately considered the RWP in its decision to list the LPC. FWS thus formally removed the LPC from the endangered species list in April 2016. At this point, landowners could still voluntarily enroll in the RWP, but doing so no longer fulfills an ESA legal obligation. Without mandatory ESA protections after the delisting, many conservationists are concerned about the extent to which the species conservation status will decline as habitat is lost to energy development and agricultural conversion.

Here, we use remote sensing data and machine learning approaches to quantify the extent of habitat loss and degradation across LPC range since the species was delisted. Our objective was to calculate the extent and impact of anthropogenic habitat loss within that has occurred since the species was delisted in 2015. This information can inform the Species Status Assessment being assembled by the Fish & Wildlife Service as part of a process to determine whether the species warrants listing under the ESA.

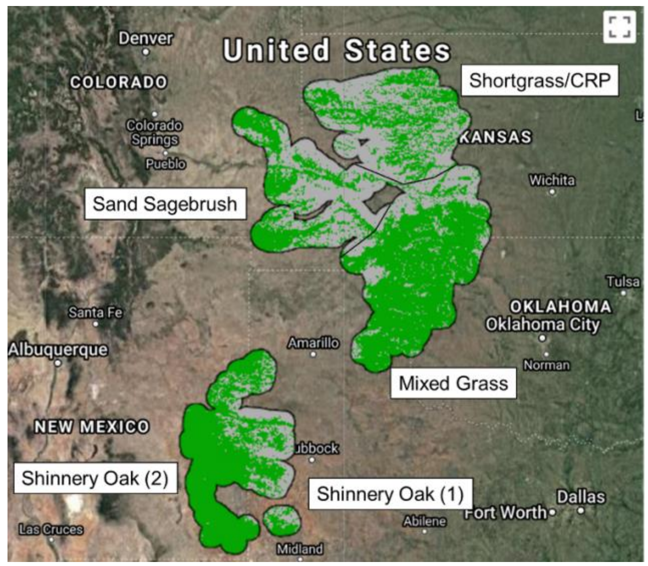

Figure 1. Lesser prairie chicken ecoregions of the southern great plains used to define the extent of habitat loss analysis. Green areas within ecoregion polygons indicate the extent of extant LPC habitat as of 2015, as indicated by National Land Cover Database data.

Methods

We used a land cover change detection algorithm (Evans & Malcom 2021) based on the methods used to update the National Land Cover Change dataset (Jin et al. 2013) to detect and quantify new anthropogenic development occurring in the range of the lesser prairie chicken since delisting. This algorithm uses freely available Sentinel-2 satellite imagery data (Drusch et al. 2012) and analyzes pairs of images collected from the same location to identify pixels that have been converted to bare ground. The change detection algorithm code is publicly accessible in a GitHub repository (https://github.com/mjevans26/ACD_methods/EE_code/Python).

We analyzed changes between median composite images collected in the summer (Apr. - Aug.) of 2016 and the summer (Apr. - Jun.) of 2020. This time period was selected to compare the most recent imagery available at the time of analysis with the comparable season corresponding to the earliest dates at which consistent coverage of the Sentinel-2 system was available. April 2016 also aligns with the date at which the LPC was removed from the Endangered Species List.

To create median composites for each time period, we first harmonized images within each ecoregion. This was done to account for baseline differences in reflectance between adjacent passes of the Sentinel-2 satellite system that occur on different days, which contribute to the single 'before' or 'after' image for an ecoregion. We calibrated pairs of images using a histogram matching procedure drawing data from areas of overlap between adjacent images. This method was applied iteratively among passes according to longitude, such that the westernmost image served as the reference.

We ran the analysis within the five LPC ecoregions referenced by WAFWA, FWS and others, which encompass a 10 mi buffered area around what is considered suitable lesser prairie chicken habitat. Lesser prairie chicken range has been modeled and estimated by the U.S. Geological Survey and FWS (Cummings et al. 2017). Because we did not have access to this estimated occupied range spatial data, we consider suitable habitat as areas categorized as either grassland or shrub/scrub in the 2016 National Land Cover Database (Jin et al. 2019) in the ecoregions (Figure 1).

The output of the land cover change detection algorithm is a six-band image in which each band represents a spatially standardized (i.e., z-score) metric indicating change. We applied post-processing steps to this output to distinguish anthropogenic changes from noise. A previous sample of change detection algorithm output at over 100,000 locations collected at 100 study sites has been used to develop linear discriminant analysis (LDA) parameters that distinguish habitat loss from other land cover changes. These parameters have been estimated for five different land cover types, and we used those optimized for shrub/scrub to convert change detection output to a single LDA score per pixel.

We optimized an LDA threshold distinguishing developed and undeveloped pixels using a spatial subset of each ecoregion. Within these areas we manually labeled polygons as true anthropogenic change and those that were spurious. We then used an ROC analysis to identify the threshold that minimized the total omission plus commission error. Output pixels from the change detection algorithm that exceeded this threshold after being transformed by the LDA parameters were designated as areas of new development. To help eliminate spurious single pixel changes we performed successive 1-pixel erosion and dilation around these pixels.

In addition to eliminating habitat, anthropogenic development can degrade surrounding habitat for LPC by inducing avoidance of tall, noisy structures. We use a 200 m buffer around new development to delineate degraded areas, as recommended in the LPC Range-wide Conservation Plan (Figure 2). We selected a reduced set of new development pixels to buffer only those representing new development rather than expansion of existing infrastructure. We used a similar procedure to that used to identify optimum LDA thresholds, again labeling change polygons as either being new landscape features or expansion of existing infrastructure and performing an ROC analysis to identify a size threshold that best distinguished the two classes.

In addition to direct habitat loss, fragmentation can detrimentally affect the survival and persistence of species. We therefore also calculate changes in habitat fragmentation as a result of anthropogenic habitat losses. We summarize habitat fragmentation using a simple, intuitive metric – distance to edge, defined as the distance of all habitat pixels to the nearest non-habitat pixel (i.e. edge). We summarized changes in fragmentation by comparing the distribution of distance-to-edge values before and after accounting for new development, and report the 25th, 50th, 75th, and 99th percentiles of these distributions within ecoregions. Lower distance indicates greater fragmentation.

Figure 2. Examples of anthropogenic habitat loss automatically detected within the range of the Lesser Prairie Chicken. The underlying satellite imagery is a median mosaic of Sentinel-2 images collected in New Mexico between April, 2020 and June, 2020. Purple polygons delineate 200 m buffered areas around disturbances after August, 2016.

Following these procedures, we produced a set of change polygons in each ecoregion, a set of change polygons within LPC habitat and a set of polygons representing a 200 m buffer surrounding changes within LPC habitat. Using these three output datasets, we report 5 metrics indicating the level of habitat loss and disturbance occurring over the study period:

1. Number and area of anthropogenic disturbances
2. Number and area of anthropogenic disturbances within LPC habitat
3. Area of buffered impacts
4. Area of buffered impacts within LPC habitat
5. Increase in fragmentation within LPC habitat

Additionally, we summarize the amount of LPC habitat converted to agriculture using the cropland data layer (CDL) from the U.S. Department of Agriculture (Boryan et al. 2011). These data identify cultivated areas at 30m resolution annually. We identify all pixels previously identified as LPC habitat (i.e., shrub/scrub or grassland) in 2016 NLCD data that were subsequently categorized as 'cropland' in 2019 CDL data.

All datasets were accessed and analyses using the Google Earth Engine platform (Gorelick et al. 2017). The code used to run all steps of this analysis is available in a Google Collaboratory notebook (https://github.com/mjevans26/ACD_methods/LPC.ipynb).

Results

We used an LDA threshold of 3.0 to distinguish new development from background changes, and a size threshold of 2500 m2 to distinguish expansion of existing infrastructure from new development. Within validation areas, rates of omission (0.13) and commission (0.14) errors were low.

In total we detected 9,773 instances of anthropogenic habitat loss within LPC ecoregions between summer 2016 and summer 2020. Of these, 6,710 occurred within existing LPC habitat. These instances corresponded to a total of 78 km2 of LPC habitat loss. When we considered degradation of habitat within 200 m of new development 924 km2 of LPC habitat was degraded. Disturbances were not evenly distributed among ecoregions. The two ecoregions containing Shinnery Oak Prairie experienced a greater proportion of habitat loss due to new development (Table 1).

Overall habitat fragmentation rates did not change in the Sand Sagebrush, Shortgrass CRP, or Mixed Grass ecoregions, as indicated by nearly identical distributions of distance-to-edge measurements between before and after accounting for new development. Fragmentation increased in both Shinnery Oak ecoregions as indicated by reduced values of the 25th, 50th, and 75th percentiles of the distribution of distance-to-edge among habitat pixels before and after accounting for new development (Figure 3). Given that the number and area of changes increased, the stable distribution of fragmentation rates indicate that total affected area increased in parallel.

The data indicate that 3,118 km2 of LPC habitat were converted to agriculture between 2015 and 2019, the most recent year for which cropland extent data were available. Northern ecoregions, specifically Sand Sagebrush Prairie and Shortgrass/CRP experienced the highest rates of conversion of LPC habitat to agriculture between 2015 and 2019 (Table 2).

Table 1. Instances and area of new anthropogenic development occurring within Lesser Prairie Chicken ecoregions between summer (Apr. – Aug.) 2016 and summer (Apr. – Jun.) 2020.

		New development		New development within habitat		
Ecoregion	*Habitat (km²)*	*N*	*Area (km²)*	*N*	*Area (km²)*	*200 m buffered area (km²)*
Shinnery Oak Prairie (1)	1,551	413	2.68	306	2.15	40.26 (2.6%)
Sand Sagebrush Prairie	14,556	797	5.46	323	2.47	35.80 (0.2%)
Shortgrass CRP Mosaic	13,308	352	1.57	246	1.24	26.87 (0.2%)
Shinnery Oak Prairie (2)	31,511	4,432	56.43	3,525	51.49	570.44 (1.8%)
Mixed Grass Prairie	36,343	3,779	27.73	2,310	20.39	251.20 (0.7%)

Table 2. Habitat loss due to conversion to agriculture within ecoregions of the Lesser Prairie Chicken.

Ecoregion	***Habitat (km²)***	***Converted (km²)***	***Percentage***
Shinnery Oak Prairie (1)	1,551	58.37	3.76%
Sand Sagebrush Prairie	14,556	598.18	4.11%
Shortgrass/CRP Mosaic	13,308	572.82	4.30%
Shinnery Oak Prairie (2)	31,511	885.96	2.81%
Mixed Grass Prairie	36,343	1,002.98	2.76%

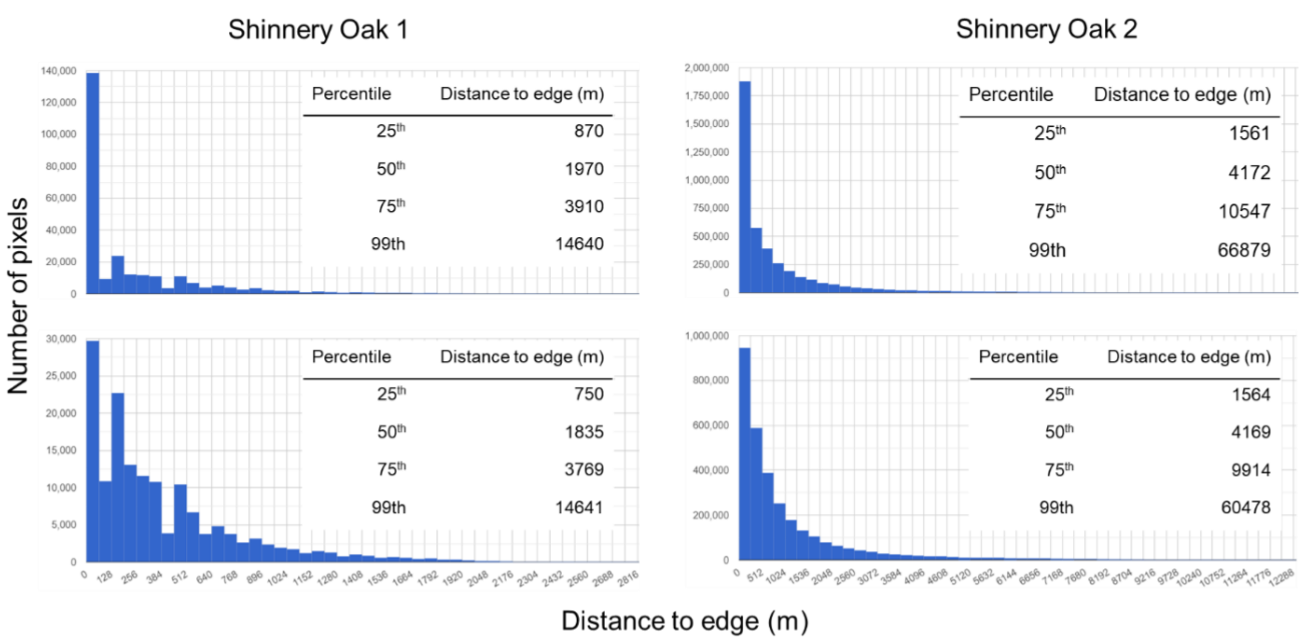

Figure 3. Distributions of habitat fragmentation indices among pixels of Lesser Prairie Chicken habitat before (top) and after (bottom) accounting for habitat loss between 2016 and 2020 within Shinnery Oak Prairie ecoregions. Fragmentation was measured as the minimum distance from each habitat pixel to the nearest edge. Tables display the 25th, 50th, 75th, and 99th percentiles of each distribution.

DISCUSSION

In this analysis, we took a conservative approach to estimating loss of LPC habitat using freely available satellite data, recently developed change detection algorithms, and official U.S. Government data. We found that thousands of instances of new development have occurred within LPC ecoregions since the species was delisted, the majority of which occurred within LPC habitat, and thousands of square kilometers of the species' habitat have been developed outright or converted to agriculture.

The satellite data show thousands of changes across the species' habitat since 2016, totaling 77.7 km2 of direct change in just five years. Visual inspection of before and after satellite imagery indicates that the great majority of these changes are related to energy extraction – either oil/natural gas infrastructure or wind turbines (e.g. Figure 2). Meaningful proportions of the remaining LPC habitat were further degraded by these developments, which as much as 2% of habitat in ecoregions being encompassed by 200 m buffers around new infrastructure. The direct loss and accompanying degradation of habitat due to new development were most pronounced in the southern range of the species, within ecoregions spanning New Mexico and Texas.

Indirect effects such as habitat fragmentation as captured by distance-to-edge also indicate extensive habitat harm to the LPC. In particular, the distribution of the distance to edge among all areas of habitat shifted towards shorter distances, particularly in the Shinnery Oak Prairie ecoregions. As these southern regions experienced the greatest percent habitat loss due to new development, and the majority of this was due to a proliferation of (relatively) small oil and gas infrastructure (e.g., Figure 4), it was unsurprising that fragmentation increased most in these areas.

While southern ecoregions experienced the greatest loss and fragmentation of LPC habitat, the opposite pattern was true of habitat loss due to agricultural conversion. Data from the U.S. Department of Agriculture show extensive cropland conversion of LPC habitat since 2016 throughout the species' range. In northern ecoregions, as much as 4% of habitat was converted to agriculture.

The thresholds chosen for both selected changed pixels based on LDA score, and the size of change polygons to buffer almost certainly eliminated areas of real anthropogenic change. Many narrow, linear features including new roads are not accounted for in the analysis—these features are often too narrow to be fully detected in 10 m imagery of Sentinel-2—nor are infrastructure features like transmission lines which are also known to induce avoidance behavior in a number of grouse species. Even with these limitations, it is clear that anthropogenic change in the LPC range has been substantial since the court-ordered delisting in 2015.

We are unable to determine the extent to which implementation of the RWP has altered the course of habitat changes for the LPC. Effectiveness is a product of two factors: the enrollment rate (area covered) and the effectiveness of enrollment on habitat change. We

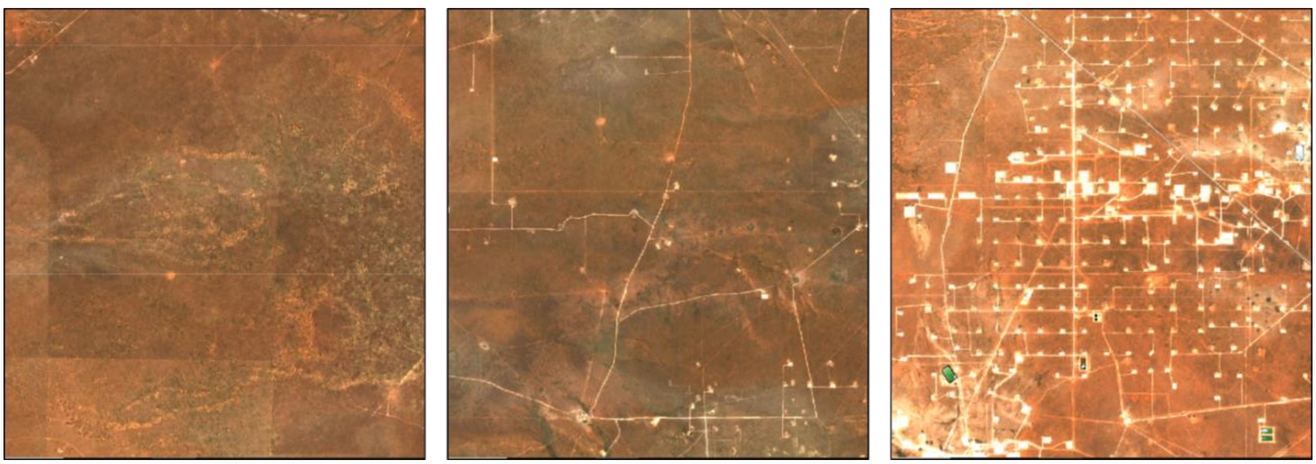

Figure 4. Sentinel-2 satellite imagery collected during April – June, 2020 showing different levels of habitat fragmentation. Low (left), medium (center), and high (right) habitat fragmentation was measured as the distance of all habitat pixels to the nearest non-habitat pixel.

know that the enrollment rate in RWP is very low (Streater 2020), which indicates that overall effectiveness is at best similarly very low. Without spatially explicit data on which areas are enrolled, we cannot test using satellite and other data whether actual, on-the-ground implementation of RWP activities is effective at stopping or slowing LCP habitat conversion. Any conservation program such as RWP will need this level of transparency to allow for independent evaluation of program effectiveness to inform the overall conservation status of listed species or those that may warrant listing.

Taken together, the data and this analysis using conservative thresholds show that recent and ongoing destruction, modification, and curtailment of the LPC habitat is extensive. We anticipate that direct and local indirect threats are more extensive given the limitations of available data, as noted above. Further, we do not account for ongoing large-scale factors such as the effects of climate change, whether effects on habitat or on other ESA threat factors such as disease and predation, which further exacerbate the threats landscape for the species.

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Contributions

Michael Evans led the analyses and writing, Jacob Malcom contributed to the project design and editing. Imagery for analyses is in the public domain from Sentinel-2, viewed using Google Earth Engine.

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